Hedging and Speculative Pressures and the Transition of the Spot-Futures Relationship in Energy and Metal Markets

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Abstract

This paper examines the impact of hedging and speculative pressures on the transition of the spot-futures relationship in metal and energy markets. We build a Markov regime switching (MRS) model where hedging and speculative pressures affect the transition probabilities between a stronger and weaker spot-futures relationship. It is found that hedging pressure increases the likelihood of transition, i.e. destabilises the existing spot-futures relationship, while speculative pressure reduces it, i.e. stabilises the relationship, in the copper, crude oil and natural gas markets, but this effect is relatively weak in the silver and heating oil markets. We also examine whether these findings generate practical benefits by testing the hedging effectiveness of the minimum variance hedge ratios (MVH) derived from the MRS models with hedging and speculative pressures. A relatively strong reduction of the portfolio variance, hedger's utility and value at risk (VaR) is observed in the energy markets.

JEL classification: G13

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1. Introduction

In the commodity markets where the spot (cash) and the futures markets are closely linked, a price change in the spot market will simply be echoed in the futures market if a constant equilibrium exists between two markets, which is known as 'the spot-future parity'(Sarno & Valente, 2000). This can be expressed in simple logarithmic form as:

$$F_{t,T} = S_t + r(T - t) \tag{1}$$

where $F_{t,T}$ is the logarithmic price of a futures contract at time t which expires at time T, S_t is the logarithm of spot price at time t, and r is the interest rate. In the spot-future parity, the percentage changes in both S_t and $F_{t,T}$ will be equal since the coefficient of S_t is one. However, this does not mean that the spot and the futures prices will be identical. The difference between the spot and the corresponding futures prices, $(F_{t,T} - S_t)$, is defined as 'the basis' (Fama & French, 1987). The basis is equal to the interest foregone, $r(T - t)$, in Equation (1). More generally, the basis is a combination of the interest foregone during storage, the marginal storage cost and the marginal convenience yield, according to the theory of storage (Fama & French, 1988), or alternatively the sum of an expected premium as a forecast bias and an expected change in the spot price (Fama & French, 1987), in the expectancy model.

The components of the basis may vary as the market experiences shocks (Fama & French, 1987). Some components may exhibit a switching behaviour similar to a market cycle between two states (McQueen & Thorley, 1991), while others reflect random supply and demand shocks. The change in the basis can then be modelled as:

$$\Delta\left(F_{t,T} - S_t\right) = \Delta F_{t,T} - \Delta S_t = \mu'_{s_t} + u'_t \tag{2}$$

where μ'_{s_t} represents the amount of the change in the basis in a state S_t and u'_t is the random error term at time t.

The assumption of constant equilibrium between the spot and the future returns (ΔF and ΔS) in Equations (1) and (2) can be relaxed by adding a coefficient φ for ΔF, which follows the transition of μ'_{s_t}. Rearranging Equation (2) for ΔS then it yields[1]:

$$\Delta S_t = \mu_{s_t} + \varphi_{s_t} \Delta F_{t,T} + u_t \tag{3}$$

[1] This specification is consistent with the price discovery role of the futures prices for spot market transactions (Garbade & Silber, 1983) as discussed in the hedge ratio literature.

where $u_t = -u_t'$,$\mu_t = -\mu_t'$ and φ_{s_t} is expected to be unity in equilibrium. This is an empirical model for 'the spot-futures relationship', which also can help to find hedger's minimum variance hedge ratio (φ) in the futures market.

Following Hamilton (1989)'s seminal work, the transitional or cyclical economic behaviour has been frequently modelled using a Markov regime switching (MRS) model, e.g., McQueen & Thorley (1991), Gray (1996), among many others. The transition of the spot-futures relationship in Equation (3) has also been modelled by Markov switching models by a large body of existing literature. For example, Sarno & Valente (2000) show that a MRS model appropriately captures the dynamic spot-futures relationship in the oil market. The MRS model is revealed to improve the performance of the minimum variance hedge (MVH) ratios (Alizadeh & Nomikos, 2004; Chen & Tsay, 2011). Since Klaassen (2002) finds that a MRS-GARCH model can significantly improve the performance of volatility forecasting in the foreign exchange markets, MRS-GARCH-based models are also used for modelling commodity futures markets (Alizadeh, Nomikos, & Pouliasis, 2008; Lee, 2009, 2010; Pan, Wang, & Yang, 2014; Philip & Shi, 2016).

The transition probabilities govern a transition between states (or regimes) in a MRS model and can be time-varying, conditional on other variables such as the average basis (Alizadeh & Nomikos, 2004). However, according to Filardo (1998), the information variables in the transition probability equations should be 'contemporaneously conditionally uncorrelated with the unobserved state, St' to have the consistent and asymptotically normal MLE estimators. The use of the basis-based measures in both mean and transition probability equations as Alizadeh & Nomikos (2004) may be a concern particularly because the mean equation itself is a general form of the change in the basis, as seen in Equations (2) and (3). This necessitates the use of an alternative variable specifically in the transition probability equation. The investors' hedging and speculative pressures (a.k.a. trading pressures) in the futures market, measured by actual positions taken by investors such as the trading pressure index developed by Wang (2001) and the net percentage long position used by De Roon et al. (2000), could have weaker correlation with unobserved states since the trading pressures are not technically converted to the mean equations like basis. However, note that past trading pressures may be still correlated to the state of the market[2], e.g. stronger long trading pressure in the previous day is correlated with state 2. If this is the case, as recommended by Filardo (1994, 1998), the mean and the transition probability equations is jointly estimated to avoid this issue. On the other hand, the trading pressure may have a stronger and more direct impact on the transition than the basis-based measures. This is because the traders' positions would lead to actual trading in the future since they have to

[2] The average correlations between regime probabilities and the associated trading pressures are low, i.e. below 0.04, in all 6 sample markets in this study.

close out the positions and thus may more strongly affect the transition probabilities of the spot-future relationship.

Futures markets provide hedging opportunities for the holders of underlying assets and highly rewarding speculative opportunities to other traders. For example, hedgers take a short position in the futures market to reduce the risk associated with the initial long position in spot markets (Hirshleifer, 1990). As speculators enter the market on the opposite side of the contracts as counterparties to hedgers, hedging pressure in the futures markets is related to the hedger's risk premium paid to speculators when transferring non-marketable risk (De Roon et al., 2000). As hedgers can take a long or short position in the futures market to decrease the price or income risk, the overall impact is determined by their net positions, which is known as 'hedging pressure' (De Roon et al., 2000). In the agricultural and foreign exchange futures markets, net long hedging pressure is found to have a negative relationship with subsequent returns (Wang, 2001, 2004). Likewise, 'speculative pressure', represented by speculators' net position, can also affect spot prices (Parsons, 2010), futures prices (Kaufmann, 2011; Wang, 2004), and futures market volatility (Cifarelli & Paladino, 2011) in various markets. Therefore, we expect trading pressures have an impact on the relationship between spot and futures prices. If traders' reaction to trading pressures symmetrically affects spot and futures prices to the same extent, the previous spot-futures relationship may still hold, but when their response is asymmetric, the spot-futures relationship can change to another state.

However, little research has been conducted to reveal the impact of hedging and speculative pressures on the transition of the spot-futures relationship. In order to fill this gap, this paper investigates, for the first time, whether hedging and speculative pressures affect the transition probabilities of the spot-futures relationship using a MRS error correction model of spot and futures returns, which makes the first contribution of this paper. Our study differs from Alizadeh & Nomikos' (2004) investigation of hedge ratios by using the trading pressures instead of basis to determine the regime transmission probabilities. We use two different measures of hedging and speculative pressures: the investor trading pressure index (Wang, 2004); and the net percentage long position (De Roon et al., 2000) with five different moving windows. Secondly, we apply our model in three metal (copper, gold and silver) and three energy (crude oil, heating oil and natural gas) markets[3] and further investigate whether hedging and speculative pressure can improve the performance of the minimum variance hedge ratio (MVH). Earlier empirical evidence has already shown that simple MRS models can provide the time-varying MVH that improves hedging effectiveness in several spot and futures markets over static OLS and multivariate GARCH alternatives (Alizadeh & Nomikos, 2004; Alizadeh et al., 2008; Lien, 2009). However, multivariate GARCH models often underperform static

[3] We focus on these markets because the data used to construct trading pressure measures are only available for some commodity markets. See Section 3 for detailed explanations.

OLS models (Alexander & Barbosa, 2007; Copeland & Zhu, 2010). More complicated MRS-GARCH models could outperform the static OLS strategy (Alizadeh et al., 2008; Salvador & Aragó, 2014; Philip & Shi, 2016), but they often incur high transaction costs (Lee & Yoder, 2007; Lee, 2010).

This paper finds that hedging and speculative pressures are statistically significant in determining the transition of the spot-futures relationship in most of the cases in copper, gold, crude oil and natural gas markets but relatively weakly in silver and heating oil markets. Net long hedging pressure tends to increase the transition probability, while net long speculative pressure decreases it in five out of the six markets, with the exception of gold markets. That is, net long hedgers are more likely to trigger the transition of the existing spot-futures relationship, but net long speculators are more likely to sustain the current relationship. Moreover, the pressure measures are statistically stronger than the basis measures when tested them together in the transition probability equations. However, heterogeneities are also found across different commodity markets. For example, in the gold market, which serves as a safe-haven asset, the results show that hedging pressures decrease the chance of transition while speculative pressures increase it, indicating the unique characteristics of hedgers and speculators operating in the gold market. This may be because traders in the gold market are more subject to government policies and macroeconomic factors such as inflation and exchange rate risk (Ciner, 2001). In addition, net long hedging pressure is more likely to trigger a transition to a stronger spot-futures relationship in the copper market, but to a weaker relationship in the energy markets.

We derive the MVHs using the MRS models with hedging and speculative pressures in the transition probability equations and test their hedging performances against various benchmark strategies including: naïve hedge; OLS; univariate GARCH; multivariate GARCH; and the MRS without pressure measures. We test in-sample and out-of-sample performances using different performance measures: portfolio variance; utility level; and value-at-risk (VaR). The reduction in the portfolio variance and utility is greatest in the energy markets on average, followed by the metal markets, which also perform well. The reduction in the VaR is largest in both the metal and energy markets. In terms of the performance in individual commodity markets, hedging performance improvements are observed to be relatively strong in the copper, silver, crude oil and natural gas markets. Out-of-sample performance is found to be better than in-sample results, indicating that trading pressures are good indicators for future spot and futures price movements.

The remainder of the article is organised as follows. Section 2 explains how the measures of hedging and speculative pressures are created and the methodology to test their impact on the transition of the spot-futures relationship. Section 3 describes the data generated for empirical analysis. Section 4 presents the empirical results. Section 5 utilises the minimum variance hedge (MVH) ratios derived in Section 4 and analyses their hedging effectiveness. Section 6 concludes this paper.

2. Hedging and speculative pressures and the transition of the spot-futures relationship

Following Wang (2001, 2004), hedging and speculative pressures in the futures markets are calculated based on traders' open interests, which are measured by the number of contracts not closed on a specific day. The distinction between hedging and speculative pressures is commonly made by the types of traders who have open interests. For the US commodity futures markets, the Commitments of Traders (CoT) reports of the US Commodity Futures Trading Commission (CFTC) formally summarise two types of large reportable traders' open interests: commercial; and non-commercial traders. A commercial trader is defined as a trader who 'uses futures contracts in that particular commodity for hedging' and 'where they are economically appropriate to the reduction of risks in the conduct and management of a commercial enterprise' (The CFTC, 2016). All other reportable traders are classified as non-commercial traders whose main purpose is speculating. Commercial traders' open interests form the basis for measuring hedging pressure while non-commercial traders' open interests are used to measure speculative pressure.

