# Differentiated Assets: An Experimental Study on Bubbles[†]

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## Abstract

In this paper, we study if and how having two differentiated assets affects bubble formation. We consider differences in assets' intrinsic characteristics as well as trading regulations that help differentiate two otherwise identical assets. We find that, compared to trading regulations, differences in assets' intrinsic characteristics encourage more arbitrage across assets and thus help reduce mispricing significantly. We also find that short-term speculation does not depend on how assets or markets are being differentiated. As a result, short-term speculation cannot be used to explain why bubbles are smaller when two assets are intrinsically different than when they are not.

Classification Codes: C91; F34
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## 1. Introduction

The bubble-and-crash phenomenon in experimental asset markets, first reported in Smith, Suchanek, and Williams (1988), has been shown to be rather robust to various manipulations in the experimental design (see, for example, King et al. (1993), Van Boening et al. (1993), Porter and Smith (1995)).[1] In all these markets, an asset with a life of 15 or 30 periods is traded. The asset pays a common dividend to all holders at the end of each trading period; and the dividend structure is common knowledge to all traders. Rather than tracking the fundamental value, which is derived from the expected dividend for the number of periods remaining, prices tend to exhibit a prolonged boom and crash pattern in a vast majority of the markets studied in the literature.

Note that the bubble-and-crash phenomenon has also been observed in a setting where two assets are traded in two separate double-auction markets simultaneously. Fisher and Kelly (2000) study rate-of-return parity in such an environment. The main treatment variable that they consider is the expected dividends of the assets. In some treatments the two assets pay exactly the same expected dividend, whereas in some others one asset pays twice as much. They find that bubbles not only exist in both markets but also positively correlate with each other. Childs and Mestelman (2006) manipulate the expected dividend as well as the variance of the dividends. Their findings are consistent with Fisher and Kelly's in that bubbles occur in both markets and that rate-of-return parity receives less support as the assets become more differentiated.

[1] In addition to trading experience that has been shown to be able to consistently eliminate bubbles (see Smith et al., 1988; Van Boening et al., 1993; Dufwenberg et al., 2005; Haruvy et al. 2007), Noussair and Tucker (2006) find that the presence of a complete set of futures markets is able to facilitate backward induction and thus help eliminate bubbles in the spot market. Lei and Vesely (2009) find that a pre-market phase in which subjects passively experience the realization of a dividend stream can prevent bubbles from occurring. Lugovskyy et al. (2010) study a tâtonnement trading institution that is used to address the lack of common knowledge of rationality as well as the lack of rationality itself. They find that bubbles are significantly attenuated with the tâtonnement trading institution.

The main objective of this paper is to continue the research line initiated by Fisher and Kelly (2000) and investigate if and how differences in assets' characteristics affect investors trading strategies and, as a result, the magnitude of bubbles. Motivated by empirical evidence which suggests that bond markets are in general less susceptible to the dramatic boom-and-crash price pattern, we first construct a bond-market-like laboratory environment where investors are free to trade assets that can be differentiated not only from their dividend payments but also from their maturity periods.[2] The research questions we ask are as follows: Does the existence of multiple assets that can be differentiated from their dividends and/or maturities help reduce mispricing, and if so, why? To tackle these questions, we adopt a 2×2 design in which an asset called X has a 30-period life duration and pays, on average, 7 francs per period as a dividend. These intrinsic characteristics are fixed in all treatments. The characteristics of an alternative asset called Y, on the other hand, vary depending on the treatment. It pays either the same expected dividend as X or twice as much. In terms of its life duration, it lasts either 30 or 15 periods. As a result, we have the following four treatments for this set of the experiment: SdurSdiv (baseline), SdurDdiv, DdurSdiv, and DdurDdiv, where S, D, dur, and div stand for same, different, duration, and dividend, respectively.

If we assume that traders have common and rational expectations, we would expect prices to follow fundamental values in both markets. But since the evidence of the bubble-and-crash phenomenon is so overwhelming in the literature, we feel that evaluating a hypothesis of no bubbles is a bit insensitive. Instead, we propose the following hypothesis for evaluation.

[2] See, for example, Johnson and Young (2002), Young and Johnson (2004), and Jones and Wilson (2004) for bond market volatility vs. stock market volatility.

**Hypothesis 1:** *Price deviations from the fundamental in either X or Y market do not depend on if and how the two assets are intrinsically different.*

We also evaluate the relative price between the two assets against the prediction of rate-of-return parity as in Fisher and Kelly (2000) and Childs and Mestelman (2006). The null hypothesis that we advance for evaluation is stated as follows.

**Hypothesis 2:** *Deviations from the prediction of rate-of-return parity do not depend on if and how the two assets are intrinsically different.*

In addition to studying if and how differences in assets' intrinsic characteristics affect the bubble formation, we also design a second set of the experiment to investigate if and how policies or regulations that help differentiate two otherwise identical assets affect the intensity of bubbles. The first regulation that we consider is a securities transaction tax. Note that a securities transaction tax (STT) or a Tobin tax has long been considered by some as a policy tool to curb short-term speculation, reduce volatility, and improve market efficiency in stock or foreign exchange markets (see, for example, Tobin, 1984; Stiglitz, 1989; Summers and Summers, 1989; Palley, 1999).[3] But this policy instrument has never received that much attention or any serious support until recently. In the wake of the current economic crisis, the European Union has

[3] Skeptics, on the other hand, argue that the adverse effects of a STT on market liquidity may well destabilize the market rather than stabilize it. For instance, Kupiec (1995) argues that a STT that reduces a taxed asset's liquidity may increase investors' required rate of return and thus make it difficult to mitigate the degree of mispricing. Schwert and Sequin (1993) note that, since a STT affects noise and fundamental traders indiscriminately, it is not clear if the tax would have a greater impact on noise traders. There are also concerns over the coverage or the enforcement of a STT. Campbell and Froot (1994) argue that a STT would encourage traders to shift trading from the taxed asset to its untaxed close substitutes or from the domestic market to offshore ones. The migration from one market to another, according to Westerhoff and Dieci (2006), generates an ambiguous impact on the markets as a whole. Empirical studies undertaken so far have yet been able to produce much convincing evidence to suggest that STTs can help reduce market volatility in either stock or foreign exchange markets (see, for example, Roll, 1989; Umlauf, 1993; Dooley, 1996; Hu, 1998; Aliber et al., 2003).

proposed a financial transaction tax on trading of stocks, bonds and derivative contracts.[4] While this proposal has received full support from France and Germany, primarily for revenue-raising and other political reasons, the UK, home to the biggest financial center in Europe, has vigorously opposed to it. Without a global agreement, as it argues, an EU-wide transaction tax would easily chase transactions elsewhere and thus could hardly serve as an effective revenue-raising or even a market-stabilizing tool.

Whether or not a regional transaction tax can be an effective revenue-raising tool is not within the scope of this study. Instead, we are more interested in the effectiveness of its traditional aims, namely, to discourage speculative trading and to improve market efficiency. The research questions we ask are as follows: Given that transactions are free to move from one market to another, would a transaction tax imposed on one asset cause transactions to migrate to its untaxed substitute? How does such a tax affect asset prices? Does it help reduce mispricing at least in the taxed market? To answer these question, we introduce a treatment, called Taxy, where the intrinsic characteristics of X and Y are exactly the same as in the baseline SdurSdiv treatment. A fixed transaction tax that is about 0.5% of the initial fundamental value is imposed on asset Y. Note that our paper is not the first study to investigate the effects of transaction fees or STTs on bubble magnitude or market volatility. King et al. (1993) find that a fixed transaction fee has mixed effects on the intensity of bubbles. Bloomfield et al. (2009) find that a STT discourages informed traders' activity as much as it does to the uninformed. As a result, the tax has no significant impact on pricing errors or market efficiency. Both King et al. and Bloomfield et al. investigate the effects of STTs in a single-market environment and thus cannot address issues concerning trading migration from a taxed asset to its untaxed substitutes. Hanke et al.

[4] The text published by the European Commission on September 28, 2011 proposes a tax of 0.1% on trading of stocks and bonds and a tax of 0.01% on all derivatives transactions.

(2010) is the only study that introduces a STT in a two-market setting. In a treatment where only one asset is subject to the transaction tax, Hanke et al. observe a significant amount of trading being shifted to the untaxed market and that market efficiency decreases dramatically in the taxed one. Our Taxy treatment differs from Hanke et al. in the following ways. First, assets' fundamental values in Hanke et al. follow a random walk without drift, implying that, in any given period, future fundamental values are not known to subjects. In our study, fundamental values follow a downward trend that is constructed in the same way as in Smith et al. (1988). Also as in Smith et al., both current and future fundamental values are common knowledge to all traders. Therefore, we believe that our study is much simpler and more comparable to the literature pioneered by Smith et al.. Second, while Hanke et al. use a tax rate of 0.5%, we choose a fixed transaction fee in order to further simplify our environment.

