THREE ESSAYS ON THE EFFICIENCY OF REAL ESTATE MARKETS

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by
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ABSTRACT

This dissertation consists of three essays related to the efficiency of real estate markets.

The first essay attempts to explain the causes of these inefficiencies by attributing them to unique characteristics of real estate markets. We consider an experimental asset market where all investors receive the same dividend from a known probability distribution. In particular we examine the impact of transaction costs, short selling restrictions, and divisibility of assets on market efficiency. We find that short selling restrictions prevent traders from reducing prices, contribute to prolonged bubbles, and hence lead to inefficient markets. Relaxing the short selling constraint increases the trading volume, reduces prices, increases the occurrence of “bust cycles”, but does not result in prices tracking fundamentals. Transaction costs do not exacerbate the inefficiency of the market. Conversely, they reduce the occurrence and magnitude of bubbles and cause prices to track fundamentals more closely. Imposing transaction costs also lowers trading volume. Introducing a more divisible asset reduces the magnitude of bust cycles and improves the overall efficiency of the market. We also design an experimental market where we combine these three attributes of real assets. We find the transaction prices in this experimental market to be higher, the boom and bust cycles to be longer and trading volume to be smaller compared to the experimental market where there are no transaction costs, short selling is allowed and the asset is divisible.

The second essay examines the impact of the volatility of cash flows/dividends on the volatility of prices. We consider a simple experimental environment where subjects trade in an asset which provides dividends from a known probability distribution. The expected value of the dividends is identical in all experimental treatments. The treatments vary with respect to the volatility of dividends. We find that when dividends are more volatile, transaction prices are lower. We also find that the volatility of prices is lower in the treatment with highly volatile dividends. In addition, as expected, trading volume is lower when cash flows are less volatile.
In the third essay, we use theoretical models of land prices and house price volatility in urban areas previously developed in the literature and investigate the differences in appreciation of house prices and their volatility across different geographic regions of the United States. The variables that are shown in the models to be important in affecting the variance of housing returns are identified. The empirical investigation of these variables shows that, as expected by the model, the variance of housing return is found to be positively and significantly related to the variance of household income, land leverage, and transportation costs. The variance of housing returns is found to be negatively and significantly related to the growth of household income and the real estate transfer tax rate.
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Essay 1

**WHAT AFFECTS THE EFFICIENCY OF THE REAL ESTATE MARKET: AN EXPERIMENTAL STUDY**

Abstract

Real estate markets are generally considered to be less efficient than financial markets. We attempt to explain the causes of these inefficiencies by attributing them to unique characteristics of real estate markets. We consider an experimental asset market where all investors receive the same dividend from a known probability distribution. In particular we examine the impact of transaction costs, short selling restrictions, and divisibility of assets on market efficiency. We find that short selling restrictions prevent traders from reducing prices, contribute to prolonged bubbles, and hence lead to inefficient markets. Relaxing the short selling constraint increases the trading volume, reduces prices, increases the occurrence of “bust cycles”, but does not result in prices tracking fundamentals. Transaction costs do not exacerbate the inefficiency of the market. Conversely, they reduce the occurrence and magnitude of bubbles and cause prices to track fundamentals more closely. Imposing transaction costs also lowers trading volume. Introducing a more divisible asset reduces the magnitude of bust cycles and improves the overall efficiency of the market. We also design an experimental market where we combine these three attributes of real assets. We find the transaction prices in this experimental market to be higher, the boom and bust cycles to be longer and trading volume to be smaller compared to the experimental market where there are no transaction costs, short selling is allowed and the asset is divisible.

**Keywords:** Market Efficiency, Bubbles, Experimental Economics
1.1 Introduction

A central idea in asset valuation theory is that the value of an asset is equal to the discounted present value of its rationally expected cash flows. An asset market is said to be efficient if prices closely follow fundamental values. Furthermore, if the market is efficient, in equilibrium prices should change only when new information that affects market participants’ expectations about the cash flows becomes available. On the other hand, if asset prices persistently deviate from their fundamental values, “bubbles”\(^1\) may form in the market. The existence of bubbles can result in misallocation of capital and resources, affect investment decisions, and have considerable economic impact. Therefore, it is important to understand the causes of bubble formation and examine ways to reduce or eliminate them. This is especially important for the real estate markets, where vast amounts of capital are invested. When we consider the fact that approximately half of all the wealth in the world is real estate\(^2\), it becomes obvious that the existence of bubbles in real estate markets may have large implications for the overall economy. Examples include the savings and loan crisis of the 1980s, the Asian financial crisis of 1997, and the current mortgage crisis. Thus, it is important that we better understand the factors which may contribute to the formation of bubbles in real estate markets.

Real estate has several important attributes that differentiate it from financial assets. Real estate is heterogeneous, indivisible and has unique location. In addition, real estate markets are characterized by high transaction costs, lack of short selling opportunities, high cost of obtaining information, illiquidity, and high government regulation. All of these attributes affect the efficiency of the market to varying degrees.

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1 We define a bubble as asset prices being persistently higher than can be justified by the asset’s fundamentals characteristics.
2 Based on a 1991 estimate by Ibbotson Associates.
In this essay, we focus on three attributes of real estate: transaction costs, short selling restrictions and divisibility of assets. Our objective is to provide experimental evidence on the individual impact of each of these three attributes on the efficiency of real estate markets. We hypothesize that each of these attributes makes it more difficult or costly for traders to act on opportunities created by divergences between the current price and the fundamental value of the asset, hence making the market less efficient.

We find that imposing transaction costs has two effects. First, as can be expected, the volume of trade decreases dramatically. Second, contrary to our initial hypothesis, occurrence and magnitude of bubbles are reduced dramatically and the market becomes more efficient in the presence of transaction costs. When short selling is not allowed, the market is characterized by a high volume of trade and the emergence of large and prolonged bubbles. Allowing short selling reduces the likelihood and the magnitude of a bubble. However, short selling does not induce prices to closely track fundamental values. Introducing short selling has the effect of reducing overall price levels below fundamental values and significantly increasing the volume of trade. As expected, introducing a more divisible asset also reduces the magnitude of bubbles and increases the overall efficiency of the market.

In one of our experimental markets we combine all of the three attributes of real estate markets above; high transaction costs, no short selling, and indivisibility. In another experimental market, we mimic financial markets by eliminating transaction costs, allowing for short selling and making the asset more divisible. Comparing the two experimental markets, we find that the asset prices are higher, the boom and bust periods are longer and the turnover is smaller in the market that resembles the real estate markets.

Over the years, a vast theoretical, empirical and experimental literature on market efficiency has developed. Any list of the articles on this topic would be incomplete at best. Seminal theoretical
articles on the issue include Hayek (1945), Muth (1961), Fama (1970), Lucas (1972) and Grossman (1976). There have also been numerous empirical attempts to test the predictions of the theoretical literature (examples in real estate include Linnemann, 1986; Gau, 1987; Case and Shiller, 1989; Gatzlaff, 1995; Fu and Ng, 2001). However, empirical studies have a critical weakness: the most important variable, the fundamental value of the asset, is unobservable. Consequently, results of empirical studies are inconclusive. Another disadvantage of using field data is that many of the potentially important market attributes cannot be isolated from each other; hence their individual impact cannot be examined. These problems can be overcome through experimental methodology. In experimental studies, we can structure markets in such a way that the fundamental values of the assets are known with certainty. Furthermore, we can control for traders’ expectations of future cash flows, news available to them, as well as short-selling restrictions. Therefore, we are able to directly test the informational and allocational efficiencies of the market.

In this essay, we offer an experimental analysis of the informational efficiency of real estate markets. The rest of the essay is organized as follows. Section 1.2 reviews the relevant literature and states our hypotheses. Section 1.3 presents a detailed description of the different experimental treatments in this study. Section 1.4 presents the data and reports the results. Section 1.5 concludes and points out future directions. References are listed in Section 1.6.

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3 The literature distinguishes between the informational, allocational and production efficiencies of a market. Informational efficiency is achieved when observed prices reflect fundamental asset values and prices immediately adjust to new information. Allocational efficiency refers to whether or not assets are held by individuals who value them the most. Production efficiency refers to the optimal use of resources in the production process.

4 In an experiment, a treatment refers to a design with a particular combination of factors. An additional treatment usually changes one factor while holding all others constant. Any differences between treatments are likely to be caused by the factor that was tested.
1.2 Background

In this section we review the literature and state our hypotheses.

1.2.1 Review of the Relevant Experimental Literature

Since Smith’s seminal article was published in 1962, there has been an explosion in the quality and quantity of research in the area which has become known as “experimental economics.” A significant portion of this literature deals with the informational and allocational efficiencies of experimental asset markets. Typically data collected in experiments are compared with the predictions of the rational expectations theory (Muth, 1961 and Lucas, 1972). This theory assumes that individuals take all available information into account in forming expectations and act upon those expectations. For example, Plott and Sunder (1982) test the rational expectations theory by conducting a simple double oral auction experiment where some of the traders, called “insiders”, have more access to information than others. They find that initially prices are far from efficient levels predicted by the rational expectations theory. In Plott and Sunder (1982), prices eventually start to converge to efficient levels, highlighting the importance of traders’ experience in achieving price convergence. In Forsythe et al. (1982) prices converge to efficient levels after three or four periods, when near-100% efficiency is reached. The speed with which prices converge to equilibrium levels increases when futures are introduced into the market.

A related stream of experimental research deals with the occurrence and causes of the so-called “bubbles”. The existence of pricing bubbles, defined as asset prices being persistently higher than their fundamental values\(^5\), was first studied in a laboratory environment by Smith et al. (1988).

\(^5\) This is the definition of bubbles we will be using throughout the essay.
This study considers spot asset trading in an environment where all investors receive the same dividend from a known probability distribution at the end of each trading period. Bubbles are observed in 14 of the 22 sessions conducted. In most of the experiments, bubbles are followed by crashes, which are characterized by asset prices falling sharply to or below their fundamental values. Considering the fact that the market environment is extremely simple, it is rather surprising that bubbles would form in these experiments. However, Smith et al. (1988) results have been replicated in numerous later studies, including King et al. (1993), Van Boening et al. (1993), Porter and Smith (1995), Fisher (1998), Noussair, Robin, and Ruffieux (2001), Lei et al. (2001), Porter and Smith (2003), and Haruvy and Noussair (2006). All of these studies feature an experimental design which features an asset with a finite lifetime, typically 15 or 30 periods. The asset pays dividend every period and apart from a possible fixed terminal value this dividend is the only source of value. The important characteristic of these markets is that all the traders receive identical dividends and the dividend structure is common knowledge. The common pattern is that of a price bubble, a sustained occurrence of high transaction volumes at prices significantly higher than the fundamental value, followed by a crash to prices near or below fundamental values toward the end of the asset’s life.

In particular, Porter and Smith (1995) test whether bubbles are formed because of dividend risk aversion in a market with uncertain dividends. Their results show that the market is not more efficient when the dividends are certain. The occurrence and magnitude of bubbles is not significantly lower in the treatment with certain dividends compared to the treatment with uncertain dividends. Likewise, Noussair, Robin, and Ruffieux (2001) construct a market where the fundamental value of the asset is constant throughout its lifetime. The market is inefficient in the sense that keeping the value of the asset constant fails to eliminate price bubbles. Lei et al. (2001) consider an asset market where speculation is not allowed. Traders are randomly assigned to either “Buyer” or “Seller” types, so each trader can either sell assets or buy them, but cannot do both, hence eliminating the ability of a player to buy for the purpose of resale later. The common theme of “boom” and “bust” cycles is still
observed. The results suggest that the divergence of prices from fundamentals is not caused by the lack of common knowledge of rationality, which may lead to speculation.

In this study, we conduct experiments to test the effects of three attributes on market efficiency. In particular, we incorporate into the experimental design three attributes of real estate markets: transaction costs, short selling restrictions and (in)divisibility of the asset. We first consider the baseline experimental treatment where the characteristics of the asset traded are similar to characteristics of financial assets. We then consider additional experimental treatments, each capturing some of the important features of the real estate markets.

Each experimental treatment is intended to measure the effect of an institutional change on the efficiency of the market. Here, efficiency is measured by the degree to which prices track fundamentals and occurrence of bubbles and crashes, as well as other quantitative measures.

The first treatment has the most restrictive market conditions and we hypothesize that this market design results in the least efficient outcome. In the first treatment, called NSS-TC (abbreviation for no short sales - transaction costs), there is a 10% transaction cost to the sellers, and short selling is not allowed. The second treatment, NSS (no short sales) is the same as NSS-TC, except there are no transaction costs. The third treatment, SS (short sales) relaxes the short selling restriction. Traders can short sell as many units as they wish, as long as they meet a cash reserve requirement. The next two treatments are designed to measure the effect of the divisibility of the asset on market efficiency. Divisibility is captured by increasing the number of assets and decreasing the dividend amounts, i.e. reducing the amount needed to invest in the asset. In the SS-MA (short sales - multiple assets) treatment, there are four times as many assets, which provide one fourth of the dividends in each state of the world. Finally, the fifth treatment, NSS-MA (no short sales - multiple assets) is similar to SS-MA, except short selling is not allowed. While the SS-MA treatment measures the
combined effect of short selling and divisibility, the \textit{NSS-MA} treatment is designed to measure only the effect of divisibility. Notice that among the five treatments, \textit{NSS-TC} most closely resembles the real estate markets and \textit{SS-MA} is most similar to financial markets. Summary information about the five treatments is provided in Table 1-1.

1.2.2 Research Hypotheses

Our initial conjecture is that the efficiency of the market will be adversely affected by the presence of transaction costs, by the absence of short selling and by the indivisibility of the asset. Here we state our initial hypotheses.

\textbf{Hypothesis 1:} In the presence of transaction costs, the difference between prices and fundamentals is larger when compared to the “zero transaction costs” treatment.

The rationale for this hypothesis is that higher transaction costs make it more difficult for traders to react to new information or to the divergence between the current price and the fundamental value of the asset. Traders will not buy (sell) unless the difference between the current price and the fundamental value of the asset is at least as large as the transaction costs.

The second and third hypotheses test the conventional wisdom: the availability of short selling reduces the occurrences of bubble formation. Miller (1977), for example, argues that the cause of asset market bubbles is a constraint on the ability of traders to speculate on future downward movements of prices. Following this line of thought, we make two hypotheses, one strong and the other weaker.
**Hypothesis 2:** In the presence of short selling, bubbles are less likely to occur and prices are more likely to track fundamental values.

The second, weaker conjecture states that relaxing short selling restrictions does not necessarily lead to prices tracking the fundamentals. The restrictions simply increase the supply of assets, thereby reducing their equilibrium price. This leads us to the next hypothesis:

**Hypothesis 3:** Short selling reduces price levels.

The last attribute of the real estate market considered in our experiments is the lumpiness or (in)divisibility of the asset. The standard microeconomic theory requires that for the competitive equilibrium, we need the goods to be (infinitely) divisible. In the real world, not many goods meet this requirement. The indivisibility of assets is, perhaps, most pronounced in the real estate markets. This follows from the fact that even the smallest investment, whether it is a piece of land, a residential or a commercial property, requires a significant capital outlay. For all practical purposes, it is impossible to break a single real estate investment into smaller units. Shares of real estate investment trusts (REITs), which are public or private companies that invest in real estate, are a notable exception. Directly-held real estate, however, is relatively indivisible compared to financial assets. The fourth hypothesis states that this indivisibility of real assets reduces the efficiency of the market.

**Hypothesis 4:** Prices track fundamentals more closely in a market with divisible assets than in a similar market with lumpy assets.
1.3 Experimental Design and Procedures

In this section we describe how the experiments are planned, designed and actually conducted.

1.3.1 General Structure

The experimental sessions were conducted at the Pennsylvania State University. The subjects are undergraduate and graduate students enrolled at the university. Subjects were not allowed to participate in more than one session. For participating in a session that lasted about 90 minutes, subjects received a US$5 dollar show-up fee, in addition to the money they earned based on their performance in the session. Actual earnings ranged from US$6.81 to US$41.21, and the average earning was US$19.59.

Our sessions are complimentary to those of Haruvy and Noussair (2006). For that reason, we review their design here and relate it to ours. Table 1-1 shows the summary information about the five treatments considered in this essay. The NSS and SS treatments are conducted by Haruvy and Noussair (2006). The NSS-TC, SS-MA, and NSS-MA treatments are conducted by us at Penn State.

The parametric structure of the experiments is based on Smith et al. (1988). There are 15 trading periods in each session. At the end of each trading period, the asset (which is called a “share” in the experiment) pays a dividend that is determined by an independent four-point distribution. A roll of a four-sided die determines which one of the dividends will be paid per share for that period. The four possible values of dividends are 0, 8, 28 and 60 francs (the experimental currency), for the NSS-TC, NSS, and SS treatments, and 0, 2, 7, and 15 francs for the SS-MA and NSS-MA treatments. The dividends are assigned in random order with a probability of 25%.

This is potentially an important condition. There is ample evidence in the literature that the occurrence and magnitude of bubbles is significantly reduced (and in some cases eliminated) when subjects are experienced. Following induced-value theory, subjects’ compensation is directly tied to their performance.
expected dividend stream per period is 24 francs for the NSS-TC, NSS, SS treatments and 6 francs for the SS-MA and NSS-MA treatments. In this experiment, dividends are the only source of value for the share, so the fundamental value of the share is equal to the expected future dividend stream. Thus, the fundamental value of the share in any period \( t, t=1,\ldots,15 \), equals \( 24*(16-t) \) francs for the NSS-TC, NSS, SS treatments, and \( 6*(16-t) \) francs for the SS-MA and NSS-MA treatments.

This particular market structure is chosen for several reasons. First, this is a very simple market that makes sharp predictions about the price levels. Calculating the fundamental values of the shares in each period is straightforward. Therefore, should bubbles and crashes occur, we can readily observe them. Second, we only need to consider the informational efficiency here. We need not worry about the allocational or production efficiency. In our experiment, all traders have identical preferences expressed by the dividend structure, so the theory does not make any predictions about allocational efficiency. Likewise, there is no production, so we cannot speak of production efficiency. Therefore, the market in our experiment is efficient if it is informationally efficient, i.e. if prices are equal or close to fundamental values. Third, this particular design is known in most trials to produce bubbles, whose existence seems to be relatively robust to many changes in the market organization. This allows us to analyze the occurrence of bubbles with institutional changes, such as introducing transaction costs, relaxing short selling restrictions, and increasing the aggregate supply of the asset. Fourth, using the same parameters allows us to directly compare our results to those of previous studies, including Smith et al. (1988) and Haruvy and Noussair (2006) and obtain sharper conclusions about the impact of transaction costs, short selling and the divisibility of the asset.

In each session, subjects participate in a market for an asset which has a 15-period life. We use a fictitious currency called “francs” during the experiments\(^8\). At the end of each session, the

\(^8\) It is convenient to define payments in a fictitious currency, rather than dollars. This allows the experimenter to retain the privacy of parameters throughout multiple sessions of an experiment. In addition, the conversion rate
traders’ money balances in francs are converted to US dollars. The subjects are paid in dollars at the conversion rate of 100 francs = 1 US dollar. In the NSS-TC, NSS, and SS treatments, each share provides dividends of 0, 8, 28, and 60 francs with equal likelihood. Since the dividends are the same to all traders, traders have identical preferences. Traders only differ with respect to their endowments. There are three trader types and three subjects of each type (total of nine subjects) in each session. In the first three treatments, Type I traders have an endowment of 225 francs and 3 units of shares; Type II traders have 585 francs and 2 units; and Type III traders have 945 francs and 1 share. In the SS-MA treatment, each share provides dividends of 0, 2, 7, and 15 francs, each with equal likelihood. Type I traders are endowed with 225 francs and 12 units of shares; Type II traders have 585 francs and 8 units; and Type III traders have 945 francs and 4 units. These parameters are chosen to make sure that the expected earnings from all four treatments are identical. The expected earnings for all trader types is US$18.05 in all four treatments. The experimental design parameters are summarized in Table 1-2.

We use the z-Tree software developed by Fischbacher (2007) to create an electronic continuous double auction market that is similar to the market environment created by Smith (1962).

### 1.3.2 Timing of the Sessions

Before conducting the sessions, we made sure that the subjects who had signed up to participate in an experimental session had not participated in another session before. This is important because prior experience has been repeatedly shown to affect the subjects’ strategies in experimental asset markets.

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9 The conversion rate is chosen such that participating in a session must exceed a subject’s opportunity cost. Typically this opportunity cost is defined as being 50 to 100 percent higher than the typical campus hourly wage for students. When our sessions were conducted, the average hourly wage for students working on campus was about $8.00.
Upon arrival, the subjects receive written instructions explaining how the electronic auction market works, and how the subjects’ earnings are calculated\textsuperscript{10}. Then the experimenter reads the instructions aloud and goes over an example to illustrate the process of making offers and bids, as well as buying and selling shares. The subjects are thus trained in the z-Tree interface. After the instructions are read and the experimenter answers any questions the subjects may have, the subjects participate in three training periods, where they practice buying and selling shares. The earnings or losses during the training periods do not count towards final earnings.

After the training periods, the subjects participate in a market consisting of 15 four-minute periods. The subjects receive their initial endowments in francs and shares. These endowments differ depending on the trader type, as described earlier. In each session, there are 3 subjects of each type, for a total of 9 traders. During the four-minute trading period, subjects are free to buy and sell their shares, as long as they follow the rules. For example, in the NSS treatment, subjects are not allowed to short sell their shares. If a subject has no shares, but tries to sell a share, the computer prevents her from doing so. The subjects’ money balance and their inventory of shares carry over from one period to the next, up to the last period (15\textsuperscript{th} period). After the last dividend payout in period 15, the shares have no terminal value and are therefore worthless.

The money earned or lost during the 15 periods is converted into US dollars and the subjects are paid in US dollars at the end of the session. A subject’s earnings in a session are equal to the initial money endowment plus dividends earned from shares held minus dividends paid on shares sold short (for SS and SS-MA treatments) plus money received from the sales of shares minus the money spent to buy shares.

