Arbitrage Opportunities: Anatomy and Remediation

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Abstract: We introduce an experimental design where arbitrage opportunities emerge reliably and repeatedly. We observe significantly higher sell-side than buy-side arbitrage opportunities. We study ways to mitigate them. Relaxing margin requirements, shortsale restrictions, or both have neither statistically nor economically significant effects. Increasing competition (more participants, each with small stakes), and more impactful, participants stakes (few wealthy participants each with large exposures), generate large reductions in arbitrage opportunities. Hence, we advocate increased competition for small markets, and allowance for large stakes in large markets, rather than relaxation of rules on margin purchases or shortsales.

Keywords: Limits of arbitrage, Experimental asset markets, Market capitilization

JEL Classification Numbers: C92, D53, G12

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1 Introduction

Arbitrage is a financial transaction that nets a certain increase in cash holdings while not degrading the portfolio's value in any potential state of the world. When an arbitrage opportunity presents itself, market participants will presumably compete for its execution until the value is fully dissipated. On the other side of these transactions, the traders incurring certain losses can't do so indefinitely and their market participation is eventually extinguished. This 'invisible hand' effect is often called a no arbitrage condition and is one of the defining characteristics of a complete and competitive market. This no arbitrage condition is an assumption of many fundamental theories of finance: for example, the Modigliani-Miller capital structure propositions (Modigliani and Miller, 1958), the Black-Scholes option pricing formula (Black and Scholes, 1973) and the arbitrage asset pricing theory (Ross et al., 1973; Ross, 1976).

Even though no arbitrage arguments are compelling and useful in developing models of financial markets, persistent arbitrage opportunities occur with surprising frequency in developed markets. Through the lens that astute traders will compete away any arbitrage, empirical studies - in almost tautological fashion - find that traders' capacities to fully compete are somehow shackled. We enumerate a set of commonly identified restraints on traders' abilities to fully compete. Then we describe a laboratory experiment that provides control or eliminates of each of them.

First, limitations on short sales prevent traders from profitably supplying sufficient amounts of an asset to extinguish an arbitrage opportunity. Persistent arbitrages often emerge in equity carve-outs in which a corporation spins off a division into a new corporation. A well known example, and detailed by Lamont and Thaler (2003), was the spin off Palm by 3Com. On March 2, 2000, 3Com sold a fraction of its stake in Palm to the general public via an initial public offering (IPO) for Palm, and retained ownership of 95 percent of the shares for the purpose of spinning off its remaining shares of Palm to its shareholders before the end of the year. 3Com shareholders would receive about 1.5 shares of Palm for every share of 3Com that they owned, so the price of 3Com must be at least 1.5 times the price of Palm. This lower bound occurring if 3com's value after the spin off was zero. After the first day of trading, Palm closed at $95.06 a share, implying that the price of 3Com should have have been at least $145. Instead its price was $81.81. Lamont and Thaler analyze a large number of such carve out arbitrages and find that short sales limitations, arising from high costs of execution[1] and institutional restraints, are the predominant reason for such persistence arbitrages. In the case of 3Com, brokerage firms and institutional investors who controlled much of Palms stock generally agreed not to lend the stock to short sellers prior to the IPO date.

Second, limitations on leveraged purchases prevent traders from buying a sufficient amount of an asset to extinguish an arbitrage opportunity. Researchers have treated the 2007 financial crisis as an exogenous shock to the lending and standard practices offered on liquidity for arbitrage opportunities. For example, Mancini-Griffoli and Ranaldo (2011) examine arbitrages that entail borrowing in one currency and lending in another to take advantage of interest rate differentials while avoiding exchange rate risk. They show that arbitrage profits were large after 2007 Financial Crisis, persisted for months and involved borrowing in dollars. Empirical analysis suggests that insufficient funding liquidity in dollars kept traders from arbitraging away excess profits.

Third, noise trader risks (De Long et al., 1990; Shleifer and Vishny, 1995) and the limited horizons of arbitragers is also a common explanation for persistent arbitrage. Noise traders, who either have an incorrect model of fundamental value or trade on the basis of ancillary motivations, generate mis-pricing and arbitrage opportunities. However, the unpredictability of noise traders' beliefs creates a risk in the price of the asset that deters rational arbitrageurs from aggressively betting against them. The arbitrageurs are usually highly specialized investors who are risk averse and have relatively short investment horizons. As a result, their willingness to take positions against noise traders is limited. An example of persistent arbi-

[1] The high cost of short sales, because of limited supply of loaned shares, have also been identified as a primary reason for persistent arbitrages associated with closed-end funds Pontiff (1996).

trage associated with noise trader risk is provided by Scruggs (2007) who examines the return for two pairs of Siamese twin stocks: Royal Dutch/Shell and Unilever NV/PLC. These unusual pairs of fundamentally identical stocks provide a unique opportunity to investigate two facets of noise trader risk: the fraction of total return variation unrelated to fundamentals, i.e., noise, and the short-run risk borne by arbitrageurs engaged in long-short pairs trading. She finds that about 15% of weekly return variation is attributable to noise.

Fourth, insufficient market capitalization can also be the reason for persistent arbitrage. When there is an increasing number of potential arbitrageurs, they can collectively eliminate an arbitrage opportunity with individually smaller and inherently less risky positions. Alternatively if a fixed number of arbitrageurs individually have higher levels of initial wealth and decreasing risk aversion with respect to wealth, they will have a propensity to take riskier positions to exploit, and subsequently eliminate, arbitrage opportunities. An example is Chinese A and B stock markets: two classes of common shares with identical voting and dividend rights, but traded by two different sets of traders. Class A shares were restricted to domestic residents while class B shares were confined to foreign investors during the period 1993-2000. Despite their identical payoffs and voting rights, class A shares traded on average for 420% more than the corresponding B shares. In 2001, the Chinese Securities Regulatory Commission allowed their residents to trade B shares. This regulatory change triggered a dramatic decline of prevailing B-share discounts from 80 percent to 40 percent (Karolyi et al., 2009).

We design a series of controlled laboratory experiments that allow us to control for the noise risk limitation and to test the veracity of the other three limitations. In each experiment, there are two commodities in the market; a non-interest bearing and non-dividend paying commodity called pesos and an asset that pays a peso denominated dividend at the end of each period and a fixed terminal redemption value. The dividend sequence of the asset is determined by randomly selecting without replacement from a set of values whose cardinality is the number of market periods. Consequently, the sum of future dividends and the terminal value is certain at every point of time. Therefore a riskless arbitrage can be executed with a single transaction. In fact, any transaction whose price differs from the fundamental value is a realized arbitrage.[2]

In the baseline scenario, we mimic market conditions under which persistent arbitrage can arise by imposing the first two limitations: hard short sale and leveraged purchase constraints. At the beginning of the market, each trader receives the same portfolio endowment of pesos and units of the asset. When a trader's available asset holding reaches zero, she is not allowed to sell more units. Further, we do not provide her a facility to borrow pesos which can be used to purchase units of the asset. From this baseline we develop two experimental designs: one that examines the impact of market frictions and one that examines the impacts of market capitalization.

In our first experimental design we vary the presence of short sale and leveraged purchase constraints. In the "Short sale" environment, we allow any trader to hold a negative quantity of the asset up to a limit that is sufficient to absorb the aggregate endowment of pesos at the minimum possible fundamental value of the asset. In the "Liquidity" environment, we provide a facility from which any trader can borrow at a zero interest rate. The leverage limit allows a single trader to purchase the entire aggregate endowment of the asset at its maximum possible fundamental value. In the "Liquidity + Short sales" environment, we remove all market frictions, i.e. allow both short sale and leveraged purchases. In our second experimental design we vary the capitalization in the market while maintaining leveraged purchase and short sale constraints. In the "Competition" treatment, we increase the number of traders by 150% with traders retaining baseline endowments. In the "Big endowment" treatment, we increase the baseline endowments by 150% but maintain the same number of traders.

Our experimental results show that when traders face liquidity and short sale constraints,

[2] The concept that riskless arbitrage involves at least two simultaneous transactions is likely entrenched in many readers' minds. However this is based in the almost universal presence of fundamental value risk (Ross et al., 1973; Ross, 1976) in which a riskless arbitrage is only obtained by buying an asset at lower price than that same asset is simultaneously sold.

we observe significant arbitrage with significantly higher sell-side than buy-side opportunities. Elimination of market frictions does not diminish arbitrage. When we allow generous short sales, the frequency of arbitrage does not diminish but asset prices decrease in general. Allowing generous leverage purchasing does not diminish arbitrage and sell-side opportunities grow even more dominant. When we add both leveraged purchases and short sales, we found arbitrages of similar magnitudes but greater frequency to those in the Baseline. Increasing market capitalization diminishes arbitrage. We find that increasing the number of traders reduces the magnitude of arbitrages but increases their occurrence. When we hold the number of participants constant but increase the size of their portfolio endowments both the average size and frequency of arbitrage are reduced.

We find the market frictions are binding for some subjects. In the baseline, there is a noticeable clustering of corner portfolios, either all peso or all asset. Introducing short sale or leveraged purchase results in a spread of terminal portfolios beyond these corners. Removing all market frictions make the spreads more extreme. Terminal portfolios do not vary only in composition but also value, or in other words wealth inequality. Introducing short sale or leveraged purchase results in an increasing spread of the distribution of terminal wealth. Even though increasing the number of traders reduces arbitrage and improves market efficiency, it also drives greater wealth inequality. In contrast, increasing the initial portfolio endowment for each trader not only reduces arbitrage but also diminishes wealth inequality.

There is scant experimental experimental research explicitly examining arbitrage. Some notable exceptions are Rietz (2005) who studies arbitrage in a contingent claims political stock market; Charness and Neugebauer (2017) who evaluate the Modigliani and Miller capital structure proposition; and O'Brien and Srivastava (1991) who study information aggregation in markets for multiple asset and find persistent arbitrage foils traditional statistical tests of informational efficiency. These studies all find persistent arbitrage but none examines whether the elimination of market frictions or market deregulation reduces it.

In contrast, a large experimental literature has examined price efficiency in asset markets and found that prices usually deviate significantly from the fundamental value, with a bias for over-pricing (Smith et al., 1988; Porter and Smith, 1994). These price deviations are not arbitrages because the independently drawn dividends create risks in the total sum of dividends one receives from purchasing and then holding a unit of the asset until termination. To our knowledge there is one exception to this fundamental value risk. Porter and Smith (1994) demonstrate that when the asset dividend stream is certain, overpricing is not significantly reduced relative to when dividend uncertainty. We note that most of these studies looked at monotonically decreasing dividend paths[3] and some researchers, e.g. Kirchler et al. (2012), have argued this decreasing fundamental path is counter intuitive and a source of mis-pricing. Our design generates non-monotonic fundamental value paths. A limited number of these experimental studies investigated how market frictions affect price deviations. Relaxing short-selling constraints lowers prices in experimental asset markets, but does not induce prices to track fundamentals (Haruvy and Noussair, 2006; Ackert et al., 2006). In contrast, allowing borrowing increases overpricing in the market Ackert et al. (2006).

