Rate-of-return parity in Experimental Asset Markets

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Abstract

This paper applies experimental methods to evaluate the completeness of arbitrage and rate-of-return parity in simultaneous asset markets in which the assets are denominated in different currencies. Two assets, which return uncertain, but known, dividends in each trading period, are traded over twenty periods, after which the asset has no value. Results indicate that risk neutral rate-of-return parity is a strong predictor of relative asset prices when assets have common expected dividends and the expected dividends have common variances. The predictive power of risk neutral rate-of-return parity is reduced as the assets become differentiated.

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1. Introduction

Rate-of-return parity states that the return on two assets will be equalized due to arbitrage. When the assets are denominated in different currencies, expected changes in the exchange rate must be taken into account. When applied to the safest financial instruments the result is uncovered interest rate parity. The empirical support for uncovered interest-rate parity is mixed. Ayuso and Restoy (1996), Chinn and Meredith (2004) and Dutton (1993) find cause to support uncovered interest-rate parity, while Fama (1984) and Mayfield and Murphy (1992) do not.

It is difficult to control for factors that may confound the observation of rate-of-return parity. There are at least three major confounding factors. One factor is the difficulty of capturing expectations. Current methods for estimating expectations are fraught with difficulties. A large number of factors could impact expectations (Froot and Frankel, 1989a). The factors that could impact expectations are not limited to those based on a rational model of exchange rates. Weather, political issues, prices of fundamental inputs, and the mood of investors may all play a roll in determining expectations. There also is the potential inconsistency between objective and subjective probabilities. This makes it difficult to identify the expectations held by individuals considering engaging in international arbitrage (Fama, 1984; Mayfield and Murphy, 1992).

Another confounding factor is the lack of perfectly identical financial instruments. If the instruments being considered are neither perfectly identical nor seen to be perfectly identical by investors, rate-of-return parity cannot be confirmed without first measuring and accounting for these differences. This is non-trivial, and has been acknowledged in investigations of uncovered interest rate parity through the use of identical or as close to identical assets as possible.

The third factor is friction in capital and goods markets (Obstfeld and Rogoff, 2000). Trades in these markets often involve substantial risk, uncertainty and significant transaction costs. These must be taken into consideration before rate-of-return parity can be accepted or rejected.

Different authors have taken different approaches to addressing the confounding factors ex post in international financial market data. These different approaches have lead to different conclusions depending on the method employed and the data used. Previous methods apply variations of the underlying premise that confounding factors must be dealt with ex post. This assumes that there is no source of data in which these confounding factors do not arise. This is not the case. It is possible to generate data that avoid these confounding factors.

An attempt to generate data that avoid confounding factors was undertaken by Benzion et al. (1994), who use survey data to capture the expectations and discount rates of individuals with respect to real assets. Their results do not support rate-of-return parity. Frankel and Froot (1987) and Froot and Frankel (1989b) use survey data to explore exchange rate predictions, a closely related topic.

The weakness of using surveys to collect data on expectations is that the questions are hypothetical. The participant does not have to suffer (or enjoy) the consequences of whatever action she says she would take in response to the scenario described in the survey. A laboratory environment in which participants receive experimenter induced rewards related to actions and in which changes in the participants' rewards come primarily from experimenter-induced rewards avoids the weakness of surveys.[1]

A laboratory environment can be created to reduce confounding factors and control unavoidable ones. Exchange rates can be fixed with certainty, asset dividends can be well defined, and the information to which traders have access can be known by the experimenter. If rate-of-return parity is observed in an environment free of confounding issues, and in which participants' actions are motivated by salient and dominant rewards, support can be lent to the basic principle behind uncovered interest rate parity as a real phenomenon.

Smith, Suchanek and Williams (1988, SSW hereafter) report a double auction experiment designed to examine the price behaviour of an asset which provided an uncertain dividend in a each of a series of time periods. In this environment there are two assets, currency and the dividend-bearing asset. Risk-neutral expected-profit maximizing traders will engage in no trades, bids and asks in each period will approach the sum of expected dividends over the remaining periods. SSW, as well as those who follow, find prices differ from the risk-neutral expected value of dividend streams.[2] In general, experiments with inexperienced subjects display price bubbles and crashes. In the early periods of a market session the dividend-paying asset trades below the risk-neutral value of the expected dividend stream. In the middle periods the asset typically trades at a price in excess its risk-neutral value. In the final periods, the asset trades for less than the risk-neutral expected value of the dividend stream. The implication is that rate-of-return parity between laboratory currency and the dividend paying asset is not observed. This is generally described as a failure of inter-temporal arbitrage or a rejection of risk-neutral pricing.

This sort of environment does not capture one of the essential characteristics of tests of rate-of-return parity when applied as uncovered interest rate parity: the requirement that the assets in question must be as close to identical as possible. One asset pays a dividend each period and the other does not. A laboratory environment with two dividend-paying assets is required to evaluate rate-of-return parity. Fisher and Kelly (2000, hereafter FK) were the first to use this environment.

FK create an environment in which two assets paying uncertain dividends every period are traded in separate simultaneous double-auction markets. These markets are linked by a *common currency*. The authors argue that the relative asset prices constitute the exchange rate in this environment, and support for rate-of-return parity can be observed if the relative asset prices conform to the value predicted by the nature of the two assets. FK report price bubbles, thus rate-of-return parity between the assets that pay dividends and the currency is not observed. Rate-of-return parity is observed between the two assets that pay dividends. This result is of vital importance for the application of rate-of-return parity. Rate-of-return parity can hold between two assets even if risk-neutral expected-dividend pricing is not obtained. Rate-of-return parity is not dependent on a specific relationship between the price of the asset and its dividend value but the relationship between the prices of two assets.

Some of the characteristics of the FK design can be improved to sharpen their results. First, a common currency should be avoided. This may have created too strong a link between the assets that pay dividends in the minds of subjects. Rate-of-return parity is often applied to assets denominated in different currencies and this aspect can be recreated in the laboratory. Second, mixing experienced and inexperienced traders should be avoided, unless this is a specific treatment variable. SSW show that subject experience has a significant impact on rate-of-return parity between currency and a dividend-paying asset in the laboratory. Mixing participants with different trading experience as in FK confounds the impact of the treatment variables and trader experience. Finally, an unbalanced design should be avoided. While this can be dealt with using statistical techniques, the main purpose of conducting laboratory experiments was to limit the impact of confounding factors and the need for advanced statistical techniques.

