ParaLead:
Corporate Governance Free from Corporate Governors

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Abstract:

Almost all corporations are governed through voting and the election of agents like the Board of Directors. However, voting mechanisms are prone to agency problems such as moral hazard and free-riding. This paper introduces *Parallel Markets* as an alternative governance mechanism that does not require voting or Board of Directors. Rather, it derives the optimal decisions from market equilibrium prices.

For any decision, first, the current shareholders generate the set of decision choices (*decision initiatives*). Then the mechanism replicates the shares of the company for each choice. These shares are conditional on whether the choice is selected. Speculators can buy and sell these conditional shares, resulting in an equilibrium price for the conditional shares under each choice. Then the choice with the highest price is selected and ratified as the effective decision. The other choices and their conditional shares are voided, and their transactions are refunded. Therefore, the mechanism autonomously selects and ratifies the choice that maximizes the market capitalization of the company.

As a proof of concept, we implemented this mechanism in a web application and demonstrated its functionality via online experimentation. The results are close to optimal despite the small group size, thin markets, small incentives, and short periods to reach equilibrium.

Keywords: Prediction Markets, Corporate Governance, Financial Technology, Blockchain, Smart Contracts, Decentralized Autonomous Organizations, Decentralized Autonomous Corporations.

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1. Introduction

The corporation can be an efficient way of organizing business enterprises by serving as a nexus of contracts that simplifies the contracting problem. Each stakeholder can contract directly with the corporation, rather than with each of the other stakeholders. Corporations allow for the separation of ownership (*residual risk-bearing*) and control (*decision-making*) so that investors and managers can specialize. Moreover, owners, investors or shareholders can reach unity of decision by delegating the decision-making authority to one decision-maker (or a few). Otherwise, it would be too costly for many shareholders to participate in all decision-making processes (Fama & Jensen, 1983). Fama and Jensen (1983) outlined four steps in organizational decision processes (i.e. governance): (1) *Initiation* or suggestion of decision choices and actions (initiatives), (2) *ratification* or selection of a decision choice out of the suggested initiatives, (3) *implementation* of the ratified decision and (4) *monitoring* the execution of the ratified decision.

1.1. Motivation

While the delegation of the decision-making authority has benefits, it is also costly. Central authorities are susceptible to moral hazard and single point of failure (SPOF). They do not necessarily have the same objectives as the investors or owners do. When the decision-makers are not the owners or residual claimants and are not considerably affected by their decisions, they may deviate from the interests of the owners due to agency conflicts, that are costly to control. Roe (2004) outlined various internal and external corporate governance institutions (mechanisms) that try to control such agency problems. As he explained, the most important institutions are markets (for products, managerial labor, and capital) and the Board of Directors. Other institutions involve the board in one way or another. It is the board that has the ultimate responsibility to hire and fire managers, set management compensation contracts, review the performance of senior managers and executives, and monitor and ratify managerial decisions on behalf of the shareholders. The board is a mechanism that aims to mitigate agency problems by separating the decision management (*initiation* and *implementation*) from decision control (*ratification* and *monitoring*), so that the top managers are responsible for decision management and the directors control them (Fama & Jensen, 1983).

However, the board mechanism is imperfect and sometimes ineffective in seeking shareholders' interests (Bebchuk, et al., 2002; Bebchuk & Fried, 2003). This inefficacy can be ascribed to vertical and horizontal governance problems (Roe, 2004). The vertical problem is that the directors' incentives can differ from those of all or some subset of shareholders, thereby introducing further agency problems. The horizontal problem is about the conflicts of interest between the close controlling shareholders and the distant shareholders. In corporations with diffuse ownership, shareholders themselves can have different levels of incentives, access to information, and ability to evaluate information. Especially the distant and minority shareholders lack adequate information and understanding of the business to engage in the selection and control of the board. Therefore, the dominant shareholders mostly control the board and thus all of the resources and decisions, leading to rent-seeking and abuse of power.

Considering the deficiencies of the board mechanism, one might suggest eliminating the Board of Directors and letting the shareholders make decisions directly through voting where the voting power is proportional to the number of shares. While this mitigates the vertical problem, it worsens the horizontal problem as the vulnerabilities in the voting mechanisms created the horizontal problem in the first place.

The first vulnerability in the voting mechanism is the tyranny of the majority, where a subset of shareholders (e.g. with 51% of the shares) control 100% of the resources and decisions and ignore the other shareholders' interests. Second, there is free-riding, as small shareholders lack adequate incentives to do proper research and cast meaningful votes (Cvijanovic, et al., 2019). Generally, non-market mechanisms do not incentivize participants enough to discover and reveal the value of the alternatives accurately (Ba, et al., 2001). The free-riders enable one or a few dominant shareholders to control or influence more than 50% of the meaningful voting power, resulting in the tyranny of a minority.

To mitigate these vulnerabilities, some corporations (or regulations) require a supermajority of votes for some decisions. However, this exacerbates the situation because it gives veto power to a minority of shareholders. For example, under Hong Kong law, 10% of the "free-floating" shares can block a buyout. In 2006, Henderson Land, a company in Hong Kong, offered to buy out its affiliate, Henderson Investment. It was a good offer and thus Henderson Investment's share price increased. However, a few hedge funds who had about 2.7% of the outstanding shares (more than 10 percent of the free-floating shares) voted against the buyout, resulting in a large drop in the share price. They made more profit from their short position in the company (Hu & Black, 2006).

Third, with more than two choices, any voting scheme falls under the conditions of the Muller-Satterthwaite impossibility theorem. Precisely, the plurality rule violates the *Independence of Irrelevant Alternatives* (Shoham & Leyton-Brown, 2010). This makes the collective decisions sensitive to strategic voting, empty voting, and other manipulations. As a result, sometimes a small group can manage and control all the decisions (i.e. tyranny of the minority). Even with only two choices, the efficiency of a voting scheme depends on the number of votes required for a decision (Buchanan & Tullock, 1961). Buchanan and Tullock explained that smaller numbers make external costs larger because a few individuals can impose costs on others. Larger numbers (more inclusive) result in lower external costs, but higher decision-making costs because it is harder (more restrictive) to reach an agreement among more people. Therefore, the optimal number of individuals required to consent is somewhere in the middle. When there is a "*right*" choice or a "*ground truth*", which most people can detect, the majority vote is a good criterion (Ertekin, et al., 2013), but it is not when the evaluation of choices requires effort and expertise. Disagreement among the voters increases when evaluation becomes more difficult (Gillick & Liu, 2010).

In short, voting schemes cannot aggregate dispersed information effectively and are prone to manipulations. Current governance institutions like Board of Directors and various government regulations are attempts to safeguard against the frictions and shortcomings of the voting paradigm. However, they themselves are often the results of some voting arrangements and are susceptible to the same flaws.

1.2. Solution

Given the limitations of the existing governance mechanisms, this study introduces the Automated Governance methods which are derived from the concept of e-constitutions introduced by Khaledi (2018). These methods enable participants (e.g. shareholders) to propose (suggest) the initiative decisions or choices (initiation). Then the best decision choice is selected and ratified based on market equilibrium prices (Parallel Markets). The managers or employees can implement the ratified decisions, and a judicial system, an information system, or a Blockchain can enforce them (Khaledi, 2018). Information technologies can also help shareholders to monitor the implementation of the ratified decisions. Therefore, these automated governance methods can replace the Board of Directors with shareholders (initiation and monitoring) and speculators (ratification). Joyce, et al. (2012) described rules and roles as components of governance. The automated governance methods define precise governance rules but obviate the need for governance roles such as directors. This results in self-governed collaboration without relying on cooperation, trust, or external authority. Investors can exercise their control rights independently by trading for or against each decision choice. They can externally monitor managers and orient their decisions toward the interests of the residual claimants. This almost eliminates the agency problems at the governance level.

Essentially, the automated governance methods crowdsource the governance of an organization. The crowdsourcing paradigm not only challenges the traditional hierarchical structures for decision making, but also blurs the organizational "*boundaries*" that separate the contributors "*inside*" an organization from the "*outsiders*" (Thuan, et al., 2017). Sakamoto and Bao (2011) used crowdsourcing to produce creative solutions for a social problem and found that the best ideas from the crowd are as novel and useful as the best ones from the experts. Gottschlich & Hinz (2014) cited several studies showing the effectiveness of user-generated content (crowdsourced) for investment decisions in the stock market.

1.3. Parallel Markets

The Parallel Markets mechanism uses stock price[2] as a criterion to estimate the expected value of the company under each choice, and autonomously selects the choice that results in the highest market capitalization. This mechanism replaces votes with transactions. Price is a collective decision that is resistant to attacks, free riding, tyranny of the majority, and many manipulations possible under voting. Price is the most efficient aggregation of dispersed information and is a sufficient statistic that summarizes individual valuations into a collective valuation (Hayek, 1945). Such a collective valuation can yield a group utility function that unshackles the collective decision making process from the impossibility theorems (Scott & Antonsson, 1999). Lo (1998) showed that the speculative financial markets almost perfectly aggregate all relevant information into the stock prices.

On the other hand, Blume et al. (2010) claimed that markets are open to gaming because participants can transfer money from one account to another and trade with themselves to manipulate the price. However, in most speculative homogenous markets, the central exchange clears the offers against the *best* counteroffers, not particular ones. If a participant tries to make a trade at a price far from the equilibrium price, his bid or ask will first clear the existing asks or bids that are closest to the equilibrium price, not his own counteroffer at his planned price. The only way to trade with oneself (or accomplice) is outside the market, which does not affect the market price. In the market, the manipulators should incur the cost of clearing all counteroffers up to the desired price when trying to move the price. Hanson et al. (2006) observed in experimental markets that the manipulation attempts do not affect the accuracy of prices. In fact, if other traders are enough informed and able to enter the market, they will make a profit by trading against the apparent manipulation attempts as Hanson and Oprea (2009) and Newman (2012) found out in prediction markets. Particularly, in prediction markets, more experienced traders can earn higher returns by trading against biases (Cowgill & Zitzewitz, 2015). Generally, the speculative markets reward the informed traders who push the price towards the true value thereby revealing their real beliefs, but these markets punish those who try to push the price away from the true value.

Prediction markets use equilibrium prices to predict future events. Participants invest in stocks that are tied to different potential outcomes in the future. Such markets have been remarkably accurate at predicting the results of political elections and sports events (Coles et al., 2007). In prediction markets, participants can trade contracts whose payoffs are tied to a certain future event. Over time, the participants reveal their true beliefs and the contracts' prices will reflect their collective judgment on the probability of each choice.

[2] Instead of stock price, one may use a more complex measure of value like *Tobin's q*, as in Black et al. (2006).

However, it works only if the outcomes can be determined in a near future. As a consequence, prediction markets are mostly applied for short-term predictions.

Other relevant concepts are decision markets (Hanson, 2002), preference markets (Coles et al., 2007), imagination markets (LaComb et al., 2007), and idea markets (Soukhoroukova et al., 2011). They use prediction markets to evaluate and predict the success of ideas, decisions, features, and new technologies at their early stages. To this end, they should tie payoffs to some observable outcome, on which participants can bet (Blohm et al., 2011). However, often the true value of the outcomes cannot be observed or determined in a near future. Therefore, the only observable short-term outcome is the endogenously emerging prices. Tying the payoffs to the prices turns these markets into "*beauty contests*", wherein the payoffs depend on the expected payoffs (Keynes, 1936). This is a self-fulfilling prophecy that results in herding behavior, wherein prices do not reflect the real value or success chance of the choices.

Soukhoroukova et al. (2011) analyzed several payoff methods to cope with this problem. One method is to wait for the information about the actual values to become available as *Foresight Exchange* does. However, the value of real-world ideas and decisions may be revealed after decades, and payoffs this far in the future provide weak incentives for trading and investing. Another method is to use a proxy measure as a leading indicator for the actual value of the ideas and decisions. But, defining such proxy measures for new ideas is very difficult in real business settings, which are complex and uncertain. Such proxies can give wrong incentives and open the door for manipulations and strategic trading. It also defeats the purpose of using the market price to estimate expected values and chances of success. A common proxy is to use a panel of experts to rate and subjectively estimate the values and the odds of success for ideas and decisions. It is difficult to determine who is an expert and then incentivize them to make proper assessments. Besides, usually, the most knowledgeable people are the ones who trade and invest in the choices. This introduces conflicts of interest. Moreover, when the final valuation is up to a group of people, traders try to second guess those people's perceptions, rather than assessing the actual values.

The Parallel Markets mechanism solves this problem by linking the payoffs to the stream of future profits from investing in a choice. Therefore, as in public corporations, the prospect of profits, which is an objective exogenous outcome, drives the prices. As Fama and Jensen (1983) described, "*Stock prices are visible signals that summarize the implications of internal decisions for current and future net cash flows*." Actually, the financial market prices have become more informative on predicting the future cash flows as the data processing and information costs have declined (Bai et al., 2016).

We expect the Parallel Markets mechanism to be highly decisive like prediction markets. Prediction markets usually have only one outcome with a high price whose difference with other prices increases over time (Coles et al., 2007). The only selection criterion in the Parallel Markets mechanism is the maximum price and thus only the relative prices of the highest-valued alternatives matter. Therefore, the selection is not sensitive to the over-optimism bias common in prediction markets (Cowgill & Zitzewitz, 2015). Moreover, in each period the highest valued alternatives are more likely to be confirmed, and thus are traded more often and priced more precisely (at least relative to each other). When there are too many choices in a period, the Parallel Markets platform should sort the alternatives based on their prices so as to make the highest-priced choices more visible and thus evaluated and traded more frequently.

1.4. Outline

The structure of the paper follows the Design Science Research (DSR) methodology (Hevner et al., 2004). As Hevner, et al. explained, a DSR should develop technology-based solutions for practical problems. This introduction (section 1) presented the motivation and theoretical foundations to show the relevance of the topic to research. The relevance of the topic to business practice is obvious, as many like Bebchuk and Roe have pointed out the limitations of the existing governance structures.

DSR should produce a viable artifact in the form of a construct, a model, a method, or an instantiation (Hevner et al., 2004). The Parallel Markets mechanism is an artifact that provides a solution for an identified problem (corporate governance). This mechanism relies on the efficient market theory, assuming that equilibrium share prices reflect the value of the company, at least relatively (i.e. higher prices correspond to higher values). Moreover, it is based on *shareholder primacy*, making the primary goal of the company increasing the value for shareholders, measured by market capitalization. Section 2 describes this artifact and appendix A presents a web application that instantiated it as a proof by construction.

In constructing the artifact, DSR requires rigorous methods that utilize available means to reach desired ends while obeying laws in the problem domain (Hevner et al., 2004). Section 3 proposes such a method to develop and test the Parallel Markets mechanism as the artifact. In this method we simulate a company as a mutual fund that is controlled by its shareholders through the Parallel Markets mechanism.

The utility, quality, and efficacy of the artifact must be rigorously demonstrated via well-executed evaluation methods (Hevner et al., 2004). Section 4 provides the results of the experiment as evidence for the feasibility and functionality of the Parallel Markets mechanism. Section 5 presents the subject level analysis and provides insights on how people interact with this mechanism and with markets in general.

Since the results of the experiments are not ideal, section 6 points out the challenges facing the Parallel Markets mechanism and introduces the automated primary markets to replace the secondary markets for the mechanism to cope with these challenges. Accordingly, the *Parallel Primary Markets* mechanism provides liquidity based on a price function similar to the bonding curve contracts. Experimental evaluation of the Parallel Primary Markets mechanism is more complex and a topic for another research.

Effective DSR must provide clear and verifiable contributions and it must be presented effectively for relevant management audiences (Hevner et al., 2004). The concluding remarks (section 8) summarizes the contributions of this study which are threefold: The Parallel Markets mechanism (artifact), an improvement to it (Parallel Primary Markets), and a scientific method to test and experiment governance mechanisms in general. Overall, this paper communicates this research to advocate for further research in this area and to guide for practical applications of the proposed mechanisms.

2. Automated Governance

Information technologies have made new forms of governance possible as they have opened new ways for "idea generation" (suggestion) and "idea selection" (Kornish & Hutchison-Krupat, 2017). This section introduces some automated governance methods that are based on the Parallel Markets mechanism to govern a company, a corporation, a DAO (*Decentralized Autonomous Organization*), or a DAC (*Decentralized Autonomous Corporation*). As Wang et al. (2019) described, DAOs (and DACs) rely on blockchains as the technology layer and tokens as the incentive layer. They also should have a governance layer to make collective decisions.

Here we assume that governance happens through one or more rounds of decision making. In each decision round, we need a mechanism to *generate* and collect some alternative decision choices and then a mechanism to *select* one of the choices. Therefore, each decision round is composed of (at least) two stages: a *suggestion* period followed by a *selection* period.

2.1. Suggestion Periods

In one configuration, each decision round starts with identifying (or raising) a decision matter (or issue) according to some pre-determined rules. This starts a suggestion period, during which one or multiple proposals can be submitted (proposed) for the decision matter. A proposal can refer to a solution, a policy, a contract, a decision initiative, a decision choice, a decision address, a proposal address, a contract address, a policy address, and the like. Proposals can be proposed by managers, shareholders, investors, employees, an open crowd or a set of qualified proposers according to some predetermined rules. Financial and non-financial rewards can incentivize more and better proposals. To incentivize original proposals (instead of copying) proposals can be kept confidential until the end of the suggestion period. At the end of the suggestion period, all or some of the proposals are revealed as decision choices or choices for the decision matter. To limit the number of choices, the governance method can filter out proposals that do not meet some pre-determined criteria. For example, they should be in English language. The proposals that meet the pre-determined criteria are considered qualified proposals and become choices for the selection period. The choices represent alternative futures for the company. Figure 2-1 illustrates the steps for making a decision in one decision round according to this configuration.

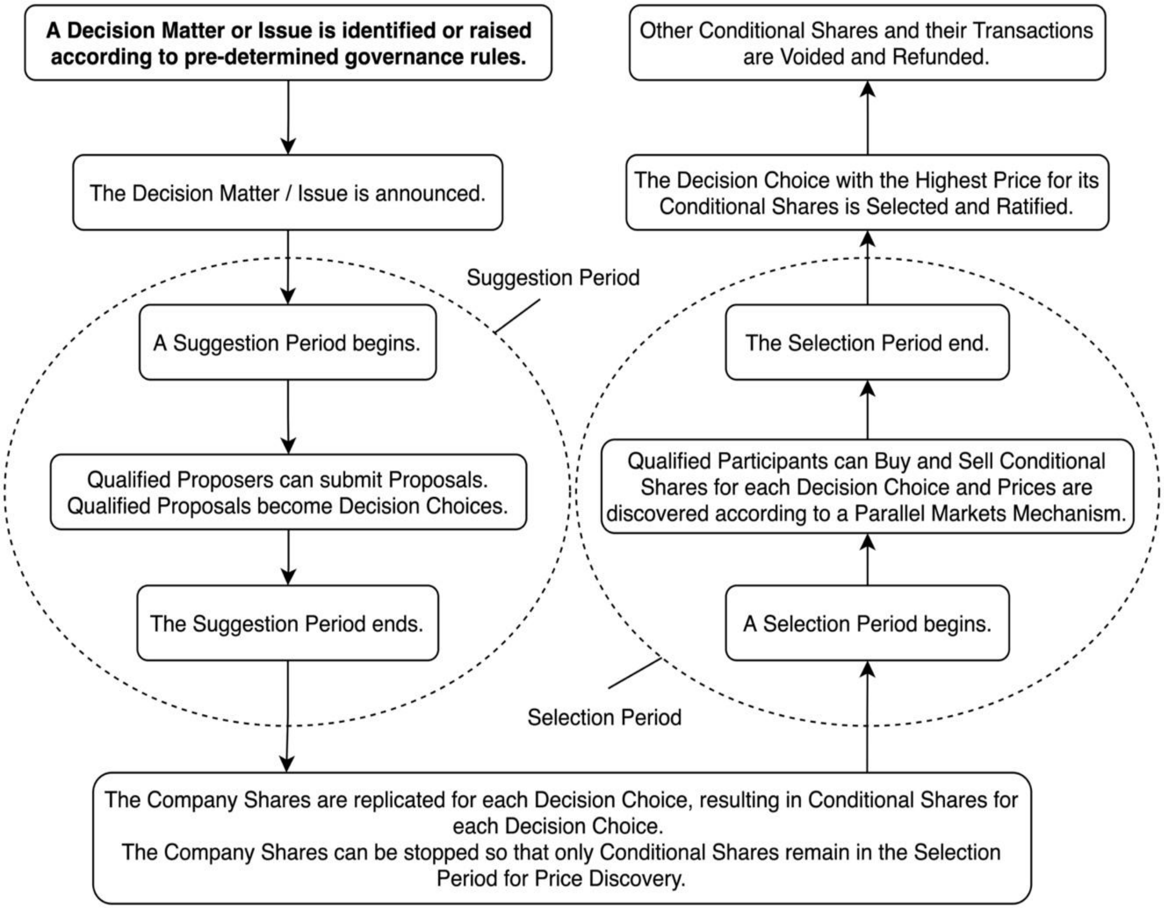


Figure 2-1. The Flowchart for an Automated Governance Method

In an alternative configuration, a decision round starts when a proposer proposes a qualified proposal (amendment) according to some pre-determined rules. Then the qualified proposal becomes one choice and "Status Quo" becomes another choice and there is no suggestion period. Therefore, the selection period starts with two choices which are "Accepting" and "Rejecting" the proposal.

