The Forecasting Ability of Internet-Based Virtual Futures Market

An-Sing Chen  
Department of Finance  
National Chung-Cheng University, Taiwan  
finasc@ccunix.ccu.edu.tw

Jyun-Cheng Wang  
Institute of Technology Management  
National Tsing-Hua University, Taiwan  
Email: jcwang@mx.nthu.edu.tw

Shu-Ching Yang  
Graduate Institute of Education  
National Sun Yat Sen University, Taiwan  
Email: shying@mail.nsysu.edu.tw

Abstract: Internet-based virtual futures markets (VFMs) have been used in predicting election results and movie ticket sales. We construct an Internet-based VFM to predict an underlying stock price. Results of Granger causality tests and tests of directional accuracy show that a VFM with only a small number of participants (75) is able to generate informative futures prices useful in the prediction of the underlying stock price. Moreover the participants were not professional investors but merely undergraduate finance students with only a cursory introduction to futures trading. Our results provide additional evidence supporting the use of VFMs in forecasting and show that VFMs are powerful forecasting tools.

Keywords: Internet; virtual futures market, virtual markets, forecasting

Introduction

The use of Internet-based virtual futures markets is a powerful and previously unexplored approach that can be used to predict the stock markets. It is well known in the finance literature that futures prices are powerful forecasters of spot asset prices. In fact, many popular existing financial assets (e.g. stock market index mutual funds, currency, major government bonds, etc) have active futures markets and their futures prices are used widely by financial forecasters as inputs to their forecasting models. However, in the real world, not all financial assets have active (brick and mortar) futures markets. For example, it is only in the past 2 years that the London Stock Exchange (LSE) started to trade futures contract on individual stocks, and so far, they have been limited to contracts on a select group of well-established companies.

Suppose that an investor is interested in investing money in say Taiwan Semiconductors (TSM). However, there does not currently exist an active futures market for TSM anywhere in the world. Is it possible for to create in virtual space a feasible futures market for TSM? Would this futures market be informative in the sense that, are the futures prices generated by the virtual futures market useful in the forecasting of the underlying spot prices (in this case TSM stock prices)? Additionally, how small can the virtual futures market be and yet be informative? Can an Internet-based virtual futures market with only 75 or so participants generate informative futures prices useful in predicting the underlying asset? What caliber must the futures market participants be? Do they have to be experienced
futures traders? Or can they be ordinary college finance students with interest in the stock market? Also, what incentive structure should the virtual futures market use? Should it be based on real money as in the brick and mortar futures markets where traders gain and lose real money depending on their futures positions? Or would a simple prize system of incentives suffice and produce the same results? Or can a system of punishments in a classroom setting (i.e. lower grades for poor performing students) be used and still generate informative futures prices? These are only a glimpse of the many interesting research questions that can be researched. This study should be considered preliminary and only as a first step. Later studies are planned to address related issues in more detail and with more robust research methodologies.

Related Research and Concepts

The basic concept of an Internet-based futures market involves bringing a group of traders together via the Internet and allowing them to trade shares of virtual futures contracts on an underlying asset of common interest. These futures contracts conceptually represent a bet on the future market prices of the underlying asset, and their value depends on the realized market price of the underlying asset at a fixed date in the future specified by the futures contract. In this sense, a virtual futures market (VFM) extracts and cumulates the assessments of its participants concerning the future price of the underlying asset.

Forecasting future asset prices based on past data requires that past data contain useful extractable information about future (Lutkepohl (1993)). In the case of financial assets, however, the usefulness of past data is of heated debate. Believers of the efficient market hypothesis (Fama (1970, 1991)) believe that current asset prices reflect nearly all useful information concerning the asset in question thereby causing asset prices to behave in a random walk fashion. This results in the assertion that asset prices cannot be predicted from past data alone. Futures prices are, however, are generated by participants betting on the outcome of future market prices and are by definition not past data but instead are forward looking information. Futures prices are therefore, in theory, feasible predictors of future asset prices. Thus, the application of Internet-based virtual futures markets is a promising approach that can be used to predict future asset prices. In the Internet virtual futures market, the applicable futures contract can be constructed to represent a bet on the outcome of the future market asset prices, and their value, therefore, will depend on the realization of these market asset prices. Once the outcome of a specific market situation is known (i.e. the future market asset price is known), each share of the virtual futures contract receives a payoff according to that specific market outcome (e.g., $1 for each unit purchased).