We proceed by presenting the details of our two experimental experimental designs in the next section. After which we present our results section. The results are organized around how our various treatments impact three key factors: how arbitrage emerges in terms of buy-side versus sell-side opportunities, as well as the relative incidence of arbitrage arising from limit versus market order; market price efficiency; and degree of terminal wealth inequality. We conclude with discussions of how our results speak to effective market mediation and regulation.

[3] Some exceptions are (Noussair and Powell, 2010) and (Noussair et al., 2001).

2 Experimental design

2.1 Assets, dividends and arbitrage

Consider a world with two commodities. One is a non-interest bearing and non-dividend paying commodity called "pesos," whose units we express in ₱. The second is an asset that lives for five periods, pays a publicly observed peso dividend at the conclusion of each period and provides a commonly known terminal redemption of ₱21. The sequence of the asset's dividends is generated by randomly selecting **without replacement** from the following set of values: $\{-6, -6, -6, 6, 6\}$. At any point in time we know with certainty the value of the sum of the remaining dividends and the terminal redemption value. Consequently, as long as we only value the closing balance of pesos after terminal redemptions[4], the asset always has a known and certain peso equivalent. This peso equivalent is the fundamental value of the asset.

The potential time paths of the fundamental value exhibit a variety of patterns, distinguishing this environment from other experimental studies of multi-period lived assets. Figure 1 presents the set of all potential fundamental value paths. All paths start at the value of fifteen in period one. Then the path either increases by six when a -6 dividend is drawn or decreases by six when a 6 dividend is drawn. The maximum potential fundamental value of thirty-three is realized when the first three dividend draws are -6. The minimum potential fundamental value of three is realized when the first two dividend draws are 6. In period five all dividend paths either reach the value of fifteen or twenty-seven.

What is arbitrage in this world? When there is an exchange of a unit of the asset for an amount of pesos which differs from the fundamental value, an arbitrage has occurred. If the amount of pesos is below the fundamental value, we call it a buy arbitrage; the buyer has ensured herself a certain gain in her final pesos holdings. Consider an example. Suppose it

[4] Or alternatively we don't discount the stream of dividends, are indifferent over the sequence by which the future dividends are realized, or have non-Bayesian subjective beliefs about when a remaining dividend value will be drawn.

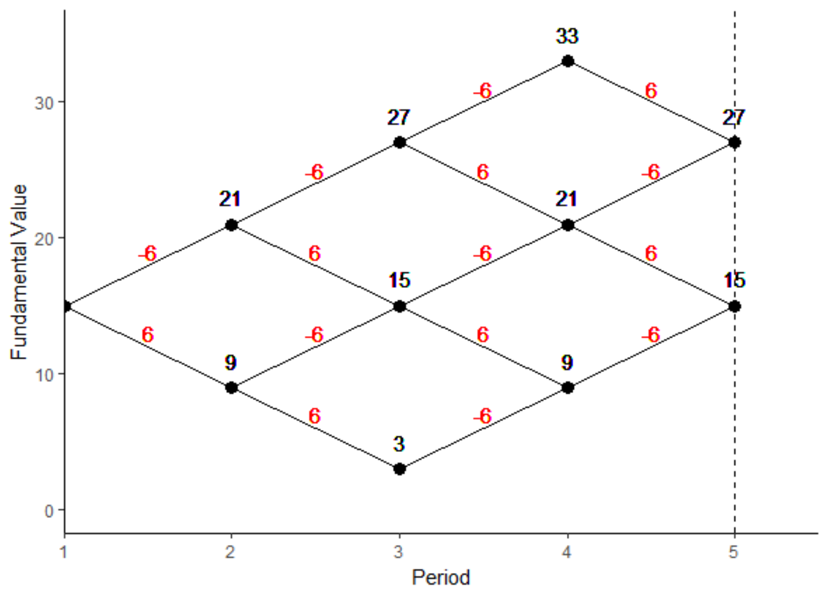

Figure 1: The set of all possible fundamental value paths across the five periods; the y-axis, and numbers above nodes are fundamental values, and the numbers above the branches are the realized dividend values

is period two and the period one dividend was ₱6. The fundamental value of the asset is now ₱9. If a trader purchases a unit of the asset at a price of ₱4, her final pesos holdings will assuredly increase by ₱5 assuming she holds the asset until the redemption.

When there is an exchange of a unit of the asset for an amount of pesos which is above the fundamental value, we call it a sell arbitrage. Consider another example. Suppose it is period four and the previous three dividends were ₱6, ₱-6, and ₱6. The fundamental value of the asset is now ₱9. If a trader sells a unit of the asset at a price of ₱14, she assuredly increases her final pesos holdings by ₱5.

2.2 Market microstructure

All trades take place in a continuous double auction. Each period, prior to the dividend realization, there is a fixed length of time in which traders may generate publicly observable messages which can lead to bilateral trades. There are four types of messages traders can submit. The first two are limit orders. A limit bid is an amount of pesos at which the trader is willing to purchase a unit of the asset. A limit ask is an amount of pesos a trader is willing to accept to provide a unit of the asset. These limit bids and asks are publicly displayed in the "order book." Limit bids are listed from highest to lowest, while limit asks are listed from the lowest to highest. We impose rules restricting the submission and removal of limit orders. Any new limit bid must exceed any limit bid in the order book, and any new limit ask must be lower than any other limit ask in the order book. A trader can freely withdraw a limit order from the order book as long as it is not the highest bid or lowest ask. We defer discussion of other restrictions that are conditional upon a trader's portfolio. Whenever a trader submits a limit bid above the current lowest limit ask a trade is triggered at the limit ask price. Likewise, when a trader submits a limit ask below the current highest limit bid, a trade occurs at the limit bid price. We evacuate the order book when a trading period concludes.

There are two other types of messages a trader may submit: market buys and market sells. A trader submits a market buy when she wishes to purchase a unit at the lowest limit ask in the order book. This generates a transaction in which the trader submitting the market buy and trader who submitted the lowest current ask trade at that ask. Similarly, a trader submits a market sell when she wishes to sell a unit of the asset at the highest limit bid in the order book. This generates a transaction in which the trader submitting the market sell and the trader who submitted the current highest bid trade at that bid. Note that whenever a transaction occurs the involved limits order(s) are removed from the order book. We forbid traders from submitting market and limit orders that transact with their own limit orders. We defer discussion of other restrictions on market orders that are conditional upon a trader's portfolio.

These rules define a continuous double auction, and allow for three types of arbitrage opportunities: explicit, implicit and unrealized. Each of these can manifest as either a buy or sell arbitrage. In an explicit arbitrage either a limit ask is submitted lower than the fundamental value and is accepted by a market buy or matched with a subsequent limit bid (explicit sell arbitrage), or a limit bid is submitted exceeding the fundamental value and is accepted by a market sell or matched with a subsequent limit ask (explicit buy arbitrage). When a limit ask is submitted which exceeds the fundamental value and is subsequently accepted, or when a limit bid is submitted below the fundamental value and is subsequently accepted, this is called implicit arbitrage. The former is an implicit sell arbitrage and the latter is an implicit buy arbitrage. Finally, when a limit ask is submitted below the fundamental value, or a limit bid is submitted above the fundamental value, but the trading period expires with the limit order still in the order book this is called an (buy or sell accordingly) unrealized arbitrage.

2.3 Endowments, feasible portfolios and market frictions

We complete the specification of the microeconomy by noting there are n traders each with a common portfolio endowment of pesos and units of the asset, $(\mathring{\mathrm{P}}, \mathring{A}) = (100, 3)$.[5] The specification of additional rules on limit and market orders define the sets of feasible commodities (i.e. portfolios) and, at the same time, market frictions. These market frictions are forms of short sale and leveraged purchase constraints.

We restrict limit asks and market sells conditional upon a trader's current holding of assets and her limits orders in the order book. These are short sale constraints. We define the short sale limit K as a lower bound on the number of assets held in a trader's portfolio less the number of limit asks she owns in the order book. When this difference reaches the lower bound K she can no longer submit any limit asks or market sell orders. When $K = 0$ there are no short sales permitted in the market. When we allow for short sales, we adopt an alternative level of $K = -235$. When the minimum possible fundamental value of the asset of three is realized, $K = -235$ is still sufficient for any one trader to absorb the aggregate endowment of pesos in the market. When a trader holds a negative quantity of the asset at the conclusion of a trading period they "pay" rather than receive the dividend for each negative unit. If they hold a negative quantity of the asset at the end of period 5, they must

[5] The number of traders and the common endowment is public knowledge.

pay the terminal redemption for each short sold unit of the asset.

We also restrict limit bids and market buys conditional upon a trader's current peso holdings and her limit bids in the order book. These are leverage constraints. We define the leverage limit L as a lower bound on a trader's peso holdings less the total value of pesos she has committed to limit bids in the order book. When $L = 0$ there is no facility to borrow pesos from in order to purchase units of the asset. At times we provide a facility from which any trader can borrow pesos without interest. In this case the alternative leverage limit is $L = -600$. At this limit any trader can purchase the entire aggregate endowment of the asset at its maximum possible fundamental value of ₱33. If a trader holds a negative quantity of pesos after period 5, then she must pay this balance from her terminal redemption values of her final asset holdings.

2.4 Experimental treatments

We create the first of two experimental treatment designs by turning on and off the short sale and leveraged purchase constraints. When we impose short sale and leverage constraints, i.e. maximal market frictions, a trader's portfolio is approximately[6] constrained to the positive orthant of the Cartesian plane. This is depicted as region I in Figure 2, which includes the individual traders' common endowment $(\mathring{P}, \mathring{A}) = (100, 3)$. We call this our "Baseline" environment.

When we allow for short sales the set of feasible portfolios approximately extends to include both regions I and II, where the short sale limit $K = -235$ is indicated by the horizontal dashed line. We call this our "Short sale" treatment. When we allow for leveraged purchases, but no short sales, the feasible set of portfolios consists of regions I and III, where the vertical dashed line indicates the leverage limit $L = -600$. We call this our "Liquidity" treatment. When we remove all market frictions, i.e. allow for both short sales and leveraged

[6]When a trader takes a position with a large asset-to-peso ratio it is possible for her peso holding to be negative through the realization of negative valued dividends. In such cases, we dont force her to sell assets to comply with the non-negativity of pesos constraint, but do forbid her from submitting limit bids and making market buys.

purchases, the set of feasible portfolios consist of regions I through IV. We call this our "Liquidity + short sales" treatment.

