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Abstract: This study conducts experimental asset markets to examine the effects of circuit breaker rules on market behavior when agents are uncertain about the presence of private information. Our results unequivocally indicate that circuit breakers fail to temper unwarranted price movements in periods without private information. Agents appear to mistakenly infer that others possess private information, causing price to move away from fundamental value. Allocative efficiencies in our markets are high across all regimes. Circuit breakers perform no useful function in our experimental asset markets.

JEL classification: D82; G18

Key words: circuit breaker, experimental asset markets, trading interruption, private information

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Circuit Breakers With Uncertainty About the Presence of Informed Agents: I Know What You Know … I Think

This study examines the effect of circuit breakers on market behavior when agents are uncertain about the presence of private information. In our experimental asset markets traders know the probability that there is private information in the market. We investigate whether market-wide trading halts play a useful role in moderating unwarranted price movements in periods *without* private information. These periods are particularly interesting because all trade is uninformative but some traders may erroneously infer otherwise. If some agents mistakenly believe that there is private information in the market, they may mimic others' trading behavior, drawing still others in and causing asset prices to spiral away from fundamental value. Camerer and Weigelt (1991) provide some evidence of such information mirages (see also Anderson and Holt (1997)). We investigate whether circuit breakers dampen or prevent price movements away from fundamental value, particularly in periods in which private information is absent.[1]

Limited empirical research examines the role of circuit breakers in markets (Lauterbach and Ben-Zion (1993), Santoni and Liu (1993), and Goldstein and Kavajecz (2000)) because such studies are replete with challenges.[2] It is nearly impossible to *isolate* the effect of impediments to trade on market behavior using archival methods. Stock prices and associated volatility change for a variety of reasons that may or may not be related to shifts in underlying fundamentals. Archival methods also are unable to ascertain what would have happened in the absence of circuit breakers. Further, the NYSE circuit breaker rule has been activated only

once since being instituted. However, recent research suggests that the probability of an extreme market movement is non-negligible (Booth and Broussard (1998), Bakshi and Madan (1999)).[3] Thus, significant issues remain unresolved.

With an experimental method we can control the distribution of information across traders and time and conduct an investigation that cannot be completed using data from naturally occurring markets. We are able to compare market outcomes under three circuit breaker regimes: market closure, temporary halt, and no interruption. Ackert, Church, and Jayaraman (2001) provide some recent experimental evidence on the effect of a circuit breaker rule. In their experiment, a subset of agents always receives private information about asset value. By design, asset prices should move away from an uninformed expectation toward an informed one as information is disseminated. Ackert, Church, and Jayaraman conclude that a circuit breaker rule does not inhibit price movement toward the informed price, though agents advance trade in anticipation of a breaker being triggered.

In the current study, circuit breakers may have the beneficial effect of mitigating unwarranted price movements. In periods without a subset of informed agents, asset prices should not deviate from the uninformed expectation. But uninformed agents do not know whether others' actions reflect informed or uninformed trade, and they may incorrectly infer that price signals are informative. If agents mistakenly believe that others' actions reflect private information, circuit breakers may temper deviations from fundamental value. In this case, circuit breakers may protect against large, non-information-based price movements.

The results of this study indicate unequivocally that circuit breakers fail to temper unwarranted price movements. In fact, breakers that trigger a temporary halt appear to have a

detrimental effect. Our data suggest that with a temporary halt, price moves away from fundamental value in periods without private information. This result may occur because a temporary halt provides traders time for introspection, allowing them to dwell on irrelevant or unimportant information (e.g., Tordesillas and Chaiken (1999)). In turn, agents may be more likely to mistakenly infer that others possess private information. We do not, however, find any evidence that circuit breakers affect trading volume in the absence of private information. Allocative efficiencies in our markets are high across all market regimes with or without a circuit breaker rule. We conclude that circuit breakers play no useful role in our experimental asset markets.

The remainder of this paper is organized as follows. Section 1 provides a framework. Section 2 describes our experimental design and procedures and provides price and allocation predictions. Section 3 presents empirical tests and evidence on market dynamics with and without circuit breakers. Section 4 provides discussion of the results and concludes the paper.

1. Framework

A large literature examines whether asset prices efficiently disseminate and aggregate diverse information. Grossman and Stiglitz (1976 and 1980) provide a theoretical basis that suggests that equilibrium asset prices aggregate and reveal private information. Experimental research shows that when a subset of agents is known to be informed, asset prices reflect private information about asset value (Plott and Sunder (1982), Banks (1985), Sunder (1992), and Ackert, Church, and Shehata (1997)). But little research has examined market behavior when the presence of private information is uncertain. As an exception, Camerer and Weigelt

(1991) conduct experimental asset markets in which some periods include private information and all traders know the probability that a subset of agents is informed in a particular period. They provide some evidence to support the occurrence of information mirages. Over 47 experimental periods in which private information is absent, 13 mirages are identified (or 27.7 percent of the time).[4] Hence, experimental data suggest that in some instances agents overreact to uninformative trades. In addition to the price-path dependence reported by Camerer and Weigelt (1991), Anderson and Holt (1997) conduct experiments in which subjects make sequential, public predictions and find evidence of cascades.

In some theoretical models of behavior with asymmetric information, agents infer information from previous behavior when decisions are made sequentially. Importantly, agents may rationally follow the decisions of others, even though previous decisions are not necessarily based on superior private information. For example, in an information cascade it is optimal for an agent to ignore private information and follow the behavior of others (Bikhchandani, Hirshleifer, and Welch (1992)).[5] Although ignoring private information can be rational, inefficient outcomes may result (Banerjee (1992), Avery and Zemsky (1998)). Most notably, if earlier decisions are based on incorrect private information, subsequent decisions may be sub-optimal.

In our experimental markets, agents do not know whether others possess private information, and they must appraise whether others' actions reflect informed or uninformed trade. Decisions are not strictly sequential as traders interact when buying and selling in a double auction asset market. We investigate the effect of circuit breakers on the resulting price behavior. In equilibrium, price fully reveals private information and is equal to its fundamental

value. If a circuit breaker is triggered in our markets, agents must assess whether asset prices are deviating away from or moving toward fundamental value. The markets are designed such that, in the absence of private information, circuit breakers are triggered when prices are deviating away from fundamental value. Thus, triggering the circuit breaker stops, at least temporarily, unwarranted price movements.

The unwarranted price movements we examine are disequilibrium phenomena. In the sequential decision-making models of Banerjee and Bikhchandani, Hirshleifer, and Welch, it is not irrational for an agent to follow the decisions of others, disregarding private information. In our experiment price mirages appear because of agent error. In a period in which no agent has private information, traders do not know that prices are uninformative. As in Camerer and Weigelt, a mirage results when agents mistakenly infer information from prices when prices do not convey information.

We include two circuit breaker rules in our experimental design: market closure and temporary halt. With closure, the market is shut down once a breaker is triggered, which prevents any further departure from fundamental value. With temporary halt, the market is interrupted and then restarted. The temporary halt may provide for a cooling-off period or, alternatively, it may exacerbate price deviations (i.e., introspection may reinforce beliefs that others possess private information). We compare asset prices in markets with circuit breakers to prices in markets that do not include any trading restrictions. The design allows us to determine whether circuit breakers (1) temper unwarranted price movements in the absence of private information and (2) affect the occurrence of information mirages.

We also investigate the effect of circuit breakers on trading volume. Ackert, Church, and Jayaraman (2001) report that agents advance trade in markets with circuit breakers. We examine whether this result obtains in periods without private information. For such a result, agents likely believe that asset value differs from the uninformed expectation (i.e., agents mistakenly believe that others possess private information).

In addition, we examine whether asset holdings are consistent with theory. Importantly, Camerer and Weigelt (1991), Bossaerts and Plott (2000), and Bossaerts, Plott, and Zame (2000) report that while pricing is consistent with theory, certificate holdings are not. Camerer and Weigelt report that prices are consistent with full revelation of information whereas trading patterns are consistent with partial revelation. However, allocative efficiencies are quite high even in the absence of private information and improve as traders gain experience. We report the allocative efficiency of the markets providing a measure of the extent to which certificates are held by the traders with the highest valuation. Because circuit breaker rules, when triggered, reduce trading time, allocative efficiencies may suffer.

2. Experimental Method and Predictions

2.1. Design and Overview

We conduct nine experimental asset markets, each consisting of 15 periods. All markets have eight traders who are inexperienced in that none participated in an earlier session. Table 1 provides an overview of the experimental parameters. In markets 1-3 trading is shut down on a permanent basis if a circuit breaker is triggered (market closure). In markets 4-6 trading is halted on a temporary basis if an extreme price movement activates a circuit breaker (temporary halt). Finally, in markets 7-9 participants are free to transact without any threat of a trading interruption (no interruption).

In each period, market participants trade certificates with one-period lives and receive a common dividend for each certificate held at period-end. At the beginning of each period, participants receive an index card that indicates the dividend for the period or "000" (when uniformed). The instructions indicate that, in each period, there is a 50 percent chance that two of eight traders will be privately informed of the dividend for the period. The fraction informed each period is reported in Panel B of Table 1. The presence or absence of informed agents is not disclosed at period end.

2.2. Procedures

At the beginning of each market session participants receive a set of instructions, which an experimenter reads aloud.[6] Substantially all participants are master's students at Georgia Tech who have successfully completed a required finance course or are currently enrolled in the course. The average compensation across the 72 traders in our markets is $31.82, which

includes trading earnings, a $3.00 bonus if on time for the session, and $2.00 for completing a post-experiment questionnaire. The markets take approximately two hours to complete.

At the beginning of each period, agents are endowed with two certificates and $200 cash. In addition, they receive an index card, which indicates whether they are informed. Further, agents are told whether they have to pay a personal tax on dividend earnings. The tax varies across agents and periods. Agents are instructed that, in each period, one-half of them (four out of eight) have a zero tax rate and the remainder have a 30 percent tax rate. Whether a particular agent pays a zero or 30 percent tax on dividend earnings in a particular period is determined randomly prior to the market by the experimenters, with the constraint that informed traders always have a tax rate of zero. We vary tax rates across agents to provide an incentive to trade.