However, open interest cannot easily be compared across markets or over time since it is an absolute measure. To overcome this problem, Wang (2001, 2004) constructs the following measures of trading pressure for hedgers and speculators.[4] His indices (HSI and SSI) are calculated as follows:

$$HSI_{t,k}^{j} = \frac{NOI_{C,t}^{j} - \min(NOI_{C,t}^{j}, k)}{\max(NOI_{C,t}^{j}, k) - \min(NOI_{C,t}^{j}, k)} \tag{4}$$

$$SSI_{t,k}^{j} = \frac{NOI_{N,t}^{j} - \min(NOI_{N,t}^{j}, k)}{\max(NOI_{N,t}^{j}, k) - \min(NOI_{N,t}^{j}, k)} \tag{5}$$

where j is a commodity indicator, t is the time index, and k is the length of moving window used to calculate a historical maximum and minimum. Net open interest (NOI) is calculated by subtracting short open interest (SOI) from long open interest (LOI). In particular, NOI_C and NOI_N are commercial and non-commercial traders' net open interests, respectively. NOI has a positive value if the traders' long positions are larger than their short positions, while it has a negative value if they have relatively

[4] Hedging and speculative pressures are technically different from investor sentiment which is normally measured by a survey of analysts (Clarke & Statman, 1998; Fisher & Statman, 2000). Investor sentiment, such as optimism, pessimism or psychological foundations (Baker & Wurgler, 2007), can partly drive hedging and speculative pressures, but we assume that risk transfers or speculative profits are the main drivers.

larger short positions. Historical minimum (min) and maximum (max) values of NOI are identified over a moving window from t-k to t, e.g., k is 1 year in Wang's studies (2001, 2004). The value of HSI and SSI lies between 0 and 1. If its value is higher, this indicates that net long positions are closer to a historical high in a moving window while a lower value means that it is closer to a historical low. HSI and SSI essentially measure the relative long hedging or speculative pressure at time t against the historical maximum and minimum net open interest.

In another aspect, De Roon et al.'s (2000) net percentage long position is also adopted to measure hedging and speculative pressures. The k-week average hedging and speculative pressures (AHGP and ASCP) at time t are defined as:

$$AHGP_{t,k}^{j}=\frac{1}{k}\sum_{i=0}^{k-1}\frac{LOI_{C,t-i}^{j}-SOI_{C,t-i}^{j}}{LOI_{C,t-i}^{j}+SOI_{C,t-i}^{j}}=\frac{1}{k}\sum_{i=0}^{k-1}\frac{NOI_{C,t-i}^{j}}{TOI_{C,t-i}^{j}} \tag{6}$$

$$ASCP_{t.k}^{j}=\frac{1}{k}\sum_{i=0}^{k-1}\frac{LOI_{N,t-i}^{j}-SOI_{N,t-i}^{j}}{LOI_{N,t-i}^{j}+SOI_{N,t-i}^{j}}=\frac{1}{k}\sum_{i=0}^{k-1}\frac{NOI_{N,t-i}^{j}}{TOI_{N,t-i}^{j}} \tag{7}$$

where TOI is the total open interest as the sum of long and short open interests. AHGP and ASCP are an average of the long-position version of the normalised net short exposure (Ruf, 2012). It should be noted that we switch LOI and SOI in the original formula to create a net long exposure that is compatible with HSI and SSI. The value of AHGP and ASCP lies between -1 and 1. AHGP and ASCP measure the average relative long hedging or speculative pressure over time t, but against the average total open interest over past k periods. They are also essentially the measures of trading pressures, which are similar to HSI and SSI.

The dynamic impact of hedging and speculative pressures on the spot-futures relationship is modelled using a Markov regime switching model as developed in Equation (3). Considering two regimes or states of the spot-futures relationship (s_t=1 and 2)[5] and the state-dependent variance of the normally-distributed error term, Equation (3) can be rewritten as:

$$\Delta S_t=\mu_{s_t}+\varphi_{s_t}\Delta F_t+u_{t,s_t} \tag{8}$$

where $u_{t,s_t}\sim N(0,\sigma_{s_t}^{2})$.

[5] The three-state models are tested, but they are not preferred to the two-state models in terms of Schwarz information criterion or they fail to provide unique coefficients. These results are consistent with Alizadeh & Nomikos (2004).

Following Salvador & Arago (2014), we also modify the mean equation, Equation (8), by adding the lagged basis as the error correction term because cointegration between the spot and futures price is expected to exist due to their parity condition shown in Equation (1).

$$\Delta S_t = \mu_{s_t} + \varphi_{s_t} \Delta F_t + \lambda_{s_t} b_{t-1} + u_{t,s_t} \tag{9}$$

where $b_t = S_t - F_t$, which is now defined as the basis. The coefficient λ_{st} shows the speed of adjustment in each state or the short-term within-state dynamics of the relationship, and φ represents a short-term spot-futures relationship. In the meantime, the between-state dynamics are captured by switching all coefficients including φ and the transition probabilities as explained below. Equation (9) is used as the mean equation in the following analysis. Note that state 1 can be now defined as the state closer to the short-term equilibrium, i.e. φ is closer to 1, and state 2 is the state with some degree of deviations. Therefore, state 1 and 2 are simply defined as the states with stronger and weaker short-term spot-futures relationship, respectively.

It is also necessary to specify how a state (s_t) or a regime behaves, which in turn determines the state-specific spot-futures relationship. The state variable s_t evolves through a first-order Markov process (Hamilton, 1989), as commonly assumed in the MRS models. That is, a current state depends on only one immediately preceding state that implicitly contains all the information about past states, as shown below.

$$\Pr(s_t \mid s_{t-1}) = \Pr(s_t \mid s_{t-1}, s_{t-2}, \ldots) \tag{10}$$

where Pr is the (conditional) probability of being in one state.

A transition between states is governed by transition probabilities. When the transition probabilities are constant, they can be defined as follows:

$$\begin{cases} \Pr(s_t = 1 \mid s_{t-1} = 1) = p_{11} \\ \Pr(s_t = 2 \mid s_{t-1} = 1) = p_{12} = 1 - p_{11} \\ \Pr(s_t = 1 \mid s_{t-1} = 2) = p_{21} = 1 - p_{22} \\ \Pr(s_t = 2 \mid s_{t-1} = 2) = p_{22} \end{cases} \tag{11}$$

where p_{ij} provides the probability that state i will be followed by state j.

However, transition probabilities are likely to be time-varying if hedging and speculative pressure can influence the spot-futures relationship. For example, traders' pressure may accelerate the transition of the spot-futures relationship if they take opposite positions in the spot and futures markets and consequently increase price differentials between the two markets. However, if traders take the same positions in both markets to make arbitrage or speculative profits, the current spot-futures price relationship may be more likely to hold.

Time-varying transition probabilities are modelled in a separate transition probability equation that accommodates exogenous variables (Diebold, Lee, & Weinbach, 1994) or random coefficients (Lee, Yoder, Mittelhammer, & McCluskey, 2006). We adopt the first method to allow the impact of hedging and speculative pressures to be investigated using separate equations. Following Diebold et al. (1994) and Marsh (2000), the transition probabilities between two states in Equation (11) can be further specified as[6]:

$$\begin{cases} \Pr(s_t = 1 \mid s_{t-1} = 1) = p_{11} = 1 - \Phi(c_0 + \beta_1 TP_{t-1}) \\ \Pr(s_t = 2 \mid s_{t-1} = 1) = p_{12} = 1 - p_{11} = \Phi(c_0 + \beta_1 TP_{t-1}) \\ \Pr(s_t = 1 \mid s_{t-1} = 2) = p_{21} = 1 - p_{22} = \Phi(c_1 + \beta_2 TP_{t-1}) \\ \Pr(s_t = 2 \mid s_{t-1} = 2) = p_{22} = 1 - \Phi(c_1 + \beta_2 TP_{t-1}) \end{cases} \tag{12}$$

where Φ is a logistic function, $\Phi(x) = 1/(1+\exp(x))$, c's and β's are coefficients and TP_t are the measures of trading (hedging and speculative) pressures (HSI, SSI, AHGP and ASCP). The transition probabilities are now time-varying and depending on the degree of long hedging or speculative pressures. The study of Alizadeh & Nomikos (2004) shows that transition probabilities depend on the 4-week average basis as the basis may have the power to explain some of the spot and futures price movement (Fama and French, 1987). The spot and futures basis and their 4-week average basis are used as benchmark measures.

Equation (12) specifies that net long pressure (higher HSI/SSI and positive AHGP/ASCP) and net short pressure (lower HSI/SSI and negative AHGP/ASCP) have opposite impacts on the transition probability. This is because hedgers and speculators are likely to trade with each other in the futures market. That is, net long hedging pressure is correlated to net short speculative pressure, and net short hedging pressure is correlated with net long speculative pressure. Thus, if net long hedging and speculative pressures have contrasting effects on the transition of the spot-futures relationship[7], the adoption of net long and net short positions by the same type of traders will also have the opposite effect. For the sake of simplicity, only net long pressure will be used hereafter.

In Equation (12), statistically significant coefficients β_1 and β_2 mean that hedging or speculative pressure affects the transition of the spot-futures relationship. In particular, a significantly positive β_1

[6] p_{12} and p_{21} are specified as a logistic function, unlike (1-logistic function) shown in their papers. However, the logistic regressions in the two specifications are the same. We adopt the specification in this paper because the focus of this study is on the transition probabilities to the alternative state, and β_1 and β_2 can directly correspond to p_{12} and p_{21}. See Alizadeh & Nomikos (2004).

[7] The empirical analysis conducted in this study confirms this finding.

indicates that net long hedging or speculative pressure tends to initiate a transition from state 1 to state 2, while a positive β_2 means that the transition probability from state 2 to state 1 is increased. The parameters are estimated by the maximum likelihood estimation (MLE) method (see Diebold et al. (1994) for technical details). In addition, the use of lagged pressure variables in the transition probability equations is also likely to satisfy the contemporaneous conditional erogeneity condition that could invalidate the results obtained from the MLE (Filardo, 1998).

3. The data

The Commitment of Traders (CoT) report of the US Commodity Futures Trading Commission (CFTC) is a weekly report containing open interest data, which is released at 3:30pm on each Friday, based on the Tuesday data in the same week. The CoT reports are available for commodity futures contracts such as energy, metal and agricultural products, in addition to other assets like interest rates, equities and the foreign exchange futures contracts. This study focuses on energy and metal futures markets since they have a higher relative size of open interest to trading volume[8] and, consequently, the impact of open interest on the transition of the spot-futures relationship is likely to be stronger. Additionally, agricultural futures markets are excluded since they may be more exposed to the effects of seasonality due to the cost of storage (Fama & French, 1987). The change of spot and futures relationship may be due to the strong impact of seasonality. Furthermore, to avoid a potential impact of thin trading (Holmes & Rougier, 2005), energy and metal futures markets with a relatively high volume are used in the analysis. The data for the CoT reports are collected from clearing members, reporting dealers and brokers. They are classified into commercial and non-commercial traders' open interests as described in Section 2. Non-reportable positions are the difference between the total open interest and reportable positions, and because their classification is formally unknown, they are excluded from our analysis[9].

The data are obtained from six futures markets and their corresponding spot markets: three metal futures markets for copper (high grade), gold (100oz) and silver (5000oz) on the Chicago Mercantile Exchange; and three energy futures markets for crude oil (light), heating oil and natural gas on the New York Mercantile Exchange. A continuous series of futures settlement prices are used, which roll

[8] The ratios of open interest to average daily trade volume in our sample are 4.13 (copper), 3.37 (gold), 3.57 (silver), 2.75 (crude oil), 3.02 (heating oil) and 4.31 (natural gas). These are higher than futures contacts most-traded in the other categories such as e-mini S&P500 (equity, 1.24), 10-year T-note (interest rate, 2.97) and Euro (foreign currency, 1.11) on the Chicago Mercantile Exchange (CME).

[9] These may be regarded as small speculators' positions, but because their impact is likely to be minimal it can safely be excluded.

over on the first day of the contract month to the futures price with the next nearest maturity date to avoid rolling-over on the expiry date which may cause excessive volatility (Ma, Mercer, & Walker, 1992)[10]. Friday prices are used since we also investigate a practical use of the CoT report that is published earlier on the same day. The sample period is from 1 March 1996 to 14 March 2014 (942 weekly observations). The first 842 observations are used for in-sample analysis and the last 100 observations of both the prices and open interest series are reserved as an out-of-sample forecasting period. Both the price and open interest data are obtained from DataStream.