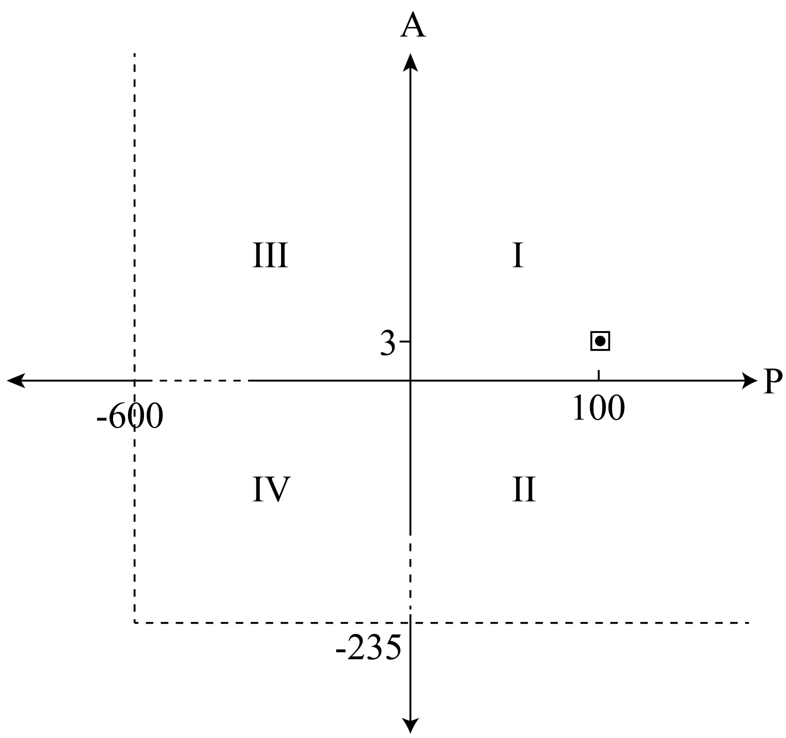

Figure 2: Feasible commodity spaces: the alternative sets of feasible portfolios as determined by alternative combinations of short sale and leverage constraints.

Our second experimental design by varies the aggregate wealth of the two-good economy while maintaining our baseline levels of market frictions. We do this through the manipulation of the number of traders, n, or the size of the traders' portfolio endowments. We utilize the same baseline as from our first experimental design, an economy with eight traders, $n = 8$, each with a portfolio endowment of $(\mathring{P}, \mathring{A}) = (100, 3)$. Next, we consider a 2.5 fold-replication of this baseline economy. In other words we enlarge the economy by including 2.5×8, or 20, traders each with the same portfolio endowment of $(100, 3)$. This leads to a 150% increase in the aggregate wealth, from ₱1160 in the Baseline treatment to ₱2900, while maintaining a per capita initial wealth of ₱145. We call this our "Competition" treatment. Our other capitalization manipulation is to maintain $n = 8$ while increasing initial portfolio endowments so that aggregate wealth is ₱2900. This is achieved by giving four traders the portfolio endowment $(250, 7)$ and the other four traders $(250, 8)$. We call this our "Big endowment" treatment. Table 1 summarizes our experimental designs.

Table 1: The two experimental treatment designs

(a) Treatment design 1: 2x2 factorial treatment design on short sales and leverage constraints

		Leveraged purchase	
		No	Yes
Short sales	No	Baseline	Liquidity
	Yes	Short sale	Liquidity + Short sale

(b) Treatment design 2: three capitalization variations

	Baseline	Competition	Big Endowment
Number of traders	8	20	8
Portfolio endowment	$(100, 3)$	$(100, 3)$	$(250, 7)/(250, 8)$

Note: For treatment design 1, we have 8 traders in each experimental session, and each trader has a portfolio endowment $(100, 3)$. Each treatment cell in both design is applied to five experimental sessions.

2.5 Experimental procedures

Our two experimental designs incorporated a total of six treatments: Baseline, Short sales, Liquidity, Liquidity + Short sales, Competition and Big endowment. We used a between subject design; each experimental session experiences exactly one of the six treatments. For each treatment we conducted five sessions.

We started each experimental session by providing each participant a hard copy of the instructions[7] which we asked them to read quietly along with a monitor who reads them aloud. This established public mutual knowledge regarding all aspects of the experimental session. After reading the instructions, we required traders to privately and correctly answer at least nine out of ten questions to demonstrate their adequate understanding of the dividend structure, how experimental earnings were determined and the trading rules. At this point we initiated a sequence of five independent markets, each lasting five periods. We paid the

[7]We provide a translated set of these instruction in the Appendix. Original versions in Mandarin are available upon request.

traders for only one of the five markets. At the conclusion final market, the monitor rotated a bingo cage and selected randomly from the five balls to determine which market we would use to determine the traders' earnings. Traders were paid their earnings privately and the session concluded.

The five markets were independent in the following sense. We reset the traders' initial portfolio endowments prior to each market. We also used a new independent realization of the dividend sequence.[8] An extensive literature examining experimental markets for a finite but multi-period asset with symmetric information on the dividend process, initiated by the seminal work of Smith et al. (1988) and recently surveyed by Palan (2013), has established that mispricing is greatly dissipated after a cohort of traders has twice experienced the same market but with different dividend. We are not aware of any study which uses an asset living for as few as five trading periods. For this reason we extended the number of market repetitions.

We next provide details on our computerized implementation of the continuous double auction.[9] Each of the five trading periods in a market lasts for two minutes. Figure 3 presents an annotated screen capture of the trading screen used in the experiment. In the top portion of the screen a trader can find information about the realized and yet unrealized dividends, and her closing portfolios in each of the previous trading periods of the current market. In the middle portion of the screen she can find her current portfolio, and the amount of available pesos and asset units which she can use to make limit and market orders. We provide, in the middle of the screen, the fields by which she can make limit orders and the buttons she can use to make market orders. Below this, she can find the order book. In the lower right portion, she can find a list and a plot of all the current period transaction prices.

[8] Prior to the experimental session, the monitor used a bingo cage to determine the dividend sequence for each of the five markets. The monitor inserted a written record of each dividend sequences into an envelope. The monitor taped these envelopes to a platform that all traders could see during the experiment. After each market, the monitor opened the just concluded market's envelope and projected its contents. This was done to publicly confirm the dividend sequence and verify procedural integrity.

[9] We programmed the continuous double auction experiment using z-Tree 3.2.8 (Fischbacher, 2007) by modifying code generously provided by Michael Kirchler.

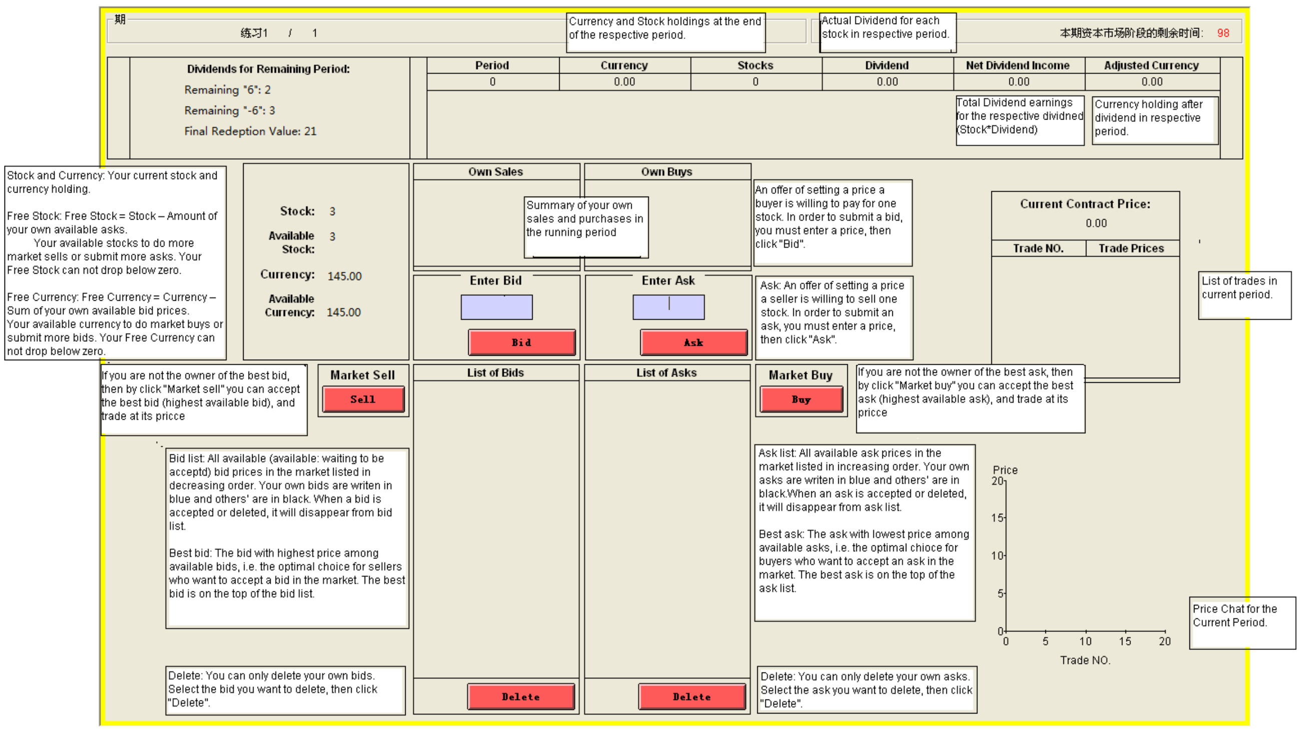

Figure 3: The trading screen of the continuous double auction

We conducted all sessions at the Finance and Economics Experimental Laboratory (FEEL) at Xiamen University. All three hundred traders consisted of undergraduate or master students attending Xiamen University. They came from various schools, such as law, computer science, chemistry and biology. But the most represented schools, with around 40% of the traders, were economics - which houses finance majors - and management. Most participants had previous experience in other studies at FEEL, but none had any previous experience in asset market experiments. We only allowed traders to participate in a single session. We recruited subjects using the ORSEE subject recruitment system (Greiner, 2004). There were approximately 1600 students in the subject pool database from which we randomly selected members to send e-mail invitations. The e-mail invitations conveyed that the experiment would last no longer the two and one-half hours and they would receive a show-up fee of ¥10. We added a trader's earnings from the selected market to her show-up fee. These market earnings were converted from pesos to Chinese Yuan at an exchange rate of ₱3 to ¥1. There was limited liability, and if a trader had a negative pesos balance she only received her show-up fee. This affected only one out of the three hundred traders.

3 Results

3.1 Arbitrage

We begin by presenting the times series of nominal arbitrages in each experimental market. Figures 4-9 display for each treatment a stack of five plots. Each layer of a stack corresponds to one of the five experimental sessions. The vertical-axis measures the peso amount of an arbitrage: the horizontal-axis measures continuous time.[10] For each trading period we provide two pairs of numbers. The top pair reports the number of realized and unrealized sell arbitrages while the bottom pair reports the number of realized and unrealized buy

[10]We break the layer into five segments, one for each five market iterations. These are demarcated by the thick vertical lines. Each of these market segments is further divided into five sub-segments, one for each trading period, which we demarcate by the thin vertical lines.

arbitrages.

The midpoint of the vertical-axis is zero, and the magnitude of plotted values above this reference line are the nominal peso amounts of sell arbitrages, and the magnitude of those below are the nominal peso amounts of buy arbitrages. Let's first consider sell arbitrages. We mark explicit and implicit sell arbitrage transactions with upward and downward pointing triangles respectively. We use a similar practice to mark realized buy arbitrages. We mark unrealized arbitrage opportunities by black triangles plotted at the closing time of a trading period.

These time series plots convey our study's key findings. In the Baseline treatment, Figure 4 exhibits consistent arbitrages across markets with more Sell than Buy arbitrage.[11] When we allow generous leverage purchasing, see Figure 5, arbitrage does not diminish and becomes even more Sell arbitrage dominated. Adding Short sales, see Figure 6, does not diminish the frequency of arbitrage but does suppress prices in general; Buy arbitrage is now more frequent than Sell arbitrage. When we add both leveraged purchases and short sales, see Figure 7, we observe arbitrage of similar magnitude to the Baseline levels but with greater frequency. Returning to a world with market frictions but a larger number of traders, see Figure 8, seemingly reduces the magnitude of arbitrages but increases volume tremendously. Holding the number of participants constant but increasing the size of their portfolio endowments, see Figure 9, reduces the average size of arbitrage and its frequency.