\textsuperscript{10} Instructions for the NSS-TC treatment are provided in Appendix A-1. A screenshot of the main trading period is shown in Appendix A-2.
1.4 Results

We begin our analysis of the data with a visual inspection. Figures 1-1 – 1-3 present the median prices and trading volumes for each session for the five experimental treatments. Figure 1-1 shows the data from the NSS-TC and NSS treatments and highlights the main differences between these two treatments.

The left panels of Figure 1-1 indicate that bubbles occur in all five sessions of the NSS-TC and NSS treatments. Bubbles occur more frequently in the NSS treatment, in which the median price exceeds the fundamental value in 23 of the 30 periods (77%). In the NSS-TC treatment, the median price is higher than the fundamental value in 30 out of 45 periods (67%). In terms of volume, the number of trades is clearly higher in the NSS treatment.

Figure 1-2 shows the median price and volume information for the SS and SS-MA treatments. In the SS treatment, the median price is lower than the fundamental value in 37 periods out of 45 (82%). Prices are lower than fundamental values in 19 of 45 periods (42%) of the SS-MA treatment. More importantly, as the lower left panel of Figure 1-2 clearly indicates, prices are significantly closer to fundamentals in the SS-MA treatment. The trading volume is higher in the SS treatment, which is in contrast to the expectation that more units would be traded in the SS-MA treatment.

Figure 1-3 shows the median price and volume information for the NSS-MA treatment. Prices are lower than fundamental values in 23 of 45 periods (51%). Overall, the pattern of median trading prices is similar to that of the SS-MA treatment. The first session of NSS-MA, where the magnitude of the bubble is large, seems to be an exception.

From the left panel of Figure 1-1, we can see that the NSS treatment is more inefficient than the NSS-TC session – the magnitude of the bubble is much larger in the NSS treatment. In supporting
our results, we consider the effect of institutional changes on transaction prices at specific points in time. In our experiments, the natural measure of time is a trading period. We use the median transaction price\(^{11}\) over all prices in a given period. We do not use other measures, such as the last transaction price or prices in the last few periods, because there is a very large variation in observed prices within a period. This is especially true for initial periods of all sessions.

The quantitative measures of efficiency are shown in Table 1-3. We start the quantitative examination by defining two main measures of differences between median prices and fundamental values. These measures, “Total dispersion” and “Average bias,” are shown in the last two columns of Table 1-3. Total dispersion is the sum (over 15 periods) of the absolute deviations of median period price from fundamental values. In equation form: \(\text{Total dispersion} = \sum |\text{Median}_t - f_t|\), where \(\text{Median}_t\) denotes the median transaction price in period \(t\) and \(f_t\) denotes the fundamental value in period \(t\). A low Total dispersion means that asset prices closely correspond to fundamental values. A high Total dispersion means that prices diverge from fundamentals.

The other main measure of differences between median prices and fundamental values is the Average bias, which is the average over 15 periods of the deviation of median period price from fundamental value in the period. That is: \(\text{Average bias} = \sum (\text{Median}_t - f_t)/15\), where \(\text{Median}_t\) and \(f_t\) are the median transaction price and fundamental value in period \(t\), respectively. If Average bias is close to 0, this means that on average prices are close to fundamentals. A large positive (negative) Average bias indicates that prices are on average much higher (lower) than fundamentals. Average bias is a measure of whether mean prices deviate from fundamentals, while Total dispersion is a measure of variability. It is possible for Average bias to be very low (if both positive and negative bubbles occur) but for Total dispersion to be high. Therefore, Total dispersion and Average bias together provide us with a much better understanding of the market than either measure does by itself.

\(^{11}\) The results do not change significantly if we use mean trading prices instead of median prices.
In addition to *Total dispersion* and *Average bias*, we use five other measures of trading volume and divergence of observed prices from fundamentals: *Amplitude, Normalized deviation, Turnover, Boom duration, and Bust duration*. *Amplitude* is the difference between the ratio of the highest deviation of average prices from fundamental value and the ratio of the lowest deviation of average prices from fundamental value. That is: \( \text{Amplitude} = \max_t \left\{ \frac{(P_t - f_t)}{f_t} \right\} - \min_t \left\{ \frac{(P_t - f_t)}{f_t} \right\} \), where \( P_t \) and \( f_t \) are the average transaction price and the fundamental value, respectively. *Normalized deviation* is the deviation of all transaction prices, normalized by the total number of shares available. In equation form: \( \text{Normalized deviation} = \sum \sum |P_{it} - f_t|/(100*TSU) \),\(^{12}\) where \( P_{it} \) is the price of the \( i^{th} \) transaction in period \( t \), and TSU is the total stock of units that traders hold. *Turnover* is a measure of trading activity, and shows the trading volume in a session expressed as a portion of the total inventory of shares available. The formula is: \( \text{Turnover} = \frac{\sum q_t}{(TSU)} \), where \( q_t \) is the quantity of units of the asset exchanged in period \( t \) and TSU is the total stock of shares that traders hold. *Boom duration* is the greatest number of consecutive periods during which the median prices exceed fundamentals within a session. *Bust duration* is the greatest number of consecutive periods during which the median prices are below fundamentals within a session. We now proceed to the discussion of the results.

**Result 1:** In the presence of transaction costs, the difference between prices and fundamentals is smaller compared to the “zero transaction costs” treatment. In other words, the NSS-TC treatment is more efficient than the NSS treatment.

**Support for Result 1:** Table 1-3 shows that the *Average Bias* is much lower in the NSS-TC treatment than in the NSS treatment. When averaged over all sessions, the *Average bias* is -2.42 for the NSS-TC treatment, compared to 42.8 for the NSS treatment. The *Total Dispersion* measure

\(^{12}\) The reason for dividing the statistic by 100 is to make it comparable to statistic used in previous studies, including Haruvy and Noussair (2006).
indicates that the variability of median prices from fundamentals is also lower in the NSS-TC treatment (1081 vs. 1320 in NSS). In addition, both Amplitude and Normalized Deviation measures are smaller in NSS-TC. As seen in the bottom left panel of Figure 1-1, with zero transaction costs, very large bubbles form when short selling is not allowed. In the NSS treatment, the Boom duration (greatest number of consecutive periods that median transaction prices are above fundamental values) averages 11.5 periods.

While we also observe a bubble in the NSS-TC treatment, its magnitude is much smaller. This fact is somewhat surprising and contrary to our hypothesis. We conjecture that this is due to the low volume of trade. The significant difference between trading volumes is measured by the Turnover variable, which is shown in the fifth column of Table 1-3. Turnover in NSS (12.20) is more than twice that in NSS-TC (4.81). Since traders must pay a 10% commission on every share they sell, they trade less actively. Only the traders who expect to make a per-trade profit larger than the transaction cost will participate. This significant transaction cost could also discourage less sophisticated or “naïve” traders from participating in the market.

The result that the NSS-TC treatment is more efficient is further supported by statistical tests. Table 1-4 reports the results of Wilcoxon tests for comparing the means of the median prices in the five treatments and fundamental values over all 15 periods. The reported values are normal approximations and the two-sided p-values are shown in parentheses. The null hypothesis is that the means of the median prices in the NSS-TC treatment and fundamental values are equal. The alternative hypothesis is that the samples compared have different means. As shown in Panel A of

13 As Figures 1-1 – 1-3 reveal, there is considerable fluctuation in prices in the first few periods of all sessions. Therefore, it may argued that there is some learning occurring in the first few periods and one should only analyze the median transaction prices of the last 10 periods. With this in mind, we conduct the Wilcoxon tests comparing the median prices in all five treatments with the median prices of all other treatments and fundamental values over the last 10 periods. The results of these Wilcoxon tests are reported in Panel B of Table 1-4. When only the last 10 periods are considered, the overall results are largely consistent with the case when all 15 periods are considered.
Table 1-4, we fail to reject the null hypothesis. The statistic is 0.18 and the p-value is 0.859. Therefore, the means of median prices in the TC treatment are not statistically different from the fundamental values.

**Result 2:** Under short selling, prices do not track fundamental values. Prices under the SS treatment are below fundamental values.

**Support for Result 2:** This result is strikingly clear from the top left panel of Figure 1-2. Prices are lower than fundamental values in 37 of 45 periods. In addition, Table 1-2 shows that under the SS treatment, the *Average Bias* is negative (-77.1). This would be extremely unlikely if the prices were equally likely to be above and below fundamental values. The SS treatment is also characterized by very active trading, as measured by the *Turnover* measure. Since the median prices are significantly lower than fundamental values in all but two periods under SS, we do not find support for Hypothesis 2.

Result 2 is also supported by the Wilcoxon tests. When we compare the means of median prices in the SS treatment and fundamental values for all 15 periods, we safely reject the null hypothesis at the 1% significance level. The statistic is 3.52 and the p-value is 0.00. When only the last 10 periods are considered, we reject the null hypothesis at the 10% level.

On the other hand, under short selling, prices do not track fundamentals. Rather, they are systematically lower compared to when short selling is not allowed. Indeed, when we look at the data, we find support for our Hypothesis 3.
**Result 3:** Prices are lower when short selling is allowed.

**Support for Result 3:** Under SS treatment, median transaction prices are significantly lower than in the NSS treatment. *Average Bias* is -77.1 in SS. In other words, on average, the median prices are lower than fundamental values by 77 francs. This is a large difference, considering the fact that fundamental values vary between 24 and 360 francs. In contrast, *Average Bias* is 42.8 in the NSS treatment. In addition, we also observe a large difference between the two treatments when it comes to the *Bust* and *Boom durations*. In the SS treatment, the *Bust durations* (greatest number of consecutive periods that median transaction prices are below fundamental values) average almost 13 periods, in contrast to 3 periods in the NSS treatment. Prices only approach fundamental levels in the last 2-3 periods.

The hypothesis that the prices are lower in the SS treatment is confirmed by the tests as well. The null hypothesis that the median prices of NSS and SS treatments are equal is rejected at the 1% significance level, both when all 15 periods or the last 10 periods are considered. From Table 1-4, the statistics (p-values) are 4.90 (0.000) and 3.69 (0.000) for all 15 and last 10 periods, respectively.

Thus, we find that when short selling is allowed, prices are below fundamental values. One reason for this may be that short selling simply increases the supply of shares available. Assuming that demand for these types of assets is downward-sloping, increasing the supply would reduce the prices.

Next, we consider the SS-MA treatment, which features a larger number of assets. This last treatment is introduced to test the effect of the “lumpiness” or divisibility of real assets on the efficiency of the market.
**Result 4:** When short selling is allowed, prices track fundamentals more closely in a market with divisible assets than in one with lumpy assets.

**Support for Result 4:** By any measure of market efficiency we consider in this essay, SS-MA performs significantly better than SS. As can be seen from the left panels of Figure 1-2, median transaction prices tend to follow fundamental values quite closely under the SS-MA treatment. Neither *Boom cycles* (6 periods on average) nor *Bust cycles* (3.7 periods) are very long. *Average Bias* for SS-MA is only -2.38, compared to -77.1 for SS. Likewise, *Total Dispersion* (195 vs. 1,261.5), *Normalized Deviation* (0.8 vs. 26.91), *Amplitude* (0.91 vs. 1.92) all compare favorably against the SS treatment. Overall, the data supports our hypothesis that when assets are divisible, the market tends to be more efficient, with prices tracking fundamentals more closely.

Statistically, when we compare the median prices in the SS-MA treatment to fundamental values, we fail to reject the null hypothesis that their means are equal. The statistic is 0.54 (0.19) and the p-value is 0.588 (0.847) when all 15 (last 10) periods are considered.

Finally, we consider the NSS-MA treatment. We have seen that the market is significantly more efficient when short selling is allowed *and* when the goods are divisible (in the SS-MA treatment). However, the difference between the NSS and SS-MA treatments is due to two factors: short selling and divisibility of the asset. Therefore, we cannot be certain which one of these factors is responsible for differences between the two treatments. The fifth treatment, NSS-MA, where the asset is divisible but short selling is not allowed, was designed to test the effect of divisibility only. In other words, the difference between NSS and SS is due to short selling while the difference between NSS and NSS-MA is due to divisibility. Data from NSS-MA yields the following result:
Result 5: Prices track fundamentals more closely in a market with divisible assets even when short selling is not allowed.

Support for Result 5: Compared to the NSS treatment, the NSS-MA treatment results in significantly more efficient prices. The Average Bias is only -0.91 (lowest among all treatments) compared to 42.8 for NSS. Likewise, Total Dispersion is only 218.7 compared to 1,320 for NSS. Statistically, the median transaction prices in the NSS-MA treatment are different from median prices in the NSS treatment (the statistic is 2.12, p-value is 0.034). Furthermore, median prices in NSS-MA are not statistically different from fundamental values (the statistic is 0.19, p-value is 0.85). Therefore, the market with divisible assets is efficient even when short selling is not allowed.

In our comparison of different experimental treatments above, we identified the individual impact of each of the three asset characteristics, i.e., the impact of transaction costs, short selling, and indivisibility, on the efficiency of the market. We next study the combined impact of these three characteristics. In particular, we compare the experimental market closest to a real estate market with the experimental market closest to a financial market. These two experimental markets are the NSS-TC treatment where there are high transaction costs, no short selling is allowed, and the asset is bulky, and the SS-MA treatment where there are no transaction costs, short selling is allowed and the asset is divisible, respectively. The comparison of the two experimental markets yields the following result:

Result 6: Compared to the experimental market SS-MA, the experimental market NSS-TC involves higher median asset prices, longer boom and bust periods and lower turnover.

Support for Result 6: As displayed in Table 1-3, all measures of the magnitude of bubbles except Turnover are higher in the NSS-TC sessions than in the SS-MA sessions. A
boom lasts about 9.67 periods in the NSS-TC sessions compared to 6 periods in the SS-MA sessions. A bust lasts 4 periods in the NSS-TC sessions, compared to 3.7 periods in the SS-MA sessions. Table 1-4 shows that the median asset prices are also higher in the NSS-TC sessions than the SS-MA sessions. The difference in median prices is not significant when we consider all 15 periods (p-value of 0.643). However, if we consider the last 10 periods, the difference in median prices between the two markets becomes significant at the 10% level (p-value of 0.074). The magnitude of the difference in prices becomes bigger in the last 10 periods as well. While the average median price in the NSS-TC treatment is only 6.9 units higher than the average median price in the SS-MA treatment over 15 periods, the difference goes up to 35.9 units in the last 10 periods (Table 1-4, Panels A and B). The median prices, averaged over all three sessions of NSS-TC and SS-MA treatments are displayed in Figure 1-4. There are some clear differences in the price behavior between the two treatments. The bust cycle in the NCC-TC treatment occurs in the first 5 periods while the last 10 periods is a long boom cycle. On the other hand, the bust cycle in the SS-MA treatment occurs in the first 5 periods and again towards the end of the session. Furthermore, the boom cycle is shorter in duration and smaller in magnitude. If we focus on the last 10 periods, the NCC-TC market has longer and larger boom cycles than the NSS-MA market. The two graphs also illustrate why the average difference in prices of the two markets is considerably higher in the last 10 periods than in all 15 periods. The median prices in the NSS-TC market are much lower than fundamental values initially, and they are much higher than fundamentals in the middle, hence the deviations from the fundamentals cancel each other out to a large extent. In the SS-MA market, however, prices are only slightly lower than fundamentals initially and then slightly higher than fundamentals in the middle of the session.
1.5 Conclusions and Future Directions

This essay incorporates some of the fundamental characteristics of the real estate market into an experimental spot market and examines how each of these characteristics affects the efficiency of the market. The characteristics in question are transaction costs, short selling restrictions and the divisibility of assets.

Data from a total of 14 experimental sessions provide a number of interesting answers. First, introducing transaction costs to a market with short selling restrictions does not increase the occurrence and magnitude of price bubbles. On the contrary, prices are closer to fundamentals in the market with transaction costs than in the market with zero transaction costs. This implies that the reduction in transaction costs due to improvements in information technology might be contributing to overvaluation in markets. Second, relaxing the short selling constraint reduces average transaction prices but does not bring market prices near fundamental values. Allowing short selling drives transaction prices significantly below fundamentals, leading to negative bubbles. This result is consistent with previous studies’ findings. Third, when assets are more divisible, prices seem to track fundamentals more closely. This result holds both in the experimental market where short selling is allowed and the experimental market where it is not.

In one of our experimental markets we combine three attributes of real estate markets; high transaction costs, no short selling, and indivisibility. In another experimental market, we mimic financial markets by eliminating transaction costs, allowing for short selling and making the asset more divisible. We find the median transaction prices to be higher, the boom and bust periods to be longer and the turnover to be smaller in the market that resembles real estate markets.

\[14\] In particular, the relatively recent availability of information, advice, tools, and websites on the Internet that facilitate buying and selling of real estate may have reduced the overall cost of real estate transactions and brought new participants into the market. This is a hypothesis that can be tested empirically in the future.
We do not claim that all of the potential sources of inefficiencies in real estate markets have been captured here. Our hope is that this essay serves as a first step in examining the contribution of unique features of real assets into the efficiency of the market. Experimental research into the efficiency of real estate markets can be further developed in several ways. First, we need to consider additional characteristics which make real estate unique. The most important of these include the heterogeneity of assets, costliness of obtaining information, and illiquidity. We plan to design and conduct additional experiments incorporating these features.
1.6 References


Figure 1-1: Time Series of Median Transaction Prices and Volumes Over Time, NSS-TC and NSS Treatments

The panels on the left show median transaction prices for periods 1 through 15. In period 10 of the NSS-TC treatment, there was no trade. For that period, the median price is taken as the average of median prices in periods 9 and 11. In the NSS-TC treatment, no short selling is allowed, and sellers are charged a transaction cost of 10% of the selling price on every transaction. In the NSS treatment, there is no transaction cost, but short selling is not allowed. The dotted line is the fundamental value, which is equal to the expected value of the dividend stream of one unit of share. The panels on the right show transaction volume in terms of the number of shares bought and sold.
Figure 1-2: Time Series of Median Transaction Prices and Volumes Over Time, SS and SS-MA Treatments

The panels on the left show median transaction prices for periods 1 through 15. The dotted line is the fundamental value, which is equal to the expected value of the dividend stream of one unit of share. In the SS treatment, traders can short sell shares, but must keep cash balance greater than or equal to the expected dividend value of their short positions. In the SS-MA treatment, the number of assets available is four times that in other treatments and the dividends are one-fourth of dividends in the NSS-TC, NSS and SS treatments. The panels on the right show transaction volume in terms of the number of shares bought and sold.
Figure 1-3: Time Series of Median Transaction Prices and Volumes Over Time, the NSS-MA Treatment

The panels on the left show median transaction prices for periods 1 through 15. The dotted line is the fundamental value, which is equal to the expected value of the dividend stream of one unit of share. In this treatment, there is no transaction cost, but short selling is not allowed. The number of assets available is four times that in other treatments and the dividends are one-fourth of dividends in the NSS-TC, NSS and SS treatments. That is, the starting balance of francs and shares available to Trader types I, II, and III are (225, 12), (585, 8), and (945, 4), respectively. The panels on the right show transaction volume in terms of the number of shares bought and sold.
Figure 1-4: Time Series of Median Transaction Prices of 3 Sessions for the NSS-TC and SS-MA Treatments

The top panel shows the average of median transaction prices for the three sessions of the NSS-TC treatment over periods 1 through 15. The NSS-TC treatment is closest to a real estate market in that it involves transaction costs, no short selling, and a bulky asset. The bottom panel shows the average of median transaction prices for the three sessions of the MA treatment over periods 1 through 15. The SS-MA treatment is closest to a financial market in that it involves short selling, a divisible asset and no transaction costs.
Table 1-1: Information about the Sessions

Three sessions for each of the NSS-TC, SS-MA, and NSS-MA treatments were conducted. All of these nine sessions were conducted at Penn State from between January and September of 2007. Data from the NSS and SS treatments are adopted from Haruvy and Noussair (2006). They conducted two sessions of the NSS treatment and three sessions of the SS treatment at Emory and University of Texas at Dallas.

