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Technical Trading Strategy in Spot and Future Markets: Arbitrage Signaling

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Abstract

This study examines the intraday price lead-lag relationship between TFEX Index futures or single stock futures and their underlying cash indices using high frequency minute data. Threshold Vector Error Correction Model is practiced to estimate the short-run adjustment parameters. A portfolio is afterward constructed on the basis of pair trading strategy to evaluate the performance of the model and its predictability power. An additional signal from trading volumes of futures and cash indices is acquired to reduce the risk of wrong positioning since the adjustment process is not necessarily symmetric. The result from Granger causality test suggests that most of the time future price movements lead its underlying cash price but, for some certain periods, eventual relationship can bi-directional. The returns of portfolio under pair trading strategy with signal from TVECM model and trading volume moving average is relatively high in comparison with traditional pair trading strategy.

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Content

Chapter1 Introduction

In November 2006 Thailand Futures Exchange (TFEX) was established providing traders a new alternative of investment namely single stock future which is considered as a derivative. Since then, trading in this contract has grown steadily and dramatically. The benefits of trading futures are derived from economic incentives on traditional financial instrument namely stocks and bonds. First, Future contracts provide means of risk allocation. Second, futures can summarize useful price information within the economy. And third, derivatives can reduce the transaction costs within the market. According to the reasons, futures contracts widely become a hedging tool which can eliminate certain risks of holding stocks and increase the welfare of portfolio's holders when their portfolios more closely meet their objectives.

Future derivatives seem to benefit investors only if their prices are tightly linked to the prices of their underlying assets. If the price of a future contract moves independently, this financial instrument will not be an effective risk-management tool. However the independent moves between the two prices can be cited to occur solely in short-run according to the well-known cost-of-carry model of future and spot. The theory states the long-run relationship of the two prices or, in econometrics, that the two prices are cointegrated. The presence of short-run independent moves, mostly in practice, draws out many studies to explain the relationship using different means and techniques. In several markets, future prices are found to lead the cash prices—Stoll and Whaley (1990), Chan (1992), and Tse (1995). The discovery can be in a contrast. Shyy, Vijayraghavan and Scott-Quin (1996) reported the opposite direction. And also another view of bi-directional causal relationship is reported by Liu and Zhang (2006), Mukherjee and Mishra (2005) and Abhyankar (1998).

The discovery of lead-lag relationship within markets is a strong empirical evidence to market inefficiency. Any mispricing becomes an arbitrage opportunity. Mispricing often reflects an arrival of a piece of news to a group of investors who impound new information into prices of the market they are in and cause a shift to the price's behaviour. So, it would take a period of time for the rests of investors of both markets to take into account the new information and adjust their holdings. As a result, market efficiency grows under a period of time and opportunities of arbitrage profit can be taken.

The nature of lead-lag relationship seems predictable but in practice the idea is partially correct. As new information arrives, the investors of second-hand news have to bear the cost of approaching information and also the cost of afterward portfolio reallocation including transaction cost, interest rate risk, dividend risk and buying-selling restrictions. Thus, the arbitrage activities are not taking immediately as the mispricing occurs. Now the investors' decision become whether the profits of reallocating their portfolio after the information exceed the costs they are facing. These actions lead the adjustment to exhibit different behaviours at each time and the length of time it takes varies in each situation. Recent financial literatures, namely Hansen and Seo (2002) suggest that the dynamic adjustment between two markets within the model may be non-linear due to the presence of transaction cost preventing the holders from adjusting continuously. Consequently, some financial literatures suggest the construction of different regimes of investors' decision-- Theissen (2011), Tse and Chan (2010), Marten and Kofman (1998) and Sunthorn Thongthip (2010). The regimes under no adjustment are represented by a band called no-arbitrage band. This no arbitrage band can be a beneficial tool in investment decision making. Investors are to invest only if the mispricing occur and exceed the no-arbitrage band.

The construction of no-arbitrage band was based on the econometric concept of threshold cointegration introduced by Balke and Fomby (1997). They suggested that the adjustment does not need to occur instantaneously but only once the deviations exceed some critical threshold, allowing the presence of inaction or no convergence band. The extension model developed to capture this market behaviour is the Threshold Vector Correction Model (TVECM). In this model, the error correction term is spitted into regimes which respond varyingly to each deviation based on different threshold critical values. As the asset holders are facing constraints in trading assets in both markets (spots and futures) forcing them to take discrete actions, the dynamic relationship between prices should be characterized as nonlinear. Thus the nonlinear TVECM is to be employed to explain the asymmetric bidirectional causality and also price transmissions between these two markets both in short-run and long-run. Similar examination of prices is applied to create a trading strategy called "Pair Trading." When two prices which are found historically to be cointegrated, exhibit a considerably large gap between them, investors are incentivized to take a short-position of the higher price and take a long-position of the lower price with a belief that both prices will soon converge to their mean and enjoy a profit. Consistently, in the case where future exceeds spot price and a significant mispricing presents, the TECM model Sunthorn Thongthip (2010) suggested a short in future and a long in cash stock or index in order to receive the arbitrage profit as both prices establish tendency to converge. When the convergence takes place, the arbitrage profit (investors gain) is the combination short profit from future and margin gain from the rise of cash or index taken out all transaction costs.

Beside the signal from TVECM, the power of price prediction can be enhanced with the information within the trading volume. The importance of trading volume is clear but most implications of asset model focus only on the behaviours of return. Ohara (1995) offered a survey of literatures showing the positive correlations of trading volume and absolute returns under theoretical market microstructure models and also literatures involving asymmetrically informed agents. An arrival of a good news results in a price increase, whereas a bad news drive the price down, Bollerslev and Jubinski (1999). These events are often accompanied with above-average trading activities within the market. The change of trading volume in this manner can be described by disagreements among traders who are asymmetrically informed. Ones with the correct news would force the market to adjust a new equilibrium with a new price. Such actions are often accompanied by above-average volume surge. According to the so-called Mixture of Distribution Hypothesis (MDH), prices and trading volume are driven by the same underlying latent news arrival. Clark (1973), Lee and Rui (2002) and Epps and Epps (1976) investigated the variability in price and volume traded and suggested, with underlying theoretical framework, that absolute change in price should be positively correlated with volume traded because of joint dependence on a common directing latent variable.

The inference of the MDH is often applied to the markets widely by technical analysts who construct their own rules of trading based on historical data, news and numerical evidences. Trading volume, as an additional tool to enhance the predictability of price movement, is developed in several ways and empirically found to be beneficial since it is described to contain traders' behaviours and expectations. The more information investors have, the more precise prediction can be made. Consequently, the study of price relationship between future market and cash market as regards using more than one volume series to favour the prediction would become an interesting topic in financial consideration.

Statement of the Problem

As the dynamic adjustment, with the persistence of a long-run equilibrium, is found to be non-linear using the technique of threshold cointegration, any mispricing beyond no arbitrage band becomes arbitragers' opportunities. The disequilibrium is described by asymmetric new information arrivals between two markets. Traders of the two markets take different actions corresponding to new information they have and hence posing pressure to the prices while trading volume surge is accompanying. Financial studies suggested that these behaviours are not just coincidence. They are directed by a process. The consistent finding is expected to be reassured in this study as shown in Figure 1.

Figure 1: SET 50 Index and SET 50 Index Future Price Series

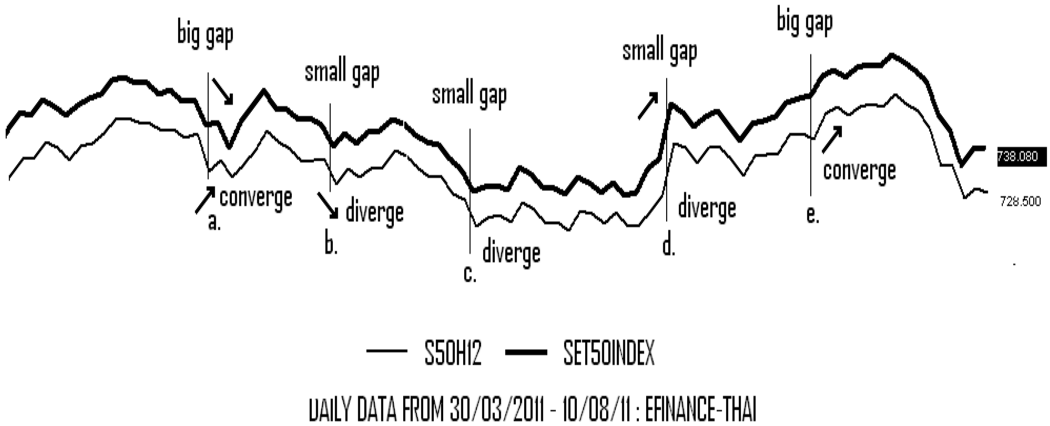


Figure 1 shows author's illustration of daily data plot of SET50 Index Future price and the SET50 Stock Index between 30th of March to 10th of September 2011. The relation of the two prices is clear i.e. cointegrated. Point a. to e. shows the predictable adjustments of the two prices. A large enough divergence of the prices is followed by a convergence adjustment and any too small gap is corrected by an afterward divergence.

These movement behaviours become speculative investment strategy based on the idea that the relationship will remain the same. This idea is similar to the well-known "pair-trading strategy". The strategy involves choosing a pair of stocks which is evidenced to share same fundamentals and their prices always co-move. By taking a long-short position on the pair, a profit could be made when prices converge to their mean. Obviously, any stock price and its future contracts are derived from exactly the same fundamentals and exhibit a long-run equilibrium of movement.