Agents receive a dividend for each certificate held at period end. The dividend is determined by drawing from a distribution of five dividends: $3.50, $4.25, $5.00, $5.75, and $6.50. Each dividend is equally likely, so the mean payout is $5.00. The dividend per period is randomly determined by the experimenters prior to the experiment and the same sequence is used across all markets.[7] This sequence is reported in Panel B of Table 1. The dividend is publicly announced at period end.

The experimental markets are organized as double oral auctions. Traders are free to make verbal offers to buy or sell one certificate at a designated price at any time, and all offers are publicly announced and recorded. Outstanding offers stand until accepted or replaced by a better bid or ask price. Short sales are not permitted. If a circuit breaker is not triggered, all

market periods last four minutes. Participants are not informed of the number of periods to be conducted.

In the markets without trading restrictions, agents are free to trade certificates without interruption. In the markets with circuit breakers, trading may be stopped or temporarily halted when there are large upward or downward price movements in the market for *all* certificates.[8] Participants are told that market movements are positively, but not perfectly, correlated with the prices of the certificates they trade. Our circuit breaker rules are designed to reflect the fact that actual rules tie interruptions in trading to movements in the overall market, as measured by the DJIA.

After each completed transaction, the circuit breaker rule is evaluated. The probability of a trading halt increases as the price moves away from $5.00, the uninformed expected value of a certificate. The probability of a halt is 50 percent if the price moves at least 10 percent but less than 20 percent from $5.00. The probability of a halt increases to 90 percent if the price moves 20 percent or more from $5.00. An experimenter determines whether trading is stopped or temporarily halted by drawing a card from one of two decks. The first set has 5 (5) cards labeled “stop” (“go”) and the second has 9 (1) labeled “stop” (“go”).

In the market closure condition, the market does not reopen until the following period if a breaker is triggered. In the temporary halt condition, trading is suspended for 30 seconds. After a suspension, trading resumes as before with the circuit breaker rule for transaction price ranges centered on the last transaction price prior to the trading interruption. A temporary trading halt, however, is never triggered in the last 60 seconds of a period.

After the experimenter announces the period's dividend, traders calculate their cash balance by multiplying the number of certificates held by their after-tax dividend and adding their earnings from certificate holdings to their cash on hand. Certificates and cash are not carried forward across periods. Each trader's endowment is reinitialized at the start of the following period.

At the end of the experiment participants are paid in cash. Trading profit is converted to take-home earnings by multiplying profit by 20 percent. While the experimenters finish the paperwork, participants complete a post-experiment questionnaire. The questionnaire allows us to gather general information about the traders and how they viewed the experiment.[9]

2.3. Price and Allocation Predictions

Theoretical price and allocation predictions are easily derived assuming risk neutrality. As noted by Bossaerts and Plott (2000), price behavior in an experiment can be directly assessed using the distance between theoretical predictions and actual observed prices. In the absence of private information, the predicted price is simply the uninformed expectation ($5.00) and certificates are expected to be held by traders with a zero personal tax rate. With private information, the dividend paid is fully revealed in prices if prices are rationally determined because private information is perfect. In this case, uninformed traders learn from price signals and the predicted price is the period's dividend ($3.50, $4.25, $5.00, $5.75, or $6.50). Excess demand exists at any lower price. Certificates will be held by informed *and* uninformed traders who pay no taxes. Table 2 summarizes these rational expectations price and allocation predictions.

As noted previously, in the absence of private information, circuit breakers are centered around the uninformed expectation so that a breaker should never be triggered if prices are rationally determined. Under rational expectations, deviations from price predictions and allocative efficiencies should not differ across the market closure, temporary halt, and no interruption conditions. Even with private information, price should equal the informed price predictions if information dissemination is instantaneous. However, allocation predictions may not hold if trading is interrupted by the trigger of a circuit breaker rule because traders simply would not have the time to complete all advantageous trades.

3. Results

3.1. Asset Prices

Figures 1–9 plot the time series of transaction prices for the nine experimental asset markets. The figures also include the risk neutral, expected price per period, conditioned on the presence of private information (informed price). The horizontal axis denotes the period with a "u" when private information is absent (uninformed period) and an "i" when it is present (informed period). The uninformed expectation is $5.00, which is the mean of the dividend distribution. As in Table 2, the informed expectation is the period's dividend, which is known by a subset of agents. For the markets with circuit breakers, the figures show the breaker boundaries, denoted by dashed lines, and an indication of whether the breaker is triggered, denoted by a vertical, bold-type line.

A casual inspection of the figures suggests that, in periods without private information, asset prices sometimes wander away from the uninformed expectation. For example, refer to

periods 11 and 12 in the three temporary halt markets (figures 4-6). By comparison, in periods with private information, asset prices generally move toward the uninformed expectation, though in many instances prices do not adjust enough (i.e., prices fall short of the predicted price). We also note that circuit breakers are triggered frequently and the breakers appear to be activated in both informed and uninformed periods. Next we turn to formal tests of asset prices. First we examine periods without private information, which are our primary focus, and then turn to periods with private information.

3.1.1. Periods Without Private Information. We compute the average, absolute deviation in the closing price per period from the uninformed price, normalized by the uninformed price (NAPD). The means and standard deviations by market condition are shown in Panel A of Table 3. To provide insight into how market behavior evolves over time, the data are reported separately for early (periods 1-7) and late (periods 8-15) trading periods. In the early trading periods, no significant differences are observed. For the late trading periods, the NAPD in the temporary halt condition is large in comparison to the other two conditions. Tukey pairwise tests indicate that the NAPD for the temporary halt group in the late trading periods is significantly different from the NAPDs for the other two groups at $p < 0.01$. Over late trading periods, price deviations from the uninformed expectation are *greater* in the temporary halt condition, which suggests that temporary breakers do not serve a beneficial role in preventing unwarranted price movements. The deviations becoming larger over time suggests that behavior does not converge to rational expectations predictions even with experience.

Next, we performed a repeated measures analysis-of-variance (ANOVA) to parsimoniously examine the data from all periods without private information. The analysis

includes three independent variables: market condition, period, and an interaction term. The dependent variable is the NAPD per period for each session. We are primarily interested in the effects of market condition on the NAPD per period. The resulting F-statistic for market condition tests whether the average NAPD per session (averaged across all periods without private information) differs across the three groups. We find that market condition is significant at $p = 0.064$ ($F = 4.48$). Pairwise tests indicate that the mean of the temporary halt group is greater than that of the no interruption group at $p = 0.056$.

The price data suggest that circuit breakers that temporarily halt trading do not prevent price from wandering away from the uninformed price. To gain insight into the data, we investigate the frequency with which transaction prices and closing prices deviate from the uninformed price by at least 10 percent. We chose 10 percent because such a deviation is necessary to trigger a circuit breaker. As reported in Panel B of Table 3, transaction prices deviate from the uninformed price by at least 10 percent over the later periods much more frequently in the temporary halt condition (52.3 percent) than in the market closure (10.7 percent) and no interruption (4.9 percent) conditions. The χ^2-statistic of 69.84 indicates that deviations in transaction prices, relative to 10 percent, are not independent of market condition ($p < 0.001$). Inferences are similar looking at the closing prices (refer to Panel C of Table 3).

To gain additional insight into price behavior in the temporary halt condition, we examine price movement subsequent to a temporary halt. We observe that a temporary halt occurs in nine of 24 periods. In seven of nine periods, price moves farther away from the uninformed price once trading resumes or remains very near the price that triggered the breaker. In one period, price moves back toward the uninformed price; however, closing price still

deviates from the uninformed price by at least 10 percent.[10] Hence, temporary halts do not appear to curb large deviations in price from the uninformed price.

Next we examine the price data to ascertain whether agents overreact to uninformed trade. Agents are presumed to incorrectly infer that private information is present in the market if the price consistently deviates from the uninformed price. Operationally, we classify a period as one in which traders overreact to uninformed trade if the following rule is satisfied: three or more consecutive trades occur at prices that produce absolute deviations from the uninformed price of at least 10 percent *and* the closing price per period produces an absolute deviation of at least 15 percent. In the 24 periods without private information, the rule is satisfied once in the market closure condition, seven times in the temporary halt condition, and never in the no interruption condition.[11] The χ^2-statistic of 12.09 is significant at $p = 0.002$. Temporary trading halts appear to have a detrimental effect on market behavior. In these markets, agents appear to be more likely to mistakenly infer that others possess private information. Time for introspection arising from a temporary halt may reinforce beliefs that others have access to superior information. Prior findings suggest that introspection inhibits individuals' abilities to distinguish between important and unimportant information and diminishes the quality of decisions (Wilson and Schooler (1991) and Tordesillas and Chaiken (1999)). Our data are consistent with these findings.

3.1.2. Periods With Private Information. Next we examine the role of a circuit breaker rule in periods with a subset of informed agents. We compute the average absolute deviation in the closing price per period from the informed price, normalized by the informed price. The means and standard deviations by market condition are reported in Panel A of Table

4 for early and late trading periods. Tukey pairwise tests indicate that none of the means are significantly different from one another at conventional levels (in all cases $p > 0.10$).[12]

Again, we perform a repeated measures ANOVA to parsimoniously examine the data from all periods with private information. The independent variables include market condition, period, and an interaction term. The dependent variable is the NAPD per period for each session. We find that market condition is not significant at conventional levels ($F = 2.88$, $p = 0.133$). The findings suggest that circuit breakers do not inhibit price from moving toward the informed expectation, which is consistent with the results of Ackert, Church, and Jayarman (2001).