The patterns of the spot and the futures prices in six commodity markets are depicted in Figure 1 and Figure 2. The spot and the futures prices for the same commodity look identical, as would be expected from the theoretical relationship described in Section 1. The overall patterns seen in each group of commodities (metal and energy) are roughly similar. Specifically, gold and silver in the metal markets and crude oil and heating oil in the energy markets show a strong similarity, but each commodity market has its own distinctive movements to some degree.

(Insert Figure 1 here)

(Insert Figure 2 here)

The descriptive statistics for the spot and futures returns are summarised in Table 1. Although the mean returns are similar for the spot and the corresponding futures markets, a difference exists in the standard deviation between the two markets, which may indicate a degree of variability in the spot-futures relationship, except for the gold market. All the pairs of spot and futures prices are cointegrated with the coefficient very close to 1. This shows the existence of the long-term spot-futures relationship and also supports the use of the error correction model in the mean equation (Equation (9)).

(Insert Table 1 here)

The time-series patterns of hedgers' (commercial traders) and speculators' (non-commercial traders) net open interests (NOI) are depicted in Figure 3 and Figure 4, respectively. They show a stronger heterogeneity across the markets than the price data. Net open interests are used to calculate hedging and speculative pressures such as HSI, SSI, AHGP and ASCP, as defined in Section 2. The average correlation between hedgers' net long and speculators' net short open interests in all six markets is -0.97, showing that they are likely to be a counterparty in trading futures contracts.

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[10] The choice of roll-over methods may lead to different time-series properties of continuous price series (Ma, Mercer, & Walker, 1992). However, since no evidence has been presented for the best method, this study adopts a simpler roll-over method without price adjustment that may cause biases in variances and correlation (Ma et al., 1992). On the other hand, the absence of maturity effect in the commodity futures markets (Daal, Farhat, & Wei, 2006) may alleviate the impact of different roll-over methods (Carchano & Pardo, 2009).

(Insert Figure 3 here)

(Insert Figure 4 here)

The measures of hedging and speculative pressure are calculated using the formulae given in Equations (4), (5), (6) and (7). For all four measures, 50-week and 4-week moving windows are used. A 50-week (one year) moving window is chosen to represent the long-term trading pressure or the trading pressure when settlements dates are within the next 50 weeks which covers most of futures trading volume. It also corresponds with the length originally used in Wang (2001)'s measurement. For the comparison with the 4-week average basis used by Alizadeh & Nomikos (2004), the 4-week AHGP and ASCP are also used.[11] A 4-week moving window is for short-term trading pressure when settlement dates are with the next 4 weeks, which fits with a traditional monthly cycle. For Markov switching models, a state in which a stronger spot-futures relationship exists is defined as 'state 1', while the alternative state in which a weaker relationship exists becomes 'state 2'. The descriptive statistics of all the measures of hedging and speculative pressures, NOIs and TOIs are summarised in Table 2. It is shown that the HSI and SSI measures are around 0.5 and the standard deviations are smaller than the corresponding means. This suggests the HSI and SSI measures are relative stable. AHGPs are generally negative and ASCPs are mostly positive, except for natural gas market, which has opposite signs compared to other markets. The deviations of AHGPs and ASCPs are larger than corresponding means, implying these measures are more volatile. The open interests are sizeable for gold, crude oil and natural gas markets; however, the net open interest for natural gas is relatively small. In addition, natural gas is the only one out of the 6 markets who has a positive net open interest, i.e. long position is more than the short position. This indicates that the investors in natural gas market may behave differently from other markets.

(Insert Table 2 here)

4. Empirical results

The estimation results of the MRS models with hedging and speculative pressures, obtained from Equations (9) and (12), are presented in Table 3 and summarised in Table 4. It shows the importance of pressure measures in determining the transition of the spot-futures relationship in general. Particularly in copper, gold and crude oil markets, the measures of trading pressure significantly affect transition probabilities in 22 out of 30 cases in terms of significant β_1 or β_2. On the other hand,

[11] 4-week HSI and SSI are not used because finding a historical maximum/minimum over 4 observations may generate excessive variability in the values.

they show relatively weak degree of the significance in silver, heating oil and natural gas markets only in 9 out of 30 cases. This indicates that the role of trading pressure is rather market-specific. However, the benchmark measures, i.e. the basis and the 4-week average basis, show insignificance in all markets except only one case. The trading of commodity futures may be more strongly affected by open interest than the basis, contrary to Alizadeh & Nomikos's (2004) findings for the stock index futures markets[12]. The reason for this difference could be that the stock index futures market has stronger presence of hedgers than the commodity futures markets, which are more likely to respond to changing level of basis risk than speculators[13].

(Insert Table 3 here)

(Insert Table 4 here)

Table 5 presents the estimates of the two important coefficients (φ and λ) obtained from the models with the four selected pressure measures (HSI50, AHGP4, SSI50 and ASCP4)[14] based on relative significance. The estimated values of φ_1 show that a state with a stronger short-term spot-futures relationship (state 1) is indeed closer to a one-to-one relationship between spot and futures returns. Relatively small estimates of φ_1 in the natural gas markets may indicate that the spot prices for natural gas are more strongly affected by non-market factors such as weather, seasonality and inventories (Brown & Yücel, 2008). In general, net long hedging pressure works as a destabilising force on the existing spot-futures relationship by triggering a transition, while net long speculative pressure stabilises it by preventing a transition[15], except for the case of the gold markets. However, each market exhibits a unique response to the pressures. For example, in the copper markets, hedgers' net long pressure is likely to cause a transition from state 2 to state 1, but speculators' net long pressure is likely to sustain state 2. A possible explanation is that commercial buyers of coppers, who tend to take a long position in both spot (for current use) and futures (for future consumption) markets, restore a closer link between the two markets. Speculators who take long positions in the copper futures market may not operate in the spot market and thus weaken the link.

(Insert Table 5 here)

[12] According to Alizadeh & Nomikos' (2004) results, the 4-week average basis significantly affects a transition from state 2 (weaker) to state 1 (stronger relationship) in a sample which covers stock index futures markets. They did not test the pressure measures.

[13] The ratios of hedgers' open interest to total reportable open interest are 0.62 and 0.57 in energy and metal futures markets in the sample period, respectively. However, those in S&P500 and NASDAQ100 futures markets are 0.83 and 0.81, respectively.

[14] Absolute hedging and speculative pressures, |(HSI or SSI) -0.5| and |AHGP and ASCP|, are also tested. The results are available upon request from the authors.

[15] It can also be said that net short speculative pressure destabilises the spot-futures relationship and net short hedging pressure stabilises it. These contrasting effects are also consistent with the explanation given in Section 2.

The energy markets share similar properties with the copper market but with slight differences. Net long pressure from hedgers increases a transition from state 1 to state 2, but pressure from speculators is more likely to sustain in state 1. That is, when hedgers' long positions dominate the energy futures markets, this weakens the link between spot and futures returns, possibly because long hedgers in the oil and gas markets respond to external shocks, e.g. weather shocks, differently from cash buyers. However, speculators may respond symmetrically to an economy-wide demand shock in both markets.

In the gold markets, the impacts are reversed. In both transitions between state 1 and state 2, net long hedging pressure stabilises an ongoing relationship, while speculators' net long pressure is likely to trigger a transition. A possible explanation is that gold contracts are also traded to hedge against inflation and exchange risks and are thus influenced by economic factors and central bank policies (Ciner, 2001). For example, rising inflation increases the demand from hedgers for gold in both spot and futures markets and thus stabilises the spot-futures relationship. However, speculators may use futures contracts rather than spot contracts when they are bullish. The role of gold also explains why gold markets behave differently from silver in our sample, as shown in Narayan, Narayan & Zheng (2010)'s study.

Table 6 provides the selected estimation results for the same model, as shown in Equations (9) and (12), when both the pressure measures and the basis are used in the transition probability equations. In general, the measures of hedging and speculative pressure maintain their significance even in the presence of basis measures. However, a loss of significance shows the role of trading pressure could be market-specific and particularly not robust in the copper markets[16].

(Insert Table 6 here)

5. The application in minimum variance hedging

The empirical analysis in Section 4 has revealed that hedging and speculating activities significantly affect the spot-futures relationship. This implies that pressure measures can be applied to the models used in empirical finance to improve their performance. For example, trading pressure (hedging and speculative pressures) may enhance the performance of the minimum variance hedge

[16] This may be due to relatively strong correlation between pressure measures and the basis in the copper markets where the highest positive correlation is observed between speculators' open interest and the basis. The correlation is 0.157 in the copper markets, but the next highest one is 0.045 in the gold markets.

ratio (MVH) in terms of improving its hedging effectiveness. This is feasible since the MVH is derived from the spot-futures relationship, as shown in Equation (3).

The aim of hedging is to reduce the risk associated with investment portfolios as a hedger is traditionally specified as a pure risk minimiser (Ederington, 1979). One of the hedging strategies used in the futures market involves taking opposite positions in the spot and the futures markets for the same underlying asset. Gains or losses in the spot market are hedged by the opposing movement in the futures market. To decide how much to buy or sell in each market, a hedger has to calculate a hedge ratio which is the ratio of the futures contracts to buy/sell to one contract of the same size of underlying assets to sell/buy. It is commonly supposed that spot market holdings are fixed and that a hedger decides futures market holdings (Ederington, 1979).

If a hedger holds φ futures contracts per 1 spot contract, φ is his hedge ratio. The return on the hedged portfolio is calculated as follows:

$$r_{p,t} = \Delta S_t - \varphi \Delta F_t \tag{13}$$

The variance of the hedged portfolio is:

$$\sigma_p^2 = \sigma_S^2 + \varphi^2 \sigma_F^2 - 2\varphi \sigma_{SF} \tag{14}$$

where σ^2_S and σ^2_F are the variances of spot and futures returns, respectively, and σ_{SF} is the covariance between them.

The minimum variance hedge ratio (MVH) is the value of φ that minimises σ^2_p. It is obtained by solving the first order conditions for the minimisation of σ^2_p in Equation (14). It is the ratio of the covariances between the spot and futures returns to the variance of futures returns.

$$\varphi_t = \frac{cov(\Delta S_t, \Delta F_t)}{\mathrm{var}(\Delta F_t)} = \frac{\sigma_{SF}}{\sigma_F^2} \tag{15}$$

The MVH can also be obtained by estimating the value of φ in the following linear regression model, which is done by rewriting Equation (13) and adding the random error term u_t.

$$\Delta S_t = \mu + \varphi \Delta F_t + u_t \tag{16}$$

where $u_t \sim N(0, \sigma^2)$. This is identical to the spot-futures relationship specified in Equation (3). As long as the spot-futures relationship in Equation (16) remains constant, there will be one estimated MVH value that minimises a hedger's portfolio risk i.e., static hedging. However, it is unrealistic to assume that the MVH will remain constant over time.

Two models are popularly used to provide the time-varying MVH for dynamic hedging: GARCH and Markov regime switching (MRS) models. Multivariate GARCH models are associated with time-varying covariances and variances, as in Equation (15), and consequently generate dynamic hedge ratios (Gray, 1996; Kavussanos & Nomikos, 2000; Park & Switzer, 1995). For example, Park and Switzer (1995) use a bivariate constant correlation GARCH(1,1) model. However, GARCH-based models can produce MVHs which are overly volatile and thus incur excessive transaction costs (Lien, 2009).

Markov regime switching models of the spot-futures relationship considered in Sections 1 and 2 also generate a dynamic hedge ratio, which is the value of φ in Equation (8). Since two states exist, MRS models actually provide two separate minimum variance hedge ratios (MVH) conditional on different states, namely, φ_1 and φ_2. The hedging effectiveness of φ_1 and φ_2 could be separately evaluated in each corresponding regime, but this may not be useful since the hedgers must consider the time-varying probability of being in a specific regime given the conditional transition probabilities. Therefore, a dynamic MVH is calculated as a weighted-average of two state-dependent MVHs where weights are time-varying regime probabilities (Alizadeh & Nomikos, 2004; Alizadeh et al., 2008).

$$\varphi_t = \pi_{t,1}\varphi_1 + (1-\pi_{t,1})\varphi_2 \qquad (17)$$

where $\pi_{t,1}$ and (1- $\pi_{t,1}$) are the regime probabilities that a state is either 1 or 2, respectively, or in other words, Pr(s_t=1) and Pr(s_t=2). The regime probabilities are generated as by-products in the estimation process.