Figure 2: Mispricing between Price series and Speculative Movement

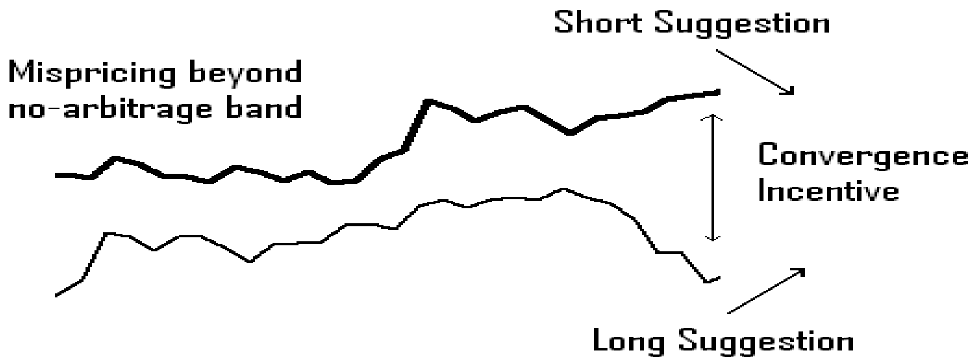


Figure 2 shows a closer-look of mispricing between future and cash price. When the movement exhibits a large gap, if two prices are cointegrated, investors are incentivized to take a short-position of the higher price and take a long-position of the lower price with a belief that both prices will soon converge to their mean and enjoy a profit. Consistently, in the case where future exceeds spot price and a significant mispricing presents, the TECM model of Sunthorn Thongthip (2010) suggested a short in future and a long in cash stock or index in order to receive the arbitrage profit as both prices establish tendency to converge. When the convergence takes place, the arbitrage profit (investors' gain) is the combination short profit from future and margin gain from the rise of cash or index taken out all transaction costs.

However, the convergence is not always occupied by both prices. Sole price adjustment might occur. If only one price is in disequilibrium, taking positions in both markets could double the cost while the gain from trading is only one-sided since there is only one price that move toward another. In this case the overall cost could overwhelm the profit gain.

Figure 3: Movement Hypothesis of Price Series and Their True Stochastic Trend

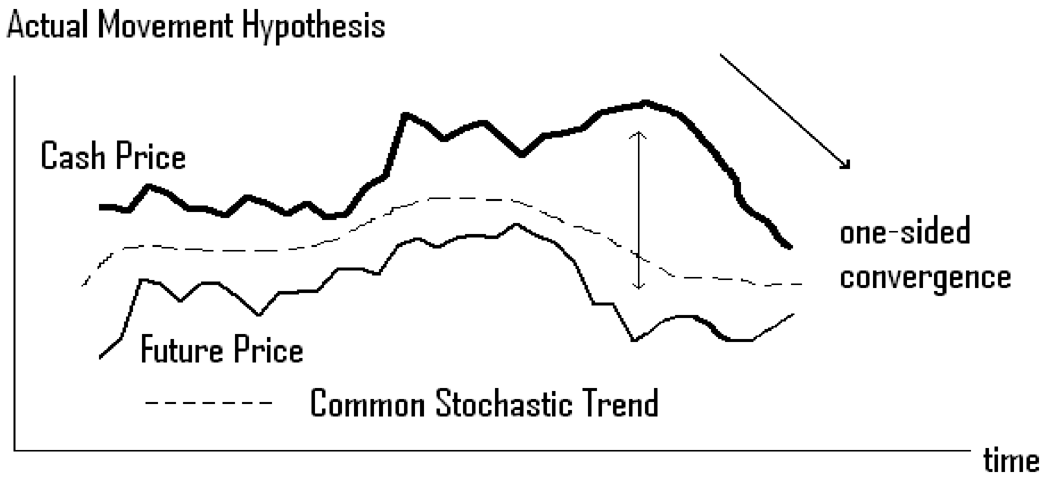


Figure 3 shows a situation of one-sided convergence behaviour. In this case, only one price was driven away from the long-run equilibrium shown by the "common stochastic trend line" while another is moving along with the true trend. So the adjustment process only occurs with the price that meanders from the real trend. As regards the hypothesis, mispricing between future and cash prices can be of six different situations where an arbitrage opportunity exists assuming that both prices are subjective to the same stochastic trend-- two cases of one-sided convergence, two cases of on-sided divergence and the cases of two-sided convergence and divergence.

To prevent the loss from wrong position and non-profitable transaction cost, another indicator is needed as a tool to determine the actual behaviour of adjustment. Volume traded in each market will be studied whether it can be an accurate indicator for the correct common stochastic trend. And under the Mixture of Distribution Hypothesis, the true adjustment process with correct information should influence the trading volume in at least one market. If the volume traded can signal the right positioning, investors can benefit more from less wasting transaction cost.

Research Objectives of the Study

1. To see the short-run and the long-run relationship between SET single stock cash prices and their TFEX future prices.
2. To determine the short-run adjustment process and causalities between the two prices.
3. To determine the existence of arbitrage opportunities between two markets.
4. To construct a buy/sell signal to any arbitrage opportunities with information from Threshold model and trading volume.
5. To perform a portfolio experiment under certain trading rules.

Scope of the Study

This study uses data set of SET's single stock price series, SET50 index series and their corresponding future derivatives under different frequencies which varies from 1-minute to 1-hour. Prices of each series are calculated at their open of the period. The selection criteria for choosing the most appropriate one or more pairs of price series depend basically on liquidity and volatility.

Chapter 2 Frameworks and Literature Reviews

Pair Trading

One quantitative method of speculation known to financial analysts is to find two series of prices that move together historically. When the spread between the prices widen, the strategy is to short-sell the higher price and long-buy the lower one. If those price series establish the same behavior as they have done so far, the convergence after any deviation will profit those in the market with mentioned position.

Figure 4: Two Price Series under Pair Trading Strategy

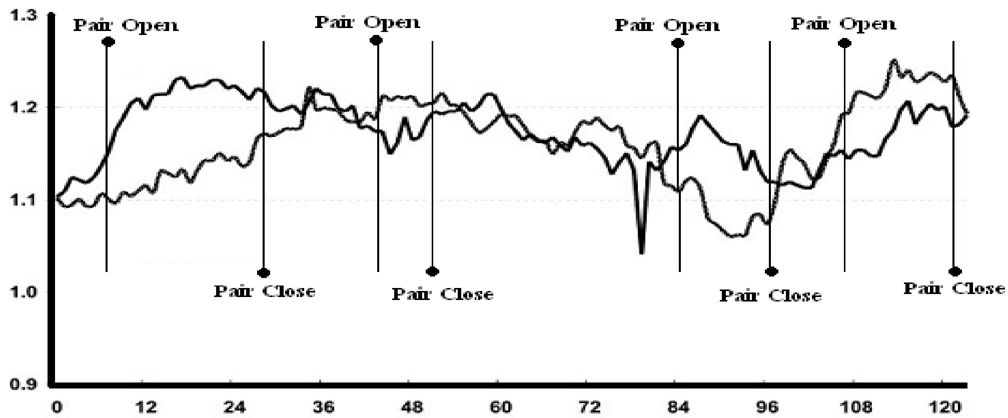


Figure 4 illustrates an example of a pair of prices used in pair trading strategy. The strategy's intuition is a selection of a pair of two stocks which are founded on the same fundamentals for instance, two companies' stocks within the same industry who are sharing the same market. These behaviors imply market efficiency according to the Law of One Price with equally adjusted the market share of each company. Beside baskets of stocks, pair trading is also done with stocks' derivatives since those derivatives' prices establish strong co-movement with their indices and are intuitively underlain by their assets' fundamentals. Future derivative and its index are the study's interest. If pair trading strategy works in future derivative market, future contract and its underlying asset are said to be mean reverting followed the theoretical cost-of-carry model and fully efficient market assumption.

There are three common questions often raised against pair trading strategy. Firstly, "Even though a pair of price historically moves together, is it necessary that after a period of divergence the two prices will move toward each other again?" Secondly, "How large should the price gap be when a buy-sell position is to be taken?" The last question is "Is the convergence behavior one-sided or two-sided or, correspondingly, should the position be taken in both asset future and cash or just in one market?" These three questions are the main issue through this study.

The process of examination of prices to answer the first question is called "Price Discovery." In the long-run, if the two prices have a common equilibrium, they are mean-reverting. Mean reversion guarantees that prices always exhibit tendency to move toward each other.

Mean Reversion and the Cost of Carry

The co-movement behavior between two prices can be explained quantitatively by the idea of cointegration. Follows Enders (2004), if two series fluctuated with the same non-stationary factors, then the prices could be cointegrated. Econometrically, the cointegrated series can be said to have the same stochastic trend. Ignoring cyclical and seasonal term two series can be decomposed into

$$f_t = u_{ft} + e_{ft} \tag{2.1}$$

$$s_t = u_{st} + e_{st} \tag{2.2}$$

where f_t and s_t represent two series of prices, u_{it} represents a stochastic non-stationary process at time t and e_{it} is a stationary irregular component at time t.

If f_t and s_t are both stationary at their first difference and the linear combination $\beta_1 f_t + \beta_2 s_t$ is stationary for all non-zero values of β_1 and β_2, f_t and s_t are said to be cointegrated of order (1,1). Since the irregular component e_{it} is precluded to be stationary, the cointegration between f_t and s_t implies that $\beta_1 u_{Ft} + \beta_2 u_{St}$ is also stationary and can be written as

$$u_{Ft} = -\frac{\beta_2}{\beta_1} \tag{2.3}$$

Thus, up to the scalar $\frac{\beta_2}{\beta_1}$ the two price series must have the same stochastic trend if they are cointegrated of order (1, 1), and for simplicity let $\frac{\beta_2}{\beta_1} = \beta$ and the cointegrated $f_t + \beta s_t$ is stationary.