Next we determine the frequency with which transaction prices deviate from the informed expectation by at least 10 percent. The data, reported in Panel B of Table 4, indicate that, over all transactions, deviations of at least 10 percent occur frequently in each market condition. The χ^2-statistics of 3.94 for early periods and 3.83 for late periods indicate that price deviations, relative to 10 percent, are independent of market condition ($p = 0.140$ and $p = 0.148$, respectively). In general, price appears to adjust slowly away from the uninformed expectation. But price typically approaches the informed expectation. The closing price per period is within 10 percent of the informed price the majority of the time in each market condition, particularly in the late trading periods (refer to Panel C of Table 4). Further, deviations in the closing price per period, relative to 10 percent, are independent of market condition for early and late periods ($p = 0.858$ and $p = 0.492$, respectively).

If asset prices adjust to reflect private information, circuit breakers are likely to be triggered. In the market closure condition, circuit breakers are triggered in ten of 21 periods,

with draws also occurring in ten periods. We find that when the market is shut down, price stops short of the informed price six times and overshoots the informed price four times. In the temporary halt condition, circuit breakers are activated in six of 21 periods, with draws occurring in nine periods.[13] When the market is halted temporarily, price stops short of the informed price four times and overshoots the informed price twice. When the market is reopened, price either moves toward the informed price or remains at its current level.

3.2 Trading Volume

Table 5 reports the average number of transactions per period by market condition. Fewer transactions occur in the market closure condition than in the other two conditions. The average number of transactions per period is 6.34, 8.00, and 8.80 for the market closure, temporary halt, and no interruption conditions, respectively. This finding is not surprising because trading occurs over a shorter period of time when the market shuts down. As shown in Table 5, trading periods are open on average less time in the market closure condition (180 seconds) than in the temporary halt (229 seconds) or no interruption (240 seconds) conditions. Tukey pairwise tests indicate that the differences between the market closure condition and the other two conditions are significant at $p < 0.01$.

In the following analyses, we normalize the number of transactions per period by the number of seconds that the trading period is open. As before, we first examine behavior in periods without private information and then periods with private information and present the analysis for early and late trading periods.

3.2.1. Periods Without Private Information. We compute the average trading volume per second in periods without private information. The means and standard deviations by market condition are shown in Panel A of Table 6. None of the pairwise comparisons are statistically significant at conventional levels.[14] We also investigate normalized trading volume before and after a temporary halt. The difference is not statistically significant. Our findings suggest that, in the absence of private information, circuit breakers do not affect trading volume. This result contrasts with Subrahmanyam's (1994) conjecture that circuit breakers compel agents to advance their trades. Likewise, the result is contrary to the experimental findings of Ackert, Church, and Jayaraman (2001). But a fundamental difference is that our result applies to periods in which private information is absent. Subrahmanyam's (1994) theoretical model includes information asymmetries. In addition, in Ackert, Church, and Jayaraman (2001) a subset of agents is informed every period and all agents know of the information asymmetry.

3.2.2. Periods With Private Information. The means and standards deviations of normalized trading volume in periods with private information are shown in Panel B of Table 6. The mean of the market closure group is greater than that of the other two groups. Further inspection of the data suggests that, for the market closure group, volume per second is larger in periods with halts than in periods without halts. However, Tukey pairwise tests indicate that the differences are not significant at the ten percent level.[15] Next we investigate normalized trading volume before and after a temporary halt. We find that the mean volume before the halt (0.078) is greater than the mean volume after the halt (0.029), though the difference is not statistically significant with $p = 0.117$. Subrahmanyam (1994) and Ackert, Church, and Jayaraman (2001) conjecture that circuit breakers lead agents to advance their trades in periods with private

information. Though we find no statistically significant effect of a circuit breaker rule on trading volume, our results are not inconsistent with this notion. Importantly, in our markets there is greater uncertainty because agents do not know whether there is private information in the market.

Next we test for differences in the trading behavior of uninformed and informed agents. For each market condition, we compute the number of transactions per period involving each type of agent, normalized by the number of seconds that the trading period is open. We conduct paired t-tests and find that informed agents are involved in significantly more transactions than uninformed agents in the market closure and temporary halt conditions.[16] By comparison, the difference is not significant at conventional levels in the no interruption condition. Our results suggest that, in markets with a circuit breaker rule, fewer transactions involve only uninformed agents. Yet trades between uninformed agents with tax rates of zero and 30 percent can be mutually advantageous. In the next subsection, we investigate allocative efficiencies.

3.3 Allocative Efficiency

Allocative efficiency is measured by the proportion of certificates held by traders with a zero tax rate. Our data indicate that, consistent with the rational expectations prediction, traders who pay no taxes on dividend earnings hold more certificates.

3.3.1. Periods Without Private Information. Panel A of Table 7 reports the mean allocative efficiency for periods without private information for early and late trading periods. The mean allocative efficiency is 0.766, 0.833, and 0.750 for the market closure, temporary halt, and no interruption conditions, respectively. Tukey pairwise tests indicate no significant differences across circuit breaker conditions for early periods at the ten percent level. For the late trading periods, the market closure group is significantly less efficient than the temporary halt group at $p = 0.067$. In periods without private information, traders with zero tax rates hold more certificates even if, as in the temporary halt condition, price improperly adjusts. Thus, even erroneous price movements can promote allocative efficiency because those with a zero tax rate are motivated to hold certificates.

3.3.2. Periods With Private Information. Panel B of Table 7 reports the mean allocative efficiency for periods with private information. Although mean allocative efficiencies are high, they indicate partial rather than full revelation of information. With full revelation of information, allocative efficiencies would not differ significantly from one. As our measures differ significantly from one in most cases, we conclude that partial revelation of information is indicated. Tukey pairwise tests indicate no significant differences across circuit breaker conditions for the early periods. For the late periods, efficiency in the market closure condition is significantly less than that in the temporary halt condition at $p = 0.014$. Although price

deviations from rational expectations predictions are larger in the temporary halt condition, more certificates are held by the correct trader type.[17]

4. Discussion and Concluding Remarks

This study examines the effect of circuit breakers on market behavior when agents are uncertain about the presence of private information. Circuit breakers have the potential to play a useful role under these conditions if unwarranted price movements are tempered. Most notably, if agents mistakenly infer that others possess private information, circuit breakers may prevent prices from deviating from the uninformed expectation.

Our results indicate unequivocally that circuit breakers have no beneficial effect in tempering unwarranted price movements. In fact, breakers that trigger a temporary halt appear to have a detrimental effect. Our data suggest that with a temporary halt, agents are more likely to mistakenly infer that others possess private information, which causes price to move away from the uninformed expectation. We do not find a similar result with market closure.

Notably, in periods without private information, price deviations from the uninformed expectation are greater in markets with temporary halts than in those with market closure. This result raises an interesting question. If temporary halts fail to prevent unwarranted price movements, why would the possibility of market closure cause prices to be closer to the uninformed expectation? When faced with the possibility of a trading interruption, agents in our markets, as in securities markets like the NYSE, are faced with making decisions under time pressure. In such a situation, the decision-maker faces a real dilemma because mistakes can be made by acting too quickly *or* by waiting too long, particularly as windows of opportunity may

no longer be available (Payne, Bettman, Luce (1996)). In the case of a temporary halt, windows of opportunity re-open as the market does. With market closure looming, traders are subject to greater time pressure. They have fewer opportunities to reverse decisions or act on information.

A vast literature in psychology and decision-making examines how people respond under time pressure. Importantly, individuals may adapt and accelerate information processing and focus on important information (Ben Zur and Breznitz (1981)). With moderate time pressure, decision makers' performance improves, as they focus on relevant cues and exclude the peripheral (Easterbrook (1959)). Decision makers increase speed so that they can incorporate more relevant information in the time available.

Consistent with this evidence, in our experiment the threat of market closure may have the effect of forcing participants to rapidly assimilate relevant, available information. As pointed out by Eisenhardt (1993, page 121), in environments with great stress due to time pressure, "the decision-making dilemma … comes from the fact that it is easy to make mistakes by deciding too soon and equally ineffective to delay choices or to imitate others." Traders are time constrained so that the risks inherent in imitating others are significant. They must focus on important information and avoid dwelling on extraneous cues. By comparison, in markets with temporary halts, agents have extra time on their hands when the circuit breaker rule is triggered. The temporary halt may cause agents to focus on irrelevant information, which has an unfavorable effect on price behavior. Our results suggest that further research is necessary to systematically investigate the effects of time pressure and introspection on investors' behavior. A laboratory setting provides a conducive environment to perform such research.

The data fail to suggest that circuit breakers have a significant impact on trading volume or allocative efficiencies in our markets. We conclude that circuit breakers play no useful role whatsoever in our experimental asset markets.