2.2. Selection Periods

To detect the best choice, ideally, we want to try each choice in a parallel universe and evaluate the value of the company under each choice. Then go back in time and pick the choice that would result in the highest value for the company. Unfortunately, it is not feasible yet. So, this section introduces a slightly different mechanism called *Parallel Markets*.

According to this mechanism, at the beginning of the selection period, the company ownership shares are replicated for each and every choice. These new shares are conditional on whether the choice is selected or not. Hence, they are referred to as conditional shares. Each shareholder will have the same number of conditional shares for each choice as he had for the (unconditional) company ownership shares immediately prior to replication. A set of the conditional shares is converted to company ownership shares if its corresponding choice is selected at the end of the selection period.

After replicating company shares, a selection period begins and participants, investors or traders can buy and sell the conditional shares for each choice in a separate market. These markets operate in parallel to discover the price for the conditional shares for each choice. People can trade the shares for each choice assuming that it will be implemented. Market prices can be determined through *Continuous Double Auction* (CDA), which is frequently applied in financial markets. These equilibrium prices reflect the expected values for the hypothetical futures of the company given all the available information. Figure 2-2 illustrates how prices of multiple conditional shares can change in parallel markets during two decision rounds.

At the end of the selection period, the set of conditional shares with the highest price (or another measure of value) becomes the (unconditional) ownership shares of the company, its transactions are confirmed, and its corresponding choice is ratified as the effective decision and the winning choice. However, the conditional shares of other choices and their transactions are voided and refunded to their investors and traders. Voiding the non-winning choices limits the risk of buying precarious choices.

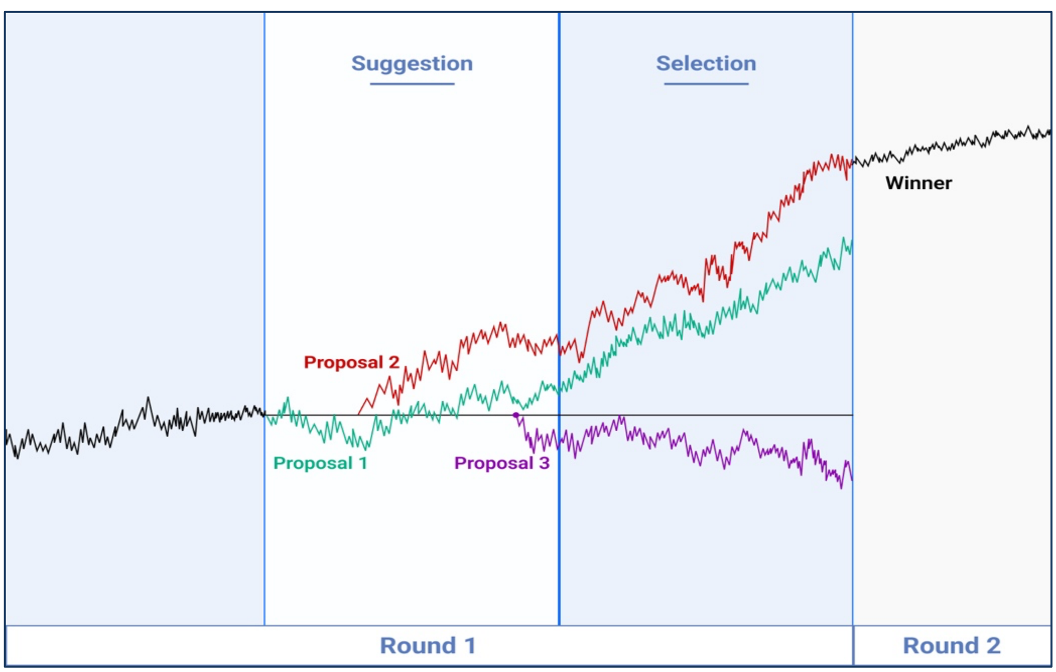


Figure 2-2. Decision-making in using the Parallel Markets mechanism

Liquidity

One challenge facing the Parallel Markets mechanism is liquidity. Generally, markets work better with more liquidity, which enables participants to make a transaction immediately without changing the price significantly (Coles et al., 2007). On the other hand, a "thin market" with too few trades cannot effectively aggregate information (Healy et al., 2010). Markets need several participants and several trades to reach a meaningful equilibrium price for evaluation, whereas other evaluation methods like rating and voting, only need one or two participants and one shot to result in a meaningful evaluation using an aggregation function (Blohm et al., 2011). Markets should have at least 30 participants to be efficient (Christiansen, 2007).

However Parallel Markets need multiple times more participants and trading activities to reach enough liquidity because multiple markets are running simultaneously, and each trader can meaningfully participate in one of them at any time. Therefore, the choices steal liquidity from each other. To mitigate this problem, we need to control the number of choices so not to have too many low-quality ones, which could be time consuming and costly to evaluate. To this end, we can apply one or a combination of the following methods.

1. There can be a *fixed fee* for proposing each decision choice. This deters spam submissions, but a too large of a fee may also deter risk-averse proposers to submit potentially superior proposals.

2. There can be a *betting contest* for suggestions. Proposers can pay to bet on their suggestions. Then the suggestions are sorted according to the payments. A larger betting amount indicates the proposer's higher confidence in his suggestion. Winning proposers can be rewarded proportional to their bets.

3. The proposers can be limited to shareholders. Particularly, only shareholders who *own more than a specific number of shares* (e.g. 1%) can suggest a decision choice. We already see that shareholder proposals are taken more seriously than the management proposals (Cvijanovic et al., 2019).

4. The decision choices can be *sorted based on the number of shares* their proposers have at the time.

	Filtering	**Sorting**
Per Choice	A *Fixed Fee* for each suggestion	*Betting Contest* for suggestions
Per Proposer	Proposers with more than 1% shares	Based on Proposers' shares

Table 2-1. The mechanisms to control the number of choices

Accounting Technicalities

Another challenge for Parallel Markets is some accounting technicalities. An order or transaction can involve recalculating the available balances for each participant for each set of the conditional shares. Therefore, in addition to the cash balance, each person has two *conditional* balances associated with each choice. The *winning balance* (W_i) is realized if the choice (i) wins, and the *void balance* (V_i) is refunded if the choice (i) voids. The winning balance is the fund from selling conditional shares for a choice during the selection period. When a shareholder sells conditional shares for a choice, the transferred cash is not confirmed unless and until the choice wins. If the choice wins and its conditional shares are confirmed, its winning balances for all individuals are confirmed and added to their cash balances, otherwise, they are voided along with the choice's conditional shares. The winning balance cannot be cashed out or used to buy conditional shares for other choices, but it can buy conditional shares for the same choice. Thus, during a trading period, the available balance for each person to buy choice i is calculated as follows:

$$A_i = B + W_i - \sum_k O_{ik} - \sum_{j \neq i} Ramp\left(\sum_k O_{jk} - W_j\right) \qquad (2-1)$$

Wherein, B is the individual's real cash balance and O_{ik} is the amount of money locked due to the person's buy order k on choice i. A buy order on a choice can use the cash balance as well as the winning balance for that choice. Since buy orders can use the cash balance, buy orders on other choices can also reduce the available balance on a choice. This happens when the total of buy orders on another choice (j) exceeds the winning balance (W_j) for that choice so they would take money from the cash balance B. The Ramp function reflects that. This ensures that there will never be a negative balance for any choice.

Another constraint is that during a selection period, an individual cannot withdraw his available balances, but he can withdraw his available balance on the winning choice at the end of the selection period. However, during the selection period, we know exactly one choice will win and its winning balance will be confirmed. Therefore, to facilitate withdrawal, we can let a person withdraw the least of his available balances across all choices. To this end, we normalize each individual's winning balances such that when an individual's winning balance for every choice is positive, the minimum of them is added to his cash balance and is deducted from all his conditional winning balances (W) so the individual's minimum winning balance across all choices becomes zero. In short, after each transaction, for the seller party:

$$min\,\{W_i | i \in All\ Choices\} > 0 \;\mapsto\; B \coloneqq B + min\{W_i\}\,;\ \forall i{:}\ W_i \coloneqq W_i - min\{W_i\} \qquad (2-2)$$

It should be noted that this has an effect only if the person sells conditional shares for all choices, in which case, this facilitates the withdrawal of the minimum of the balances. However, this operation is not reversible, and once converted into cash balance, it can only be used to buy conditional shares once, not multiple times.

Moreover, each person has a *Void Balance* (V_i) for each choice (i) when buying its conditional shares. The money an individual spends to buy conditional shares for a choice should be refunded if the choice and its conditional shares are voided. If the choice wins and its conditional shares are confirmed, its void balances (for all individuals) are discarded, otherwise, they are refunded and added to the cash balances. During a selection period, we know that each choice either wins or voids. Thus, we normalize each individual's balances for each choice so that either his winning balance or his void balance for that choice is zero. To this end, when both of an individual's conditional balances for a choice are positive, the minimum of them is added to the individual's cash balance and is deducted from both of his conditional balances so that one of them is always zero. In short, for each individual after each transaction for each choice:

$$min\{W_i, V_i\} > 0 \mapsto B \coloneqq B + min\{W_i, V_i\};\ W_i \coloneqq W_i - min\{W_i, V_i\}\ ;\ V_i \coloneqq V_i - min\{W_i, V_i\} \quad (2-3)$$

At the end of the selection period, the choice with the highest price wins (i=w) and becomes the effective decision. The distribution of conditional shares for the winner choice becomes the distribution of ownership shares for the company. And the cash balance for each individual is updated according to:

$$B \coloneqq B + W_w + \sum_{j \neq w} V_j \quad (2-4)$$

, wherein W_w is the individual's winning balance for the winning choice and V_j is his void balance for each choice j, which is not the winning choice.

3. Experimental Design

There have been several studies on crowdsourcing and user-generated content. However, the main novelty of this study is a new selection mechanism that relies on the equilibrium prices to select and ratify one choice out of many. Therefore, this section focuses on testing and experimenting with the evaluation and selection stage in the Parallel Markets mechanism to demonstrate its feasibility and viability.

As a proof of concept, the Parallel Markets mechanism is implemented in a web application and tested via online experimentation on Amazon Mechanical Turk (MTurk). MTurk is a web service that enables outsourcing or crowdsourcing simple tasks to human workers from all over the world (Davis & Lin, 2011). It provides a reasonable and cost-effective platform with diverse participants who are more representative of a real labor market than university students are (Mason & Watts, 2009). Appendix A presents the control panel and the important user pages in this web application. The web application includes an automatic exchange to match the buy and sell orders and clear them. To match buyers and sellers for each particular choice, the *continuous double auction* (CDA) is implemented exactly as (Cole et al., 2007) have described. Such a fully automated electronic exchange serves as a market maker (Ba et al., 2001).

To evaluate the performance of a governance mechanism, instead of looking into the properties of the mechanism (e.g. fairness criteria), we look at the outcome of the mechanism hypothesizing that the quality of the outcome reflects the quality of the process (i.e. mechanism). This enables us to evaluate and compare governance mechanisms for real-world practice without trying to overcome the impossibility theorems.

Accordingly, we need to evaluate the quality of the outcomes of the process efficiently and objectively. Unfortunately, in the real world, it takes a long time for a governance mechanism to result in a measurable outcome, and even then, the quality of the outcome is affected by various factors and is mostly subjective. Therefore, here we define an artificial decision problem whose solutions can be objectively and immediately evaluated. This problem requires participants to make retroactive investment decisions as if they are in the past. They should choose between different investment alternatives for a fictitious mutual fund at specific points in time. The mutual fund simulates a company with participants as its shareholders.

This is a unique problem that has no practical application in the real world but has several desirable properties. First, the performance of the alternatives can be evaluated objectively without dealing with raters and interrater reliability issues. Particularly, historical prices have minimal measurement errors. Second, the solutions to this specific problem have only one dimension of quality (i.e. return) and there is no uncertainty or risk involved. Third, this is essentially an investment planning problem without the forecasting part. So, it does not require any expertise in financial forecasting, and thus laymen (subjects) can understand it and evaluate choices in a limited time. Decisions involving financial forecasts would require substantial knowledge and a long time to yield meaningful variations in performance.

We did not enable participants to chat or talk with each other, because a lack of interaction, isolated learning, and diversity can improve the accuracy of collective predictions or decisions (Hong, et al., 2012). Moreover, in real-world market settings, it is hard to acquire any valuable information for free. Usually, people have conflicts of interest, and acquiring information is costly, so the (free) signals cannot be trusted. Hence, the lack of reliable communication in experiments is closer to reality.

The instructions presented to the participants are as follows:

Imagine it is 1/1/2019 and you have $5 cash balance plus 33.5 shares out of the one million shares in a mutual fund. On this day the mutual fund owns no asset other than $100,000 in cash, so each share is worth $0.10 at the beginning. The mutual fund will have the opportunity to invest during each of the next five months. The shareholders (including you) decide collectively where the mutual fund invests in each month. At the beginning of each month, there is a 10-minute selection process that results in one investment decision for the entire group in the entire month. At the end of each month, the mutual fund liquidates the investment, and then the investment process repeats.

The first selection round takes place on January 1st, when your group has 10 minutes to select an investment portfolio or choose to hold onto the cash until the end of January. We then skip ahead to February 1st when the second round takes place and your group can reinvest the new fund's cash in a new investment portfolio or hold onto the cash until the end of February. Similarly, the third, fourth, and fifth rounds take place on March 1st, April 1st and May 1st respectively. Each month, the mutual fund can reinvest its cash in an effort to increase it or can hold onto its cash for the month. There are no transaction costs or fees.

In the end, the total monetary value of the mutual fund (on June 1st) is calculated and you will see a short survey. If you stay in the game until the end and complete the survey, you will be paid your (individual) cash balance plus the dollar equivalent of your shares in the final mutual fund on June 1st, 2019. Your payoff will be at least $5 and at most $30 depending on your participation:

Your payoff =

*Your cash balance + (Your number of shares) * (Final value of mutual fund) / (One Million)*

In addition, the participant with the highest final payoff will receive a $20 bonus!

In each round, you can use historical data on websites such as CoinMarketCap to calculate the performance of each portfolio, which is the weighted average of the performance of its assets. If your group decides to hold cash for a month, the total value will not change (performance = 1). Please have a calculator or Excel sheet ready.

<u>*Selection Process*</u>***:*** *During each 10 minutes round each person can trade (buy and sell) the shares of the mutual fund under different investment alternatives (choices). For each of these choices, you can sell your shares of the mutual fund or you can use your cash balance to buy shares of the mutual fund for each choice. Hence, we call it Parallel Markets. There are no transaction costs or cancellation fees for trades.*

Your individual trades will result in one group decision each round. At the end of each round, the choice with the highest price is selected as the investment for that month. The transactions and shares for this choice are confirmed but the transactions and shares for other choices are voided as if they never existed. This reduces your risk if a choice's price declines. The shareholders of the selected choice will own the same number of shares for every choice in the next round, but of course, only one of those choices will be selected and confirmed.

<u>*Hint:*</u> *Each round, you should evaluate each choice and try to buy it at a price lower than its share value and sell it at a price higher than its share value. You can make money both ways if you estimate the share value for a choice. You want to sell the over-priced choices and buy the underpriced ones.*

4. Results

We recruited 69 subjects from *MTurk* to participate in the experiment on July 7th, 2019, and 59 of them completed the experiment. While it is not a large group and cannot provide a liquid market (let alone liquid Parallel Markets), it provided enough transactions and orders for each choice in each round so that the mechanism resulted in a reasonable decision every round. However, admittedly the final prices were not very close to the values of the choices. In the early rounds, the choices were overpriced and in the later rounds, they were underpriced. We considered two possible criteria for the selection of a choice: the last transaction price and the maximum offered price of the unfulfilled (remaining) bids at the end of the trading period. The choice with the highest level wins. They both resulted in the same choice every round.

There were five rounds with each round taking 10 minutes. There were between three and six choices in each round. Every round, the first choice (choice 0) was "*Holding Cash*". Table 4-1 presents the volume of transactions for each choice in each round. It also includes the total volume of transactions per round. The second round with $338.83 of transaction volume had the highest transaction volume. The total sum of transaction volumes throughout the experiment was $1371.8.

	Rounds				
Choices	**1**	**2**	**3**	**4**	**5**
Holding Cash	$ 16.64	$ 140.92	$ 39.61	$ 46.76	$ 59.80
Portfolio 1	$ 117.01	$ 109.55	$ 24.18	$ 90.18	$ 83.08
Portfolio 2	$ 60.44	$ 52.01	$ 68.44	$ 35.00	$ 106.06
Portfolio 3	$ 81.20	$ 34.35	$ 6.99	$ 66.34	
Portfolio 4			$ 9.19	$ 40.39	
Portfolio 5			$ 68.66		
Volume per Round:	$ 276.29	$ 338.83	$ 220.07	$ 282.68	$ 253.93

Table 4-1. The transaction volumes for every choice in each round

During the first period, there were four choices including one choice for holding cash. The other three choices were three portfolios as figure 4-1 presents. This figure was generated at the end of the period. The number in the first brackets for holding cash (choice 0) is the value of the mutual fund then. The performance of choice 0 (hold cash) is always one. The numbers in the brackets of other choices indicate their calculated performances or ROIs. The portfolios with performances higher than one are profitable. The numbers in the parentheses are the results of the trades in the Parallel Markets at the end of the period. Appendix B provides this information for all the other four rounds (2, 3, 4, and 5).

Figure 4-2 illustrates the results of the Parallel Markets in a chart. The yellow bars are the actual objective values of the choices calculated using the historical prices. The blue bars show the highest unfulfilled buying offers remained at the end of the period. The green bars represent the last transaction prices at the end of the period. As figure 4-2 shows, at the end of the first round, all bids were cleared for choice 0 (holding cash). Other than that, both the last transaction price and the maximum unfulfilled bid are the highest for portfolio 3, which has the maximum value (i.e. actual best choice). Figure 4-3 illustrates how the prices for different choices changed during the first 10 minutes trading period. Appendix B provides this diagram for all the other four rounds (2, 3, 4, and 5).