The MRS models with trading pressures (MRS-TP), specified in Equations (9) and (12), can also provide the MVH under the same approach shown above. Note that the pressure measures are included individually in the MRS-TP models. The hedging effectiveness of the MVH derived from the MRS-TP models can then be tested against that of the MVHs obtained from other hedging strategies. Dynamic hedging strategies such as the MRS model without trading pressure and multivariate GARCH model are used as benchmarks. Also, three static hedging strategies are employed. Firstly, the naïve hedging strategy involves buying one futures contract per one spot contract and not changing the hedge ratios over time, i.e. φ =1 for all t values. Secondly, the static OLS strategy estimates φ in the following equation using historical data and maintains the same MVH, which is a non-MRS version of Equation (9):

$$\Delta S_t = \mu + \varphi \Delta F_t + \lambda b_{t-1} + u_t \qquad (18)$$

Lastly, a univariate GARCH model, which allows for heteroscedasticity, is estimated with the mean equation (Equation (18)) to generate the MVH using Equation (15).

These strategies are simple to implement and do not incur transaction costs from rebalancing. However, they have a clear disadvantage in that the static hedge ratio may not be appropriate if the market conditions change frequently. Therefore, five dynamic hedging strategies are additionally tested: the MRS with constant transition probabilities; the MRS with time-varying probabilities with the basis or the 4-week average basis; and two strategies based on multivariate GARCH models – the diagonal BEKK and dynamic conditional correlation (DCC).

The performances of the derived MVHs are evaluated using several evaluation methods, both in-sample and out-of-sample methods. First, we compare the reduction in the variances of the hedged portfolio returns. The variances of the hedged portfolio (σ^2_p) are calculated as:

$$\mathrm{var}(\Delta S_t - \varphi_t \Delta F_t) \tag{19}$$

where t=1 to T for in-sample performance and t=T+1 to T+h for out-of-sample performance, and where T is the number of in-sample observations and h is the length of the forecasting period.

Second, if a hedger is a utility maximiser, as commonly assumed in economics and finance literature, rather than a pure risk minimiser, a measure for utility may be more appropriate as this also considers the expected returns, the level of risk perceived by the traders and their degree of risk aversion as part of the hedgers' utility (Alizadeh & Nomikos, 2004; Kroner & Sultan, 1993; Salvador & Aragó, 2014). It is calculated as:

$$E[U(x_{t+1})] = E[x_{t+1}] - \kappa\, \mathrm{var}(x_{t+1}) \tag{20}$$

where $x_t = \Delta S_t - \varphi_t \Delta F_t$, the return to a hedged portfolio, and κ is the degree of risk aversion. A hedger's expected utility increases in terms of expected return but decreases in risk. Following Alizadeh & Nomikos (2004), Alizadeh et al. (2008), Lee (2010), Salvador & Aragó (2014) and a number of other papers in hedging performance, it is assumed that the expected hedged portfolio return is zero and the degree of risk aversion κ is 4[17].

Lastly, we also adopt a measure frequently used by practitioners, such as in Cotter & Hanly's (2006) study: namely, the value at risk (VaR) which represents the amount of investment exposed to a pre-specified level of risk. The value of the VaR, given initial wealth (W_0) and confidence level (α), is calculated as follows:

[17] Following one of the anonymous reviewer's comment, we also release the zero return restriction on hedged portfolio. We use historical mean returns as the expected returns to calculate hedger's utility and is available upon request.

$$VaR = W_0(E[x_{t+1}] + Z_\alpha\sqrt{\mathrm{var}(x_{t+1})}) \tag{21}$$

where Z_α is the quantile of normal distribution at α. W_0 is assumed to be $ 1 million in this study and Z is -1.645 given a 95% confidence level.

The MRS models with pressure measures, expressed in Equations (9) and (12), are first estimated as explained in Section 2. As a result, the regime probabilities are obtained. In Figure 5, the regime probabilities of the MRS model with HSI50 are presented as an example. The patterns of regime probability are unique in each market, indicating that the change in the spot-futures relationship could be market-specific. Once the regime probabilities and the coefficient φ of the MRS models are estimated, the MVHs for hedging are calculated using Equation (17). Since the transition probabilities are affected by hedging and speculative pressures, the estimated MVHs reflect both the changes in those pressures and the transition between the two different states. As an example, Figure 6 presents the MVHs obtained using the MRS model with HSI50. The hedge ratios for copper, crude oil and heating oil move around 1 while the ratios for gold, silver and natural gas are smaller than the naive hedge. All the hedge ratios exhibit some mean-reverting characteristics.

(Insert Figure 5 here)

(Insert Figure 6 here)

Table 7 (below) shows the reduction in the variance of a hedged portfolio calculated using Equation (19). The results obtained from benchmark models such as: naive; OLS; univariate GARCH; simple MRS; multivariate GARCH-BEKK; and DCC, are also presented. The MVH derived from the MRS-TP using hedging or speculative pressure, generated the largest variance reduction in energy markets (Panel B) in terms of the market average (70.901%). In particular, the reduction is stronger for out-of-sample testing, where the model outperforms all other MRS-based benchmarks. The MRS model with trading pressures performs the best for in-sample and out-of-sample analysis, for crude oil market. However, in the heating oil and natural gas markets, the MRS models generally do not outperform simpler models like the OLS. The performance MRS-TP for the metal markets (Panel A) is also among the best, following the DCC model and is similar to MRS with average basis. In silver market, the MRS model with ASCP is the best among all models, for both in-sample and out-of-sample analysis. The increase in the hedgers' utility level (Equation (20)) is presented in Table 8. The results are similar to that in Table 7. The MRS-TP hedge ratios can achieve great utility improvement, especially for energy markets.

(Insert Table 7 here)

(Insert Table 8 here)

Table 9 shows the results of the VaR reduction of Equation (21). It is found that the all the four MRS-TP model outperforms other models in the energy markets (ranked 1st to 4th in average improvement), and it is mostly due to its superior out-of-sample performance. The reduction in the VaR of MRS-TP models in the metal markets is also very strong. They outperform the other non-MRS benchmarks and MRS with AHGP is the best among all competing models, but the difference from the benchmark MRS models is very small. The results support the usefulness of MRS-TP model in managing the financial risk of energy and metal markets.

(Insert Table 9 here)

In summary, hedging and speculative pressure play a significant role in the transition of the spot-futures relationship in metal and energy markets. In general, hedgers' net long pressure increases the transition probabilities, but speculators' net long pressure decreases them. However, some variation is observed across the markets. For example, the impacts of the pressures are reversed in the gold markets. This indicates that the findings could be market-specific rather than universal. Trading pressure is utilised in the transition probability equations of the MRS models to provide the minimum variance hedge ratios. The MVHs improve hedging effectiveness in terms of a smaller variance and lower VaR, for the energy markets in particular, but they only have a limited effect in the metal markets where the benefits are occasionally weaker than those obtained by simpler strategies.

6. Conclusion

This study examines the impact of hedging and speculative pressure on the spot-futures relationship, specifically in three metal (copper, gold and silver) and three energy (crude oil, heating oil and natural gas) markets. In particular, two different measures of trading pressures under five different moving windows are calculated using hedgers' and speculators' open interests. These measures are then incorporated into the Markov regime switching models to determine the time-varying transition probabilities. We further examine the performance of the optimal hedge ratios generated from the Markov regime switching models with trading pressures.

Our results show that metal and energy markets, particularly the copper, gold, crude oil and natural gas markets, are strongly subject to the impact of hedging and speculative pressures. Net long pressure from hedgers is more likely to destabilise the spot-futures relationship, i.e., lead to a transition to another state. For example, it causes a switch to a stronger relationship in the copper markets and to a weaker relationship in the gold, crude oil and natural gas markets. Conversely, net long speculative pressure can stabilise the current state of the spot-futures relationship. These findings are consistent with the view that speculators have a stabilising impact, as suggested by Friedman

(1953) and Cox (1976). However, hedgers and speculators have the opposite effect in the gold markets, possibly because traders in the gold market are more subject to government policies and macroeconomic factors such as inflation and exchange rate risk (Ciner, 2001).

The findings also have practical implications. Essentially, hedging and speculative pressures should be considered by hedgers and investors who cover both spot and futures markets, as trading pressures could change an existing spot-futures relationship. In particular, the minimum variance hedge ratios generated by the MRS models with hedging and speculative pressures have been tested against various hedging models. A reduction in the portfolio variance, hedger's utility and VaR is observed for both in-sample and out-of-sample data in the energy markets, but the effect is weak in the metal markets. Financial risk managers who adopt hedge ratios generated from our model can achieve greater variance reduction and better hedging performance. For future research, further investigation into the use of hedging and speculative pressures can provide practical benefits in terms of understanding return and volatility predictability (Manera, Nicolini, & Vignati, 2016; Wang, 2004), and other hedging and feedback trading strategies (Pan et al., 2014), among many other topics that are related to the spot-futures relationship.

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Table 1. Descriptive statistics of spot and futures returns and cointegration tests

Panel A	Metal Markets					
	Copper		Gold		Silver	
	Spot	Futures	Spot	Futures	Spot	Futures
Mean	0.0011	0.0011	0.0012	0.0012	0.0013	0.0013
Sts. Dev.	0.0386	0.0374	0.0237	0.0236	0.0415	0.0426
Skewness	-0.7770	-0.7905	-0.1692	-0.0865	-1.0320	-1.1770
Kurtosis	7.3195	7.5809	7.7556	5.8087	8.7801	10.0873
JB stat	915.8	1020.6	987.8	344.1	1637.0	2423.7
Q(4) p-value	0.0010	0.0260	0.3740	0.4870	0.5270	0.4720
ADF(4) p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Johansen trace test - log price						
H_0: r=0 (p-value)	0.0001		0.0001		0.0001	
H_0: r=1 (p-value)	0.8600		0.5372		0.8509	
Coefficient - spot prices	-1.0038		-1.0011		-0.9984	

Panel B	Energy Markets					
	Crude Oil		Heating Oil		Natural Gas	
	Spot	Futures	Spot	Futures	Spot	Futures
Mean	0.0018	0.0018	0.0017	0.0018	0.0007	0.0007
Sts. Dev.	0.0523	0.0503	0.0604	0.0486	0.1100	0.0738
Skewness	-0.2661	-0.7003	-1.4657	-0.2992	2.2913	0.0073
Kurtosis	7.7023	7.3307	43.0343	4.8528	47.7888	3.8894
JB stat	973.3	900.3	70026.2	164.7	88091.7	34.4
Q(4) p-value	0.0010	0.0610	0.0000	0.0750	0.0000	0.4260
ADF(4) p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Johansen trace test - log price						
H_0: r=0 (p-value)	0.0001		0.0000		0.0000	
H_0: r=1 (p-value)	0.6375		0.6464		0.1575	
Coefficient - spot prices	-0.9991		-0.9943		-0.9927	

Notes: This table presents the summary statistics of spot and futures returns. Std. Dev. denotes the standard deviation of returns, JB statistic is Jarque-Bera statistic and Q(4) is the Ljung-Box test with 4 lags. ADF is the Augmented Dickey Fuller test with 4 lags. Cointegration is tested between spot and futures log prices by Johansen trace tests. r is the number of cointegrating vectors. Coefficients are the normalised coefficients of spot prices where the cointegrating vector is [1, 0, -1].