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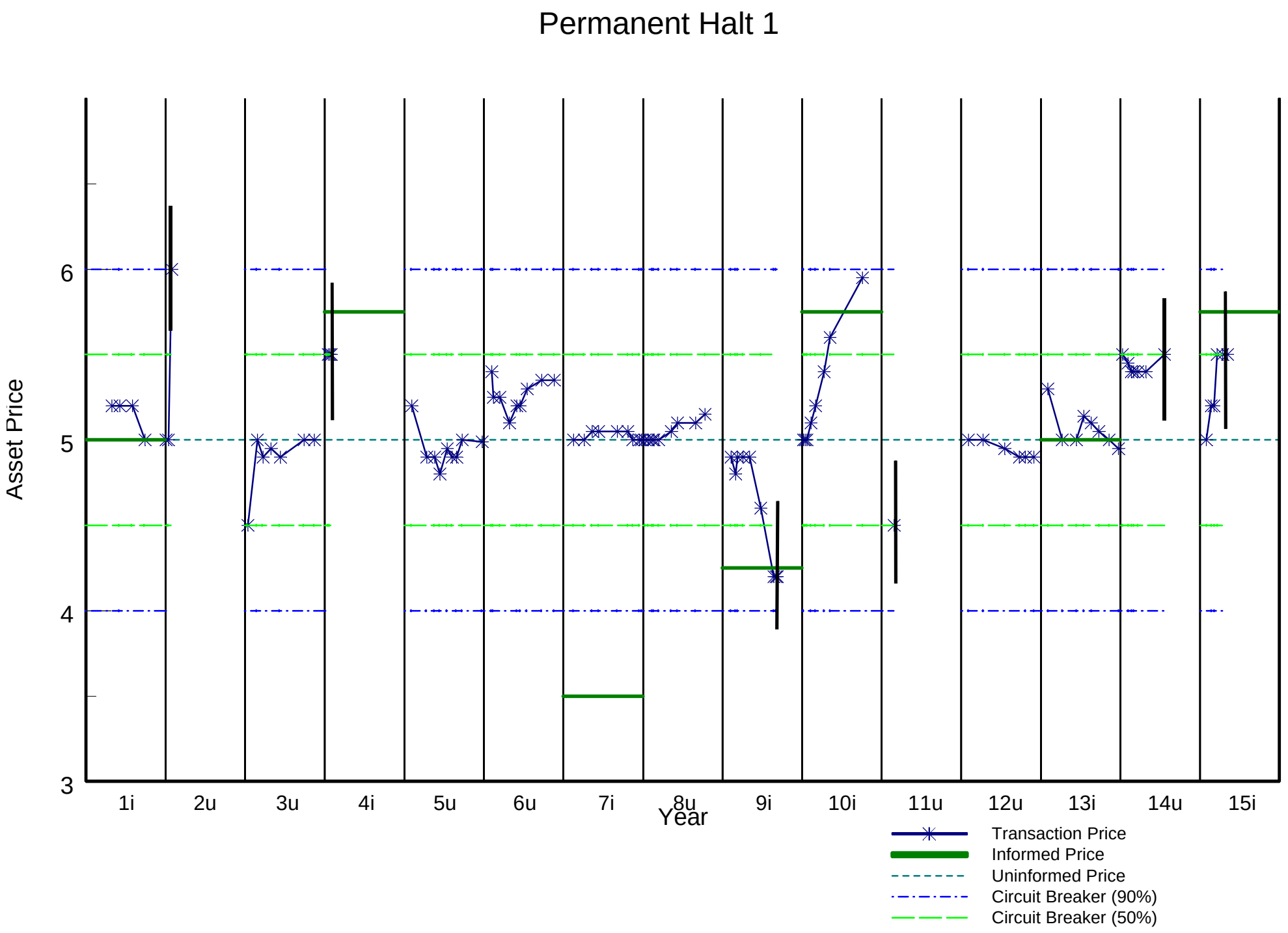
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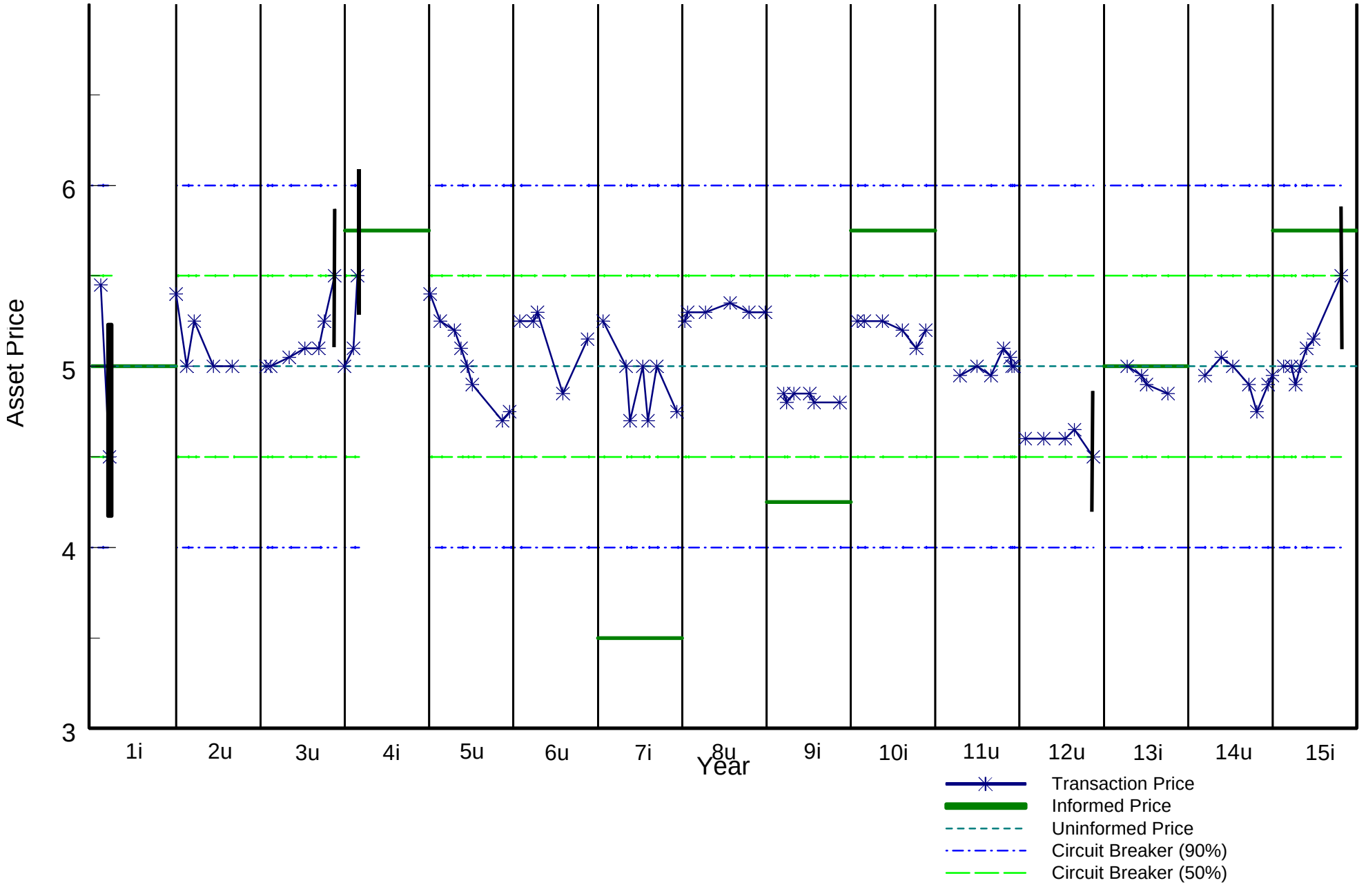
Circuit Breaker (90%)
Circuit Breaker (50%)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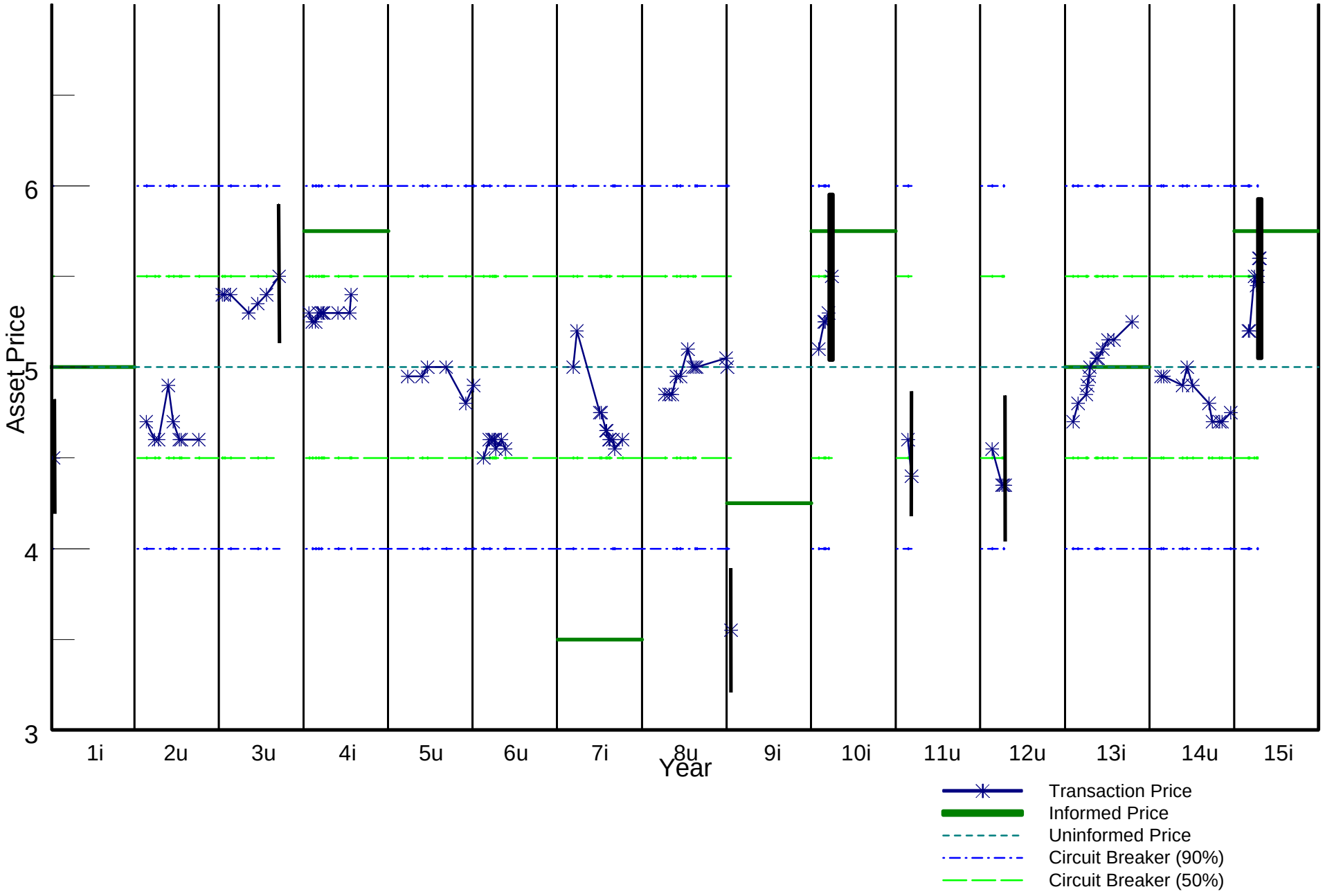
Circuit Breaker (90%)
Circuit Breaker (50%)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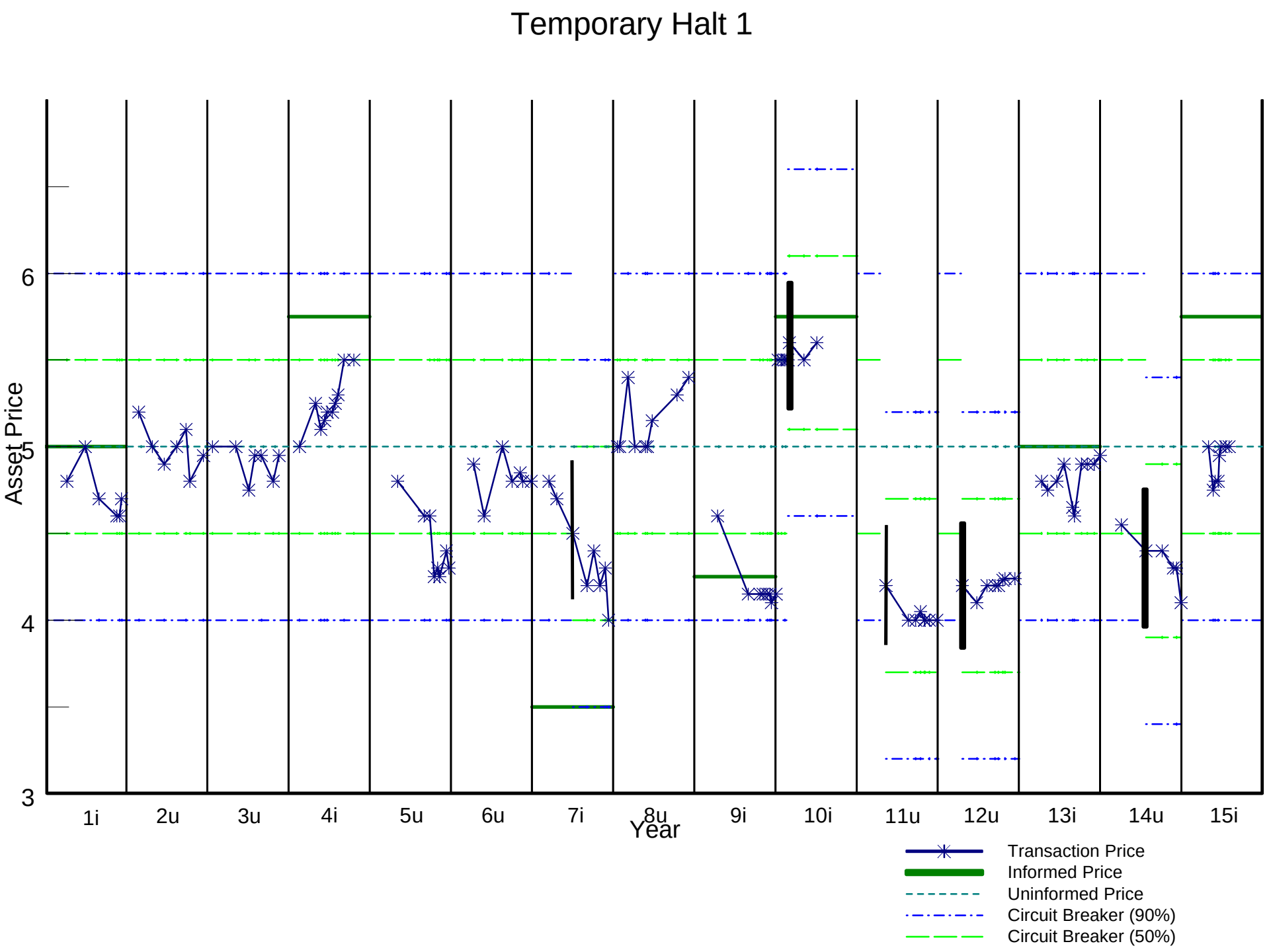