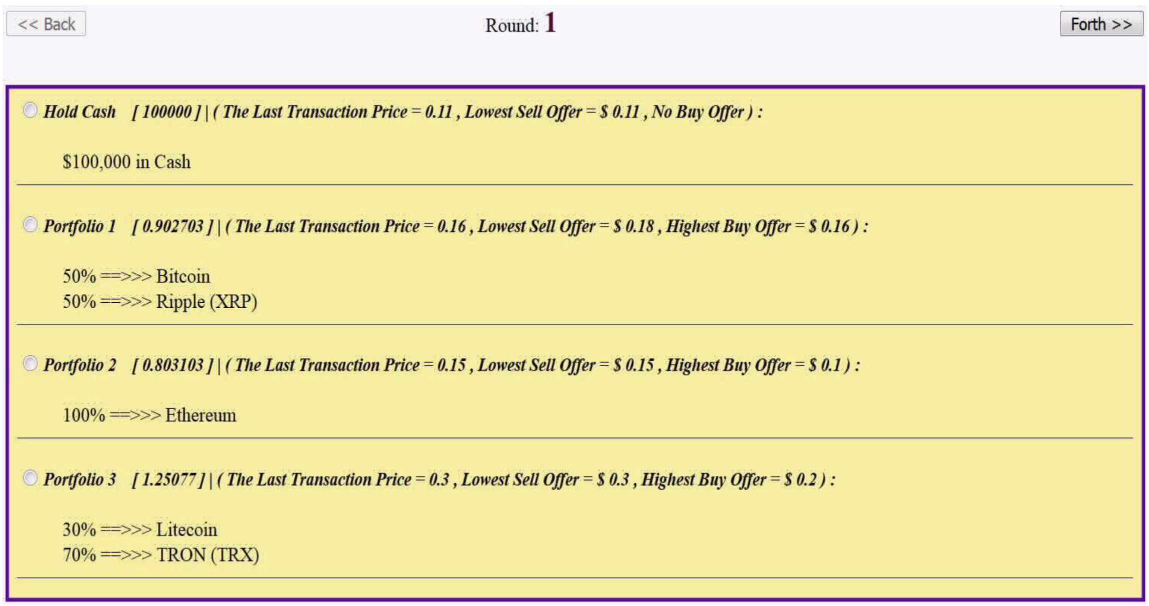


Figure 4-1. Alternative Choices (Markets) in the First Round

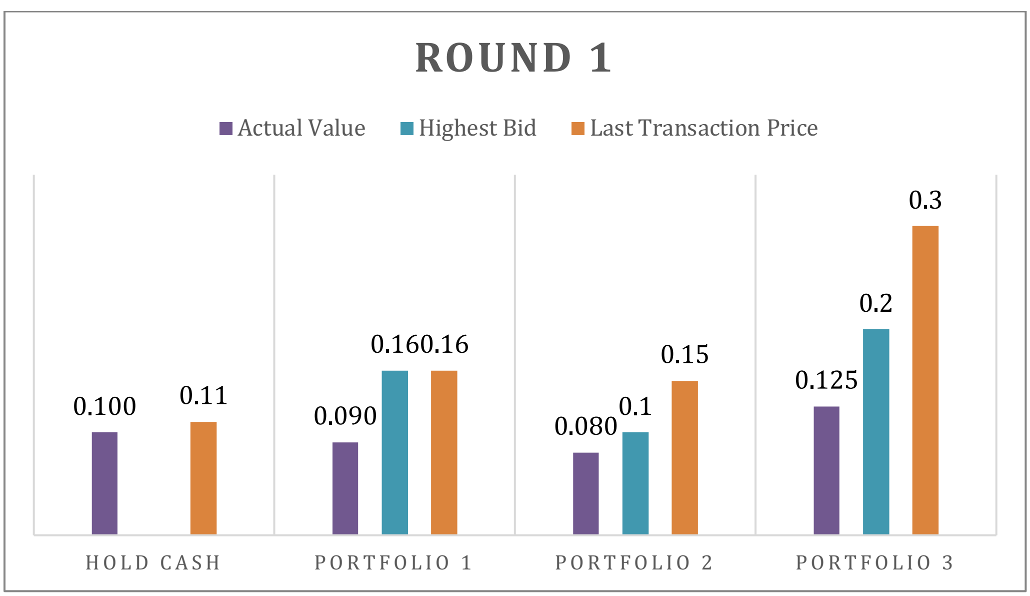


Figure 4-2. Results of the Parallel Markets at the end of the First Round

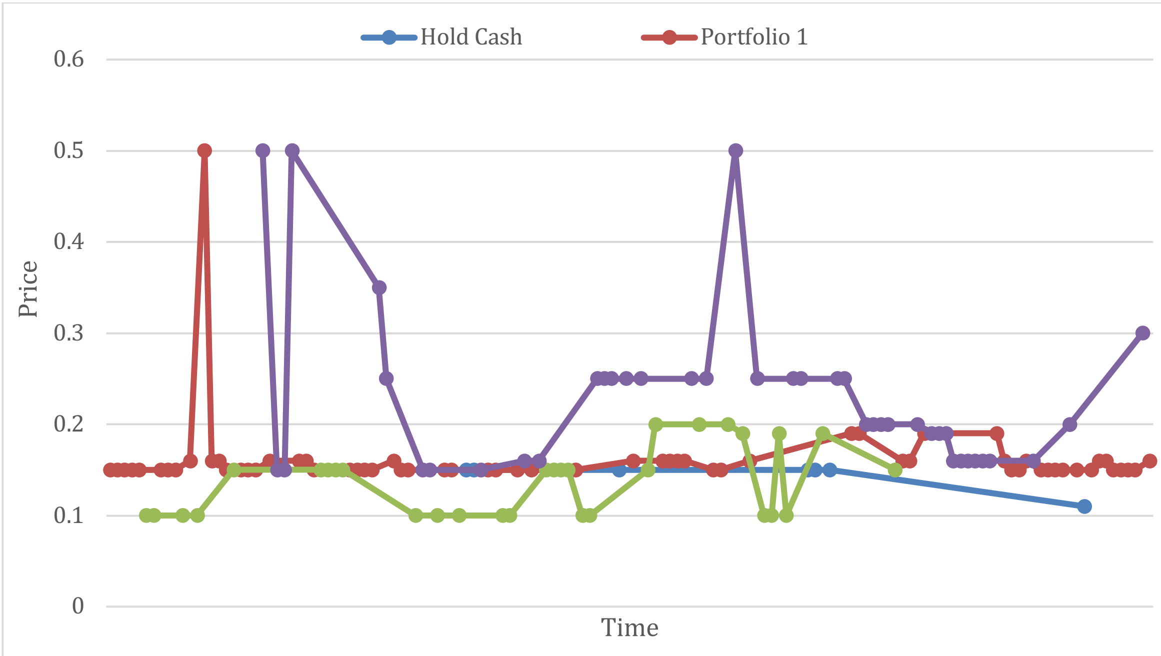


Figure 4-3. Transaction prices for conditional shares under different choices during Round 1

Figures 4-4 presents the results of the Parallel Markets at the end of the second round. The numeric data are in appendix B. The value of the mutual fund (choice 0) grew to $125K during the first month, because the last choice won at the end of the previous round. Figure 4-4 shows that portfolio 1 has the highest value and also has the highest price and bidding price and thus it wins in this round. In both the first and second rounds, the Parallel Markets were very decisive and the highest price is far from the second price.

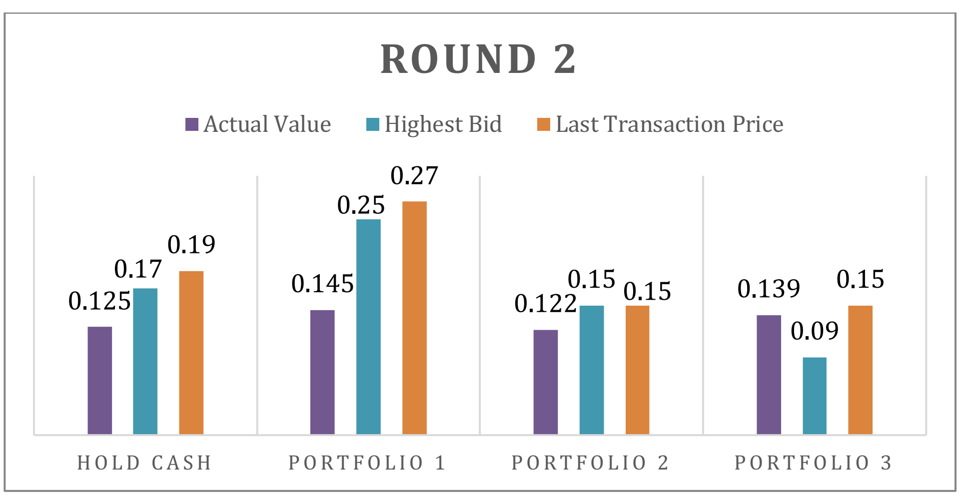


Figure 4-4. Results of the Parallel Markets at the end of the Second Round

We designed the choices in the third round so as to challenge the functionality of the Parallel Markets mechanism. As figure 4-5 shows the third round had six choices (markets). This results in a thin market for each choice considering the small number (69) of participants. Furthermore, we designed the choices so that the values of portfolios 1, 2, 4, and 5 are very close to each other. Accordingly, we have a tie among the prices of the top three choices (2, 3, and 5) as figure 4-5 shows. Even though the winner is not the choice with the maximum value, the value of the winner choice is only 1% less than the value of the top choice. This shows that the Parallel Markets still can result in acceptable selection even in very thin markets, short trading time, and small incentives.

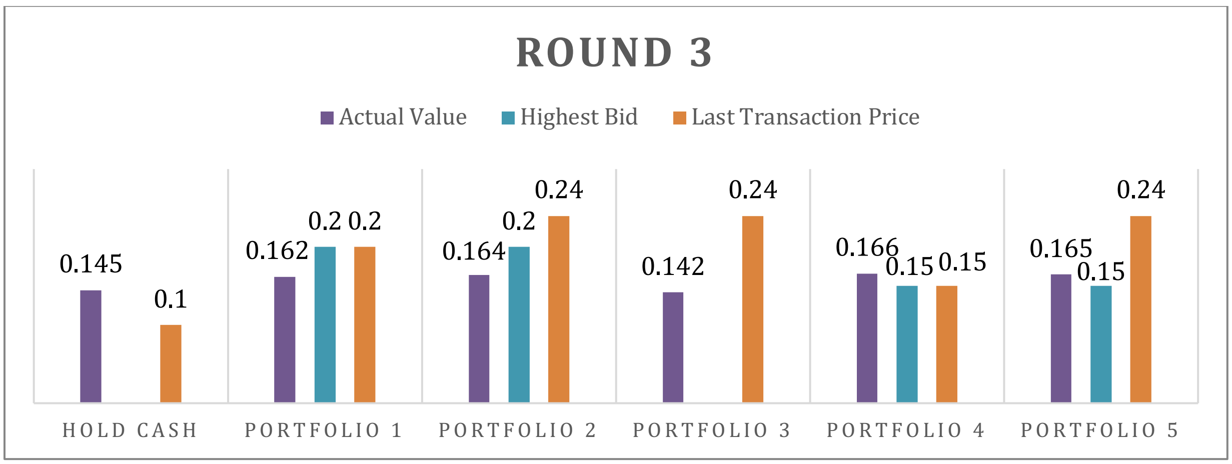


Figure 4-5. The Results of the Parallel Markets at the end of the Third Round

The fourth round had five choices and therefore again we had thin markets. Figure 4-6 illustrates the results for the fourth round. The choice with the highest value is portfolio 3. Based on the highest bid, there is a tie between portfolio 3 and 2, but based on the last transaction price, portfolio 2 wins. This means that the Parallel Markets mechanism with thin markets cannot be always accurate.

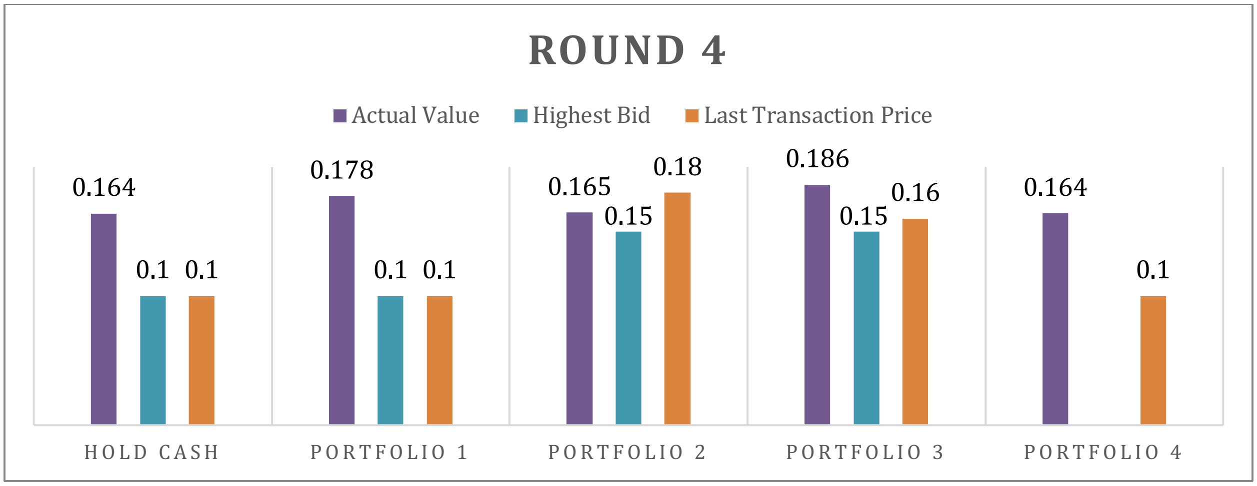


Figure 4-6. The Results of the Parallel Markets at the end of the Fourth Round

The fifth round had three choices where two choices had close values and very similar portfolios as Appendix B shows. As figure 4-7 shows, all choices are undervalued. That is perhaps because some participants preferred to have cash balance rather than shares at the end. This is understandable because participants were playing only for the monetary reward and it was their first time playing in this game. So, their decisions in the last round were affected by uncertainty regarding their remunerations. In this round, the choice with the highest value did not win, but the value of the winner choice is only 2% less than the value of the best choice (maximum value).

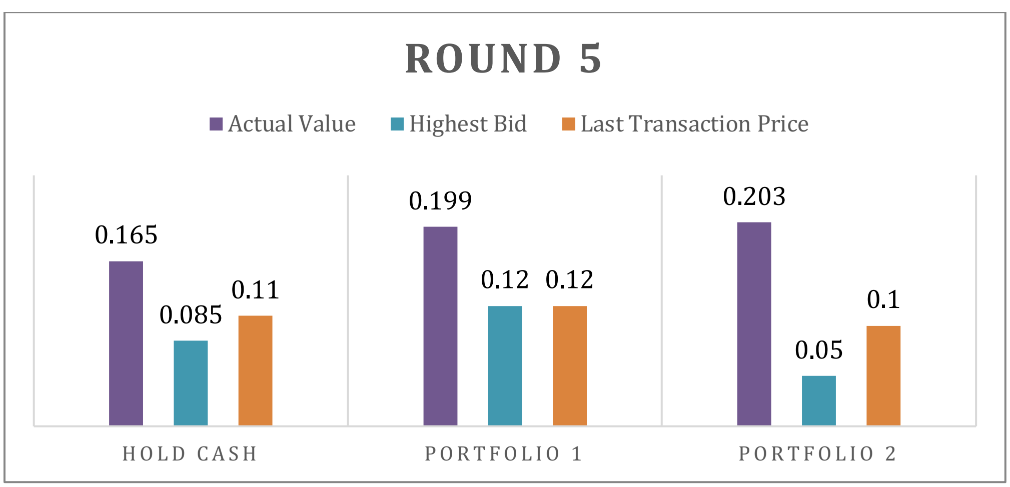


Figure 4-7. The Results of the Parallel Markets at the end of the Fifth Round

Overall, the results demonstrated the functionality of the Parallel Markets mechanism. Therefore, it can be used to make decisions without a central authority. The performances of the Parallel Markets are relatively acceptable considering the small number of participants (thin markets), the small incentives that they have (few dollars each round), their lack of expertise in the financial markets (MTurk workers), and the short length of time in each round (10 minutes). Most likely, in the real stock markets, there are many more participants with larger incentives and more trading activities. Also, many of them are professional traders who do not let any arbitrage opportunity go wasted. Moreover, they will have more time to analyze and calculate the values of the choices thoroughly.

5. Subject Level Analysis

There were two surveys, one before and one after the trading game. At first 69 subjects participated and did the first survey (i.e. treatment delivery), but 10 of them abandoned the experiment before the end (i.e. attrition = 14.5%). The remaining 59 participants stayed until the end and completed the final survey (i.e. treatment adherence). Their average age was 35 and 31% of them were female and 95% were English speakers. The older participants were less likely to speak English (ρ=-.*48*). On average, it took a participant 8.2 minutes to answer the first survey and 4.3 minutes to answer the final survey. The times taken to do the surveys were positively correlated (ρ=.*57*) and also were affected by the age and language of the participants. It took the older participants longer times to finish the surveys after controlling for language. The English speakers did the first survey significantly faster, but language had no significant effect on the time taken to finish the final survey. Table 5-1 presents the OLS regression coefficient estimates obtained by IBM® SPSS®. Figure 5-1 illustrates the path diagram for the Structural Equation Model (SEM).

Dependent Variable	Predictor	Coefficient	Standard Error	Standardized β	*P*
First Survey (in seconds)	*English*	-419*	226	-.26	.07
	Age	8.0*	4.8	.23	.1
*N=59 , df (for residuals)= 56 , R^2=.42 , F = 5.92*** (p=.005)*					
Final Survey (in seconds)	*English*	5.07	77.1	.01	.95
	Age	5.02***	1.64	.42	.003
*N=59 , df (for residuals)= 56 , R^2=.42 , F = 5.94*** (p=.005)*					

Table 5-1. OLS coefficient estimates for the model on the survey times (* ≡ p <0.1, *** ≡ p <0.01)

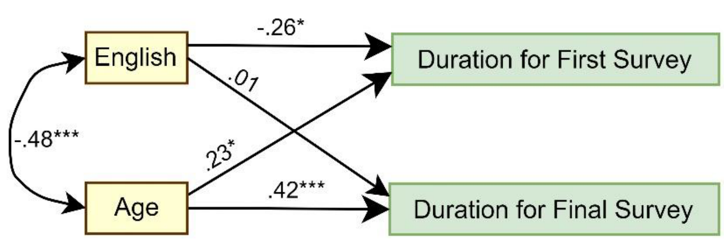


Figure 5-1. Path diagram with standardized estimates for the survey times (* ≡ p <0.1, *** ≡ p <0.01)

To measure how well the participants understood the instructions, the first survey included two questions as manifests for the Comprehension construct:

Comprehension1: *Are the instructions clear and understandable?*

[1 = Very confusing…10 = Completely clear and easy to understand]

Comprehension1: *How well did you comprehend the rules of the game?*

[1 = I could not understand them at all…10 = I understood them completely]

The average responses to these two questions were 8.5 and 8.7 respectively and they were positively correlated ($\rho=.74$), supporting that they reflect the same latent variable. To measure the participant' financial knowledge, the first survey included two questions as manifests for the Knowledge construct:

Knowledge1: *What do you think is your level of expertise in the financial markets?*

[1=Never heard of it … 10= A professional trader]

Knowledge2: *How do you compare yourself to others in terms of financial literacy?*

[1=Everybody knows better than me …. 10= I know better than 99% of people]

The average responses to the above questions were 5.51 and 5.51 respectively and they were positively correlated ($\rho=.8$), supporting that they reflect the same latent variable.

The first hypothesis (H1) is that Knowledge (in financial markets) is positively associated with Comprehension (of the instructions). That is because the instructions included financial terms (e.g. mutual fund, shares, etc…), and participants with financial knowledge can better understand financial terms.

The second hypothesis (H2) is that being an English speaker is positively associated with higher Comprehension. It is obvious because the instructions were in English.

The third hypothesis (H3) is that people who reported to have more financial knowledge expected to earn more rewards in the experiments. That is because they are more confident. To measure expected earning, the first survey included this question:

Expected Earning: *How much do you think you will earn in this game?*

.$5 .$5-$7 .$7-$10 .$10-$13 .$13-$16 .$16-$20 .$20-$25 .$25-$30 .$30-$40 .$40-$50

The choices ranged from \$5 to \$50 and the participants on average chose the 4th choice, which is between \$10 and \$13.

The fourth hypothesis (H4) is that Comprehension is positively associated with giving the correct answer to a check question about the instructions. The first survey included this check question:

> Correctness: *How many rounds are there in the game?*
>
> *[1 = One… 10 = Ten]*

The correct answer is five. If the subject gave a wrong response, the program prompted him/her to read the instructions carefully and recorded this mistake as level zero for a check. Only five out of 59 participants (8.5%) provided an incorrect response.[3]

The fifth and sixth (H5 & H6) hypotheses are that Comprehension and Knowledge are positively associated with the Final Balance respectively. The final balance was the sum of the cash balance and the cash value of the number of shares each participant owned at the end. The average final balance for a participant was \$11.68 and the sum of the final balances for 59 participants was \$689.28.

The seventh and eighth (H7 & H8) hypotheses are that Comprehension and Knowledge are positively associated with the Transaction Volume respectively. The transaction volume was the sum of the absolute volumes (in dollars) of the transactions each participant made throughout the game. The absolute volume for each transaction is the price times the number of shares transacted. On average each participant made total transactions of \$44.72 in volume and the sum of transaction volumes in the game was \$1319.24 for the 59 participants and \$1371.8 for all 69 participants.

To test these hypotheses, I used IBM® SPSS® AMOS 26.0 and included age and gender as control variables in the SEM. Table 5-2 provides the estimated coefficients and their p values, and Figure 5-2 provides the path diagram with the standardized coefficients (β) for the complete SEM in AMOS.

Performing backward elimination results in a more parsimonious (reduced) model with better fitness statistics. Table 5-3 shows the coefficients for the reduced model and Figure 5-3 presents the standardized estimates of its SEM path diagram.