<table>
<thead>
<tr>
<th>Session</th>
<th>Treatment</th>
<th>Experimenter</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NSS-TC</td>
<td>Ikromov&amp;Yavas</td>
<td>No short sales permitted, sellers charged a 10% commission, endowments of Types I, II, III are 3, 2, and 1 shares, respectively.</td>
</tr>
<tr>
<td>2</td>
<td>NSS-TC</td>
<td>Ikromov&amp;Yavas</td>
<td>No short sales permitted, sellers charged a 10% commission, endowments of Types I, II, III are 3, 2, and 1 shares, respectively.</td>
</tr>
<tr>
<td>3</td>
<td>NSS-TC</td>
<td>Ikromov&amp;Yavas</td>
<td>No short sales permitted, sellers charged a 10% commission, endowments of Types I, II, III are 3, 2, and 1 shares, respectively.</td>
</tr>
<tr>
<td>4</td>
<td>NSS</td>
<td>Haruvy&amp;Noussair</td>
<td>No short sales permitted, endowments of Types I, II, III are 3, 2, and 1 shares, respectively.</td>
</tr>
<tr>
<td>5</td>
<td>NSS</td>
<td>Haruvy&amp;Noussair</td>
<td>No short sales permitted, endowments of Types I, II, III are 3, 2, and 1 shares, respectively.</td>
</tr>
<tr>
<td>6</td>
<td>SS</td>
<td>Haruvy&amp;Noussair</td>
<td>Cash balance $\geq 24*(16-t)*(\text{net short position})$, endowments of Types I, II, III are 3, 2, and 1 shares, respectively.</td>
</tr>
<tr>
<td>7</td>
<td>SS</td>
<td>Haruvy&amp;Noussair</td>
<td>Cash balance $\geq 24*(16-t)*(\text{net short position})$, endowments of Types I, II, III are 3, 2, and 1 shares, respectively.</td>
</tr>
<tr>
<td>8</td>
<td>SS</td>
<td>Haruvy&amp;Noussair</td>
<td>Cash balance $\geq 24*(16-t)*(\text{net short position})$, endowments of Types I, II, III are 3, 2, and 1 shares, respectively.</td>
</tr>
<tr>
<td>9</td>
<td>SS-MA</td>
<td>Ikromov&amp;Yavas</td>
<td>Cash balance $\geq 6*(16-t)*(\text{net short position})$, endowments of Types I, II, III are 12, 8, and 4 units, respectively.</td>
</tr>
<tr>
<td>10</td>
<td>SS-MA</td>
<td>Ikromov&amp;Yavas</td>
<td>Cash balance $\geq 6*(16-t)*(\text{net short position})$, endowments of Types I, II, III are 12, 8, and 4 units, respectively.</td>
</tr>
<tr>
<td>11</td>
<td>SS-MA</td>
<td>Ikromov&amp;Yavas</td>
<td>Cash balance $\geq 6*(16-t)*(\text{net short position})$, endowments of Types I, II, III are 12, 8, and 4 units, respectively.</td>
</tr>
<tr>
<td>12</td>
<td>NSS-MA</td>
<td>Ikromov&amp;Yavas</td>
<td>No short sales, cash balance $\geq 6*(16-t)*(\text{net short position})$, endowments of Types I, II, III are 12, 8, and 4 units, respectively.</td>
</tr>
<tr>
<td>13</td>
<td>NSS-MA</td>
<td>Ikromov&amp;Yavas</td>
<td>No short sales, cash balance $\geq 6*(16-t)*(\text{net short position})$, endowments of Types I, II, III are 12, 8, and 4 units, respectively.</td>
</tr>
<tr>
<td>14</td>
<td>NSS-MA</td>
<td>Ikromov&amp;Yavas</td>
<td>No short sales, cash balance $\geq 6*(16-t)*(\text{net short position})$, endowments of Types I, II, III are 12, 8, and 4 units, respectively.</td>
</tr>
</tbody>
</table>
Table 1-2: Experimental Design Parameters

The initial endowments and the dividend structure are identical in the NSS-TC, NSS, and SS treatments. In these three treatments, Type I traders receive 225 francs and 3 units of share; Type II traders receive 585 francs and 2 units; and Type III traders receive 945 francs and 1 unit of share. Each share yields a dividend of 0, 8, 24, or 60 francs with equal likelihood in each period. The expected dividend per period is 24 francs. The fundamental value of a share in the first period is 360 francs and decreases by the expected dividend each period.

In the SS-MA and NSS-MA treatments, Type I traders receive 225 francs and 12 units of share; Type II traders receive 585 francs and 8 units of share; and Type III traders receive 945 francs and 4 units of share. Each share yields a dividend of 0, 2, 7, or 15 francs with equal likelihood in each period. The expected dividend per period is 6 francs. The fundamental value of a share in the first period is 90 francs and decreases by the expected dividend each period.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Endowment (francs; units of shares)</th>
<th>Dividend, francs (p=1/4)</th>
<th>Expected dividend per period, francs</th>
<th>Intrinsic (dividend) value per share in Period 1, francs</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSS-TC</td>
<td>(225;3)</td>
<td>(0, 8, 28, 60)</td>
<td>24</td>
<td>360</td>
</tr>
<tr>
<td>NSS</td>
<td>(225;3)</td>
<td>(0, 8, 28, 60)</td>
<td>24</td>
<td>360</td>
</tr>
<tr>
<td>SS</td>
<td>(225;3)</td>
<td>(0, 8, 28, 60)</td>
<td>24</td>
<td>360</td>
</tr>
<tr>
<td>SS-MA</td>
<td>(225;12)</td>
<td>(0, 2, 7, 15)</td>
<td>6</td>
<td>90</td>
</tr>
<tr>
<td>NSS-MA</td>
<td>(225;12)</td>
<td>(0, 2, 7, 15)</td>
<td>6</td>
<td>90</td>
</tr>
</tbody>
</table>
Table 1-3: Observed Values of Bubble Measures

This table reports the observed values of various measures of the magnitude of bubbles in each of the 4 treatments. \( \text{Amplitude} = \max_{t} \{(P_t - f_t)/f_t\} - \min_{t} \{(P_t - f_t)/f_t\} \), where \(P_t\) and \(f_t\) are the average transaction price and the fundamental value, respectively. \( \text{Normalized deviation} = \sum \sum |P_{it} - f_t|/(100*TSU) \), where \(P_{it}\) is the price of the \(i\)th transaction in period \(t\), and \(TSU\) is the total stock of units that traders hold. \( \text{Turnover} = (\sum q_t)/(TSU) \), where \(q_t\) is the quantity of units of the asset exchanged in period \(t\). The boom and bust durations are the greatest number of consecutive periods that median transaction prices are above and below fundamental values, respectively. \( \text{Total dispersion} = \sum \{|\text{Median}P_{it} - f_t|\} \), where \(\text{Median}P_{it}\) denotes the median transaction price in period \(t\). \( \text{Average Bias} = \sum (\text{Median}P_{it} - f_t)/15. \)

<table>
<thead>
<tr>
<th>Session number</th>
<th>Treatment</th>
<th>Amplitude</th>
<th>Norm. deviation</th>
<th>Turnover</th>
<th>Boom duration</th>
<th>Bust duration</th>
<th>Total dispersion</th>
<th>Average bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NSS-TC (1)</td>
<td>1.39</td>
<td>6.07</td>
<td>5.72</td>
<td>10</td>
<td>5</td>
<td>861</td>
<td>-5.6</td>
</tr>
<tr>
<td>2</td>
<td>NSS-TC (2)</td>
<td>1.53</td>
<td>3.31</td>
<td>1.89</td>
<td>12</td>
<td>1</td>
<td>841</td>
<td>9.4</td>
</tr>
<tr>
<td>3</td>
<td>NSS-TC (3)</td>
<td>2.42</td>
<td>11.09</td>
<td>6.83</td>
<td>7</td>
<td>6</td>
<td>1541</td>
<td>-11.1</td>
</tr>
<tr>
<td></td>
<td><strong>Avg NSS-TC</strong></td>
<td><strong>1.78</strong></td>
<td><strong>6.82</strong></td>
<td><strong>4.81</strong></td>
<td><strong>9.67</strong></td>
<td><strong>4</strong></td>
<td><strong>1081.0</strong></td>
<td><strong>-2.42</strong></td>
</tr>
<tr>
<td>4</td>
<td>NSS (1)</td>
<td>1.98</td>
<td>3.46</td>
<td>8.39</td>
<td>12</td>
<td>3</td>
<td>533</td>
<td>23.8</td>
</tr>
<tr>
<td>5</td>
<td>NSS (2)</td>
<td>3.25</td>
<td>25.50</td>
<td>16</td>
<td>11</td>
<td>3</td>
<td>2,107</td>
<td>61.8</td>
</tr>
<tr>
<td></td>
<td><strong>Avg NSS</strong></td>
<td><strong>2.61</strong></td>
<td><strong>14.48</strong></td>
<td><strong>12.20</strong></td>
<td><strong>11.5</strong></td>
<td><strong>3</strong></td>
<td><strong>1,320</strong></td>
<td><strong>42.8</strong></td>
</tr>
<tr>
<td>6</td>
<td>SS (1)</td>
<td>3.84</td>
<td>57.77</td>
<td>41.33</td>
<td>2</td>
<td>13</td>
<td>1,855</td>
<td>-114.2</td>
</tr>
<tr>
<td>7</td>
<td>SS (2)</td>
<td>1.25</td>
<td>13.60</td>
<td>18.11</td>
<td>4</td>
<td>10</td>
<td>925</td>
<td>-50.4</td>
</tr>
<tr>
<td>8</td>
<td>SS (3)</td>
<td>0.66</td>
<td>9.36</td>
<td>11.89</td>
<td>1</td>
<td>14</td>
<td>1,004.5</td>
<td>-66.8</td>
</tr>
<tr>
<td></td>
<td><strong>Avg SS</strong></td>
<td><strong>1.92</strong></td>
<td><strong>26.91</strong></td>
<td><strong>23.77</strong></td>
<td><strong>2.3</strong></td>
<td><strong>12.7</strong></td>
<td><strong>1,261.5</strong></td>
<td><strong>-77.1</strong></td>
</tr>
<tr>
<td>9</td>
<td>SS-MA (1)</td>
<td>0.98</td>
<td>0.58</td>
<td>2.5</td>
<td>2</td>
<td>7</td>
<td>252.5</td>
<td>-14.30</td>
</tr>
<tr>
<td>10</td>
<td>SS-MA (2)</td>
<td>0.36</td>
<td>0.49</td>
<td>4.93</td>
<td>5</td>
<td>1</td>
<td>89.5</td>
<td>-4.9</td>
</tr>
<tr>
<td>11</td>
<td>SS-MA(3)</td>
<td>1.40</td>
<td>1.33</td>
<td>8.78</td>
<td>11</td>
<td>3</td>
<td>243</td>
<td>12.07</td>
</tr>
<tr>
<td></td>
<td><strong>Avg SS-MA</strong></td>
<td><strong>091</strong></td>
<td><strong>0.8</strong></td>
<td><strong>5.40</strong></td>
<td><strong>6</strong></td>
<td><strong>3.7</strong></td>
<td><strong>195</strong></td>
<td><strong>-2.38</strong></td>
</tr>
<tr>
<td>12</td>
<td>NSS-MA(1)</td>
<td>2.91</td>
<td>3.77</td>
<td>16.94</td>
<td>10</td>
<td>3</td>
<td>273</td>
<td>16.1</td>
</tr>
<tr>
<td>13</td>
<td>NSS-MA(2)</td>
<td>1.56</td>
<td>0.77</td>
<td>9.43</td>
<td>6</td>
<td>4</td>
<td>110.5</td>
<td>-0.63</td>
</tr>
<tr>
<td>14</td>
<td>NSS-MA(3)</td>
<td>1.46</td>
<td>1.46</td>
<td>5.69</td>
<td>0</td>
<td>15</td>
<td>272.5</td>
<td>-18.17</td>
</tr>
<tr>
<td></td>
<td><strong>Avg NSS-MA</strong></td>
<td><strong>1.65</strong></td>
<td><strong>1.99</strong></td>
<td><strong>10.69</strong></td>
<td><strong>5.3</strong></td>
<td><strong>7.3</strong></td>
<td><strong>218.67</strong></td>
<td><strong>-0.91</strong></td>
</tr>
</tbody>
</table>
Table 1-4: Statistical Significance of the Wilcoxon Tests

This table reports the results from the Wilcoxon tests comparing the sample means of median transaction prices in the five treatments compared to fundamental values and median prices in other treatments. The null hypothesis is that the means of the two groups are equal. Panel A is compiled by comparing means of median transaction prices in all 15 periods. Panel B is compiled by comparing means of the last 10 periods. A positive (negative) statistics indicates that the mean of median transaction price of the row treatment is higher (lower) than that of the column treatment.

p-values are shown in parentheses. FundP denotes the fundamental value.

* indicates significance at the 10% level
** indicates significance at the 5% level
*** indicates significance at the 1% level

Panel A: Mean of Median Prices – All 15 Periods

<table>
<thead>
<tr>
<th></th>
<th>NSS-TC</th>
<th>SS</th>
<th>SS</th>
<th>SS-MA</th>
<th>NSS-MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>FundP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>192</td>
<td>189.6</td>
<td>235</td>
<td>114.9</td>
<td>182.5</td>
<td>188.4</td>
</tr>
</tbody>
</table>

Wilcoxon test results - All 15 periods

Null hypothesis: The difference of means of median prices in two samples = 0

<table>
<thead>
<tr>
<th></th>
<th>FundP</th>
<th>NSS-TC</th>
<th>NSS</th>
<th>SS</th>
<th>SS-MA</th>
<th>NSS-MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>FundP</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSS-TC</td>
<td>-0.18</td>
<td>(0.859)</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSS</td>
<td>1.88</td>
<td>(0.060)*</td>
<td>(0.029)</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS</td>
<td>-3.52***</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>SS-MA</td>
<td>-0.54</td>
<td>(0.588)</td>
<td>(0.643)</td>
<td>(0.032)</td>
<td>(0.004)</td>
<td>-</td>
</tr>
<tr>
<td>NSS-MA</td>
<td>-0.190</td>
<td>(0.850)</td>
<td>(0.623)</td>
<td>(0.034)</td>
<td>(0.000)</td>
<td>(0.714)</td>
</tr>
</tbody>
</table>

* Median prices for the SS-MA and NSS-MA treatments are multiplied by 4.
Table 1-4 Continued

Panel B: Mean of Median Prices – Last 10 Periods

<table>
<thead>
<tr>
<th>FundP</th>
<th>NSS-TC</th>
<th>NSS</th>
<th>SS</th>
<th>SS-MA</th>
<th>NSS-MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>132</td>
<td>180.3</td>
<td>223.4</td>
<td>104.5</td>
<td>144.1</td>
<td>155.4</td>
</tr>
</tbody>
</table>

Wilcoxon test results – Last 10 periods

Null hypothesis: The difference of means of median prices in two samples = 0

<table>
<thead>
<tr>
<th></th>
<th>FundP</th>
<th>NSS-TC</th>
<th>NSS</th>
<th>SS</th>
<th>SS-MA</th>
<th>NSS-MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>FundP</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSS-TC</td>
<td>2.43**</td>
<td>(0.015)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSS</td>
<td>3.08***</td>
<td>(0.002)</td>
<td>(0.205)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS</td>
<td>-1.78*</td>
<td>(0.094)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS-MA</td>
<td>0.19</td>
<td>(0.847)</td>
<td>(0.074)</td>
<td>(0.018)</td>
<td>(0.220)</td>
<td></td>
</tr>
<tr>
<td>NSS-MA</td>
<td>0.92</td>
<td>(0.355)</td>
<td>(0.496)</td>
<td>(0.039)</td>
<td>(0.069)</td>
<td>(0.717)</td>
</tr>
</tbody>
</table>

* Median prices for the SS-MA and NSS-MA treatments are multiplied by 4.
Abstract

The value of an asset is equal to the present value of its expected future cash flows. It is affected by the magnitude, timing and riskiness, or volatility, of the cash flows. We hypothesize that if the expected values of two assets’ cash flows are equal, the value of the asset with more volatile cash flows will be lower. Furthermore, we examine the impact of the volatility of cash flows/dividends on the volatility of prices. We consider a simple experimental environment where subjects trade in an asset which provides dividends from a known probability distribution. The expected value of the dividends is identical in all experimental treatments. The treatments vary with respect to the volatility of dividends. We find that when dividends are more volatile, transaction prices are lower. We also find that the volatility of prices is lower in the treatment with highly volatile dividends. In addition, as expected, trading volume is lower when cash flows are less volatile.

Keywords: Efficient Market Hypothesis, Cash Flow Volatility, Price Volatility, Experimental Economics
2.1 Introduction

The efficient markets theory of speculative markets has long been known in the finance literature. According to this theory, the speculative markets efficiently incorporate all public information about fundamentals and any new relevant information about fundamentals is quickly reflected in prices, which are in turn described as some form of expected present value. In this form, the efficient markets theory has played a major role in academic finance.

However, several apparent anomalies to the efficient markets hypothesis have been noted by empirical researchers. These include the January effect, the Monday effect, the small firm effect, the price/earnings ratio effect and others. But of all apparent anomalies, potentially the most damaging to the efficient markets hypothesis is that speculative asset prices appear to be too volatile to be accounted for by theory. Many economics and finance researchers believe that stock prices are too volatile to be fully attributed to market fundamentals. According to Shiller’s seminal paper (1981a), stock prices from the 1870s to 1970s are five to thirteen times more volatile than can be justified by new information. Leroy and Porter’s 1981 study, conducted independent of Shiller, also reports that the variability of actual stock price movements is too large to be explained by the present value of future earnings. While Shiller’s study was criticized by other researchers for its methodology, his important result of excess volatility of stock prices has not been reversed15.

Since these anomalies seem to suggest that the simple present-value model fails to explain the behavior of stock markets, economists have attempted to develop model specifications to explain stock price volatility. One approach is to relax the constant discount rate assumption and allow investors to be risk averse, maintaining the idea that stock prices are exclusively determined by market

fundamentals. However, these variable discount rate specifications (Campbell and Shiller, 1988) provide only marginal support for the model in explaining stock price volatility.

Another approach to explain data is to incorporate speculative bubbles into the model. While different authors present different formal definitions of a bubble, the basic intuition is summarized by Stiglitz (1990): “if the reason that the price is high is only because investors believe that the selling price will be high tomorrow – when “fundamental” factors do not seem to justify such a high price – then a bubble exists”. The existence of speculative bubbles in financial markets has brought heated debates and currently there is no consensus on whether bubbles are consistent with the rationality assumption. As Wu (1997) points out, in the empirical literature (partly due to the lack of power of testing procedures), general specification tests for stock market bubbles yield mixed results\textsuperscript{16}.

In this study, we report the results from a series of economic experiments designed to measure the impact of the variability of cash flows on prices, on price volatility, and on trading volume. First, we examine the efficiency of a very simple experimental market\textsuperscript{17} that features an asset with certain cash flows. Since the cash flows are certain, the expected value of the asset is also known throughout the experiment. We ask the question: “If the future cash flows that an asset provides are certain, do the observed transaction prices follow the asset’s fundamental value?”

Second, we complicate the experimental environment by introducing uncertainty about the cash flows provided by the asset, but keeping the expected value of the asset unchanged. Are these new markets with uncertain cash flows efficient? If not, are they more or less efficient than markets where there is no uncertainty about future cash flows?

\textsuperscript{16} Some articles reject the null hypothesis of no bubbles, while others report the opposite (e.g. Rappoport and White, 1993; West, 1987; Dezhbaksh and Demirguc-Kunt, 1990; Diba and Grossman, 1988)

\textsuperscript{17} The details of the three markets are explained in Section 2.3.
Third, we look at the volatility of transaction prices in markets with varying degrees of cash flow volatility. Are transaction prices more volatile when there is more uncertainty about the future cash flows generated by assets traded? Or is the opposite true? More generally, what are the implications of the uncertainty of cash flows for the volatility of prices?

Finally, we consider the overall trading activity in the three markets. Are markets more active in terms of trading volume when the asset’s future cash flows are more uncertain or vice-versa?

The rest of this essay is organized as follows. Section 2.2 provides the background for the experiments and lists our conjectures. Section 2.3 describes the conduct of the nine experimental sessions. Section 2.4 demonstrates the results from the three experimental treatments and provides support for those results. Section 2.5 concludes and Section 2.6 lists the references.
2.2 Background

The task of determining the fundamental value of an asset held for an extended period has three parts: a) estimating the returns (rent for land, dividends for stocks, etc); b) estimating the terminal value at the end of the holding period; and c) deciding on the discount rates to convert future returns into current values (Stiglitz, 1990). The current price of the asset will rise if investors’ expectations of returns or terminal value improve or the discount rate is reduced.

There are a number of equity valuation techniques used both in academic research and by practitioners. They generally require forecasting the future but differ in the item that must be forecasted. Some techniques forecast cash flows, others forecast dividends, some forecast earnings, and yet others forecast operating profit. The most popular valuation techniques include the discounted cash flows model, the dividend discount model, and the residual income model.

In standard accounting and finance literature, the valuation of equity is assumed to be based on expected dividend payoffs (Penman, 1998). In equation form, $P_t$, the intrinsic equity price at time $t$, can be stated as follows:

$$P_t = \sum_{\tau=0}^{\infty} \rho^{-\tau} E_t$$

The payoffs, $d_{t+\tau}$, are dividends at the end of each future period, $t+\tau$. $E_t$ indicates an expectation that is conditional on information at time $t$ and $\rho$ represents the discount rate.

Of course, this equation assumes that the analyst forecasts an infinite stream of dividends. In practice, however, forecasts are made for a finite number of years. Consequently, this truncation requires estimating some kind of “terminal value”. Terminal values can often have a significant effect.
on the valuation, but their calculation sometimes relies on shaky assumptions (Penman, 1998). Thus, a number of studies have dealt with bringing some order to finite-horizon valuation by formulating many of the popular valuation techniques on a common basis. As such, Penman and Sougiannis (1998) contrast discounted cash flow analysis, dividend discount techniques, and techniques based on accrual earnings when each are applied with finite-horizon forecasts. They compare valuations based on average ex post payoffs over various horizons, with and without terminal value calculations with ex ante market prices to discover the error introduced by each technique. Penman (1998) shows that some valuation models that are apparently different in fact yield the same valuation.

The problem of estimating terminal values, as well as forecasting future dividends, can be eliminated by using experimental methodology, where most of the important market parameters can be set by the experimenter. We design such a market in which an asset provides dividends every trading period, as well as a terminal value. The details of the experimental design are explained in Section 2.3. We measure the efficiency of this experimental market as well as the volatility of prices at which the asset is traded.

It is important to clarify what we mean by the term “efficiency”. Burton Malkiel, in his 2003 article, uses a definition of efficient financial markets that such markets “do not allow investors to earn above-average returns without accepting above-average risks”. According to this definition, markets can be efficient even if they sometimes make valuation errors, as was the case in the Internet bubble of 1999-2000. Markets can be efficient even if some of the market participants are irrational or if stock prices exhibit greater volatility than can apparently be explained by fundamentals (such as dividends or earnings). Malkiel argues that many economists believe in efficiency because they “view markets as amazingly successful devices for reflecting new information rapidly and, for the most part, accurately. But the true litmus test of the efficiency of financial markets, according to Malkiel, is the (in)ability of investors to earn above-average risk adjusted returns."
The definition of market efficiency used by Malkiel is quite general. In this essay, we use a more restrictive definition. When we say the market is efficient, we mean that not only is information quickly reflected in prices and there are no possibilities of above-average risk adjusted returns, but also that the assets are priced correctly. In other words, in an efficient market, the prices of assets being traded closely follow their fundamental values.