Since the linear combination of two series exist and found to be stationary i.e. are cointegrated, it can be said that the relationship of both prices are stable or present a long run relationship. The stock cash price and its future are also series that empirically establish long run equilibrium. There are several financial theories to explain the relationship between these two prices and the best-known is the cost of carry model. The cost-of-carry model theoretically summarizes of the meaning of the cointegrating parameter β as the cost of carrying a future derivative asset over time until its maturity date. This model is based on the idea that the price of an asset for delivery in the future should be equal to its current spot price plus the cost of carrying it over time. Mathematically, the equation is

$$E_t(s_t) = s_t(the\ cost\ of\ carrying\ asset\ over\ time) \tag{2.4}$$

In financial market, arbitrage strategy seeks to exploit pricing inefficiencies for the same asset in the cash and futures markets, in order to make riskless profits. The arbitragers would typically seek to "carry" the asset until the expiration date of the futures contract, at which point it would be delivered against the futures contract. The mentioned costs incurred as a result of an investment position. These costs can include financial costs, such as the interest costs on bonds, interest expenses on margin accounts and interest on loans used to purchase a security, and economic costs, such as the opportunity costs associated with taking the initial position. This cost-of-carry model provide explanation for variations in cash and future prices and also the long-run mean reverting process between prices. This cost of carry explanation is consistent with the cointegration concept. Rearranging the equation yields

$$f_{t,T} - s_t\left(1 + b_{t,T}\right) = 0 \tag{2.5}$$

which implies that theoretically the linear combination of future price and cash price are stationary and thus, future and cash price series are cointegrated and share the same stochastic trend. The parameter $1 + b_{t,T}$ represents the linear combination parameter which is corresponding to the cost of carry.

The applications of the cost-of-carry are often used to model relationship between commodities and their future derivatives but this study adopts the model into financial assets which are considered intangible. Implication should be differed from commodity market. The construction of cost-of-carry of model applied to financial assets are initiated by Sraffa (1932) incorporated with Keynes own rate of interest.

Own rate of interest

Sraffa (1932) simply derived the idea that any market explicitly producing a price for purchase or sales of an asset in the future invariably have an interest rate component. "Any exchange of present goods for a promise to deliver goods in the future has the economic character of loan" Hicks (1939). For more specification, "forward transactions can always be reduced to or replicated by a spot transaction plus an explicit loan of some kind" Sraffa (1932).

These loans can be said to be subject to some natural rates of interest determined by largely exogenous factors. In the economy with both money and credit, the bank rate in the loan market for funds should be set equal to the natural rate of interest. Sraffa extended the idea of having multiple natural rates of interest. These rates can be explained by disequilibrium of saving and investment. Natural rates of interest for any asset for which there is a forward market can be defined as

$$x_{t,T} = r_{t,T} + \frac{s_t - f_{t,T}}{s_t}\,. \tag{2.6}$$

Equation 2.6 says that the asset's natural rate is equal to the time value of money $r_{t,T}$ combined with the premium or discount of spot price of the asset for delivery at time T (the second term of the right hand side). Together with Keynes real own interest rate derivation, the rate is defined by

$$x_{t,T} = q_{t,T} - c_{t,T} + l_{t,T}. \tag{2.7}$$

The rate is constructed by the combination of asset yield (q), physical cost of storage(c) and asset's liquidity premium (l). And equalizing the two formulations yields

$$\frac{s_t - f_{t,T}}{s_t} + r_{t,T} = x_{t,T} = q_{t,T} - c_{t,T} + l_{t,T}. \tag{2.8}$$

The relationship of the two assets can then be rearranged as

$$f_{t,T} = s_t\left(1 + r_{t,T} - x_{t,T}\right). \tag{2.9}$$

This equation explains the relationship between the forward purchase price and the spot price which express the real cost of carry.

$$\mathrm{f_{t,T}} = \mathrm{s_t}\left(1 + \mathrm{r_{t,T}} - \mathrm{q_{t,T}} + \mathrm{c_{t,T}} - \mathrm{l_{t,T}}\right) = \mathrm{s_t}(1 + \mathrm{b_{t,T}}) \tag{2.10}$$

The equation $\mathrm{f_{t,T}} = \mathrm{s_t} + \mathrm{b_{t,T}s_t}$ is later on modeled as the well-known cost-of-carry where the term $\mathrm{b_{t,T}s_t}$ exhibits the cost of carrying of the asset over time until the maturity period T.

Fully Efficient Market Hypothesis

The model is also supported by Fully Efficient Market Hypothesis which states that if the market is fully efficient (all information is symmetric among agents within the market) the expected cash price at the maturity date of its future contract's price and its future price today should be the same since any costs incurred during the period are already taken into account in everyone's expectation.

$$\mathrm{f_{t,T}} \approx \mathrm{E_t(s_T)}. \tag{2.11}$$

Theoretically, the cost of carry model under Fully Efficient Market Hypothesis predicts that future price with maturity date T reflects the cost of carrying a stock or index look-alike asset until the expiration of the future. As approaching the maturity date, the cost of carrying the asset vanishes over time. If the market is fully efficient, the gap between f_t and S_t should be constant at any time t and should provide no arbitrage opportunity in the long run. But if the market is not fully efficient in the short run, there would exist an opportunity for arbitragers to take in a position in the market and enjoy costless short run profit. The relationship between the cost of carry and Fully Efficient Market Hypothesis can be shown by equalizing equation 2.4 and equation 2.11.

$$\mathrm{f_{t,T}} = \mathrm{E_t}(\mathrm{s_T}) = s_t(\text{the cost of carrying asset over time}) \tag{2.12}$$

Short run Arbitrage force

In the situation where future price f_t is higher than the cash price plus the cost of carrying $\mathrm{s_t}(1 + \mathrm{b_{t,T}})$, or

$$\mathrm{f_{t,T}} - \mathrm{s_t}(1 + \mathrm{b_{t,T}}) > 0 \tag{2.13}$$

, there exists an arbitrage opportunity to exploit profit from the market since the combination exhibit mean reverting behavior in the long run. The future price is now relatively expensive of equivalently the asset's cash price is relatively cheap. Arbitrager who are seeking profits will hedge their position by buying the cheap asset (S_t) and short-sell the expensive one (f_t). As long as the difference is not equal to zero, arbitrage opportunities persist. The demand force of buying the relatively-cheap cash price will drive the cash price up and at the same time the selling force will lower the relatively-expensive future price. This way, the arbitrage force will narrow up the gap between $\mathrm{f_{t,T}} - \mathrm{s_t}(1 + \mathrm{b_{t,T}})$ until the difference reaches zero again. If the case is where cash price exceeds future price, or

$$\mathrm{f_{t,T}} - \mathrm{s_t}(1 + \mathrm{b_{t,T}}) < 0 \tag{2.14}$$

, the selling force of relatively expensive asset (S_t) will drive the cash price down and the demand for futures will pull the price up. Overall, the gap is increased back to zero.

Under the expectation model of cost of carry, the future price and cash price can deviate from its long run equilibrium, but it can only occur in short run. Any mispricing will be driven back to the equilibrium by the arbitrage force within the market and two prices are said to be mean-reverting.

Price Discovery and Short run Adjustment process

The presence of co-movement between future price and cash price is an important evidence that long run equilibrium persists consistently with the cost-of-carry model. But, in short run, both price series are influenced by each own irregular terms which create deviations along the path. If the series are to return to their long run equilibrium, the movement of at least a price series must respond to the magnitude of past mispricing. One explanation to the deviation occurs for a period of time is the lag of information flow between the two markets. If one market receives new information which reflects the correct stochastic path of both series, the series with wrong information tends to meander and create deviation among the series. As the mispricing occurs, it draws arbitragers and traders with correct information to take a position in the market to earn profit. This explanation is clear that the magnitude of past mispricing influences the adjustment process of the system. So the appropriate model should take into account the magnitude of past deviation to form the series.

$$\Delta s_t = \alpha_s(f_{t-1} - \beta s_{t-1}) + e_{st} \ \ where\ \alpha_s > 0. \tag{2.15}$$

$$\Delta f_t = \alpha_f(f_{t-1} - \beta s_{t-1}) + e_{ft} \ \ where\ \alpha_f < 0. \tag{2.16}$$

If the mispricing term $f_{t-1} - \beta s_{t-1} > 0$ is large relatively to the long run relationship, which also implies that last period future price was relatively expensive, the arbitragers will short-sell the future contracts to earn profit and/or long-buy the relatively cheap cash price. Such actions will increase the price of s_t and decrease the price of f_t in the next period in respond to the magnitude of $f_{t-1} - \beta s_{t-1}$with α_s and α_f as the speed of adjustment of each series. This model can also be extended to include the influence of previous lag terms of past prices and the influences of irregular terms over both series.

$$\Delta s_t = a_0 + \alpha_s(f_{t-1} - \beta s_{t-1}) + \sum a_{1i}\,\Delta s_{t-i} + \sum a_{2i}\,\Delta f_{t-i} + e_{st} \quad (2.17)$$

$$\Delta f_t = b_0 + \alpha_f(f_{t-1} - \beta s_{t-1}) + \sum b_{1i}\,\Delta s_{t-i} + \sum b_{2i}\,\Delta f_{t-i} + e_{st} \quad (2.18)$$