[3] At first, I wanted to include the check question as an item for Comprehension, but the correlation was not large enough. (i.e. no convergent validity)

Association	Coefficient	Standard Error	Standardized β	p
Construct: Comprehension → Comp1	1***	0	.778	<.001
Construct: Comprehension → Comp2	1.145***	.204	.953	<.001
Construct: Knowledge → Know1	1***	0	.899	<.001
Construct: Knowledge → Know2	1.005***	.145	.882	<.001
H1: Knowledge → Comprehension	.374***	.108	.551	<.001
H2: English Speaking → Comprehension	1.063	.747	.185	.155
H3: Knowledge → Expected Earning	.422***	.143	.391	.003
H4: Comprehension → Correctness	5.121*	2.754	.252	.063
H5: Comprehension → Final Balance	.281	.368	.136	.445
H6: Knowledge → Final Balance	.04	.254	.028	.876
H7: Comprehension → Transaction Volume	3.982	8.534	.083	.641
H8: Knowledge → Transaction Volume	2.881	5.895	.088	.625
Control: Age → Comprehension	-.007	.016	-.06	.643
Control: Gender → Comprehension	-.143	.323	-.052	.657
Control: Age → Knowledge	-.03	.024	-.169	.207
Control: Gender → Knowledge	-1.048*	.543	-.26	.054
N=59 , df = 36 , χ^2 = 42.63 (p=.21) , CMIN = 42.63 , RMR = 20.3 , GFI = .89 , CFI = .96 , RMSEA = .06				

Table 5-2. Path coefficient estimates for the complete SEM w/ latent variables (* ≡ p <0.1, *** ≡ p <0.01)

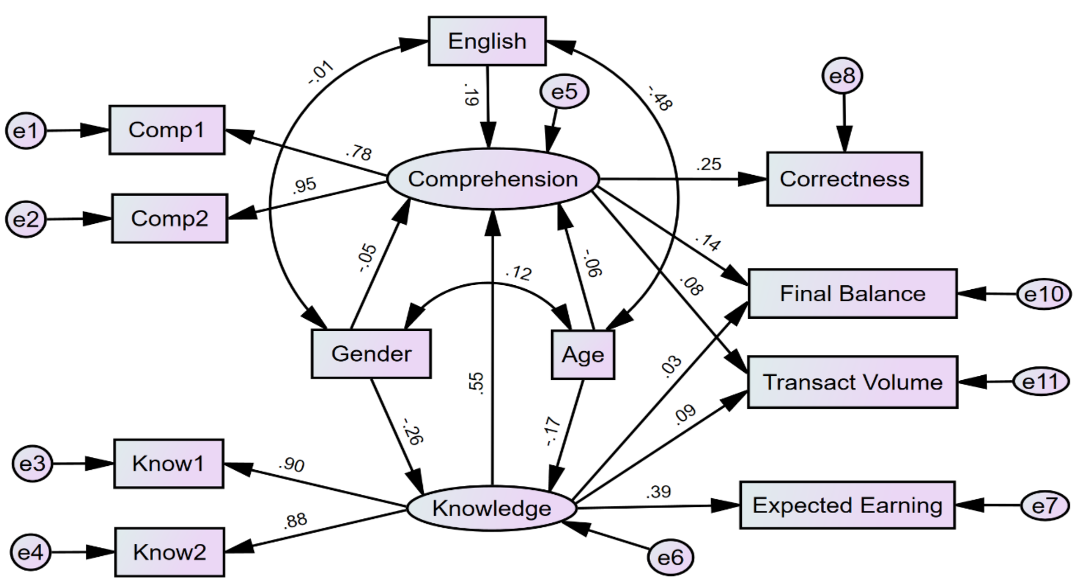


Figure 5-2. Path diagram with the standardized estimates for the complete SEM in AMOS

Association	Coefficient	Standard Error	Standardized β	*p*
Construct: Comprehension → Comp1	1***	0	.767	<.001
Construct: Comprehension → Comp2	1.169***	.220	.962	<.001
Construct: Knowledge → Know1	1***	0	.895	<.001
Construct: Knowledge → Know2	1.011***	.146	.885	<.001
H1: Knowledge → Comprehension	.389***	.108	.581	<.001
H2: English Speaking → Comprehension	1.236*	.662	.220	.062
H3: Knowledge → Expected Earning	.423***	.144	.392	.003
H4: Comprehension → Correctness	5.018*	2.793	.242	.072
Control: Gender → Knowledge	-1.163**	.543	-.289	.032
N=59 , df = 18 , χ^2 = 17.89 (p=.46) , CMIN = 17.89 , RMR = 2.16 , GFI = .93 , CFI = 1.00 , RMSEA = 0				

Table 5-3. Path coefficient estimates for reduced model w/ latent variables (* ≡ p <0.1, ** ≡ p <0.05, *** ≡ p <0.01)

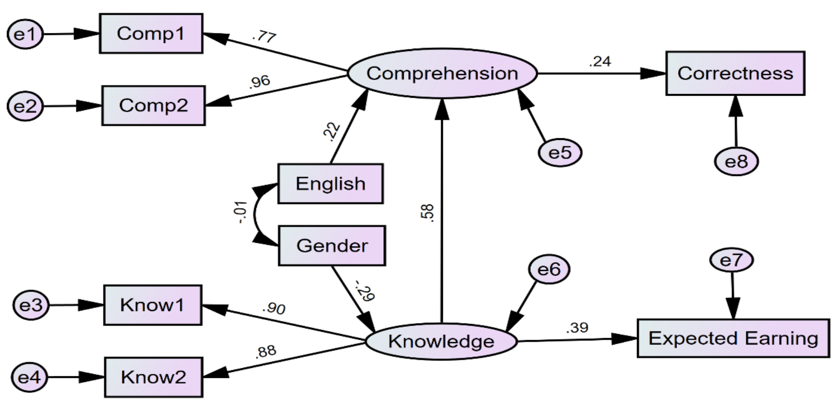


Figure 5-3. Path diagram with the standardized estimates for the reduced model in AMOS

The control variables had no effect, except gender (male=0, female=1) had a negative effect on knowledge, meaning that women on average reported being less knowledgeable than men in financial markets. The results supported hypotheses H1 to H4 but did not support hypotheses H5 to H8. Naturally, we expect that the subjects with more knowledge about the financial markets and more understanding of the game should make more transactions and gain a larger final balance. However, they did not do that. This points us to the main shortcoming of these experiments. Perhaps, the amounts of rewards were not large enough to incentivize participants to trade more, especially in a calculated manner. However, those who engaged in more trading should have made more profit. So, I hypothesize (H9) that higher transaction volume is positively associated with a larger final balance for each participant. Furthermore, in the previous section, we saw that in the final rounds the choices were underpriced. Therefore, those who made more buying than selling in the last two rounds should have higher final balances. To measure that, I defined this variable for each participant:

Net volume in the last two periods = Volume of Buy Transactions – Volume of Sell Transactions

, and I hypothesize (H10) that higher Net volume in the last two periods is positively associated with the final balance. Now I define three more variables as the answers to three questions in the final survey:

Ease: *Was the game easy to follow?*

[1 = No it was very confusing … 10 = Yes it was completely clear and easy]

Quality: *How were the overall quality of the game and the website?*

[1 = Very poor … 10 = Very effective]

Final Rating: *The final outcome is as follows. Please rate it.*

[1 = The worst possible outcome … 10 = The best outcome with maximum profit]

(Below this question they saw the final winner choice.)

The average response levels were 6.4, 7.4, and 5.6 for the Ease, Quality, and Final Rating respectively. The next hypothesis (H11) is that those who perceived the game to be easier to follow made more transactions. That is because they should have found it easier to engage in trades. Similarly, I hypothesize (H12) that those who have perceived the game and website to have higher quality, have made more transactions. That is because a higher-quality website would facilitate trading more effectively. The next hypothesis (H13) is that higher (perceived) quality of the website is positively associated with the perceived ease of following the game. That is because a higher quality website would make it easier for the participants to follow the game and its process. Also, those who perceived the game to be of higher quality should have perceived the outcome of the game of higher quality as well. So, I hypothesize (H14) that the higher perceived quality of the game is positively associated with the higher ratings for the final outcome.

To test the above hypotheses, I included age and gender as control variables and estimated the path coefficients using AMOS. Backward elimination results in a reduced model with significant coefficients as Table 5-4 presents. Figure 5-4 illustrates the path diagram for the reduced model.

The results supported hypotheses H9, H10, H12, H13, and H14 but not H11, implying that *the perceived ease of the game* does not lead to more trading. Again, that can be ascribed to the small rewards for trading. Among the control variables, age had negative associations with *Ease* and *Transaction Volume*, implying that older participants found the game harder to follow and made fewer transactions. Also, gender had a positive association with the net transaction volume in the last two periods. That means, women were more likely to buy the underpriced shares at the end.

Association	Coefficient	Standard Error	Standardized β	*p*
H9: Transaction Volume → Final Balance	.01**	.004	.23	.031
H10: Net Volume Last Periods → Final Balance	.145***	.029	.54	<.001
H12: Quality → Transaction Volume	6.35*	3.39	.23	.061
H13: Quality → Ease	.555***	.12	.48	<.001
H14: Quality → Final Rating	.359***	.11	.4	<.001
Control: Age → Ease	-.087***	.026	-.35	<.001
Control: Age → Transaction Volume	-1.32*	.73	-.22	.07
Control: Gender → Net Volume Last Periods	4.42*	2.62	.22	.092
N=59 , df = 19 , χ^2 = 19.36 (p=.43) , CMIN = 19.36 , RMR = 30.28 , GFI = .93 , CFI = .995 , RMSEA = .018				

Table 5-4. Path coefficient estimates for reduced model w/ final measures (* ≡ p <0.1, ** ≡ p <0.05, *** ≡ p <0.01)

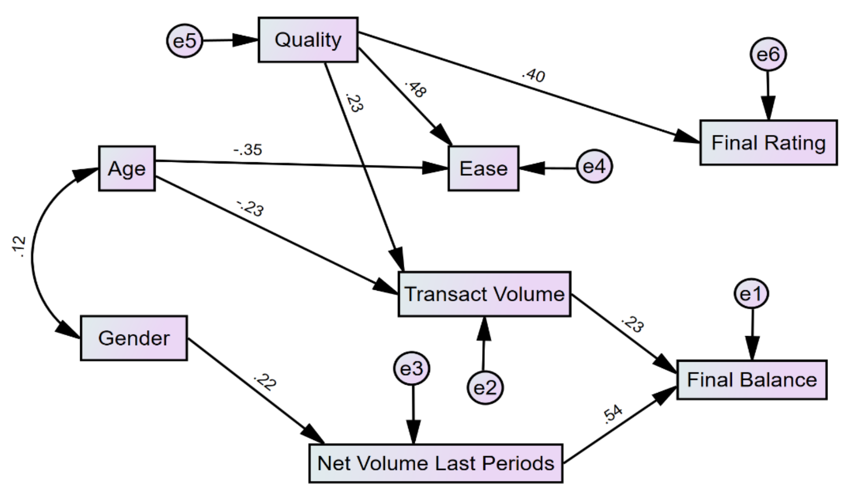


Figure 5-4. Path diagram with the standardized estimates for the reduced model with the final measures

Overall, the findings are not surprising, but they are limited due to the small sample size and small incentives for active participation.

6. Parallel Primary Markets

The Parallel Markets mechanism described in section 2 is based on using secondary markets or derivatives markets to discover prices. Therefore, the number of outstanding shares is fixed. In such markets, each offer should be cleared by counteroffer(s). This can stack up unfulfilled offers in queues. Therefore, it needs many orders (offers) to attain enough liquidity and discover prices accurately. This section introduces *Automated Primary Markets* as an alternative mechanism to fulfill orders and discover prices without counteroffers or an exchange.

6.1. Automated Primary Markets

An Automated Primary Market mechanism is similar to the *bonding curve contracts* (Riady, 2018) but replaces the bondholders with shareholders who are the residual claimants and share the profits (dividends). Based on this mechanism, the company guarantees to buy and sell shares at price *f(s)*, which is an increasing function of the total number of outstanding shares (s) at any time. This can fulfil every order instantaneously by issuing and burning shares, thereby changing the number of outstanding shares. When a buy order is placed, the company automatically issues and sells out shares at the calculated price based on this function. This dilutes existing shares. When there is a sell order, the company buys back the shares at the calculated price and burns them. Therefore, the company itself can always provide full liquidity using Automated Primary Markets without trusting an exchange or any outside party.

Here, we use the same function *f(s)* for bidding and asking prices. Since the share price increases continuously according to this function, to buy Δs number of shares, the buyer should pay:

$$\Delta F = \int_{s_1}^{s_2} f(s) \,.\, ds = F(s_2) - F(s_1) \qquad (6-1)$$

Where s_1 is the initial number of outstanding shares and $s_2 = s_1 + \Delta s$ is the new number of shares after the purchase. *F(.)* is the indefinite integral of price function *f(.)* and ΔF is the amount of fund transferred to buy those shares. Similarly, when someone sells shares, the company buys them at price *f(s),* which decreases continuously as the number of outstanding shares decreases. Therefore, selling Δs number of shares will yield the seller $\Delta F = F(s_1) - F(s_2)$ in cash. We can set the constant for the indefinite integral such that $F(0) = 0$. Therefore, *F(s)* is the amount of the company's equity fund when there are *s* outstanding shares. Figure 6-1 illustrates an example of such a price function and the resulting equity fund.

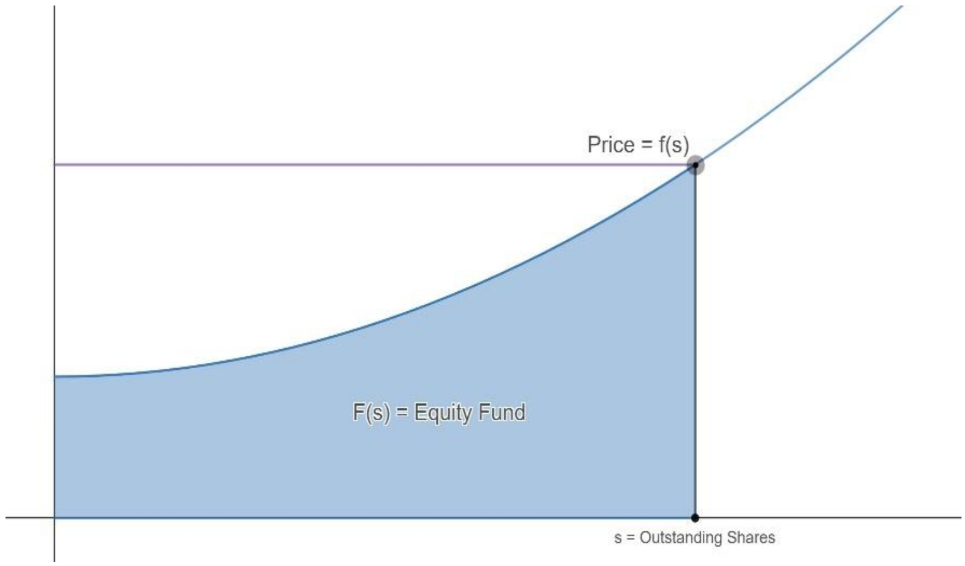


Figure 6-1. The number of outstanding shares determines price through price function f(s)

If we use the primary markets mechanism instead of secondary markets in the Parallel Markets governance mechanism, constraint (2-1) is not required anymore, because with this new mechanism, there is no outstanding offer at any time and each order is fulfilled instantaneously. The challenge is that the prices imposed by the price function *f(s)* should reflect the value of the company. Under this mechanism, the number of outstanding shares (and their price) depends on supply and demand, which in turn depend on the expected value of the company. Traders can buy and sell shares based on their perceived valuation of the shares, but when they buy (sell) shares, the number of outstanding shares increases (decreases), and thus the value of each share is diluted (enriched) if the value of the company stays constant. Therefore, the monotonicity of the price function makes the price even more sensitive to the value of the company because any deviation (if any) triggers two forces (*s* and *f(s)*) that can push the price toward equilibrium.

6.2. Parallel Primary Markets

As before, we need to control the number of proposals in each round. To this end, the system can use two more methods in addition to the four methods discussed in section 2:

5- The proposers can deposit funds to invest in their proposals at the beginning of the selection period before others. Then at the beginning of the selection period, the system sorts the choices based on their proposers' initial investments (or shares' initial prices). A larger initial investment indicates the proposer's higher confidence in his suggestion. Moreover, this rewards the proposers of superior suggestions by giving them the privilege to be the first who buys shares of their own choices.

6- The choices can be sorted based on the number of shares their proposers will have after the initial investment in their choices.

Under the Parallel Primary Markets mechanism, the price function is the same for all choices during each selection period, as figure 6 – 2 shows. However, different choices have different expected values and returns (r_s & r_d) and this results in different equilibria for them. Therefore, they will sell a different number of shares, reach different prices, and raise different amounts of funds. We expect the equilibrium prices of the choices reflect their expected values. At least the choice with the highest price has the highest value.

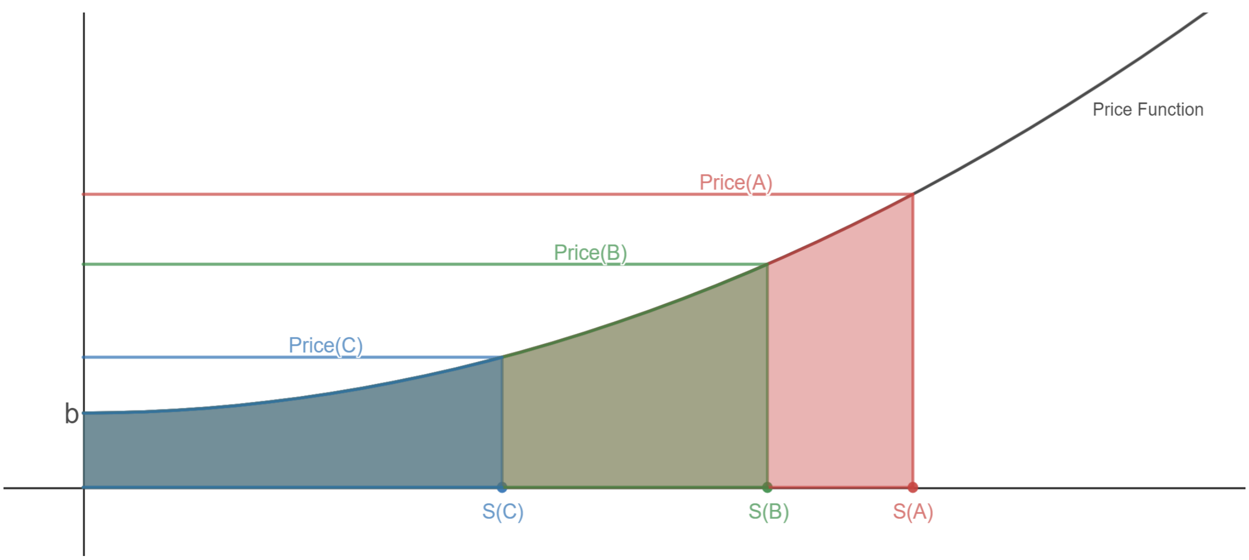


Figure 6-2. Parallel Primary Markets with three choices: S(.) denotes the number of outstanding shares and Price(.) denotes the equilibrium price for each choice.

When using automated primary markets, the orders are fulfilled instantaneously. Appendix C shows the transaction page for placing orders in the Parallel Primary Markets. Once a person places an order, the order is processed according to the flowchart shown in figure 6-3. This figure shows an accounting process similar to what is described in section 2. At the end of each selection period, the choice with the highest price (most shares) wins and becomes the effective decision. The number of shares for this choice and their distribution among individuals become the number of outstanding shares for the company and their distribution. The winning balances (W_w) for the winner choice become cash, but its void balances (V_w) are discarded because its transactions are confirmed. On the other hand, the shares for other choices and their winning balances (W_i) are discarded, but their void balances (V_i) are refunded and added to their cash balances. Then the cash balance of each individual is updated based on equation 2-4 restated here:

$$B := B + W_w + \sum_{j \neq w} V_j \qquad (2-4)$$

, wherein B is the person's cash balance and W_w is his winning balance for the winner choice. V_i is the void balance for choice i, which is not the winning choice. The funds collected for the winner choice are invested in the company, but the funds collected for the other choices (void balances) are returned.

The realization of profit or loss or distribution of dividends can be implemented via a transformation of the price function as discussed in the previous section. This will change the amount of the equity fund without changing the number of shares. This transformation can be executed at any time, but to avoid complications we better not do it during the selection periods when there are multiple versions of the shares.