Circuit Breaker (50%)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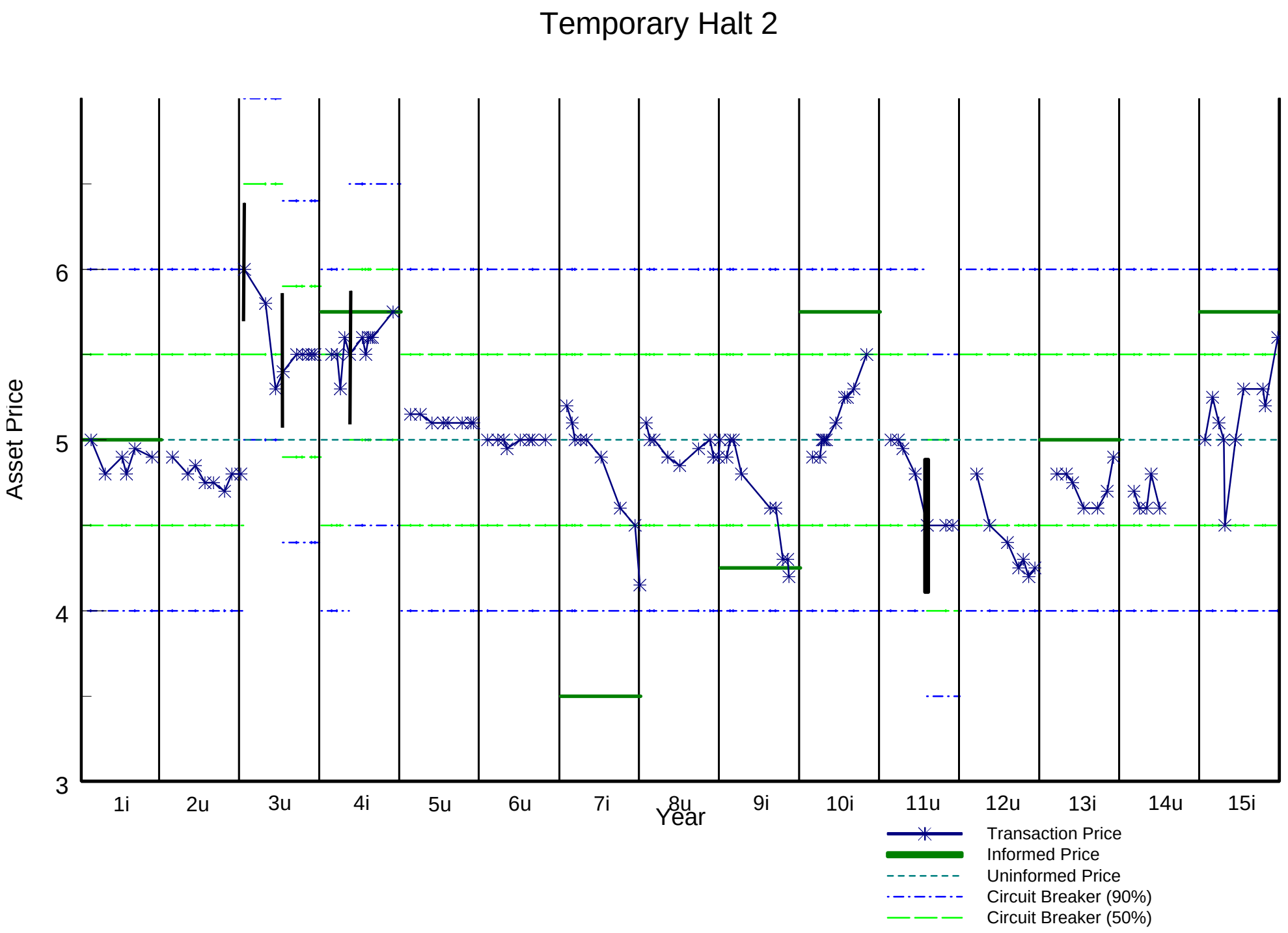
Circuit Breaker (90%)
Circuit Breaker (50%)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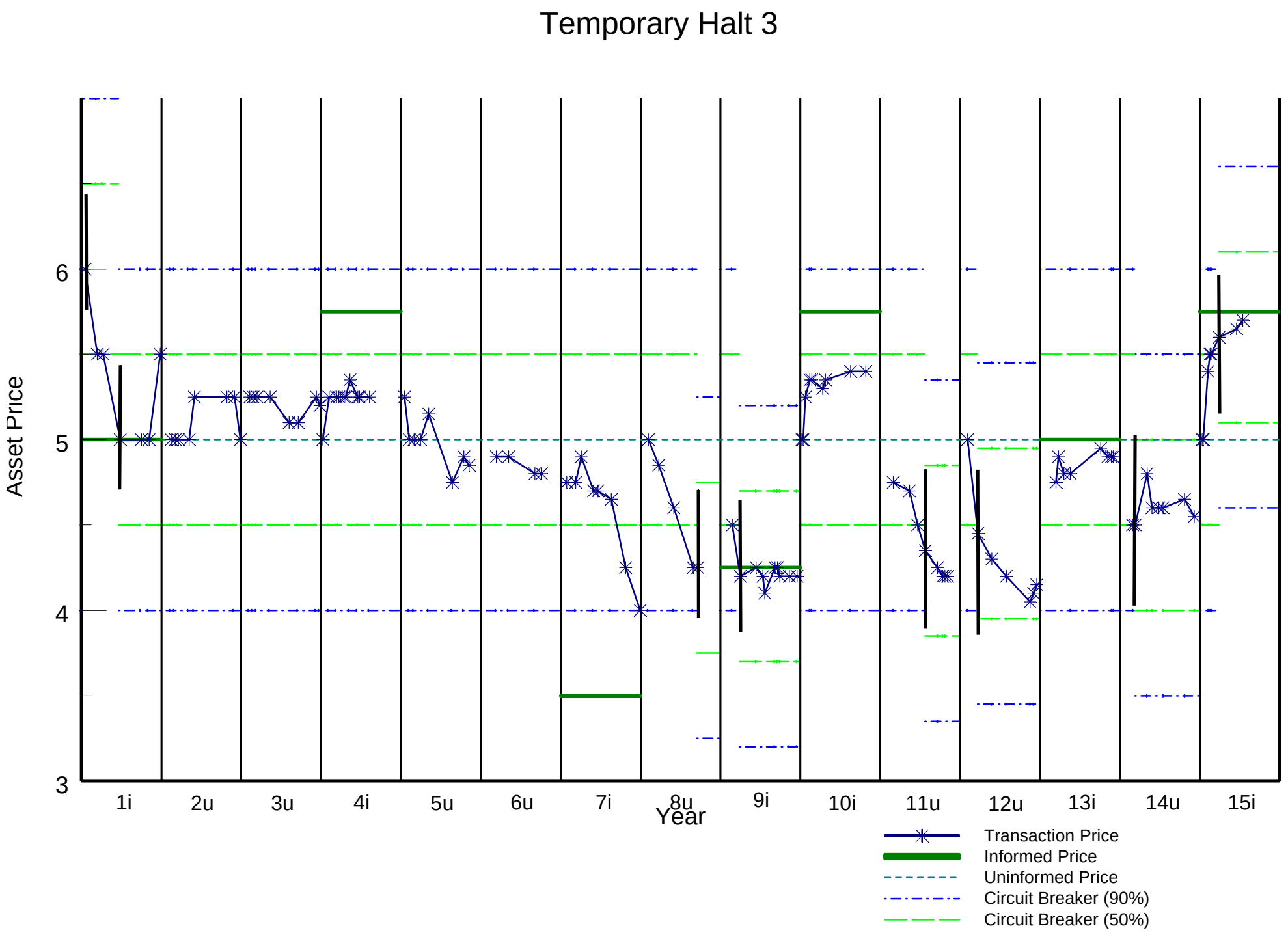
Circuit Breaker (50%)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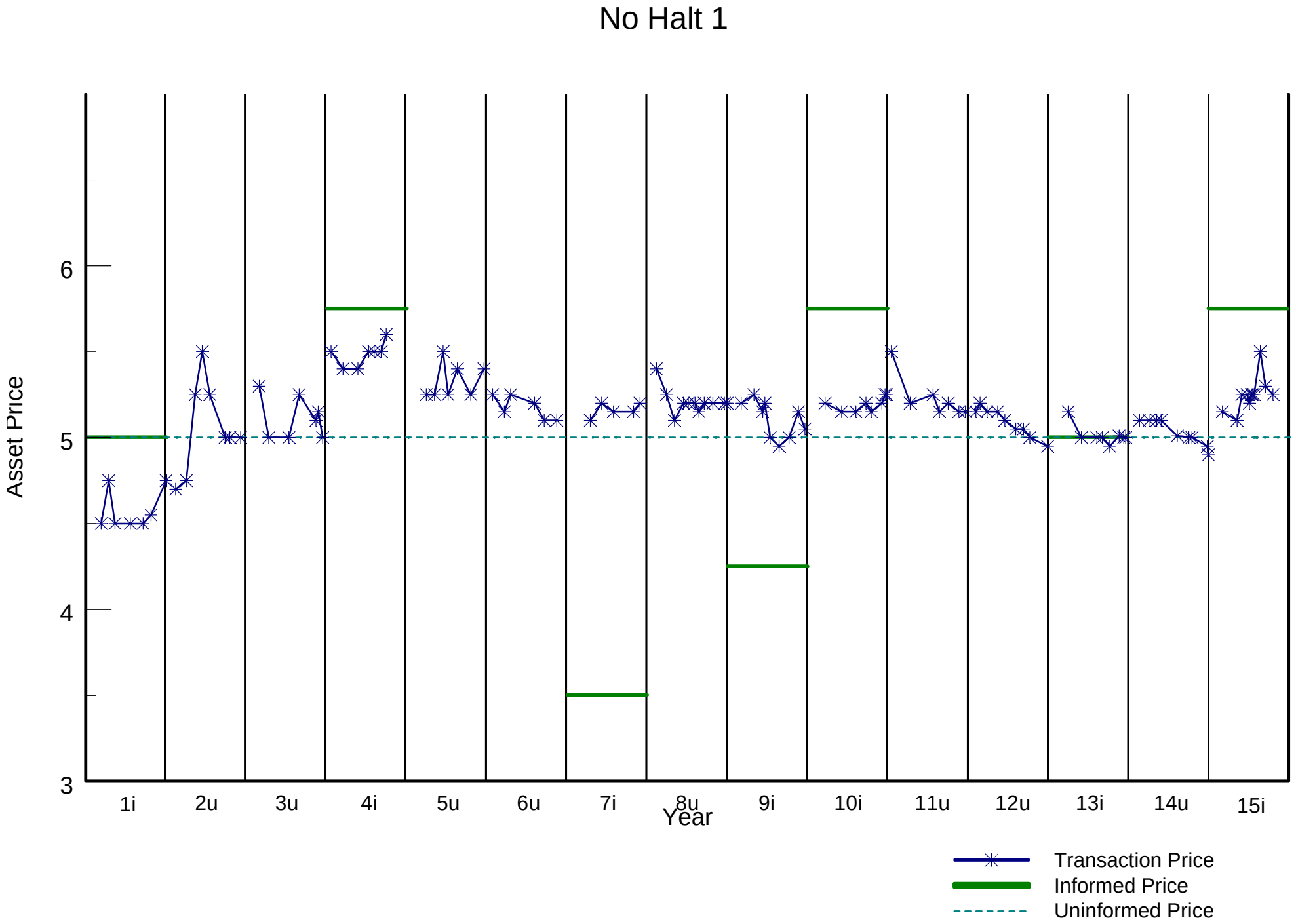