VFM were first applied in the form of a political futures market to predict the outcome of the Bush versus Dukakis 1988 U.S. Presidential Election with participation restricted to members of the University of Iowa community (Forsythe et al. (1992)). An interesting result from their study is that they found that the predictions derived from their VFM outperforms opinion polls in terms of forecast accuracy. Their results also show that their VFM performed well even though their participants are not a representative sample of the electorate.

More recently, Spann and Skiera (2003) applies the concept of VFMs to solve short- and medium-term business forecasting problems. These business forecasting problems differ from those taken into consideration by political futures markets in aspects of complexity, information availability, incentive structure, and prediction frequency.

Compared to brick and mortar futures markets, Internet-based VFMs provide many advantages. Participants can conveniently access the VFM from almost anywhere in the world at any time. This means the Internet increases the pool of possible participants and allows, if necessary, the anonymity of traders on the VFM. VFMs also allow for almost real-time reaction to futures prices to additional information and, hence, a quick prediction of the impact of that information on future market situations. Using VFMs for research frees the researcher from the burden of weighting and aggregating different expert opinions as this is achieved by the trading mechanism of the VFM. This
is because participants (traders) of the VFM weight their assessments by the volume and the price of the purchase or sale order they place or accept. VFM also provide participants with a natural incentive to reveal their true assessments (Forsythe et al. 1999) if an adequate remuneration is properly linked to the participants’ performance on the VFM. That is, in a VFM, the losers in effect provide the remuneration for the winners. This means the price of collecting this information concerning the future is virtually zero once the VFM is established in cyberspace. Compared with consumer surveys that remunerate consumers for their participation in a survey, a VFM is obviously much more cost effective in terms of information extraction. Wertenbroch and Skierra (2002) show, for example, that consumers’ willingness to pay significantly differs according to the incentive structure being provided.

Theoretical Foundations

Futures are contracts to do something a later date. The obligation of the buyer and seller are defined in the contract. Only the price and number of contracts are negotiated at the time of transaction. That futures prices can be useful in forecasting is based on well-established economic rationale. The theoretical foundations are the Hayek Hypothesis (Hayek (1945)) and the efficient market hypothesis (Fama (1970, 1991)). According to the efficient market hypothesis, a market is efficient if all available information is always reflected in the prices. Therefore, as long as the futures market is efficient, the traded price of the futures contract should reflect information concerning the future and, thus, be useful for forecasting. The Hayek hypothesis states that the price mechanism in a competitive market is the most efficient instrument to aggregate the asymmetrically dispersed information of market participants. This being the case, it provides a rationale for why the VFM in providing a trading mechanism and market to aggregate and display individual assessments in futures contracts should be efficient. In a VFM individual assessments of future outcomes are tradable contracts and participants compete on the basis of their individual assessments. VFM therefore create a market for generating information useful for forecasting by aggregating information that is then reflected in the futures prices.

Experimental Market

The participants for our VFM experiments are undergraduate finance majors at a private college in northern Taiwan. A total of 75 players (students) were involved. Each player attended an initial training session, and also received detailed written instructions concerning our VFM. We construct a fully functional futures exchange with interface design based on typical Internet brokerage firms. From the users point of view, buying and selling futures contracts using our VFM are not much different from issuing orders and trading stocks via a typical Internet brokerage account. Our interface design thus provides easy transition from Internet stock trading to the VFM environment and reduces the participants' learning curves, since the vast majority of our players already have trading experience using traditional Internet brokerages. Our design should also allow for increased generalization of our findings by controlling for interface design peculiarities.