Table 2. Descriptive statistics of the measure of hedging and speculative pressures, net open interest and total open interest

		Metal Markets			Energy Markets		
		Copper	Gold	Silver	Crude Oil	Heating Oil	Natural Gas
HSI50	Mean	0.5366	0.5061	0.5503	0.4839	0.5218	0.5282
	Std. Dev.	0.3398	0.3170	0.3134	0.3018	0.2895	0.3165
HSI12	Mean	0.5055	0.5173	0.5268	0.4923	0.4924	0.5158
	Std. Dev.	0.3820	0.3801	0.3870	0.3757	0.3737	0.3992
AHGP50	Mean	-0.0914	-0.2463	-0.4858	-0.0234	-0.0848	0.0123
	Std. Dev.	0.1547	0.2796	0.1134	0.0394	0.0444	0.1183
AHGP12	Mean	-0.0875	-0.2544	-0.4837	-0.0254	-0.0832	0.0197
	Std. Dev.	0.1843	0.2949	0.1427	0.0521	0.0588	0.1240
AHGP4	Mean	-0.0728	-0.2469	-0.4496	-0.0417	-0.0823	0.0211
	Std. Dev.	0.1930	0.2890	0.1729	0.0723	0.0710	0.1246
SSI50	Mean	0.4634	0.4903	0.4459	0.5210	0.4746	0.4604
	Std. Dev.	0.3384	0.3173	0.3111	0.2963	0.2895	0.3222
SSI12	Mean	0.4848	0.4813	0.4767	0.5071	0.5068	0.4867
	Std. Dev.	0.3851	0.3801	0.3826	0.3714	0.3708	0.3983
ASCP50	Mean	0.1179	0.2209	0.5367	0.0987	0.1917	-0.0897
	Std. Dev.	0.2749	0.4732	0.1829	0.1738	0.2531	0.3170
ASCP12	Mean	0.1120	0.2375	0.5334	0.1006	0.1900	-0.1068
	Std. Dev.	0.3428	0.5040	0.2333	0.2346	0.3264	0.3749
ASCP4	Mean	0.1006	0.2482	0.5150	0.1496	0.1765	-0.0896
	Std. Dev.	0.3517	0.4998	0.2578	0.2914	0.3600	0.4046
NOI	Mean	-5942.39	-98016.57	-42409.94	-60544.97	-19542.45	24330.36
	Std. Dev.	18675.16	102292.81	18750.34	100179.85	18362.58	67648.51
TOI	Mean	135745.80	439697.20	140548.10	1217935.00	285166.70	691507.10
	Std. Dev.	46696.07	225231.50	29315.14	534064.40	105635.20	291756.40

Notes: HSI and AHGP are the measures of hedging pressure: hedgers' trading pressure index and average hedging pressure shown in Equation (4) and (6). SSI and ASCP are the measures of speculative pressure: speculators' trading pressure index and average speculative pressure shown in Equation (5) and (7). The suffix number indicates the number of weeks used as a moving window to calculate a value of each measure. NOI is net open interest as long less short open interest. TOI is total open interest as a sum of hedgers' or speculators' open interests.

Table 3. The impact of hedging and speculative pressures on the transition probabilities of spot-futures relationship

			Metal			Energy		
	Index		Copper	Gold	Silver	Crude Oil	Heating Oil	Natural Gas
Hedging Pressure	HSI50	β_1	-0.9945	-1.8959***	-0.7340	0.3280	1.9309**	3.0039***
		p-value	0.1720	0.0079	0.2739	0.3232	0.0279	0.0098
		β_2	-0.9431	-3.7247***	-0.5526	-0.5642	-0.6183	0.4612
		p-value	0.1339	0.0051	0.7813	0.5639	0.6011	0.5492
	HSI12	β_1	-0.1326	-1.4903**	-0.7958	0.1892	0.8415	1.7890*
		p-value	0.8288	0.0144	0.1287	0.4914	0.1673	0.0534
		β_2	-1.2425*	-2.0986**	3.6540	-0.0001	-1.1870	0.4292
		p-value	0.0650	0.0323	1.0000	0.9998	0.1501	0.4857
	AHGP50	β_1	-0.6463	1.1589	2.3577	9.2688***	-2.0316	0.3408
		p-value	0.6551	0.3099	0.2510	0.0022	0.6895	0.8729
		β_2	6.6271***	-1.0336	-0.2086	-0.1938	0.0360	-0.6166
		p-value	0.0000	0.1838	0.9699	0.9755	0.9951	0.7608
	AHGP12	β_1	0.0922	-1.3804*	2.2702*	7.1589***	1.5057	1.0578
		p-value	0.9398	0.0594	0.0575	0.0012	0.7169	0.5972
		β_2	4.7843***	-0.0001	-0.0991	-0.3006	0.4481	-0.7581
		p-value	0.0003	0.9999	0.9867	0.9468	0.9309	0.7121
	AHGP4	β_1	2.1353*	-0.5206	1.7976	6.0951***	2.4298	1.9516
		p-value	0.0759	0.6824	0.1084	0.0017	0.5909	0.3356
		β_2	5.6726***	-1.6749**	0.0223	-4.8553	0.2266	-0.0059
		p-value	0.0000	0.0214	0.9964	0.2826	0.9624	0.9976
Speculative Pressure	SSI50	β_1	-1.6905**	1.9837***	-1.0688*	-0.2943	-1.4100*	-2.9696***
		p-value	0.0221	0.0051	0.0941	0.3799	0.0724	0.0060
		β_2	-1.6324**	4.0243***	1.0349	0.5900	-0.0027	-0.6327
		p-value	0.0270	0.0042	0.7024	0.5543	0.9980	0.3796
	SSI12	β_1	-0.2146	1.4875**	-0.0921	-0.2652	1.1057	-2.7656***
		p-value	0.6982	0.0165	0.8592	0.3376	0.1889	0.0035
		β_2	-1.6816**	2.1677**	2.4319	0.0912	-0.8513	-0.7235
		p-value	0.0324	0.0283	0.3025	0.8838	0.1457	0.2514
	ASCP50	β_1	-0.7570	0.4440	-0.3033	-1.2537**	-0.2492	0.2918
		p-value	0.3191	0.3228	0.9577	0.0325	0.7552	0.7160
		β_2	-5.0992***	-0.7804	-0.5236	0.3241	-1.6892	0.6450
		p-value	0.0000	0.2359	0.6071	0.7848	0.1529	0.3696
	ASCP12	β_1	-0.8378	0.5390	-0.5236	-0.9953**	-0.0938	-0.2170
		p-value	0.1920	0.1965	0.6071	0.0196	0.9012	0.7143
		β_2	-1.2637*	-0.3805	-0.3033	0.6166	-1.1935	0.1001
		p-value	0.0572	0.5621	0.9577	0.4562	0.2015	0.8791
	ASCP4	β_1	-1.0362*	0.6858*	-0.1656	-0.7678**	-0.4653	-0.9774
		p-value	0.0943	0.0998	0.9663	0.0371	0.4743	0.1465
		β_2	-1.7958***	-0.0002	0.4317	0.7591	-0.8347	-0.2209
		p-value	0.0064	0.9998	0.6183	0.3537	0.2643	0.7031
Benchmark	Basis	β_1	2.5269	0.0541	0.9749	-0.0812	-2.6234*	0.2679
		p-value	0.2685	0.9999	0.7759	0.9998	0.0855	0.8272
		β_2	1.0328	-0.0002	-0.2423	0.0637	1.1605	2.3840
		p-value	0.6449	1.0000	0.9723	0.9988	0.5874	0.8254
	AvgBasis	β_1	2.3357	0.0548	1.3873	0.6053	1.4397	0.7876
		p-value	0.2673	0.9999	0.6388	0.9908	0.3507	0.5989
		β_2	1.1793	-0.0002	-1.4857	0.0472	0.3603	-2.2019
		p-value	0.6222	1.0000	0.9992	0.9996	0.8672	0.7079

Notes: This table summarises the significance of net long hedging and speculative pressures in the transition probability equations in the MRS model of the spot-futures relationship, HSI and SSI are hedgers' and speculators' trading pressure index by Wang (2001), shown in Equation (4) and (5). AHGP and ASCP are an average of hedging and speculative pressures by De Roon et al. (2000), shown in Equation (6) and (7). The suffix shows the number of weeks used as a moving window. β_1 and β_2 are the estimates of the coefficient in the transition probability equations. P-values are shown below the estimated coefficients. Two benchmarks we used are the basis (Basis) and the 4-week average basis (AvgBasis) as in Alizadeh & Nomikos (2004). ***, ** and * indicates the statistical significance at 1%, 5% and 10% level, respectively.

Table 4. Summary: the statistical significance of hedging and speculative pressures in Table 3

			Metal			Energy		
	Index		Copper	Gold	Silver	Crude Oil	Heating Oil	Natural Gas
Hedging Pressure	HSI50	β_1		---			++	+++
		β_2		---				
	HSI12	β_1		--				+
		β_2	-	--				
	AHGP50	β_1				+++		
		β_2	+++					
	AHGP12	β_1		-	+	+++		
		β_2	+++					
	AHGP4	β_1	+			+++		
		β_2	+++	--				
Speculative Pressure	SSI50	β_1	--	+++	-		-	---
		β_2	--	+++				
	SSI12	β_1		++				---
		β_2	--	++				
	ASCP50	β_1				--		
		β_2	---					
	ASCP12	β_1				--		
		β_2	-					
	ASCP4	β_1	+	+		--		
		β_2	---					
Benchmark	Basis	β_1					-	
		β_2						
	AvgBasis	β_1						
		β_2						

Notes: This table summarises the findings in Table 3. + and - indicate the positive and negative impact of the net long pressure on the transition of the spot-futures relationship, respectively. β_1 and β_2 are the estimates of the coefficient in the transition probability equations. +++ and --- indicate the statistical significance at 1% level and ++ and -- indicate the statistical significance at 5% level. + and – mean the significance at 10% level. Refer to Table 3 for more details.

Table 5. Estimation results of the MRS model with hedging and speculative pressures

	Index		Metal			Energy		
			Copper	Gold	Silver	Crude Oil	Heating Oil	Natural Gas
Hedging Pressure	HSI50	φ_1	1.0046***	1.0046***	0.9606***	1.0008**	1.0118***	0.8693***
		λ_1	0.4558***	0.4558***	0.9718***	0.9974***	0.5823***	0.4273***
		φ_2	0.9602***	0.9602***	0.8228***	0.8946***	0.9157***	0.8449***
		λ_2	0.4358***	0.4358***	0.9215***	1.0261***	0.5829***	0.7746***
		β_1	-0.9945	-1.8959***	-0.7340	0.3280	1.9309**	3.0039***
		β_2	-0.9431	-3.7247***	-0.5526	-0.5642	-0.6183	0.4612
	AHGP4	φ_1	1.0032***	1.0032***	0.9566***	1.0008***	1.0124***	0.8714***
		λ_1	0.4558***	0.4558***	0.9718***	0.9974***	0.5825***	0.4298***
		φ_2	0.9663***	0.9663***	0.8830***	0.8957***	0.9152***	0.8451***
		λ_2	0.4358***	0.4358***	0.9217***	1.0260**	0.5824***	0.7652***
		β_1	2.1353*	-0.5206	1.7976	6.0951***	2.4298	1.9516
		β_2	5.6726***	-1.6749**	0.0223	-4.8553	0.2266	-0.0059
Speculative Pressure	SSI50	φ_1	1.0039***	0.9401***	0.9495***	1.0008***	1.0116***	0.8712***
		λ_1	0.4504***	0.9603***	0.9607***	0.9974***	0.5603***	0.4278***
		φ_2	0.9565***	0.8723***	0.8364***	0.8943***	0.9161***	0.8437***
		λ_2	0.4102***	1.1751***	0.9134	1.0261**	0.5707***	0.7702***
		β_1	-1.6905**	1.9837***	-1.0688*	0.5900	-1.4100*	-2.9696***
		β_2	-1.6324**	4.0243***	1.0349	-0.2943	-0.0027	-0.6327
	ASCP4	φ_1	1.0035***	0.9389***	0.9596***	1.0008***	1.0129***	0.8701***
		λ_1	0.4558***	0.9578***	0.9607***	0.9974***	0.5824***	0.4292***
		φ_2	0.9800***	0.8737***	0.8056***	0.8951***	0.9124***	0.8448***
		λ_2	0.4358***	1.1485***	0.9140***	1.0266**	0.5824***	0.7632***
		β_1	-1.0362*	0.6858*	0.4317	-0.7678**	-0.4653	-0.9774
		β_2	-1.7958***	-0.0002	-0.1656	0.7591	-0.8347	-0.2209

Notes: This table shows the estimation results of the MRS models with the selected measures of hedging and speculative pressures. φ_s and λ_s are the estimated coefficients in state s in Equation (9). β_1 and β_2 are the estimates of the coefficient in the transition probability equations. ***, ** and * indicate the statistical significance at 1%, 5% and 10% level, respectively.