We quantify the visually suggested effects of market frictions and capitalization by reporting summary statistics for All, Sell and Buy arbitrage by treatment in Table 3. Within each of these arbitrage types we consider implicit, explicit and either kind of arbitrage. For each category we report two statistics. The first statistic is the mean of the arbitrage magnitude conditional upon a transaction being the considered arbitrage type. The second statistic is the proportion of all trades which are of the considered arbitrage type.

The Baseline treatment generates the largest magnitude of arbitrage with an average of

[11] This is consistent with the large body of literature on experimental asset markets, but our findings provide an important extension of these results to a non-monotonic and certain fundamental value paths.

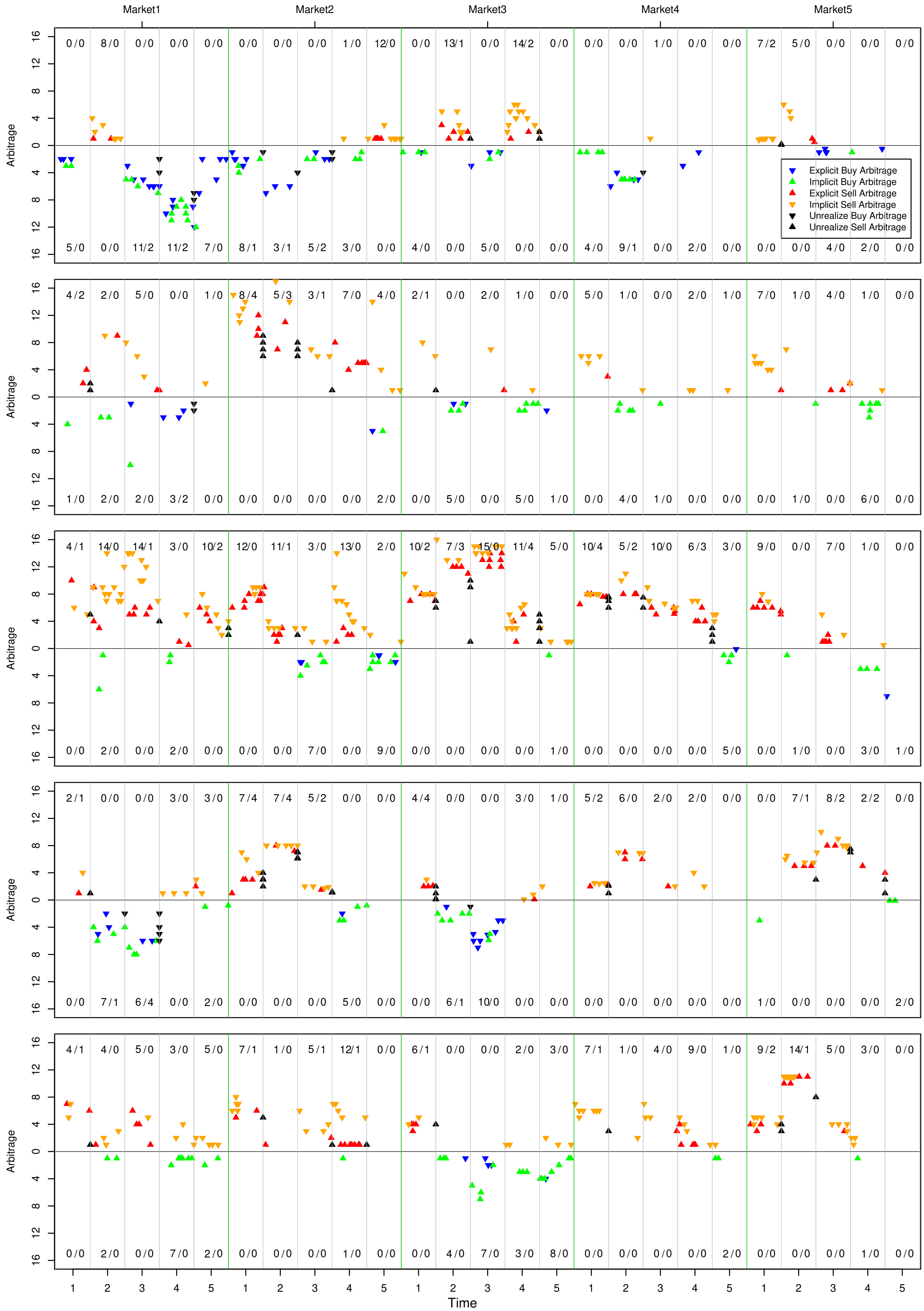

Figure 4: Arbitrage time series plots for all sessions: Baseline treatment.

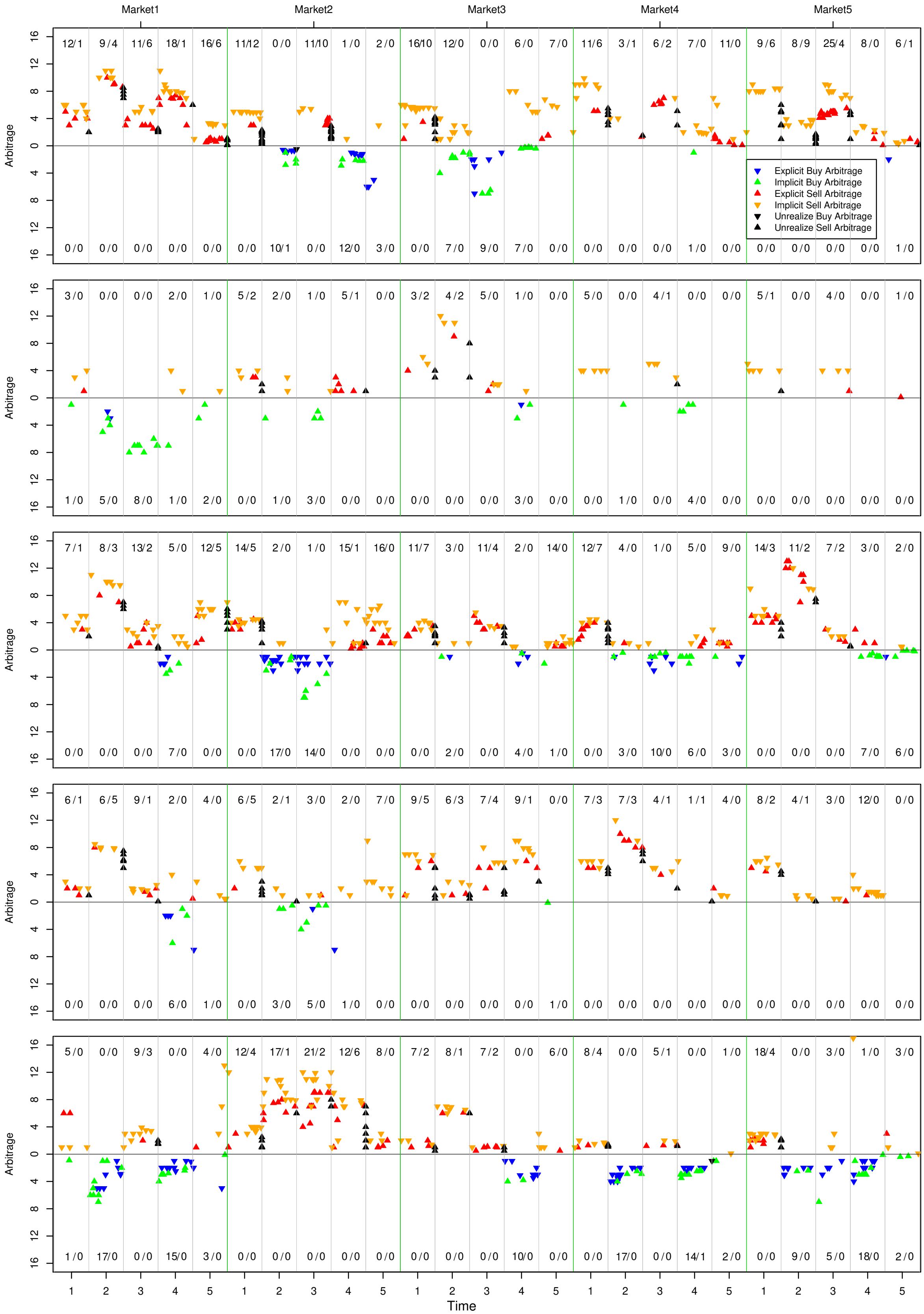

Figure 5: Arbitrage time series plots for all sessions: Liquidity treatment.

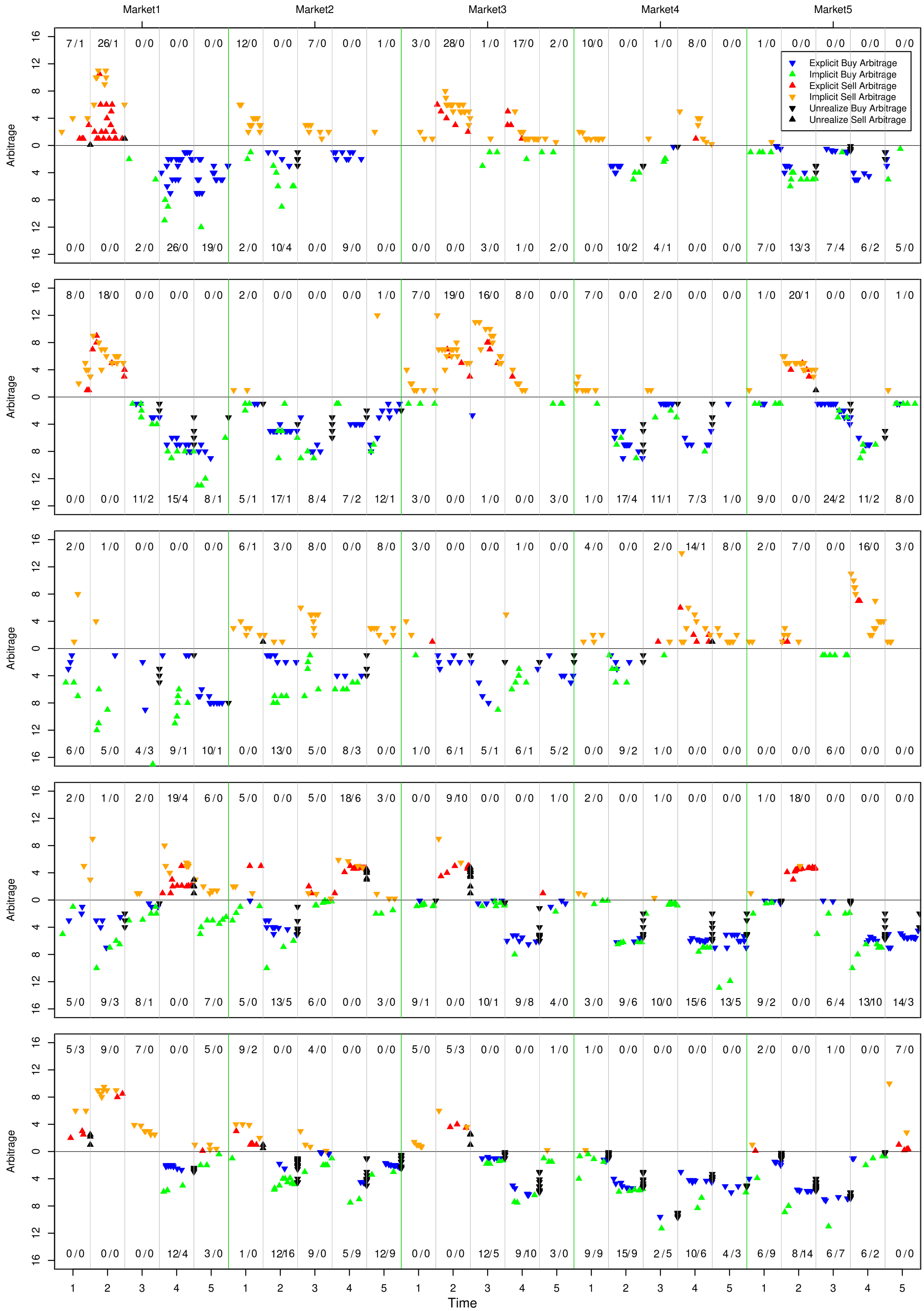

Figure 6: Arbitrage time series plots for all sessions: Short sale treatment.