We choose Taiwan Semiconductors (TSM) as our underlying asset. TSM is a major global semiconductor manufacturer with substantial investor following in Taiwan. Moreover, there does not currently exist a futures market for TSM stock, making TSM an ideal underlying asset for our laboratory experiment. Only limit orders are considered in this study. Order submissions in our VFM, therefore, consist of price-quantity pairs. Market orders are not permitted. Just as in regular Internet brokerages, traders are permitted to cancel their orders at anytime. The futures contracts traded are one-week contracts with expiry set at 12:00 midnight Friday. At that time, all entered futures contracts expire and players holding the losing end of the contract will have virtual money deducted from their accounts and players holding the winning end of the contract will have the appropriate amount added to their accounts.
Since virtual money is used in our experiments, we provide an alternative incentive structure to motivate the participants. The incentive structure we impose for our VFM is that of punishment for poor performance. Specifically, participants were told that at the end of the semester, a portion of their grades will depend on the amount of virtual money they have in their VFM accounts.

All students were given 500,000NT (New Taiwan Dollars) of virtual money at the beginning of the experiment. Students were given one-week practice run before actual experiment began. The actual experiment began on 8/9/2003 and concluded on 8/28/2003, for a total of 20 days. For each day, 5 observations of futures price and corresponding TSM underlying price are recorded, giving us a total of 100 pairs of futures and corresponding underlying stock price for use in statistical analysis.

Securities with more extreme values tend to be prices less efficiently in experimental settings. Informed traders' trading gains are likely to be largest for securities with extreme values. We control for variation over securities by trading only TSM futures contracts.

A primary benefit of using VFM experimental methodology is the ability to exercise control over features of the experiment that might influence behavior but are not the focus of the study. Our experiment design controls for 1) differences across securities 2) differences across subjects 3) differences due to learning effects.

It is well known that different subjects in laboratory markets possess different levels of intelligence, motivation, and familiarity with the experimental environment. Such differences can make it difficult to draw inferences. We attempt to minimize this potential confounding factor by using only finance undergraduate students from the same grade and school and having all participants trade securities at least twice a day.

VFM Construction

Figures 1 and 2 provide some representative screenshots from our prototype Internet futures exchange. Figure 1 shows an example screen shot of the web page displaying information concerning the current underlying (TSM) stock price. It can be seen from the figure that our interface design attempts to mimic that experienced by the user when using a typical Internet broker. This web page, for example, provides the most recent market value of the underlying stock, its ticker symbol (TSMC), and the time of last price update. As in a typical Internet broker, our prices are updated virtually instantaneously via a direct feed from the stock exchange (Taiwan Stock Exchange (TSE) in our case). The left hand side of the screen shows the major functions available to users. As can be seen, we try to incorporate all the major functions available to users of a typical Internet brokerage onto our website. Thus, from the users point of view, using our website should be no different than using typical Internet brokerages such as i.e. Ameritrade™ or Charles Schwab™.

Figure 2 shows an example screen shot of the web page displaying the entire supply and demand schedule for TSM futures contracts. Shown are the highest 10 bid prices (orders), their corresponding order amounts (number of contracts ordered), and the identity of the player (user) who issued the order. Also shown are the lowest 10 ask prices, their corresponding order amounts and player identity. The block on the left corresponds to the demand curve (schedule) for the futures contracts and the block on the right, the supply curve. Orders with the highest bid prices (or lowest ask prices) are placed on top of the queue. When two orders to buy (or sell) have the same price, they are queued on a first come first served basis and the order that came in first will have first priority in execution. For example, in the supply curve shown (the block on the right), both PECO33 and PECO009 have issued an order to sell 50 TSM futures contracts with the same ask price of 62.5. In this case, PECO0033 is placed on top and queued ahead of PECO009 in the supply schedule because she has issued her order before PECO009. Orders are executed when the supply and demand schedules intersect, that is when the bid price is greater than or equal to the (lowest) ask price or,
conversely, when the ask price is less than or equal to the (highest) bid price. The supply and demand schedule is updated on a real time basis every time players issue new price/quantity orders to buy or sell futures contracts. Players can update the supply and demand schedule they see manually, by hitting the refresh button on their Internet browser.