The research presented in this paper is a systematic evaluation of rate-of-return parity in an environment that, while complete, is relatively free of confounding factors. To reduce the number of confounding factors the exchange rate between the two currencies is fixed and known to all traders, the distribution of potential dividends to each asset is known to all traders (as are expected dividends and the variances of the expected dividends), and the number of trading periods is known to all traders. Treatment variables are the expected dividends of each dividend-paying asset and the variance of the expected dividend of these assets. There are four different scenarios studied in the laboratory: identical dividend paying assets, assets with identical expected dividends but different variances, assets with identical variances but different expected dividends, and assets with different expected dividends and different variances. The maintained hypothesis of this essay is that all gains from arbitrage will be realized when the assets are traded simultaneously. The general findings are that arbitrage is complete in simple laboratory environments, but declines as assets become differentiated. This suggests that in a world much more complex than the laboratory, the assumption of complete arbitrage and rate-of-return parity may lead to erroneous predictions.

2. Theory and Predictions

Consider two different countries with identical dividend-paying assets that could be held by investors. Assume that the exchange rate between the two countries is perfectly fixed. Assume the asset in country A pays a return of 10% and the asset in country B pays a return of 5%. If both assets are available to investors they will choose to invest in the country A asset. The increased demand for the country A asset causes an increase in its price, thereby reducing the return. The demand for the country B asset falls, reducing its price and increasing its return. If this did not to occur investors would not be maximizing their returns. In a world of exchange rates that are not perfectly fixed, expected changes in the exchange rate must be taken into consideration. This leads to the common approximation of rate-of-return parity used in open economy macroeconomics

$$i = i^* + E(\Delta e) \tag{1}$$

where i is the domestic interest rate, i^* is the foreign interest rate, E is the standard expectations operator, and Δe is the change in the exchange rate. The implication of equation (1) is that the return on holding the two assets is equalized once accounting for the expected change in the exchange rate.

The environment of SSW makes the question of rate-of-return parity surprisingly simple. In their environment there are two assets, one that pays a dividend with a known expected value and another that pays a dividend of zero with certainty (currency). Rate-of-return parity in this environment requires no difference in the expected return to holding either asset and as both assets are priced in the same currency the exchange rate cannot change. Given the return to holding currency is zero with certainty, the expected return to holding the dividend paying asset will be zero.

This application of rate-of-return parity is often discussed in terms of backward induction or inter-temporal arbitrage. Consider the last period of an experimental session in the SSW environment. Subjects know that the asset will pay no dividends after this period. The only rational risk-neutral price is the risk-neutral expected value of that period’s dividend. If the dividend-paying asset were to sell for a greater price, a risk-neutral payoff-maximizing individual would sell any dividend-paying assets held. The same individual would also buy dividend-paying assets if the price were lower than the risk-neutral expected dividend. If all individuals are risk-neutral expected-payoff maximizing, the price of the dividend paying asset must be the risk-neutral expected-value of dividends in the final period. In the second last period of the game, this reasoning predicts that the price of the asset will be two times the risk neutral expected dividend value, therefore

$$p_t = (T - t + 1)E(d) \tag{2}$$

where T is the known number of periods in the session, t is the current period and $E(d)$ is the risk neutral expected dividend paid on the asset.

This prediction is not generally supported in the laboratory. SSW find price bubbles and crashes. The failure of rate-of-return parity in this environment may be due to a failure of backward induction. In general backward induction is not supported in experimental literature. De Long et al. (1990) provide an overlapping generations framework in which noise traders are the cause of deviations from fundamental values. This is not the only explanation. The existence of price bubbles does not necessarily negate the possibility of rational behaviour (Chakrabarti and Roll, 1999). Further, the failure of this application of rate-of-return parity does not preclude the possibility of rate-of-return parity in other situations.

The environment used by SSW is not an ideal testing ground for rate-of-return parity. One asset had a return of zero with certainty while the other asset had an uncertain return with a positive expected value. It is clear from caveats in international finance that rate-of-return parity is intended to be applied to assets that are as similar as possible. This is the main contribution of the work by FK, who create an environment in which three different assets are traded in simultaneous double-auction markets. In this environment there are two assets that pay dividends and a single currency. This environment captures an important element of rate-of-return parity, the comparability of assets. The nature of the dividends paid by either asset is also variable, thus the comparability of assets can be altered to make assets identical or slightly differentiated.

The application of rate-of-return parity to this type of environment requires an extension of the definition of return. In keeping with Chakrabarti and Roll (1999) allowance must be made for capital gains. If the return of an asset includes both potential capital gains and dividends

$$p_t = E(d + p_{t+1}) \qquad \text{for } t = 1, ..., T - 1 \tag{3}$$

Under this application of rate-of-return parity, no restriction is placed on the price of the asset unless the expected capital gain is known. If backward induction is perfect all subjects will have expected capital gains of zero, in which case equation (3) collapses to equation (2).

Equation (3) considers rate-of-return parity between assets that pay unknown dividends and currency which pays a dividend of zero with certainty. There is another pairing of assets to which rate-of-return parity must be applied. Rate-of-return parity must be applied to the two assets that pay dividends. Applying rate-of-return parity to this pairing is more complex, as the rate of return need not be equal to zero. Consider

$$R_{t,\,j} = E(d_j + p_{t+1,\,j})/\,p_{t,\,j} \tag{4}$$

where $R_{t,\,j}$ is the gross rate of return to asset j at time t. Rate-of-return parity requires that the rates of return for all assets be equal, or

$$E(d_j)/\,p_{t,\,j} \ - \ E(d_k)/\,p_{t,k} \ = \ E(\,p_{t+1,k})/\,p_{t,k} \ - \ E(p_{t+1,\,j})/\,p_{t,\,j} \tag{5}$$

where any difference in expected dividends relative to the prices of assets must be equal to the difference in expected capital gains relative to the prices of the assets. Then

$$p_{t,\,j} = [E(d_j\,)/\,E(d_k\,)]\; p_{t,\,k} \tag{6}$$

This result does not require backward induction. The same result can be achieved if agents believe that capital gains relative to prices will be equal. This provides a possible explanation for the requirement of identical assets. If assets are dissimilar, there may be little reason for agents to believe capital gains will be equal.