Circuit Breaker (90%)
Circuit Breaker (50%)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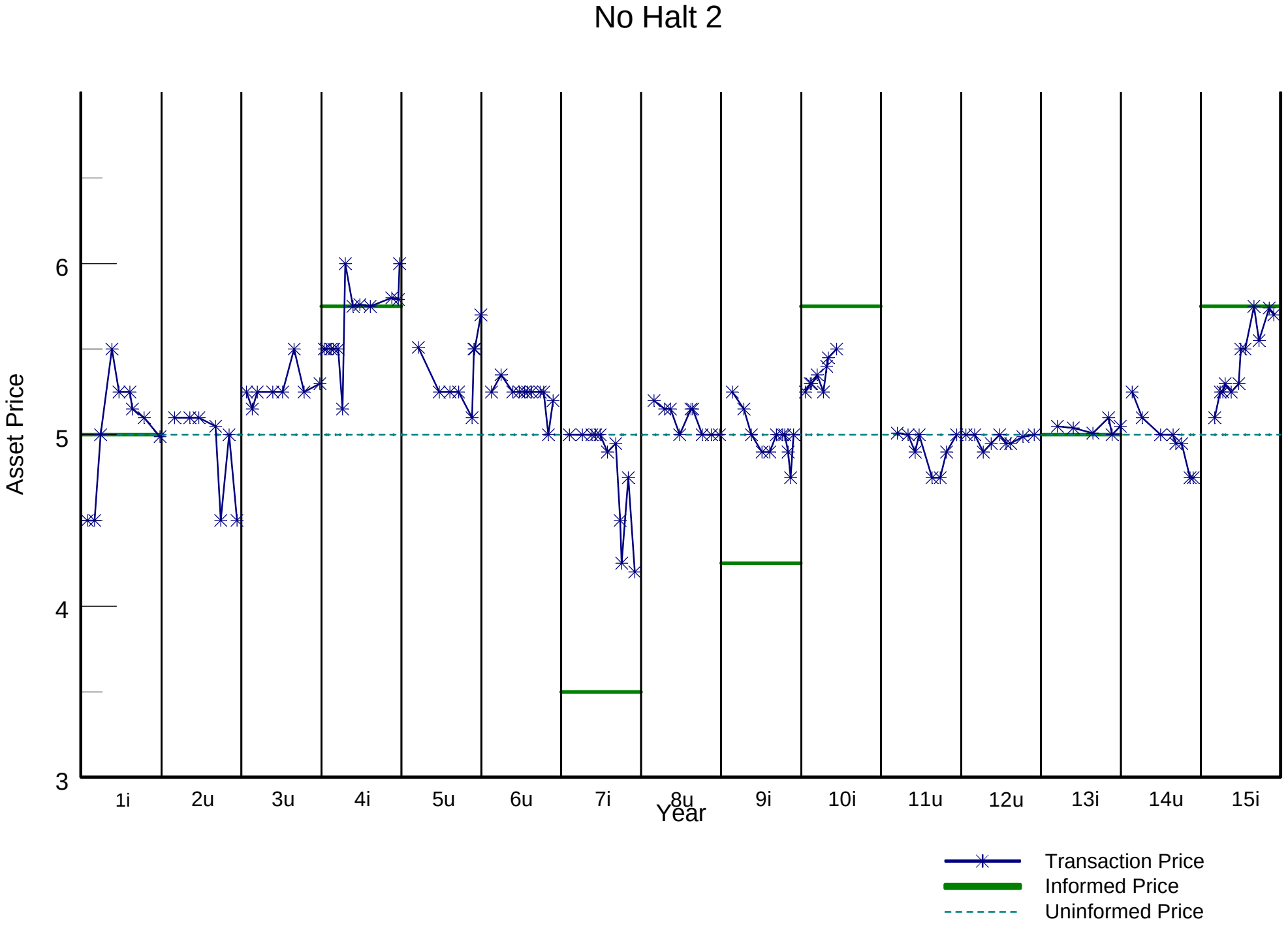
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Year
Transaction Price
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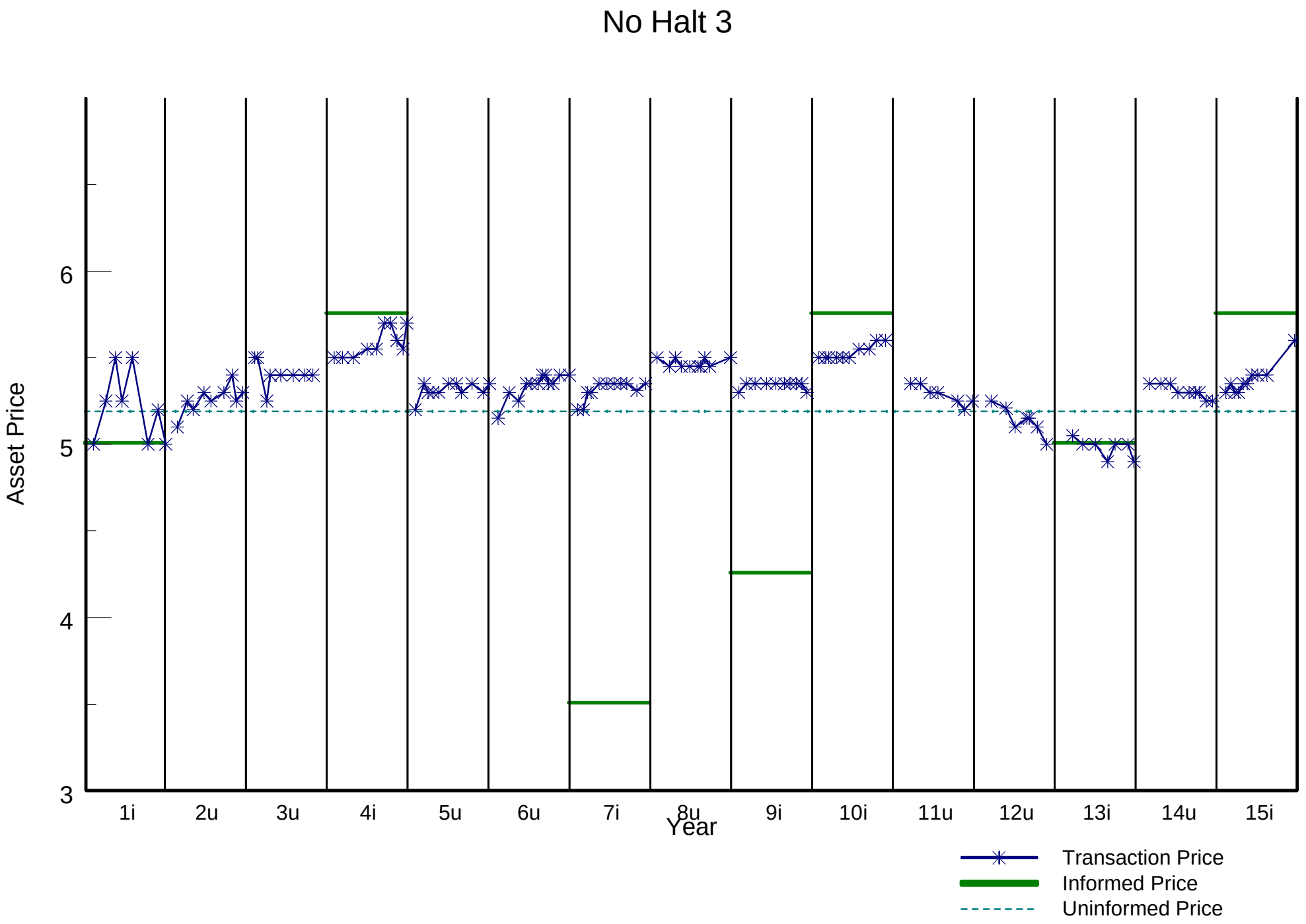
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Table 1
Experimental Overview