The second regulation we consider in this set of the experiment is a minimum holding period requirement. Other than more market-based transaction taxes, direct restrictions on capital mobility have been adopted in various forms by numerous countries to fight asset bubbles and currency appreciation.[5] To deal with surges in capital inflows, Indonesia is one of the most recent examples to implement control measures including a one- or six-month minimum holding period on certain securities. In a treatment called Holdy, we consider a policy tool similar to this rather straightforward intervention to see if such a capital control can help mitigate bubbles. Specifically, we introduce a minimum holding period of 5 that is imposed only on asset Y. To our knowledge, the only experimental study that has investigated the impact of a similar trading restriction, though for a completely different purpose, is Lei et al. (2001). To investigate if speculation is necessary to create bubbles, Lei et al. remove subjects' ability to speculate by

[5] See Ariyoshi et al. (2000) and Ostry et al. (2010) for summaries of capital controls that have been adopted since 1990s.

imposing a ban on reselling any shares acquired earlier in the experiment. They find that the ban on the reselling is not able to moderate the magnitude of bubbles unless a commodity market is also operated alongside. Note that the purpose of introducing a commodity market in Lei et al. is to simply divert excess trade that is thought to be related to decision errors in the asset market. As such, the commodity market is operated with a simple one-period supply and demand structure repeated under stationary conditions. Their laboratory environment is thus dramatically different from ours in that we have two markets operated simultaneously for trading assets that are perfect substitutes in terms of their fundamental values.

Regarding the impact of the two trading regulations on the magnitude of bubbles, we propose the following hypothesis for evaluation.

> **Hypothesis 3:** *Price deviations from the fundamental in either X or Y market of the Taxy and Holdy treatments do not differ significantly from those in the baseline SdurSdiv treatment*.

Also, since X and Y are perfect substitutes in the treatments of Taxy and Holdy, we expect that, as a response to the transaction tax or the holding period requirement imposed on asset Y, a significant amount of transactions will be shifted to market X.

> **Hypothesis 4:** *The turnover in market X (Y) is significantly higher (lower) in the Taxy and Holdy treatments than in the baseline SdurSdiv treatment.*

Finally, since Fisher and Kelly (2000) and Childs and Mestelman (2006) find that rate-of-return parity is supported when assets share the same intrinsic characteristics, we expect that deviations from the prediction of rate-of-return parity in the Taxy and Holdy treatments do not differ significantly from those in the baseline treatment.

> **Hypothesis 5:** *Deviations from the prediction of rate-of-return parity in either X or Y market of the Taxy and Holdy treatments do not differ significantly from those in the baseline SdurSdiv treatments*.

As reported in detail in Section 3, the price patterns of both assets in the baseline treatment exhibit the same bubble-and-crash phenomenon as observed in the literature. The two bubbles coincide with one another in most of the SdurSdiv sessions, which is consistent with the results reported by Fisher and Kelly (2000) and Childs and Mestelman (2006). In the other three treatments where X and Y have different intrinsic characteristics, the deviations from fundamental values are significantly smaller than in the baseline treatment. Note that this difference in the overall price pattern cannot be explained by the liquidity levels in the four treatments. Liquidity, defined as the total cash endowment divided by the initial value of all shares, has been shown to be positively correlated with asset bubbles (see, for example, Caginalp et al. (2001)). The liquidity level in, for example, DdurSdiv is much larger than that in SdurSdiv. Yet, prices in most of the DdurSdiv sessions tend to track fundamental values rather well.

While Hypothesis 1 is refuted by our data, the deviations from rate-of-return parity in SdurDdiv, DdurSdiv, and DdurDdiv are not statistically different from those in the baseline treatment, which is consistent with Hypothesis 2.

The results from Taxy reported in Section 4 indicate that, compared to the baseline treatment, the transaction tax imposed on asset Y has no significant impact on the trading volume in either market. The holding period requirement, on the other hand, significantly reduces asset

Y's turnover. Asset X's turnover remains statistically the same as in the baseline treatment. We also find that neither trading regulation is effective in reducing bubbles and that, consistent with the finding in the baseline treatment, the X and Y bubbles are almost identical in both Taxy and Holdy treatments. In sum, we find evidence that fully supports Hypotheses 3 and 5 but not Hypothesis 4.

To explain why bubbles are significantly smaller in the SdurDdiv, DdurSdiv, and DdurDdiv treatments, we decompose traders' trading activities within a given period into various categories through which the frequencies of arbitrage and short-term speculation can be constructed. We find that having two intrinsically differentiated assets tend to generate more arbitrage across assets and, as a result, reduce the magnitude of bubbles. The frequency of short-term speculation, on the other hand, does not depend on if and how assets or markets are being differentiated. Its correlation with the bubble amplitude is positive yet insignificant. Overall, our results highlight the role of arbitrage in improving market efficiency.

The rest of our paper is organized as follows. Section 2 describes the experimental design and procedures. Sections 3, 4 and 5 report the results. Section 6 concludes the paper.

## 2. The Experiment

The experiment consisted of twenty-two sessions conducted at a large state university between May 2007 and June 2009. A total of 215 subjects were recruited from City University of Hong Kong via email. Some of the subjects may have participated in economics experiments before, but none had any experience in experiments similar to ours. No subject participated in more than one session of this study. On average, sessions lasted three hours including software training, initial instruction period and payment of subjects. The experiment was programmed using the Ztree software package (Fischbacher, 2007). Trade was denominated in an experimental currency, called "francs", which was converted to Hong Kong dollars at a predetermined and publicly known conversion rate. Including a participation fee of HK$20, subjects earned an average of HK$186 (roughly US$24).[6]

There were 30 trading periods in each of the twenty-two sessions, and each period lasted 3 minutes. At the beginning of period 1, subjects were endowed with 5 units of an asset called X, 5 units of another asset called Y, and 10,000 francs of working capital. In each period, there were two markets open side-by-side for trading X and Y. Subjects were free to trade in either or both markets, one unit per transaction, using continuous double auction rules. Inventories of X and Y were carried over from one period to the next until the end of their lives. The cash balance, on the other hand, was carried over from period to period all the way to period 30.[7]

To study the impact of differences in assets' intrinsic characteristics on bubbles and crashes, we adopted a 2×2 design in which the two treatment variables were asset Y's maturity and expected dividend per period. More specifically, there were four treatments depending on whether or not assets X and Y had the same life duration and/or expected dividend per period. The characteristics of asset X described in the following were fixed across all four treatments. First, it had a life of 30 periods. Second, it paid a dividend that was drawn from a distribution of (2, 4, 6, 8, 10, 12), each with equal probability, at the end of each trading period. In other words, X's expected dividend was fixed at 7 francs per period. Asset Y, depending on the treatment, had a life of either 15 or 30 periods. In the treatments where asset Y lasted only 15 periods, each subject was given 5 units of Y at the beginning of period 1 and, after they expired and became useless, another 5 units at the beginning of period 16. This procedure was done so that the total

[6] Back in 2007, workers at fast food chains in Hong Kong earned an average hourly rate that was less than US$3.00.
[7] Dividend earnings were not included in the cash balance for making transactions.

stock of units remained constant in all periods.[8] Depending on the treatment, asset's Y's dividend payment was drawn either from (2, 4, 6, 8, 10, 12) or from (4, 8, 12, 16, 20, 24). As a result, in two of the four treatments, asset Y's expected dividend per period was the same as asset X's; whereas in two others, it was twice as much. The random draw for asset Y at the end of each period was independent from that for asset X. Asset X's and Y's dividend distribution and expected dividend per period were public information among traders. Tables that described X's and Y's expected dividend streams and thus their fundamental values in any given period were also provided to subjects. The expected dividend stream of asset X at the beginning of period $t$ equaled $7*(31-t)$, where $(31-t)$ was the number of periods remaining before X expired. The expected dividend stream of asset Y was calculated in a similar fashion. Summary information for each of the four treatments—SdurSdiv, SdurDdiv, DdurSdiv, and DdurDdiv—is given in Table 1.

[Table 1: About Here]

Of the four treatments described above, we considered the one in which X and Y were identical (SdurSdiv) as our benchmark. With this benchmark treatment, we conducted two follow-up treatments in which differences between X and Y came from institutional regulations. In the treatment called Taxy, we introduced a securities transaction tax of 2 francs, equivalent to 29% of the expected per period dividend, on asset Y (1 franc each on the buyer and seller in every trade). In the treatment called Holdy, we imposed a minimum holding period requirement on asset Y in that traders were required to hold asset Y for at least 5 consecutive periods from the time they acquired it on the market. In other words, if someone, for instance, purchased three

[8] In the instructions, we called the units of Y whose lives started from period 1 and ended at the end of period 15 asset Y1, and those units whose lives started from period 16 and ended at the end of period 30 asset Y16. Subjects were reminded that there was no difference between Y1 and Y16 except that Y1's life started from period 1 and Y16's life started from period 16.

units of Y in period 7, he would not be allowed to sell any of these three units until period 12 or later. The holding period requirement did not apply to the initial endowment which was not acquired through the market. Summary information regarding Taxy and Holdy is also provided in Table 1.