Table 6. The significance of the selected hedging and speculative pressures against the basis-based measures in the nested models.

				Metal			Energy		
		Index		Copper	Gold	Silver	Crude Oil	Heating Oil	Natural Gas
Hedging Pressure	Pair 1	HSI50	β_1		---			++	++
			β_2		---				
		Basis	β_1						
			β_2						
	Pair 2	AHGP4	β_1				+++		
			β_2		--				
		Basis	β_1						
			β_2						
Speculative Pressure	Pair 3	SSI50	β_1		+++	---			--
			β_2		+++			--	
		Basis	β_2						
			β_2						
	Pair 4	ASCP4	β_1				--		
			β_2						
		Basis	β_1						
			β_2						

Notes: This table presents the statistical significance of pressure measures when both pressures and basis-based measures are incorporated the transition probability equations, Equation (12). β_1 and β_2 are the estimates of the coefficient in the transition probability equations. + and – indicate the positive impact of the measures on the transition of spot-futures relationship, respectively. +++ and --- indicate the statistical significance at 1% level. ++ and -- represent the statistical significance at 5% level. + and – mean the significance at 10% level. Grey-shaded cells indicate the loss of significance compared with Table 4 and Table 5.

Table 7. Variance reduction of the hedged portfolios

Panel A: Metal

		Copper		Gold		Silver		Average
		In Sample	Out of Sample	In Sample	Out of Sample	In Sample	Out of Sample	
Unhedged variance		0.00164	0.00068	0.00061	0.00064	0.00185	0.00125	
Naive		93.146%	37.152%	82.316%	90.765%	90.068%	94.830%	81.380%
OLS		93.161%	37.622%	83.058%	90.076%	90.513%	95.474%	81.651%
GARCH		91.348%	38.180%	84.709%	89.496%	90.897%	95.460%	81.682%
BEKK		92.875%	38.933%	84.102%	86.448%	90.545%	94.705%	81.268%
DCC		92.839%	40.806%	83.483%	90.207%	90.426%	95.328%	82.182%
MRS		93.238%	39.240%	83.085%	90.142%	90.704%	95.482%	81.982%
MRS-TP	HPI50	93.225%	39.373%	83.002%	90.123%	90.988%	95.401%	82.019%
	AHGP4	93.212%	39.299%	83.055%	90.208%	90.775%	95.498%	82.008%
	SPI50	93.217%	39.553%	83.001%	90.131%	90.862%	95.480%	82.041%
	ASCP4	93.194%	39.415%	83.049%	90.194%	91.007%	95.497%	82.059%
	Basis	92.846%	39.429%	83.033%	90.170%	90.710%	95.436%	81.937%
	AvgBasis	93.241%	39.970%	83.034%	90.170%	90.766%	95.487%	82.111%

Panel B: Energy

		Crude Oil		Heating Oil		Natural Gas		Average
		In Sample	Out of Sample	In Sample	Out of Sample	In Sample	Out of Sample	
Unhedged variance		0.00307	0.00081	0.00423	0.00071	0.00974	0.00395	
Naive		90.530%	77.588%	63.450%	88.882%	37.660%	61.262%	69.895%
OLS		90.550%	78.037%	63.432%	89.116%	39.605%	64.214%	70.826%
GARCH		90.441%	78.129%	68.072%	82.086%	14.839%	63.934%	66.250%
BEKK		89.273%	78.359%	52.520%	83.680%	32.153%	62.320%	66.384%
DCC		90.839%	78.223%	59.954%	89.483%	39.722%	63.650%	70.312%
MRS		90.740%	78.259%	63.363%	88.894%	39.619%	64.095%	70.828%
MRS-TP	HPI50	90.740%	78.617%	63.356%	88.905%	39.619%	64.112%	70.892%
	AHGP4	90.739%	78.893%	63.361%	88.901%	39.615%	64.094%	70.934%
	SPI50	90.740%	78.610%	63.354%	88.926%	39.627%	64.106%	70.894%
	ASCP4	90.739%	78.682%	63.358%	88.908%	39.616%	64.106%	70.901%
	Basis	90.740%	78.256%	63.345%	88.931%	39.628%	64.090%	70.832%
	AvgBasis	90.740%	78.259%	63.342%	88.889%	39.624%	64.091%	70.824%

Notes: This table summarises the reduction in the variances of hedged portfolios against unhedged portfolio where the minimum variance hedge ratios are calculated from different hedging models. MRS-TP models are the MRS models with hedging and speculative pressures. Unhedged variance is the variance of spot returns without employing any hedging strategy. HSI50 and SSI50 are 50-week hedgers' and speculators' trading pressure index by Wang (2001). AHGP4 and ASCP4 are a 4-week average of hedging and speculative pressures by De Roon et al. (2000). Basis and 4-week average basis (AvgBasis) are used for comparison following Alizadeh & Nomikos (2004). The results from benchmark strategies are also presented. OLS is a static OLS method. GARCH is a univariate GARCH (1,1) and BEKK and DCC (dynamic conditional correlation) are multivariate GARCH models. The higher percentage reduction indicates the higher hedging effectiveness.

Table 8. Hedgers' utility improvement in the hedged portfolio

Panel A: Metal								
		Copper		Gold		Silver		Average
		In Sample	Out of Sample	In Sample	Out of Sample	In Sample	Out of Sample	
Unhedged utility		-0.00656	-0.00263	-0.00243	-0.00255	-0.00739	-0.00499	
Naive		93.146%	37.152%	82.316%	90.765%	90.068%	94.830%	81.380%
OLS		93.161%	37.622%	83.058%	90.076%	90.513%	95.474%	81.651%
GARCH		91.348%	38.180%	84.709%	89.496%	90.897%	95.460%	81.682%
BEKK		92.875%	38.933%	84.102%	86.448%	90.545%	94.705%	81.268%
DCC		92.839%	40.806%	83.483%	90.207%	90.426%	95.328%	82.182%
MRS		93.148%	38.105%	83.033%	90.170%	91.024%	95.402%	81.814%
MRS-TP	HPI50	93.237%	41.181%	83.012%	90.170%	91.094%	95.439%	82.356%
	AHGP4	93.212%	39.299%	83.055%	90.208%	90.775%	95.498%	82.008%
	SPI50	93.210%	41.077%	83.014%	90.201%	90.988%	95.525%	82.336%
	ASCP4	93.194%	39.415%	83.049%	90.194%	91.007%	95.497%	82.059%
	Basis	92.846%	39.429%	83.033%	90.170%	90.710%	95.436%	81.937%
	AvgBasis	93.241%	39.970%	83.034%	90.170%	90.766%	95.487%	82.111%

Panel B: Energy								
		Crude Oil		Heating Oil		Natural Gas		Average
		In Sample	Out of Sample	In Sample	Out of Sample	In Sample	Out of Sample	
Unhedged utility		-0.01226	-0.00325	-0.01692	-0.00284	-0.03894	-0.01579	
Naive		90.530%	77.588%	63.450%	88.882%	37.660%	61.262%	69.895%
OLS		90.550%	78.037%	63.432%	89.116%	39.605%	64.214%	70.826%
GARCH		90.441%	78.129%	68.072%	82.086%	14.839%	63.934%	66.250%
BEKK		89.273%	78.359%	52.520%	83.680%	32.153%	62.320%	66.384%
DCC		90.839%	78.223%	59.954%	89.483%	39.722%	63.650%	70.312%
MRS		90.740%	78.259%	63.363%	88.894%	39.619%	64.095%	70.828%
MRS-TP	HPI50	90.740%	78.374%	63.366%	88.871%	39.627%	64.095%	70.845%
	AHGP4	90.739%	78.893%	63.361%	88.901%	39.615%	64.094%	70.934%
	SPI50	90.740%	78.370%	63.351%	88.875%	39.638%	64.091%	70.844%
	ASCP4	90.739%	78.682%	63.358%	88.908%	39.616%	64.106%	70.901%
	Basis	90.740%	78.256%	63.345%	88.931%	39.628%	64.090%	70.832%
	AvgBasis	90.740%	78.259%	63.342%	88.889%	39.624%	64.091%	70.824%

Notes: This table summarises the improvement in hedger's utility level from different hedging models, against unhedged portfolio. MRS-TP models are the MRS models with hedging and speculative pressures. Unhedged utility is the hedgers' utility level when they do not employ any hedging strategy. HSI50 and SSI50 are 50-week hedgers' and speculators' trading pressure index by Wang (2001). AHGP4 and ASCP4 are 4-week average of hedging and speculative pressures by De Roon et al. (2000). Basis and 4-week average basis (AvgBasis) are used for comparison following Alizadeh & Nomikos (2004). The results from benchmark strategies are also presented. OLS is a static OLS method. GARCH is a univariate GARCH (1,1) and BEKK and DCC (dynamic conditional correlation) are multivariate GARCH models. The higher percentage improvement indicates the higher performance of hedging strategies.

Table 9. Reduction in Value at Risk (VaR) in the hedged portfolio

Panel A: Metal

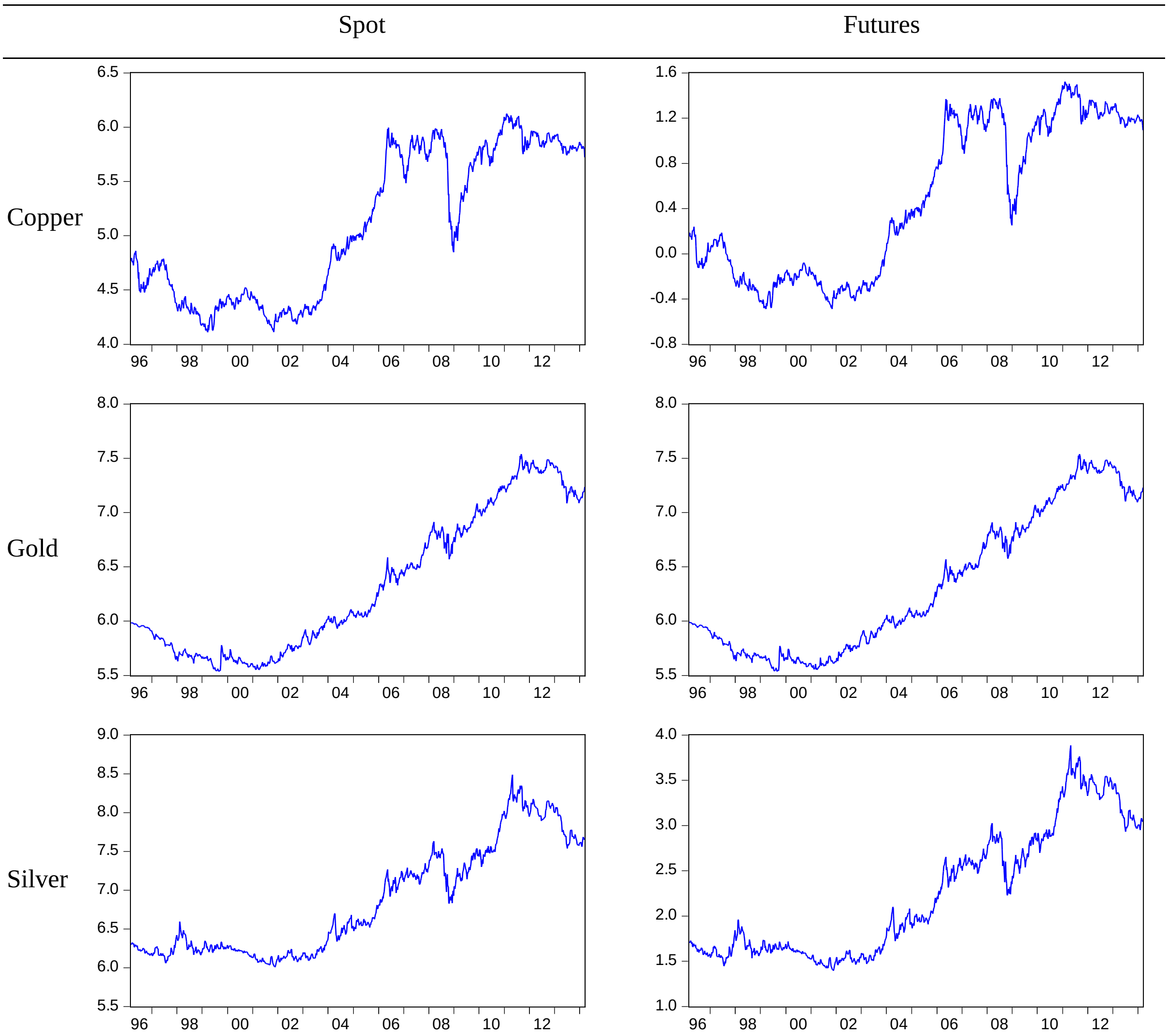
		Copper		Gold		Silver		Average
		In Sample	Out of Sample	In Sample	Out of Sample	In Sample	Out of Sample	
Unhedged VaR		-666.370	-421.823	-405.750	-415.255	-707.053	-580.934	
Naive		73.819%	20.723%	57.948%	69.511%	68.485%	77.263%	61.292%
OLS		73.848%	21.020%	58.839%	68.498%	69.198%	78.726%	61.688%
GARCH		70.586%	21.375%	60.896%	67.591%	69.828%	78.693%	61.495%
BEKK		73.307%	21.854%	60.128%	63.187%	69.251%	76.989%	60.786%
DCC		73.239%	23.063%	59.359%	68.707%	69.059%	78.385%	61.968%
MRS		73.824%	21.326%	58.810%	68.648%	70.040%	78.556%	61.867%
MRS-TP	HPI50	73.972%	22.137%	58.771%	68.572%	69.980%	78.554%	61.998%
	AHGP4	73.946%	22.089%	58.836%	68.708%	69.628%	78.782%	61.998%
	SPI50	73.956%	22.253%	58.770%	68.586%	69.771%	78.739%	62.012%
	ASCP4	73.911%	22.164%	58.829%	68.686%	70.012%	78.779%	62.064%
	Basis	73.252%	22.172%	58.809%	68.648%	69.520%	78.638%	61.840%
	AvgBasis	74.002%	22.521%	58.810%	68.648%	69.613%	78.756%	62.058%