We will start with our expectation about the overall price behavior. When there is no uncertainty about the future cash flows that an asset generates, then we expect the prices to closely follow fundamental value. The reasoning is that if the asset’s cash flows are certain, a rational trader, irrespective of her risk attitude, would not pay for that asset more than its future cash flows and she would not sell the asset for less than its future cash flows. So when cash flows of the traded assets are certain and if all traders are rational, then the transaction prices should never deviate from fundamentals.

In one of our experimental markets, the asset that is traded provides the same cash flow (called dividend in the experiment) every trading period in addition to the known terminal value in the last period. Therefore, there is absolutely no uncertainty about the future cash flows provided by the asset. In this environment, the range of feasible values of the asset in each period is in fact limited to a single point. This is the asset’s fundamental value. We would expect that rational traders would not pay for the asset more than the fundamental value, nor would they sell it for less than the fundamental value. If prices follow fundamental values, the market is efficient by our definition formulated above. This reasoning leads to the following proposition:

**Proposition 1.** The market is efficient when cash flows are not volatile.

In two of our experimental markets, there is some uncertainty about the future cash flows provided by the asset traded, although their expected values are the same in all three markets. So even
though the assets’ fundamental values are equal, the possible range of values\(^\text{18}\) (which depend on the 
luck of the draw) is much wider when cash flows are uncertain. The next proposition follows:

**Proposition 2.** The market is less efficient when cash flows are more volatile.

In markets that feature an asset with volatile cash flows, it is possible that the realized cash 
flows could be significantly lower than their expected value. In such markets, a risk-averse trader may 
agree to buy an asset only if the asking price is (sufficiently) less than the expected value of its future 
cash flows. So even if we assume that the traders are rational, if some of them are risk-averse, there is 
reason to believe that transaction prices may be lower when cash flows provided by the asset are more 
uncertain. Therefore, we hypothesize that the overall level of prices would be higher when there is 
less uncertainty about future cash flows. This leads to the following proposition:

**Proposition 3.** The prices are higher when cash flows are less volatile.

The three markets in our experiment feature assets with varying degrees of cash flow 
volatility. At one extreme, the range of plausible values is very wide at the start of the market session 
and narrows as the market proceeds. At the other extreme, there is only one plausible value in each 
period. Theory suggests that in this latter case, if all traders are rational, each transaction price is equal 
to the fundamental value of the asset. Therefore theory predicts zero price volatility in such markets. 
On the other hand, if cash flows are uncertain, it is conceivable that the actual cash flow movements 
induce some fluctuation in observed prices. Proposition 4 follows:

**Proposition 4.** Prices are less volatile when cash flows are less volatile.

Since each transaction reveals a price, trading activity plays a vital role in the process of 
information dissemination. Naturally, in a market which features an asset with cash flows known with

\(^{18}\) See Figures 2-1A and 2-3A.
certainty, there is no need for acquiring information about traders’ expectations of the value of expected future cash flows, and since each trader has the same expectation/valuation of cash flows, there are no gains from trade. On the other hand, if the asset’s cash flows are uncertain, each trade could potentially reveal some information about traders’ expectations of the value of future cash flows, and different expectation/valuation create gains from trade. Therefore, we would expect that there would be more trade in markets where the cash flows are uncertain. This expectation leads to the last proposition:

**Proposition 5.** Trading volume is lower when cash flows are less volatile.
2.3 Experimental Method

In this section, we describe the design of each of the three experimental treatments, as well as the details of how sessions were conducted.

2.3.1 Nature of Experiments

The data reported here have been collected from sessions conducted at the Laboratory for Economic Management and Auctions at the Smeal College of Business at the Pennsylvania State University. Nine experimental sessions (not including test sessions) were conducted February through May of 2008. The experimental design, summarized in Table 2-1, includes markets that feature assets with High Volatility, Low Volatility, and Zero Volatility of cash flows.

Three sessions were conducted for each market. 15 traders participated in each session, except in Session 2 of the High Volatility treatment, in which 14 traders participated.19 The subjects were undergraduate and graduate students at Penn State and were recruited through a web-based recruitment system. All subjects were inexperienced in the sense that they were only allowed to participate in one session.

Each session lasted about one hour and fifteen minutes. For their participation, subjects received a US$5 show-up fee plus an additional payment based on their performance. Subjects’ earnings were directly tied to their actions throughout the experiment, providing them with an incentive to make optimal decisions.20 The expected earnings, including the show-up fee, were $19.33. Actual earnings ranged from US$9.44 to US$34.96. The mean earning was US$19.22, with a

19 We always recruited more subjects than we needed. However, in that session, only 14 subjects came to the laboratory, even though 18 had signed up.
20 Properly using rewards helps the experimenter induce salience in the subjects (Friedman and Sunder, 1994). Salience means “the relation between actions and the reward implements the desired institution, and subjects understand the relation”.
Each market session consisted of 20 two-minute periods, organized as a computerized double auction market using the Zurich Toolbox for Ready-made Economic Experiments (z-Tree) platform (Fischbacher, 2007). This platform allows subjects to trade over a number of periods in real time. Subjects can post both bid prices and ask prices, as well as accept bid or ask prices posted by others. Appendix A-3 shows the main trading screen that subjects use to trade. The asset traded in our markets is called a “share”. In all treatments, subjects can buy or sell only one share at a time, though they can buy or sell multiple units during any given trading period.

In our experimental markets, all dividends, prices, and earnings, and money balances are expressed in terms of an experimental currency called “points”. After a session ends, subjects’ money balances are converted from points to cash and payments are made in cash.

The experiment is designed to measure the impact of the volatility of cash flows on the level of prices, as well as the volatility of prices and trading volume. Three treatments were conducted, with three sessions per treatment. The treatments differ with respect to the volatility of the cash flows. The first treatment, named High Volatility, features cash flows that are highly volatile. Specifically, at the end of each period each share pays a dividend of 20, 40, 60, or 80 points, each with ¼ probability. In addition, at the end of the 20th period, each share pays a “terminal value”, which can be either 400 or 600 points, each with ½ probability. In the second treatment, Low Volatility, cash flows are still variable, although their volatility is lower. In this treatment, dividends provided by a share at the end of each period can be 40 or 60 points, each with ½ probability. The terminal value can be either 400 or 600 points, each with ½ probability. Dividend draws in these first two treatments were independent both cross-sectionally and intertemporally. Finally, in the third treatment, named Zero Volatility, there is no variability in cash flows that a share provides. Each share pays a dividend of 50 points with certainty at the end of each period. The terminal value is 500 points, also with certainty.

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21 The information about the three treatments is summarized in Table 2-2.
Notice that in each treatment, the expected dividend per period is 50 points and the expected terminal value is 500 points. Since there are 20 periods in a session, the fundamental value of a share is 1500 points in the first period, and declines by 50 points each subsequent period. At the end of the 20th period, after the dividends and the terminal value have been paid, shares cease to exist and have zero value.

At the beginning of each session, subjects were given an initial money balance of 7,000 points and an endowment of 5 shares each. Given the expected dividends and endowments, the expected earnings in a session are $19.33. Actual earnings depend on the realized values of dividends and terminal value, as well as the subjects’ trades.

### 2.3.2 Conduct of Sessions

Upon arrival, subjects are given a few minutes to read the instructions. Then, one of the experimenters reads the instructions out loud and answers any questions that subjects may have. Once the experimenter makes sure that the subjects understand the instructions, the subjects play in 3 practice periods. The practice periods are intended to allow subjects to become familiar with the electronic market interface and learn how to post ask and bid prices, and to buy and sell shares. They are identical to actual paying periods, except that earnings in these practice periods do not count towards final earnings. In the treatments with uncertain dividends, the dividends for each period are determined by throwing a four-sided die at the end of that period. In the High Volatility treatment, each share pays a dividend of 20 points if the die reads 1, 40 points if the die reads 2, 60 points if the die reads 3, and 80 points if the die reads 4. In the Low Volatility treatment, the dividends are 40 points if the die reads 1 or 2, and 60 points if the die reads 3 or 4. For both of these treatments, a

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22 Sample instructions (for the High Volatility treatment) are provided in Appendix A-4.
share’s terminal value is 400 points if the die reads 1 or 2, and 600 points if the die reads 3 or 4. Since there is no uncertainty about the dividends or terminal values in the Zero Volatility treatment, no die is used.

Each period lasts for 2 minutes, during which the subjects can buy and sell shares. Buying and selling (or even posting ask and bid prices) is not required – subjects are allowed to hold their shares and collect dividends. Remaining time in the period is shown on the computer screen. After 2 minutes, the computer automatically ends trading. Once the dividends for the period are determined, subjects are shown the “Record screen”. This screen shows each subject: her money balance before the dividend distribution, the dividend for the period, her share holding, her dividend earnings, and her money balance after the distribution of dividends. This process is repeated for each of the 20 periods. At the end of the 20th period, in addition to dividends, the terminal value is also determined. The subjects are then shown their total earnings for the session in US dollars. Before being paid, the subjects are asked to complete a short questionnaire, which helps us better understand their decision-making process. The questionnaire is provided in Appendix A-4.  

23 The questionnaire was identical for all three treatments.
2.4 Market Behavior and Results

In this section, we provide descriptive data to review behavior of traders and the prices that result from this behavior. For each treatment, we plot: the median transaction price for each period, provide data on the frequency of transactions at prices above and below fundamental value, report several measures of price volatility and bubbles, and conduct nonparametric tests to determine whether deviations from fundamental values differ between treatments.

2.4.1 Market Behavior in the High Volatility Treatment

Figure 2-1A shows the median transaction prices for each period, along with fundamental values for the High Volatility treatment. As described earlier, in this treatment the shares’ dividends are determined from an independent four-point distribution and the terminal value is either 400 or 600 points, with equal likelihood.

Figure 2-1A shows that observed transaction prices exhibit substantial deviation from fundamental values, although there is some variation in market behavior among the three sessions. This is consistent with earlier research, including Smith et al (1988), King et al. (1993), Porter and Smith (1995), Noussair, Robin, and Ruffieux (2001), Lei et al. (2001), Porter and Smith (2003), and Haruvy and Noussair (2006). In two of the sessions (1 and 2) the median transaction price does not appear to settle close to the fundamental value until the last periods of trading. Even in the last period, the median price is not equal to fundamental value. Session 3 is an exception. Here, the median price starts out below the fundamental value in the first few periods, then quickly approaches the fundamental value. After a relatively small bubble in periods 8-10, the median price stays very close to fundamental values in the second half of session 3.
Figure 2-1A also shows hypothetical values of shares assuming the dividends are maximum possible (shown as “MaxP” in the chart) and minimum possible (shown as “MinP” in the chart). In other words, the “MaxP” – “MinP” range represents the feasible range of values for each period. If traders behave rationally (irrespective of their risk attitude), there is no reason for them to trade outside this feasible range. Therefore, if the median price in a period is outside this range, we can definitely conclude that there is a bubble. Figure 2-1A shows that there are periods in the High Volatility treatment when median prices are outside the feasible range. This example of irrational behavior is observed in periods 14-18 of Session 1 and period 1 of Session 2.

The prices outside the MaxP – MinP range are manifestations of irrational speculation where enough traders believe that prices will go further up above the MaxP level or further down below the MinP level. The absence of margin trading prevents the buyers below the MinP level from purchasing enough shares to push the price above the MinP level. Similarly, the absence of short selling prevents the sellers above the MaxP level from selling enough shares to push the price below the MaxP level.

Overall, for the High Volatility treatment, the general pattern is of median prices starting below the (declining) fundamental values until period 10, then going above fundamentals and forming a relatively small bubble, before finally approaching the fundamental value in the last two periods. This median price dynamic is clearly seen in Figure 2-2, which shows the median transaction prices for the High Volatility treatment. To construct the figure, the three sessions of the High Volatility treatment are combined to a single imaginary session and median prices for each period are calculated.

24 Note that if the median price in a period is outside the “feasible range”, then many, if not most, individual trades take place outside the range.

25 Strictly speaking, for us to make this claim, we must be able to say a reasonable confidence interval (we use a 95% confidence level) of prices falls outside the MinP – MaxP range. More specifically, there would be evidence of irrational behavior when the lower confidence level is above MaxP or when the upper confidence level is below MinP. This is observed in two sessions of the High Volatility treatment. In Session 1, the lower 95% confidence level is above the highest possible dividends (MaxP) in periods 14-18 (see Figure 2-1B). In Session 2, the upper 95% confidence level is below the lowest possible dividends (MinP) in the first period (see Figure 2-1C).
Examining transaction price data reveals that in the High Volatility treatment, more trades take place below fundamental values than above them. 40% (24 out of 60) of the median prices in the three sessions of the High Volatility treatment take place above fundamental values, while 50% (30 out of 60) take place below fundamental values. The remaining 10% (6 out of 60) of the median prices are equal to the fundamental value.

2.4.2 Market Behavior in the Low Volatility Treatment

Figure 2-3A shows the median transaction prices for each period, along with fundamental values for the Low Volatility treatment. In this treatment, the shares’ dividends are either 40 or 60, with equal likelihood, and the terminal value is either 400 or 600 points, also with equal likelihood.

As was the case with the High Volatility treatment, there is considerable variation of the price behavior among the three sessions of the Low Volatility treatment. Session 1 exhibits relatively low volatility in median prices, and sessions 2 and 3 show considerably higher volatility. What is even more striking is that in Sessions 2 and 3, there are several periods in which the median prices are outside the feasible range described above. Particularly, in periods 1-3 of Session 2 and periods 1-6 of Session 3 the median prices are below the minimum possible values. In periods 7-13 of Session 2 and periods 13-17 of Session 3 the median prices are above maximum possible values. Clearly, this is evidence of a bubble and irrational speculation26.

26 As before (see footnote 6), to support our claim of irrational behavior, we consider whether 95% confidence intervals fall outside the feasible range. In the Session 2 of the Low Volatility treatment, the upper 95% confidence level is below the lowest possible dividends (MinP) in periods 1-3 and the lower 95% confidence level is above the highest possible dividends (MaxP) in periods 8-12 (see Figure 2-3B). In Session 3, the upper 95% confidence level is below the lowest possible dividends (MinP) in periods 1-6 and 19-20, and the lower 95% confidence level is above the highest possible dividends (MaxP) in periods 13-17 (see Figure 2-3C).
Figure 2-4, which shows the median transaction prices in the Low Volatility treatment\textsuperscript{27}, suggests that median prices start at around 970 points, which is much lower than the fundamental value of 1,500 points. Median prices stay below fundamental values until the 6\textsuperscript{th} period, when they rise above fundamental values and stay above fundamentals for 11 periods. Therefore, there is a significant prolonged bubble in this imaginary “average session” of the Low Volatility treatment. Finally, in the last 3 periods median prices fall below fundamental values and, interestingly, stay below fundamental values until the last period. This behavior of median prices starting below fundamentals, forming a bubble and finally crashing, is also consistent with previous literature. In our experiments, the major difference between High Volatility and Low Volatility treatments is that the extent of the bubble is considerably larger in the latter.

Unlike the High Volatility treatment, where the majority of median prices are equal to or lower than fundamental values, in the three sessions of the Low Volatility treatment the majority of trades occur at prices above fundamental values. 53\% (32 out of 60) of the median prices take place above fundamental values, while 43\% (26 out of 60) take place below fundamental values. Only 3.3\% (2 out of 60) of median prices were equal to the fundamental value. By this measure, observed prices are higher in the Low Volatility treatment than in the High Volatility treatment.

\subsection*{2.4.3 Market Behavior in the Zero Volatility Treatment}

Figure 2-5 is the equivalent of Figures 2-1A and 2-3A, for the Zero Volatility treatment. It shows the median transaction prices for each period, along with fundamental values for the Low Volatility treatment. In this treatment, the shares’ dividends are 50 points and the terminal value is 500 points.

\textsuperscript{27} For Figure 2-4, as for Figure 2-2, the three sessions of the Low Volatility treatment are combined to a single imaginary session and median prices for each period are calculated.
Since the “feasible range” is the same as the fundamental value in this treatment, Figure 2-5 does not show the “MaxP” and “MinP” variables.

It is immediately apparent from Figure 2-5 that there are significant differences between the Zero Volatility treatment and High Volatility and Low Volatility treatments. First, the median prices follow fundamental values much more closely in the Zero Volatility treatment. This is especially true for Sessions 1 and 2, where median prices closely track fundamentals almost throughout the sessions. In Session 3, median prices do diverge from fundamental values by a significant margin, but even here they stay consistently above fundamentals, as opposed to exhibiting a bubble and crash behavior observed in High Volatility and Low Volatility treatments. Second, in Sessions 1 and 2, median prices catch up to fundamental values very quickly, within one or two periods. In High Volatility and Low Volatility treatments, median prices start well below fundamental values and stay below for a six to eight periods. In contrast, in the Zero Volatility treatment, median prices start slightly below fundamentals (with the exception of Session 1), and by period three they are at or above fundamentals. Third, median prices are generally higher in the Zero Volatility treatment compared to both other treatments.

Figure 2-6 shows the median transaction prices in the Zero Volatility treatment. As can be seen from the figure, the median prices are lower than fundamental values in the first two periods. Starting in the third period, however, median prices closely track fundamental values. The highest divergence is 50 points, which is observed in 5 periods. It is worth noting that median prices never fall below fundamental values, except in the 20th period, when they are 5 points below the fundamental value (545 vs. 550).

The Zero Volatility treatment continues the trend of more median prices taking place above fundamental values when cash flows are more certain. A full two-thirds (40 out of 60, or 67%) of

28 Median prices in Figure 2-6 are calculated the same way they are calculated for Figures 2-2 and 2-4.
median prices are above fundamental values in this treatment. In contrast, only 13% of median prices (8 out of 60) take place below fundamental values, while one-fifth (12 out of 60, or 20%) are equal to fundamental values.

Finally, to make comparison of median prices in the three treatments easier, Figure 2-7 shows the median transaction prices in each of the three treatments, averaged over 3 sessions. Essentially, Figure 2-7 is Figures 2-2, 2-4, and 2-6, superimposed on one another. It is apparent from Figure 2-7 that the median prices closely follow fundamental values in the Zero Volatility treatment. On the other hand, both High Volatility and Low Volatility treatments feature prolonged and significant price bubbles. Among the two, this bubble is more pronounced in the Low Volatility treatment.

**Result 1.** The market is efficient when cash flows are not volatile.

**Support.** Visual inspection of Figure 2-5 suggests that prices in the Zero Volatility treatment closely follow the fundamental values. However, as discussed earlier, there is some variation among Sessions 1 and 2 (where median prices almost never deviate from fundamental values after the first few periods) and Session 3 (where median prices stay significantly above fundamental values from the beginning of the session until the end). Furthermore, on average, transaction prices are above fundamental values in 13.3 out of 20 periods. This number is higher in the Zero Volatility treatment than in the other two treatments. Therefore, there appears to be some evidence of inefficiency in the Zero Volatility treatment. Nevertheless, this evidence does not hold up statistically.
As Table 2-3 shows, Booms (largest consecutive number periods when the median price is at least 10% higher than the fundamental value\(^{29}\)) in the Zero Volatility treatment last on average 3.3 periods, and Busts (largest consecutive number periods when the median price is at least 10% lower than the fundamental value) last on average 1 period. Both of these measures are the lowest of all treatments. So even though prices are higher than fundamental values in more periods in the Zero Volatility treatment than in any other treatment, they do not form long booms. This suggests that prices are only slightly higher than fundamental values. Average normalized bias, which is the average (over 20 periods) deviation of the median price from the fundamental value, expressed as a percentage of the fundamental value, is 4.99% for the entire treatment. So, on average, the median prices are approximately 5% higher than fundamental values. Additional measures of price volatility, as well as trading volume are shown in Table 2-4, and are discussed later in this section (under Result 5).

Statistical tests show that neither median prices nor individual transaction prices are significantly different from fundamental values. Since the median prices are not necessarily normally distributed, the t-test is not appropriate for our purposes. We use the Wilcoxon signed-rank test to compare the means of median prices in the three treatments and fundamental values\(^{30}\). The results are shown in Table 2-5. For the Zero Volatility treatment, the hypothesis that median prices are equal to fundamental values cannot be rejected for any traditional significance level. The same is true for individual transaction prices (not shown in Table 2-5).

\(^{29}\) We use this definition (as opposed to largest consecutive number periods when the price is higher than the fundamental value) to count only periods when the median prices are substantially higher than fundamental values. For example, in the first session of the Zero Volatility treatment, the largest consecutive number of periods when the median price is higher than the fundamental value is 8. But based on our definition, there is no “Boom”, since median prices are never more than 10% higher than the fundamental value. We use a similar definition for “Bubbles”.

\(^{30}\) When we compare median prices in the three treatments with fundamental values, our null hypothesis is that the mean of median transaction prices is equal to the mean of fundamental values. Therefore we use a two-tailed test for this comparison.
In addition, when individual transaction prices (rather than median prices) are considered, the average price deviation, which is the difference between fundamental values and transaction prices, divided by fundamental values is only 0.9% of the fundamental value. So on average, individual prices are less than 1% higher than fundamental values in each period.

**Result 2.** The market is not less efficient when cash flows are more volatile.

**Support.** While there is some evidence that the market in the Zero Volatility treatment is more efficient than in the High Volatility and Low Volatility treatments, this evidence is inconclusive. On the one hand, prices in both of these treatments seem to deviate from fundamental values. As Table 2-3 shows, the High Volatility treatment is characterized by long spells of Boom (5 periods) and Bust (6 periods). The Average bias (average deviation of the median price from the fundamental value) is 52 points. The Average normalized bias (the average deviation of the median price from the fundamental value as percentage of the fundamental value) is -1.0. In other words, on average, median prices are about 1 percent lower than fundamental values. The Low Volatility treatment also features long Boom (6.7) and Bust (4.3) periods, but the Average bias is only 5.2. On average, the median prices are about 2.6 percent higher than fundamental values. In addition, Total Dispersion (the sum of absolute deviations of median prices from fundamental values) is much smaller for the Zero Volatility treatment (1,438) than for both High Volatility and Low Volatility treatments (3,673 and 3,904 respectively). On the other hand, statistically we cannot claim that either High Volatility or Low Volatility treatment is inefficient. As Table 2-5 shows, the null hypothesis that median prices are equal to fundamental values cannot be rejected for either treatment.