FK report a number of important findings. First, when traders are inexperienced, risk-neutral rate-of-return parity is not observed between the assets that pay dividends and currency: equation (2) is not observed to hold. Prices of both dividend paying assets behave in the bubble and crash manner described by SSW. Second, prices of the two dividend paying assets are highly related. Equation (6) is observed to hold. In treatments with identical dividend paying assets, rate-of-return parity is strongly observed. As the dividend structure of the assets becomes more differentiated, the degree of rate-of-return parity is reduced.

FK can be improved upon. First, in some treatments all subjects were inexperienced and in others a mixture of experienced and inexperienced subjects are used. This fact will confound the treatment effects. The experimental design can also be improved. The design used by FK is not fully factorial. All relevant aspects of the dividend paying assets are not fully interacted. The authors conduct 6 sets of sessions. For two sets (1 and 6), the expected dividends of the two assets are identical and the variances of dividends are identical. For three sets (3, 4 and 5) both expected dividends and variances differ across assets, but only for set 3 does any one asset have characteristics comparable to the characteristics of either asset in set 1 and 6. Set 2 contains only one session, whose assets are identical to those in set 3, but the dividends paid to the two assets are perfectly correlated. While this paper is particularly valuable as the first presentation of a two-asset double-auction market in a laboratory setting and it provides an introduction to identification of rate-of-return parity in laboratory environments, it does not provide a systematic study of the effects of increasingly complex environments on rate-of-return parity in the laboratory.

The purpose of this paper is to extend the examination of rate-of-return parity in a laboratory environment to discover how changes in dividend structure affect the ability of participants in laboratory double-auction asset markets to realize arbitrage opportunities and permit rate-of-return parity to emerge.

This research begins with three predictions based the theory underlying rate-of-return parity and observations of previous laboratory asset markets:

PREDICTION 1: *Rate-of-return parity will not be observed between dividend paying assets and currency. Equation (2) will not describe the prices of the dividend-paying assets.*

PREDICTION 2: *Rate-of-return parity will be observed between identical assets. Equation (6) will describe the relationship between the prices of identical dividend-paying assets.*

PREDICTION 3: *Rate-of-return parity between dividend-paying assets will fail as the assets become more differentiated with regard to expected dividend and variance.*

Prediction 2 states that uncovered rate-of-return parity will hold when assets are identical. Prediction 3, however, states that uncovered interest rate parity will be weakened by differences in the assets.

3. Experimental Environment

The experiment consists of twelve simultaneous double-auction asset market sessions run at the

McMaster Experimental Economics Laboratory. Three sessions were run for each of four treatments. Ten subjects recruited from the student population of McMaster University participated in each session. The subjects had not participated in any other session of the experiment. Payoffs to subjects ranged from $12.25 to $104.50, with a mean of $38.45 and a standard deviation of $21.19. Key components of the laboratory environment are: the markets, the behaviour of the exchange rate, the nature of the assets, and the endowments of subjects. Each of these aspects, as well as the overall experimental design are discussed in turn.

The Markets

International capital markets may be characterized as double-auction markets; this is the market institution used in the experiments discussed in Section 2. A market for Blue assets using Blue dollars as the medium of exchange and a market for Red assets using Red dollars as a medium of exchange were conducted simultaneously in a computer mediated environment.[3] Each subject had the ability to act as a trader of assets in each of the two asset markets. The assets paid uncertain, but well-defined, dividends at the end of each trading period. Specific dividend structures are the bases of the four different treatments. Instructions were distributed to each subject and then read aloud at the beginning of each session. These instructions fully describe to subjects how to enter bids and asks, as well as how to accept an outstanding bid or ask.[4] At the end of each session, subjects' final holdings of Blue dollars were converted into Red dollars at the fixed exchange rate. Subjects' holdings of Red dollars were then converted into Canadian dollars ($C) at a previously announced conversion rate.[5]

Exchange Rate Behaviour

In order to limit the number of possible confounding factors in the laboratory environment the exchange rate between the two currencies was fixed and not subject to change. The exchange rate was fixed at 1 Red dollar for 1 Blue dollar. Subjects were informed that this exchange rate would not change. This creates an environment comparable to that created by Fisher and Kelly (2000). The existence of separate currencies and a perfectly fixed exchange rate can be viewed as a framing feature.[6] In this environment, traders must exchange currencies, and have sufficient Red or Blue dollars to engage in transactions.[7]

The Nature of Assets

The majority of FK's treatments and all of the seminal asset market work of SSW use assets with four possible dividends.[8] The experiment presented in this paper is intended to be as simple as possible but still capture the risky nature of financial assets. Thus, assets paid one of only two possible dividends, high or low. The likelihood of the high dividend was fifty percent in all treatments.

The four treatments of the experiment are based on the potential dividends for the Red and Blue assets. There are two key characteristics of the potential dividends, expected value and variance. In any pairing of assets these two characteristics can either be identical or different. These characteristics are fully interacted in a factorial design.

In Treatment 1 the Red and Blue assets have identical potential dividends. The high and low dividend values are identical. In Treatment 2 the dividends of both the Red and Blue assets had the same expected value, but the expected dividend of the Blue asset had a higher variance, and consequently the Blue asset was riskier than the Red. This treatment tests the impact of asset specific risk on rate-of-return parity. In Treatment 3 the expected dividend paid to those subjects holding the Blue asset was greater than the expected dividend of the Red asset. However, the variance of the dividends paid to holders of both assets was the same. In Treatment 4 the expected dividend of the Blue asset was higher than the Red asset, but the dividend of the Blue asset also had a higher variance. The absolute difference between the variances is the same as in Treatment 2 and the difference between expected dividends is the same as Treatment 3. The Blue asset was riskier than the Red asset, but provided a greater return. This treatment allows the consideration of the impact of very dissimilar assets on rate-of-return parity. The possible dividends and differences in variances are reported in Table 1 in terms of the Red or Blue currency respectively.

In each treatment the dividends paid on Red and Blue assets are independent. In all treatments the dividend values are determined by the rolls of coloured dice. A red die was rolled to determine the dividend of the Red asset and a blue die was rolled to determine the dividend of the Blue asset. The rolls and respective dividends were recorded on a chalk board at the front of the laboratory in appropriately coloured chalk. The treatments of the factorial design are summarized in Table 2. Each of the treatment parameters is fully interacted with the others.