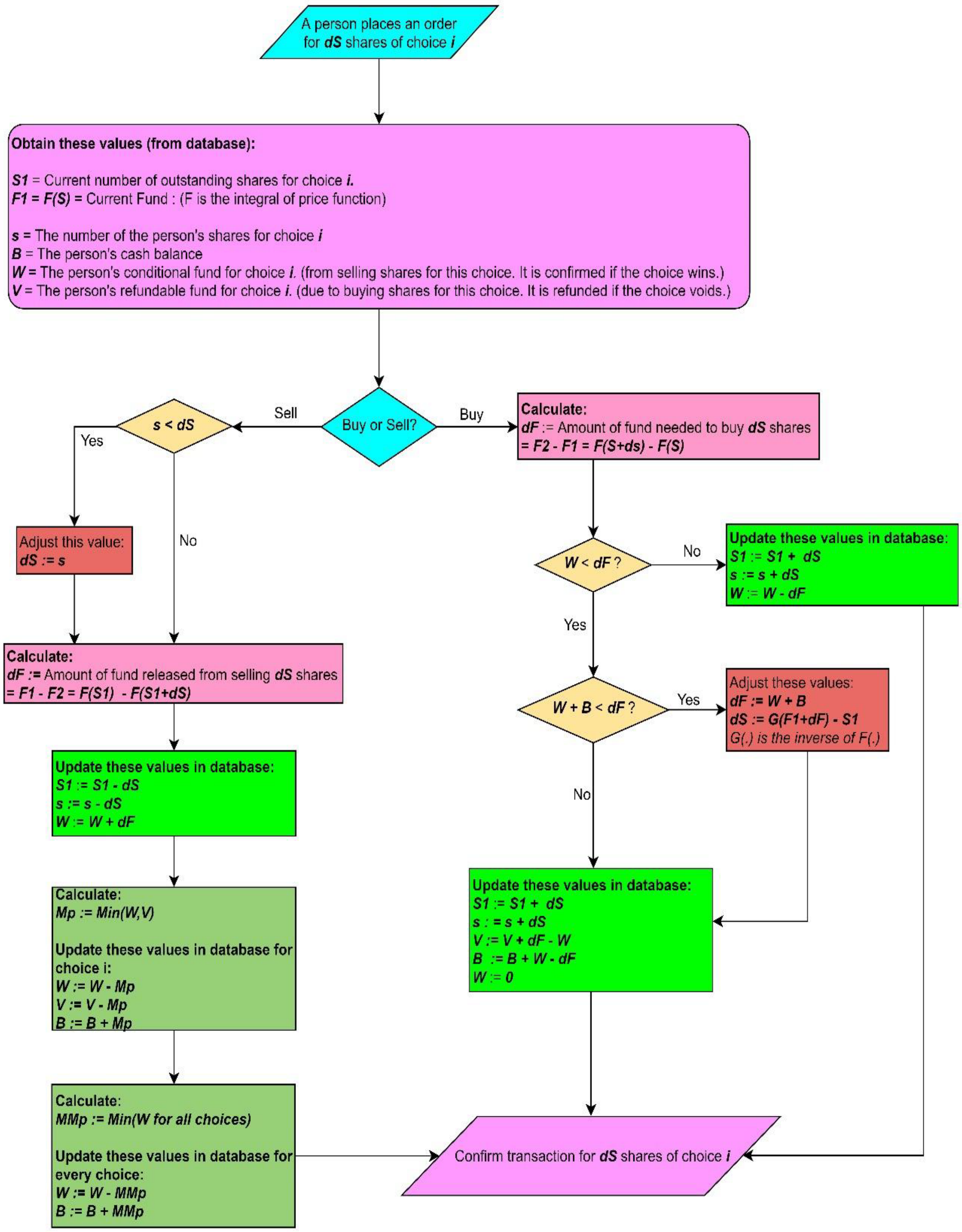


Figure 6-3. The flowchart for processing an order in the Parallel Primary Markets governance mechanism

6.3. Experimentation

Experiments for the Parallel Primary Markets will be different from the experiments for the parallel secondary markets. The trading page does not have open orders or offers anymore as Appendix C shows. The instructions are different too. The following are the instructions I suggest for experimenting with the Parallel Primary Markets governance mechanism. It uses a linear price function and multiplicative transformation, but one can easily modify it to use quadratic or other price functions and other transformations.

*<u>Imagine it is 1/1/2019</u> and you have $10 cash, which you can invest in a mutual fund (*company*). At the beginning of this day, the* company *has no assets or cash, but it can raise funds in five rounds. Each round is 10 minutes at the beginning of one of five months. The first 10 minutes round takes place on January 1st. During this round, you and others can buy shares of the* company *and supply funds for it. Then an algorithm selects where the* company *invests for January for the entire group. The computer calculates the return for January and skips ahead to February 1st when the second 10 minutes round takes place. Then again you and others can buy more shares or sell your shares. And this process repeats. Similarly, the third, fourth, and fifth rounds take place on March 1st, April 1st and May 1st.*

<u>Choices:</u> The investment choices in each round include "holding cash" and a few portfolios of cryptocurrencies. At the beginning of each month, the selection algorithm selects to invest in one of the suggested portfolios or "hold cash" until the end of the month. Then the company *applies the selected choice to the funds collected for that choice but returns the funds collected for all other choices. So, the shares are "conditional" shares depending on whether their choice is selected. At the end of each month, the* company *liquidates the investment and obtains cash if it was a portfolio. Then, the group can decide to reinvest the new cash in an effort to grow it or hold onto it for the upcoming month.*

<u>Selection Algorithm:</u> During each 10-minute round you and others can buy and sell shares of the company *for each choice assuming that the choice will be selected. Your transactions will result in one price for each choice at the end of each round, and then the choice with the highest price is selected as the investment for that month. The transactions and shares for this choice are confirmed but the transactions and shares for other choices are voided and the payments are returned. This reduces your risk if a choice's price declines. In the next round, the shareholders of the selected choice will own the same number of shares for every choice, but of course, only one of those choices will be selected and confirmed at the end. There are no transaction costs or fees.*

<u>In the end</u>, the total monetary value of the company *(on June 1st) is calculated and you will see a short survey. If you stay in the game until the end and complete the survey, you will be paid your (individual)*

cash balance plus the dollar equivalent of your shares in the final company. *Your payoff will be at least $10 and at most $30 depending on your participation:*

Your payoff =

*Your cash balance + (Your number of shares) * (Final value of the* company*) / (Final number of shares)*

In addition, the participant with the highest final payoff will receive a $20 bonus!

<u>*Hint:*</u> *Each round, you should evaluate each choice and buy its shares if its price is lower than its share value and sell its shares if its price is higher than its share value. You can make money both ways if you estimate the share value for a choice. You want to sell the overpriced choices and buy the underpriced ones. You can use historical data on websites such as CoinMarketCap to calculate the performance of each portfolio, which is the weighted average of the performance of its assets. If the algorithm selects to hold cash for a month, the total value will not change (performance = 1). Please have a calculator or Excel sheet ready.*

<u>*Share Price:*</u> *The* company *uses the price function (Price = a+b.S) to determine the share price as an increasing function of the number of outstanding shares (S). For every buy order, the* company *issues shares at the calculated price at that time, and for every sell order, the* company *buys back shares at the calculated price at that time. The values of a and b are determined at the beginning of each round. In the first round a=1 and b=1, therefore: Price = 1+S.*

Meanwhile, as S continuously changes, the price also continuously changes and thus the average price is a little different from the beginning price for each transaction.

At the end of each month, the computer adjusts the price function to reflect the new amount of funds. To this end, the parameters a and b are multiplied by the realized performance of the investment. Then the investment process repeats using the new price function.

6.4. Financing with Equity

Now first, let's assume that the company raises funds only by issuing shares in the automated primary markets and receives $F(s_e)$ amount of money by issuing s_e number of shares in a specific period. Then it invests this money on a profitable project with the expected net present value of *NPV* and expected *ROI* of r_s adjusted for inflation and risk premium. Therefore, $NPV = (1+r_s) \,.\, F(s)$ is the expected net present value of the company and its future cash flows. When there are *s* shares, the expected value of one share is:

$$v(s) = \frac{(1 + r_s).F(s)}{s} \qquad (6-2)$$

Generally, rational participants buy shares when $v(s) > f(s)$ and sell shares when $v(s) < f(s)$. Therefore, in equilibrium, $v(s_e) = f(s_e)$ and the equilibrium is stable iff $v(s_e + \varepsilon) < f(s_e + \varepsilon)$ and $v(s_e - \varepsilon) > f(s_e - \varepsilon)$. In short, s_e is the stable equilibrium level iff $v(s) - f(s)$ is zero and strictly decreasing at $s = s_e$:

$$(1 + r_s).\frac{F(s_e)}{s_e} - f(s_e) = 0 \qquad (6-3)$$

and,

$$(1 + r_s).F(s_e) - (1 + r_s).f(s_e).s_e + f'(s_e).s_e^2 > 0 \qquad (6-4)$$

Equation (6-3) as a differential equation characterizes the functions that satisfy the equation for ALL *s* and do NOT result in a nontrivial equilibrium point. Its solution is $f(s) = C.s^{r_s}$, where *C* is any constant. This function makes the participants neutral to buy or sell at any level of *s*. If $f(s) = C.s^h$ where $h \neq r_s$,then the only equilibrium point will be $s_e = 0$. This finding rules out any power function to be used in the Parallel Markets governance mechanism because the price function *f(.)* should result in one *unique positive* and *stable* equilibrium price that can be used as the selection criterion in the governance mechanism. Power functions are common in bonding curve contracts (Riady, 2018).

Monotonicity is another condition for the price function to be effective in the Parallel Primary Markets mechanism. Particularly a larger s_e should indicate a larger r_s. That is:

$$\frac{\partial s_e}{\partial r_s} > 0 \qquad (6-5)$$

Now, let's assume *f(.)* is a linear function of outstanding shares: $f(s) = a.s + b$ and $F(s) = ½\, a.s^2 + b.s$, like figure 6-4 illustrates. Then the equilibrium becomes:

$$s_e = \frac{2b.r_s}{a(1-r_s)} \quad \Rightarrow \quad f(s_e) = \frac{b(1+r_s)}{1-r_s} \quad \Rightarrow \quad F(s_e) = \frac{2b^2.r_s}{a(1-r_s)^2} \qquad (6-6)$$

It yields a valid equilibrium point for $0 < r_s < 1$, which would be the case for most investments. This also satisfies equation (6 - 4) because the following is positive for $r_s < 1$:

$$\frac{a.s_e^2}{2} + bs_e + \frac{a.r_s.s_e^2}{2} + br_s s_e - (1+r_s).(as_e + b).s_e + \ a.s_e^2 = \frac{a.s_e^2}{2} - \frac{a.r_s.s_e^2}{2} = \frac{a.s_e^2}{2}(1-r_s) > 0$$

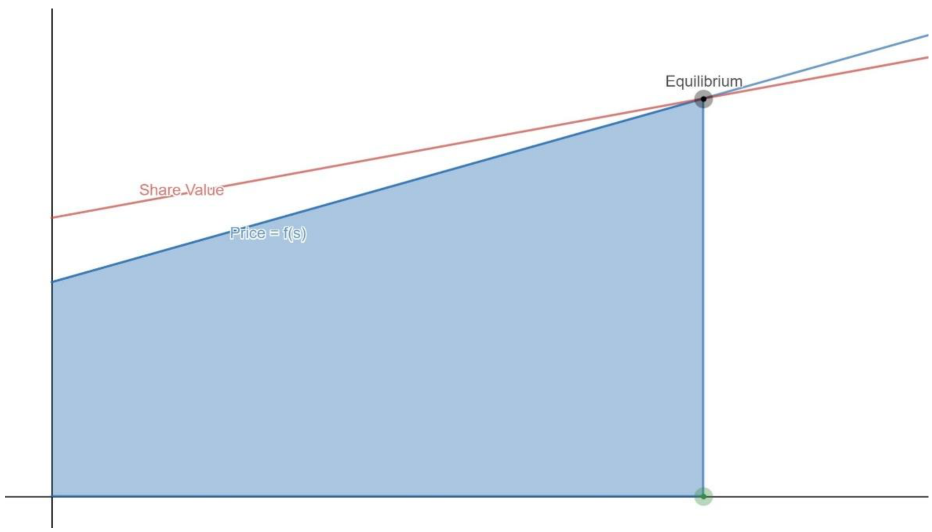


Figure 6-4. Equilibrium happens where the value per share equals the price of one share

However, if an investment has an expected *ROI* of more than 100% (adjusted for inflation and risk), the above answer results in unstable growth so that when more shares are issued the value of each share increases faster than its price. But, if we use $f(s) = a.s^2 + b$ and $F(s) = ⅓\, a.s^3 + b.s$, then:

$$s_e = \sqrt{\frac{3br_s}{a(2-r_s)}} \quad \Rightarrow \quad f(s_e) = \frac{2b(r_s+1)}{(2-r_s)} \quad \Rightarrow \quad F(s_e) = \frac{1}{3}\sqrt{\frac{1}{a}\left(\frac{3br_s}{2-r_s}\right)^3} + b\sqrt{\frac{3br_s}{a(2-r_s)}} \qquad (6-7)$$

This is a unique, positive, and stable equilibrium for $0 < r_s < 2$, which means *ROI* of less than 200%, because, equation (6-4) holds for $r_s < 2$:

$$(1+r_s)\left(\frac{a}{3}s_e^3 + bs_e\right) - (1+r_s)(as_e^3 + bs_e) + \ 2as_e^3 = \left(\frac{4}{3}as_e^3 - \frac{2}{3}ar_s s_e^3\right) = \frac{2}{3}as_e^3(2-r_s) > 0$$

6.5. Financing with Debt

While the above functions can be used for experimentation, in reality, such a company has to use debt to be able to invest in long term projects. Particularly, our company needs to keep its equity fund *F(s)* mostly liquid to be able to buy back shares upon sell orders. So, let's assume the company borrows *D* amount of debt and pays interest of d_i on it and expects *ROI* of d_r out of it. So the expected net *ROI* for debt is: $r_d = d_r - d_i$. The company may also invest the fund *F(s)* in current assets, but most likely its *ROI* will be smaller (i.e. $r_s < r_d$). As a result, $NPV = (1+r_s).F(s) + r_d.D$ is the expected net present value of the company and its future cash flows. When there are *s* shares, the expected value of one share is:

$$v(s \mid D) = \frac{(1 + r_s).F(s) + r_d.D}{s} \qquad (6-8)$$

As before, s_e is the stable equilibrium iff $v(s) - f(s)$ is zero and strictly decreasing at $s = s_e$:

$$(1 + r_s).F(s_e) + r_d.D = s_e.f(s_e) \qquad (6-9)$$

$$(1 + r_s).F(s_e) - (1 + r_s).f(s_e).s_e + f'(s_e).s_e^2 > 0 \qquad (6-10)$$

Again, the first differential equation characterizes the functions that have all *s* as equilibrium points. Its solution is the same as before: $f(s) = C.s^{r_s}$, where *C* is any constant. But if $f(s) = a.s + b$, then we have $F(s) = ½\, a.s^2 + b.s$ and:

$$s_e = \frac{b.r_s + \sqrt{b^2.r_s^2 + 2a(1 - r_s).r_d.D}}{a(1 - r_s)} \;\Rightarrow\; f(s_e) = \frac{b + \sqrt{b^2.r_s^2 + 2a(1 - r_s).r_d.D}}{(1 - r_s)} \qquad (6-11)$$

It is the only equilibrium because the negative sign before radical always results in a negative value for s_e. This satisfies all the conditions when $0 \le r_s < 1$ and $0 < r_d$, both of which are likely in practice. The long term investment yields $r_d.D$, and r_s is the return on current assets. If $r_d.D > 0$ and we hold cash for $F(s_e)$, then $r_s = 0$ and we will have:

$$s_e = \sqrt{\frac{2r_d.D}{a}} \;\Rightarrow\; f(s_e) = \sqrt{2a.r_d.D} + b \;\Rightarrow\; F(s_e) = r_d.D + b\sqrt{\frac{2r_d.D}{a}} \qquad (6-12)$$

If $r_d.D > 0$ and $0 \le r_s < 1$, we can use a proportional function (i.e. $b = 0$), which yields:

$$s_e = \sqrt{\frac{2r_d.D}{a(1-r_s)}} \;\Rightarrow\; f(s_e) = \sqrt{\frac{2a.r_d.D}{(1-r_s)}} \;\Rightarrow\; F(s_e) = \frac{r_d.D}{(1-r_s)} \qquad (6-13)$$

If $f(s) = a.s^2 + b$ as figure 6-5 shows, then $F(s) = ⅓\, a.s^3 + b.s$, and:

$$a(2-r_s).s_e^3 - 3r_s b.s_e - 3r_d.D = 0 \qquad (6-14)$$

, which is a depressed cubic equation with $p = \frac{-3r_s.b}{a(2-r_s)}$ and $q = \frac{-3r_d.D}{a(2-r_s)}$. It results in the following discriminant:

$$\Delta = 4b^3.r_s^3 - 9a(2-r_s).r_d^2.D^2 \qquad (6-15)$$

When it is less than zero, the only real root becomes the equilibrium point:

$$s_e = \sqrt[3]{\frac{3r_d.D}{2a(2-r_s)}}.\left\{\sqrt[3]{1+\sqrt{1-\frac{4(r_s b)^3}{9a(r_d.D)^2.(2-r_s)}}} + \sqrt[3]{1-\sqrt{1-\frac{4(r_s b)^3}{9a(r_d.D)^2.(2-r_s)}}}\right\} \qquad (6-16)$$

, and the other roots are complex numbers.

When the discriminant is zero, the equilibrium point is:

$$s_e = \frac{3D.r_d}{b.r_s} \qquad (6-17)$$

, but the other root (double root) is negative and thus not feasible ($s_2^* = s_3^* = \frac{-3D.r_d}{2b.r_s} < 0$).

When $\Delta > 0$, there are three real roots, but only one of them is positive ($s_e > \frac{3D.r_d}{b.r_s} > 0$), which becomes the equilibrium. The other two roots are always negative and thus not feasible as figure 6-6 illustrates. It can be shown that in every case for small enough *s*, the value is more than the price ($v(s) - f(s) > 0$). Therefore, inequality 6-10 holds when they meet on the positive side, thereby making the equilibrium stable.

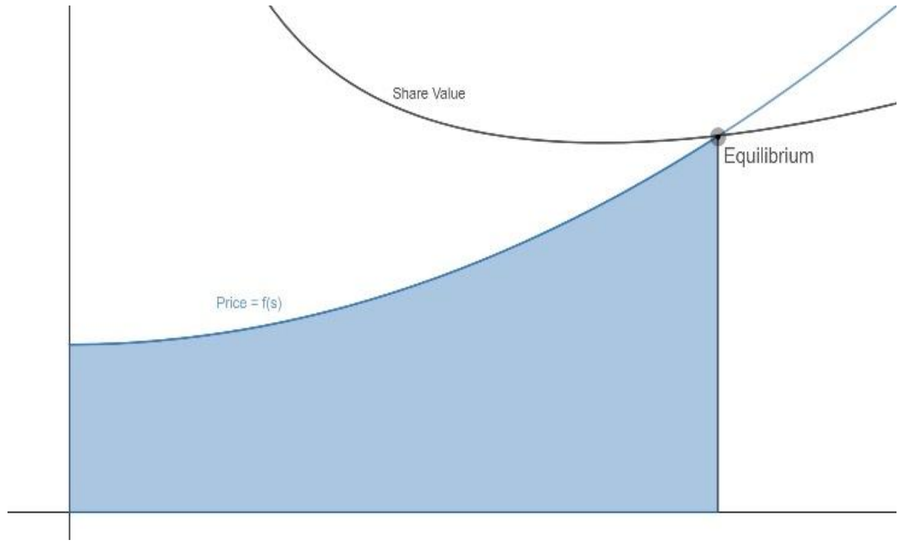


Figure 6-5. The equilibrium point is where the quadratic share price equals share value (with debt).

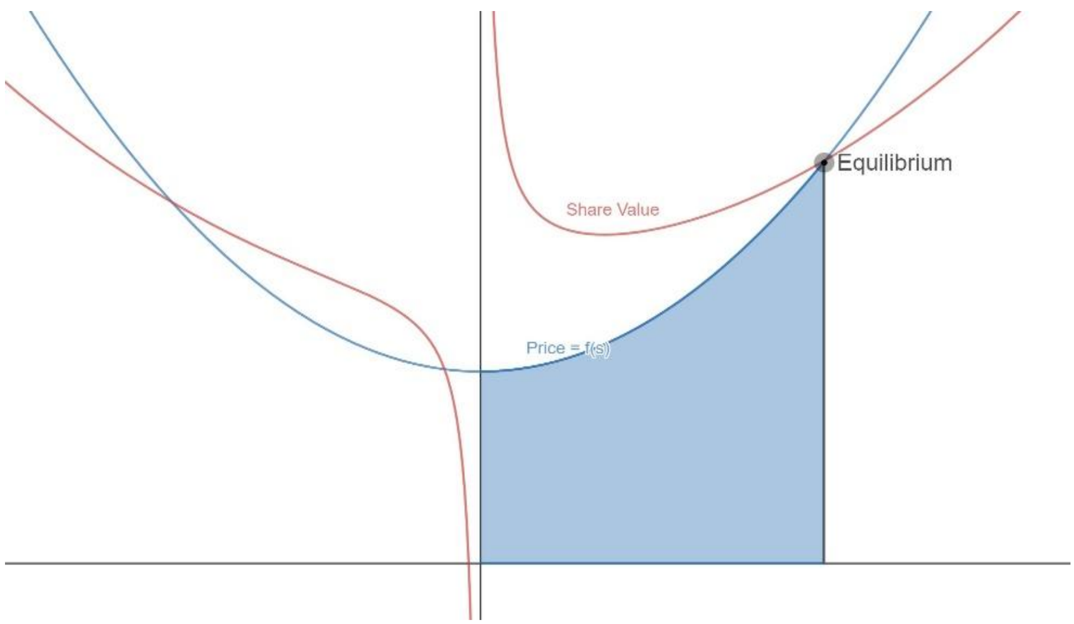


Figure 6-6. The equilibrium point is the unique positive solution for the quadratic share price (with debt).

6.6. Changes in Equity Fund

Generally, the amount of equity fund can change via three channels: (1) issuing and burning shares for buy and sell orders, (2) distribution of dividends and liquidation, and (3) realization of profits and losses.