The outline of A*Trade Online website includes four main parts, Insider Menu, Learning Center, About A*Trade and Link (see Table 1). With the exception that all trading is done in virtual space, our Internet VFM is constructed to be operationally identical to that of traditional brick and mortar futures exchanges (i.e. CBOT, CME, etc.). Table 2 provides a detailed example of how futures contracts are traded in our VFM and the associated cash flows. Suppose that player A and player B agree to trade two TSM futures contracts (based 100 shares of the underlying TSM at $60 per futures contract) on day 1. The volume of trading in day 1 would be two contracts, and open interest at the end of the day (the number of contracts outstanding) would also be two. To protect both parties against default by the opposing side, both A and B must post margin with the VFM before they are allowed to trade. In our case, the margin is $1000 per TSM futures contract for each party to the transaction.

Suppose on day 2, player A decides to sell her two futures contracts. However, as in a traditional futures exchange, the structure of the VFM is that she does not necessarily have to sell the contracts back to player B, who is currently her opposing party. That is, suppose a new entrant to the market, player C, is willing to purchase the TSM futures contracts at $61 per contract. In this case, if player A is also willing to sell her contracts at $61 then A’s original futures position can be closed out, since A is now a buyer and seller of the same futures contracts in our VFM’s computer memory banks. In effect, player C replaces player A as the opposing (long) position to player B’s short position. The cumulative volume of trading at the end of day 2 is 4 contracts but open interest remains at two.

The price of TSM futures will rise from $60 per contract to $61 per contract from day 1 to day 2. This causes the value of player A’s position to rise by $200. Since player B was the seller but the futures prices rose, the value of her position falls by $200, causing her margin deposit with the VFM to shrink to $1800.

Suppose on day 3, player C buys one more TSM futures contract, but this time at a cheaper price of $59 per futures contract with player D who taking the opposing side of the trade. The cumulative volume of trading through day 3 is now five contracts, and open interest increases to three. Because the price of TSM futures has now fallen from $61 to $59 per contract, player B gains $400 and player C loses $400. On day 4, suppose player B buys two TSM futures contracts at $59 and player C takes the opposite side. This causes the open interest to decline by 2 contracts (to 1) since the transaction offset previous positions established by players B and C. Since the futures trade price did not change and remained at $59, no profits or losses are realized by the market participants this round. On day 5, suppose player C sells one more contract at $60 and player D takes the opposing side. Open interest now declines to zero since the transaction offset previously established futures positions.

The example shows that, as in traditional futures exchanges, trading futures on our Internet VFM is a zero-sum activity. The sum of profits of the four players is zero each day. On balance, players A and B earn money, but players C and D lose money.

Testing For Granger Causality

With only 75 participants all of whom are undergraduate finance majors and not professional investors, would our constructed VFM generate useful information that can forecast the TSM underlying asset? This can be tested statistically under the Granger causality framework.

Specifically, the Granger (1969) approach to the question of whether $x$ causes $y$ is to see how much of the current $y$ can be explained by past values of $y$ and then to see whether adding lagged
values of $x$ can improve the explanation. $y$ is said to be Granger-caused by $x$ if $x$ helps in the prediction of $y$, or equivalently if the coefficients on the lagged $x$’s are statistically significant. Granger causality can be thought of as measuring the precedence and information content of one variable on another.

In mathematical notation, Granger causality can be described using bivariate regressions of the form

$$
\begin{align*}
y_t &= \alpha_0 + \alpha_1 y_{t-1} + \ldots + \alpha_L y_{t-L} + \beta_1 x_{t-1} + \ldots + \beta_L x_{t-L} + \epsilon_t \\
x_t &= \alpha_0 + \alpha_1 x_{t-1} + \ldots + \alpha_L x_{t-L} + \beta_1 y_{t-1} + \ldots + \beta_L y_{t-L} + \epsilon_t
\end{align*}
$$

(3)

for all possible pairs of $(x, y)$ series in the group. The null hypothesis tested is:

$$
\beta_1 = \beta_2 = \ldots = \beta_L = 0
$$

(4)

for each equation. Wald statistics for the above joint hypothesis can be computed to determine rejection or non-rejection of null. Specifically, the null hypothesis is that $x$ does not Granger-cause $y$ in the first regression and $y$ does not Granger-cause $x$ in the second regression.