Empirical Reviews for Price Discovery

The Price Discovery of Indexes and their future prices has been widely examined using different econometric techniques and different results are discovered. Most of the findings are consistent that the two prices are cointegrated and exhibit long run relationship. The price discovery can be explained theoretically that the prices are mean-reverting in the long-run. The idea of cointegration initiated by Engle and Granger (1987) and later Johansen (1988) was applied to explain this dynamic relationship. Alexander (1999) revised the quantitative idea of cointegration used in financial market and also presented models which are currently used for hedging in European and Asian markets. Ackert and Racine (1999) used the cost-of-carry pricing model to examine whether the spot and futures are cointegrated. The cointegrating relationship is found including index, futures and cost of carry. The short run dynamic of the series are also analyzed to determine the causal relationship among both prices. Flemming, Ostdiek and Whaley (1996), Lihara, Kato and Tokunaga (1996), Kawaller, Koch and Koch (1987), Harris (1989) and Tse (1999) found that futures can be used to determine the cash price. Shyy, Vijayraghavan and Scott-Quin (1996), in contrast, reported the opposite direction. Another view bi-directional causal relationship is reported by Abhyankar (1998), Mukherjee (2005) and Kenourgios (2004)

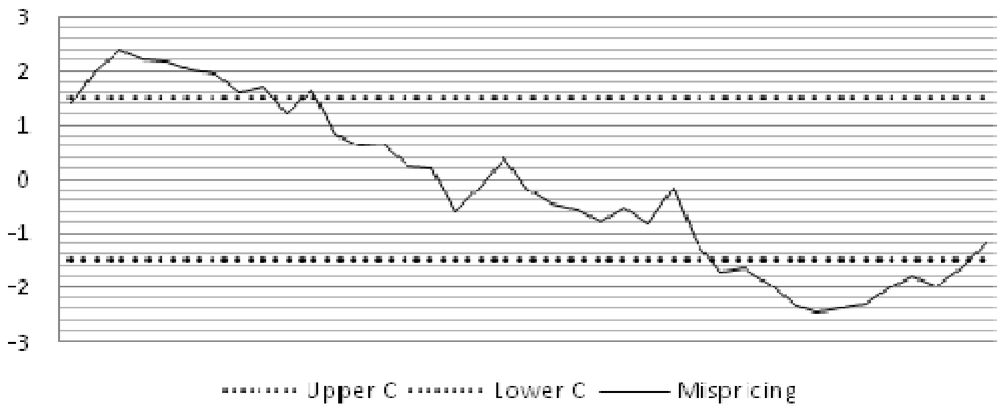
Existence of Transaction cost

The second important issue of pair trading strategy is how large should the price gap be when a position is to be taken. If the market prices trigger an arbitrage opportunity and reallocation of assets within investors' portfolios is costless, a buy-sell position will be made every time future and cash prices deviate from their long-run equilibrium. But in practice, any position made within financial markets is to be charged with fees and taxes. These transaction costs and any other market restrictions can become a main consideration of traders inside the markets. The existence of transaction cost could prevent arbitragers from instantaneous hedging as the gap $\mathrm{f_{t,T}} - \mathrm{s_t}(1 + \mathrm{b_{t,T}}) \neq 0$ because they have to revise their gain and loss before entering the market. If the overall cost of taking a position equals to C_t, arbitragers will take into account the cost of trading and enter the market only if, ignoring the bid-ask restriction,

$$\left|\mathrm{f_{t,T}} - \mathrm{s_t}(1 + \mathrm{b_{t,T}})\right| > C_t. \tag{2.19}$$

This cost of trading creates a range where there is no incentive for arbitragers. If future price is relatively cheaper or $\mathrm{f_{t,T}} - \mathrm{s_t}(1 + \mathrm{b_{t,T}}) < 0$ but the magnitude of the gap is still less than C_t, long-buy the future and short-sell the cash price strategy will not overcome the cost of trading and may not be profitable. In the case of higher future price, arbitragers will not trade any asset if the magnitude of $\mathrm{f_{t,T}} - \mathrm{s_t}(1 + \mathrm{b_{t,T}}) > 0$ is not larger than C_t. This no-incentive range can be viewed as a band, namely no-arbitrage band which has C_t as the upper bound and $-C_t$ as the lower bound of the band.

Figure 5: Size of Mispricing Gap $\mathrm{f_{t,T}} - \mathrm{s_t}(1 + \mathrm{b_{t,T}})$ and Transaction Costs



In summary, the existence of transaction costs creates three difference regimes of different magnitude of mispricing as shown in Figure 5. The mispricing sizes are assigned to three zones—upper, middle, and lower zones. The upper zone represents the size of deviation where

$$C_t > \mathrm{f}_{\mathrm{t,T}} - \mathrm{s}_{\mathrm{t}}\left(1 + \mathrm{b}_{\mathrm{t,T}}\right) > 0 \tag{2.20}$$

and the lower zone represents the mispricing size where

$$0 > f_{\mathrm{t,T}} - \mathrm{s}_{\mathrm{t}}\left(1 + \mathrm{b}_{\mathrm{t,T}}\right) > -C_t. \tag{2.21}$$

The middle zone of Figure 2.2 expresses the size of mispricing gap which is smaller the the size of transaction costs. This middle zone generates a band with no arbitrage incentive and is called “no arbitrage band.”

If $\mathrm{f}_{\mathrm{t,T}} - \mathrm{s}_{\mathrm{t}}\left(1 + \mathrm{b}_{\mathrm{t,T}}\right) > C_t$ and the two prices establish tendency to move toward the long run equilibrium, the gap will generate the demand of short-selling the future price with simultaneous demand of long-buying cash price. The arbitrage force will drive the future price down and cash price up and bring back the gap size toward zero. The unwind action to future and cash is taken if the cash price exceed future price and $\mathrm{f}_{\mathrm{t,T}} - \mathrm{s}_{\mathrm{t}}\left(1 + \mathrm{b}_{\mathrm{t,T}}\right) < -C_t$. Such actions would force the mispricing back to the band.

If the arbitrage force is not attracted to the market when the magnitude of mispricing is too low to be profitable, the correction term within the cointegration model may not have influence on the dynamic of the two series and estimated speed-of-adjustments parameters α_f and α_s could be insignificant. Under the existence of transaction cost within the market, the different magnitude mispricing does not have to be corrected in the same manner and the adjustment does not need to occur instantaneously as reflected in on constant speed-of-adjustments parameter in each series. The concept of threshold cointegration introduced by

Balke and Fomby (1997) would be more appropriate to explain the short run dynamic between the future price and the cash price. The formulation is simple. Different regimes of different magnitude of past mispricing are created to see the responses and thus different speed of adjustment parameters are estimated.

The first regime is when the magnitude of the past mispricing is less than the transaction cost, hedging in these periods are not profitable for arbitragers and the speed parameter is expected to be low.

$$\Delta s_t = a_0^{(1)} + \propto_s^{(1)} (f_{t-1} - \beta s_{t-1}) + \sum a_{1i}^{(1)} \Delta s_{t-i} + \sum a_{2i}^{(1)} \Delta f_{t-i} + e_{st}^{(1)} \quad (2.22)$$

$$\Delta f_t = b_0^{(1)} + \propto_f^{(1)} (f_{t-1} - \beta s_{t-1}) + \sum b_{1i}^{(1)} \Delta s_{t-i} + \sum b_{2i}^{(1)} \Delta f_{t-i} + e_{ft}^{(1)} \quad (2.23)$$

where $|(f_{t-1} - \beta s_{t-1})| > C_t$.

The second regime is constructed in the state that future price is relatively high and the magnitude of mispricing exceeds the transaction cost.

$$\Delta s_t = a_0^{(2)} + \propto_s^{(2)} (f_{t-1} - \beta s_{t-1}) + \sum a_{1i}^{(2)} \Delta s_{t-i} + \sum a_{2i}^{(2)} \Delta f_{t-i} + e_{st}^{(2)} \quad (2.24)$$

$$\Delta f_t = b_0^{(2)} + \propto_f^{(2)} (f_{t-1} - \beta s_{t-1}) + \sum b_{1i}^{(2)} \Delta s_{t-i} + \sum b_{2i}^{(2)} \Delta f_{t-i} + e_{ft}^{(2)} \quad (2.25)$$

where $(f_{t-1} - \beta s_{t-1}) > C_t$ and $\left|\propto_s^{(2)}\right|, \left|\propto_f^{(2)}\right|$ are expected to be higher than $\left|\propto_s^{(1)}\right|, \left|\propto_f^{(1)}\right|$ respectively.

The third regime estimates the model when cash price is over-perform and the gap is large enough compared to the cost.

$$\Delta s_t = a_0^{(3)} + \propto_s^{(3)} (f_{t-1} - \beta s_{t-1}) + \sum a_{1i}^{(3)} \Delta s_{t-i} + \sum a_{2i}^{(3)} \Delta f_{t-i} + e_{st}^{(3)} \quad (2.26)$$

$$\Delta f_t = b_0^{(3)} + \propto_f^{(3)} (f_{t-1} - \beta s_{t-1}) + \sum b_{1i}^{(3)} \Delta s_{t-i} + \sum b_{2i}^{(3)} \Delta f_{t-i} + e_{ft}^{(3)} \quad (2.27)$$

where $(f_{t-1} - \beta s_{t-1}) < -C_t$ and $|\propto_s^{(3)}|, |\propto_f^{(3)}|$ are expected to be higher than $|\propto_s^{(1)}|, |\propto_f^{(1)}|$ respectively.