## 3. Results for Differences in Assets' Intrinsic Characteristics

The left-hand panels of Figure 1 provide the time series of median transaction prices in all four sessions of the benchmark SdurSdiv treatment. In each of these panels, the closed squares/triangles connected with a black/gray solid line represent the median transaction prices of X/Y; whereas the line without any symbols represents the time series of the fundamental values.[9] It is clear that asset X's and asset Y's prices are highly correlated and, more importantly, they both follow the robust bubble-and-crash pattern. For instance, in session SdurSdiv1, both assets' prices start a bit higher than the fundamental value and stay high until they finally collapse in period 17. In session SdurSdiv2, X's median period price gradually escalates until period 27 when a sudden crash finally occurs. A similar pattern is also observed for asset Y. These observations are consistent with the results reported by Fisher and Kelly (2000) and Childs and Mestelman (2006) in that rate-of-return parity is supported between two identical dividend-paying assets, but not between the assets and currency.

[Figure 1: About Here]

The time series of median transaction prices in the SdurDdiv sessions are shown in Figure 2. Bubbles occur in sessions SdurDdiv1 and 2. Price deviations of asset Y appear to be much larger than those of asset X in SdurDdiv1. As a consequence, the relative price ratio

[9] In Figure 1 and all subsequent figures in the paper, an open square or triangle indicates that no transaction took place during that period, and the value indicated as the median price is the midpoint between the final bid-offer spread.

between X and Y in this treatment does not conform to rate-of-return parity as closely as that in the SdurSdiv treatment.

[Figure 2: About Here]

The left-hand panels of Figure 3 provide the time series of median transaction prices in treatment DdurSdiv. Note that, since asset X pays the same expected per-period dividend but lasts twice as long as asset Y, rate-of-return parity predicts that the price ratio between X and Y will be $(31-t)/(16-t)$ between periods 1 and 15 but 1 between periods 16 and 30. This prediction appears to be supported in sessions DdurSdiv1, 3, and 4, mainly because the robust bubble-and-crash phenomenon, surprisingly, does not manage to emerge in these three sessions. Price deviations from the fundamental, on the other hand, exist for both assets in the first half of session DdurSdiv2. Nevertheless, they tend to be much smaller in size compared to those in the benchmark treatment.

[Figure 3: About Here]

The time series of median transaction prices in the three DdurDdiv sessions are given in Figure 4. Although bubbles are observed in all three sessions, their magnitudes are considerably smaller than those in the benchmark SdurSdiv. On the other hand, compared to the benchmark treatment, price patterns shown in Figure 4, especially in sessions DdurDdiv1 and 2, provide weaker support for rate-of-return parity which predicts that the price ratio between X and Y will be $(31-t)/2(16-t)$ and 0.5 in the first and second halves of the experiment, respectively.

[Figure 4: About Here]

Finally, we provide trading volumes in the right-hand panels of Figures 1-4. More asset X than asset Y was traded in the benchmark SdurSdiv treatment.[10] This trading pattern, however, disappeared in the rest of the three treatments.

### 3.1 Treatment Effects on Price Deviation and Turnover

Table 2 provides the statistical summary of bubble measures that are either the same as or similar to those used in previous studies.[11] The *Price Amplitude* of a bubble, first reported by King et al. (1993), is defined as the difference between the peak and the trough of average price deviations over the life of the asset: $\max_t\{(P_t - f_t)/f_1\} - \min_t\{(P_t - f_t)/f_1\}$, where $P_t$ and $f_t$ are the median transaction price and the fundamental value in period *t*, respectively. In other words, the *Price Amplitude* measures the extent to which prices swing around fundamental values. We also report the *Normalized Average Bias* modified from the average bias reported by Haruvy and Noussair (2006). Specifically, to take into account of various fundamental patterns that are resulted from different maturity and/or different dividend payments, we define the *Normalized Average Bias* as the average deviation of period median price from the period fundamental over the asset's life duration *T*, normalized by the initial fundamental value: $\frac{\sum_t (P_t - f_t)}{T} \Big/ f_1$.[12] A *Normalized Average Bias* close to zero indicates that, on average, prices tend to stay rather close to fundamental values, whereas a large and positive *Normalized Average Bias* implies that prices exhibit a tendency to stay far above fundamental values. For the same reason described above,

[10] Since asset X was displayed on the left side of the screen in our experiment, this result is consistent with the observation in Hanke et al. (2010) in that most trading took place in the Left market than in the Right market even though both assets were exactly identical.

[11] See, for example, King et al. (1993), Van Boening et al. (1993), Porter and Smith (1995), Noussair et al. (2001), and Haruvy and Noussair (2006).

[12] In Haruvy and Noussair (2006), the average bias is defined as $\sum_t (P_t - f_t)/T$, where *T* denotes asset's life duration.

our third bubble measure *Normalized Average Deviation* is defined as the sum of all absolute price deviations that is adjusted with the asset's total stock of units, life duration, and the initial fundamental value: *Normalized Average Deviation* = $\frac{\sum_t \sum_i |p_{it} - f_t|}{f_1} \Big/ (T \times TSU)$, where $p_{it}$ denotes each transaction price *i* in period *t* and *TSU* is the total stock of units.[13] Since this measure takes not only (absolute) price deviations but also trading volumes into consideration, it has been considered as the most comprehensive bubble measure in the literature. Finally, we average the turnover over the entire course of the asset's lifetime: *Average Turnover* = $\sum_t q_t / (T \times TSU)$, where $q_t$ is the number of transactions in period *t*.

[Table 2: About Here]

The results reported in Table 2 roughly confirm the discussion described above. The price amplitude, normalized average bias, and normalized average deviation of both asset X and asset Y1 (asset Y whose life started from period 1) are, generally speaking, the largest in SdurSdiv and the smallest in treatment DdurSdiv.[14] In those sessions where asset Y had a life of only 15 periods, the bubble measures in market Y16 are smaller than those in market Y1. Taking each session as an independent observation, matched-pairs signed-rank tests suggest that the difference between Y1 and Y16 is significant in terms of their normalized average biases but not in terms of their price amplitudes or normalized average deviations.[15] These results partially support the finding by, for example, Smith et al. (1988) and King et al. (1993) that bubble

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[13] The normalized deviation reported in previous studies is defined as $\sum_t \sum_i |p_{it} - f_t| / TSU$ .

[14] The average size of bubbles in our baseline treatment SdurSdiv is comparable to those in most of the previous studies where only one asset was traded. For example, the price amplitudes are, on average, 1.24 in Smith et al. (1988), 1.87 in the equal-endowment treatment of King et al. (1993), 4.19 in Van Boening et al. (1993), 1.53 in the baseline treatment of Porter and Smith (1995), 1.21 in the baseline treatment of Porter and Smith (2003), 2.61 in the baseline treatment of Haruvy and Noussair (2006), and 8.83 in Market 1 of Haruvy et al. (2007). The price amplitudes in our X and Y markets are 1.44 and 1.37, respectively.

[15] The insignificant results about Y1's and Y16's price amplitudes and normalized average deviations might be partially due to the fact that there are only 7 observations available for the signed-rank tests here.

measures decline with experience. But note that, in Smith et al. and King et al., bubbles became smaller only after subjects had participated in the same environment with the same group of people at least once. The environment facing our subjects in the second half of the DdurSdiv and DdurDdiv sessions was not entirely the same as the first half due to the characteristics of asset X. Therefore, it is understandable that the impact of experience found in this study is not as strong as that in previous studies. Finally, in terms of quantities traded, SdurSdiv and SdurDdiv have the highest and lowest average turnover, respectively, among the four treatments.

Given that cross-sectional and time-series variation in the data is not controlled for, it is perhaps premature to assign much significance to the results reported in Table 2. In the following analysis, we adopt a population-averaged panel data linear regression model, where robust standard errors are adjusted for first-order autocorrelation and within-session correlation, to investigate the treatment effects on price deviations $\left|P_t^i - f_t^i\right| / f_1^i$ and turnover $q_t^i / TSU^i$, where $i$ = X or Y. Note that, since asset Y had a shorter maturity in DdurSdiv and DdurDdiv than in SdurSdiv and SdurDdiv, we employ data only from periods 1 to 15 whenever asset Y is involved in the regression. Results given in Table 3 include time period $t$ and dummy variables Ddiv and Ddur that equal 1 if assets differ in their dividend structure and maturity, respectively. An interaction term between Ddiv and Ddur is also included.