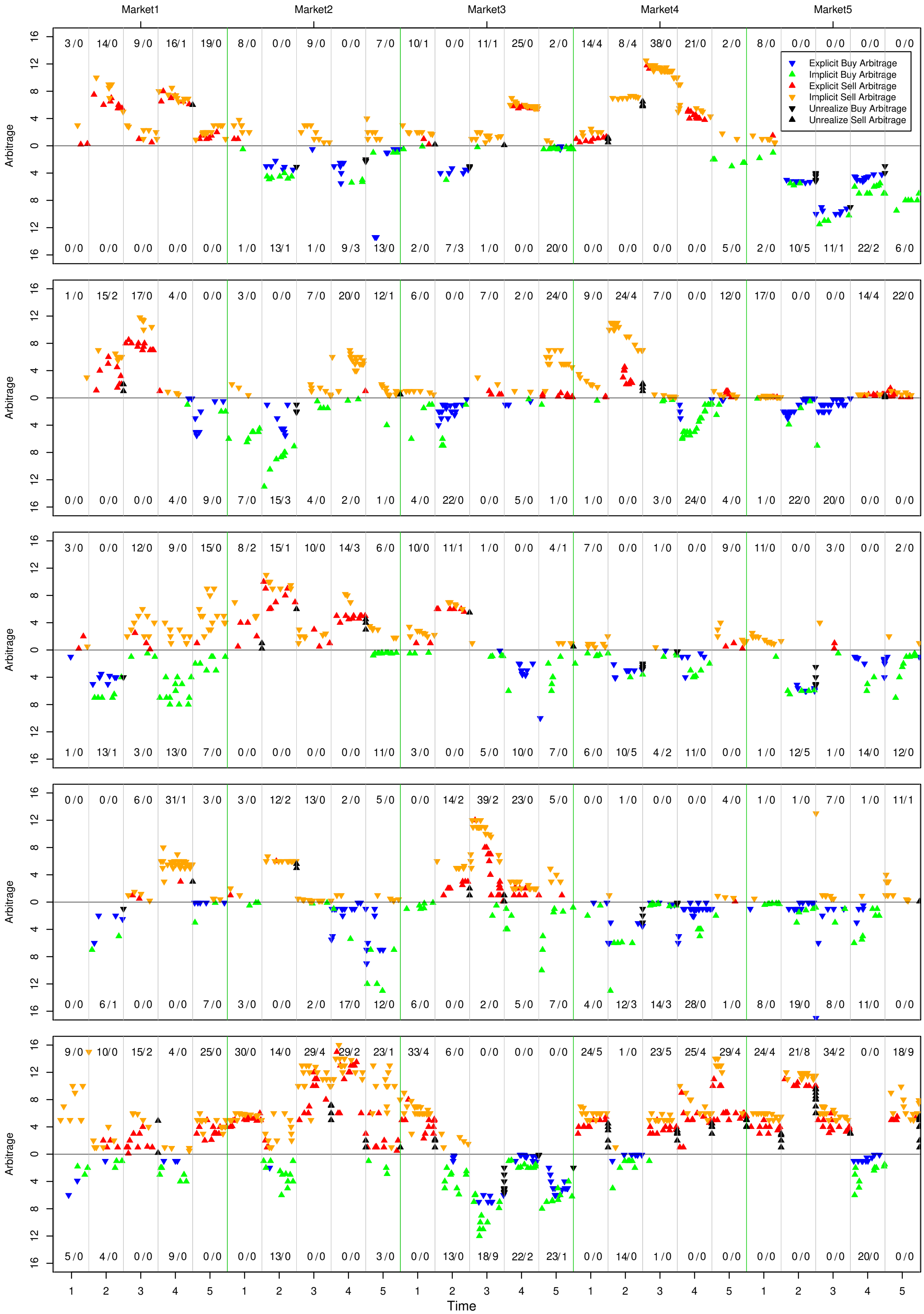

Figure 7: Arbitrage time series plots for all sessions: Liquidity + Short sale treatment.

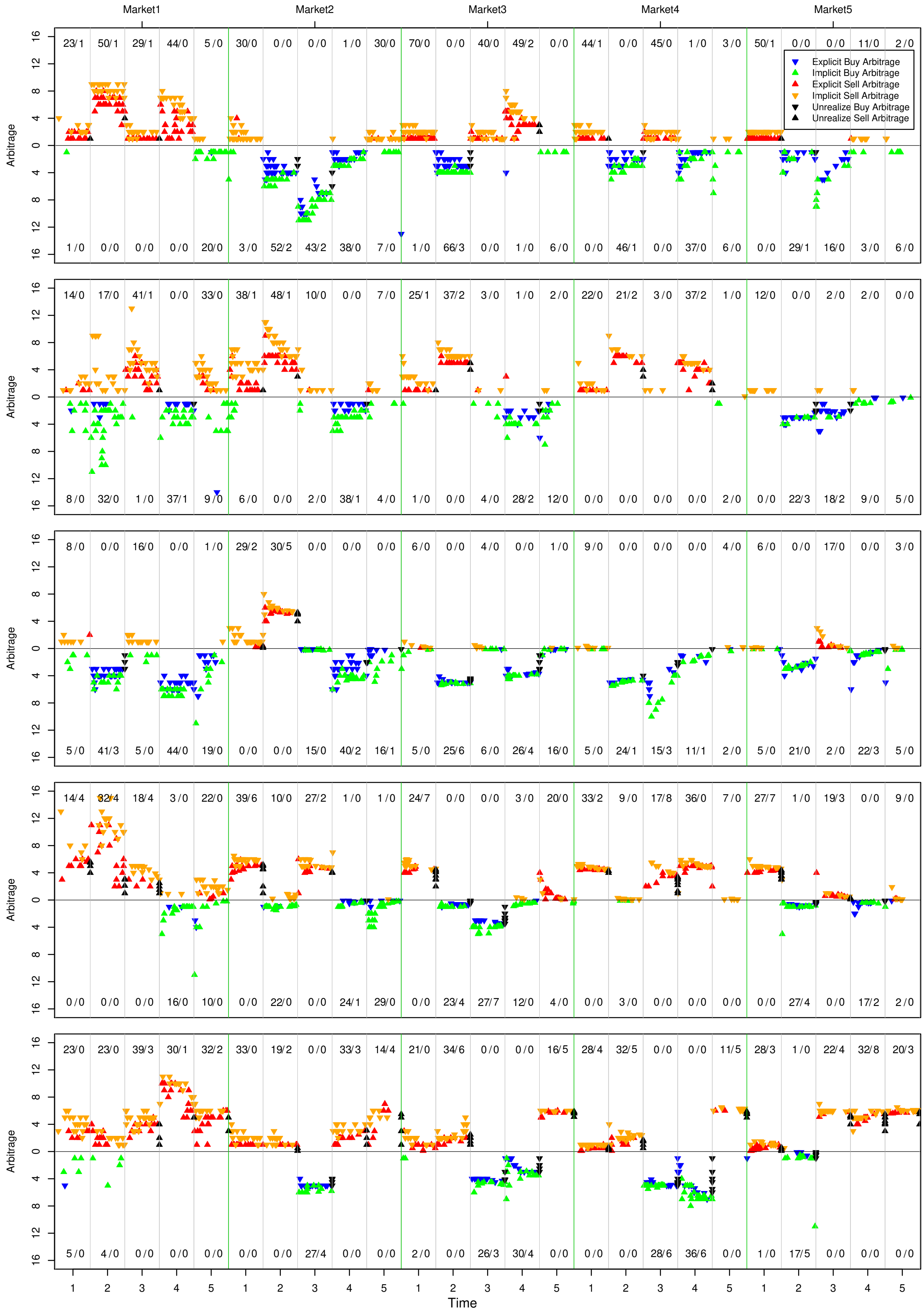

Figure 8: Arbitrage time series plots for all sessions: Competition treatment.