Endowments

In each treatment there were two endowment groups. One group received more Red dollars than Blue dollars and more Blue assets than Red assets. The other received more Blue dollars than Red dollars and more Red assets than Blue assets. The endowments are shown in Table 3. In each treatment the endowments to each group of traders have the same expected values if subjects did not trade (or if rate-of-return parity is observed between currencies and dividend paying assets).

4. Empirical Results

The laboratory sessions generate a large number of contract observations. The analysis of the data will proceed in two stages. First, conclusions are based on a visual inspections of the average transaction prices in each trading period. Second, in order to avoid the confounding issues of possible interdependence of observations, statistical analysis is performed using a single aggregated observation per session.

Visual Analysis

The left-hand panels of Figures 1-4 display the mean contract price data for each period in each of the twelve sessions of the experiment. The lines (solid or broken) without symbols represent the asset prices in each period as predicted by equation (2). The connected circles and triangles represent the average contract prices in each period. In all but one session, the bubble and crash pattern is observed. This is visual evidence that rate-of-return parity between the dividend paying assets and the corresponding currencies is not observed. This result is identical to that observed by SSW, FK and others when subjects have no previous experience and supports Prediction 1, rate-of-return parity between dividend paying assets and currency will not be observed.

Prediction 2 states that rate-of-return parity, as described by equation (6), will be observed between the dividend paying assets with similar dividend structures. In Treatment 1 the dividend structures of the assets are identical. Equation (6) predicts that the prices of the two dividend paying assets will be identical. The prices of the dividend paying assets shown in Figure 1 are indistinguishable. The deviations from rate-of-return parity (prediction errors) shown in the right-hand panels of Figure 1 show little difference from zero.[9] Therefore, rate-of-return parity is visually supported in this treatment.

In Treatment 2 dividend paying assets had the same expected dividend with different variances. Equation (6) does not include differences in the variance (and therefore risk) of the assets, and predicts that the prices of the dividend-paying assets will be equal. The dividend-paying asset price series shown in Figure 2, are very similar in each session. The right hand panels show slightly more deviation from zero than Treatment 1, but these deviations tend to be small and short lived. Thus, Prediction 2 is visually supported in this treatment. This is surprising as the existence of differences in risk is often cited as a cause of failure to observe rate-of-return parity (Franchot, 1996).

In Treatment 3 assets have different expected dividends. Based on the ratio of dividends in this treatment, rate-of-return parity predicts the price of the Blue asset will be 1.3 times the price of the Red asset. The right-hand panels of Figure 3 show more deviation from rate-or-return parity than found in Treatments 1 and 2. The tendency in sessions 3.1 and 3.2 is for adjustment towards price equality. The data do not provide support for rate-of-return parity.

Treatment 4 considers assets that differ in both expected dividend and variance of dividends. Rate-of-return parity predicts the price of the Blue asset will be 1.3 times the price of the Red asset. The results are mixed with one session showing price behaviour that is close to rate-of-return parity, one far from it and one that appears to show price convergence. Again, the data do not provide support for rate-of-return parity.

The least complex environment is Treatment 1. Treatments 2 and 3 are slightly more complex, with the assets differing in one dimension. In Treatment 4 the assets differ in two dimensions. Prediction 2 suggests that rate-or-return parity will be observed in Treatment 1. This is supported by the data. The data suggest that the introduction of risk without changing expected dividends does not appreciably impede the realization of rate-of-return parity. However, when they have different expected dividends, rate-of-return parity is less likely to be observed. Based on the visual analysis of the data, the simple environments to which Prediction 2 refers may be restricted to those in which assets have identical expected dividends (but not necessarily identical distributions of potential dividends). The more complex environments to which Prediction 3 refers may be those in which the expected dividends differ across assets. The next section presents an analysis of statistics obtained from the price data.

Statistical Analysis

Table 4 displays median Blue asset price prediction errors by treatment and session. Table 4 also includes the means and standard deviations of the median values. Median predictions errors, rather than means, are selected to characterize each session to minimize the effect of extreme values on the summary statistic. Table 5 reports the means of the absolute values of the session prediction errors by treatment and Table 6 presents the results of an OLS regression using the session median data from Table 4 and dummies representing asset dividend and variance characteristics.[10]

Tables 4 and 5 indicate that when Red and Blue assets have identical dividend structures the median prediction errors are very small (between 0 and 3.97 Blue dollars). However, when expected dividend variances differ, prediction error increases (between 6.12 and 15.13 Blue dollars). If expected dividends differ for the Blue and Red assets, the magnitudes of the prediction errors increase substantially (between 18.16 and 71.92 Blue dollars).

The regression results in Table 6 permit tests of the hypotheses that the prediction errors in each of Treatments 1 through 4 are inconsistent with rate-of-return parity. The constant term in the regression is the estimate of the deviation of the mean prediction error from rate-of-return parity when Blue and Red assets are identical (Treatment 1). The hypothesis that -0.71 Blue dollars is not different from zero cannot be rejected in favour of the alternative that it is different (p = 0.956). This provides support for observing rate-or-return parity in the laboratory.

When expected dividends are the same for Blue and Red assets, but their variances differ (Treatment 2), the estimate of the deviation of the mean prediction error from rate-of-return parity is -10.833 Blue dollars. The hypothesis that this is not different from zero cannot be rejected in favour of the alternative that it is different (p = 0.794). This suggests that changing only the variance structure of the dividend is not sufficient to interfere with the traders abilities to realize arbitrage opportunities.

If expected dividends differ, while variances are unchanged from those in Treatment 1, the extent to which rate-of-return parity is realized is affected. The estimate of the mean prediction error from rate-or-return parity is -38.51 Blue dollars. The hypothesis that this is not different from zero can be rejected in favour of the alternative that it is different (p = 0.016). Changing the expected dividend structure alone is sufficient to affect traders ability to realize potential arbitrage opportunities.

When both expected dividends and their variances change, we find a significant interaction effect between different dividends and different variances (p = 0.028). The source of the interaction is clear in Table 4. Introducing different variances resulted in the mean prediction error becoming more negative when dividends are the same (-0.71 to -10.83), introducing different variances result in large positive prediction errors in two of three sessions when dividends are different and an change in the mean prediction error from -38.51 to 18.51. Rather than augmenting the effect of the different dividend, it offsets this effect. The hypothesis that 18.51 is not different from zero cannot be rejected in favour of the alternative that it is different (p = 0.178).