[Table 3: About Here]

**RESULT 1:** *Price deviations are the largest when both assets share exactly the same intrinsic characteristics (baseline SDurSdiv). Introducing differences in assets' maturity period, dividend structure or both (treatments SdurDdiv, DdurSdiv, and DdurDdiv) significantly reduces price deviations for both assets.*

**SUPPORT FOR RESULT 1:** The estimates shown in column (1) of Table 3 imply that, compared to the baseline treatment (SdurSdiv), having an alternative asset that has the same maturity but pays a double expected dividend (SdurDdiv) reduces X's price deviations by an average of 27.29% per period. Asset X's price deviations are on average 33.22% smaller than in the baseline treatment when Y pays the same expected dividend but has a shorter life duration (DdurSdiv). The treatment effect of having an alternative asset Y that differs not only in its maturity but also in its expected dividend payment (DdurDdiv) is –27.29 – 33.22 + 30.28 = –30.23%, which is significantly different from zero ($\chi^2$ = 11.01, *p*-value = 0.0035). The estimates reported in column (3) suggest that, compared to the baseline treatment, asset Y's price deviations between periods 1 and 15 are on average 21.71%, 29.94%, and 28.81% ($\chi^2$ = 37.44, *p*-value = 0.0000) smaller in SdurDdiv, DdurSdiv and DdurDdiv, respectively. Finally, we test if the hypothesis that SdurDdiv, DdurSdiv, and DdurDdiv generate the same treatment effects and yield *p*-values of 0.2418 and 0.6352 for assets X and asset Y. ■

In terms of the trading volume, the results reported in the last column of Table 2 suggest that asset X's average per-period turnover rate is slightly higher in the baseline SdurSdiv than in all three treatments.[16] The average turnover rate of asset Y, on the other hand, does not appear to vary significantly across different treatments. In the following, we again turn to the population-averaged panel data linear regression model as described above to investigate the treatment effects on assets' turnover rates.

[16] The turnover rates in the X and Y markets of our baseline SdurSdiv treatment are 0.26 and 0.18, which are slightly smaller than in most of the previous studies where there exists only one asset for people to trade. Specifically, after adjusted for assets' life durations, the average per-period turnover rate is 0.33 in Smith et al. (1988), 0.42 in the equal-endowment treatment of King et al. (1993), 0.34 in Van Boening et al. (1993), 0.37 in the baseline treatment of Porter and Smith (1995), 0.39 in the baseline treatment of Porter and Smith (2003), 0.81 in the baseline treatment of Haruvy and Noussair (2006), and 0.15 in Market 1 of Haruvy et al. (2007).

**RESULT 2:** *Assets' turnovers are mostly unaffected by the differences between the two assets.*

**SUPPORT FOR RESULT 2:** The estimates shown in columns (2) of Table 3 indicate that, after cross-sectional and time-series variations in the data are controlled for, asset X's turnover is 16.60% lower in SdurDdiv than in the baseline SdurSdiv. Neither of the two other treatments has any significant impact on the turnovers.[17] Having said that, the hypothesis that SdurDdiv, DdurSdiv, and DdurDdiv have the same treatment effects cannot be rejected by our data ($p$-value = 0.2851). Asset Y's turnover is statistically the same across all treatments. ■

### 3.2 Treatment Effects on the Deviation from Rate-of-Return Parity

In this section, we investigate the treatment effects on the deviation from the prediction of rate-of-return parity $\left|(P_t^X / P_t^Y) - (P^X / P^Y)*\right|$. Again, to avoid the possibility that the treatment effects are confounded by different experience levels in trading asset Y during the second half of the experiment, only the first 15 periods' data are used here. The summary statistics of the absolute deviation during these 15 periods are reported in column (1) of Table 4. In the following, we turn to the same regression model that takes the cross-sectional and time-series variation in the data into consideration. The results are reported in Table 5.

[Tables 4 and 5: About Here]

**RESULT 3:** *Deviations from rate-of-return parity are not affected by if and how the two assets are intrinsically different.*

[17] The estimates reported in column (2) suggest that, compared to the baseline treatment, asset X's turnover in DdurDdiv is about –11.40% lower. This estimate is nonetheless insignificant ($\chi^2$ = 1.44, $p$-value = 0.2299).

**SUPPORT FOR RESULT 3:** The estimates shown in column (1) of Table 5 indicate that the absolute deviations from rate-of-return parity in SdurDdiv are on average 0.69% smaller than in the baseline SdurSdiv treatment. The absolute deviations in DdurSdiv and DdurDdiv are, on the other hand, 5.04% and 13.95% (= −0.69 + 5.04 + 9.60) larger than in the baseline treatment. None of the estimates is statistically significant, suggesting that Hypothesis 2 is supported by our data. ■

## 4. Results for Differences in Institutional Regulations

Figures 5 and 6 provide the time series of median transaction prices and trading volumes in treatments Taxy and Holdy, respectively. Recall that, in terms of their intrinsic characteristics, X and Y were exactly the same assets in these two treatments. Nevertheless, the trading regulations imposed on Y—a transaction tax in Taxy and a minimum holding period requirement in Holdy—made Y a more “restricted” asset than X. Therefore, it is not surprising to see from Figures 5 and 6 that less Y was traded than X in the market. But note that subjects in the benchmark SdurSdiv treatment also tended to trade more asset X than asset Y. So, it is not obvious if the transaction tax or the minimum holding duration requirement did influence Y’s trading in any significant way. In fact, the regression analysis reported in section 4.1 below indicates that only the latter has a significant impact on asset Y’s turnover. Bubbles, comparable to those in SdurSdiv in their sizes, occurred in all sessions of the two treatments. Also, like in SdurSdiv, prices of the two assets appear to be perfectly correlated. Therefore, the overall impression we have from these two treatments is that the trading regulations imposed in our study are not strong enough to make investors price the two intrinsically the same assets differently.

[Figures 5 and 6: About Here]

### 4.1 Treatment Effects on Price Amplitude and Turnover

The price amplitude, normalized average bias, normalized average deviation, and turnover of X and Y in Taxy and Holdy, shown in Table 2, are only slightly smaller than those in SdurSdiv. And if we compare the bubble measures between X and Y within the same treatment, it is clear that trading restrictions generate almost the same behavioral pattern as in the baseline treatment. That is, asset Y's price amplitude and normalized average bias are not much different from asset X's. Also, as in the baseline, the average normalized deviation of Y is much smaller than that of X. This result is mostly due to the fact that asset Y's turnover is, on average, 40%-50% lower than asset X's.

In the following, we utilize the above panel data approach to investigate if a transaction tax or a minimum holding period requirement imposed on one asset has any influence on the price amplitude and turnover of either asset. The regression results are reported in Table 6.

[Table 6: About Here]

**RESULT 4:** *The transaction tax or the minimum holding period requirement imposed on asset Y has no significant impact on either asset's price deviations.*

**SUPPORT FOR RESULT 4:** The estimates shown in columns (1) and (3) of Table 6 indicate that, compared to the baseline SdurSdiv treatment, the transaction tax and the holding period requirement has a negative impact on the sizes of bubbles. For example, compared to the baseline treatment, the transaction tax reduces X's and Y's price deviations by an average of 17.33% and 14.89%. The minimum holding period requirement has a very similar effect as the transaction tax. None of these reductions, however, is statistically significant. ■

**RESULT 5:** *The transaction tax or the minimum holding period requirement imposed on asset Y has no significant impact on asset X's turnover. Asset Y's turnover is significantly lower when the minimum holding period requirement is in effect.*

**SUPPORT FOR RESULT 5:** Asset X's turnover, shown in column (2) Table 6, is on average 3.99% and 8.82% lower in Taxy and Holdy, respectively, than in the baseline SdurSdiv treatment. Neither estimate is significantly different from zero. While the transaction tax continues to have no significant effect on Asset Y's turnover, the minimum holding period requirement reduces Y's turnover by a significant amount of 8.76%. ■

4.2 Treatment Effects on the Absolute Deviation from Rate-of-Return Parity

Column (2) of Table 4 reports the mean absolute deviation of $P_t^X / P_t^Y$ from the predication of rate-of-return parity in Taxy and Holdy. The same statistical summary from the baseline SdurSdiv treatment is also provided for direct comparisons. Also, since both assets have the same life duration of 30 periods in all three treatments, we employ the data from all periods when computing the averages. The mean absolute deviations from rate-of-return parity in Taxy and Holdy are about 8.95% and 12.72% per period, which do not appear to be much different from 10.59% in the baseline SdurSdiv treatment. Regression results summarized below provide further support to this observation.