Table 3 shows the results for the Granger causality tests for our VFM futures prices and TSM stock prices. The table shows that the null hypothesis that the VFM futures price does not Granger cause TSM stock price is rejected at a statistically significant level for the various lag specifications analyzed. Moreover, the null hypothesis that TSM stock price does not Granger cause VFM futures price is not rejected. Thus our results provide evidence showing that our VFM futures prices is useful for forecasting TSM stock price.

### Testing for Directional Accuracy

To draw a clearer picture of the forecasting power of our constructed VFM, it is useful to consider a methodology that will provide us a measure of the economic value of a forecast. The Cumby and Modest (1987) test offers a usable framework for testing. The test is essentially a test of the directional accuracy of a forecast. Directional accuracy has been shown (i.e. Leitch and Tanner (1991)) to be highly correlated with actual trading profits and a better indicator of the economic value of a forecast then conventional forecast evaluation measures such as, for example, root mean squared forecast errors (RMSEs).

To implement the test, let $\xi_t = 0$ if the futures price at say time $t$ is less than the underlying asset price at time $t$ (the VFM forecast a negative change in the underlying TSM price), and let $\xi_t = 1$ if the futures price at time $t$ is greater than or equal to the underlying asset price at time $t$ (the VFM forecast a non-negative change in the underlying TSM price). Henriksson and Merton (1981) have shown that a necessary and sufficient condition for a forecast to have any economic value is that:

$$
\Pr(\xi_t = 0 | Z_t < 0) + \Pr(\xi_t = 1 | Z_t \geq 0) = 1
$$

(5)

where $Z_t$ represents the actual change in the variable of interest (the underlying TSM stock price in our case). Therefore, to test whether a forecast can predict directional changes requires showing whether (5) holds.

When applied to this study, the resulting test for directional accuracy is based on the following regression:
The Forecasting Ability of Internet-Based Virtual Futures Market

\[ Z_i = \gamma + \beta X_i + \varepsilon_i \]  

(6)

where \( X_i = 0 \) if the VFM forecast a negative change in the underlying TSM stock price and \( X_i = 1 \) if the VFM forecast a non-negative change in the underlying TSM stock price. Under the null hypothesis that the VFM has no ability to predict directional changes of the underlying TSM stock price, \( \beta \) is equal to zero. On the other hand, if the VFM is able to predict directional changes of TSM stock price, then \( \beta \) is greater than zero.

Table 4 presents the estimated slope coefficient from the regression test of directional accuracy along with its associated \( t \)-statistic and \( p \)-value. The result shows that the VFM has significant directional forecasting ability. The estimated slope coefficient is positive and significant at the one percent level of statistical significance, indicating that the VFM consistently forecasts price changes in the same direction with actual price changes of the underlying TSM stock, and that the VFM has informational value.

Conclusions

We construct an Internet-based VFM to predict an underlying stock price. We find that a VFM with only a small number of participants (75) is able to generate informative futures prices useful in the prediction of the underlying stock price. Moreover the participants were not professional investors but merely undergraduate finance students with only a cursory introduction to futures trading. Our results provide additional evidence supporting the use of VFMs in forecasting and show that VFMs are powerful forecasting tools.

Reference List


Figure 1: Example screen shot of page displaying underlying (TSM) stock price.

Figure 2: Example screen shot of the demand schedule for TSM futures contracts.
Table 1: The framework of the website