The first channel changes the number of shares, *s,* according to the change in the equity fund, such that when someone invests ΔF into the company, Δs shares are issued where $\Delta s = s_2 - s_1 = F^{-1}(F_2) - F^{-1}(F_1)$. Here, F_1 is the initial equity fund, and $F_2 = F_1 + \Delta F$ is the new fund after issuing the shares. When someone sells Δs shares we have $\Delta F < 0$ and $\Delta s < 0$. Now, let's assume $f(s) = a.s + b$ and $F(s) = ½\, a.s^2 + b.s$, and the company currently has s_1 number of shares and $F_1 = F(s_1)$ funds. If someone invests ΔF in the company, the new number of shares will be:

$$s_2 = \frac{-b + \sqrt{b^2 + 2a(F_1 + \Delta F)}}{a} = \frac{-b + \sqrt{(as_1 + b)^2 + 2a\Delta F}}{a} = \sqrt{\left(\frac{f(s_1)}{a}\right)^2 + \frac{2\Delta F}{a}} - \beta \qquad (6-18)$$

, wherein $\beta = b/a$ is the ratio of b to a. Of course, no more than s_1 exists to be sold. Therefore, the minimum level of ΔF is $-F_1 = -F(s_1)$, which results in $s_2=0$.The second way that the equity fund can change is through the payment of dividends or distribution of funds to the shareholders. When the amount of fund changes due to factors other than changing shares, the price function can be adjusted to reflect the change in the fund. To implement such changes, we use proper transformations to adjust the price function f(.). Such transformations are discussed next when dealing with the third channel of changes.

The third channel through which, the equity fund can change is profit and loss. When there is profit, it can be distributed as a dividend to the shareholders, but what if they don't want to cash out all their profit? What if there is a loss? We need a systematic approach to deal with such changes in the equity fund. We have to adjust $f(s)$ (and $F(s)$) to reflect the new level of the fund without changing the number of shares. Here, I suggest two transformations to adjust $f(s)$; the first one holds the current price constant ($p_{new} = p_{old}$) as well as the number of outstanding shares. The other one holds the equilibrium level of shares constant ($s_{e,new} = s_{e,old}$) as well as the number of outstanding shares.

***Holding price constant*:** This makes $(s_o , f(s_o))$ the pivot point where s_o is the current number of outstanding shares and $f(s_o)$ is the current price. So, the new price function results in the same price at the current level of outstanding shares: $f_{new}(s_o) = f(s_o)$. And imposing $F_{new}(s_o) = F(s_o) + \Delta F$ will result:

$$\int_0^{s_o} f_{new}(s)\,.\,ds \; = \int_0^{s_o} f(s).\,ds \; + \Delta F \qquad (6-19)$$

This inevitably changes the equilibrium if the expectations (r_s , r_d) remain the same. Therefore, after the change in the fund, there will be transactions, and the number of outstanding shares will move towards the new equilibrium. Now, if $f(s) = a.s + b$ and $F(s) = ½\, a.s^2 + b.s$, then we have $f_{new}(s) = a'.s + b'$, where:

$$a' = a - \frac{2\Delta F}{s_o^2} \quad and \quad b' = b + \frac{2\Delta F}{s_o} \qquad (6-20)$$

But, this is limited to $\Delta F < ½\, a.s_o^2$, when realizing profit and to $(-\Delta F) < ½\, b.s_o$, when realizing loss; because we need $a' > 0$ and $b' > 0$ to have a valid equilibrium. When we realize large profits or profits in several periods, the coefficient *a* decreases very fast and the price function quickly becomes flat. Similarly, if we realize large losses or multiple losses, the intercept *b* decreases quickly and becomes zero, which means no equilibrium when there is no debt. Figure 6-7 shows this transformation and its limitations. In this figure, the red triangle is the increase in equity fund (ΔF).

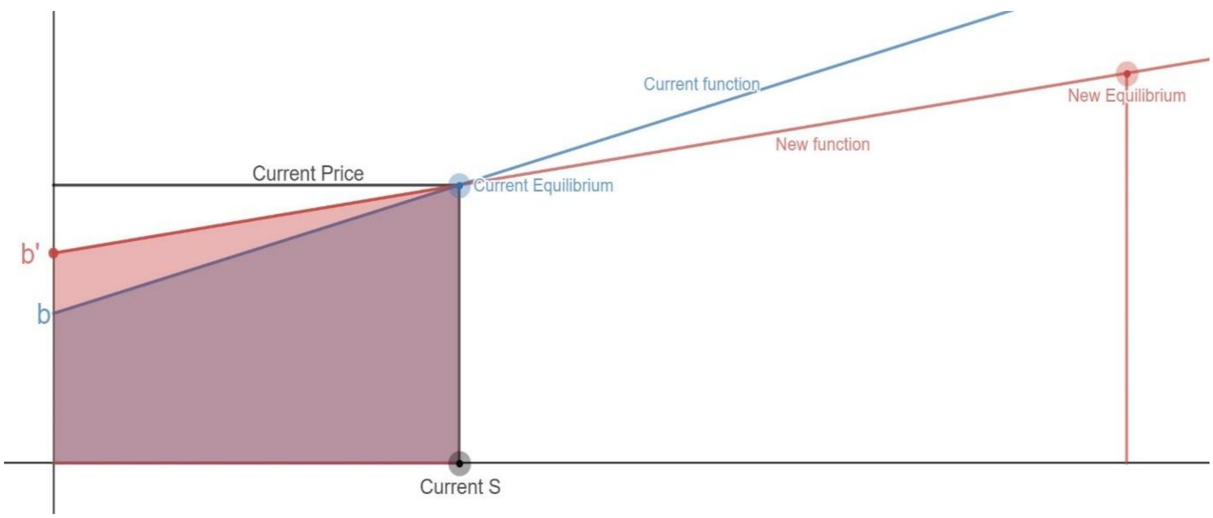


Figure 6-7. Transformation holding the (linear) price constant but letting the equilibrium point move

The limitations on fund will be much less restrictive if we use $f(s) = a.s^2 + b$ and $F(s) = ⅓\, a.s^3 + b.s$. In that case, $f_{new}(s) = a'.s^2 + b'$, where:

$$a' = a - \frac{3}{2}.\frac{\Delta F}{s_o^3} \quad and \quad b' = b + \frac{3}{2}.\frac{\Delta F}{s_o} \qquad (6-21)$$

This is limited to $\Delta F < ⅔\, a.s_o^3$, when realizing a profit and to $(-\Delta F) < ⅔\, b.s_o$, when realizing a loss. This can provide a much wider window than the linear limitation. Figure 6-8 shows this transformation and its limitations. In this figure, the red area is the increase in equity fund (ΔF).

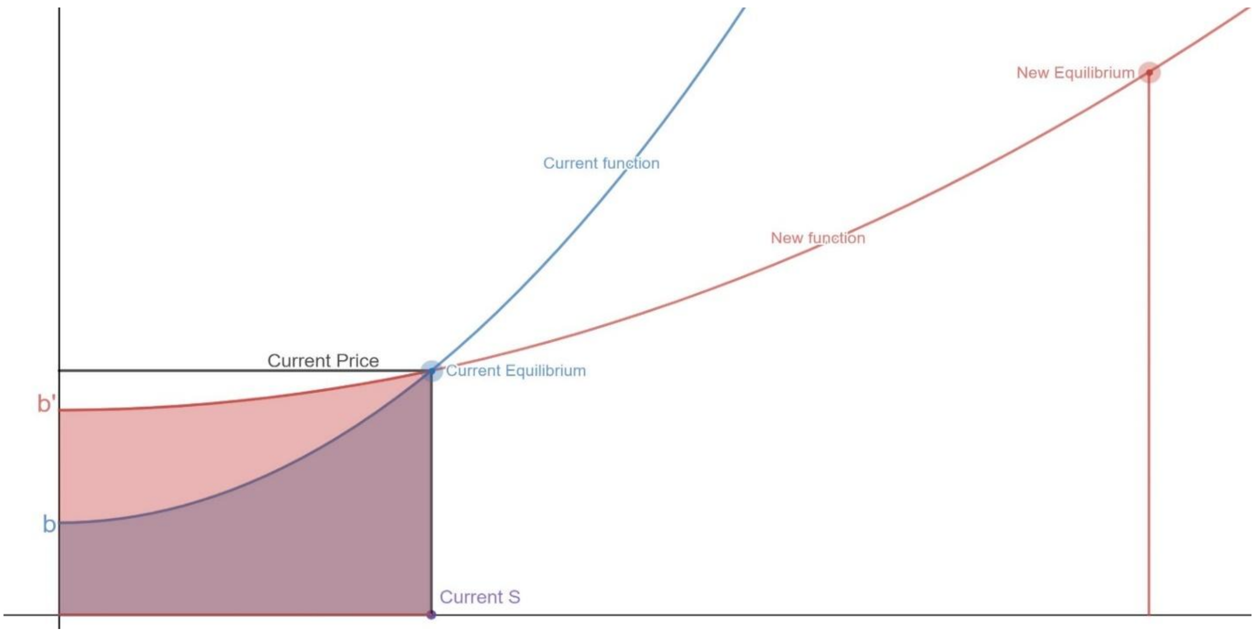


Figure 6-8. Transformation holding the (quadratic) price constant but letting the equilibrium point move

Holding equilibrium constant: The above transformations can change the equilibrium point, which might not be desirable in some situations. Moreover, they have constraints on the amount of change in the fund. So here, we suggest transformations that implement the fund change while keeping the equilibrium level constant, assuming stable expectations. When there is no debt, the transformation is simple multiplication, so it multiplies $f(.)$ by the ratio of the new equity fund to the old equity fund: $f_{new}(s) = (1+\gamma).f_{old}(s)$, wherein $1+\gamma = F_2 / F_1$ is the realized return for the fund. The *multiplicative* transformation changes the share price to reflect the new amount of equity fund without changing the number of outstanding shares or its equilibrium level. It can easily be proven that this is the only transformation that satisfies these criteria per equation (6-3). This transformation can change the fund to any nonnegative amount with no limitation. For the linear and quadratic functions, it will yield $a' = (1+\gamma).a$ and $b' = (1+\gamma).b$, where a' and b' are the new values of the parameters. This will adjust the amount of fund without changing the number of shares or β, the ratio of b to a. Figure 6-9 depicts an example of such transformation with the red area representing the added fund. The transformation can be written as follows:

$$[a'b'] \equiv \begin{bmatrix} 1+\gamma & 0 \\ 0 & 1+\gamma \end{bmatrix} [a\ b\ ] \qquad (6-22)$$

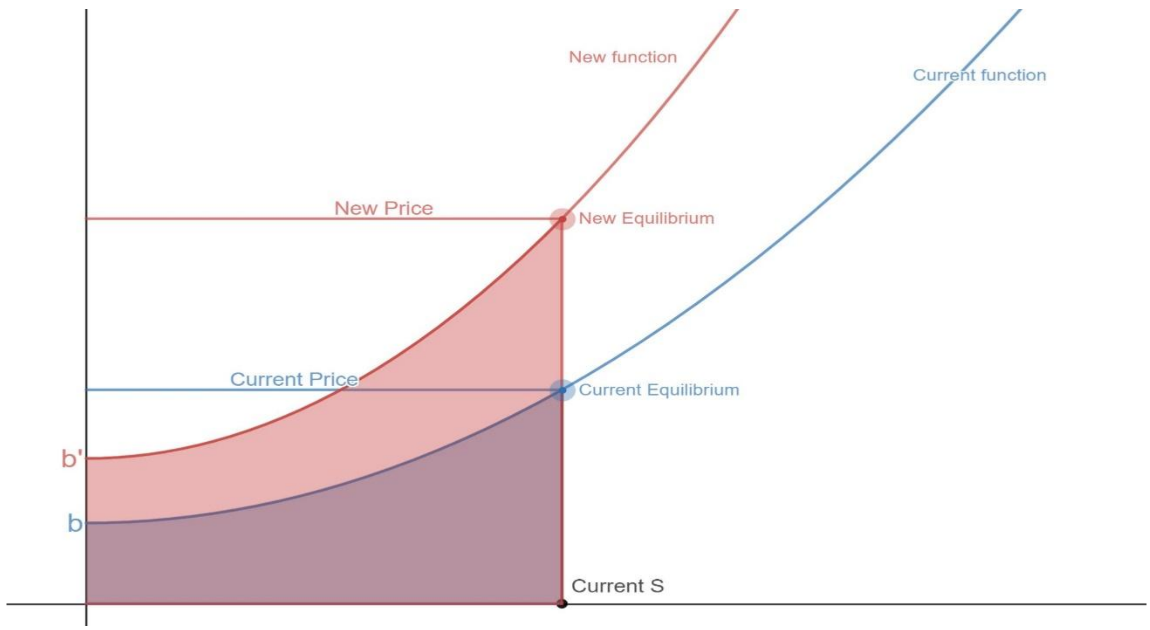


Figure 6-9. Transformation holding the equilibrium shares constant but letting the price change

However, if there is debt, and $r_d.D > 0$, this transformation can change the equilibrium level s_e according to equation (6-11). To analyze this situation we focus on linear price functions. For the linear price function, generally, the transformation should satisfy the following constraint to implement the fund increase:

$$F_2 = (1+\gamma) * F_1 \text{ è } \tfrac{1}{2}\, a'.s_o^2 + b'.s_o = (1+\gamma).(\tfrac{1}{2}\, a.s_o^2 + b.s_o) \text{ è } a'.(s_o + 2\beta') = (1+\gamma).a.(s_o + 2\beta) \qquad (6-23)$$

This constraint can be satisfied by the following class of transformations for linear price functions:

$$\begin{bmatrix} a' \\ b' \end{bmatrix} \equiv \begin{bmatrix} 1+\gamma-\eta & 0 \\ \eta.s_o/2 & 1+\gamma \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} \qquad (6-24)$$

We need to find the η that results in the same equilibrium level as before the transformation. To this end, we assume that the current number of outstanding shares is at the equilibrium level ($s_o = s_e$) and it should be equal to the new equilibrium level s'_e , which per equation (6-11) yields:

$$s'_e = s_o \;\; \Rightarrow \;\; b'.r_s + \sqrt{b'^2.r_s^2 + 2a'.(1-r_s).r_d.D} = a'.s_o.(1-r_s)$$

$$\Rightarrow \;\; a'.{s_o}^2.(1-r_s) - 2b'.s_o.r_s - 2r_d.D = 0 \qquad (6-25)$$

Now we use the general transformation (6 - 24) to state a' and b' as functions of a, b and η:

$$a\,.(1+\gamma-\eta).s_o^2.(1-r_s) - a.\eta.s_o^2.r_s - 2b(1+\gamma)s_o.r_s - 2r_d.D = 0 \qquad (6-26)$$

Therefore, we have:

$$\eta = (1+\gamma)(1-r_s-\frac{2br_s}{as_o}) - \frac{2r_dD}{as_o^2} \qquad (6-27)$$

, wherein, γ is the realized return and a and b are the current parameter values. Also r_s and $r_d.D$ are the net expected returns for the equity fund and the debt respectively. If $r_dD = 0$, then $s_o = s_e = \frac{2b.r_s}{a(1-r_s)}$ and thus $\eta=0$ per equation (6 - 27). If there is no return on the equity fund ($r_s = 0$), then $s_o = s_e = \sqrt{\frac{2r_d.D}{a}}$ per equation (6 - 26) and thus $\eta = \gamma$, which yields:

$$\begin{bmatrix} a' \\ b' \end{bmatrix} \equiv \begin{bmatrix} 1 & 0 \\ \gamma.s_o/2 & 1+\gamma \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} \qquad (6-28)$$

However, when $r_dD > 0$ and $r_s > 0$, we may approximate their values by the realized returns on equity and debt, which should satisfy:

$$\gamma = \widetilde{r_s} + \frac{\widetilde{r_d}D}{F(s_o)}$$

6.7. Numerical Example

Imagine company X has one million outstanding (ownership) shares, and its CEO retires next month. Conventionally, the board of directors would find and select the next CEO. However, an automated governance method using the Parallel Markets can find and select the next CEO as follows:

The platform opens a submission page allowing any shareholder with at least 1% shares (qualified proposers) to propose a CEO candidate. The suggestion period starts and lasts one week.

During the suggestion period, four qualified shareholders, each proposes a candidate. So, in total there are four candidates: Allen, Bernard, Cody, and Dan. The suggestion period ends.

The platform replicates the company shares for each possible CEO. Therefore, the one million company shares become four million conditional shares: one million X-if-Allen, one million X-if-Bernard, one million X-if-Cody, and one million X-if-Dan. A conditional share becomes a company share if and only if its corresponding candidate is selected as the CEO. Then the selection period starts and lasts one week.

During the selection period, traders, shareholders, and speculators can buy and sell conditional shares for each choice. Essentially each conditional share represents a possible future for the company.

The Parallel Primary Markets mechanism executes and fulfills the orders instantaneously using a price function (Figure 6-1). To fulfill buy/sell orders, conditional shares are issued/burned and the number of outstanding shares changes for each conditional share (Figure 6-8). Fulfilling the orders will change the prices and result in price discovery for the conditional shares for each choice in a different market.

Many investors know Dan has an excellent work record and experience. He has committed to improving efficiency, and the company will be more profitable if he becomes the CEO. Therefore, many investors buy X-if-Dan and as a result, the price of the conditional shares for X-if-Dan increases and becomes the highest price ($1490 per share).

On the other hand, people know that Bernard has used the corporate jet for his trips in his last company. He spends a lot of corporate money on luxury hotels. Therefore, many people believe the company will be less profitable if Bernard becomes the CEO. As a result, the price of X-if-Bernard goes down ($900 per share).

At the end of the selection period, X-if-Dan has the highest price for its conditional shares and is selected and ratified as the effective decision and is announced to the public.

Therefore, the conditional shares of X-if-Dan become the company shares X and their conditional shareholders becomes the shareholders of the company X.

On the other hand, the other three conditional shares and their corresponding transactions are voided and the funds invested in them will be returned to their investors and traders.

Change in funds with price function: Now assume that we use this price function to discover prices:

$f(S) = (S^2 / 10^9 + 50)$ dollars. ($a=10^{-9}$, $b=50$)

During the selection period, X-if-Dan reaches 1.2 million conditional shares, with price $1490 at the end of the selection period. And since it is the highest among the four choices, it becomes the company shares X. The total equity fund becomes:

$F(S) = S^3 / (3*10^9) + 50*S = \$636$ million

After Dan becomes the CEO, the company shares (X) are issued or burned to fulfill the orders based on the price function. After one month, due to some economic conditions, several shareholders sell their shares and the price of the company shares goes down to $1260 and thus the number of outstanding shares goes down to 1.1 million shares (= $\sqrt{10^9 * 1210}$) and the total equity fund becomes: $498.67 million.

Then, shortly after that, $40 million profit is realized and is deposited into the company bank account. This profit adds to the equity fund of the company making it $538.67 million. To reflect this change in the equity fund, the price function can be adjusted in different ways such as:

I. One can adjust the price function while holding the price constant. (Figure 6-6). To this end, equations 6-21 may be used wherein we have $a=10^{-9}$ and $b=50$, and $s_0 = 1.1$ million company shares. Thus, the new price function is: $f_2(S) = .955 * S^2 / 10^9 + 104.6$, because:

$$a' = 10^{-9} - 3/2 * (40*10^6)/ (1.13 * 10^{18}) = .9549 * 10^{-9}$$

$$b' = 50 + 3/2 * (40*10^6)/ (1.1 * 10^6) = 10^{-9} + 3/2 * (40)/ (1.1) = 104.545$$

II. One can multiply the price function by the ratio 538.67 / 498.67 to obtain the new price function:

$f_2(S) = (1.08 * S^2 / 10^9 + 54)$ dollars

This retains the equilibrium number of shares, but changes the current price of the shares X, making it jump as Figure 6-7 shows.

After the price function is adjusted, the new price function is used to execute the orders and issue or burn company shares and conditional shares during the selection period.

7. Discussion

While the one-group experiment in this study only provided a proof of concept for the Parallel Markets mechanism, future research may use multi-group experiments to evaluate and compare the performance of this mechanism to the performances of voting mechanisms like plurality and approval voting. For example, to have enough statistical power, one may randomly assign 1200 subjects to 12 groups with 100 subjects each, where 3 groups make decisions using the parallel secondary markets, 3 groups make decisions using Parallel Primary Markets, 3 groups make decisions using plurality voting and 3 groups make decisions using approval voting. Then run experiments on the groups sequentially in a purposefully randomized order to minimize the possible confounding effects of timing. An even better approach is to run four groups at a time, one from each governance mechanism (treatment). To this end, one can recruit 400 subjects for each round and assign them randomly (and evenly) to the four mechanisms. Thus, there will be three rounds with four treatment groups per round. Then the effects of different mechanisms (treatments) on the quality of the outcomes can be statistically estimated, testing hypotheses regarding the significance of the effects of different mechanisms on performance. I would hypothesize that the performance of the Parallel Primary Markets is the highest followed by the parallel secondary markets, followed by the approval voting scheme. I would hypothesize that the plurality voting scheme shows the least performance.

Blohm et al. (2011) compared the performance of rating scores with markets and found that rating scores result in better evaluation accuracy and higher satisfaction for the participants. They concluded that rating is more effective than trading. However, there were two issues with their experiment. First, the results were compared against some other rating scores given by a panel of experts, not against an independent objective criterion. It poses a method bias in favor of rating. Second, the results of such small-scale experiments may not necessarily be generalizable to larger-scale experiments or real-world situations, because while voting and rating mechanisms can function well in small group sizes, markets require enough liquidity to function well, as Blohm et al. have acknowledged.