Panel B: Energy

		Crude Oil		Heating Oil		Natural Gas		Average
		In Sample	Out of Sample	In Sample	Out of Sample	In Sample	Out of Sample	
Unhedged VaR		-910.835	-469.115	-1070.028	-437.940	-1623.061	-1033.638	
Naive		69.226%	52.569%	39.544%	66.656%	21.111%	37.760%	47.811%
OLS		69.258%	53.135%	39.529%	67.009%	22.286%	40.179%	48.566%
GARCH		69.082%	53.233%	43.495%	57.675%	7.717%	39.945%	45.191%
BEKK		67.248%	53.480%	31.094%	59.602%	17.631%	38.616%	44.612%
DCC		69.732%	53.334%	36.718%	67.570%	22.361%	39.709%	48.238%
MRS		69.569%	53.373%	39.472%	66.674%	22.295%	40.079%	48.577%
MRS-TP	HPI50	69.569%	53.759%	39.466%	66.691%	22.295%	40.093%	48.645%
	AHGP4	69.568%	54.058%	39.470%	66.685%	22.292%	40.078%	48.692%
	SPI50	69.569%	53.750%	39.464%	66.722%	22.300%	40.088%	48.649%
	ASCP4	69.568%	53.828%	39.467%	66.696%	22.293%	40.088%	48.657%
	Basis	69.569%	53.369%	39.457%	66.731%	22.300%	40.075%	48.584%
	AvgBasis	69.569%	53.373%	39.454%	66.668%	22.298%	40.076%	48.573%

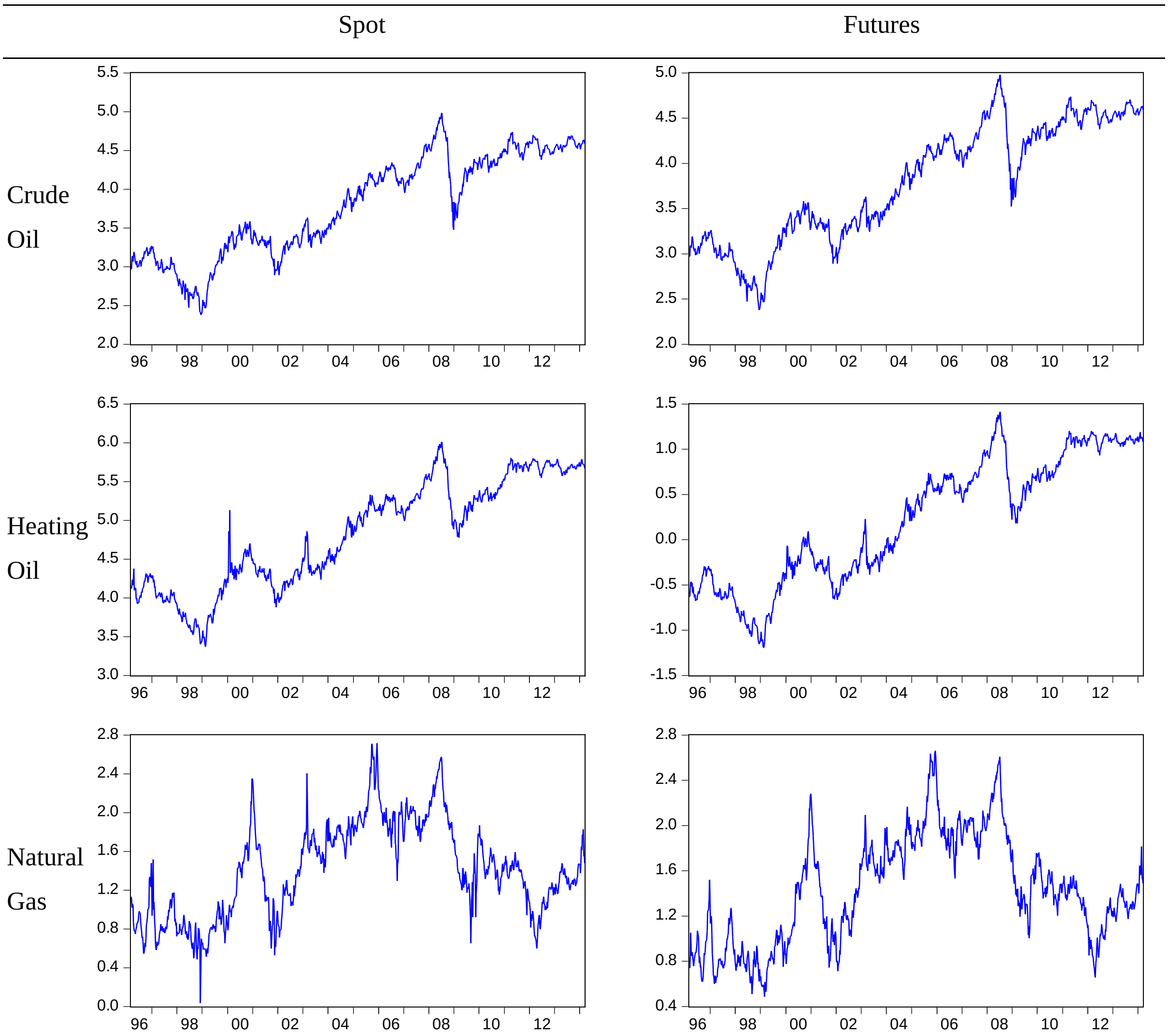
Notes: This table summarises the reduction in Value at Risk (VaR)'s calculated from different hedging models, against unhedged. MRS-TP models are the MRS models with hedging and speculative pressures. Unhedged VaR is the hedgers' VaR when they do not employ any hedging strategy. HSI50 and SSI50 are 50-week hedgers' and speculators' trading pressure index by Wang (2001). AHGP4 and ASCP4 are a 4-week average of hedging and speculative pressures by De Roon et al. (2000). Basis and 4-week average basis (AvgBasis) are used for comparison following Alizadeh & Nomikos (2004). The results from benchmark strategies are also presented. OLS is a static OLS method. GARCH is a univariate GARCH (1,1) and BEKK and DCC (dynamic conditional correlation) are multivariate GARCH models. The higher percentage reduction in VaR indicates the smaller exposure of the hedgers' portfolios to risk, so the higher hedging effectiveness.

Figure 1. Spot and futures prices – metal markets



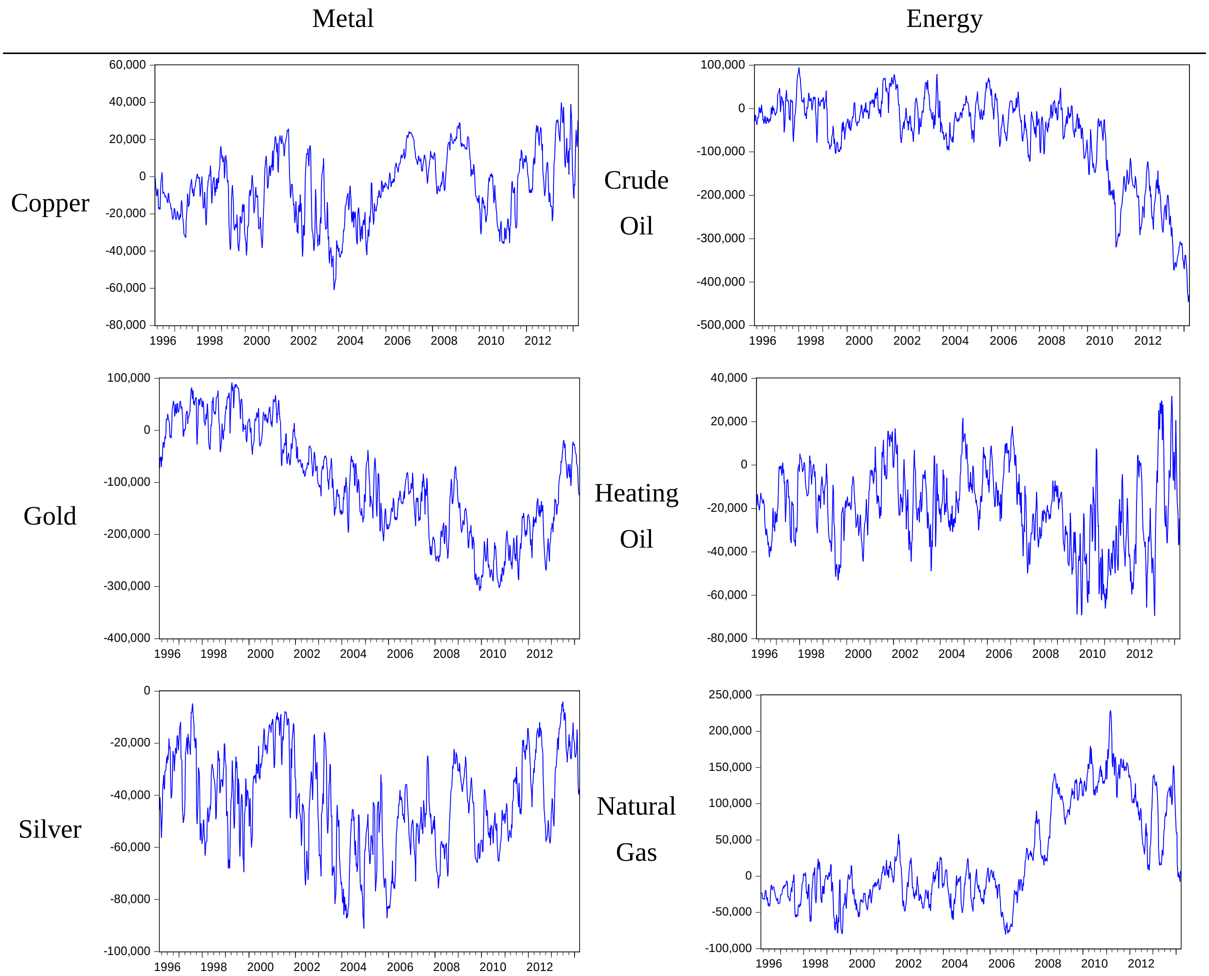
Notes: The graphs show the patterns of log spot and futures prices in the metal markets. The sample period is between 1 March 1996 and 14 March 2014.