In Panel A, the table shows the market regimes used across the experimental sessions. The circuit breaker rule that corresponds to each regime also is described. In Panel B, the table presents the number of informed traders and the dividend per period. The likelihood that two of eight traders are privately informed of the dividend in a given period is 50 percent. The dividend per period is determined by drawing from a distribution in which 3.50, 4.25, 5.00, 5.75, and 6.50 are equally likely. Across all market sessions, half the traders pay a zero tax rate on dividend earnings and half pay a 30 percent tax rate. Informed traders always have a zero tax rate.

Panel A: Market Structure

Market Condition	Market Session	Circuit Breaker Rule
Market Closure	1-3	The probability of market closure is 90 percent if the price changes 20 percent or more in either direction. The probability of market closure is 50 percent if the price changes by at least 10 percent but less than 20 percent.
Temporary Halt	4-6	The probability of a trading halt is 90 percent if the price changes 20 percent or more in either direction. The probability of a trading halt is 50 percent if the price changes by at least 10 percent but less than 20 percent. Trading halts last 30 seconds; however, the breaker is relaxed in the last minute of trading. That is, halts do not occur in the last minute.
No Interruption	7-9	None

Panel B: Pre-selected Fraction of Informed Traders and Dividend Earnings Each Period

Period	Fraction of Informed Traders	Dividend
1	2 of 8	5.00
2	0 of 8	3.50
3	0 of 8	4.25
4	2 of 8	5.75
5	0 of 8	5.00
6	0 of 8	4.25
7	2 of 8	3.50
8	0 of 8	6.50
9	2 of 8	4.25
10	2 of 8	5.75
11	0 of 8	6.50
12	0 of 8	4.25
13	2 of 8	5.00
14	0 of 8	3.50
15	2 of 8	5.75

Table 2
Price and Allocation Predictions

The table presents theoretical price and allocation predictions. If private information is fully disseminated, prices fully reveal information. Five dividend realizations are equally likely ($3.50, $4.25, $5.00, $5.75, $6.50) and half the traders pay a zero tax rate on dividend earnings and the other half pay 30 percent. In some periods two of eight traders are privately informed of the dividend to be paid. Trader types are denoted (T, x) where the tax rate (T) is zero or 30 percent and the trader is informed or uninformed (x = i, u).

Dividend	No Information		Private Information	
	Price	Allocation	Price	Allocation
3.50	5.00	(0,u)	3.50	(0, i or u)
4.25			4.25	
5.00			5.00	
5.75			5.75	
6.50			6.50	

Table 3
Analysis of Price Deviations in Periods Without Private Information

Panel A presents the means and standard deviations of the absolute deviation in asset price from the uninformed price in periods without private information. The measure is computed as the absolute value of the difference between the closing price per period and the uninformed price, normalized by the uninformed price. The data are presented separately for early and late periods. Early periods include 2, 3, 5, and 6 and late periods include 8, 11, 12, and 14. For early periods, Tukey pairwise comparisons indicate that none of the group means are significantly different at conventional levels (in all cases $p > 0.10$). For late periods, the mean of the temporary halt group is significantly different from the means of the other two groups at $p < 0.01$. Panel B presents the frequency of transaction prices that deviate, in absolute terms, from the uninformed price by 10 percent or more and by less than 10 percent (denoted |Dev|). |Dev| is independent of the market condition for early periods ($\chi^2 = 2.42$, $p = 0.298$), but not for late periods ($\chi^2 = 69.84$, $p < 0.001$). Panel C presents the frequency of closing prices per period that deviate, in absolute terms, from the uninformed price by 10 percent or more and by less than 10 percent. |Dev| is independent of the market condition for early periods ($\chi^2 = 2.48$, $p = 0.289$), but not for late periods ($\chi^2 = 7.25$, $p = 0.027$).

Panel A: Normalized, Absolute Price Deviations From Uninformed Price

Market Condition	Mean (Standard Deviation)	
	Early Periods	Late Periods
Market Closure	0.062 (0.058)	0.060 (0.048)
Temporary Halt	0.039 (0.042)	0.126 (0.057)
No Interruption	0.061 (0.041)	0.029 (0.031)

Panel B: Frequency of Deviations in Transaction Prices per Period From Uninformed Price

Market Condition	Early Periods		Late Periods	
	$\|Dev\| \geq 10\%$	$\|Dev\| < 10\%$	$\|Dev\| \geq 10\%$	$\|Dev\| < 10\%$
Market Closure	5	76	8	67
Temporary Halt	12	78	46	42
No Interruption	11	91	5	98

Panel C: Frequency of Deviations in the Closing Price per Period From Informed Price

Market Condition	Early Periods		Late Periods	
	$\|Dev\| \geq 10\%$	$\|Dev\| < 10\%$	$\|Dev\| \geq 10\%$	$\|Dev\| < 10\%$
Market Closure	3	9	5	7
Temporary Halt	2	10	8	4
No Interruption	2	10	1	11

Table 4
Analysis of Price Deviations in Periods With Private Information

Panel A presents the means and standard deviations of the absolute deviation in asset price from the informed price in periods with private information. The measure is computed as the absolute value of the difference between the closing price per period and the informed price, normalized by the informed price. The data are presented separately for early and late periods. Early periods include 1, 4, and 7 and late periods include 9, 10, 13, and 15. For both sets of periods, Tukey pairwise comparisons indicate that none of the group means are significantly different at conventional levels (in all cases $p > 0.10$). Panel B presents the frequency of transaction prices that deviate, in absolute terms, from the informed price by 10 percent or more and by less than 10 percent (denoted |Dev|). For both sets of periods, |Dev| is independent of the market condition ($\chi^2 = 3.94$, $p = 0.140$ for early periods and $\chi^2 = 3.83$, $p = 0.148$ for late periods). Panel C presents the frequency of closing transaction prices per period that deviate, in absolute terms, from the informed price by 10 percent or more and by less than 10 percent. For both sets of periods, |Dev| is independent of the market condition ($\chi^2 = 0.31$, $p = 0.858$ for early periods and $\chi^2 = 1.42$, $p = 0.492$ for late periods).