More importantly, the median prices are not significantly different between Low Volatility and Zero Volatility treatments. The only statistically significant evidence of the difference between
treatments with different cash flow volatility is that between High Volatility and Zero Volatility. The null hypothesis that the median prices in these treatments are equal is rejected at the 5% level.

**Result 3.** The prices are higher when cash flows are less volatile.

**Support.** The Average Bias column of Table 2-3, which is the average deviation of the median price from the fundamental value, shows that median prices are the lowest in the High Volatility treatment, higher in the Low Volatility treatment and highest in the Zero Volatility treatment. The Average bias is -51.6, 5.22, and 29.7 respectively, for the three treatments. So the median prices are lower than fundamental values when cash flows are most volatile, slightly higher than fundamental values when cash flows are less volatile and even higher when cash flows are not volatile. This relationship also holds up statistically\(^{31}\). Table 2-5 shows that the average of median prices in the High Volatility treatment is significantly lower than those in both the Low Volatility treatment (p value = 0.063) and the Zero Volatility treatment (p value = 0.022). However, the median prices in the Zero Volatility treatment are not significantly higher than those in the Low Volatility treatment (p value = 0.289).

**Result 4.** The prices are more volatile when cash flows are less volatile.

**Support.** Contrary to our expectation, in our experiments the transaction prices exhibit higher volatility when the cash flows are less volatile. We measure the volatility in terms of the standard deviation of individual transaction prices in each period. Table 2-4 shows the average of the standard deviation of individual transaction prices in each period. Table 2-4 shows the average of the standard deviation of individual transaction prices in each period.

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\(^{31}\) Since our null hypothesis is that the mean of median transaction prices is higher in one treatment than in the other, we use a one-tailed Wilcoxon test.
deviation of prices for each session. As the table shows, the prices are least volatile when cash flows are most volatile, i.e. in the High Volatility treatment. The average standard deviation for the entire treatment is 45.4. In the Low Volatility treatment, transaction prices are slightly more volatile, demonstrated by the higher standard deviation of prices for the treatment being 50.1. At the other extreme, the highest volatility of prices is observed when cash flows are least volatile, i.e. in the Zero Volatility treatment. The average standard deviation of prices in this treatment is 107.40, or approximately 2.4 times that of the High Volatility treatment.

The above results are not immediately apparent from Figures 2-1 – 2-7, since these figures only show median prices. So while Figures 2-1 – 2-7 give a good idea of the aggregate market behavior, they tell us nothing about individual trades. Figures 2-8, 2-9, and 2-10 show individual transaction prices in each session of the High Volatility, Low Volatility, and Zero Volatility treatments, respectively. As can be seen from Figures 2-8A, 2-8B, and 2-8C, there is some variation in individual prices in the High Volatility treatment. Sessions 1 and 2 (Figures 2-8A and 2-8B) display low variation, while Session 3 (Figure 2-8C) displays relatively high variation, especially in the first five periods. Figures 2-9A, 2-9B, and 2-9C show that the variation in individual prices is slightly higher when there is less uncertainty about dividends – there is higher variation in the Low Volatility than in the High Volatility treatment. There is also more uniformity within three sessions of the Low Volatility treatment in terms of individual price volatilities. Finally, Figures 2-10A, 2-10B, and 2-10C reveal that the individual transaction prices are most volatile in the treatment where cash flows are certain (Zero Volatility treatment). There is also considerable difference within the three sessions of this treatment. While Sessions 1 and 2 (Figures 2-10A and 2-10B respectively) do exhibit very high volatility of prices, they pale in comparison with Session 3 (Figure 2-10C), which has by far the highest volatility of individual prices of all nine sessions. The relationship of “high cash flow volatility – low price volatility” is true whether only the last fifteen periods or all twenty periods of a session are considered.
Table 2-6 reports the statistical significance of Wilcoxon tests that compare the standard deviations of prices for the three treatments. Based on the table, while volatility of prices in the High Volatility treatment is not significantly lower than that in the Low Volatility treatment, volatility in both of these treatments is significantly lower than in the Zero Volatility treatment. The difference in the standard deviations between both High Volatility – Zero Volatility and Low Volatility – Zero Volatility is significant at the 1% level.

It may be justifiably argued that prices in the first few periods in each session tend to be more volatile. Empirically this is true for all sessions of all three treatments. Much of the price discovery process takes place in the first 4 or 5 periods. Therefore, it is conceivable that prices in the first few periods of the Zero Volatility treatment are much more volatile than prices in the first few periods of the other two treatments. It is also conceivable that once prices settle into a pattern, they deviate from the average to a lesser degree in the Zero Volatility treatment. If this were true, then the standard deviation of prices for the entire session might be higher in the Zero Volatility treatment than in the other two treatments, even if prices were less volatile in the last 15 periods of the session. We check that possibility by considering the standard deviation of prices in the last 15 periods of each session, rather than for the entire session. This does not change the result: even when the last 15 periods are considered, prices are more volatile when cash flows are less volatile. According to Table 2-4, the standard deviation of prices is the lowest in the High Volatility treatment (30.4), higher in the Low Volatility treatment (45.0) and highest in the Zero Volatility treatment (67.6). In fact, Result 4 is stronger when the last 15 periods are considered. As Table 2-6 shows, the difference between standard deviations of prices in High Volatility and Low Volatility treatments as well as in High Volatility and Zero Volatility treatments is significant at the 1% level; and the difference between

32 This distinction (the first 5 periods vs. the last 15 periods) is made somewhat arbitrarily. The results would not be very different if we divided a session to “the first 4 vs. last 16 periods” or “the first 6 vs. last 14 periods”.
standard deviations of prices in Low Volatility and Zero Volatility treatments is significant at the 5% level.

**Result 5.** Trading volume is lower when cash flows are less volatile.

**Support.** As Table 2-4 shows, both turnover and average trading volume are the highest when cash flows are most volatile, i.e. in the High Volatility treatment. The average Turnover for the three sessions of the High Volatility treatment is 4.33, which means that the volume of trade is 4.33 times the total number of shares available. On average, 15.93 shares are bought and sold in each period of the High Volatility treatment. Trading volume is slightly lower in the Low Volatility treatment, Turnover being 4.23 and the Average trading volume being 15.87 per period.

While there is little difference in trading volume between the High Volatility and Low Volatility treatments, there is a discernible difference between these two treatments and the Zero Volatility treatment. For the latter treatment, Turnover is 3.69 and 13.85 shares are bought and sold every period. Table 2-7 reports the statistical significance of Wilcoxon tests that compare trading volume for the three treatments. Based on the table, the difference in trading volume between both High Volatility - Zero Volatility and Low Volatility – Zero Volatility is significant at the 5% level. In addition, Table 2-4 shows that trading volume is also higher in the treatments with volatile cash flows when only the last 15 periods of a session are considered, rather than all 20 sessions. In addition, when the last 15 periods are considered, the difference in trading volume between both High Volatility - Zero Volatility and Low Volatility – Zero Volatility is significant at the 1% level.
2.5 Discussion and Concluding Remarks

In this essay, we attempt to measure the effect of volatility of cash flows on market efficiency and the volatility of transaction prices. We design three experimental markets where the asset that is traded provides highly uncertain, moderately uncertain and certain cash flows (dividends and terminal values). We hypothesize that the market with the highest volatility of cash flows will be the least efficient, feature lowest prices and have the highest volatility of prices. We also expect that the market with certain cash flows to be most efficient, feature the highest prices and have the lowest volatility of prices. Finally, we expect the trading volume to be lower when the cash flows provided by the asset are certain, since there are no gains from trade when traders’ expectations and valuation of cash flows are identical.

Our results indicate that the market with certain cash flows (the Zero Volatility treatment) is indeed efficient. Furthermore, transaction prices are the highest under this condition. While there is some evidence that market with certain cash flows is more efficient that ones with uncertain cash flows, we cannot show statistically that the latter are inefficient.

We also find that the trading volume is higher when cash flows are less certain (under the Zero Volatility and Low Volatility treatments). This lends support to our hypothesis that when there is some uncertainty about future cash flows, each transaction may reveal some useful information to traders. Perhaps most surprisingly, we find that the individual transaction prices are more volatile when the cash flows provided by the asset are certain (least volatile). In other words, when cash flows are certain, the overall (median) market prices are less volatile, even though individual transaction prices are more volatile. This is the case despite a lower volume of trade under this condition.
2.6 References


Figure 2-1A: Time Series of Median Transaction Prices, 3 Sessions of the High Volatility Treatment

“Value” refers to the fundamental value of the asset; “MaxP” refers to the hypothetical value of the asset assuming the dividends and terminal value are maximum possible in each period; “MinP” refers to the hypothetical value of the asset assuming the dividends and terminal value are minimum possible in each period; and “MedianP’s” refer to the median transaction prices in each period of the three sessions.

Median Transaction Prices - High Volatility
Figure 2-1B: Time Series of 95% Confidence Levels, Session 1 of the High Volatility Treatment

“Value” refers to the fundamental value of the asset; “MaxP” refers to the hypothetical value of the asset assuming the dividends and terminal value are maximum possible in each period; “MinP” refers to the hypothetical value of the asset assuming the dividends and terminal value are minimum possible in each period; “Lower 95% CL” refers to the lower 95% confidence level and “Upper 95% CL” refers to the upper 95% confidence level.

![95% Confidence Levels - HV treatment - Session 1](image)

Figure 2-1C: Time Series of 95% Confidence Levels, Session 2 of the High Volatility Treatment

“Value” refers to the fundamental value of the asset; “MaxP” refers to the hypothetical value of the asset assuming the dividends and terminal value are maximum possible in each period; “MinP” refers to the hypothetical value of the asset assuming the dividends and terminal value are minimum possible in each period; “Lower 95% CL” refers to the lower 95% confidence level and “Upper 95% CL” refers to the upper 95% confidence level.

![95% Confidence Levels - HV treatment - Session 2](image)
Figure 2-2: Time Series of Median Transaction Prices, High Volatility Treatment

![Median Transaction Prices - High Volatility](image_url)
Figure 2-3A: Time Series of Median Transaction Prices, 3 Sessions of the Low Volatility Treatment

“Value” refers to the fundamental value of the asset; “MaxP” refers to the hypothetical value of the asset assuming the dividends and terminal value are maximum possible in each period; “MinP” refers to the hypothetical value of the asset assuming the dividends and terminal value are minimum possible in each period; and “MedianP”s refer to the median transaction prices in each period of the three sessions.
Figure 2-3B: Time Series of 95% Confidence Levels, Session 2 of the Low Volatility Treatment

“Value” refers to the fundamental value of the asset; “MaxP” refers to the hypothetical value of the asset assuming the dividends and terminal value are maximum possible in each period; “MinP” refers to the hypothetical value of the asset assuming the dividends and terminal value are minimum possible in each period; “Lower 95% CL” refers to the lower 95% confidence level and “Upper 95% CL” refers to the upper 95% confidence level.

Figure 2-3C: Time Series of 95% Confidence Levels, Session 3 of the Low Volatility Treatment

“Value” refers to the fundamental value of the asset; “MaxP” refers to the hypothetical value of the asset assuming the dividends and terminal value are maximum possible in each period; “MinP” refers to the hypothetical value of the asset assuming the dividends and terminal value are minimum possible in each period; “Lower 95% CL” refers to the lower 95% confidence level and “Upper 95% CL” refers to the upper 95% confidence level.
Figure 2-4: Time Series of Median Transaction Prices, Low Volatility Treatment
Figure 2-5: Time Series of Median Transaction Prices, 3 Sessions of the Zero Volatility Treatment

![Median Transaction Prices - Zero Volatility](image1)

Figure 2-6: Time Series of Median Transaction Prices, Zero Volatility Treatment

![Median Transaction Prices - Zero Volatility](image2)
Figure 2-7: Time Series of Median Transaction Prices, all 3 Sessions of the High Volatility, Low Volatility and Zero Volatility Treatments
Figure 2-8A: Time Series of Transaction Prices, Session 1 of the High Volatility Treatment

Figure 2-8B: Time Series of Transaction Prices, Session 2 of the High Volatility Treatment
Figure 2-8C: Time Series of Transaction Prices, Session 3 of the High Volatility Treatment
Figure 2-9A: Time Series of Transaction Prices, Session 1 of the Low Volatility Treatment

Figure 2-9B: Time Series of Transaction Prices, Session 2 of the Low Volatility Treatment
Figure 2-9C: Time Series of Transaction Prices, Session 3 of the Low Volatility Treatment

Individual Transaction Prices
Low Volatility Treatment - Session 3

Price/Value

Value

p
Figure 2-10A: Time Series of Transaction Prices, Session 1 of the Zero Volatility Treatment

Figure 2-10B: Time Series of Transaction Prices, Session 2 of the Zero Volatility Treatment
Figure 2-10C: Time Series of Transaction Prices, Session 3 of the Zero Volatility Treatment
Table 2-1: Experimental Design

In all treatments, all subjects start the session with an initial money balance of 7,000 points and an endowment of 5 shares. Money balances, as well as share holdings, change as subjects buy and sell shares and do not reset each period. Money balances and share holdings carry over from one period to the next. In the High Volatility treatment, each share provides a dividend of 20, 40, 60, or 80 points, each with equal likelihood. At the end of the 20th period, each share also provides a terminal value of 400 or 600 points, each with equal likelihood. In the Low Volatility treatment, each share provides a dividend of 40 or 60 points, each with equal likelihood. At the end of the 20th period, each share also provides a terminal value of 400 or 600 points, each with equal likelihood. In the Zero Volatility treatment, each share provides a dividend of 50 points with certainty. At the end of the 20th period, each share also provides a terminal value of 500 points with certainty. In all treatments, the expected dividend is 50 points and the terminal value is 500 points. The intrinsic value of a share in the first period is 1500 points and decreases by 50 points each period.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Endowment (Points, Shares)</th>
<th>Dividends, in Points (p=1/4)</th>
<th>Expected Dividend Per Period, in Points</th>
<th>Terminal Value</th>
<th>Intrinsic Value Per Share in Period 1, in Points</th>
<th>Intrinsic Value Per Share in Period t, in Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Volatility</td>
<td>(7000, 5)</td>
<td>(20, 40, 60, 80)</td>
<td>50</td>
<td>(400, 600)</td>
<td>1500</td>
<td>50*(21-t)+500</td>
</tr>
<tr>
<td>Low Volatility</td>
<td>(7000, 5)</td>
<td>(40, 60)</td>
<td>50</td>
<td>(400, 600)</td>
<td>1500</td>
<td>50*(21-t)+500</td>
</tr>
<tr>
<td>Zero Volatility</td>
<td>(7000, 5)</td>
<td>(50)</td>
<td>50</td>
<td>500</td>
<td>1500</td>
<td>50*(21-t)+500</td>
</tr>
</tbody>
</table>
Table 2-2: Information about the Sessions

Three sessions for each of the High Volatility, Low Volatility, and Zero Volatility treatments were conducted. All nine sessions were conducted at the Laboratory for Economics Management and Auctions at Penn State from between February and March of 2008.

<table>
<thead>
<tr>
<th>Session</th>
<th>Treatment</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High Volatility</td>
<td>Subjects start with a money balance of 7,000 points and an endowment of 5 shares. Dividends are 20, 40, 60, or 80 points, each with 25% probability. The terminal value is 400 or 600 points, each with 50% probability.</td>
</tr>
<tr>
<td>2</td>
<td>High Volatility</td>
<td>Subjects start with a money balance of 7,000 points and an endowment of 5 shares. Dividends are 20, 40, 60, or 80 points, each with 25% probability. The terminal value is 400 or 600 points, each with 50% probability.</td>
</tr>
<tr>
<td>3</td>
<td>High Volatility</td>
<td>Subjects start with a money balance of 7,000 points and an endowment of 5 shares. Dividends are 20, 40, 60, or 80 points, each with 25% probability. The terminal value is 400 or 600 points, each with 50% probability.</td>
</tr>
<tr>
<td>4</td>
<td>Low Volatility</td>
<td>Subjects start with a money balance of 7,000 points and an endowment of 5 shares. Dividends are 40 or 60 points, each with 50% probability. The terminal value is 400 or 600 points, each with 50% probability.</td>
</tr>
<tr>
<td>5</td>
<td>Low Volatility</td>
<td>Subjects start with a money balance of 7,000 points and an endowment of 5 shares. Dividends are 40 or 60 points, each with 50% probability. The terminal value is 400 or 600 points, each with 50% probability.</td>
</tr>
<tr>
<td>6</td>
<td>Low Volatility</td>
<td>Subjects start with a money balance of 7,000 points and an endowment of 5 shares. Dividends are 40 or 60 points, each with 50% probability. The terminal value is 400 or 600 points, each with 50% probability.</td>
</tr>
<tr>
<td>7</td>
<td>Zero Volatility</td>
<td>Subjects start with a money balance of 7,000 points and an endowment of 5 shares. Dividends are 50 points and the terminal value is 500 points.</td>
</tr>
<tr>
<td>8</td>
<td>Zero Volatility</td>
<td>Subjects start with a money balance of 7,000 points and an endowment of 5 shares. Dividends are 50 points and the terminal value is 500 points.</td>
</tr>
<tr>
<td>9</td>
<td>Zero Volatility</td>
<td>Subjects start with a money balance of 7,000 points and an endowment of 5 shares. Dividends are 50 points and the terminal value is 500 points.</td>
</tr>
</tbody>
</table>
### Table 2-3: Measures of Price Deviations from Fundamentals

This table reports the bubble measures in each of the 9 experimental sessions, as well as the averages for the 3 treatments. The first column shows the number of periods in which the median transaction price \((P_t)\) was below the fundamental value \((FV_t)\). The second column shows the duration of a Boom, which is defined by the largest consecutive number of periods when the median price was at least 10% higher than the fundamental value. The second column shows the duration of a Boom, which is defined by the largest consecutive number of periods when the median price was at least 10% lower than the fundamental value. The third column shows Peak deviation, which is the magnitude of the bubble using the normalized peak deviation in median price from fundamental value (maximum observed ((\(P_t-FV_t)/FV_t)))\). The fifth column shows Average bias, which is the average deviation of the median price from the fundamental value (Average(\(P_t-FV_t)))\). The sixth column shows Average normalized bias, which is the average deviation of the median price from the fundamental value, expressed as a percentage of the fundamental value (100*Average(\(P_t-FV_t)/ FV_t)). The seventh column shows Total dispersion, which is the sum of absolute deviations of median prices from fundamental values (Sum(Abs(\(P_t-FV_t))).

<table>
<thead>
<tr>
<th></th>
<th>Periods when (P_t&gt;FV_t)</th>
<th>Boom</th>
<th>Bust</th>
<th>Peak Deviation</th>
<th>Average Bias</th>
<th>Average Normalized Bias</th>
<th>Total Dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Volatility-1</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>0.556</td>
<td>-16.45</td>
<td>5.46</td>
<td>5411</td>
</tr>
<tr>
<td>High Volatility-2</td>
<td>8</td>
<td>6</td>
<td>9</td>
<td>0.213</td>
<td>-145.40</td>
<td>-9.05</td>
<td>4607</td>
</tr>
<tr>
<td>High Volatility-3</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>0.172</td>
<td>7.08</td>
<td>0.58</td>
<td>1000</td>
</tr>
<tr>
<td><strong>High Volatility-Average</strong></td>
<td><strong>8.0</strong></td>
<td><strong>5</strong></td>
<td><strong>6</strong></td>
<td><strong>0.314</strong></td>
<td><strong>51.59</strong></td>
<td><strong>-1.00</strong></td>
<td><strong>3673</strong></td>
</tr>
<tr>
<td>Low Volatility-1</td>
<td>14</td>
<td>3</td>
<td>1</td>
<td>0.179</td>
<td>42.50</td>
<td>4.65</td>
<td>1750</td>
</tr>
<tr>
<td>Low Volatility-2</td>
<td>10</td>
<td>10</td>
<td>4</td>
<td>0.518</td>
<td>62.52</td>
<td>8.28</td>
<td>5090</td>
</tr>
<tr>
<td>Low Volatility-3</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>0.342</td>
<td>-89.38</td>
<td>-5.28</td>
<td>4872</td>
</tr>
<tr>
<td><strong>Low Volatility-Average</strong></td>
<td><strong>10.7</strong></td>
<td><strong>6.67</strong></td>
<td><strong>4.33</strong></td>
<td><strong>0.346</strong></td>
<td><strong>5.22</strong></td>
<td><strong>2.55</strong></td>
<td><strong>3904</strong></td>
</tr>
<tr>
<td>Zero Volatility-1</td>
<td>13</td>
<td>0</td>
<td>2</td>
<td>0.047</td>
<td>-39.12</td>
<td>-1.36</td>
<td>1198</td>
</tr>
<tr>
<td>Zero Volatility-2</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>0.104</td>
<td>4.50</td>
<td>0.51</td>
<td>442</td>
</tr>
<tr>
<td>Zero Volatility-3</td>
<td>18</td>
<td>9</td>
<td>0</td>
<td>0.482</td>
<td>123.75</td>
<td>15.83</td>
<td>2675</td>
</tr>
<tr>
<td><strong>Zero Volatility Average</strong></td>
<td><strong>13.3</strong></td>
<td><strong>3.33</strong></td>
<td><strong>1</strong></td>
<td><strong>0.211</strong></td>
<td><strong>29.71</strong></td>
<td><strong>4.99</strong></td>
<td><strong>1438</strong></td>
</tr>
</tbody>
</table>
Table 2-4: Measures of Trading Volume and Price Volatility

This table reports the measures of trading volume and deviation of actual transaction prices for each of the 9 experimental sessions, as well as the averages for the 3 treatments. The first column shows Turnover, which is the total number of trades in a session divided by the number of shares of available: Turnover = \( \frac{\sum q_t}{TSU} \), where \( q_t \) is the quantity of units of the asset exchanged in period \( t \). Columns 2 and 3 report the average number of trades in a session, for all 20 periods, and for the last 15 periods, respectively. Columns 4 and 5 report the standard deviation of prices in a session, for all 20 periods, and for the last 15 periods, respectively. This is distinct from the data reported in Table 2-3, which shows measures of deviation of prices from fundamental values.