**RESULT 6:** *The transaction tax or the minimum holding duration imposed on asset Y has no significant impact on the deviation of $P_t^X / P_t^Y$ from the prediction of rate-of-return parity.*

**SUPPORT FOR RESULT 6:** The estimate of the dummy variable Taxy in column (2) of Table 5 is −1.60, implying that the absolute deviation of $P_t^X / P_t^Y$ from rate-of-return parity is on average 1.60% smaller than that in the baseline treatment. Similarly, the estimate of Holdy is 1.71, indicating that, compared to the baseline treatment, the deviation is 1.71% larger. Neither estimate is statistically significant. ■

## 5. Arbitrage vs. Speculation

In this section, we investigate why bubbles are significantly smaller when two assets are intrinsically different than when they are not. We extend the concept used to construct a measure for short-term speculation by Hanke et al. (2010) and decompose each trader's whole trading sequence in any given period into the following four types: same-offer/same-market, opposite-offer/same-market, same-offer/different-market, and opposite-offer/different-market. "Same-offer/same-market" means that two back-to-back purchases or back-to-back sales are being executed in the same market, whereas "opposite-offer/same-market" means that a purchase is followed by a sale (or vice versa) in the same market.[18] "Same-offer/different-market" and "opposite-offer/different-market" are defined similarly except that the two subsequent trades are placed in different markets. Therefore, for a trader who has a trading sequence of buy X → buy X → sell X → sell Y → buy Y, he is said to make one same-offer/same-market (buy X → buy X), two opposite-offer/same-market (buy X → sell X and sell Y → buy Y), and one same-offer/different-market (sell X → sell Y) types of trades. As a result, we can assign 1 to same-offer/same-market, 2 to opposite-offer/same-market, 1 to same-offer/different-market, and 0 to opposite offer/different market as the frequencies of all four types of trading activity for this particular trader. We then compute the relative frequency of type *i* trading activity across all traders and all times periods for each session. Table 7 provides these frequencies by treatment. It indicates that, for example, in the baseline SdurSdiv treatment, the probability that two adjacent

[18] The term "offer" here concerns only the direction of a transaction (buy or sell).

trades occur in two different markets is, on average, 48% (= 33 + 15). Furthermore, given that one switches to a different market to trade, the probability that he will place an offer opposite to the previous one is about 31% (= 15/48).

[Table 7: About Here]

While it is almost impossible to verify the motive behind each single trade from the data, it is perhaps not unreasonable to assume that a sale immediately following a purchase (or vice versa) in a different market is more an act of arbitrage across assets. In the following, we define the frequency of arbitrage across assets as the probability that two adjacent trades are of opposite offers, conditional on that they take place in different markets and that the price/fundamental ratio of the asset being sold is greater than the price/fundamental ratio of the asset being purchased. This measure is reported in the third column from the right in Table 7.

**RESULT 6:** *The existence of two intrinsically differentiated assets encourages more arbitrage conducted across markets and thus helps reduce the magnitude of bubbles.*

**SUPPORT FOR RESULT 6:** Taking each session as an independent observation, a non-parametric Mann-Whitney ranksum test rejects the hypothesis that the frequency of arbitrage across assets is independent of the assets being intrinsically different or not ($p$-value = 0.0007). In other words, the existence of two intrinsically differentiated assets does encourage traders to exploit mispricing across markets more frequently. To see if arbitrage helps reduce mispricing, we calculate the non-parametric Spearman rank correlation between the amplitudes of the two assets and the frequency of arbitrage across assets. The coefficient is –0.6402 ($p$-value = 0.0013) for asset X and –0.5871 ($p$-value = 0.0041) for asset Y, suggesting that the more frequently traders conduct arbitrage, the smaller bubbles are.[19] ■

[19] For the treatments in which asset Y lasts 15 periods, we use the amplitude of asset Y from the first half of the experiment where mispricing is more prominent. This is done to also avoid the impact of learning effects.

For the measure of speculation, we follow Hanke et al. (2010) and consider, for example, a sale immediately following a purchase (or vice versa) within a given market as an act of short-term speculation. As a result, we define the frequency of short-term speculation in a given market as the probability that two adjacent trades are of opposite offers, conditional on the probability that they are executed in the same market. This measure is reported in the last two columns of Table 7.

**RESULT 7:** *The frequency of short-term speculation is independent of whether or not assets are intrinsically different. As a result, the frequency of short-term speculation does not explain why bubbles are smaller when two assets are intrinsically different than when they are not*.

**SUPPORT FOR RESULT 7:** Taking each session as an independent observation, a non-parametric Mann-Whitney ranksum test cannot reject the hypothesis that the frequency of short-term speculation in either market is independent of the assets being intrinsically different or not ($p$-value = 0.2334 and 0.9474 for X and Y, respectively). The Spearman rank correlation coefficient between the bubble amplitude and the frequency of short-term speculation is 0.2562 for market X and 0.2560 for market Y. Neither coefficient is statistically significant ($p$-value = 0.2497 and 0.2502 for X and Y, respectively). ■

## 6. Conclusion

In this paper, we study if and how having two differentiated assets affects bubble formation. We consider differentiation that is caused by assets' intrinsic characteristics including their life durations and expected per period dividends. We also consider trading regulations such as a transaction tax and a minimum holding period requirement that have been considered by some as policy tools that would curb speculation and reduce asset mispricing. We impose these trading regulations only on one of the two markets to help differentiate two otherwise identical assets. We find that, compared to trading regulations, differences in assets' intrinsic characteristics tend to encourage more arbitrage across assets and thus help reduce mispricing significantly. We also find that short-term speculation does not depend on how assets or markets are being differentiated, and that the correlation between short-term speculation and the bubble amplitude is statistically insignificant. In other words, the smaller bubbles that we observe in treatments SdurDdiv, DdurSdiv, and DdurDdiv are more likely to be the consequence of more arbitrage, not less speculation. Overall, our results highlight the significance of arbitrage in mitigating bubbles.

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**Table 1: Summary of Treatments and Sessions**

| Treatment | Session | # of Subjects | Expected Dividend | | Life Duration | | Trans-action Tax | | Holding Period | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | X | Y | X | Y | X | Y | X | Y |
| SdurSdiv (*baseline*) | SdurSdiv1 | 10 | 7 | 7 | 30 | 30 | | | | |
| | SdurSdiv2 | 9 | | | | | | | | |
| | SdurSdiv3 | 10 | | | | | | | | |
| | SdurSdiv4 | 10 | | | | | | | | |
| SdurDdiv | SdurDdiv1 | 9 | 7 | 14 | 30 | 30 | | | | |
| | SdurDdiv2 | 10 | | | | | | | | |
| | SdurDdiv3 | 10 | | | | | | | | |
| DdurSdiv | DdurSdiv1 | 10 | 7 | 7 | 30 | 15 | | | | |
| | DdurSdiv2 | 10 | | | | | | | | |
| | DdurSdiv3 | 9 | | | | | | | | |
| | DdurSdiv4 | 10 | | | | | | | | |
| DdurDdiv | DdurDdiv1 | 10 | 7 | 14 | 30 | 15 | | | | |
| | DdurDdiv2 | 9 | | | | | | | | |
| | DdurDdiv3 | 10 | | | | | | | | |
| Taxy | Taxy1 | 10 | 7 | 7 | 30 | 30 | | √ | | |
| | Taxy2 | 9 | | | | | | | | |
| | Taxy3 | 10 | | | | | | | | |
| | Taxy4 | 10 | | | | | | | | |
| Holdy | Holdy1 | 10 | 7 | 7 | 30 | 30 | | | | √ |
| | Holdy2 | 10 | | | | | | | | |
| | Holdy3 | 10 | | | | | | | | |
| | Holdy4 | 10 | | | | | | | | |

**Table 2: Observed Bubble Measures in All Treatments**

| Treatment | Amplitude | | | Normalized Average Bias | | | Normalized Average Deviation | | | Average Turnover | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | X | Y1 | Y16 | X | Y1 | Y16 | X | Y1 | Y16 | X | Y1 | Y16 |
| SdurSdiv | 1.44 | 1.37 | | 0.48 | 0.42 | | 0.150 | 0.084 | | 0.26 | 0.18 | |
| SdurDdiv | 0.37 | 0.55 | | 0.04 | 0.08 | | 0.010 | 0.017 | | 0.09 | 0.11 | |
| DdurSdiv | 0.20 | 0.27 | 0.20 | 0.03 | 0.07 | 0.03 | 0.006 | 0.026 | 0.011 | 0.13 | 0.16 | 0.14 |
| DdurDdiv | 0.33 | 0.30 | 0.27 | 0.09 | 0.12 | 0.04 | 0.020 | 0.019 | 0.011 | 0.15 | 0.16 | 0.19 |
| Taxy | 1.00 | 1.05 | | 0.43 | 0.41 | | 0.107 | 0.065 | | 0.21 | 0.11 | |
| Holdy | 1.20 | 1.12 | | 0.39 | 0.36 | | 0.076 | 0.048 | | 0.17 | 0.10 | |

**Table 3: Effects of Intrinsic Differences on Assets' Price Deviation ($\left|P_t^i - f_t^i\right| / f_1^i$) and Turnover ($q_t^i / TSU^i$)**

| | Asset X (Periods 1-30) | | Asset Y (Periods 1-15) | |
|---|---|---|---|---|
| | (1) Price Deviation (in %) | (2) Turnover (in %) | (3) Price Deviation (in %) | (4) Turnover (in %) |
| Constant | 38.11*** (7.34) | 34.40*** (8.24) | 34.87*** (5.85) | 28.58*** (5.85) |
| Period | −0.05 (0.32) | −0.49*** (0.16) | 0.39 (0.36) | −0.55 (0.37) |
| Ddiv | −27.29** (11.35) | −16.60* (8.64) | −21.71** (9.05) | −10.32 (6.82) |
| Ddur | −33.22*** (10.25) | −12.32 (8.36) | −29.94*** (5.49) | −7.79 (7.57) |
| Ddiv * Ddur | 30.28*** (11.56) | 17.52* (9.89) | 22.84** (9.84) | 9.99 (8.36) |
| Obs. | 420 | 420 | 210 | 210 |

Notes: The table reports results from a population-averaged panel data linear regression model. The standard errors, given in parentheses, are corrected for first-order autocorrelation and within-session correlation. ***, ** and *: significant at the 1%, 5% and 10% levels, respectively.