An alternate way of evaluating the effects of changing asset characteristics is to consider the absolute deviations of prediction errors from rate-of-return parity. The means of the absolute values of the sessions medians are presented in Table 5. The mean across sessions with the same expected dividends (SD) is 6.39 and the mean across sessions with different dividends (DD) is 34.56. These are significantly different (exact randomization test, p = 0.002). The means across sessions with the same variances (SV) and across sessions with different variances (DV) are 20.22 and 20.73 respectively. These are not significantly different (exact randomization test, p = 0.974).

Regardless of the variance characteristic, going from SD to DD increases the absolute prediction error from rate-of-return parity. However, even when considering the absolute prediction errors, a interaction between DD and DV remains. Given SD, the move from SV to DV results in a significant increase in the mean absolute prediction error from 0.71 to 10.83 (exact randomization test, p = 0.050). Given DD, however, the move from SV to DV does not result in a significant change in the mean prediction error from 38.51 to 30.62 (exact randomization test, p = 0.80).

The statistical results are consistent with the visual inspection of the data presented in Figures 1-4. When both Blue and Red assets have identical dividend structures, arbitrage opportunities are realized by the traders and rate-or-return parity is observed. When the expected dividends of the two assets are identical, but their variances differ, the prediction error from rate-of-return parity increases, but it is not possible to reject the statistical hypothesis that rate-of-return parity holds. When the Blue and Red assets have different expected dividends, regardless of the underlying characteristics of the distribution of potential dividends, the absolute prediction errors increase significantly. The statistical hypothesis that rate-of-return parity holds can be rejected for the treatment with DD and SV. However, the small sample size and extreme range of prediction errors for the treatment with DD and DV makes it impossible to reject the null hypothesis that the mean prediction error is zero.

5. Conclusions

Overall, rate-of-return parity is not observed between assets that pay uncertain dividends and currency. Inexperienced subjects do not engage in sufficient inter-temporal arbitrage to generate this result. This finding matches the findings of earlier investigations of double-auction asset market experiments. In earlier studies this result is taken as a rejection of risk-neutral dividend value pricing. The results of this investigation indicate that differences in risk are not the source of this failure. Rate-of-return parity is observed between assets that pay uncertain dividends when the dividend structures of the assets are identical. This result is observed in spite of the fact that the assets paying uncertain dividends are denominated in different currencies.

The support for rate-of-return parity in the treatments in which assets have different expected dividends is much weaker than in those in which assets have the same expected dividends. The absolute prediction error in sessions in which the expected dividends for the Blue and Red assets differ are much greater than when expected dividends are the same. This suggests support for the predictions that rate-or-return parity will be more difficult to realize as the asset structures becomes more complex. In this laboratory environment, complexity is related to the expected dividends of the assets.

The results of this experiment have two major implications for international finance and open economy macroeconomics. First and foremost, rate-of-return parity between identical assets has a solid foundation in observed human behaviour as well as in theory. Second, failure to observe rate-of-return parity in field data may be caused not simply by risk premiums, but a fundamental incompatibility of the assets being compared. Asset differentiation may cause a difference in expected capital gains or act as a barrier to arbitrage in its own right.

This experiment does not exhaust variations in the environment. Much more complex environments are required to fully understand rate-of-return parity. Such environments will include a variable exchange rate. The fixed exchange rate environment does provide a first complete step. The results of this experiment illustrate the usefulness of experiments in international finance by confirming the foundation of rate-of-return parity in limited cases. Results suggest caution in applying rate-of-return parity, but do not support its rejection outright.

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Notes

1. Friedman and Sunder (1994, pp. 12-15) provide a summary of induced-value theory in laboratory economics and the role of salient rewards.

2. Sunder (1995) provides a dated survey of the literature. More receive surveys are included in Plott and Smith (2005, Section 1.3).

3. The experiment was conducted using software written by members of the McMaster Experimental Economics Laboratory specifically for simultaneous double-auction asset market experiments. Details of this environment can be obtained from the first author.

4. A screen shot and instructions are included in Appendices 1 and 2 and are available at www.economics.mcmaster.ca/mceel/papers/rrp-app.pdf

5. \$C1 = \$R66 in Treatments 1 and 2; \$C1=\$R77 in Treatments 3 and 4. The different conversion rates kept expected payoffs to subjects approximately equal across treatments.

6. While a variable exchange rate seems more natural in modern international finance, the fixed exchange rate environment must be fully explored before a variable rate can be considered.

7. A market for exchanging currencies is a feature we believe was first introduced into a laboratory macro-economy by Noussair et al. (1997), who create a complex environment capturing aspects of international trade. The environment includes markets for inputs and final products but not financial assets.

8. When asked about the choice of 4 possible dividends as opposed to another number of potential dividends Vernon Smith responded, “No reason. Four is a good round number. The software accommodates up to a six point distribution as I recall.” Personal correspondence: October 11, 2000.

9. The prediction error is measured as the difference between the actual Blue asset price and the

predicted Blue asset price given the actual Red asset price and the realization of all arbitrage opportunities. If the Blue asset price (p_B) is 500 and the Red asset price (p_R) is 400 and if rate-of-return parity predicted $p_B / p_R = 1.2$, the predicted Blue asset price would be 480. In this case, the prediction error is +20 Blue dollars.

10. This is not the only possible method for testing rate-of-return parity. ADF tests could be used to determine if equation (6) is a co-integrating relationship for each session. While this exploits the time series properties of the session data, ADF tests have low power with small sample sizes (such as twenty trading periods).

Treatment	Red Asset Dividend	Blue Asset Dividend	Difference in Variance
1	$d_R = (10,20)$: $E(d_R) = 15$	$d_B = (10,20)$: $E(d_B) = 15$	0
2	$d_R = (10,20)$: $E(d_R) = 15$	$d_B = (\ 5,25)$: $E(d_B) = 15$	75
3	$d_R = (10,20)$: $E(d_R) = 15$	$d_B = (15,25)$: $E(d_B) = 20$	0
4	$d_R = (10,20)$: $E(d_R) = 15$	$d_B = (10,30)$: $E(d_B) = 20$	75

Notes: d_j indicates the possible dividends for the Red and Blue assets in terms of Red and Blue dollars, as the subscript indicates. E represents the standard expectations operator.