<table>
<thead>
<tr>
<th>Session</th>
<th>Turnover</th>
<th>Average Trading Volume, Periods 1-20</th>
<th>Average Trading Volume, Periods 6-20</th>
<th>Standard Deviation of Prices, Periods 1-20</th>
<th>Standard Deviation of Prices, Periods 6-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Volatility-1</td>
<td>4.97</td>
<td>18.65</td>
<td>19.13</td>
<td>33.34</td>
<td>28.37</td>
</tr>
<tr>
<td>High Volatility-2</td>
<td>3.64</td>
<td>12.75</td>
<td>10.73</td>
<td>35.45</td>
<td>24.40</td>
</tr>
<tr>
<td>High Volatility-3</td>
<td>4.37</td>
<td>16.4</td>
<td>15.47</td>
<td>67.57</td>
<td>38.35</td>
</tr>
<tr>
<td><strong>High Volatility-Average</strong></td>
<td><strong>4.33</strong></td>
<td><strong>15.93</strong></td>
<td><strong>15.11</strong></td>
<td><strong>45.45</strong></td>
<td><strong>30.37</strong></td>
</tr>
<tr>
<td>Low Volatility-1</td>
<td>3.57</td>
<td>13.4</td>
<td>12.07</td>
<td>52.07</td>
<td>41.40</td>
</tr>
<tr>
<td>Low Volatility-2</td>
<td>4.72</td>
<td>17.7</td>
<td>16.07</td>
<td>55.84</td>
<td>51.04</td>
</tr>
<tr>
<td>Low Volatility-3</td>
<td>4.40</td>
<td>16.5</td>
<td>14.87</td>
<td>42.33</td>
<td>42.61</td>
</tr>
<tr>
<td><strong>Low Volatility-Average</strong></td>
<td><strong>4.23</strong></td>
<td><strong>15.87</strong></td>
<td><strong>14.34</strong></td>
<td><strong>50.08</strong></td>
<td><strong>45.02</strong></td>
</tr>
<tr>
<td>Zero Volatility-1</td>
<td>3.13</td>
<td>11.75</td>
<td>9.93</td>
<td>84.21</td>
<td>50.15</td>
</tr>
<tr>
<td>Zero Volatility-2</td>
<td>4.33</td>
<td>16.25</td>
<td>14.73</td>
<td>80.93</td>
<td>46.83</td>
</tr>
<tr>
<td>Zero Volatility-3</td>
<td>3.61</td>
<td>13.55</td>
<td>10.53</td>
<td>157.06</td>
<td>105.78</td>
</tr>
<tr>
<td><strong>Zero Volatility-Average</strong></td>
<td><strong>3.69</strong></td>
<td><strong>13.85</strong></td>
<td><strong>11.73</strong></td>
<td><strong>107.40</strong></td>
<td><strong>67.59</strong></td>
</tr>
</tbody>
</table>
Table 2-5: Statistical Significance of the Wilcoxon Tests, Median Prices and Fundamental Values

This table reports the p-values from the Wilcoxon tests comparing the sample means of median transaction prices in the three treatments with fundamental values and median prices in other treatments. The numbers in parentheses in the first row indicate the average of fundamental values and the averages of median prices for the three treatments.

The null hypothesis is that the means of the two groups are equal.

† When median prices and fundamental values are compared, we use a two-tailed test. When median prices of two treatments are compared, we use a one-tailed test.

<table>
<thead>
<tr>
<th></th>
<th>Fundamental value (1025)</th>
<th>High Volatility (973.4)</th>
<th>Low Volatility (1030.2)</th>
<th>Zero Volatility (1054.7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental value</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>High Volatility</td>
<td>0.340†</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Low Volatility</td>
<td>0.908†</td>
<td>0.063</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Zero Volatility</td>
<td>0.552†</td>
<td>0.022</td>
<td>0.289</td>
<td>-</td>
</tr>
</tbody>
</table>
### Table 2-6: Statistical Significance of the Wilcoxon Tests, Standard Deviation of Prices

This table reports the p-values from the one-sided Wilcoxon tests comparing standard deviations of individual prices in the three treatments. The numbers in parentheses in the first row indicate the average standard deviation for the treatment.

Panel A shows the results of tests when all 20 periods in a session are considered. Panel B shows the results for the last 15 periods.

#### Panel A: All 20 periods

<table>
<thead>
<tr>
<th></th>
<th>High Volatility</th>
<th>Low Volatility</th>
<th>Zero Volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(45.45)</td>
<td>(50.08)</td>
<td>(107.40)</td>
</tr>
<tr>
<td>High Volatility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Volatility</td>
<td>0.047</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Zero Volatility</td>
<td>0.002</td>
<td>0.020</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Panel B: Last 15 periods

<table>
<thead>
<tr>
<th></th>
<th>High Volatility</th>
<th>Low Volatility</th>
<th>Zero Volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(30.37)</td>
<td>(45.02)</td>
<td>(67.59)</td>
</tr>
<tr>
<td>High Volatility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Volatility</td>
<td>0.005</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Zero Volatility</td>
<td>0.014</td>
<td>0.086</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 2-7: Statistical Significance of the Wilcoxon Tests, Trading Volume
This table reports the p-values from the one-sided Wilcoxon tests comparing trading volume in the three treatments. The numbers in parentheses in the first row indicate the average trading volume for the treatment. Panel A shows the results of tests when all 20 periods in a session are considered. Panel B shows the results for the last 15 periods.

Panel A: All 20 periods

<table>
<thead>
<tr>
<th></th>
<th>High Volatility</th>
<th>Low Volatility</th>
<th>Zero Volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(15.93)</td>
<td>(15.87)</td>
<td>(13.85)</td>
</tr>
<tr>
<td>High Volatility</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Volatility</td>
<td>0.479</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Zero Volatility</td>
<td>0.025</td>
<td>0.015</td>
<td>-</td>
</tr>
</tbody>
</table>

Panel B: Last 15 periods

<table>
<thead>
<tr>
<th></th>
<th>High Volatility</th>
<th>Low Volatility</th>
<th>Zero Volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(15.11)</td>
<td>(14.34)</td>
<td>(11.73)</td>
</tr>
<tr>
<td>High Volatility</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Volatility</td>
<td>0.468</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Zero Volatility</td>
<td>0.006</td>
<td>0.005</td>
<td>-</td>
</tr>
</tbody>
</table>
ESSAY 3

VOLATILITY OF METROPOLITAN HOUSING RETURNS

WITH GROWTH CONTROLS

Abstract

We use theoretical models of land prices and house price volatility in urban areas previously
developed in the literature and investigate the differences in appreciation of house prices and their
volatility across different geographic regions of the United States. The variables that are shown in the
models to be important in affecting the variance of housing returns are identified. The empirical
investigation of these variables shows that, as expected by the model, the variance of housing return is
found to be positively and significantly related to the variance of household income, land leverage,
and transportation costs. The variance of housing returns is found to be negatively and significantly
related to the growth of household income and the real estate transfer tax rate.

Keywords: House Prices, House Price Indexes, Volatility, Transfer Taxes
3.1 Introduction and Literature Review

In the fourth quarter of 2008, Freddie Mac’s purchase-only Conventional Mortgage House Price Index (CMHPI) for the United States was a record 9.5 percent lower on a seasonally-adjusted basis than in the fourth quarter of 2007. Figure 3-1 shows the recent run-up and decline in prices in the United States, as well as the Pacific and East South Central census regions. The prices fell in all nine Census divisions between 2007:4 and 2008:4. Similar price declines were recorded by other house price indexes\(^{33}\). However, these price declines were not uniform across the country. The two census regions chosen for Figure 3-1 have exhibited the highest and lowest price volatilities over the last twenty-two years. Figures 3-2, 3-3 and 3-4 show the inflation-adjusted purchase-only CMHPI for three groups of Census regions and the United States in general. The Census regions selected for each of these three figures exhibit similar house price patterns\(^{34}\). Table 3-1 shows the twenty-five metropolitan statistical areas that recorded the biggest price declines between the second quarter of 2007 and the second quarter of 2008, based on the Conventional Mortgage Home Price Index (CMHPI). As can be seen from the table, of the 25 ranked cities with the greatest price declines over this period, all but one (Las Vegas) were in California or Florida. Moreover, the three MSAs with the biggest price declines for each of the last five quarters have been the same three: Merced, Stockton, and Modesto, all in California.

This essay is motivated by the variation in the appreciation of house prices in different areas in the United States. Figure 3-5 clearly demonstrates this variation. It is a map of the United States showing the average annual real house price appreciation rate and the variation in the appreciation rate. Some interesting geographic patterns can be detected on the map. First, the coastal areas have

\(^{33}\) These include S&P/Case-Shiller Home Price Index and the Federal Housing Finance Agency House Price Index. See Section 3.3.2 for their description.

\(^{34}\) For example, the New England, Middle Atlantic and South Atlantic Census regions (shown in Figure 3-2) exhibit price volatility that is close to that of the United States in general. On the other hand, the Census regions located in the middle of the country, the East South Central, West South Central, West North Central, and East North Central regions (shown in Figure 3-3) exhibit price volatility that is lower than that of the United States.
higher annual appreciation rates. They are in the 5-6% range and are shown in blue boxes on the map. House price appreciation rates are generally lower in the inland areas and range from 3.8% to 4.6% (these are shown in yellow boxes on the map).

Another interesting feature of Figure 3-5 is that the standard deviation of real annual house price appreciation widely varies from region to region. Specifically, the variation in house price appreciation is significantly higher in the coastal regions than in the inland regions. For example, the standard deviation of the annual real house price appreciation is 7.5% in the Pacific region and in the 4.7-5.3% range along the East Coast. In contrast, the same measure is in the 1.5-1.9% range in the Midwest, the Southeast and Southwest.

This pattern of high variability of house price appreciation rates in various regions can also be observed at the metropolitan statistical area (MSA) level. Table 3-2 shows the twenty-five metropolitan statistical areas with the highest volatility of real annual housing returns. As can be seen from the table, all except one (Las Vegas, NV) are in the coastal regions. Of the 24 coastal MSAs, 20 are in California (14) or Florida (6). In contrast, Table 3-3 shows the twenty-five metropolitan statistical areas with the lowest volatility of real annual housing returns in 1987-2008. Of these 25 MSAs, all but 7 are in the inland regions. The 7 MSAs that are in the coastal regions are all in North Carolina (4), South Carolina (2) or Georgia (1). This geographic pattern indicates that coastal regions, while enjoying higher average price appreciation rates, also face more volatile housing returns (at least from the period considered here, from 1987 to 2008).

We set out to analyze any existing theories that adequately explain the housing return patterns described above. There is considerable literature that deals with house price appreciation rates, as well as the variation in house price appreciation rates. In an early study of the cross-MSA house prices by Ozanne and Thibodeau (1983), the authors set up a cross-sectional model to explain hedonic house prices for 59 major metropolitan areas. Explanatory variables in their model include the median
household income, the number of households, an MSA-specific nonhousing price index, the mortgage rate, and others.

In a series of papers, Case and Shiller (1987, 1989, and 1990) develop their now widely-used weighted repeat sales house price indexes and use these indexes to estimate excess returns to investment in owner-occupied housing and conduct efficiency tests of housing returns. Case and Shiller (1987) use data on almost a million home sales in Atlanta, Chicago, Dallas, and San Francisco and construct quarterly indexes of existing house prices for 1970 – 1986. They apply a new technique of developing these indexes: the weighted repeat sales. Case and Shiller (1989) perform weak-form tests of market efficiency for single-family homes, based on the data from their 1987 article. Housing prices and excess returns are estimated over the period of 1980:3 – 1986:3 for Atlanta, Chicago, Dallas, and San Francisco. They find that price changes in one year tend to continue for more than a year in the same direction. A change in the log price index in a certain year and a certain city tends to be followed by a change in the same direction the following year that is a quarter to a half as large.

Case and Shiller (1991) build on their earlier results and conduct strong-form efficiency tests by examining the forecastability of excess returns and house prices with a number of forecasting variables. Consistent with their earlier results, the authors find evidence that price changes show positive serial correlation at short horizons (one year) that is statistically significant and negative correlation over longer horizons (2-4 years) that is not statistically significant. Furthermore, the ratio of construction costs to price, changes in adult population and increases in real per capita income are all positively related to excess returns or price changes over the subsequent year. The authors conclude that their results add weight to the argument that the market for single-family homes was inefficient for the period considered.

Abraham and Hendershott (1992) express real house price changes as a function of the rate of change in employment, real income growth, real construction cost inflation, and real after-tax interest rates. They find that the most important variables are real income and employment growth, although
the explanatory variables explain only about two-fifths of real price changes. The explanatory power rises to above half when lagged appreciation rates are added as an explanatory variable. The regressions explain house prices well for the Upper Midwest and Southeast, less well for the coastal cities, and poorly for Texas. The authors suggest that the explanatory power of the lagged dependent variable confirms the “inefficiency” of the owner-occupied housing market. Capozza and Seguin (1996) analyze expectations of capital appreciations in the housing market. They find that expectations impounded in the rent/price ratio successfully predict appreciation rates, when the model controls for cross-sectional differences in the quality of rental versus owner-occupied housing. The authors also demonstrate that observed rent/price ratios contain a disequilibrium component that has power to forecast subsequent appreciation rates.

Continuing their earlier work, Abraham and Hendershott (1996) divide the determinants of real house price appreciation into two groups: one that explains changes in the equilibrium price and another that accounts for the adjustment dynamics or changing deviations from the equilibrium price. The first group includes the growth in real income and real construction costs and changes in the real after-tax interest rate. The second group includes the lagged real appreciation rate and the difference between the actual and equilibrium real house price levels. The authors find that either group of variables can explain a little bit over two-fifths of the variation in real house price movements in 30 cities over the 1977-92 period. Together, they explain three-fifths. By applying their empirically supported approach to the entire country, the authors conclude that “a best guess is about a 15 percent premium on both coasts in early 1994” and that the majority of the country (namely, Midwestern and Southeastern cities) was near equilibrium in that period.

Capozza et al (2002) and Capozza et al (2004) explore the dynamics of real house prices by estimating serial correlation and mean reversion coefficients from a panel data of 62 metro areas from 1979-1995. They show that serial correlation and reversion parameters vary cross-sectionally with city size, real income growth, population growth, and real construction costs. Serial correlation is
higher in metro areas with higher real income, population growth, and real construction costs. Mean reversion is greater in large metro areas and faster-growing cities with lower construction costs. Substantial overshooting of prices can occur in cities with high correlation and low mean reversion, such as the coastal cities of Boston, New York, San Francisco, Los Angeles, and San Diego. Capozza et al (2002) suggest ways to reduce the volatility of real house prices. They agree with Shiller (1998) that the development of a futures market for housing with very low transaction prices could allow investors to take advantage of market inefficiencies. However, when such markets are not well-developed, the government could achieve the goal of dampening cycles by reducing barriers to new construction.

Glaeser et al (2005) observe that since 1950, house prices in the United States have risen regularly by almost two percent a year and the dispersion of housing prices across different cities has substantially grown. The increase in prices between 1950 and 1970 can be explained by rising housing quality and construction costs. Since 1970, price increases reflect the increasing difficulty of obtaining regulatory approval for building new homes. The authors also provide preliminary evidence that the local residents’ ability to block new projects and the cities have changed from “urban growth machines to homeowners’ cooperatives”.

For most American households, housing investment is the largest single investment and also the largest portion of their portfolio. As Shiller (1998) points out, the risk in the housing market is among the largest economic risks faced by individuals. Furthermore, housing wealth is the single most important asset class in the United States. According to the balance sheet of households and nonprofit organizations of the federal flow of funds of the United States, in the third quarter of 2008, real estate made up about 21.4 trillion dollars. The value of real estate is about 30 percent of all assets and roughly equals the combined value of corporate equity, mutual funds, and pension funds assets.

35 Federal flow of funds, Z-1, December 11, 2008 release.
held by households and nonprofits (23 trillion). Therefore, understanding the variation of housing returns is important for individual households.

While the literature on house price volatility is relatively small, this topic has received more attention in recent years. Berkovec (1989) develops a theoretical model that shows the positive relationship between risk and expected returns in owner-occupied housing. Gat (1994) uses this model to examine risk and return in neighborhood housing markets in Tel Aviv and empirically finds a positive and significant relationship between risk and return in housing markets. Crone and Voith (1999) introduce a model based on a homeowner’s utility maximization and their empirical results also supported the positive relationship between housing returns and the volatility of returns. These three studies establish and demonstrate the existence of the trade-off between risk and return in the housing market. However, their arguments are based on individuals’ utility maximization problem, rather than a general equilibrium problem. More importantly, this line of research does not address the question of why housing markets in some regions are more volatile than in other regions or whether this volatility differs across time.

Dolde and Tirtiroglu (1997) explore time-varying volatility in housing prices using data sets in Connecticut and near San Francisco from 1971 to 1994 and find evidence of time-varying volatility and positive relations between conditional variance and returns. Dolde and Tirtiroglu (2002) identify 36 volatility events in four regional housing markets from 1973 to 1993, and find associations between these volatility events and economic conditions. Miller and Peng (2006) analyze possible time variation of the volatility of single-family home value appreciation and the interactions between the volatility and the overall economy, using a large quarterly data set that covers 277 MSAs in the U.S. from the first quarter of 1991 to the second quarter of 2002. They find evidence of time varying volatility in 17% of the MSAs. They also find that the volatility is Granger-caused by the home appreciation rate and Gross Metropolitan Product growth rate. Cannon, Miller and Pandher (2006) use ZIP code level housing data to study the cross sectional role of volatility, price level, stock market risk
and idiosyncratic volatility in explaining housing returns. The empirical findings of these studies add to our understanding of house price volatility, but neither provides theoretical models for their empirical conjectures.

The goals of this study are threefold: to identify an appropriate theoretical model of house price volatility; determine potential variables that can explain the geographic pattern of differences in the variance of house price appreciation rates across different geographic regions of the United States; and empirically test whether these variables affect the variance of house price appreciation as predicted by the model.

The rest of this essay is organized as follows. Section 3.2 provides the background for the empirical analysis and lists the hypotheses that follow from previous literature. Section 3.3 describes in detail the data and the empirical model. Section 3.4 reviews the results and Section 3.5 concludes.
3.2 Background and Hypotheses

The empirical investigation in this essay is based on the monocentric urban area model developed by Capozza and Helsley (1989 and 1990). In these two papers, Capozza and Helsley derive urban land prices in a fixed lot size model under both certainty and uncertainty conditions. In a simple model in which capital is durable and landowners have perfect foresight, the price of land has four components: the value of the agricultural land rent, the cost of conversion, value of accessibility, and the value of expected future rent increase, a growth premium. The main insight from Capozza and Helsley (1989) is that in rapidly growing cities, there may be a large difference between the price of land at the boundary and the value of agricultural land rent due to the growth premium. In addition, in growing cities, the growth premium may account for half of the price of land. Capozza and Helsley (1990) develop a simple theoretical model of an urban area with growth and uncertainty and show that in equilibrium, uncertainty affects the land rents and land prices because the conversion of land (from agricultural land to urban use) is not reversible. Growth affects both agricultural and urban land prices, but not rent levels.

In a working paper, Liu (2008) extends Capozza and Helsley’s model to analyze the variance of housing returns. The model starts with the assumption of open city or free migration. In this scenario, the (local) government does not place any restrictions on the growth of the city. The households and landowners are the only two players in the model and they both maximize their respective objective functions. Starting with the household’s budget constraint and stochastic household income assumed by Capozza and Helsley, Liu derives urban land prices and the variance of housing prices.

Next, the analysis is expanded to include the government. The objective function of the government depends on the welfare of both landowners and households. Therefore, the government “maximizes the weighted summation of utility level achieved by the household and the total rent
collected by the landowners”. This results in an optimal size of urban area, which the government can choose by implementing certain growth controls, zoning restrictions, or by other measures. Finally, the variance of house price appreciation under growth control scenario. As expected, under growth control, the variance depends on the measure of growth control.

3.2.1 Hypotheses Derived from the Model

The comparative statics analysis of the variance of housing price appreciation in Liu (2008) results in several hypotheses which are empirically testable. Since local governments exercise various levels of growth control measures, we ignore the findings of the model for the case of open city in this essay. Instead, we focus only on the case of growth control. We list these hypotheses here and consider them in turn in the empirical investigation section.

Under the growth control scenario, the following hypotheses can be tested:

**Hypothesis 1:** The variance of housing returns is related to the variance of household income \( \sigma^2 \), but the direction of the relationship is ambiguous without further specifying parameters.

**Hypothesis 2:** The variance of the housing returns is related to the growth of household income \( \mu \), the extent of growth control \( \psi \), the per-unit-of-distance transportation cost \( k \), the agricultural land rent \( A \) and the cost of converting agricultural land to housing \( C^{36} \).

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36 As explained in the next section, the cost of converting agricultural land to housing is not included in the regressions due to the unavailability of data.
However, the directions of these relationships are ambiguous without further specifying parameters.

*Hypothesis 3:* The variance of housing returns is positively related to the share land in the total housing value (land leverage) $\alpha$. 
3.3 Empirical Investigation

In this section, we use MSA-level data to test the hypotheses derived from the theoretical models of Capozza and Helsley (1989 and 1990) and Liu (2008). We use cross-sectional linear regression models to empirically test each of the five hypotheses listed above.