**Table 4: Summary Statistics of $\left|(P_t^X / P_t^Y) - (P^X / P^Y)^*\right|$ (in %)**

| Treatment | (1) Periods 1 - 15 | (2) Periods 1 - 30 |
|---|---|---|
| SdurSdiv | 9.82<br>(18.54) | 10.59<br>(20.96) |
| SdurDdiv | 7.51<br>(9.26) | |
| DdurSdiv | 14.06<br>(12.37) | |
| DdurDdiv | 22.47<br>(25.09) | |
| Taxy | | 8.95<br>(37.21) |
| Holdy | | 12.72<br>(34.56) |

Standard deviations are in parentheses.

**Table 5: Treatment Effects on $\left|(P_t^X / P_t^Y) - (P^X / P^Y)^*\right|$ (in %)**

| | (1) Periods 1 - 15 | (2) Periods 1 - 30 |
|---|---|---|
| Constant | 3.37<br>(8.97) | −1.41<br>(6.95) |
| Period | 0.78<br>(0.63) | 0.79***<br>(0.24) |
| Ddiv | −0.69<br>(6.67) | |
| Ddur | 5.04<br>(6.77) | |
| Ddiv * Ddur | 9.60<br>(10.54) | |
| Taxy | | −1.60<br>(6.03) |
| Holdy | | 1.71<br>(6.14) |
| Obs | 210 | 360 |

Notes: The table reports results from a population-averaged panel data linear regression model. The standard errors, given in parentheses, are corrected for first-order autocorrelation and within-session correlation. ***: significant at the 1% level.

**Table 6: Effects of Institutional Differences on Assets' Price Deviation ($\left|P_t^i - f_t^i\right| \Big/ f_1^i$) and Turnover ($q_t^i \,/\, TSU^i$)**

| | Asset X (Periods 1-30) | | Asset Y (Periods 1-30) | |
|---|---|---|---|---|
| | (1) Price Deviation (in %) | (2) Turnover (in %) | (3) Price Deviation (in %) | (4) Turnover (in %) |
| Constant | 36.75***<br>(7.08) | 33.72***<br>(8.78) | 38.51***<br>(7.81) | 22.23***<br>(4.99) |
| Period | −0.17<br>(0.37) | −0.47**<br>(0.22) | −0.39*<br>(0.23) | −0.23*<br>(0.13) |
| Taxy | −17.33<br>(11.60) | −3.99<br>(9.77) | −14.89<br>(11.02) | −7.15<br>(4.83) |
| Holdy | −16.36<br>(10.82) | −8.82<br>(8.75) | −15.54<br>(10.06) | −8.76**<br>(4.28) |
| Obs. | 360 | 360 | 360 | 360 |

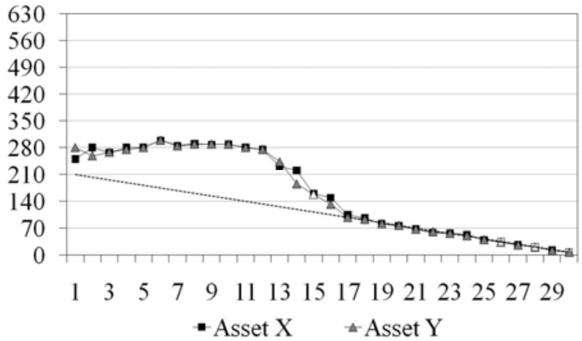
Notes: The table reports results from a population-averaged panel data linear regression model. The standard errors, given in parentheses, are corrected for first-order autocorrelation and within-session correlation. ***, ** and *: significant at the 1%, 5% and 10% levels, respectively.

**Table 7: Relative Frequencies of Different Trading Activities**

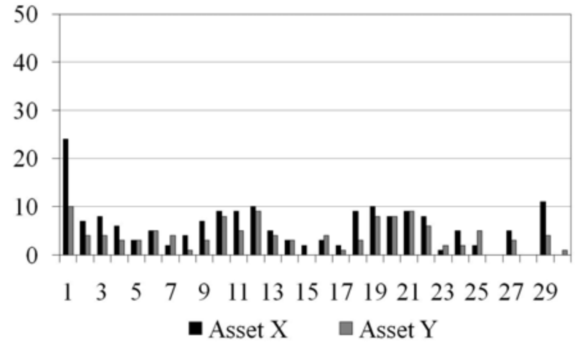
| Treatment | Same Offer | Opposite Offer | Same Offer | Opposite Offer | Frequency of Arbitrage across Assets | Frequency of Short-Term Speculation in Mkt X | Frequency of Short-Term Speculation in Mkt Y |
|---|---|---|---|---|---|---|---|
| | Same Market | | Different Market | | | | |
| SdurSdiv | 28% | 24% | 33% | 15% | 4% | 47% | 44% |
| SdurDdiv | 36% | 21% | 24% | 18% | 8% | 39% | 36% |
| DdurSdiv | 36% | 19% | 26% | 19% | 10% | 38% | 29% |
| DdurDdiv | 49% | 19% | 16% | 15% | 7% | 31% | 28% |
| Taxy | 41% | 22% | 27% | 10% | 1% | 39% | 27% |
| Holdy | 39% | 19% | 28% | 14% | 2% | 34% | 26% |