Table 1. Asset Dividends

	var (d_B) = var (d_R)	var (d_B) > var (d_R)
$E(d_B) = E(d_R)$	Treatment 1 (3 sessions)	Treatment 2 (3 sessions)
$E(d_B) > E(d_R)$	Treatment 3 (3 sessions)	Treatment 4 (3 sessions)

Table 2. Design Table: Treatments and Sessions by Dividend and Variance Characteristics

Treatment	Endowment	Red Dollars	Blue Dollars	Red Assets	Blue Assets
1	A	300	600	3	1
1	B	600	300	1	3
2	A	300	600	3	1
2	B	600	300	1	3
3	A	300	800	3	1
3	B	600	300	1	3
4	A	300	800	3	1
4	B	600	300	1	3

Table 3. Endowments of Subjects

	Same Variance		Different Variance		
	Session Medians	Means (Std. Dev.)	Session Medians	Means (Std. Dev.)	Row Mean (Std. Dev.)
Same Dividends	1.84	- 0.71	- 6.12	- 10.83	- 5.77
	0	(2.97)	- 11.25	(4.52)	(6.51)
	- 3.97		-15.13		
Different Dividends	- 71.92	- 38.51	35.28	18.51	- 10.00
	-18.97	(29.07)	38.41	(31.80)	(41.44)
	- 24.63		- 18.16		
Column Mean (Std. Dev.)		- 19.61		3.84	- 7.89
		(27.75)		(25.90)	(28.37)

Notes: For each session a measure of prediction error is calculated for each period. This measure is $\boldsymbol{\$}_t = p_{t,B} - [E(d_B)/\mathrm{E}(d_R)]\, p_{t,R}$ and these terms are defined in Section 2. The means and standard deviations reported in this table are for session medians by treatment.

Table 4. Median Blue Price Prediction Errors by Treatment and Session

	Same Variances	Different Variances	
	Means	Means	Row Mean
Same Dividends	1.94	10.83	6.39
Different Dividends	38.51	30.62	34.56
Column Mean	20.22	20.73	20.47

Table 5. Means of Absolute Values of Median Blue Price Prediction Errors by Treatment

Variable	Coefficient	Std. Error	t-statistic	p-value
Constant	-0.71	12.535	-0.06	0.956
Different Dividend	-37.797	17.727	-2.13	0.066
Different Variance	-10.123	17.727	-0.57	0.584
Interaction	67.14	25.07	2.68	0.028

Notes: There are twelve observations; F(3, 8) = 3.59 and Prob > F = 0.066; the root mean squared error is 21.711, the R-squared is 0.574, and the Adjusted R-squared is 0.414.

Table 6. Regression for Blue Price Prediction Error

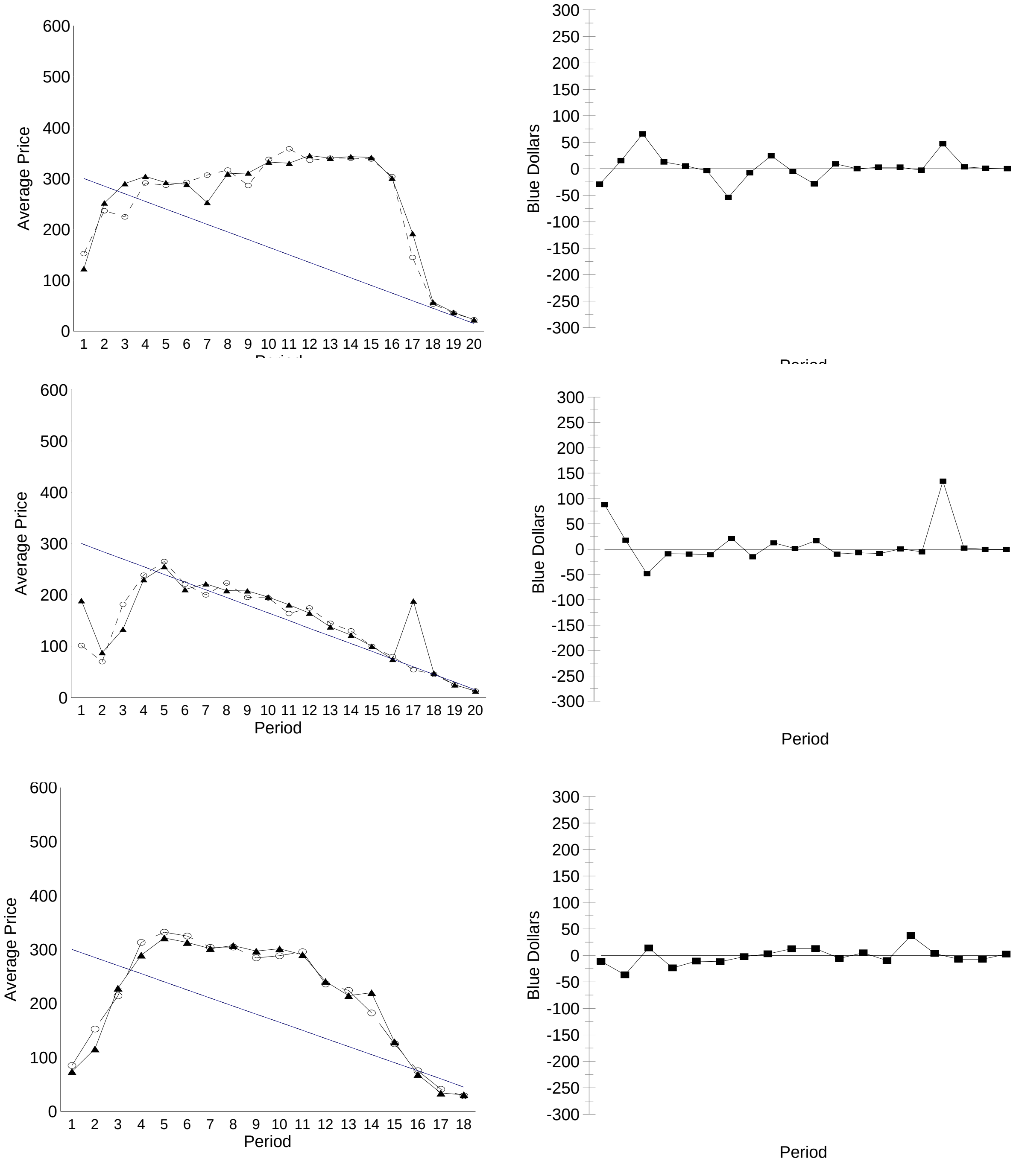

Figure 1. Treatment 1, Same Dividends and Variances, Sessions 1, 2 & 3 (Top to Bottom)