3.3.1 Regression Model Under the Assumption of Growth Control

As mentioned earlier, we only consider the hypotheses derived from the growth control scenario in the model derived by Liu (2008). Under this scenario, government can place restriction on growth or otherwise limit the supply of housing. Based on hypotheses 1 - 3 listed in Section 3.2.1, the linear regression model under growth restrictions would be:

\[
\text{var}(\delta)_i = \beta_0 + \beta_1 \mu_i + \beta_2 \sigma^2_i + \beta_3 t_{ci} + \beta_4 \text{reg}_i + \beta_5 \text{aggr}_i + \beta_6 \text{leverage}_i + \beta_7 \delta_i + \eta_i
\]

Here \(\text{var}(\delta)_i\) is the variance of the housing returns for MSA \(i (i = 1, 2, \ldots n)\). Of the independent variables, \(\beta_0\) is a constant, \(\mu_i\) is the drift or growth rate of per capita income for each MSA, \(\sigma^2_i\) is the variance of per capita income at MSA level, \(t_{ci}\) is the transportation cost of MSA \(i\), \(\text{reg}_i\) measures the regulation level of the MSA, \(\text{aggr}_i\) represents the agricultural land rent level, \(\text{leverage}_i\) represents the share of land in the total housing value for each MSA, \(\delta_i\) is the MSA level average housing returns,
and finally, $\eta_i$ is the error term. Conversion cost $C$ refers to the capital cost of converting a unit of agricultural land to urban land. It is not included in the model due to data unavailability.

The average housing returns for each MSA are included as a regressor in the empirical model. We think this is reasonable because in the financial markets risk and return of investment assets are directly related. An asset with a higher volatility or returns must compensate investors by providing higher expected returns. Real estate as an asset class also exhibits this relationship. For example, Berkovec (1989) shows in a theoretical model that risk and return are related in the owner-occupied housing market. Cannon et al (2006) empirically demonstrate that a significantly positive relation between risk and return in the U.S. housing market. Specifically, the authors find that returns rise by 2.48% annually for a 10% rise in volatility, and find a positive but diminishing price effect on returns. Therefore we include the average housing return for the MSA is included as an explanatory variable in the regression. The discount rate $r$, which is found to be important in the theoretical models, is not included in the regression model, because the discount rate does not differ significantly across MSAs. If included, it would not add to the explanation of spatial differences in housing price volatility.

### 3.3.2 Data

The data used in this study come from several different sources. These are summarized in Appendix A-6. The averages and variations of house price appreciation rate are calculated using the Conventional Mortgage Home Price Index (CMHPI) data published by Freddie Mac. The CHMPI is a quarterly index based on conforming conventional mortgages that are bought or securitized by Fannie Mae or Freddie Mac. The data do not include loans insured by the Federal Housing Administration or...
guaranteed by the Veterans Administration or “jumbo” loans. The index is based on mortgages for single family residential properties; it does not reflect condominiums, multi-family and commercial properties. The CMHPI is a weighted, repeat-sales index, meaning it measures average price changes in repeat sales or refinancing on the same properties. The information on price changes is collected from repeat mortgage transactions bought or securitized by Fannie Mae or Freddie Mac since January 1975.

The CMHPI was first published in 1994, but the index goes back to the first quarter of 1975, since mortgages in the Fannie Mae and Freddie Mac database go back to 1975. The index is published two months after the end of each quarter. Indexes are available for the United States, all nine Census divisions, the 50 states and the District of Columbia, and every metropolitan statistical area (MSA) in the United States.

Based on the CMHPI, we calculate the MSA-level nominal quarterly housing returns from the first quarter of 1987 to the second quarter of 2008. Although the MSA-level indexes are available starting in 1975, data for many MSAs are not available until 1987. Therefore we chose to use the

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38 The S&P/Case-Shiller Home Price index, which uses a similar “weighted repeat sales” methodology, includes properties financed by jumbo loans in addition to conforming loans. However, this index is only available for twenty major metropolitan areas, which is not enough for our purposes.
39 Freddie Mac also publishes a version of the CMHPI that is only based on repeat sales only and excludes refinancing mortgages. For econometric purposes an index based on market transactions are superior to an index that also includes refinancing mortgages (where appraised value is taken as market value). However, the “purchase-only” version of the CMHPI is only available at the Census region level, and unavailable at the MSA level, because of small sample sizes.
40 As of the 4th quarter 2008 release, the combined Fannie and Freddie database included 33 million matched pairs.
41 Freddie Mac periodically changes the definition of MSAs, based on the definitions of the Office of Management and Budget (OMB). The Office of Management and Budget (OMB) defines metropolitan and micropolitan statistical areas for purposes of collecting, tabulating, and publishing federal data. Starting with the 2Q 2005 release, the new MSA index series file has 352 metropolitan areas and 29 metropolitan divisions (smaller areas within larger metro areas).
42 We use the terms “house price appreciation” and “housing return” interchangeably in this essay, even though strictly speaking, return to housing includes not only the appreciation of house prices, but also the return from housing consumption.
indexes starting in 1987\textsuperscript{43}. Given the nominal quarterly returns for each MSA, we can calculate the average returns, as well as the variances and standard deviations of the returns. Since the CMHPI indexes are in nominal terms, we use the Consumer Price Index (CPI) for all urban consumers published by the Bureau of Labor Statistics to adjust the house price index for inflation to get the mean, variance and standard deviations of real quarterly housing returns. All returns reported in the essay are real returns.

As a final note on the CMHPI, there is a similar repeat-sales house price index, the FHFA House Price Index, published by the Federal Housing Finance Agency\textsuperscript{44}. The background and technical details of the CMHPI is explained in Stephens, et al (1995). The details of the FHFA HPI are explained in Calhoun (1996).

The growth and variance of household income are calculated using MSA level per capita personal income data provided by the Bureau of Economic Analysis. This is annual data series dated from 1969 to 2006. Since the personal income data is in nominal terms, the CPI is used to adjust per capita income for inflation so that we get the drift and volatility of real personal income.

The per-unit transportation cost, denoted $t_{ci}$ in the regression model, is approximated by the inverse of average daily commuting speed (in miles per minutes) of each MSA. These MSA level travel speed data are obtained from the National Household Travel Survey (NHTS) 2001, which provides authoritative data on travel by all modes of transportation, for all travel purposes, and all travel distances. The NHTS average daily commuting speed is based on the population of the MSA. We take this data and apply it the MSAs based on their 2000 populations.

\textsuperscript{43} We also tried using the unbalanced data, starting in the first quarter of 1975. The results are similar to those reported here.

\textsuperscript{44} This index used to be published by the Office of Federal Housing Enterprise Oversight and was known as the OFHEO House Price Index. On July 30, 2008, the Housing and Economic Recovery Act of 2008 combined OFHEO and the Federal Housing Finance Board (FHFB) to form the new Federal Housing Finance Agency (FHFA). The FHFA HPI uses the same Fannie Mae/Freddie Mac combined database and essentially the same statistical methodology. Therefore, the differences between the CMHPI and FHFA HPI are extremely small.
Agricultural land rent data are approximated by the average returns to agricultural land (dollars per acre). The data were calculated using the Census of Agriculture data from the United States Department of Agriculture (USDA), and is computed as \((\text{value of all agricultural products sold} + \text{government payment} – \text{total farm production expenses})/\text{total farmland area}\). Unfortunately these data are available at the state level and not the MSA level. We use state level data to approximate MSA level data for our purposes.

In our regressions, we take real estate transfer taxes as a proxy for growth controls\(^{45}\). The real estate transfer taxes are taxes imposed by the state, county or local governments on the sale or transfer of property located in the state. Thirty-eight states and the District of Columbia impose transfer taxes at the state level, the county level or both. Twelve states do not collect transfer taxes\(^{46}\). The tax is based on the consideration paid for or the fair market value of the property and is collected by the local official responsible for recording deeds to real estate\(^{47}\). The transfer tax data used in this study is provided by the National Association of Realtors and the Federation of Tax Administrators. Where taxes are collected, they range from a 0.01 percent in Colorado to 2.2 percent in D.C. In about two-thirds of the states imposing the tax, the rate is below 0.5 percent of the property’s value. In seven states and D.C., the state tax rate is 1 percent or higher.

Transaction costs are very high in real estate markets, including housing markets, and are much higher than in financial markets. There are many costs associated with the transfer of real estate, including brokerage commissions, costs of search, costs of search, cost of financing, and others. Of these costs, transfer taxes are unique in the sense that they are measurable and must be paid with each

\(^{45}\) It could be argued that better measures of growth controls are available. For example, Malpezzi in his 1996 study “Housing Price, Externalities, and Regulation in U.S. Metropolitan Areas” develops an index of regulation or growth control for 56 MSAs. Since this number is smaller than the 271 MSAs we are using in this study, we use transfer taxes as a proxy for growth controls.

\(^{46}\) Alaska, Idaho, Indiana, Mississippi, Missouri, Montana, New Mexico, North Dakota, Oregon, Texas, Utah, Wyoming

\(^{47}\) Real estate transfer taxes are sometimes called deed recordation taxes.
transfer. In states where they are collected, transfer taxes must be paid by either buyer or seller and the tax rate is determined by the state.

The land leverage data, which measure land’s share in the value of the home, are obtained from Davis and Palumbo’s 2006 article “The Price of Residential Land in Large US cities”. Unfortunately, this essay provides the land leverage data for only 46 cities, which is a subsample of all metropolitan statistical areas. Therefore, we run two sets of regressions. First, we run regressions assuming open migration and growth control using only this subsample of 46 large MSAs. Then, we run regressions using land leverage data imputed using Monte Carlo simulations. Liu (2008) uses the MCMC (Markov Chain Monte Carlo) simulation method to impute the missing land leverage data. After the MCMC imputation, the sample size is increased to 271 observations on land leverage data. Table 3-4 provides the descriptive statistics for the data used in this study.

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48 I would like to thank Lexian Liu for providing these data.
3.4 Results

We first start with running the linear regressions for the subsample of MSAs for which Davis and Palumbo (2005) provide land leverage data. Later we expand the sample to include 271 MSAs.

3.4.1 Small Sample Regression Results

Table 3-5 shows the results for the small sample regression with 46 MSAs. The dependent variable is the variance of real housing return. Since the value of the variance of household income volatility is very large, it would lead to an extremely small coefficient estimate. Therefore, we use the standard deviation of household income volatility $\sigma$.

We can verify by looking at the second column of Table 3-5 whether the data support our conjectures. Based on the sign and significance of the coefficient of household income volatility $\sigma$, we can say with confidence that hypothesis 1 is satisfied: the variance of housing return is positively and significantly (at the 1% level) related to the variance of household income.

Furthermore, we can see that hypothesis 2 is also satisfied, since all coefficients of all the relevant variables are significant. From our data, it appears that the variance of housing returns is positively related to household income volatility, transportation costs, average housing return, and land leverage. It is negatively related to household income growth. Importantly, the results of the regression show that the volatility of returns on housing is positively and significantly related to the average housing return, which demonstrates the expected risk-return relationship in the housing market.
Our proxy for growth controls, real estate transfer taxes $T$ are found to be negatively related to the variance of housing return, although this coefficient is only marginally significant. This implies that, ceteris paribus, higher real estate transfer tax rates lead to a lower variance of housing returns\(^{49}\). Agricultural land rent appears to be insignificant both in the statistical and economic senses. This is likely due to the lack of precision in estimating agricultural land rent data.

Based on the Table, hypothesis 3 (variance of housing returns is positively related to the share of land in the total value of the house – land leverage) is also satisfied, but only marginally so. Even though the coefficient the land leverage variable has the expected positive sign, it is significant only at the 10% level.

### 3.4.2 Large Sample Regression

As was mentioned earlier, Davis and Palumbo (2005) provide land leverage data for only 46 large cities. To check the results from this small sample regression for robustness, we would like to have this data for most, if not all MSAs in the United States. Liu (2008) uses Markov Chain Monte Carlo simulations to impute the share of land in the total house value (land leverage) for 271 MSAs in the United States. We use this expanded data set to run the cross-sectional linear regressions described above under the growth control scenarios.

Table 3-6 displays the results from cross-sectional regressions using imputed land leverage data. As can be clearly seen from the table, the results are very consistent with those in Table 3-5. The signs of all the coefficients are the same.

\(^{49}\) This result appears to be consistent with a result from our first essay, which suggests that imposing significant transaction costs can mitigate the efficiency of a market.
Based on the table, the variance of housing return is also positively and significantly related to household income volatility, land leverage, average housing return and transportation costs. On the other hand, it is negatively and significantly related to household income growth and real estate transfer taxes. The effect of agricultural land rent is insignificant. All of these results are consistent with the small sample regression results (reported in Table 3-5).

One major difference from the small sample regression is that in the large sample regression, all the coefficients are highly significant in the statistical sense. In short, we can conclude that the hypotheses confirmed using small sample regressions are also confirmed with the large sample regression.
3.5 Conclusions and Future Directions

This essay uses theoretical models of land prices and house price volatility in monocentric urban areas developed by Capozza and Helsley (1989 and 1990) and Liu (2008) and investigates the differences in house price appreciations and their volatilities across different geographic regions of the United States. The variables that are shown in the models to be important in affecting the variances of housing returns are identified. Testable hypotheses on these variables are developed, based on the implications of the theoretical models. The empirical investigation of these variables shows that, as expected by the model, the variance of housing return is found to be significantly and positively related to the variance of household income, land leverage and transportation costs. It is found to be significantly and negatively related to the growth of household income and the real estate transfer tax rate.

Research into this issue can be extended in a number of ways. First, the theoretical model might allow for a special case of stochastically changing population. Intuitively, the size of the population and the number of households can affect the returns to housing as well as the variance of returns. More importantly, better quality and more extensive data would be very useful in gaining deeper understanding of housing returns and their variances. The major shortcoming of this study is the lack of high quality data on land leverage, transportation costs, growth controls for all 381 metropolitan statistical areas in the United States. The empirical work conducted here could be significantly improved by using data that is more suitable, given the theoretical framework.
3.6 References


Figure 3-1: The Inflation-Adjusted Purchase-Only Conventional Mortgage Home Price Index for the East South Central and Pacific Census Regions and the United States, 1987:1 – 2008:4
Figure 3-3: The Inflation-Adjusted Purchase-Only Conventional Mortgage Home Price Index for the East South Central, West South Central, West North Central, and East North Central Census Regions and the United States, 1987:1 – 2008:4.
Figure 3-5: Average Annual Real House Price Appreciation Rates and the Standard Deviations of Annual Real House Price Appreciation Rates in the Nine Census Regions, Based on the Conventional Mortgage Home Price Index, 1987 – 2008
<table>
<thead>
<tr>
<th>Rank</th>
<th>MSA</th>
<th>Annual house price decline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Merced CA</td>
<td>-38.4%</td>
</tr>
<tr>
<td>2</td>
<td>Stockton CA</td>
<td>-34.5%</td>
</tr>
<tr>
<td>3</td>
<td>Modesto CA</td>
<td>-31.6%</td>
</tr>
<tr>
<td>4</td>
<td>Salinas CA</td>
<td>-26.2%</td>
</tr>
<tr>
<td>5</td>
<td>Riverside-San Bernardino-Ontario CA</td>
<td>-25.9%</td>
</tr>
<tr>
<td>6</td>
<td>Vallejo-Fairfield CA</td>
<td>-24.7%</td>
</tr>
<tr>
<td>7</td>
<td>Port St Lucie-Fort Pierce FL</td>
<td>-23.9%</td>
</tr>
<tr>
<td>8</td>
<td>Naples-Marco Island FL</td>
<td>-23.4%</td>
</tr>
<tr>
<td>9</td>
<td>Cape Coral-Fort Myers FL</td>
<td>-22.7%</td>
</tr>
<tr>
<td>10</td>
<td>Bakersfield CA</td>
<td>-21.8%</td>
</tr>
<tr>
<td>11</td>
<td>El Centro CA</td>
<td>-21.7%</td>
</tr>
<tr>
<td>12</td>
<td>Sacramento-Arden-Arcade-Roseville CA</td>
<td>-20.0%</td>
</tr>
<tr>
<td>13</td>
<td>Las Vegas-Paradise NV</td>
<td>-19.9%</td>
</tr>
<tr>
<td>14</td>
<td>Yuba City CA</td>
<td>-19.8%</td>
</tr>
<tr>
<td>15</td>
<td>Madera CA</td>
<td>-19.8%</td>
</tr>
<tr>
<td>16</td>
<td>Sarasota-Bradenton-Venice FL</td>
<td>-19.3%</td>
</tr>
<tr>
<td>17</td>
<td>Fresno CA</td>
<td>-19.3%</td>
</tr>
<tr>
<td>18</td>
<td>Punta Gorda FL</td>
<td>-19.0%</td>
</tr>
<tr>
<td>19</td>
<td>West Palm Beach-Boca Raton-Boynton Beach, FL</td>
<td>-18.9%</td>
</tr>
<tr>
<td>20</td>
<td>Palm Coast FL</td>
<td>-18.9%</td>
</tr>
<tr>
<td>21</td>
<td>Vero Beach FL</td>
<td>-18.8%</td>
</tr>
<tr>
<td>22</td>
<td>Fort Lauderdale-Pompano-Deerfield FL</td>
<td>-18.7%</td>
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<td>23</td>
<td>Santa Barbara-Santa Maria-Goleta CA</td>
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<td>24</td>
<td>Santa Ana-Anaheim-Irvine CA</td>
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</tr>
<tr>
<td>25</td>
<td>Oxnard-Thousand Oaks-Ventura CA</td>
<td>-17.4%</td>
</tr>
</tbody>
</table>
Table 3-2: The Twenty-Five Metropolitan Statistical Areas with the Highest Volatility of Real Annual Housing Returns in 1987-2008

<table>
<thead>
<tr>
<th>Rank</th>
<th>MSA</th>
<th>Variance of real annual housing return</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Merced CA</td>
<td>0.0114</td>
</tr>
<tr>
<td>2</td>
<td>Stockton CA</td>
<td>0.0105</td>
</tr>
<tr>
<td>3</td>
<td>Modesto CA</td>
<td>0.0101</td>
</tr>
<tr>
<td>4</td>
<td>Hinesville-Fort Stewart GA</td>
<td>0.0100</td>
</tr>
<tr>
<td>5</td>
<td>Salinas CA</td>
<td>0.0095</td>
</tr>
<tr>
<td>6</td>
<td>Riverside-San Bernardino-Ontario CA</td>
<td>0.0095</td>
</tr>
<tr>
<td>7</td>
<td>Naples-Marco Island FL</td>
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<tr>
<td>8</td>
<td>Vero Beach FL</td>
<td>0.0091</td>
</tr>
<tr>
<td>9</td>
<td>Port St Lucie-Fort Pierce FL</td>
<td>0.0089</td>
</tr>
<tr>
<td>10</td>
<td>Yuba City CA</td>
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<tr>
<td>14</td>
<td>Palm Coast FL</td>
<td>0.0084</td>
</tr>
<tr>
<td>15</td>
<td>Cumberland MD</td>
<td>0.0082</td>
</tr>
<tr>
<td>16</td>
<td>Cape Coral-Fort Myers FL</td>
<td>0.0082</td>
</tr>
<tr>
<td>17</td>
<td>Santa Barbara-Santa Maria-Goleta CA</td>
<td>0.0082</td>
</tr>
<tr>
<td>18</td>
<td>El Centro CA</td>
<td>0.0082</td>
</tr>
<tr>
<td>19</td>
<td>Madera CA</td>
<td>0.0081</td>
</tr>
<tr>
<td>20</td>
<td>Punta Gorda FL</td>
<td>0.0081</td>
</tr>
<tr>
<td>21</td>
<td>Visalia-Porterville CA</td>
<td>0.0081</td>
</tr>
<tr>
<td>22</td>
<td>Santa Ana-Anaheim-Irvine CA</td>
<td>0.0081</td>
</tr>
<tr>
<td>23</td>
<td>Fairbanks AK</td>
<td>0.0080</td>
</tr>
<tr>
<td>24</td>
<td>Sacramento-Arden-Arcade-Roseville CA</td>
<td>0.0080</td>
</tr>
<tr>
<td>25</td>
<td>Las Vegas-Paradise NV</td>
<td>0.0080</td>
</tr>
<tr>
<td>Rank</td>
<td>MSA</td>
<td>Variance of real annual housing return</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Springfield IL</td>
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</tr>
<tr>
<td>2</td>
<td>Louisville KY</td>
<td>0.00053</td>
</tr>
<tr>
<td>3</td>
<td>Indianapolis IN</td>
<td>0.00054</td>
</tr>
<tr>
<td>4</td>
<td>Charlotte NC</td>
<td>0.00055</td>
</tr>
<tr>
<td>5</td>
<td>Columbus OH</td>
<td>0.00056</td>
</tr>
<tr>
<td>6</td>
<td>Cincinnati OH</td>
<td>0.00056</td>
</tr>
<tr>
<td>7</td>
<td>Lexington-Fayette KY</td>
<td>0.00056</td>
</tr>
<tr>
<td>8</td>
<td>Fort Worth-Arlington TX</td>
<td>0.00057</td>
</tr>
<tr>
<td>9</td>
<td>Raleigh-Cary NC</td>
<td>0.00057</td>
</tr>
<tr>
<td>10</td>
<td>Houston-Baytown-Sugar Land TX</td>
<td>0.00058</td>
</tr>
<tr>
<td>11</td>
<td>Memphis TN</td>
<td>0.00058</td>
</tr>
<tr>
<td>12</td>
<td>Dallas-Plano-Irving TX</td>
<td>0.00058</td>
</tr>
<tr>
<td>13</td>
<td>Greenville SC</td>
<td>0.00058</td>
</tr>
<tr>
<td>14</td>
<td>Dayton OH</td>
<td>0.00059</td>
</tr>
<tr>
<td>15</td>
<td>Knoxville TN</td>
<td>0.00059</td>
</tr>
<tr>
<td>16</td>
<td>Gary IN</td>
<td>0.00059</td>
</tr>
<tr>
<td>17</td>
<td>Jackson MS</td>
<td>0.00059</td>
</tr>
<tr>
<td>18</td>
<td>Greensboro-High Point NC</td>
<td>0.00059</td>
</tr>
<tr>
<td>19</td>
<td>Durham NC</td>
<td>0.00060</td>
</tr>
<tr>
<td>20</td>
<td>Davenport IA</td>
<td>0.00061</td>
</tr>
<tr>
<td>21</td>
<td>Oklahoma City OK</td>
<td>0.0012</td>
</tr>
<tr>
<td>22</td>
<td>Cleveland-Elyria-Mentor OH</td>
<td>0.0012</td>
</tr>
<tr>
<td>23</td>
<td>Atlanta-Sandy Springs-Marietta GA</td>
<td>0.0012</td>
</tr>
<tr>
<td>24</td>
<td>Columbia SC</td>
<td>0.0013</td>
</tr>
<tr>
<td>25</td>
<td>Chattanooga TN</td>
<td>0.0013</td>
</tr>
</tbody>
</table>
Table 3-4: Descriptive Statistics of Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs.</th>
<th>Mean</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance of real housing return</td>
<td>271</td>
<td>0.003</td>
<td>0.002</td>
<td>0.002</td>
<td>0.000</td>
<td>0.018</td>
</tr>
<tr>
<td>Average housing return $\delta$</td>
<td>271</td>
<td>0.016</td>
<td>0.014</td>
<td>0.013</td>
<td>-0.013</td>
<td>0.061</td>
</tr>
<tr>
<td>Income growth $\mu$</td>
<td>271</td>
<td>174.2</td>
<td>168.4</td>
<td>57.0</td>
<td>14.8</td>
<td>375.1</td>
</tr>
<tr>
<td>Income volatility $\sigma$</td>
<td>271</td>
<td>1971.3</td>
<td>1911.7</td>
<td>579.1</td>
<td>660.2</td>
<td>4159.4</td>
</tr>
<tr>
<td>Transportation cost $tc$</td>
<td>271</td>
<td>1.926</td>
<td>1.923</td>
<td>0.138</td>
<td>1.661</td>
<td>2.759</td>
</tr>
<tr>
<td>Transfer tax $T$</td>
<td>271</td>
<td>0.301</td>
<td>0.160</td>
<td>0.385</td>
<td>0</td>
<td>2.2</td>
</tr>
<tr>
<td>Agricultural land rent</td>
<td>271</td>
<td>69.61</td>
<td>56.28</td>
<td>55.99</td>
<td>2.15</td>
<td>288.52</td>
</tr>
<tr>
<td>Land leverage</td>
<td>271</td>
<td>0.386</td>
<td>0.340</td>
<td>0.158</td>
<td>0.199</td>
<td>1.894</td>
</tr>
</tbody>
</table>