Panel A: Normalized, Absolute Price Deviations From Informed Price

Market Condition	Mean (Standard Deviation)	
	Early Periods	Late Periods
Market Closure	0.161 (0.160)	0.057 (0.048)
Temporary Halt	0.087 (0.062)	0.033 (0.034)
No Interruption	0.149 (0.212)	0.077 (0.083)

Panel B: Deviation in Transaction Price per Period From Informed Price

Market Condition	Early Periods		Late Periods	
	|Dev| ∃ 10%	|Dev| < 10%	|Dev| ∃ 10%	|Dev| < 10%
Market Closure	31	20	32	47
Temporary Halt	33	42	29	77
No Interruption	37	44	40	70

Panel C: Deviation in the Final Price per Period From Informed Price

Market Condition	Early Periods		Late Periods	
	|Dev| ∃ 10%	|Dev| < 10%	|Dev| ∃ 10%	|Dev| < 10%
Market Closure	4	5	3	9
Temporary Halt	4	5	1	11
No Interruption	3	6	3	9

Table 5
Descriptive Data on Trading Volume and Time per Period

The table presents the average number of transactions per period by market condition. The table also reports the average number of seconds per period that markets in the closure and temporary halt conditions are open for trading. With no interruption, markets are always open 240 seconds, which is the maximum number of seconds per period for trading in all market conditions. The periods with private information are denoted with a superscripted I.

Period	Market Closure		Temporary Halt		No Interruption
	Transactions	Seconds	Transactions	Seconds	Transactions
1^{I}	2.67	101	6.33	220	8.00
2	5.00	166	7.67	240	8.00
3	7.00	208	8.00	220	7.67
4^{I}	5.33	100	10.33	230	10.00
5	7.67	240	8.00	240	8.67
6	7.33	240	6.33	240	9.67
7^{I}	9.00	240	8.33	230	9.00
8	8.67	240	8.00	230	10.00
9^{I}	5.33	138	9.00	230	10.00
10^{I}	6.33	179	9.33	230	8.67
11	3.33	107	7.67	210	7.33
12	5.00	173	7.33	220	8.33
13^{I}	8.00	240	8.33	240	7.00
14	8.00	204	6.33	220	8.67
15^{I}	6.67	117	8.67	230	11.00
Average	6.34	180	8.00	229	8.80

Table 6
Analysis of Trading Volume Normalized by the Time the Market is Open

Panel A presents the means and standard deviations of the normalized trading volume per period in periods without private information. The normalized trading volume is the number of transactions per period divided by the number of seconds that the market period is open. The data are presented separately for early and late periods. Early periods include 2, 3, 5, and 6 and late periods include 8, 11, 12, and 14. For both sets of periods, Tukey pairwise comparisons indicate that none of the group means differ significantly at conventional levels (in all cases $p > 0.10$). Panel B presents the means and standard deviations of trading volume per period in periods with private information. The data are presented separately for early and late periods. For both sets of periods, Tukey pairwise comparisons indicate that none of the group means differ significantly at conventional levels (in all cases $p > 0.10$).

Panel A: Normalized Volume per Period in Periods Without Private Information

Market Condition	Mean (Standard Deviation)	
	Early Periods	Late Periods
Market Closure	0.038 (0.024)	0.037 (0.012)
Temporary Halt	0.032 (0.007)	0.033 (0.006)
No Interruption	0.035 (0.008)	0.036 (0.005)

Panel B: Normalized Volume per Period in Periods With Private Information

Market Condition	Mean (Standard Deviation)	
	Early Periods	Late Periods
Market Closure	0.071 (0.064)	0.053 (0.030)
Temporary Halt	0.037 (0.009)	0.038 (0.005)
No Interruption	0.038 (0.014)	0.038 (0.008)

Table 7
Analysis of Allocative Efficiency

Panel A presents the means and standard deviations of allocative efficiency per period in periods without private information. Allocative efficiency is defined as the proportion of certificates held by traders with a zero tax rate. The data are presented separately for early and late periods. Early periods include 2, 3, 5, and 6 and late periods include 8, 11, 12, and 14. For early periods, Tukey pairwise comparisons indicate that none of the group means differ significantly at conventional levels (in all cases $p > 0.10$). For late periods, the mean of the market closure group is significantly different from that of the temporary halt group at $p = 0.067$. Panel B presents the means and standard deviations of allocative efficiency per period in periods with private information. The data are presented separately for early and late periods. Early periods include 1, 4, and 7 and late periods include 9, 10, 13, and 15. For early periods, Tukey pairwise comparisons indicate that none of the group means differ significantly at conventional levels (in all cases $p > 0.10$). For late periods, the mean of the market closure group is significantly different from that of the temporary halt group at $p = 0.014$.

Panel A: Periods Without Private Information

Market Condition	Mean (Standard Deviation)	
	Early Periods	Late Periods
Market Closure	0.766 (0.183)	0.771 (0.181)
Temporary Halt	0.833 (0.147)	0.912 (0.095)
No Interruption	0.750 (0.148)	0.800 (0.156)

Panel B: Periods With Private Information

Market Condition	Mean (Standard Deviation)	
	Early Periods	Late Periods
Market Closure	0.681 (0.218)	0.766 (0.215)
Temporary Halt	0.847 (0.160)	0.969 (0.063)
No Interruption	0.694 (0.241)	0.839 (0.182)

Endnotes

[1] We focus on market-wide mandated trading halts triggered by extreme market movements. Other trading restrictions include the NYSE's Rule 80A restricting stock index arbitrage, the price limits commonly imposed in futures markets, and firm-specific trading halts called in response to order flow imbalances or pending news releases.

[2] Other empirical research examines whether trading restrictions (e.g., firm-specific trading halts and price limits) affect price volatility and market efficiencies. The results are inconclusive. For example, while some researchers argue that trading restrictions reduce volatility (Ma, Rao, and Sears (1989a, 1989b)), others find that volatility increases (Lee, Ready, Seguin (1994)), and still others find little effect on the market in the long run (Overdahl and McMillan (1998)).

[3] Bakshi and Madan (1999) provide a theoretical and empirical investigation of the economics of stock market crashes. Using a long time series of daily data on the DJIA, they document that the probability of a daily stock price decline in excess of five percent is about 25 percent. Booth and Broussard (1998) also investigate the stochastic behavior of large movements in the DJIA and estimate the probability that a circuit breaker will be triggered. If the circuit breaker is kept at its current initial level of ten percent, it is likely to be triggered once every 6.38 periods (Table 3, p. 198).

[4] Four mirages are characterized as sustained and nine as temporary. The distinction is made on the basis of whether the mirage persists throughout the entire period or only part of the period.

[5] Models of cascades proposed in the literature are applicable in numerous contexts. For example, Welch (1992) provides an application to the IPO market. When IPO shares are sold sequentially, imitation is optimal and cascades result because investors can learn from the purchasing behavior of others.

[6] The instructions are available from the authors upon request.

[7] See Cason and Friedman (1996) on the benefits of using a pre-selected sequence.

[8] Although the U.S. circuit breaker rule only calls for trading interruptions when there are downward price movements, circuit breakers can be activated if there is a dramatic upward price movement in some foreign markets. For example, the Russian stock market closed half an hour early on January 1, 2000 as the RTS1-Interfax index soared 16.83% after Boris Yeltsin announced his resignation (The World's Markets: Moscow).

[9] Participants' responses to the post-experiment questionnaire suggest that they found the experiment interesting and the monetary incentives motivating. Participants responded on a

seven-point scale as to how interesting they found the experiment, where 1 = not very interesting and 7 = very interesting. The mean response was 6.11. Participants also responded on a seven-point scale as to how they would characterize the amount of money earned for taking part in the experiment, where 1 = nominal amount and 7 = considerable amount. The mean response was 5.15.

[10] In one of nine periods, no further transactions occurred once the market reopened.

[11] The results are virtually identical if the rule is modified so that only *two* consecutive trades are required at prices that produce absolute deviations from the uninformed expectation of at least 10 percent (*and* the closing price per period produces an absolute deviation of at least 15 percent). In the 24 periods without private information, the rule is satisfied once in the market closure condition, eight times in the temporary halt condition, and never in the no interruption condition. The χ^2-statistic of 14.48 is significant at $p = 0.001$.

[12] Notably, the mean of the temporary halt condition is generally less than those of the other two conditions, though not significantly different. Further examination of the data suggests that when the informed price is less than the uninformed price, asset prices do not always adjust to reflect the informed price in the market closure and no interruption conditions. By comparison, when the informed price is greater than the uninformed price, asset prices typically adjust to reflect the informed price. These results produce the relatively high standard deviations in the early periods for the market closure and no interruption conditions (refer to Panel A of Table 4).

[13] Recall that temporary halts cannot be triggered in the last minute of trading. Thus, draws do not necessarily occur if the transaction price lies outside the breaker boundaries. We identify three periods in which transactions occur in the last minute at prices outside the breaker boundaries.

[14] In addition, we perform a repeated measures ANOVA. The independent variables include market condition, period, and an interaction term. The dependent variable is the normalized trading volume per period for each session. We find that market condition is not significant at conventional levels ($F = 0.49$, $p = 0.634$).

[15] Again we perform a repeated measures ANOVA. We find that normalized trading volume is not affected by market condition ($F = 1.97$, $p = 0.220$).

[16] Though not reported, the results are similar using nonparametric, Wilcoxon matched-pairs tests.

[17] We also examine the relative profitability of informed and uninformed traders. Ackert, Church, and Jayaraman report that the distribution of trading profit among agents is not affected by a circuit breaker rule and, over, time, the wealth of informed and uninformed agents does not differ. We also find that the market condition has no significant impact on profit. However,

informed agents are able to exploit uninformed agents and generate greater wealth, unlike the markets of Ackert, Church, and Jayaraman. This finding is not surprising because, in our markets, private information perfectly reveals asset value.