Figure 6: No Arbitrage Bound of Mispricing Gap

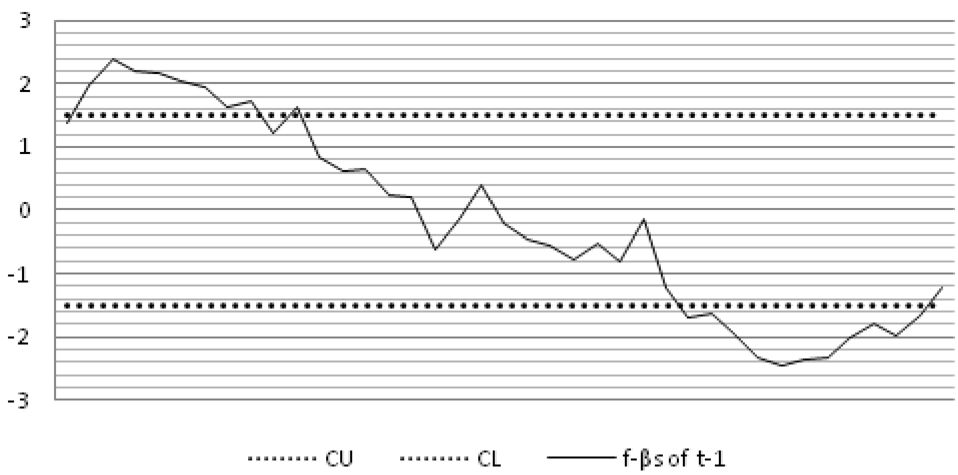


Figure 6 shows the temporal size of last period mispricing. The first regime is corresponding to the construction of no-arbitrage band indicated by CU and CL. The second and the third regime are shown in the region above CU and below CL respectively. If the speed-of-adjustment parameters in each of the three regimes are estimated to be significantly different, the implication of threshold model and the assumption that transaction cost influences the short run dynamic of the system is valid. Mathematically, CU > CL and $\alpha^{(1)} \neq \alpha^{(2)} \neq \alpha^{(3)}$ must be significant.

Empirical Reviews for Threshold cointegration model

As mentioned, transaction costs within the market distort the short run behavior of traders at each period and the system is said to exhibit asymmetric or non-linear lead-lag relationship in short run. Koutmos and Tucker (1996) modeled the joint distribution of future and index using bivariate Error Correction EGARCH to describe short term dynamics while preserving long-run relationship between the two markets. They found that prices are asymmetric function of past innovations and the degree of volatility within future market is higher. They also report a non-linear adjustment of the prices according to different news arrival. Hansen and Seo (2002) suggested that the dynamic adjustment between two markets within the correction model may be non-linear due to the presence of transaction cost preventing the holders from adjusting continuously. Stigler (2010) offered and overview on the field of threshold cointegration from the seminal paper of Balke and Fomby (1997) along with recent developments. He also derived the idea of cointegration and described the implementation to the model. Lin, Chen and Hwang (2003) used the TECM model to examine asymmetric causal relationship between spot and futures in Taiwan. Their findings are threshold cointegration and bidirectional relationship tested by Granger-Casaulity test based on the TECM model. Esteve (2009) used threshold cointegration to analyze the nonlinear behavior of stock prices and its dividends contrary to the linear Present-Value model. Sunthorn Thongthip (2010) applied the cost of carry model along with Threshold Cointegration techniques to explain the mispricing between SET50 Index and its future.

Volume Signaling

The third important issue about pair trading strategy is how investors can know that the coming convergence behavior is one-sided or two-sided. Although the position of selling the winner and selling the loser is considered risk-free, the cost fee must be paid to both assets' markets. If investors know the true trend or the exact equilibrium of the prices, investing in only one asset could reduce the cost of overall transaction in the case that one-sided convergence occurs. In order to determine the true trend, investors may need one or more additional tools. One strong and commonly available is the trading volume. Trading volume is another quantity, beside prices, that can also summarize transactions and behavior of traders in respond to news arrivals. Consequently, trading volume can be additional tools as it has a strong correlation with price series. Their relationship can be explained by Mixture of Distribution Hypothesis.

Mixture of Distribution Hypothesis

The proposition of the framework states that daily volume traded and daily price changes are driven by the same underlying latent variable, specifically news-arrival or information flow. The arrival of unexpected news resulting in price change is accompanied by above-average trading activity in the market as the disagreement among traders is being adjusted to the new equilibrium. This leads to the interest of testing of the positive correlation between volatility of price and the trading volume. The joint distribution of daily return and trading volume are modeled as a bivariate normal conditional on Information arrivals;

$$r_t \ \vdots \ I_t \sim N(0, \sigma^2 I_t) \tag{2.28}$$

$$V_t \ \vdots \ I_t \sim N(a + bI_t, cI_t) \tag{2.29}$$

where r_t = daily return which is assumed to be i.i.d. with mean zero and variance of σ^2, V_t = daily volume and I_t = Information flows at time t. Equation 2.28 and 2.29 clearly show that the dynamics of volatility process of returns are dependent on time series behavior of I_t which also affects the dynamic of trading volume. According to the hypothesis, any significant movement of a price is always accompanied by a remarkable movement of trading volume. This way, the behavior of price movement can partially be predicted with the change in trading volume

Correct Trend and Trading Volume

Technical analysts use the historical data to establish rules for buying and selling with objective of maximizing their profits along with minimizing their risks by increasing the predictability power of their tools. This analysis is based on two premises. First, the market's behavior patterns do not change meanderingly overtime, or are believed to establish trends. And the market's way of responding to new uncertainties is often similar to the way it handle them in the past, predictable behavior. This implies the pattern of dealing with future uncertainties. The patterns of prices movement are assumed to recur in the future and this pattern can be used in predictive purposes. Second relevant investment information may be distributed efficiently, but it is not distributed perfectly. Some investors who are superior in analysis and insight would always act first. Therefore valuable information can be deduced by studying transaction activities. These contribute the idea of technical analyst that changes in prices and trading volume reflect the informed investors' behavior.

On simple axiom known to technical analysts is that if a price is to change significantly there must be disagreements between investors within the market which trigger a large transaction and drive the price up or down. The disagreements can be explained to emerge from asymmetric informational flows. Those with the correct information move first and create an amount of transaction in a market. For example, if new information arrive investors of the future market first, those investor will hedge a position and keep themselves along with the correct trend of the market. Later on when investors inside the cash market receive the same new information, they will adjust their position to keep a proper range with the long run equilibrium. This is the situation where the future market is leading the cash market. If the disagreements can cause large enough mispricing, the adjustment process will be occupied solely by the cash price. The situation when the cash market receives the news first is likewise.

Moving Average Rules is one of the simplest and most popular trading rules among technical analysts. It can capture a change in trading behavior of investors of the market. When a surge in trading volume occurs, it can be implied that a group of investors is reallocation their position. According to the rule, buy and sell signal is generated by two moving averages of the level of series--a long period moving average and short period moving average. A signal of a significant move of traders is detected when short average is above the long moving average. Theoretically, the use of moving average rules is based on the fact that the time series are volatile and believed to subject to a trend; when short average break the long average, a trend is supposed to initiate. In addition to the use of moving average rules, a band of averages distance is often introduced to eliminate noisy signal and ensure that a trend is really initiated. This study will use the moving average volume of both future and cash market to indicate the leader market when the two prices generation a deviation from their long run mean.

Empirical Reviews for Volume Signaling

Numerous studies have examined the correlation between price change and trading volume, and empirical evidences have supported the hypothesis that they are tightly tied up. Chordia and Swaminathan (2000) examined the interaction between trading volume and predictability of stock returns and concluded that trading volume play an important role in disseminating market-wide information. Lee and Rui (1999) concluded that there exists a positive feedback relationship between trading volume and returns volatility in three stock markets New York, Tokyo and London. Epps (1976), along with causal relationship of trading volume to absolute stock returns result, concluded that trading volume is used to measure disagreement as traders revise their reservation prices based on new information into the market. The greater degree of disagreement among traders brings about the larger level of trading volume. Wang (1994) modeled the link between the heterogeneity among investors and behavior of trading volume to price dynamic. He found that volume is positively correlated to absolute change in prices and dividends.

The existence of a strong contemporaneous correlation between trading volume and price volatility was rationalized by a framework called Mixture of Distribution Hypothesis (MDH), Clark (1973). According to the MDH returns and volume are driven by the same latent news-arrival. Ohara (1995) offered a survey of literatures showing the positive correlations of trading volume and absolute returns under theoretical market microstructure models and also literatures involving asymmetrically informed agents. Bollerslev and Jubinski (1999) examined the equity volatility and volume for firms currently composing S&P 100 Index consistent with MDH. Blume, Easley and O'Hara (1998) investigated the informational role of transactions volume in options markets. They developed an asymmetric information model in which informed traders may trade in option or equity markets and predicted an important informational role for the volume of particular types of option trades and concludes negative and positive option volumes contain information about future stock prices.

Lamoureux and Lastrapes (1990) provided the empirical supports for time dependence of daily stock returns and volume traded according to a process generating information flow to the market. Daily volume was taken into the variance equation and the result was the disappearance of GARCH in daily return data. Fleming, Kirby and Ostdiek (2004), instead, suggested using state-space method to examine the volatility (GARCH Effects) and relation to volume under MDH framework because volume-augmented GARCH models are subject to simultaneity bias. Consequently, they found evidence of a large non-persistent component of return volatility that is contemporaneous related to non-persistent component of trading volume.