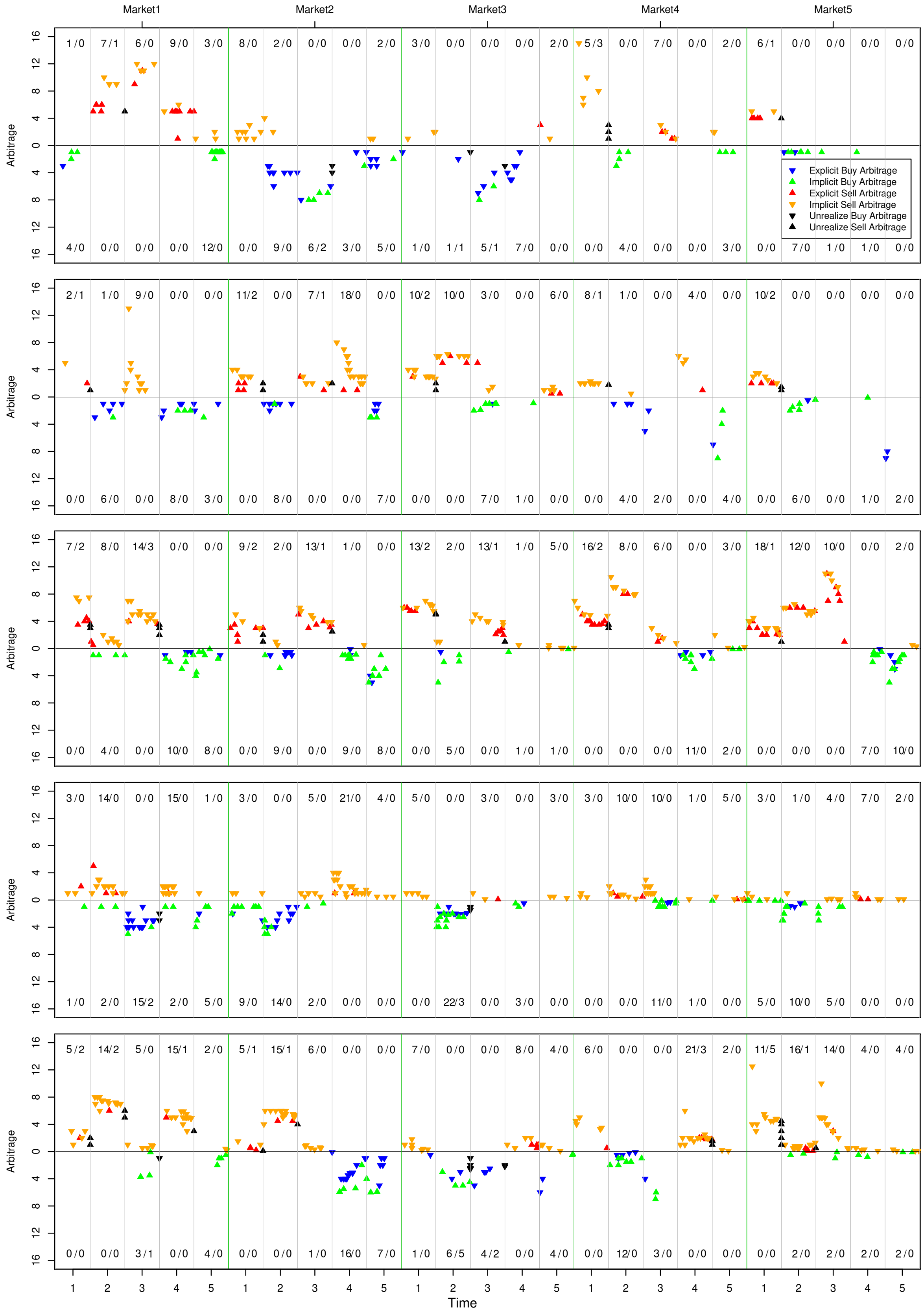

Figure 9: Arbitrage time series plots for all sessions: Big Endowment treatment.

Table 2: Summary statistics by arbitrage type and treatment: mean arbitrage magnitude and the percentage of trades that are of a given arbitrage category

	All Arbitrage			Sell Arbitrage			Buy Arbitrage		
	Either	Explicit	Implicit	Either	Explicit	Implicit	Either	Explicit	Implicit
Competition	3.20	2.93	3.39	3.36	3.05	3.55	2.99	2.80	3.14
	86%	36%	51%	50%	19%	30%	36%	16%	20%
Big Endowment	2.75	2.71	2.76	3.13	3.10	3.14	2.13	2.36	1.97
	81%	25%	56%	50%	12%	38%	32%	13%	18%
Baseline	4.70	4.55	4.79	5.41	5.00	5.65	3.16	3.53	2.95
	88%	33%	55%	60%	23%	38%	28%	10%	18%
Liquidity	3.69	3.05	4.10	4.20	3.50	4.58	2.36	2.17	2.53
	91%	35%	56%	66%	23%	43%	25%	12%	13%
Short sale	3.86	3.74	3.98	3.77	3.65	3.81	3.93	3.77	4.15
	89%	42%	47%	35%	10%	25%	54%	31%	22%
Liquidity + Short sale	4.19	3.55	4.62	4.93	4.45	5.19	2.98	2.49	3.44
	89%	35%	54%	55%	19%	36%	34%	16%	18%

Table 3: Test the difference between the magnitude of sell arbitrage and that of buy arbitrage

	Sell Arbitrage	Buy Arbitrage	t	p-value
Competition	3.36	2.99	4.09	0.000
Big Endowment	3.13	2.13	7.17	0.000
Baseline	5.41	3.16	8.98	0.000
Liquidity	4.20	2.36	12.10	0.000
Short sale	3.77	3.93	0.94	0.347
Liquidity + Short sale	4.93	2.98	9.36	0.000

₱4.70. Increasing capitalization by Competition or Big Endowment reduces the magnitude of the arbitrage to ₱3.20 and ₱2.75 respectively. These reductions are larger than we observe with leveraged purchases, ₱3.69, or short sales, ₱3.86. More over, simultaneously relaxing both types of frictions increases the average arbitrage amount to ₱4.19: counter to what we expect to happen when liberating the invisible hand.

Also, Sell arbitrage is more prevalent than Buy arbitrage in terms of magnitude and proportions. In fact, the majority of trades are Sell arbitrages in all treatments. The Short sale treatment is the exception. The magnitude of Sell arbitrage in this treatment is the lowest of the non-capitalization treatments. Further, Sell arbitrage only makes up 35% of the total transactions, while Buy arbitrage makes up the majority, 54%. This is consistent with Haruvy and Noussair (2006) who find that short sales tend to dampen prices while failing to establish rational expectation ones.

Table 3 also provides insights into the microstructure of how arbitrage occurs. In all treatments, Implicit arbitrage occurs more frequently than Explicit arbitrage. Further in all cases, except for Buy arbitrage in the Baseline and Big endowment treatments, the average magnitude of Implicit exceeds Explicit ones. To summarize, the strategy to generate the most frequent and largest arbitrages is to submitting limit asks above the fundamental value.

We provide further statistical evidence of our results and investigate the dynamic evolution of arbitrage in our markets through linear regression analysis. The average arbitrage amount in a trading period is our unit of observation, and we filter out periods where there are no arbitrages. The varying number of arbitrages across periods introduces a structural form of heteroskedasticity. Accordingly, we use weighted least squares (WLS) regression models.[12] For concern out of other forms of heteroskedasticity we use robust standard errors clustered at the session level when making statistical inferences.

We report the results of these WLS regressions in Table 4 for three dependent variables: All, Sell and Buy arbitrage. For each of these dependent variables we first estimate a simple treatment dummy-variable model. Notice this simply recreates the values given in Table 3. In these dummy-variable models, the t-statistics confirm that the capitalization treatments reduce the magnitude of All and Sell arbitrage, but only the Big endowment treatment significantly reduces this magnitude for Buy arbitrage. Removing market frictions does not reduce the magnitude of any type of arbitrage. In the second version of the WLS models we control for dynamic effects by introducing the variables Market iteration, to capture learning across asset lives, and Trading period, to control for the constriction of dividend paths with the number of periods.[13] Here we find there is a statistically significant, but low-valued, learning trend across Market iterations; but the treatment effects are robust to adding this

[12]If we assume that the unobserved error of each arbitrage is independently and identically distributed, then the variance of the period average is inversely proportional to the number of arbitrages. To correct for this we use the efficient weighted least square regression technique, (Houthakker, 1951), by which we multiply the values of the dependent and independent variables by the square root of the respective period's arbitrages.

[13]Note, we have zero indexed these two variables, so that constant term reflects the average magnitude of arbitrage of trading period 1 in the first Market iteration.

control. Our final models include the period's Cash-Asset ratio, a commonly identified factor that drives the formation of asset bubbles in experimental asset markets (Caginalp et al., 1998; Kirchler et al., 2012). We find this factor significant, positively for Sell arbitrage and negatively for Buy arbitrage.

Table 4: Weighted least square regression results for All, Sell, and Buy Arbitrage. t-statistics reported in parentheses. We use robust standard errors clustered at the session level in our statistical analyses.

	All Arbitrage			Sell Arbitrage			Buy Arbitrage		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Competition	-1.50*	-1.50*	-1.34*	-2.05*	-2.11*	-1.94*	-0.17	-0.075	-0.097
	(-2.22)	(-2.21)	(-2.34)	(-2.33)	(-2.40)	(-2.19)	(-0.25)	(-0.11)	(-0.14)
Big endowment	-1.96**	-1.94**	-2.00**	-2.27**	-2.28**	-2.29**	-1.03*	-0.96*	-0.63
	(-2.89)	(-2.88)	(-2.94)	(-2.81)	(-2.87)	(-2.81)	(-2.32)	(-2.27)	(-1.56)
Constant	4.70***	5.40***	4.18***	5.41***	6.07***	4.41**	3.16***	3.51***	4.21***
(Baseline level)	(7.16)	(6.54)	(5.19)	(6.26)	(6.17)	(4.51)	(6.13)	(5.75)	(4.83)
Liquidity	-1.01	-0.97	-0.77	-1.21	-1.19	-0.85	-0.80	-0.71	-0.86
	(-1.10)	(-1.07)	(-0.95)	(-1.06)	(-1.07)	(-0.78)	(-1.25)	(-1.11)	(-1.20)
Short sale	-0.84	-0.78	-0.70	-1.64	-1.67	-1.95*	0.77	0.90	0.97
	(-1.44)	(-1.39)	(-1.47)	(-1.83)	(-2.07)	(-2.43)	(1.10)	(1.31)	(1.32)
Liquidity	-0.51	-0.38	-0.50	-0.48	-0.41	-0.64	-0.18	0.044	0.083
+ Short sale	(-0.46)	(-0.36)	(-0.49)	(-0.34)	(-0.30)	(-0.45)	(-0.38)	(0.10)	(0.18)
Market iteration		-0.25**	-0.20*		-0.22*	-0.16		-0.25*	-0.25*
		(-3.65)	(-2.25)		(-2.64)	(-1.44)		(-2.60)	(-2.61)
Trading period		-0.15	-0.12		-0.15	-0.20		0.011	-0.018
		(-1.34)	(-1.27)		(-0.80)	(-1.29)		(0.10)	(-0.15)
Cash-Asset Ratio			0.41***			0.51***			-0.45*
			(6.52)			(5.93)			(-2.30)
R^2	0.05	0.07	0.21	0.07	0.08	0.29	0.06	0.09	0.15
Observations	731	731	731	543	543	543	430	430	430

3.2 Market efficiency

Efficient market theories often rely upon a no-arbitrage assumption. This relationship is abundantly clear in our set-up as the dividend process renders every mis-priced transaction an arbitrage. In this subsection we investigate how our various treatments impact market efficiency. Here we focus on price deviations from the fundamental value, as symmetric information and homogeneous traders' preferences make price efficiency a sufficient condition for market efficiency. Here we find that differential degrees of arbitrage leads to similar differences in market efficiency.

The summary statistics in Table 5 suggest that increases in capitalization improve market efficiency, while the relaxations of market frictions fail to do so. The first column, FV, reports the average realized fundamental value across trading periods and the second column, Price, reports the average of the average price within periods. We report the results of t-tests that Price = FV, by using dagger indicators for rejections. We reject no price bias for the Baseline and all of the market friction treatments, but we fail to reject no price bias in the capitalization treatments. In the last column we report the average volume of transactions in a period. Remarkably, volume is statistically greater in all treatments relative to the Baseline. Both the Competition and Liquidity + Short Sale treatments have very high volumes.

The next four columns of Table 5 report various commonly used price efficiency measures (Stöckl et al., 2010) and compare them to the Baseline levels. The third column, PD, is the average difference of the average transaction price of a period and the fundamental value; the second column value less the first column value. In this case we evaluate whether this deviation is statistically differs from the Baseline treatment. Here we find our two capitalization treatments have smaller price biases. The Short sale treatment has a lower bias, but is in fact negative and of a similar magnitude as the Baseline.