**Figure 1: SdurSdiv Treatment**

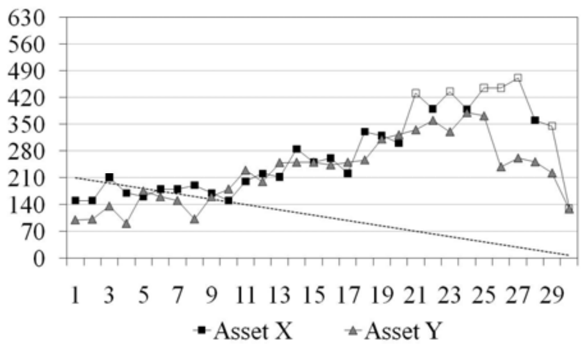
SdurSdiv1 Median Prices



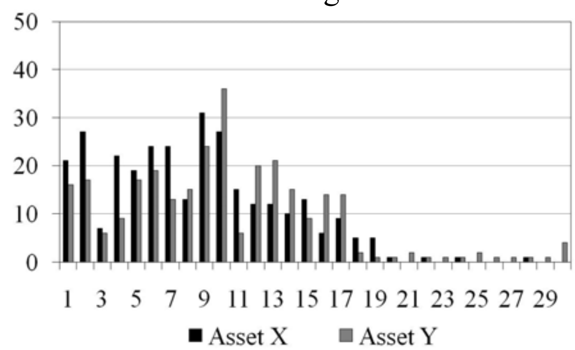

SdurSdiv1 Trading Volumes



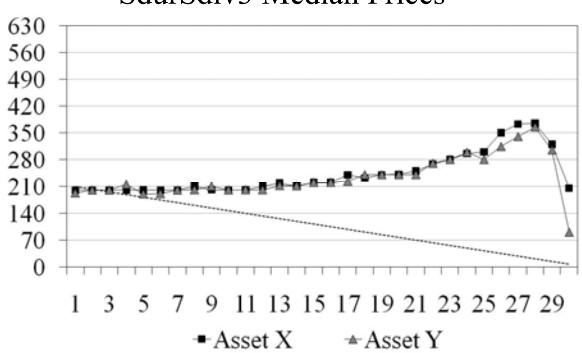

SdurSdiv2 Median Prices



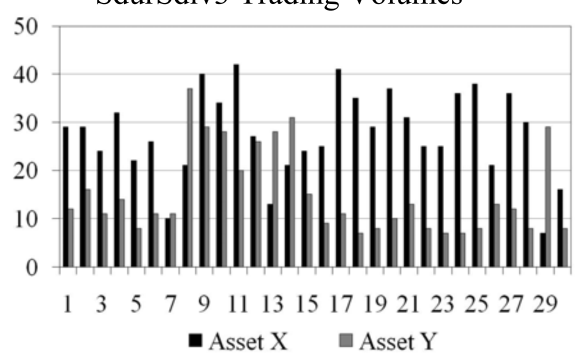

SdurSdiv2 Trading Volumes



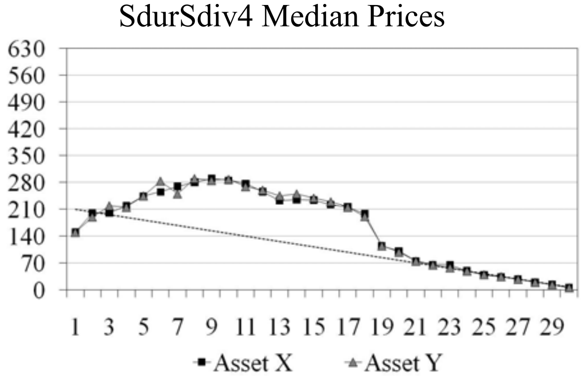

SdurSdiv3 Median Prices



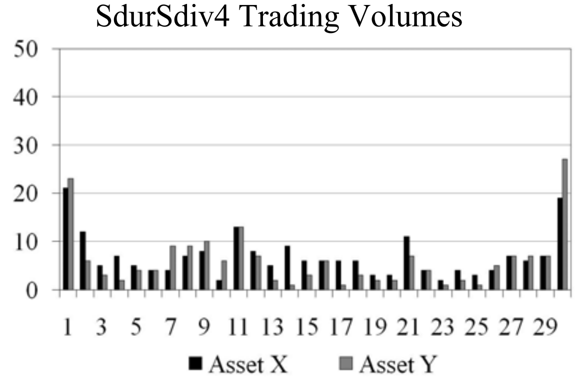