Chapter3 Research Methodology

Data and Selection Criteria

The focus of the study is future derivatives and their underlying assets. The two main products listed in Thailand Future Exchange market are SET50 Index future and Single stock future of equity assets. The data used in estimation are obtained from Efinancethai.com via e-finance smart portal software as prices' series of frequency one minute, three minutes, five minutes, ten minutes and thirty minutes from September 12th 2011 to November 14th 2011. Since there is a list of price series to be chosen, the selection criteria for a candidate pair is based on the liquidity of trading of each series. First, the one with more than 10% of missing volume trade (no trade) will be out listed. Then, the rest will be sorted by the amount of low-volume observation. An observation's volume is considered low when the current trading volume is lower than the average of the last five observations.

Estimation of Long Run Price Discovery

To empirically prove that any two series are mean reverting, long run equilibrium between prices should present according to the cost of carry relation of future contract price and its underlying cash price. The estimation of future series $F_{t,T}$ maturity at time T and cash series S_t in this study adopts the cost of carry relation of Marten, Kofman and Vorst (1998) and the model of expected future price is

$$F_{t,T} = S_t{}^{(r-q)(T-t)e_t} \tag{3.1}$$

where r and q represent risk free interest rate and dividend yields of the cash asset. The estimation of the model will use the log-linearized form which is

$$lnF_{t,T} = a_0 + a_1 lnS_t + \in_t \tag{3.2}$$

where a_1 represents the term (r-q)(T-t) and $\in_t$ represents the error term. In the rest of the paper, $lnF_{t,T}$ and lnS_t will be symbolized as $f_{t,T}$ and s_t respectively.

In order to examine the long run relationship, cointegration of $f_{t,T}$ and s_t is to be found. A unit root test on each series is to be performed the test for cointegration necessitates that each of the integrated series must be nonstationary, specifically I(1) and the linear combination of the two series to be stationary. The most common and easily-implemented test is Augmented Dickey Fuller Test of Unit Root. If any pair of series is found to be cointegrated of order (1, 1) with significant cointegrating vector, it can be concluded that the two series are mean reverting and share long run equilibrium.

Estimation of Short Run Dynamic and Adjustment Process

The principal feature of cointegrated variables is that their time paths are influenced by the magnitude of any deviation from long run equilibrium. If the tendency toward the long run equilibrium always presents, at least the movement of some variables must respond to the magnitude of the mispricing. The dynamic model suitable would be error correction mechanism. The short term dynamics of future price and cash price are influenced by the deviation from equilibrium namely "correction terms (Z_{t-1})." The more general model of CI (1, 1) is to be formulated by introducing the lag of each price in to the system as follows

$$\Delta s_t = a_0 + \propto_s z_{t-1} + \sum a_{1j} \Delta s_{t-j} + \sum a_{2j} \Delta f_{t-j} + \in_{st} \tag{3.3}$$

$$\Delta f_t = b_0 + \propto_f z_{t-1} + \sum b_{1j} \Delta s_{t-j} + \sum b_{2j} \Delta f_{t-j} + \in_{st} \tag{3.4}$$

where $z_{t-1} = (s_{t-1} - \beta f_{t-1})$ and β is the cointegration coefficient. a_{1j}, b_{1j} are the coefficients of the lags of Δs_t and a_{2j}, b_{2j} are coefficients of lag of Δf_t . The coefficients from estimation reflect the casual relationship between future and cash price.

Since the causal relationship can be bi-directional, the vector form of the log-linearized cost of carry can be formulated as Vector Auto Regressive (VAR) with error correction terms as

$$\begin{bmatrix} \Delta s_t \\ \Delta f_t \end{bmatrix} = \begin{bmatrix} a_0 \\ b_0 \end{bmatrix} + \begin{bmatrix} \propto_s \\ \propto_f \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \boldsymbol{a_{1j}} & \boldsymbol{a_{2j}} \\ \boldsymbol{b_{1j}} & \boldsymbol{b_{2j}} \end{bmatrix} \begin{bmatrix} \Delta \boldsymbol{s_{t-j}} \\ \Delta \boldsymbol{f_{t-j}} \end{bmatrix} + \begin{bmatrix} \epsilon_s \\ \epsilon_f \end{bmatrix} \tag{3.5}$$

where $ECT_{t-1} = \begin{bmatrix} 1 & -\beta \end{bmatrix} \begin{bmatrix} s_{t-1} \\ f_{t-1} \end{bmatrix}$

This formulation can be extended to allow the adjustment process to occur only after the size of ECT_{t-1} exceeds some critical threshold values. The extended version namely Threshold Vector Error Correction Model (TVECM) can capture asymmetric behaviors of the adjustment process and divide them into different regimes of different speed of adjustment parameters $\propto_s$ and $\propto_f$.

$$\begin{bmatrix} \Delta s_t \\ \Delta f_t \end{bmatrix} = \begin{bmatrix} a_0 \\ b_0 \end{bmatrix} + \begin{bmatrix} \propto^i{}_s \\ \propto^i{}_f \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \boldsymbol{a_{1j}} & \boldsymbol{a_{2j}} \\ \boldsymbol{b_{1j}} & \boldsymbol{b_{2j}} \end{bmatrix}^i \begin{bmatrix} \Delta \boldsymbol{s_{t-j}} \\ \Delta \boldsymbol{f_{t-j}} \end{bmatrix} + \begin{bmatrix} \epsilon_s \\ \epsilon_f \end{bmatrix} \quad . \tag{3.6}$$

The speed parameters $\propto_s$ and $\propto_f$ are estimated differently in each regime for i = 2 in the case that there are one threshold critical value and i = 3 in the case of two threshold critical values. The 2-regime case estimates the equation

$$\begin{bmatrix} \Delta s_t \\ \Delta f_t \end{bmatrix} = \begin{bmatrix} a_0 \\ b_0 \end{bmatrix} + \begin{bmatrix} \begin{bmatrix} \propto^1{}_s \\ \propto^1{}_f \end{bmatrix} \\ \begin{bmatrix} \propto^2{}_s \\ \propto^2{}_f \end{bmatrix} \end{bmatrix} ECT_{t-1} + \begin{matrix} \begin{bmatrix} \boldsymbol{a_{1j}} & \boldsymbol{a_{2j}} \\ \boldsymbol{b_{1j}} & \boldsymbol{b_{2j}} \end{bmatrix}^1 \\ \begin{bmatrix} \boldsymbol{a_{1j}} & \boldsymbol{a_{2j}} \\ \boldsymbol{b_{1j}} & \boldsymbol{b_{2j}} \end{bmatrix}^2 \end{matrix} \begin{bmatrix} \Delta \boldsymbol{s_{t-j}} \\ \Delta \boldsymbol{f_{t-j}} \end{bmatrix} + \begin{bmatrix} \epsilon_s \\ \epsilon_f \end{bmatrix} \tag{3.7}$$

and for 3-regime, the equation is

$$\begin{bmatrix}\Delta s_t\\ \Delta f_t\end{bmatrix}=\begin{bmatrix}a_0\\ b_0\end{bmatrix}+\begin{matrix}\begin{bmatrix}\propto^1{}_s\\ \propto^1{}_f\end{bmatrix}\\ \begin{bmatrix}\propto^2{}_s\\ \propto^2{}_f\end{bmatrix}\\ \begin{bmatrix}\propto^3{}_s\\ \propto^3{}_f\end{bmatrix}\end{matrix}ECT_{t-1}+\begin{matrix}\begin{bmatrix}\boldsymbol{a_{1j}} & \boldsymbol{a_{2j}}\\ \boldsymbol{b_{1j}} & \boldsymbol{b_{2j}}\end{bmatrix}^1\\ \begin{bmatrix}\boldsymbol{a_{1j}} & \boldsymbol{a_{2j}}\\ \boldsymbol{b_{1j}} & \boldsymbol{b_{2j}}\end{bmatrix}^2\\ \begin{bmatrix}\boldsymbol{a_{1j}} & \boldsymbol{a_{2j}}\\ \boldsymbol{b_{1j}} & \boldsymbol{b_{2j}}\end{bmatrix}^3\end{matrix}\begin{bmatrix}\Delta \boldsymbol{s_{t-j}}\\ \Delta \boldsymbol{f_{t-j}}\end{bmatrix}+\begin{bmatrix}\epsilon_s\\ \epsilon_f\end{bmatrix}. \qquad (3.8)$$

The estimation process of these models follows three steps. First, the cointegrating vectors (1, β) are to be estimated and used to construct the correction term ($Z_{t-1} = s_{t-1} - \beta f_{t-1}$). Second, the number of threshold values is set up and threshold critical values are to be grid-searched such that the speed-of-adjustment estimates behave differently in each regime. The criterion for grid-searching is the minimum sum of square of residuals. Third, each grid search model is replaced with different number of lag terms and the selection of the optimal model is to be done by using AIC and SBIC selection criteria.

Experimental Portfolio Evaluation

The existence of short run deviation reflects the inefficiency of markets' informational flow and its inertia which can cause disagreement among investors within the markets. As a deviation occurs, an adjustment process takes place. This process is explained to be driven by arbitrage forces. This paper constructs an experimental portfolio to show the existence of arbitrage opportunities and profits over the transaction costs which is the key to asymmetric short-run dynamic of the two cointegrating price series.

Trading Rules

The first section of the study has already raised an issue of when should a position be initiated as mispricing occurs. The answer is found in the TVECM model. A position is initiated as the observation's mispricing is relatively high and provides arbitrage incentive. The position includes short position of the winner price and a long position of the loser price. In TFEX, the cash price of candidate series is strictly higher than the future price so the position can be specified as short-sell the cash price and long-buy the future price. The position is closed by unwinding each contract when the mispricing is back inside the no-arbitrage band. The return of the portfolio is calculated afterward. The return from short position is equal to the price at the open-position date minus the price at the close-position date. And the return from long position equals the price at the close date minus the price at the open date. The cost of trading will take into account the transaction costs after a position is closed. Table 2 shows the return and the cost of trading one future contract. In this study, SET50 Index is assumed to be tradable contract with exactly the same transaction fee as TFEX's SET50 future contract.