<table>
<thead>
<tr>
<th>Content</th>
<th>Items</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trading</td>
<td>A fully functional exchange market</td>
</tr>
<tr>
<td></td>
<td>Modify Personal Data</td>
<td>Update information, show/hide personal information</td>
</tr>
<tr>
<td></td>
<td>Trading Records</td>
<td>Store your trades for the record</td>
</tr>
<tr>
<td></td>
<td>Issued Orders</td>
<td>To buy / sell</td>
</tr>
<tr>
<td>Insider Menu</td>
<td>Personal Asset</td>
<td>Show the current balance of an account</td>
</tr>
<tr>
<td></td>
<td>Open Orders</td>
<td>Orders not yet completed</td>
</tr>
<tr>
<td></td>
<td>Market Value</td>
<td>Current value of one’s assets</td>
</tr>
<tr>
<td></td>
<td>Set Up Your Agent</td>
<td>Tuning the parameter to make agents work for you</td>
</tr>
<tr>
<td></td>
<td>What Your Agent Did</td>
<td>Details agents’ capability</td>
</tr>
<tr>
<td>Learning Center</td>
<td>First Here?</td>
<td>Providing some self-instructional materials for learners’ references.</td>
</tr>
<tr>
<td></td>
<td>Stock Future</td>
<td>Learning what stock future is</td>
</tr>
<tr>
<td>Agent</td>
<td>Agent’s Trade List</td>
<td>Show what an agent has traded</td>
</tr>
<tr>
<td></td>
<td>Agent’s Net Income</td>
<td>Balance of an agent player’s account</td>
</tr>
<tr>
<td>About a Trade</td>
<td>A*Trade Members</td>
<td>Members privileges explained</td>
</tr>
<tr>
<td></td>
<td>What A*Trade Aims at</td>
<td>The purpose of this site</td>
</tr>
<tr>
<td></td>
<td>How A*Trade Do</td>
<td>The nature of the trade we conduct</td>
</tr>
<tr>
<td></td>
<td>Contact Us</td>
<td>We will respond to your questions</td>
</tr>
<tr>
<td>Link</td>
<td></td>
<td>Providing related links and information for learners’ references</td>
</tr>
</tbody>
</table>

Table 2: Example of how futures contracts are traded in the VFM and associated cash flows

<table>
<thead>
<tr>
<th>Time</th>
<th>Buyer</th>
<th>Seller</th>
<th>Cumulative Contract Volume</th>
<th>Open Interest</th>
<th>Futures Price</th>
<th>Contract Value</th>
<th>Daily Profit or Loss</th>
<th>Margin Cash Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>B</td>
<td>2</td>
<td>2</td>
<td>60</td>
<td>6000</td>
<td>-2000</td>
<td>-2000</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>A</td>
<td>4</td>
<td>2</td>
<td>61</td>
<td>6100</td>
<td>200</td>
<td>-2000</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>D</td>
<td>5</td>
<td>3</td>
<td>59</td>
<td>5900</td>
<td>400</td>
<td>-1000</td>
</tr>
<tr>
<td>4</td>
<td>B</td>
<td>C</td>
<td>7</td>
<td>1</td>
<td>59</td>
<td>5900</td>
<td>400</td>
<td>2000</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td>C</td>
<td>8</td>
<td>0</td>
<td>60</td>
<td>6000</td>
<td>100</td>
<td>1000</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>20</td>
<td></td>
<td>200</td>
<td>200</td>
<td>-300</td>
<td>0</td>
</tr>
</tbody>
</table>

*the required margin deposit for the VFM is $1000 per TSM futures contract for each party to the transaction*
### Table 3: Granger Causality Test Results

<table>
<thead>
<tr>
<th>Lags: 1</th>
<th>Null Hypothesis:</th>
<th>Wald-Stat</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future does not Granger Cause Stock</td>
<td>17.1281</td>
<td>0.00088</td>
<td></td>
</tr>
<tr>
<td>Stock does not Granger Cause Future</td>
<td>8.52038</td>
<td>0.01058</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lags: 3</th>
<th>Null Hypothesis:</th>
<th>Wald-Stat</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future does not Granger Cause Stock</td>
<td>2.88047</td>
<td>0.09534</td>
<td></td>
</tr>
<tr>
<td>Stock does not Granger Cause Future</td>
<td>0.92922</td>
<td>0.46553</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lags: 5</th>
<th>Null Hypothesis:</th>
<th>Wald-Stat</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future does not Granger Cause Stock</td>
<td>9.94954</td>
<td>0.04372</td>
<td></td>
</tr>
<tr>
<td>Stock does not Granger Cause Future</td>
<td>2.56329</td>
<td>0.23426</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4: Slope coefficient for directional accuracy test

<table>
<thead>
<tr>
<th>β</th>
<th>t-statistic</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.637</td>
<td>3.966</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Note: \( H_0 : \beta = 0 \) is the null hypothesis that the VFM has no ability to predict directional changes of the underlying TSM stock price.

* indicates significance at the 1% level.