SdurSdiv3 Trading Volumes




SdurSdiv4 Median Prices




SdurSdiv4 Trading Volumes



## Figure 2: SdurDdiv Treatment

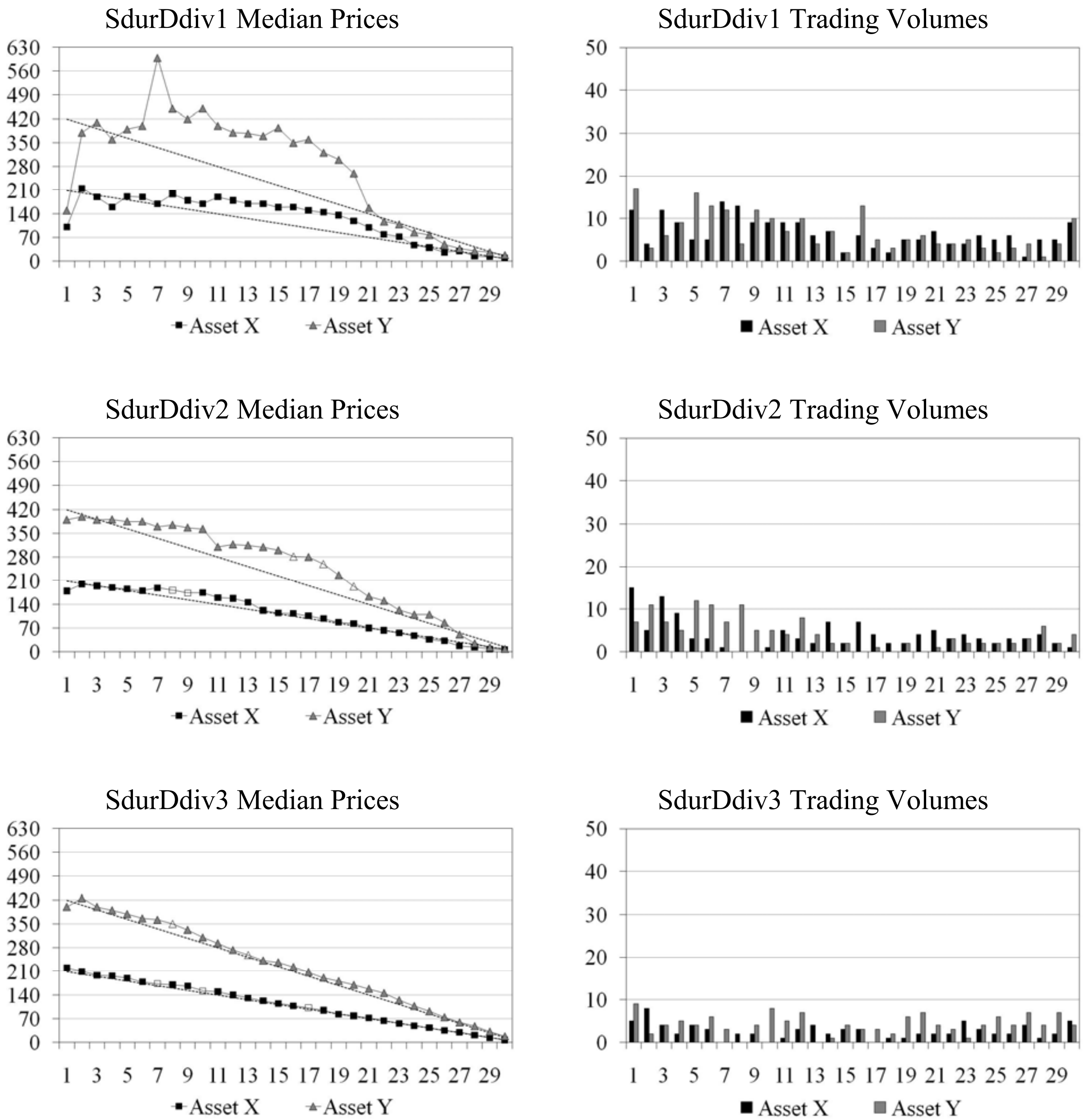


**Figure 3: DdurSdiv Treatment**

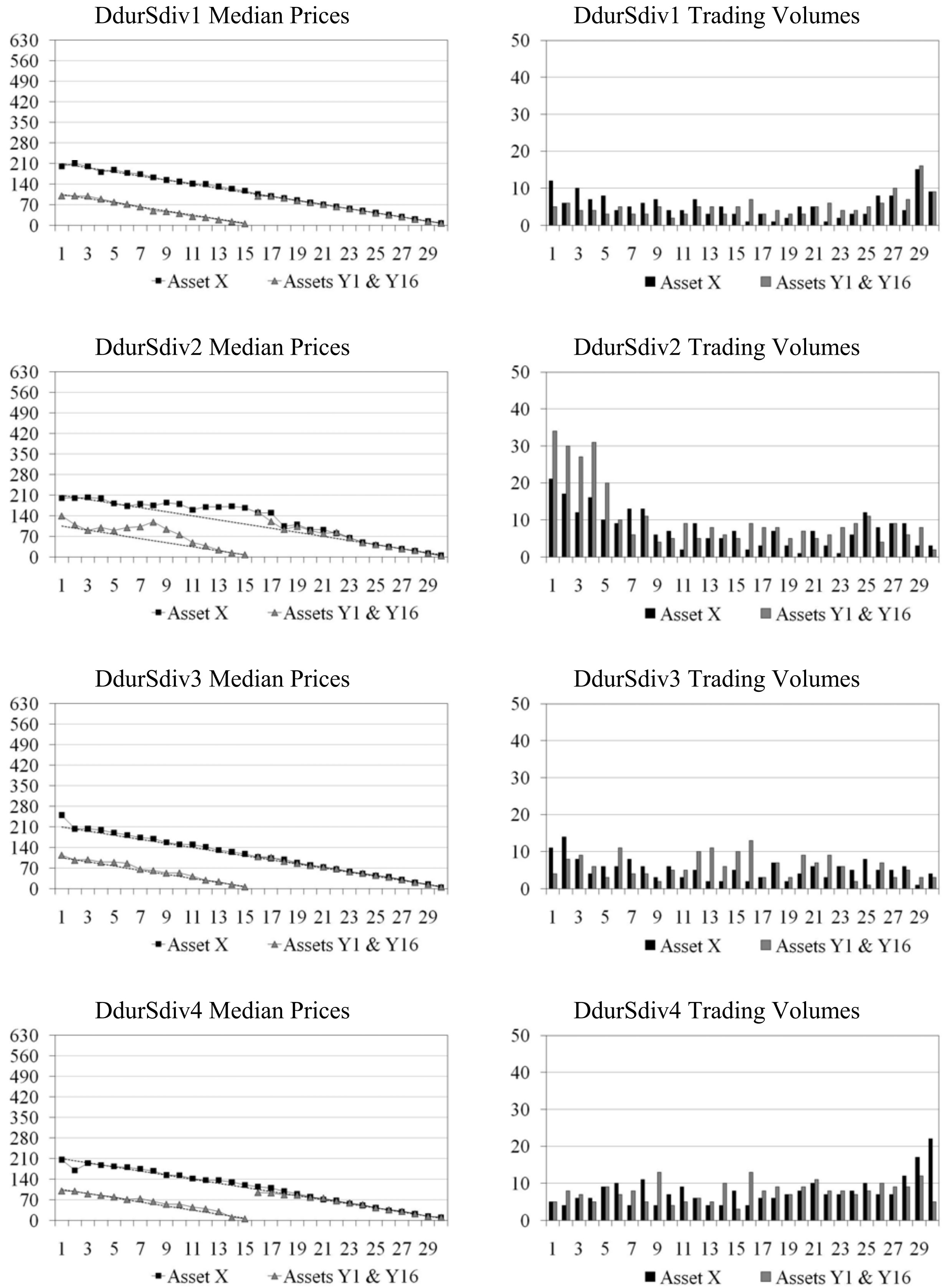


**Figure 4: DdurDdiv Treatment**

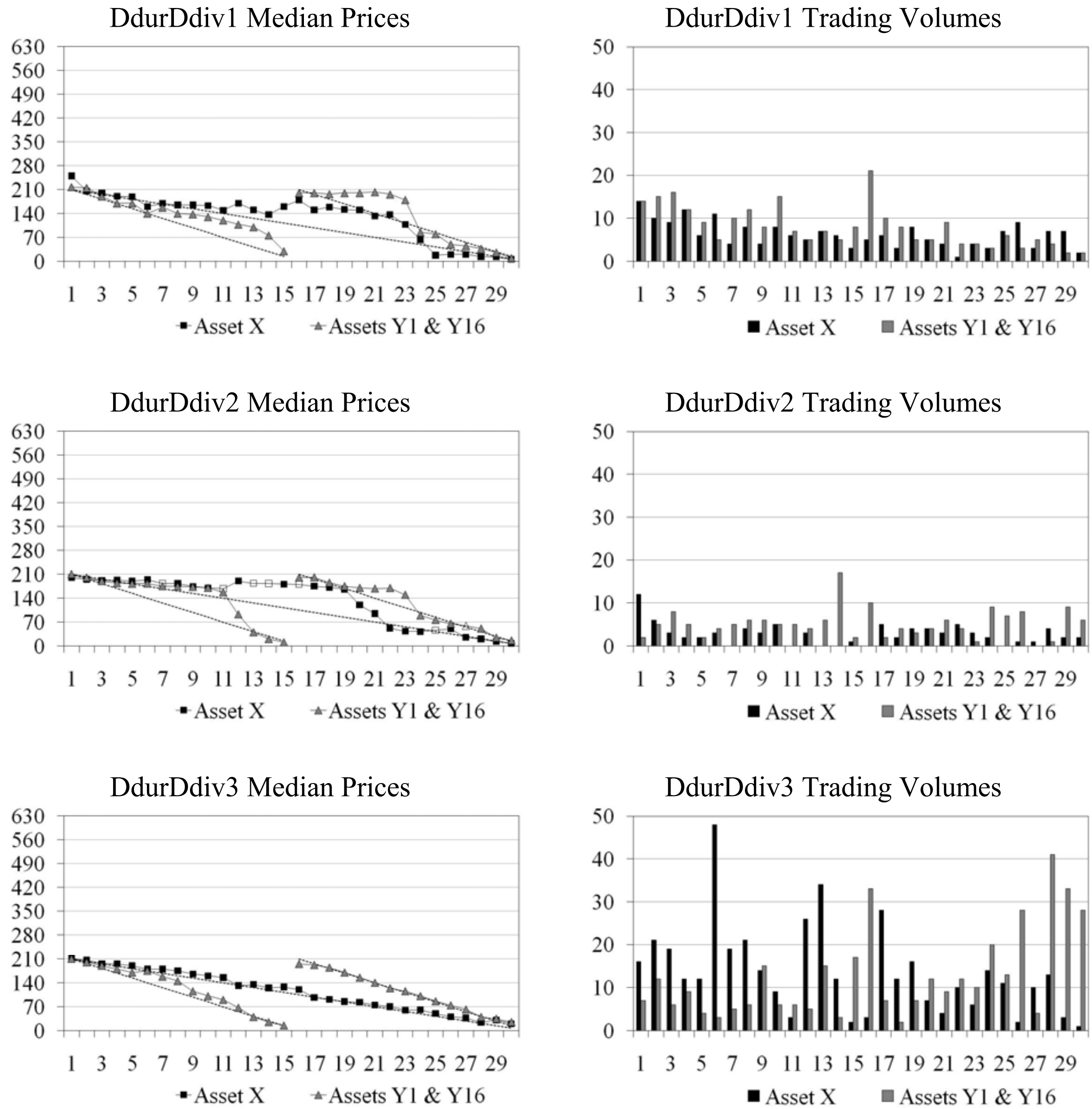


**Figure 5: Taxy Treatment**

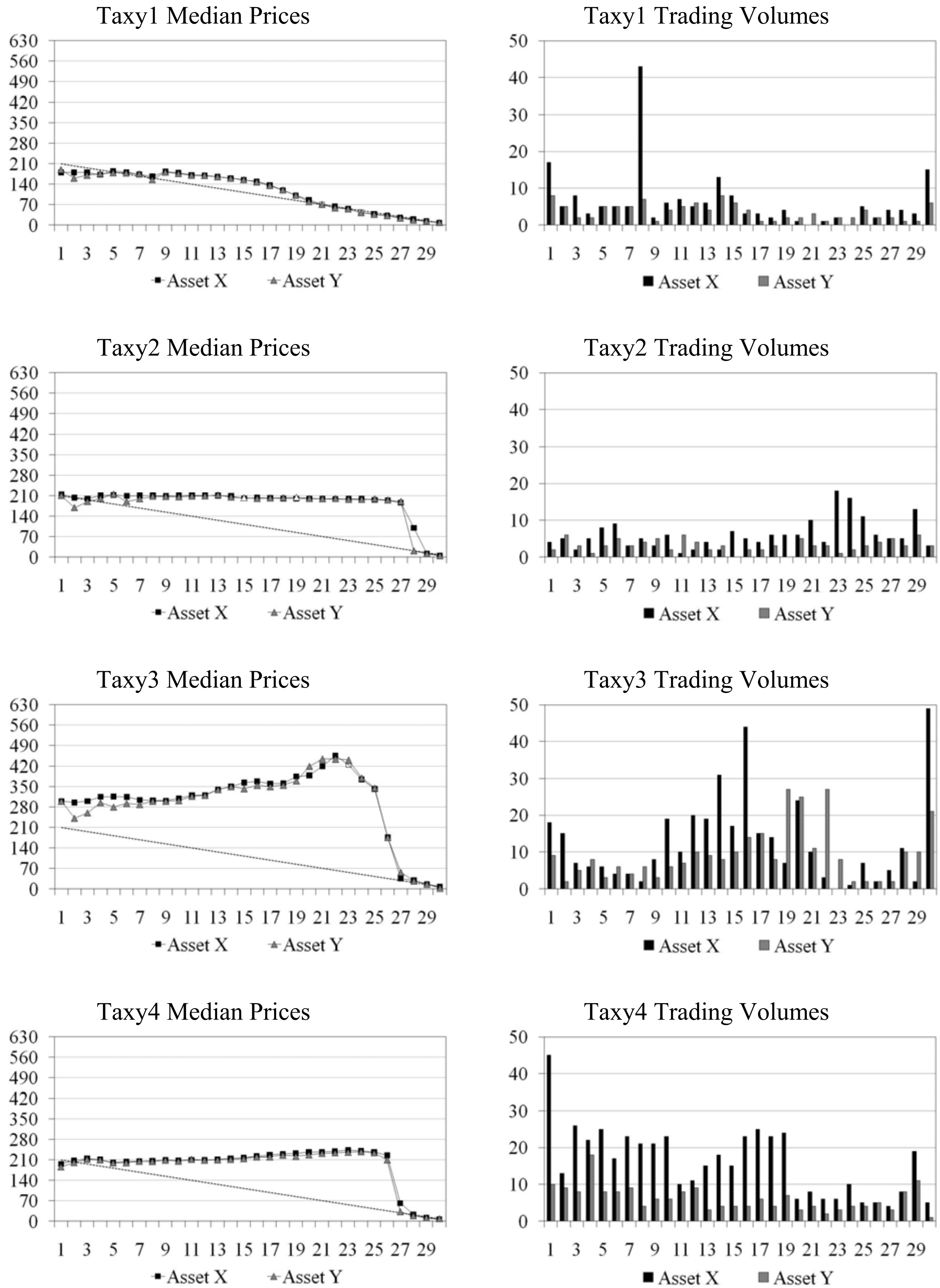


**Figure 6: Holdy Treatment**