In conclusion to trading with pair trading strategy in accompany with signal of initiation from TVEM model, a position is initiated when the arbitrage force is strong enough to drive the size of mispricing gap back to zero i.e. the mispricing size breakout the no-arbitrage band. This strategy become an alternative technique to pair trading strategy that simply uses two standard deviation size of mispricing gap as a position trigger.

Figure 7: Trading Rule under Three-Regime TVECM

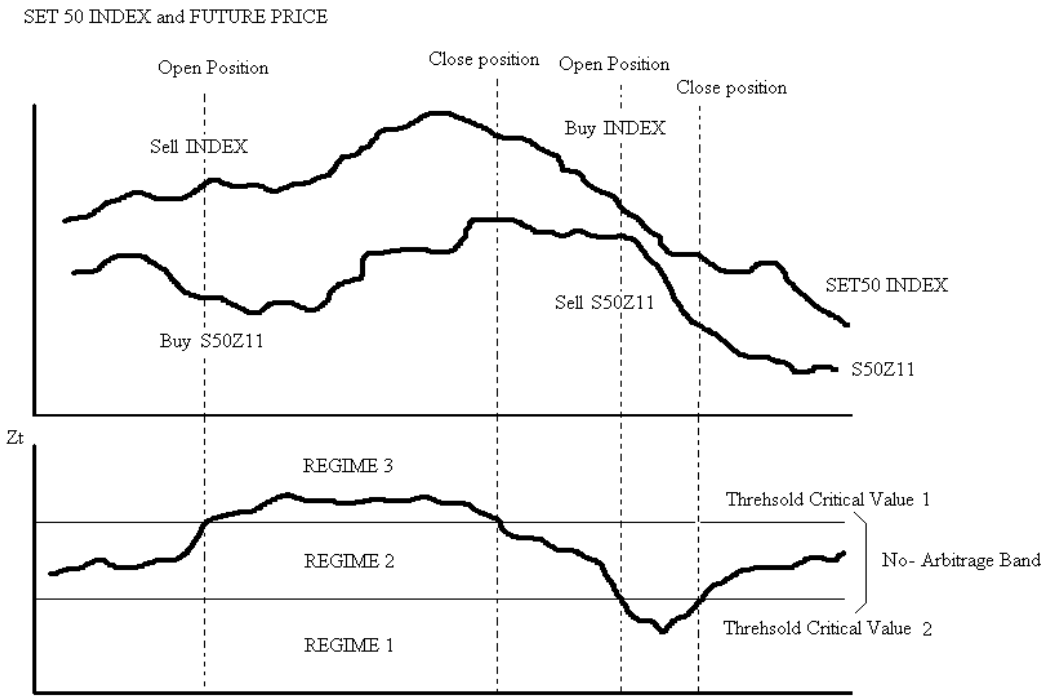


Figure 7 illustrates the three regime case. Six speed-of-adjustment parameters are estimated and the data is divided into three different regimes. The first regime belongs to the observations with no arbitrage incentive. The second regime contains observations where the deviations between prices are considerably large and the correction mechanism are driving both the winner and the lose prices conversely back to their long run mean. The last regime contains observations where the mispricing is relatively too small compared to the long run mean. The short/long position for the last regime is done in the sense that both prices are moving away from each others. The calculation of return and profits is the same as in two-regime case.

Trading Volume as leader Indicator

The irregularities within trading volume can be observed by the Volume Moving Average technique. The long-run moving average is computed using longer period length compared to the short-run moving average, so the average moves with the current volume but does not fluctuate as much. This long-length period moving average is considered a long-run trend. By using this long-term trend, any irregularities in trading volume can be tracked by the shorter-length moving average (Brock, Lakonishok, LeBaron, 1992). The underlying notion is that volume contains information regarding the quality of information in the past (Blume, Easley, O'Hara, 1994). Empirically, changes in price accompanied by high trading volume are more likely to be remarkable than the ones accompanied with low volume. The way to signal the current leading price can be generated by comparing the volatility caused by an amount of transactions within either cash market or future market. Each of the market volume series will be examined in a simplest form of moving average called "Simple Moving Average Difference" or "Simple Moving Average Oscillator". A short moving average is calculated by

$$\mathrm{SR_t} = \mathrm{V_t}\ \text{current trading volume at time t} \tag{3.9}$$

and a long moving average of order m

$$\mathrm{LR_t(m)} = \frac{1}{\mathrm{m}}\sum_{\mathrm{i=0}}^{\mathrm{m-1}} \mathrm{V_{t-i}} \tag{3.10}$$

where V_{t-i} represents series of volume at time t and their lags. The volume oscillator of each volume series is calculated by $\mathrm{SR_t}/\mathrm{LR_t(m)}$. This study uses m = 50.

The contemporaneous correlation of arbitrage force and volume volatility is to be observed numerically and graphically by comparing the periods where short-run moving average exceeds the long run moving average and the period where mispricing of future and cash prices exhibits arbitrage incentive. The calculation of relative moving average of trading volumes of both markets can be made using either the difference of ratio.

Figure 8: Mispricing Beyond No-Arbitrage Band of TVECM and Contemporaneous Trading Volume Surge

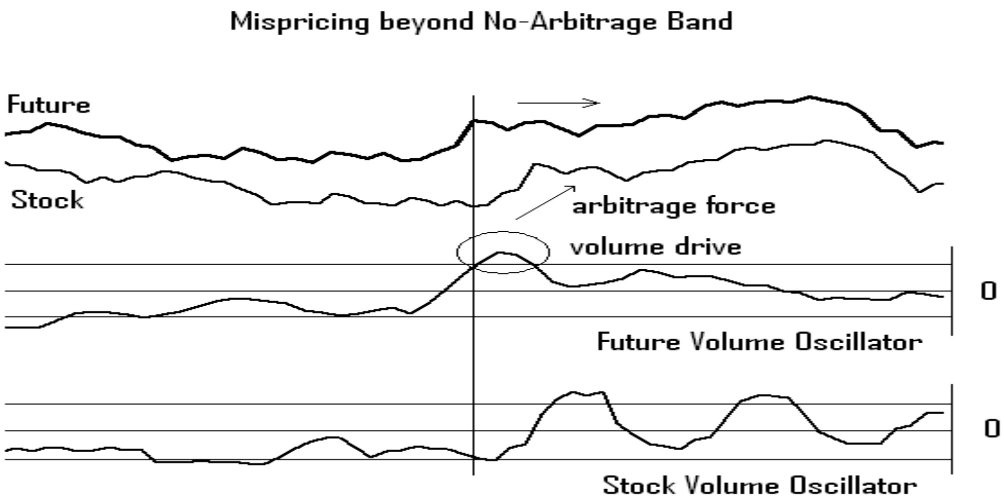


Figure 8 shows the contemporaneous correlation between the mispricing beyond no-arbitrage band of future and cash price series and the relative comparison of two volume oscillators. This is the case where significant mispricing occurs at the moment the future volume oscillator is relatively higher than the one of the cash price. According to the presumption of chapter two, future price is the leading series and it is moving along with the correct trend. As a result, the short run dynamic of adjustment process will be taken solely in the cash market and the convergence is one-sided.

This strategy presumes that threshold cointegration techniques within futures and cash markets provide a signal to initiate an arbitrage position while volume moving average technique offers a right positioning by telling the true lead-lag relationship of the moment. If there exists a leader which implies later one-sided convergence, the prevention of wrong positioning and double cost problem can be done.

To summarize the trading strategy proposed by this study, the no-arbitrage band estimated by TVECM model triggers an appropriate time to open a position in price series and the signal from trading volume precisely indicate which series are to be hedged. The position can be made either in both series in the case of two-sided convergence/divergence or solely in one series when one-sided convergence/divergence occurs.

Chapter4 Empirical Results

Data Series Selection

The candidate pair chosen for estimation and evaluation under pair trading rule is the SET50 Index series and SET50 Index Future of December maturity date (S50Z11) and the optimal frequency of SET50 Index and future is the 10-minute data series. Trading period ranges from 12th September 2011 to 11th November including 42 trading days with 1320 observations. Every listed single stock future is found to have low liquidity in any frequency throughout 3-month trading period because they contain over 30% missing observations.

Long-run relationship

Figure 9: Scatter Plot of Logarithmic Future and SET 50 Index

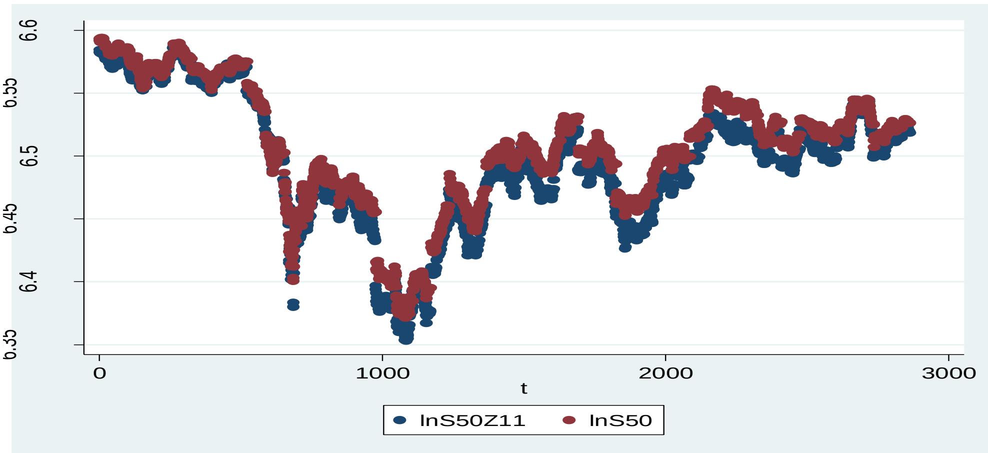


Figure 9 illustrates the scatter plot of SET50 Index and SET50Z11 which explicitly exhibit co-movement behavior shown in. Econometrically, long-run equilibrium between future and cash prices necessitates that both series must be cointegrated of order (1, 1) with implication that the two series must be I(1) and the residual of their estimated linear combination must be stationary.