Table 3-5: Cross-sectional Regression for the Growth Control Scenario and Sample Size =46

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient (t-statistic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.0081 (-2.95)***</td>
</tr>
<tr>
<td>Income growth $\mu$</td>
<td>-0.00013 (2.43)**</td>
</tr>
<tr>
<td>Income volatility $\sigma$</td>
<td>0.00001 (2.25)**</td>
</tr>
<tr>
<td>Land leverage</td>
<td>0.00453 (1.70)*</td>
</tr>
<tr>
<td>Average housing return $\delta$</td>
<td>0.00724 (2.96)***</td>
</tr>
<tr>
<td>Transportation cost $tc$</td>
<td>0.00411 (3.13)***</td>
</tr>
<tr>
<td>Transfer tax $T$</td>
<td>-0.00017 (1.73)*</td>
</tr>
<tr>
<td>Agricultural land rent</td>
<td>0.00000 (-0.95)</td>
</tr>
</tbody>
</table>

Observations 46  
$R^2$ 0.67  
$Adj. R^2$ 0.61  

Dependent variable: Variance of housing return  
t-statistics are shown in parentheses  
*** significant at 1%, ** significant at 5%, * significant at 10%.
Table 3-6: Cross-Sectional Regression for the Growth Control Scenario with Imputed Land Leverage Data, Sample Size =271

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient (t-statistic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.0179 ((-9.03)***)</td>
</tr>
<tr>
<td>Income growth $\mu$</td>
<td>-0.00007 ((-6.13)***)</td>
</tr>
<tr>
<td>Income volatility $\sigma$</td>
<td>0.0001 ((5.19)***)</td>
</tr>
<tr>
<td>Land leverage</td>
<td>0.00267 ((2.48)***)</td>
</tr>
<tr>
<td>Average housing return $\delta$</td>
<td>0.00677 ((5.97)***)</td>
</tr>
<tr>
<td>Transportation cost $tc$</td>
<td>0.00517 ((6.65)***)</td>
</tr>
<tr>
<td>Transfer tax $T$</td>
<td>-0.00021 ((2.83)***)</td>
</tr>
<tr>
<td>Agricultural land rent</td>
<td>-0.0000 ((-0.53))</td>
</tr>
</tbody>
</table>

Observations: 271
$R^2$: 0.43
$Adj. R^2$: 0.42

Dependent variable: Variance of housing return

t-statistics are shown in parentheses

*** significant at 1%, ** significant at 5%, * significant at 10%.
Appendix A-1: Instructions for the NSS-TC Treatment

Instructions for Treatment 1 (NSS-TC)

1. General Instructions

This is an experiment in the economics of market decision making. These instructions explain how the decisions you make determine your earnings from this session. The experiment will consist of a sequence of trading periods in which you will have the opportunity to buy and sell in a market. The currency used in the market is francs. All trading will be in terms of francs. The cash payment to you at the end of the experiment will be in dollars. The conversion rate is 100 francs to 1 dollar. In addition to any profits you earn in the market, you will also receive an additional $5 (equivalent to 500 francs) for your participation today.

2. How to use the computerized market

The goods that can be bought and sold in the market are called Shares. On the left-most column of your computer screen, in top left corner, you can see the Money you have available to buy Shares and in the middle of the column, you see the number of Shares you currently have.

If you would like to offer to sell a share, use the text area entitled “Enter ask price” in the second column. In that text area you can enter the price at which you are offering to sell a share, and then select “Submit Ask Price”. Please do so now.

You will notice that nine numbers, one submitted by each participant, now appear in the third column from the left, entitled “Ask Price”. The lowest ask price will always be on the bottom of that list and will be highlighted. If you press “Buy”, the button at the bottom of this column, you will buy one share for the lowest current ask price. You can also highlight one of the other prices if you wish to buy at a price other than the lowest.

Please purchase a share now by highlighting a price and selecting “Buy”. Since each of you had put a share for sale and attempted to buy a share, if all were successful, you all have the same number of shares you started out with. This is because you bought one share and sold one share.

When you buy a share, your Money decreases by the purchase price. When you sell a share, your Money increases by 90% of the sales price (this will be explained later).

You may make an offer to purchase a unit by selecting “Submit bid price.” Please do so now. Type a number in the text area “Enter bid price.” Then press the red button labeled “Submit Bid Price”.

You can sell to the person who submitted an offer if you highlight the offer, and select “Sell”. Please do so now for one of the offers.
3. Specific Instructions for this experiment

The experiment will consist of 15 four-minute trading periods. In each period, there will be a market in which you may buy and sell shares. Shares are assets with a life of 15 periods, and your inventory of shares carries over from one trading period to the next. You may receive dividends for each share in your inventory at the end of each of the 15 trading periods.

At the end of each trading period, including period 15, the experimenter will roll a four-sided die to determine the dividend for the period. Each period, each share you hold at the end of the period:

- earns you a dividend of 0 francs if the die reads 1
- earns you a dividend of 8 francs if the die reads 2
- earns you a dividend of 28 francs if the die reads 3
- earns you a dividend of 60 francs if the die reads 4

Each of the four numbers on the die is equally likely. The average dividend in each period is 24. The dividend is added to your cash balance automatically.

After the dividend is paid at the end of period 15, there will be no further earnings possible from shares.

4. Selling more shares than you own

In this market, you cannot sell more shares than you own. That is, you may not own a negative number of shares.

5. Commissions

In this market, when you SELL a share, you pay 10 percent of the selling price as “sales commission”. For example, if A sells one share to B for 60 francs, then B pays A 60 francs, but A only receives 54 francs (60 – 60*10% = 54). You may think of this as the experimenter acting as a broker who charges sellers (but not buyers) a 10 percent commission. Thus, when you sell a share, 10% of the selling price is automatically deducted from your Money.

6. Average Holding Value Table

You can use your AVERAGE HOLDING VALUE TABLE to help you make decisions. There are 5 columns in the table. The first column, labeled Ending Period, indicates the last trading period of the experiment. The second column, labeled Current Period, indicates the period during which the average holding value is being calculated. The third column gives the number of holding periods from the period in the second column until the end of the experiment. The fourth column, labeled Average Dividend per Period, gives the average amount that the dividend will be in each period for each unit held in your inventory. The fifth column, labeled Average Holding Value Per Unit of Inventory, gives the average value for each unit held in your inventory from now until the end of the experiment. That is, for each unit you hold in your inventory for the remainder of the experiment, you will earn on average the amount listed in column 5.
Suppose for example that there are 7 periods remaining. Since the dividend on a Share has a 25% chance of being 0, a 25% chance of being 8, a 25% chance of being 28 and a 25% chance of being 60 in any period, the dividend is on average 24 per period for each Share. If you hold a Share for 7 periods, the total dividend for the Share over the 7 periods is on average $7 \times 24 = 168$. Therefore, the total value of holding a Share over the 7 periods is on average 168.

### Average Holding Value Table

<table>
<thead>
<tr>
<th>Ending Period</th>
<th>Current Period</th>
<th>Number of Holding Periods</th>
<th>Average Dividend Per Period</th>
<th>Average Holding Value Per Share in Inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
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<td>15</td>
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<td>360</td>
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<tr>
<td>15</td>
<td>2</td>
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<td>336</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>13</td>
<td>24</td>
<td>312</td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>12</td>
<td>24</td>
<td>288</td>
</tr>
<tr>
<td>15</td>
<td>5</td>
<td>11</td>
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</tr>
<tr>
<td>15</td>
<td>6</td>
<td>10</td>
<td>24</td>
<td>240</td>
</tr>
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<td>15</td>
<td>7</td>
<td>9</td>
<td>24</td>
<td>216</td>
</tr>
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<td>15</td>
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</tr>
<tr>
<td>15</td>
<td>14</td>
<td>2</td>
<td>24</td>
<td>48</td>
</tr>
<tr>
<td>15</td>
<td>15</td>
<td>1</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>
7. Your Earnings

Your earnings for the experiment will equal the amount of cash that you have at the end of period 15, after the last dividend has been paid, plus the $5 you receive for participating. The amount of cash you will have is equal to:

The money you have at the beginning of the experiment

+ dividends you receive for the shares you own

+ money received from sales of shares

- money spent on purchases of shares

You will now play in three practice periods. Your actions in the practice periods do not count toward your earnings and do not influence your position later in the experiment. The goal of the practice periods is only to master the use of the interface. Please be sure that you have successfully submitted bid prices and ask prices. Also be sure that you have accepted both bid and ask prices. While you are selling a share, notice the 10% difference between your selling price and the money you actually receive. It is important that you do not talk or in any way try to communicate with other people during the experiment. If you violate the rules, you will be asked to leave the experiment. You are free to ask questions, by raising your hand, at any time during the experiment.
Appendix A-2: A Screenshot of the Main Trading Period for Experiments

<table>
<thead>
<tr>
<th>Period</th>
<th>1 of 15</th>
<th>Remaining Time [sec]: 7</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Money</th>
</tr>
</thead>
<tbody>
<tr>
<td>€0.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shares</th>
<th>4</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Ask Price</th>
<th>Purchase Price</th>
<th>Bid Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100</td>
<td>950</td>
<td>750</td>
</tr>
<tr>
<td>1000</td>
<td>980</td>
<td>850</td>
</tr>
<tr>
<td>990</td>
<td>980</td>
<td>850</td>
</tr>
<tr>
<td>980</td>
<td>990</td>
<td>880</td>
</tr>
</tbody>
</table>

Enter ask price: 980

Enter bid price: 750

Submit Ask Price
Buy
Submit Bid Price
Sell
Appendix A-3: The Main Trading Screen of the Computerized Market
Instructions for Treatment 1 (HV)

1. General Instructions

Welcome. This is an experiment in the economics of market decision making. The funds for this study have been provided by the Smeal College of Business. These instructions explain how the decisions you make determine your earnings from this session. The experiment will consist of a sequence of trading periods in which you will have the opportunity to buy and sell in a market. The currency used in the market is points. You will start the experiment with 7,000 points. This includes your $5 showup fee. The cash payment to you after the experiment will be in dollars. The conversion rate is 750 points to 1 dollar. Notice that the more points you earn, the more cash you will receive at the end of the study.

2. Specific Instructions for this experiment

The goods that can be bought and sold in the market are called Shares. You will start with 5 shares in your inventory. There are two ways to make money in this market. First, you can earn money from holding shares and receiving dividends. Second, you can make money by selling and buying shares.

The experiment will consist of 20 two-minute trading periods. In each period, there will be a market in which you may buy and sell shares. Shares are assets with a life of 20 periods, and your inventory of shares carries over from one trading period to the next.

You will receive dividends for each share in your inventory at the end of each period. After the 20th period, an additional terminal value will be paid for each share. The dividends and the terminal value are determined as explained below. There will be no other payments for your shares after the 20th period.

At the end of each trading period, the experimenter will roll a four-sided die to determine the dividend for that period. At the end of each period, each share you hold:

- earns you a dividend of 20 points if the die reads 1
- earns you a dividend of 40 points if the die reads 2
- earns you a dividend of 60 points if the die reads 3
- earns you a dividend of 80 points if the die reads 4

Each of the four numbers on the die is equally likely. Therefore the average dividend in each period is 50 points. Your earned dividends are added to your money balance automatically.

The roll of the die that determines the dividend for the 20th period also determines the terminal value of each share. A share’s terminal value is determined as follows:

- the terminal value is 400 if the die reads 1 or 2
- the terminal value is 600 if the die reads 3 or 4
3. Selling more shares than you own
In this market, you cannot sell more shares than you own. That is, you may not own a negative number of shares.

4. Average Holding Value Table
You can use your Average Holding Value Table below to help you make decisions. There are 5 columns in the table. The first column, labeled Beginning of Period, indicates the period during which the average holding value is being calculated. The second column, labeled Remaining Periods, shows the number of periods in which dividends will be paid. The third column, labeled Average Dividend per Period, gives the average amount of dividend that will be paid in each period for each share held in your inventory. The fourth column, labeled Average Terminal Value, shows the average terminal value per share at the 20th period. The fifth column, labeled Average Holding Value Per Share, gives the average value for each share held in your inventory from the current period until the end of the experiment. That is, for each unit you hold in your inventory for the remainder of the experiment, you will earn on average the amount listed in the fifth column.

Suppose, for example, that there are 7 periods remaining. Since the dividend on a share has a 25% chance of being 20, a 25% chance of being 40, a 25% chance of being 60 and a 25% chance of being 80 points in any period, the dividend is on average 50 points per period for each share. If you hold a share for 7 periods, the total dividend for the share over the 7 periods is on average $7 \times 50 = 350$ points. The terminal value has a 50% chance of being 400 and 50% chance of being 600, and on average it is 500 points. Therefore, the total value of holding a Share over the 7 periods is on average 850 points.
# Average Holding Value Table

<table>
<thead>
<tr>
<th>Beginning of Period</th>
<th>Remaining Periods</th>
<th>Average Dividend per period</th>
<th>Average Terminal Value at the end of period 20</th>
<th>Average Holding Value per Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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5. How to use the computerized market

You will use the computer interface to buy and sell shares in this market. The main trading screen shows your current Money balance and the Number of shares you have available. **You can only buy or sell one share at a time.** Please refer to the following screenshot of the main trading screen.

To offer to SELL a share, you can use the text area entitled “Enter ask price” in the second column. All the submitted ASK prices (offers to sell shares) will be sorted from highest to lowest (worst to best). Each new ask price must improve on the existing ask prices. That is, for an ASK price to be acceptable, it must be smaller than or equal to all the available ask prices. The computer enforces this rule throughout the experiment.

When some other trader accepts your ask price, s/he buys your share at that price by highlighting it and clicking the “BUY” button.

Likewise, to BUY a share, you can use the text area entitled “Enter bid price”, on the right-most column. All the submitted BID prices (offers to buy shares) will be sorted from lowest to highest (worst to best). Each new bid price must improve on the existing bid prices. That is, for a BID price to be acceptable, it must be greater than or equal to all the available bid prices. The computer also enforces this rule.
When some other trader accepts your bid price, s/he sells you a share at that price by highlighting it and clicking the “SELL” button.

When you buy a share, your Money decreases by the purchase price. When you sell a share, your Money increases by the sales price. The prices at which trades take place are listed in the central column in chronological order.

6. Your Earnings

Your earnings for the experiment will equal the amount of money that you have at the end of period 20, after the last dividend and terminal value have been paid. The amount of money you will have is calculated as follows:

Your initial money balance

+ Dividends you receive for the shares you own

+ Money received from sales of shares

- Money spent on purchases of shares

+ Terminal value per share times the number of shares held

Your final earnings will equal your points balance converted to dollars at the rate of 750 points = 1 dollar. Your earnings will be deposited to your LionCash+ by the end of the day.

You will now play in three practice periods. Your actions in the practice period do not count towards your earnings and do not influence your position later in the experiment. The goal of the practice periods is to let you become familiar with the game interface. Please make sure that you know how to buy and sell shares before the end of the practice periods.

It is important that you do not talk or in any way try to communicate with other people during the experiment. If you violate the rules, you will be asked to leave the experiment. You are free to ask questions, by raising your hand, at any time during the experiment.
Appendix A-5: Questionnaire for the High Volatility Treatment

Questionnaire
The Pennsylvania State University
Smeal College of Business

Questionnaire
Volatility experiment – Treatment 1 (HV)

Date: ______________

Computer Number______

Academic Year (Freshman, Sophomore, Junior, Senior, Graduate) ______________

Gender (Male/Female) _________________

Age _______

Major __________________________________________

1. Were the instructions clear to you?
   Yes, very clear       Reasonably clear       Not at all clear

2. Was the game complicated to you?
   Yes                No

3. Please briefly describe your overall strategy for playing this game.

4. What do you think the price of a share should be in period 10?
5. During a trading period, what (if anything) did you learn from asks, bids or completed trades?

6. What do you think was the most important thing one would needed to do to make money in this game?

7. Was there anything in particular that you didn’t like about the design of the game?

8. Have you participated in a similar experiment before? Yes No

9. How would you rate your risk-taking attitude? Please circle the number that fits your profile.
   
   1   2   3   4   5   6   7
   Risk averse Neutral Risk-loving

10. Please circle the amount of time you were given to trade in a period?
   
   1   2   3   4   5   6   7
   Too little time Just the right amount Too much time

11. Regarding the consistency of your trading strategy during the session:
   
   a. Were your trading strategies influenced by your Money balance?
      
      Yes    No
   
   b. Did you trade more confidently in later periods?
      
      Yes    No
### Appendix A-6: Data Sources and Definitions

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<tr>
<th>Variable</th>
<th>Data Used, Period</th>
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<td>quarterly returns for MSAs in the United States</td>
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<td>Inflation</td>
<td>Consumer Price Index (for all urban consumers)</td>
<td>Bureau of Labor Statistics</td>
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<td>Growth and variance of household income for MSAs</td>
<td>Personal per capita income, 1987 - 2006</td>
<td>Bureau of Economic Analysis</td>
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<td>Transportation cost for MSAs</td>
<td>Average daily commuting speed in each MSA in 2001</td>
<td>National Household Travel Survey</td>
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<td>Agricultural land rent</td>
<td>Average returns to agricultural land</td>
<td>Census of Agriculture, United States</td>
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<td>Land leverage</td>
<td>Land’s share in the value of the house</td>
<td>Davis and Palumbo (2006) and Liu (2008)</td>
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<td>Real estate transfer taxes</td>
<td>Transfer taxes collected by states and/or counties in 2006</td>
<td>National Association of Realtors and Federation of Tax Administrators</td>
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VITA
NURIDDIN IKROMOV

EDUCATION
The Pennsylvania State University, Ph.D., Real Estate, 2009
The Pennsylvania State University, B.S. (with highest distinction), Marketing, 2001

DISSERTATION
“Three Essays on the Efficiency of Real Estate Markets “

INTERESTS
Research: Market Efficiency, Behavioral Economics, Experimental Economics, Valuation
Teaching: Real Estate Finance, Real Estate Investment, Financial Markets and Institutions,
Experimental Economics, Real Estate Development

PUBLICATION
Third International Student Conference Proceeding “Empirical Models in Social Sciences”,
295-311.

AWARDS AND HONORS
Smeal Dissertation Research Award, Penn State University, 2007
Smeal Dissertation Research Award, Penn State University, 2006
Insurance and Real Estate Department Research Grant, Penn State, 2007
Friedman Real Estate Scholarship, Penn State, 2004
Norman and Ardeth Frisbey International Student Award, Penn State, 2002
Dean’s List, Penn State University, every semester between Fall 1998 – Spring 2001

CONFERENCE PRESENTATIONS
Izmir International Conference, Izmir, Turkey, April 2007
American Real Estate and Urban Economics Association Doctoral Session, New Orleans,
January 2008
American Real Estate Society Doctoral Seminar, Captiva Island, Florida, April 2008
American Real Estate and Urban Economics Association Annual Meetings, San Francisco,
January 2009
American Real Estate Society Annual Meetings, Monterey, CA, April 2009

TEACHING EXPERIENCE
Real Estate 420: Analysis of Real Estate Markets, Penn State University, Spring 2006, Spring
2007
Real Estate 409: Real Estate Finance and Investment, Penn State University, Spring 2005
Real Estate 301: Real Estate Fundamentals, Penn State University, Summer 2003-2007