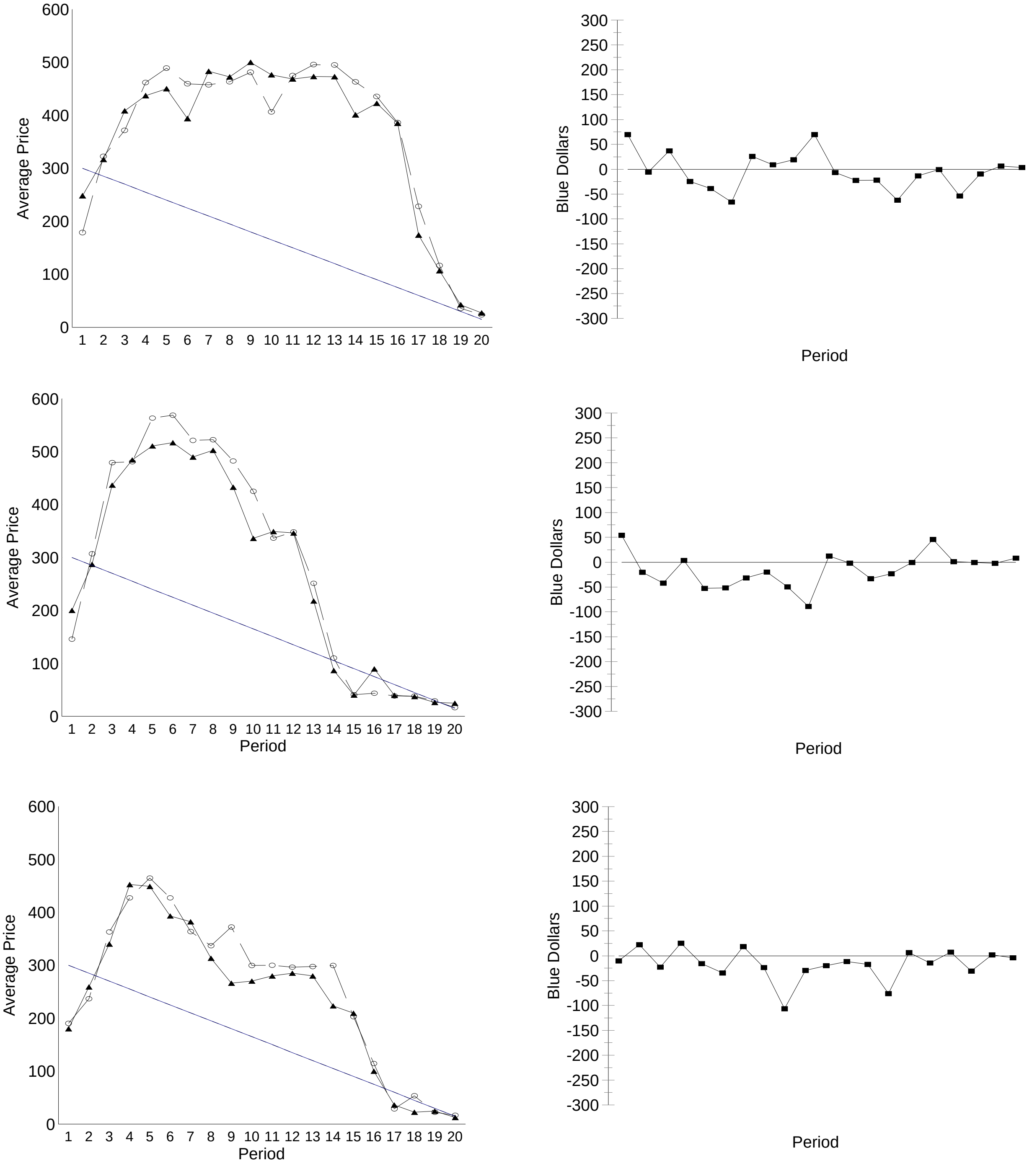

Figure 2. Treatment 2, Same Dividends, Different Variances, Sessions 1, 2 & 3 (Top to Bottom)