Mean Reverting Behavior

Since the movement of future and cash prices are theoretically mean reverting according to fully efficient market hypothesis. The previous-period mispricing is taken into account to formulate the dynamic. Thus the future price and the index are estimated in VECM form resulting in Table 1.

Table 1: Results of Vector Error Correction Model Estimation

$\Delta lnS50\ Index$	***Coefficients***	***Standard Error***
Correction Term	-.0062636	.0193518
InS50Z11	.3053621	.0469361
InS50Index	-.2974549	.0536419
Constant Term	-.0000552	.0001076
$\Delta lnS50\ Future$	***Coefficients***	***Standard Error***
Correction Term	.0493192	.0225591
InS50Z11	.0106514	.0547152
InS50Index	-.0307979	.0625324
Constant Term	-0.0000706	.0001254

The result of Vector Error Correction Model follows theoretical assumption. The coefficient of the correction term $z_t = (s_{t-1} - \beta f_{t-1})$ or speed of adjustment reflects the adjustment toward long-run equilibrium mechanism of Δs_t and Δf_t . The speed parameter of Δs_t equation is 0.0062681 with negative sign. If the last period mispricing gap $z_t = (s_{t-1} - \beta f_{t-1})$ is positive which implies that cash price was relatively expensive compared to future price, the mechanism should drive the cash price down. The Δf_t is also adjusting with positive estimates of 0.0493192.

The magnitude of the speed of adjustment of both Δs_t and Δf_t equations are remarkably small which means that the convergence process takes over hundred periods. This is an evidence of non-linear adjustment that the process does not have to occur instantly as prices deviate but it responds differently with different magnitude of the mispricing gap. Transaction costs framework mentioned in chapter two has already explained the situation and led to the estimation of threshold vector error correction model.

Threshold Vector Error Correction Model Estimation

By following three steps of TVECM estimation, the result of three-regime case are summarized in Table 2

Table 2: Result From TVECM Estimation under Three-Regime Case

Numbers and Parameters	Values
Cointegrating Vector	(1, - 1.00185)
Number of Lags	3
Threshold Values	-0.01011026, 0.0058504
Coefficient ECT F (upper regime)	-0.0511
Coefficient ECT S (upper regime)	-0.0215
Coefficient ECT F (middle regime)	0.0105
Coefficient ECT S (middle regime)	0.0366

Coefficient ECT F (lower regime)	0.3878
Coefficient ECT S(lower regime)	0.5809
% of observations in Upper, Middle and Lower	21.4%, 71.9%, 6.9%
Number of Observations	1321
Granger Leader	S50Z11

Portfolio Performance

To evaluate the performance of trading strategy using signals from TVECM and trading volumes, three portfolios are constructed. The first portfolio is constructed with in-sample prediction to see precision of TVECM model. The second portfolio is constructed using time rolling technique to see the out-sample prediction performance. And the last portfolio adopts the traditional pair trading strategy which uses two standard deviation mispricing size to initiate buy-sell signal. This traditional strategy is to be used as a benchmark of comparison between the three portfolios.

Table 3: Summary of all Portfolios' Performance in THB

and Percentage of Return to Margin

No Volume Signal	**Return of Proprietary**	**Return of Retail**	**# of contracts B/S**
In-Sample	70,600 (100.86%)	27,400 (39.14%)	54
Out-Sample	23,800 (34%)	-3,400 (-4.86%)	34
Traditional	4,800 (6.86%)	-4,500 (-6.43%)	48
With Volume Signal	**Return of Proprietary**	**Return of Retail**	**# of contracts B/S**
In-Sample	115,290 (164.7%)	102,340 (146.2%)	37
Out-Sample	103,670 (148.1%)	86,070 (123%)	22
Traditional	116,000 (165.7%)	92,000 (131.43%)	30

Table 3 shows the return of the three portfolios—in-sample portfolio, out-sample portfolio and traditional portfolio. The first four rolls of the table contain the net return of all portfolios. Both in-sample and out-sample yield higher profits than the traditional portfolio. This can be inferred that the signal from TVECM estimation can trigger more precise position than the signal from two standard deviations. The results also suggest using additional signal from trading volume since it can remarkably increase the net gain of every portfolio. The profits is increased by 44,690 THB in the in-sample portfolio, by 79,870 THB in the out-sample portfolio and by 111,200 THB in the traditional portfolio. This increase in profits can be interpreted in two folds. First, the number of transactions and the cost paid is reduced since the eventual leader is identified. Buying/selling of both markets' contracts is no longer necessary. Second, the marginal gain from buy-sell position is exactly equal to the true mispricing size since the true converging series is determined

Chapter5 Conclusion

Summary

10-minute data series of SET50 and SET50 Z11 are acquired though trading liquidity criteria and are estimated to analyze their long run relations and the short run dynamics. The trading period ranges from 12th of September 2011 to 11th of November 2011 including 42 trading days with 1320 observations.

This study proposes a trading strategy sprouting from well-known pair trading strategy. Historical co-movement behaviors are used predict future ones. The guarantee of the co-movement behavior is done through the idea of cointegration proposed by Engle and Granger and is theoretically supported by financial cost of carry and Keynesian own rate of interest initiated by Sraffa. Price discovery and short run dynamic of future and index series are also found using Vector Error Correction Mechanism model estimation. The result is clear that the two prices are mean-reverting. Future deviation are preclude to exhibit tendency to regain equilibrium. Granger causality test suggests that SET50 index future is the leading series.

The result of low speed of adjustment parameter estimated in VECM model is corresponding with the hypothesis of asymmetric short-run adjustment between prices. The key to nonlinear adjustment is the transaction costs within the market. It prevents arbitragers from instant hedging when mispricing occurs since they have to revise their net gain from taking a position. For more precision, the speed-of-adjustment parameters are divided into different regimes of different magnitude using Threshold Vector Error Correction model. The first signal used in pair trading to trigger buy-sell position is generated when a mispricing is larger or smaller than a critical threshold.

One weak point of pair trading strategy is that a hedging in both market costs investors both markets' fees. The convergence process could only take place in one series. Double trades double the costs. The study, in addition, proposes another signal called volume moving average to identify the eventual leading series when a mispricing occurs.

Three different experimental portfolios are constructed to evaluate the performance of the signal from TVECM estimation and the signal from trading volume. The first is the in-sample portfolio evaluation. Signal from TVECM triggers 27 positions with 108 bought-and-sold transactions. By adding the volume signal to the portfolio, the number of transactions reduced to 74 and the net benefit is increased from 70,600 THB to 115,290 THB calculated proprietary desk cost of 50 THB per transaction or from 27,400 THB to 102,340 THB calculated at retail investor cost of 450 THB per transaction. The out-sample portfolio is constructed using time rolling techniques with five-day rolling ahead. The number of transactions is reduced by 24 when trading volume signals are added. Net benefit increases from 23,800 THB to 103,670 THB calculated proprietary desk cost and from loss of 3,400 THB to 86,070 THB calculated at retail investor cost. In comparison to traditional pair trading strategy, signal from TVECM estimation can trigger more precise position than criteria of two standard deviations used in traditional pair trading. But when trading volume signals are added to traditional pair trading strategy, the net profit of this strategy can dominate both in-sample and out-sample portfolio. Trading volume signal can increase profits from 4,800 THB to 116,000 THB calculated at proprietary cost and from loss of 4,500 THB to 92,000 THB calculated at retail investor cost.

The performance of these three portfolios is consistent with the framework of the study. Signals from estimated threshold critical values are more precise than signals from two standard deviations criteria. Without trading volume TVECM portfolio yields higher profits compared to the traditional portfolio. The three portfolios also show the performance of trading volume moving average. By adding volume signals, the number of transactions is reduced and hence reduced transaction costs. One-sided convergence problem is also solved and, as a result, net profits of all portfolios increase.

Suggestion and Contribution to Policy

The existence of arbitrage opportunities reflects inefficiency of the two markets as the correct information of the cost of carry and the true relationship between future and cash prices are not symmetrically distributed among all investors. The longer the two prices take their position outside the no-arbitrage band, the higher inertia of informational flow can be inferred. In order to shorten the process of adjustment and retrieve price equilibrium, investors of both markets should be provided with symmetric information. For instance, when a price is being manipulated by a large number of transactions from a group of institutions, such action should be revealed to prevent disagreement among investors which can drive prices outside the no-arbitrage band. The following statements belong to author's opinion. The increase in money velocity without generating any products should be considered as a gambling. This is a crucial reason for high liquidity of trading SET50 future derivative contracts. People love gambling. Future contract should be used as a tool to reduce the risk of price volatility but there are many finding states that index future increases the volatility in the market. A considerably large number of equities within SET 50 list are already backed up with single stock futures. If most equities within the list are backed up, trading SET50 index future contract should no longer be necessary even though it generates large amount of money to Stock Exchange of Thailand because it at the same time generate inefficiency to the market.

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