Under PD a positive and negative price deviation will tend to cancel each other out. To counter this, we examine the average absolute price deviation, APD. Under this measure we

Table 5: Summary statistics for Market Efficiency

	FV	Price	PD	APD	RPD	RAPD	Volume
Big endowment	17.50	18.15	0.66***	2.22***	0.12	0.19	9.87***
	(6.29)	(4.92)	(3.17)	(2.35)	(0.46)	(0.43)	(5.00)
Competition	17.21	17.81	0.61***	2.56**	0.11*	0.20*	30.41**
	(5.20)	(3.77)	(3.38)	(2.28)	(0.36)	(0.32)	(11.87)
Baseline	17.21	19.08†††	1.95	3.39	0.22	0.29	6.48
	(5.73)	(4.59)	(4.27)	(3.24)	(0.56)	(0.53)	(3.55)
Liquidity	18.74	20.86†††	2.17	3.01	0.20	0.24	9.23***
	(5.94)	(4.16)	(3.36)	(2.63)	(0.38)	(0.36)	(5.18)
Short sale	16.92	15.70††	-1.22***	3.11	0.00***	0.20	10.85***
	(5.20)	(2.57)	(3.88)	(2.62)	(0.33)	(0.26)	(5.05)
Liquidity + Short sale	16.44	17.50††	1.06*	3.10	0.19	0.28	17.40***
	(5.56)	(3.77)	(4.08)	(2.85)	(0.54)	(0.49)	(7.98)

Note 1: PD refers to Prices Deviation. $PD = Price - FV$, where FV refers to the fundamental value of the asset. APD refers to Absolute Price Deviation. $APD = |Price - FV|$. RPD refers to Relative Price Deviation. RPD = $(Price - FV)/FV$. RAPD refers to Relative Absolute Deviation= $|Price - FV|/FV$.
Note 2: In the table, we reported the mean values of these measurements. The standard deviations are in parentheses.
Note 3: We conducted t tests to examine the difference between the baseline and other treatments. If we observe the measurement in a treatment is significantly below that in the baseline, then we use $*$'s indicate p-value of t test. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$. If we observe the measurement in a treatment is significantly above that in the baseline, then we use †'s indicate p-value of t test. $^{\dagger\dagger\dagger}p < 0.01, ^{\dagger\dagger}p < 0.05, ^{\dagger}p < 0.1$.

find only the capitalization treatments lead to a significant increase in market efficiency.

Some may argue that proportional price deviations are more meaningful than nominal deviations. In our environment the fundamental value can range from ₱3 to ₱33, which could lead to meaningful proportional differences. Columns 5 and 6 of Table 5 report the average relative price deviations, RPD, and the relative absolute price deviations, RAPD. We only marginal evidence of market efficiency for the Competition treatment in terms of these two measures.

3.3 Terminal portfolios and wealth distributions

Arbitrage, in our setting, generates wealth redistribution. A clear welfare concern is how do market frictions and capitalization impact wealth inequality. Figure 10 depicts wealth inequality and heterogeneity of terminal portfolios through an array of density plots with iso-wealth lines for zero wealth and the valuation of the initial endowment plotted for reference. In the Baseline plot, there is a noticeable clustering of corner portfolios, either all pesos or all asset, suggesting market frictions are binding. When we allow just short sales there is a predictable spread of terminal portfolios holding negative asset quantities. Moreover, traders appears to have heterogeneous capabilities in managing this market feature. A number of traders' portfolios lie near the zero wealth line, including some who have lost all of their peso and asset endowments. Introducing just liquidity results in a spread of leveraged terminal portfolios, but not as many near zero wealth portfolios as in the Short sale treatment. In the Liquidity + Short sale treatment the diversity of terminal portfolios and wealth distributions is more extreme than one would get from simply summing the "spreads" of the Liquidity and Short sale treatments.

Our two forms of increased capitalization both effectively reduced arbitrage and market inefficiencies, but have differential impact on terminal portfolios and wealth distributions. In the Big endowment treatment, we divide the terminal values by two and one-half to put it on the same scale as the other treatments. Here we see density massed on interior portfolios and little dispersion in wealth. The Competition treatment has more profound impact. We see mass is more concentrated on the corner portfolios. Further there is an increasing variance in wealth as the final asset holdings go to zero. There are also a number of traders who seem to "lose it all."

We quantify the relative inequality of wealth distributions by calculating the Gini coefficient[14] of the terminal wealth levels given in Figure 10. We report these values in Table 6. These Gini coefficients confirm our observations that one finds the lowest wealth inequality in our Big endowment treatment, and the greatest inequality in the Competition and Liquidity + Short sale treatments. We find this result regarding the Competition treatment surprising. On one hand, the tremendous increase in liquidity, both in terms of total values of limit orders and the number of orders in the books, reduces arbitrage - and in turn inducing greater market efficiency. But on the other hand, this form of increased competition

[14]The Gini coefficient is defined a $G = \sum_{i=1}^{M} \sum_{j=1}^{M} \sum_{s=1}^{5} \sum_{t=1}^{5} |w_{i,s} - w_{j,t}| \big/ 2M \sum_{i=1}^{M} \sum_{s=1}^{5} w_{i,s}$, where M is the total number of traders in a treatment, 40 in all except for 100 in the Competition treatment, and $w_{i,s}$ is trader i's earnings in Market s.

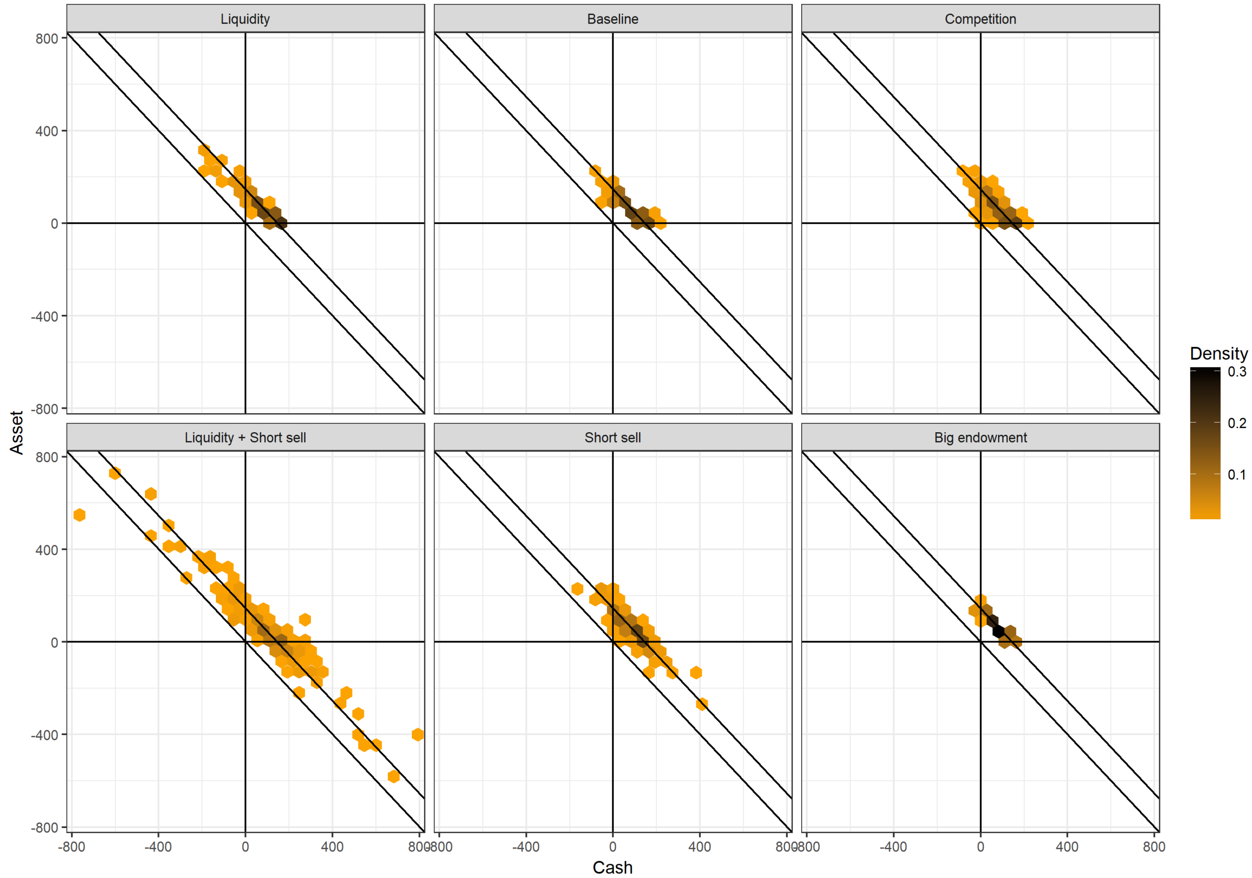

Figure 10: The empirical distributions of terminal portfolios plotted by hexagonal binning. Each asset unit held is by its terminal P21 redemption. The two reference lines with slope of -1 represent equi-wealth portfolios of the initial endowment and zero.

drives greater wealth inequality.

Table 6: Gini Coefficient of terminal wealth for each treatment

Treatment	Gini Coefficient
Competition	0.098
Big endowment	0.032
Baseline	0.078
Liquidity	0.071
Short sale	0.118
Liquidity + Short sale	0.192

4 Conclusion

The absence of arbitrage is an important indicator of well functioning and efficient asset markets. Consequently, the frequent occurrence of persistent arbitrage in financial markets prompts regulators to seek out reforms to extinguish these occurrences. Regulators have a myriad of reform levers they can pull but there is a dearth of causal evidence on the effectiveness of these levers. Our study generates surprising causal evidence on the effectiveness of alternative policies. Namely the general relaxation of short sales and leveraged purchases does not reduce arbitrage opportunities while increasing income inequality. In contrast, increased market capitalization reduces arbitrage opportunities. This comes with the caveat that simply increasing the number of similarly wealthy traders can lead to increases in wealth inequality.

U.S. and Chinese financial markets, and their respective regulatory bodies, illustrate alternative challenges and approaches to financial market regulation. Chinese regulators have typically imposed stricter regulations on short sales and leveraged purchases. For instance, Chinese rules require traders to have at least ¥500,000 (around $80,000) in their margin account while traders in US usually need only $2000 in their accounts. Chinese regulators have considered allowing more liberal limitations on short sales and leveraged purchases. Our experiments suggests more liberal limitations will not diminish arbitrage, but will increase wealth inequality. Such increases could have widespread consequences as retail investors dominate Chinese stock markets.

U.S. financial markets are mature and offer access to investors from most parts of the world. In contrast Chinese markets are still developing and have been closed to foreign investors and until recently were only were accessed by a small proportion of Chinese households. However, the past decade has seen a dramatic increase the number of domestic households investing in Chinese stock markets and a gradual granting of access to foreign traders. To elaborate, retail investors account for around 85 percent of transactions in Chinese stock markets. This is unlike other major stock markets, which are dominated by professional money managers. Our experimental results suggests this trend increases the risk of greater wealth inequality, and suggest one way to garner the benefits of more limited arbitrage while mitigating this risk. Increase trader endowments not their number. In practical terms this could be achieved through the development of larger institutional investors in which individual households take vested interests. But such recommendations of consolidation in markets must also caution that this could lead to monopolistic power and excess management fees charged to the public if left unchecked.