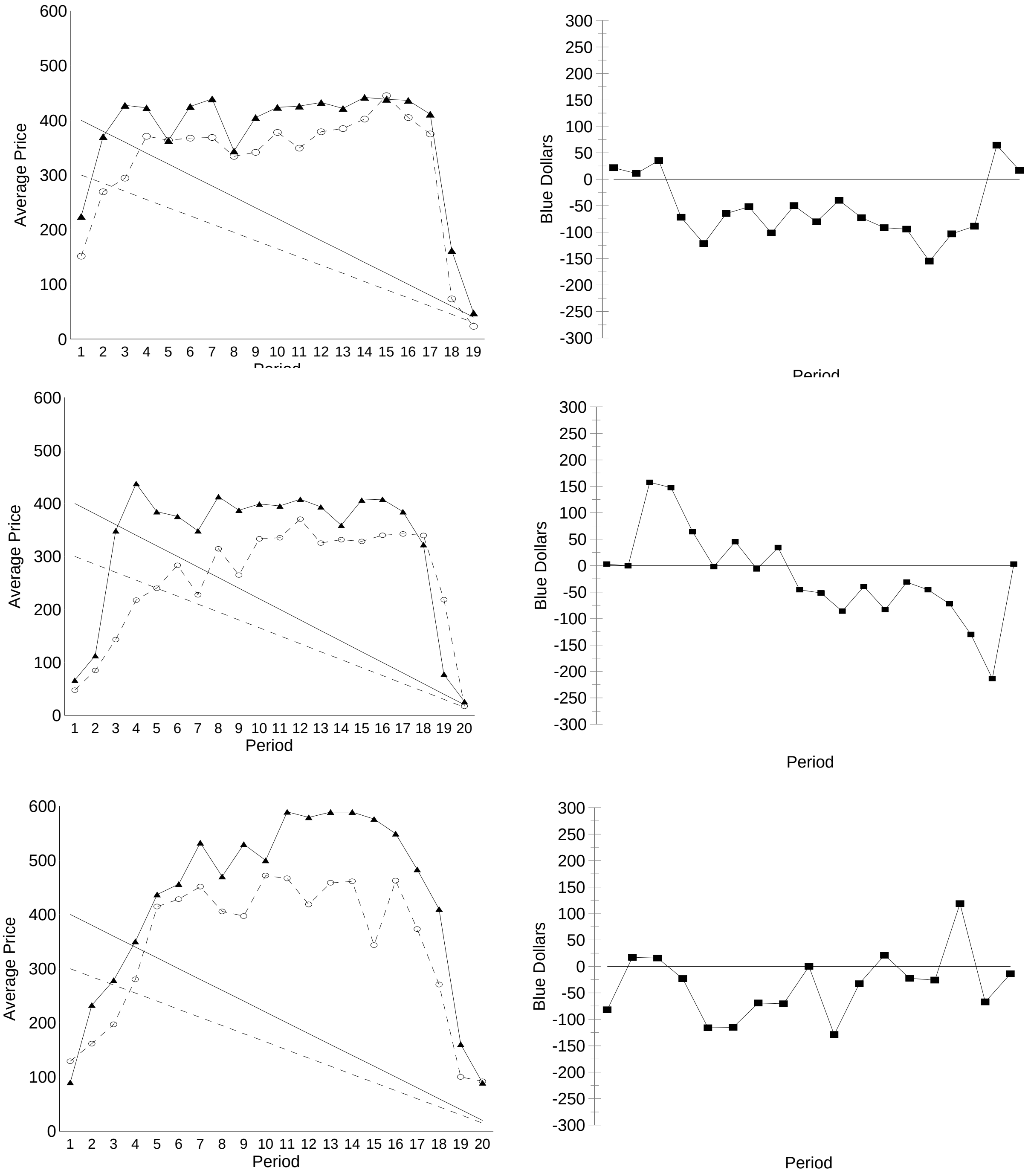

Figure. 3. Treatment 3, Different Dividends, Same Variances, Sessions 1, 2 & 3 (Top to Bottom)

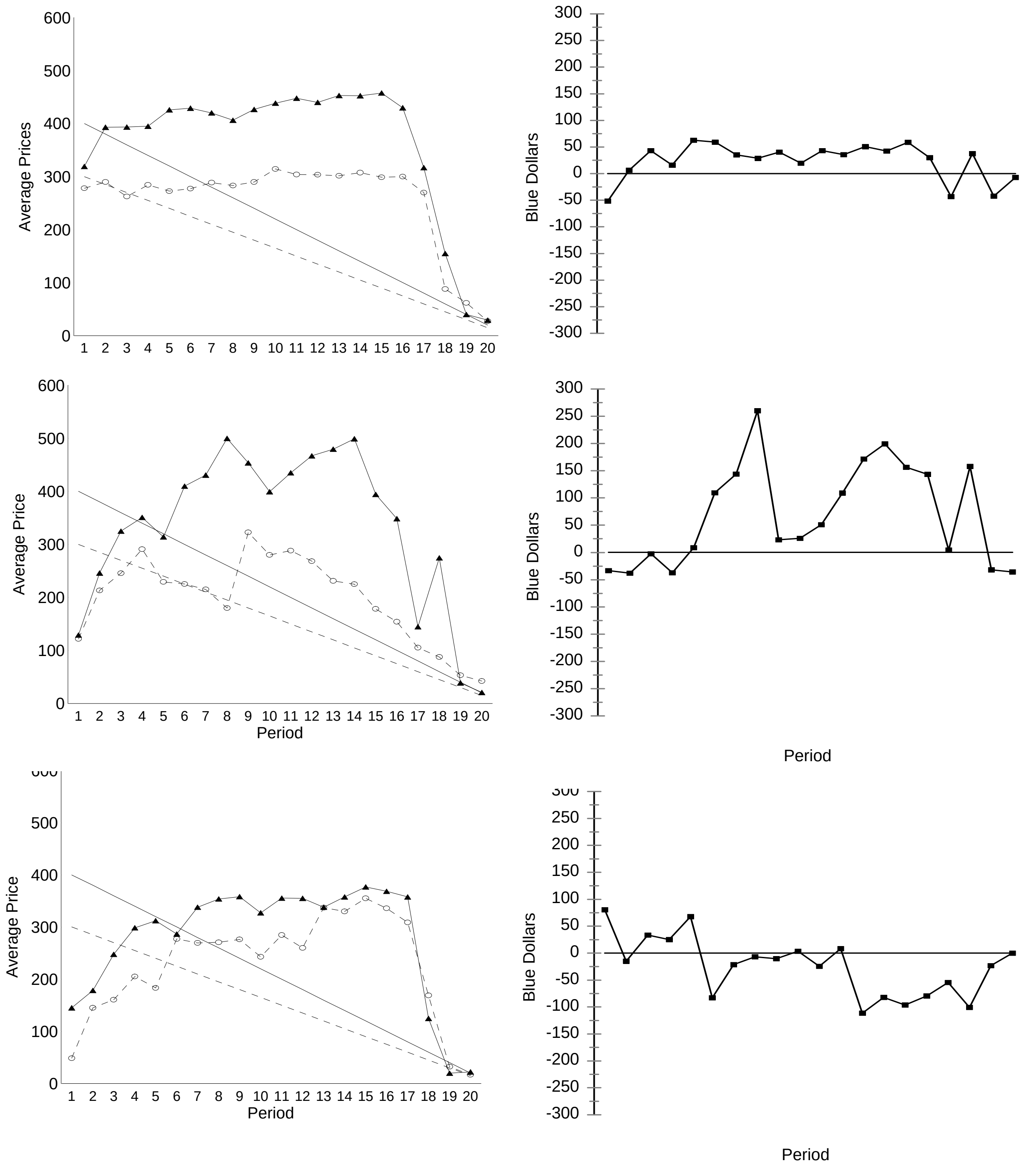

Figure. 4. Treatment 4, Different Dividends and Variances, Sessions 1, 2 & 3 (Top to Bottom)