When we move from small scale experimentation to large-scale real-world practice, the markets become more liquid and thus more accurate while the voting and rating mechanisms become more susceptible to the free-riding problem, the tyranny of the majority, and other manipulations and conflicts of interests (Cvijanovic, et al., 2019). Moreover, the performance and accuracy of markets can improve over time because the smart traders benefit from their informed decisions, survive in the market, trade more, and exert more influence on the prices. The inexpert traders incur the costs of their uninformed deals and eventually fade out of the market. But such evolutions do not happen under voting or rating mechanisms.

One limitation of our experiment is external validity. The group was small (69 subjects), the duration of the process was one hour and the incentive was too small. Moreover, the design problem (retroactive investment plans) is very unique. While this particular problem helps with internal validity, construct validity, and reliability, it poses a threat to external validity and ecological validity because it is not a practical problem in the real world. Future research may apply the Parallel Markets mechanism to solve more realistic decision problems, which would need an elaborate measure of quality. Also using fake money could make experiments seem more realistic.

A drawback of the Parallel Primary Markets mechanism is that it is too complicated for ordinary subjects in a low-cost experiment to understand it in a short time. So, a new method needs to be applied to test it. It can be a combination of simulation and online experimentation. One may use empirical data to train a machine learning program to imitate the decisions of rational traders. And then simulate the performance of the Parallel Primary Markets mechanism using virtual subjects. As Zwass (2010) explained, models and frameworks for co-creation demand continuous development and improvement.

One question in designing Parallel Markets is the length of the selection (trading) periods. How long should we wait for the prices to reach such level of equilibrium that the order of the top choices doesn't change anymore? This requires experimentation and empirical studies and perhaps some adjustment rule or formula in the mechanism so that the length of the waiting time increases (decreases) when the market is more volatile (stable) than expected.

Another question is who can submit decision initiatives (choices) and proposals? If we limit the submission rights to the shareholders, the question is what percentage or how many shares should one have to submit a proposal? If we require a large percentage, there will be too few proposals and we lose diversity and inclusivity. If the threshold is too small, there can be too many low-quality proposals and therefore too many parallel markets will take away liquidity from each other. This can lead to thinner markets and longer times to reach equilibrium prices. So again, we need experimentation and empirical studies to discover the optimal threshold. One might also incorporate an adjustment rule and a formula to increase (decrease) the threshold when there are too many (too few) submissions. One can use a small threshold (e.g. $\geq 1\%$ share), but have the system sort the choices based on the last transaction prices, the highest bids, and the number of shares that the proposers have. This facilitates better evaluation when there are too many submissions.

To implement the Parallel Markets mechanism for a real-world company, first, we need a platform to collect the decision choices as proposals from the shareholders. Second, we should enable people to trade decision choices in parallel to discover their equilibrium prices. Third, we need to execute the winner choice (the highest price) automatically or enforce it upon the company's management and executives. Fourth, the platform should void shares of other decision choices and their transactions and return the funds corresponding to the voided decision choices.

This platform should not be controlled by the managers of the company. One approach is to have a stock exchange (e.g. NYSE) collect the possible choices centrally and have them traded like other stocks. A less centralized approach is to let brokers collect the proposals and issue conditional future contracts for them. Each contract is tied to an escrow account and becomes effective only if it reaches the highest price among its counterparts. Otherwise, it becomes void and returns the funds. These contracts are traded in the derivatives markets to have their prices discovered. Ironically, many manipulation problems like empty voting were brought about by the derivatives markets (Barry et al., 2013). To enforce the highest priced choice upon management, we need an amendment to the operating agreement or to the articles of incorporation to establish a legal basis.

Public corporations can adopt the Parallel Markets mechanism (primary or secondary) through multiple stages. First, they can replace shareholder voting with the Parallel Markets mechanism for approving proposals. Then the Parallel Markets mechanism makes the decisions that were made directly by shareholders. Then they delegate the authority of the Board of Directors to the Parallel Markets mechanism. At this point, the board becomes nominal to comply with the SEC regulations. Then they may delegate the decisions of CEO, CFO, … to the Parallel Markets mechanism depending on the nature (confidentiality, technicality…) of the decisions. Eventually, the parallel market mechanism decides who has what authority and who makes what decisions.

It is worth noting that while the Parallel Markets mechanism can replace the Board of Directors and shareholder voting, we still need other governance institutions like lawsuits, gate-keeping, professionalism, capital structure, and bankruptcy as Roe (2004) described. As Roe explained, markets are good to limit shirking by managers but may not deter stealing if the amount is small compared to the company's total value. This is particularly true when using the Parallel Markets mechanism.

Interestingly some decision choices may violate some regulations or laws and result in fines for the corporation. The prospect costs of such violations reduce the company's profitability under such choices, making them less likely (not impossible) to win in Parallel Markets. However, sometimes the costs of compliance outweigh the costs of violation, and it may be efficient to violate some laws and pay the fines. Such level of efficiency may not be possible under the traditional corporate structures where the company's profit is not the decision makers' only concern. They may consider other factors like their reputation.

8. Conclusion

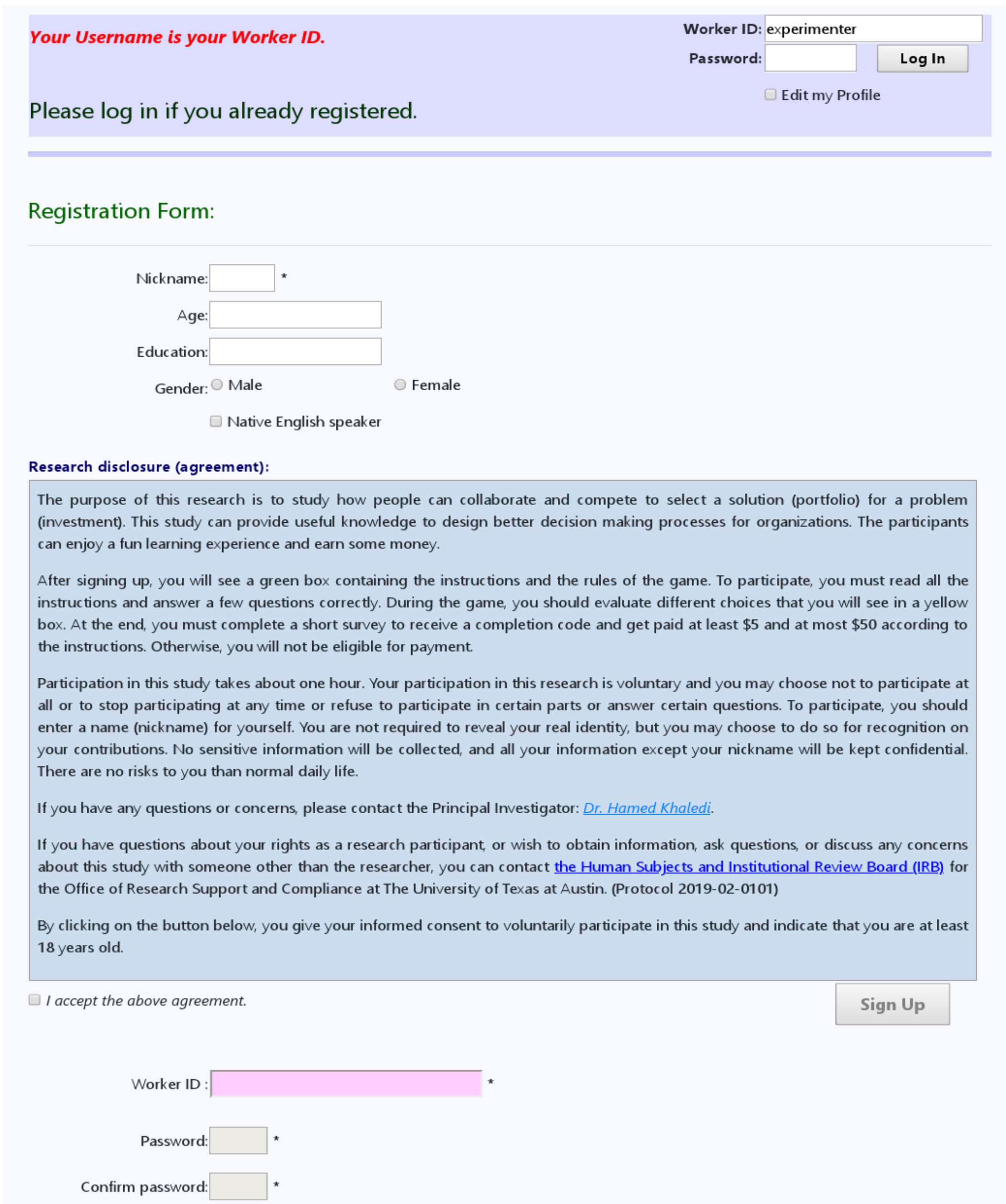
The contributions of this paper are threefold. First, it introduces the Parallel Markets mechanism as an alternative governance mechanism that uses the market equilibrium prices to select and ratify decisions without voting or the Board of Directors. This mechanism is resistant to agency conflicts, free-riding, the tyranny of the majority, and many other manipulations possible under voting. Second, this paper improves the Parallel Markets mechanism by combining the primary markets with the bonding curve contracts. This "Parallel Primary Markets" mechanism does not need as many participants to yield reliable equilibrium prices and can reach decisions faster. Third, this study proposes an experimental method to test and evaluate governance mechanisms objectively based on their outcomes rather than their internal properties or any normative value assumptions.

One can implement an automated governance method in a smart contract on a generalized blockchain like Ethereum or Solana. As Morrison, et al (2020) have explained, decentralized governance mechanisms can be implemented as smart contracts on blockchains. Using Blockchain will increase the transparency and liquidity of the market and increase the speed of transactions (Yermack, 2017). This will result in reaching equilibrium prices in shorter periods.

The *ParaLead* project (paralead.org) has used Solidity to implement an automated governance method based on the Parallel Primary Markets mechanism on the Ethereum blockchain. While most DAOs and DACs are based on some kind of voting mechanism (Anand & Chauhan, 2020), *ParaLead* uses market equilibrium prices and no voting or board of directors.

Appendix A

This section explains the web application that serves as a platform to conduct experiments on governance mechanisms. Figure A-1 illustrates the login/registration page on the web application. It also shows the consent form approved by IRB (protocol 2019-02-0101).



Your Username is your Worker ID.

Worker ID: experimenter

Password: Log In

Edit my Profile

Please log in if you already registered.

Registration Form:

Nickname: *

Age:

Education:

Gender: Male Female

Native English speaker

Research disclosure (agreement):

The purpose of this research is to study how people can collaborate and compete to select a solution (portfolio) for a problem (investment). This study can provide useful knowledge to design better decision making processes for organizations. The participants can enjoy a fun learning experience and earn some money.

After signing up, you will see a green box containing the instructions and the rules of the game. To participate, you must read all the instructions and answer a few questions correctly. During the game, you should evaluate different choices that you will see in a yellow box. At the end, you must complete a short survey to receive a completion code and get paid at least $5 and at most $50 according to the instructions. Otherwise, you will not be eligible for payment.

Participation in this study takes about one hour. Your participation in this research is voluntary and you may choose not to participate at all or to stop participating at any time or refuse to participate in certain parts or answer certain questions. To participate, you should enter a name (nickname) for yourself. You are not required to reveal your real identity, but you may choose to do so for recognition on your contributions. No sensitive information will be collected, and all your information except your nickname will be kept confidential. There are no risks to you than normal daily life.

If you have any questions or concerns, please contact the Principal Investigator: *Dr. Hamed Khaledi*.

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher, you can contact the Human Subjects and Institutional Review Board (IRB) for the Office of Research Support and Compliance at The University of Texas at Austin. (Protocol 2019-02-0101)

By clicking on the button below, you give your informed consent to voluntarily participate in this study and indicate that you are at least 18 years old.

I accept the above agreement. Sign Up

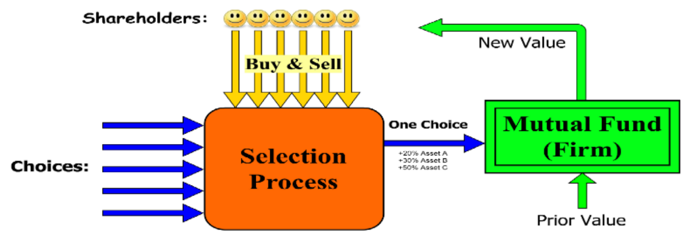
Worker ID : *

Password: *

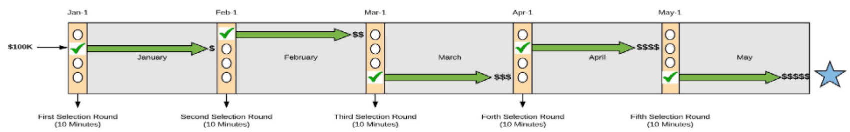
Confirm password: *

Figure A-1. The First Page of the Application Letting User to Log In and Sign Up.

Figure A-2 shows the visual directions for the participants. It complements the instructions.



TimeLine:



Perfromance of one Portfolio (One Choice):

Example: If on Jan 1st the firm invests 30% of its cash on coin A and 70% on coin B, then on Feb 1st this is the amount it will have:

$$Value_{Feb1} = Value_{Jan1} * \left[0.3 * \frac{Price(A)_{Feb1}}{Price(A)_{Jan1}} + 0.7 * \frac{Price(B)_{Feb1}}{Price(B)_{Jan1}}\right]$$

Share Value (for Each Choice):

$$Value\ of\ One\ Share = \frac{Final\ Value\ of\ Mutual\ Fund}{Number\ of\ Outstanding\ Shares}$$

The Prices:

	1-Jan-2019	1-Feb-2019	1-Mar-2019	1-Apr-2019	1-May-2019	1-Jun-2019
Bitcoin (BTC)	3746.71	3460.55	3853.76	4105.36	5,350.91	8,573.84
EOS	2.57	2.32	3.54	4.17	4.83	8.52
Ethereum (ETH)	133.42	107.15	136.84	141.47	162.19	268.43
Ripple (XRP)	0.352512	0.310839	0.315066	0.309195	0.30949	0.438711
LTC (Litecoin)	30.46	31.72	46.24	60.77	74.3	114.47
Cardano (ADA)	0.040984	0.038441	0.043112	0.069651	0.070338	0.089462
NEM (XEM)	0.064185	0.040572	0.042631	0.055242	0.056169	0.098231
TRON (TRX)	0.018892	0.025325	0.023878	0.023507	0.023969	0.03306
Lisk (LSK)	1.35	1.12	1.22	1.72	1.74	2.08
Verge (XVG)	0.006851	0.005936	0.00597	0.007476	0.00748	0.009996

How to Navigate CoinMarketCap.com:

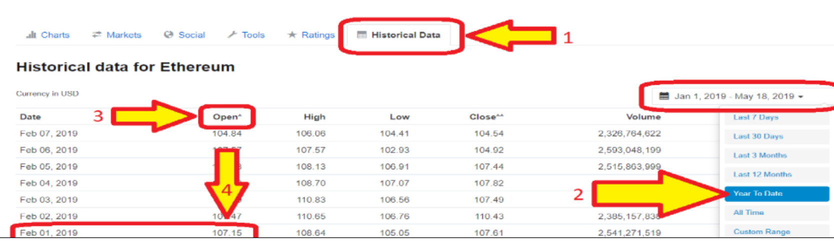


Figure A-2. Visual Directions for Participants

Figure A-3 shows the trading page. This page enables each participant to buy and sell the shares of the company under different choices. They can see the prices for the previous transactions. They can also see the existing offers that they or other participants have made. They can submit new buy or sell orders for the shares of the company under each choice.

Figure A-3. Trading page for participants in the parallel secondary markets governance mechanism

Figure A-4 shows the control panel of the application. In this panel, the experimenter can set up the parameters to define a decentralized governance mechanism and schedule it to run at a specific time. Once it goes live it allows people to register to participate in solving a specific problem. Then after recruiting participants it starts enforcing the decentralized governance rules on the participants.

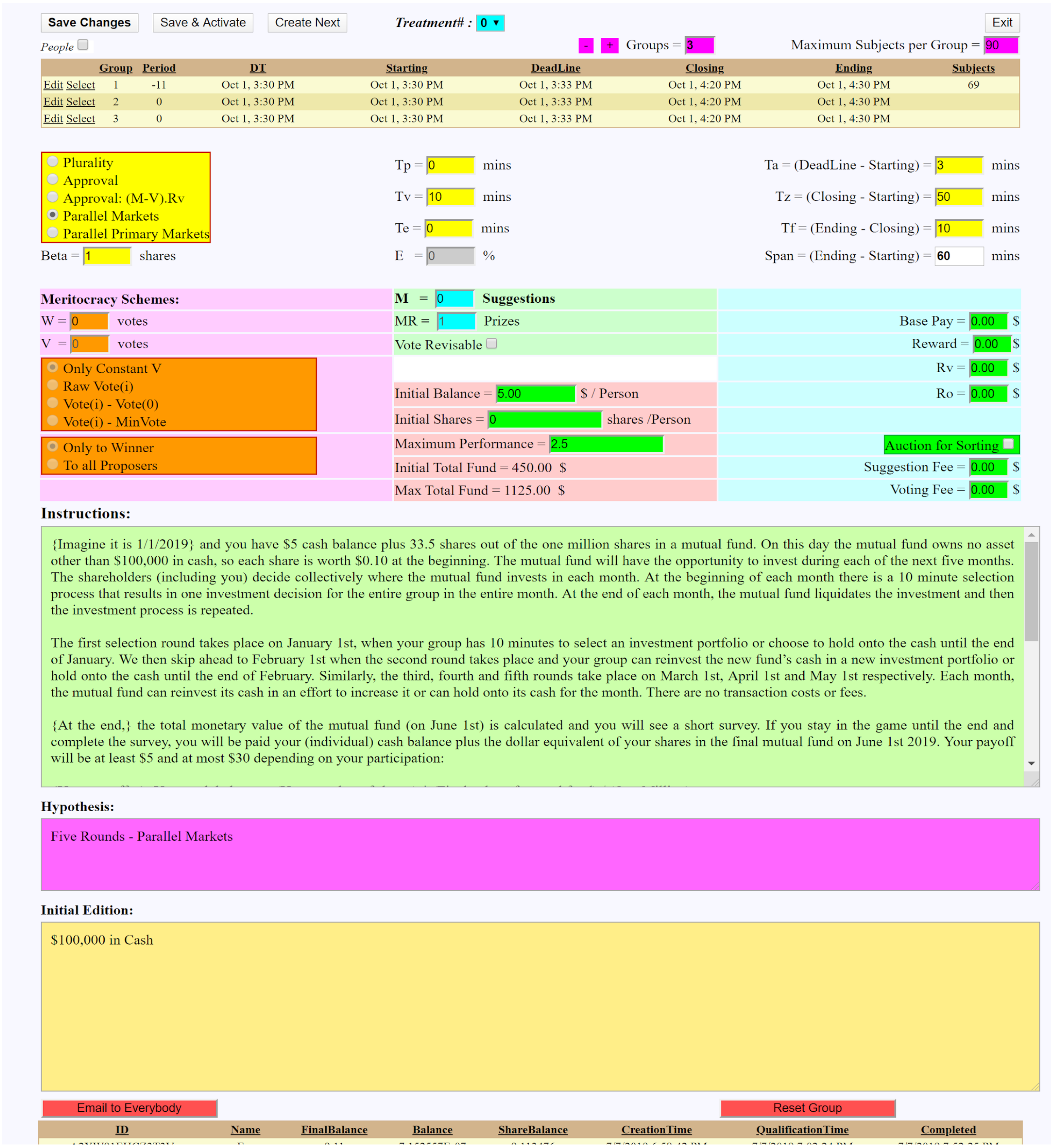


Figure A-4. Control Panel for the Experimenter

Appendix B

This section provides the numerical results for the four rounds from the second round to the fifth round. The results include the prices and latest offers (orders) that the experimenter can see at the end of each round. Figures B-1, B-3, B-5, and B-7 present the results at the end of rounds 2, 3, 4, and 5 respectively. Furthermore, figures B-2, B-4, B-6, and B-8 present the price fluctuations during the 10-minute trading periods of rounds 2, 3, 4, and 5 respectively.