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A Experiment Instructions

These instructions are for Short-sale+Liquidity Treatment. Instructions for other treatments are available upon request.

Welcome and thank you for participating in our experiment on decision-making in asset markets. If you read these instructions carefully and make good decisions, you might earn a considerable amount of money, which will be paid to you in cash at the end of the experiment. We request you do not use hand phones, laptop computers, or use the lab's desktop computer except for the experimental software application. Please refrain from talking for the duration of the experiment, or looking at others' computer monitors. If at some point you have a question, please raise your hand and we will address it as soon as possible. You must observe these rules, otherwise we will have to exclude you from this experiment and all associated payments, and ask you to leave.

The currency used in the experiment is called pesos, and at the end of the experiment we will convert pesos into RMB at the rate of ₱3 = ¥1. Your earnings from the experiment plus a ¥10 participation fee will be your total earnings. At the conclusion of the experiment, we will ask you to sit quietly, while we call you up one at a time to receive your final cash payoffs. When we call your name, please come to the sign-in counter at the front of the room. You will then receive you earnings in private. Thus, we do not reveal your earnings to other subjects, other subjects' earnings to you, nor provide any additional information regarding the amount of money earned in this session or study including the ranks of payoffs.

The experiment will consist of you engaging in 5 independent asset markets sequentially. At the end of the last market, we will show you a complete summary table showing your earnings for each market. Then, the experimenter will use the bingo cage to determine which market is selected to determine your final earnings. There are five balls numbered from 1 to 5 in the bingo cage. The experimenter will rotate the bingo cage until the first ball drops out. These balls are exactly the same except the number on the surface, so they have the equal chance to be selected. For example, if ball three drop out first, then your earnings in the third market will be your earnings from this experiment.

You will participate in 5 independent asset markets, which means that the pesos earnings of different markets are unrelated. The trading system, trading rules and assets traded in the market are the same in all 5 asset markets. Every market will last for 5 trading periods, and each period lasts 2 minutes. In these instructions, we are going to answer the following questions: What is the asset we will trade? and How does the trading system work?

What is the asset we will trade?

In all markets there is a single type of asset you can buy or sell. Prior to the first round of trading in each asset market, each participant will be given 3 units of the assets and ₱700, in which ₱600 needed to be returned at the end of the market. In each of the markets, you can purchase units of the asset unless your currency holding is negative or available currency is negative. In today's markets you can hold a negative quantity of assets, and you can sell assets unless your asset holding is -235 or the available asset is zero.

At the end of each trading period, every unit of the asset will generate a dividend. A dividend is an amount of pesos paid to or extracted from the owner of each asset unit. This amount may differ across periods, but the amount is the same for each asset unit in a certain period. At the end of each period, your dividend income will be the product of that period's dividend and your asset holding at the conclusion of that period. When you receive a positive dividend and your asset holding is positive, or when you receive a negative dividend and your asset holding is negative, your dividend income will be positive and that amount will be added to your currency holdings. When you receive a positive dividend and your asset holding is negative, or when you receive a negative dividend and your asset holding is positive, your dividend income will be negative and that amount will be deducted from your currency holdings. There are two possible dividend values; namely ₱-6 pesos and ₱6. For example, if you have -3 assets at the end of fourth period and the dividend for that period is 6 pesos, then 18 pesos will be deducted from your currency holdings at the end of fourth period.

In every asset market, ₱-6 dividend will occur exactly 3 times and ₱6 dividend will occur exactly 2 times. However, the order of these 5 dividends is random. Prior to the start of the experiment, we will determine the dividend order for each of the three markets respectively. Prior to this session, we determined each dividend order by placing into the bingo cage three yellow balls and two red balls (each color represent a type of dividend.) The experimenter then rotated the bingo cage to select balls one at a time without replacing the selected balls to the cage. The order of the 5 dividends matches the sequence of the selected balls. The experimenter recorded the five dividend orders on different sheets of paper. Then, she put the paper into an envelope, which was then placed on the platform. At the conclusion of each asset market, the experimenter will project on the large screen that period's list of predetermined dividends to confirm they match the dividends observed during of the market.

During an asset market, each period's dividend will be revealed at the end of the period. The only information you will receive regarding current and future dividend amounts is how many periods remain for each dividend type. (This information is provided in the upper left of the trading screen.). You currency balance - adjusted for any positive or negative dividend income - and inventory of assets will carry over in each trading period of an asset market. For example, if you have 4 assets and ₱680 at the end of period 2, and the dividend of period

2 is ₱-6, then you will have 4 assets and ₱656 at the beginning of period 3. However, your currency balance and inventory of assets will not carry from one market to next market.

At the conclusion of the market (i.e., after dividend payments or deduction of the 5th period), your inventory of assets will be liquidated. If your inventory is positive, you need to sell all your assets to the experimenter at the per unit price of ₱21; if your inventory is negative, you need to buy units of the asset from the experimenter at the per unit price of ₱21 to make your inventory to zero. Then, you also need to pay ₱600 loan. Your pesos earnings after the liquidation of asset inventory and paying back your loan will be your market pesos earnings. For example, if at the conclusion of the 5th period your inventory of asset is -2 assets and ₱740, and the dividend of period 12 is ₱-6, then you need to buy 2 assets from the experimenter by paying 42 pesos. Thus, in this example, your asset market earnings would be $740 + (-6) * (-2) + 21 * (-2) - 600$ or ₱90. Therefore, your earnings for each market is the sum of the following elements:

- (plus) Your endowment of ₱700.
- (plus) Your total earnings from selling assets.
- (minus) Your total cost of purchasing assets.
- (plus) The total dividends you earned.
- (minus) The total dividends you paid.
- (plus) When your inventory is liquidated, the pesos you can earn from selling assets.
- (minus) When your inventory is liquidated, the pesos you need pay to buy assets.
- (minus) At the end of the market, you need to return the ₱600 loan.

How does the trading system work?

The trading system for the asset market is called a double auction, in which you are a trader - meaning that you can act as both a seller and a buyer of units of the asset. Once you enter the trading screen - subjects are given a printed copy of the trading screen as shown by Figure 3 alongside their printed copies of the instructions - you can trade till the remaining time (showed in the upper right-hand of the screen) turns to zero.

The market view has seven areas:

1. In the upper left-hand corner you will find a table showing the remaining number of each type of dividend, and the final asset redemption value.

2. Below the first area is another table which shows the current number of assets you own, the number of assets you have available to sell or offer for sale, the amount of pesos you currently hold, and the amount of currency available you have to purchase or to make bids to purchase units of the asset.

3. The top right-hand side of the screen provides for each trading period you final currency and asset holdings, the dividend value, period dividend income, and final currency holding adjusted for this dividend income. Below this area is a pair of tables showing lists of the units sold and purchased for the current trading period.

4. The center area of your screen is where you take market actions and can observe current market conditions. Here you can enter a bid price at which you are willing to purchase a unit in the "Enter Bid" box, then click "Bid", or you can click on the "Buy" button in the "Market Buy" to purchase a unit at the current lowest ask (offer to sell) price in the market. You can enter an ask price at which you are willing to sell a unit in the "Enter Ask" box, or you can click on the "Sell" button in the "Market Sell" box to sell a unit at the current highest bid in the market.

   The "List of Bids" and "List of Asks" provide public information on current market conditions (all participants see this information except which Bid/Ask prices belong to specific other participants.). "List of Bids" gives all of the available (waiting to be accepted) bids in the market while the "List of Asks" gives all of the available asks in the market. Your outstanding bids and asks will be give in Blue text. Note that you can delete one of your bids or asks by selecting it using your mouse and then clicking on the delete button.

5. On the right hand side of your screen you find two summaries for contract prices for the current period. First, there is a table which gives the last trade price at the top and then sequence of previous trading prices. Below this table, you will find a graph displaying the current trading period asset prices.

6. On the left hand side of your screen you can see a calculator. This calculator is based on the converting table. If you input certain amount of pesos earnings, you can know the amount of Points converted from this amount of pesos earnings.

7. Finally, the bar at the top of the screen shows the current trading period and the time remaining in the period.

How to make trades?

As suggested there are four types of actions you can take in a trading period; (1) submit a bid price to purchase a unit, (2) submit an ask price to sell a unit, (3) purchase a unit by accepting the lowest outstanding ask, and (4) sell a unit by accepting the highest outstanding bid. You can also do these in any sequence you want. For example, you can simultaneously have an outstanding bid, an outstanding ask, and then purchase at the lowest ask in the market (as long as it is not your outstanding ask.) You may also have multiple outstanding bids and/or asks at a given time.

There are some basic rules governing what bids and asks you may submit or accept. 1) When you submit a new bid, it must be larger than the current highest bid and you must have at least the bid amount of currency available. 2) When you submit a new asks, it must be smaller than the current lowest ask and you must have at least one unit of the asset in available assets (Note, whenever you successfully submit an ask your inventory of available assets is reduced by one.) 3) If you attempt to buy a unit at the current lowest ask, then you must have enough available currency and you can't purchase from yourself. 4) If you attempt to sell at the current bid, you must have a unit available and you can't sell to yourself. 5) You may delete any bid or ask you submit as long as it is neither the current highest bid or lowest ask.

When a contract occurs, the associated bid or ask is removed to from the List of Bids or Asks. If you are involved in the contract, your currency holdings and asset inventory will be automatically adjusted. Finally, when the trading period ends all bids and asks are removed from the appropriate lists (and the associated asset units and currency are credited back to the participants).

To summarize, you may purchase a unit of the asset in two ways; you may submit a bid price to buy that becomes the current highest bid and another participant "sells" to you, or you may choose to "buy" at the current lowest ask. Likewise you may sell an asset in two ways; you may submit an ask price to sell that becomes the current lowest ask and another participant "buys" from you, or you may choose to "sell" at the current highest bid.

B Quiz

After reading the instructions, subjects were required to correctly answer nine out the ten questions in the following quiz before they could proceed in the experiment.

1. Will your earnings of this experiment be your total earnings from all five market?
2. If you have 2 units of asset and ₱735 at the end of period five of market one, how many units of asset and pesos you are going to have at the beginning of period one of

market two?

3. If you get ₱6 dividend for the first period and ₱-6 for the second period, how many ₱6 dividends and ₱-6 dividends left for the remaining three periods?
4. If you have -5 units of asset and ₱759 at the end of period four but before receiving or paying the dividend, and the dividend of that period turns out to be ₱-6, what will be your pesos holdings after the dividend?
5. If you have an ask listed on the market and you have 237 units of available asset, can you accept the highest bid on the market by clicking "Sell" in the "Market Sell" box.
6. If you have zero unit of asset but 235 units of available asset, can you accept the highest bid on the market by clicking "Sell"?
7. Can you accepted your own bid or ask? If one of your asks is the lowest ask on the market, can you delete it?
8. Suppose your pesos holding is ₱60, and your available pesos is ₱30. If you delete one of your bid whose price is ₱10, then what will be your pesos holding and available pesos after the deletion?
9. If you have -5 units of asset and ₱824 at the end of period five of market three but before receiving or paying the dividend, and the dividend of that period is ₱6, what will be your earnings of market three?
10. If you have 4 units of asset and ₱683 at the end of period five of market two but before receiving or paying the dividend, and the dividend of that period is ₱-6, what will be your earnings of market two?