Figure 2. Spot and futures prices – energy markets



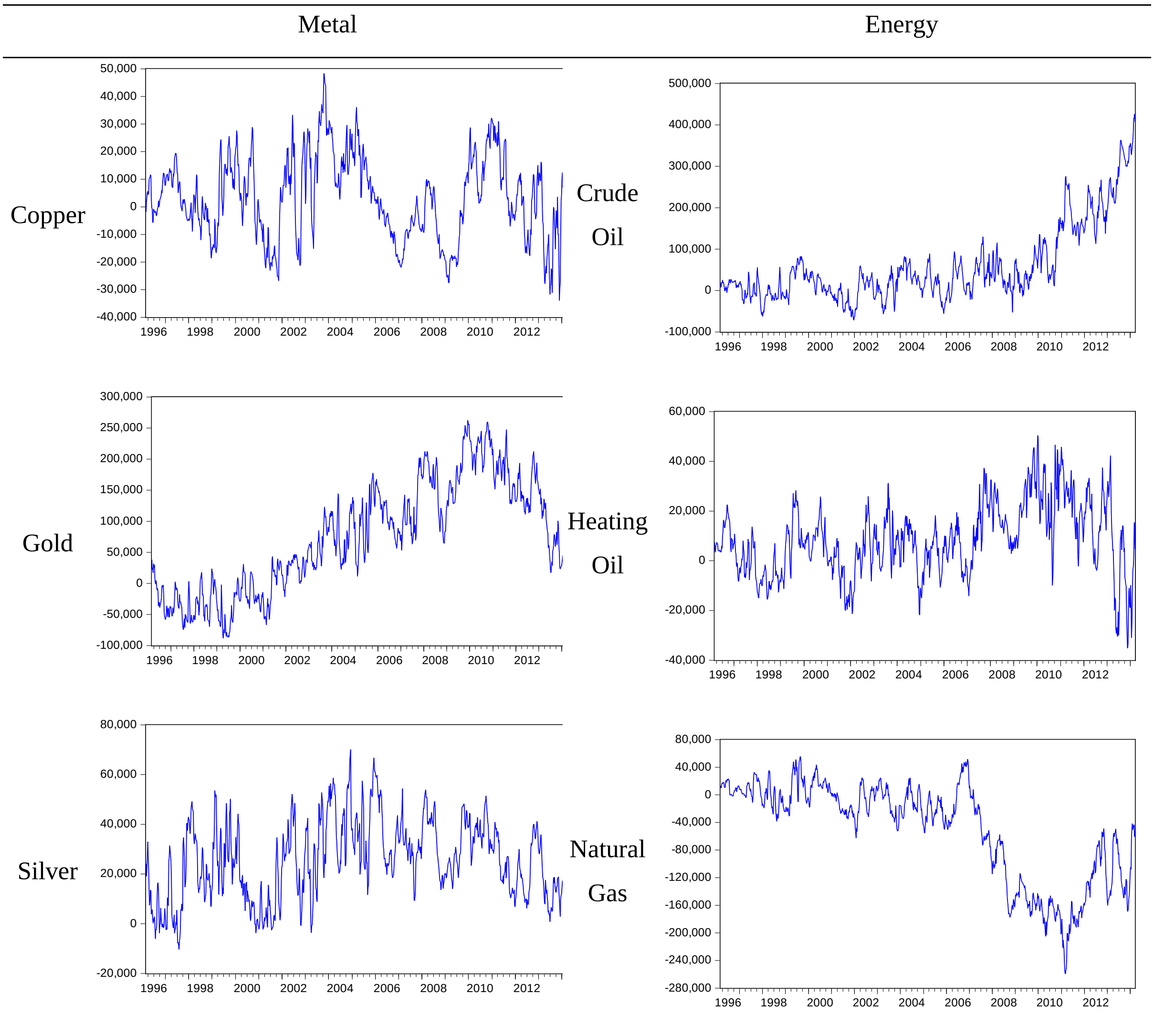
Notes: The graphs show the patterns of log spot and futures prices in the energy markets. The sample period is between 1 March 1996 and 14 March 2014.

Figure 3. Hedgers’ net open interest – metal and energy markets



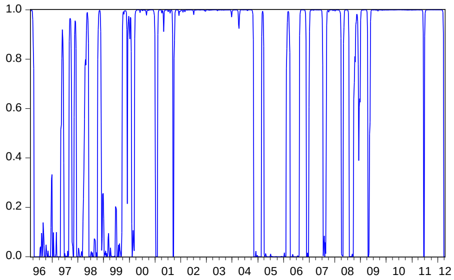
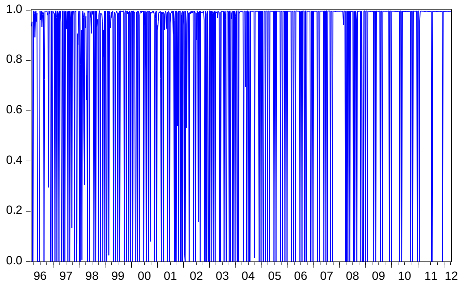
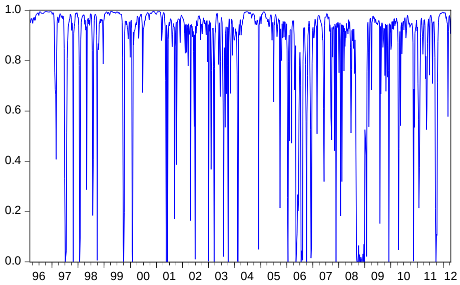
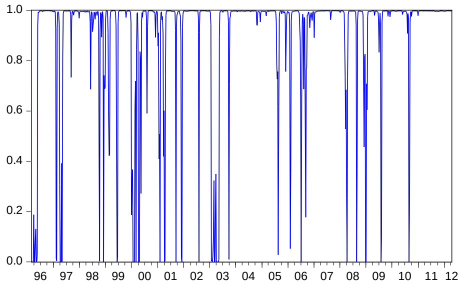
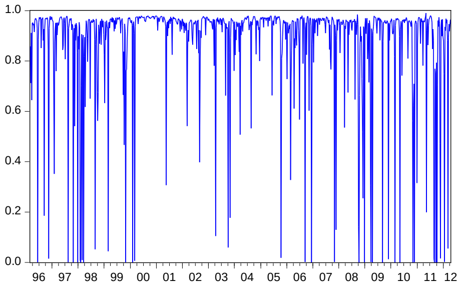
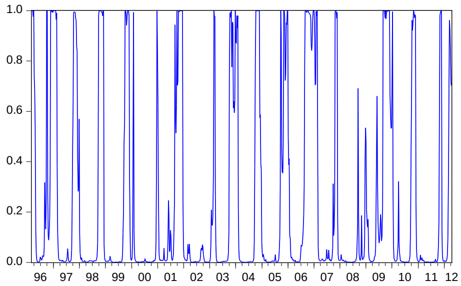
Notes: The graphs show the pattern of hedgers’ net open interest calculated as commercial traders’ long interest less short interest. The sample period is between 1 March 1996 and 14 March 2014.

Figure 4. Speculators' net open interest – metal and energy markets



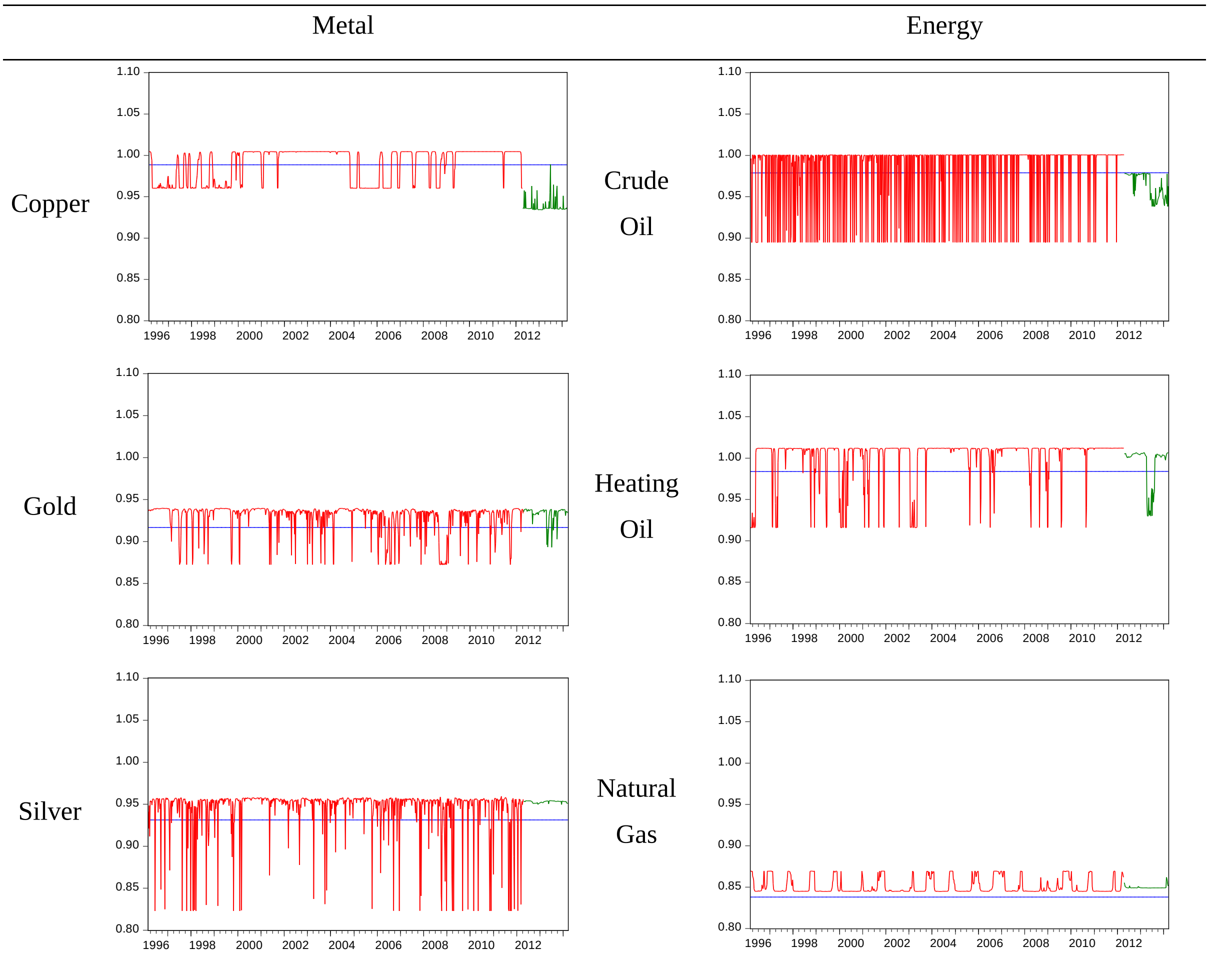
Notes: The graphs show the pattern of speculators' net open interest calculated as non-commercial traders' long interest less short interest. The sample period is between 1 March 1996 and 14 March 2014.

Figure 5. Regime probabilities that the spot-future relationship is in state 1 in the MRS model with hedging pressure (HSI50).

	Metal		Energy
Copper		Crude Oil	
Gold		Heating Oil	
Silver		Natural Gas	

Notes: The graphs present regime probabilities that are smoothed probabilities conditional on all information in the sample.

Figure 6. The minimum variance hedge ratio (MVH) from the MRS models with hedging pressure (HSI50).



Notes: The graphs show the minimum variance hedge ratios (MVHs) from the MRS model with HSI50 as an example. It including out-of-sample MVHs (last 100 observations). A straight line is the MVH provided by the static OLS method as a benchmark.