Hold Cash [125077] | (The Last Transaction Price = 0.19 , Lowest Sell Offer = $ 0.18 , Highest Buy Offer = $ 0.17) :

$125,077.00 in cash

Calculation:

The investment choice selected on January 1st:

30% ==>>> Litecoin
70% ==>>> TRON (TRX)

Its performance was 1.250770
Prior value of the mutual fund (on January 1st) was $100,000.00
*New Value = Prior Value * Performance = $125,077.00*

Portfolio 1 [1.15606] | (The Last Transaction Price = 0.27 , Lowest Sell Offer = $ 0.27 , Highest Buy Offer = $ 0.25) :

40% ==>>> Bitcoin
20% ==>>> EOS
40% ==>>> Ripple (XRP)

Portfolio 2 [0.975869] | (The Last Transaction Price = 0.15 , Lowest Sell Offer = $ 0.18 , Highest Buy Offer = $ 0.15) :

20% ==>>> Ripple (XRP)
50% ==>>> TRON (TRX)
30% ==>>> Verge (XVG)

Portfolio 3 [1.10862] | (The Last Transaction Price = 0.15 , Lowest Sell Offer = $ 0.18 , Highest Buy Offer = $ 0.09) :

60% ==>>> Cardano (ADA)
40% ==>>> Lisk

Figure B-1. The Alternative Choices (Markets) in the Second Round

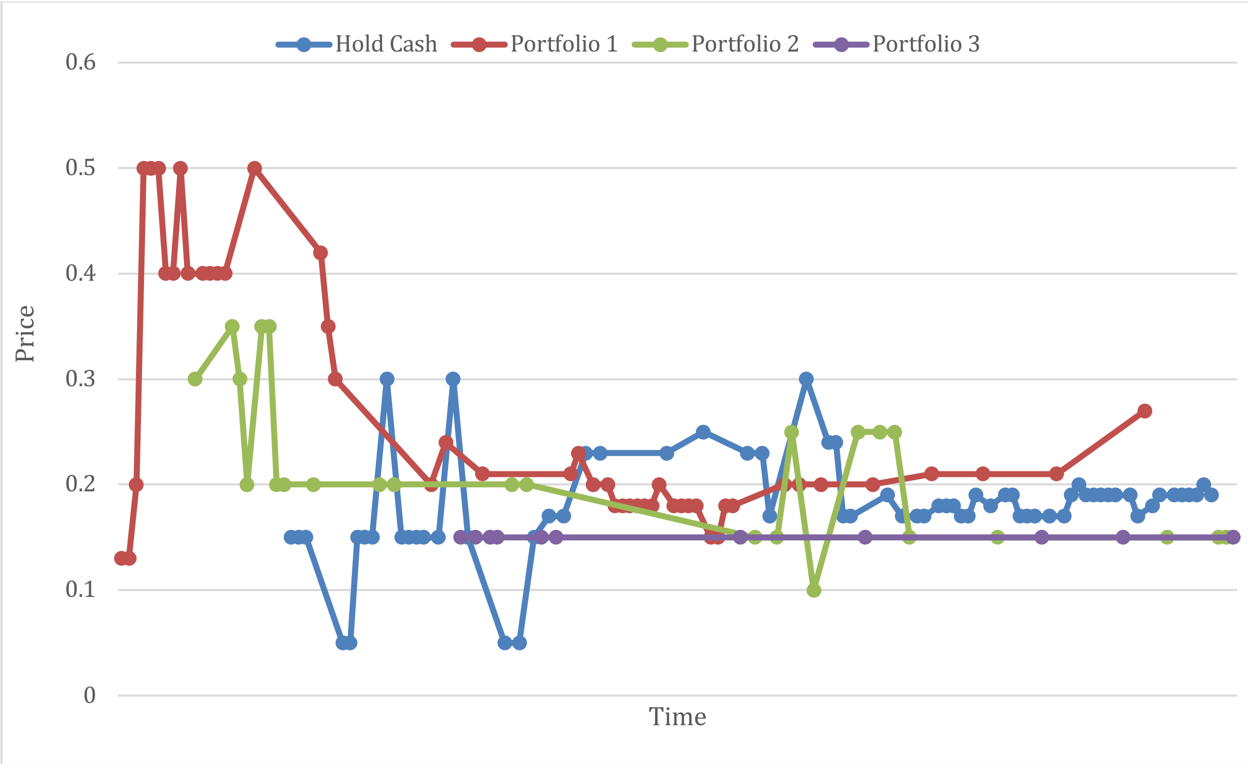


Figure B-2: Share transaction prices for different choices during round 2

Figure B-3. The Alternative Choices (Markets) in the Third Round

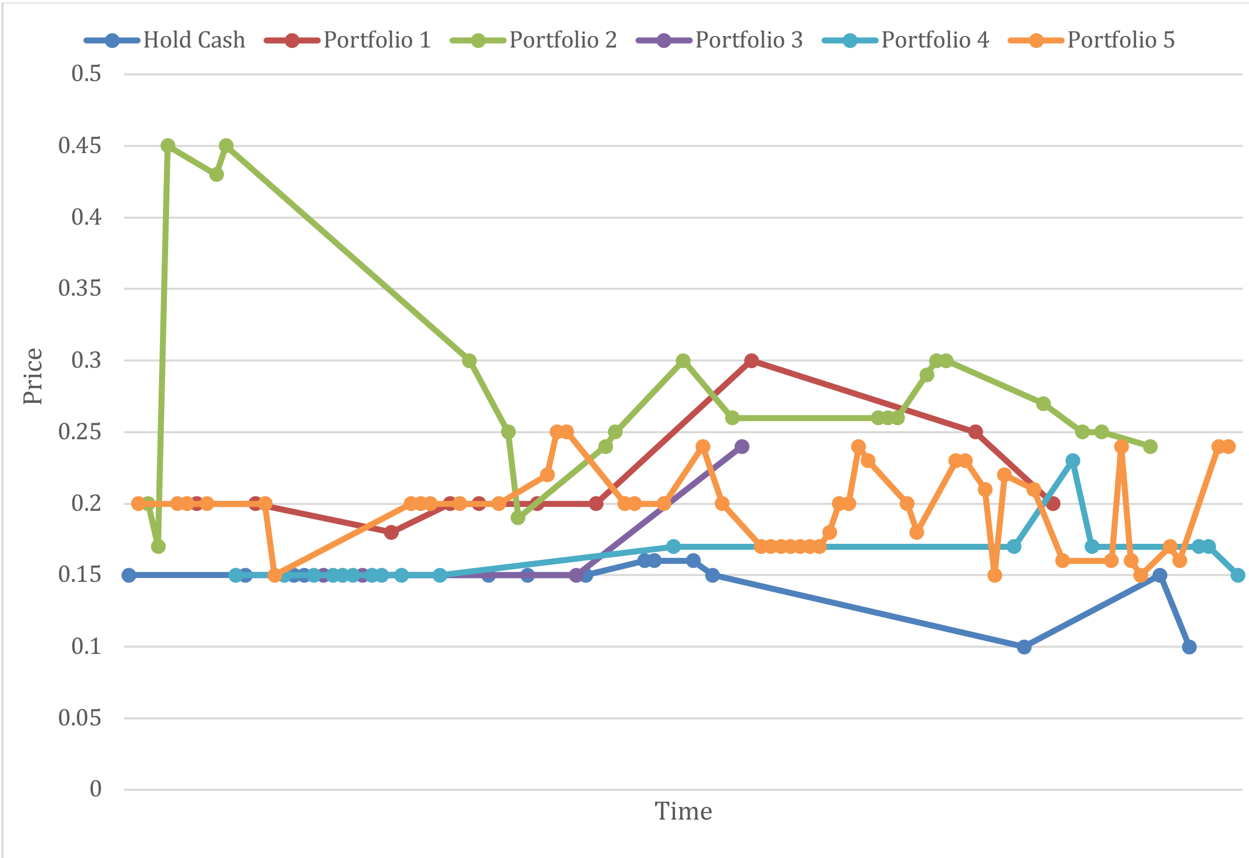
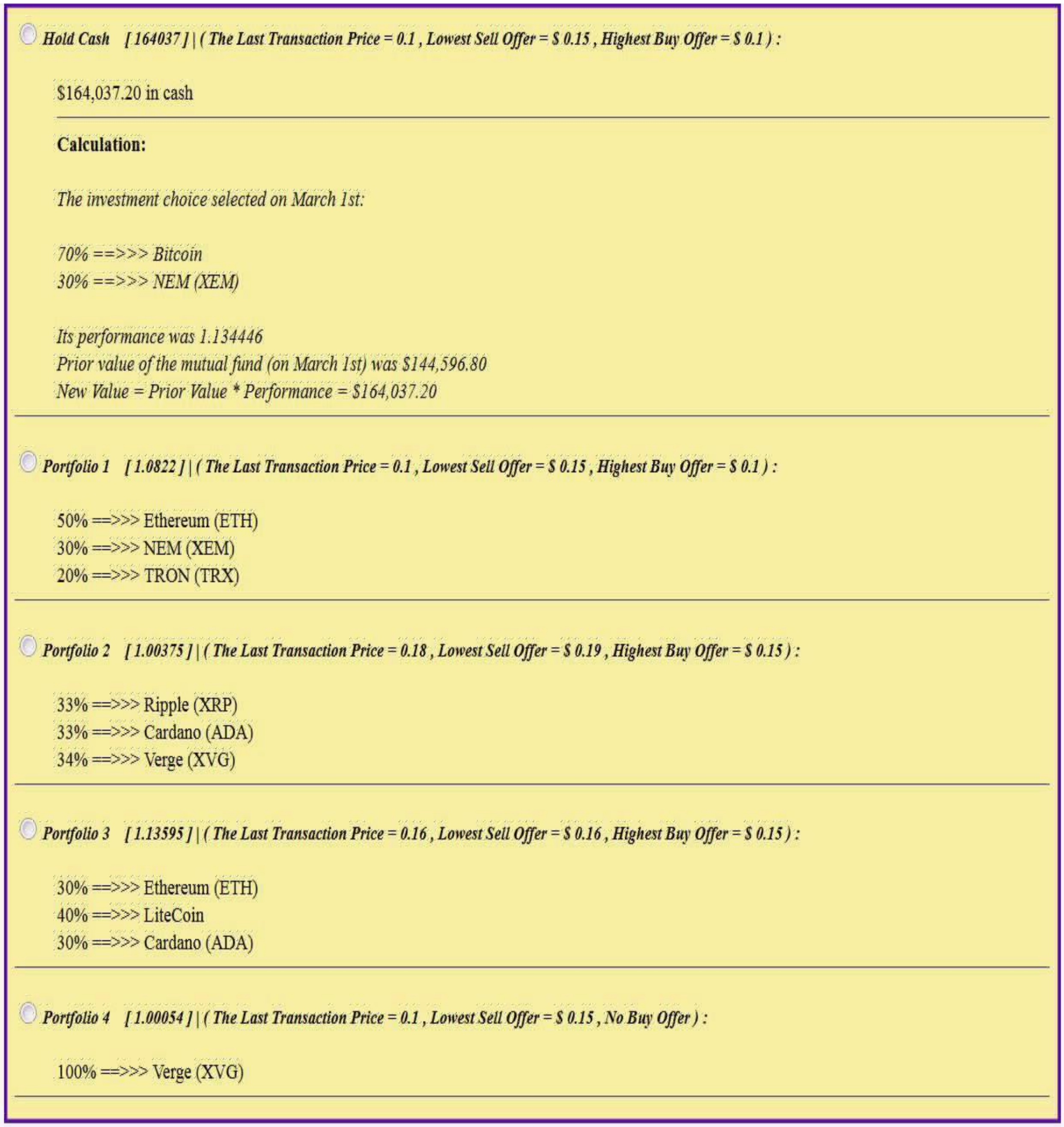


Figure B-4. Share transaction prices for different choices during round 3



Hold Cash [164037] | (The Last Transaction Price = 0.1 , Lowest Sell Offer = $ 0.15 , Highest Buy Offer = $ 0.1) :

$164,037.20 in cash

Calculation:

The investment choice selected on March 1st:

70% ==>>> Bitcoin
30% ==>>> NEM (XEM)

Its performance was 1.134446
Prior value of the mutual fund (on March 1st) was $144,596.80
*New Value = Prior Value * Performance = $164,037.20*

Portfolio 1 [1.0822] | (The Last Transaction Price = 0.1 , Lowest Sell Offer = $ 0.15 , Highest Buy Offer = $ 0.1) :

50% ==>>> Ethereum (ETH)
30% ==>>> NEM (XEM)
20% ==>>> TRON (TRX)

Portfolio 2 [1.00375] | (The Last Transaction Price = 0.18 , Lowest Sell Offer = $ 0.19 , Highest Buy Offer = $ 0.15) :

33% ==>>> Ripple (XRP)
33% ==>>> Cardano (ADA)
34% ==>>> Verge (XVG)

Portfolio 3 [1.13595] | (The Last Transaction Price = 0.16 , Lowest Sell Offer = $ 0.16 , Highest Buy Offer = $ 0.15) :

30% ==>>> Ethereum (ETH)
40% ==>>> LiteCoin
30% ==>>> Cardano (ADA)

Portfolio 4 [1.00054] | (The Last Transaction Price = 0.1 , Lowest Sell Offer = $ 0.15 , No Buy Offer) :

100% ==>>> Verge (XVG)

Figure B-5. The Alternative Choices (Markets) in the Fourth Round

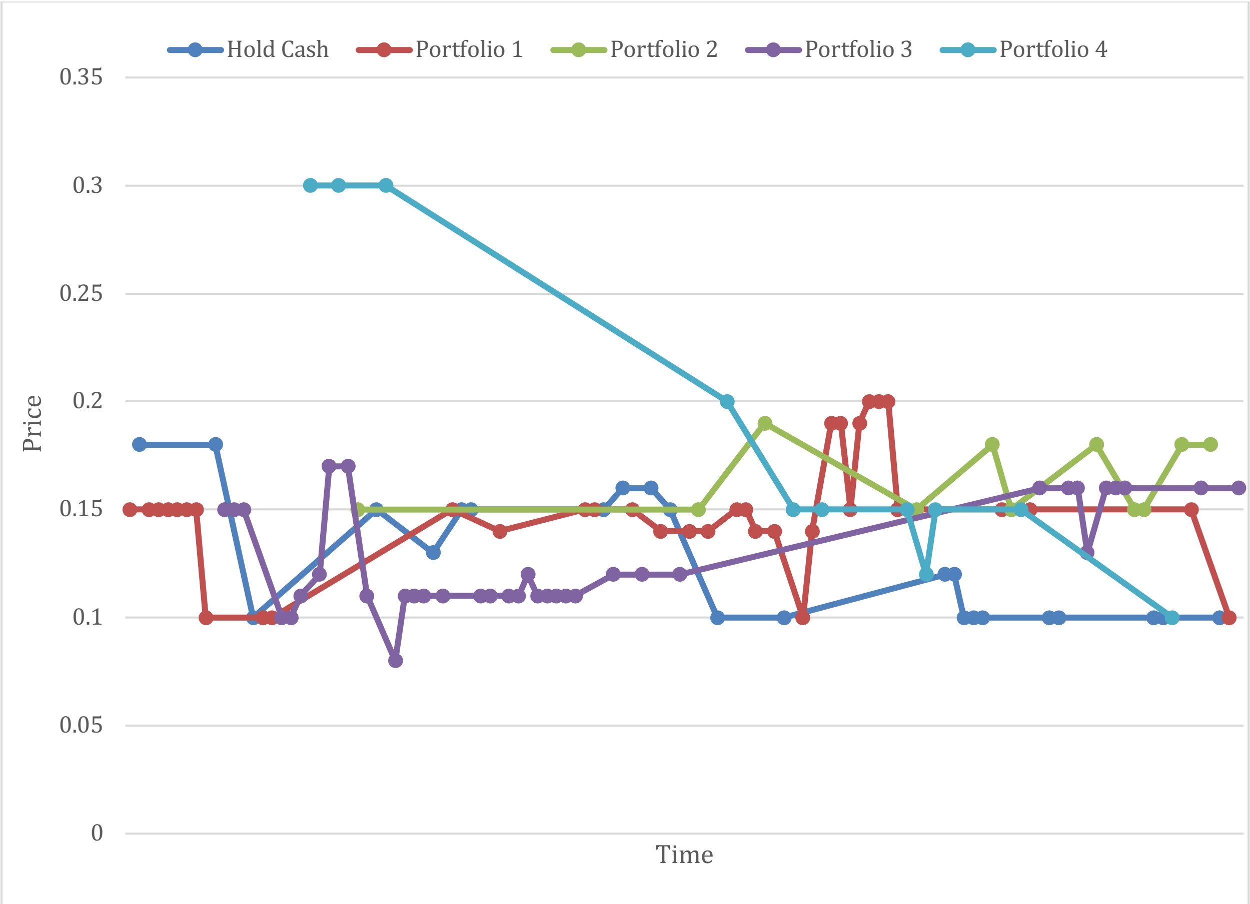


Figure B-6. Share transaction prices for different choices during round 4

Hold Cash [164653] | (The Last Transaction Price = 0.11 , Lowest Sell Offer = $ 0.11 , Highest Buy Offer = $ 0.085) :

$164,652.70 in cash

Calculation:

The investment choice selected on April 1st:

33% ==>>> Ripple (XRP)
33% ==>>> Cardano (ADA)
34% ==>>> Verge (XVG)

Its performance was 1.003752
Prior value of the mutual fund (on April 1st) was $164,037.20
*New Value = Prior Value * Performance = $164,652.70*

Portfolio 1 [1.20687] | (The Last Transaction Price = 0.12 , Lowest Sell Offer = $ 0.13 , Highest Buy Offer = $ 0.12) :

15% ==>>> Cardano (ADA)
85% ==>>> Lisk

Portfolio 2 [1.23364] | (The Last Transaction Price = 0.1 , Lowest Sell Offer = $ 0.1 , Highest Buy Offer = $ 0.05) :

50% ==>>> Cardano (ADA)
50% ==>>> Lisk

Figure B-7. The Alternative Choices (Markets) in the Fifth Round

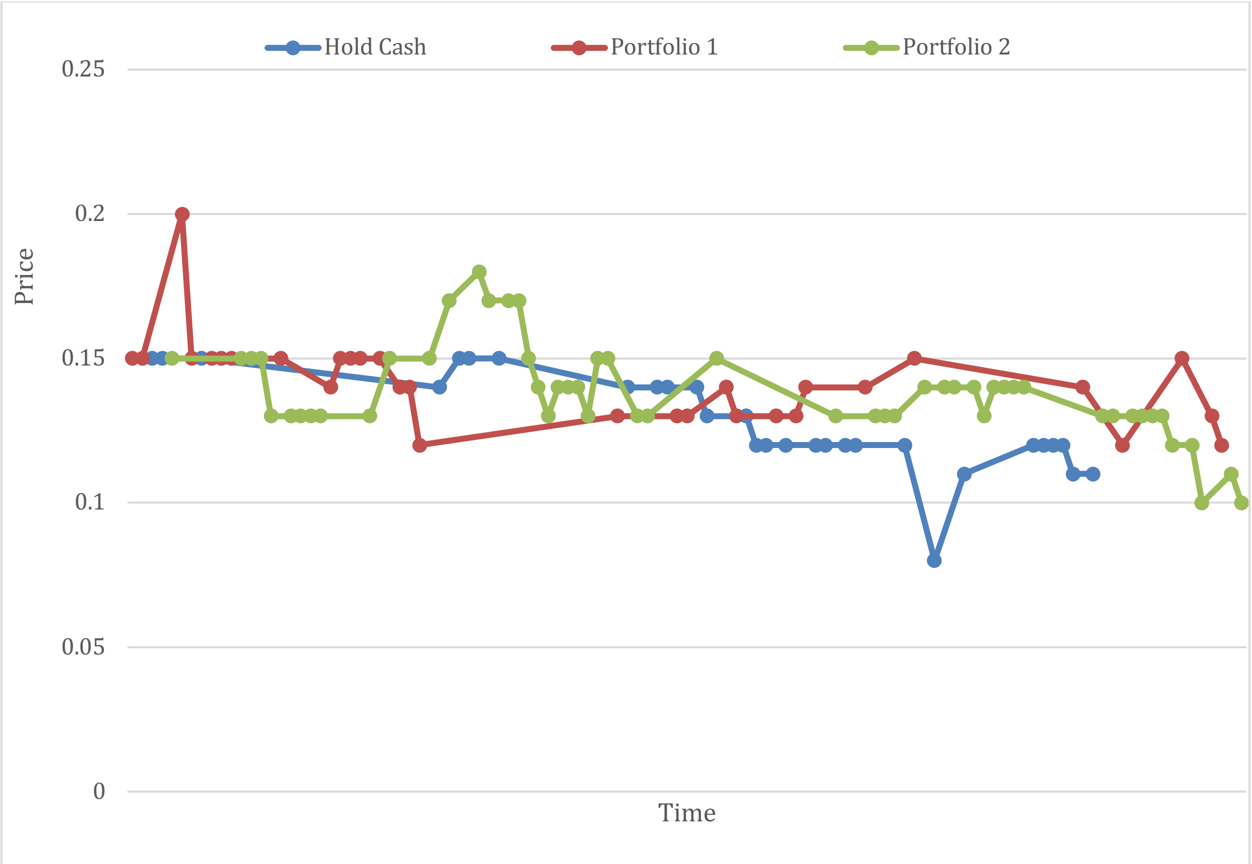


Figure B-8. Share transaction prices for different choices during round 5

Appendix C

Figure C-1 presents the transaction page for the participants in the Parallel Primary Markets.

Figure C-1. The transaction page for participants in the Parallel Primary Markets

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