Predictability of Financialization and Co-movement in Commodity Market: What is the Role of Technical Indicators

Abstract: This paper investigates the financialization and structural co-movement of 26 commodities futures by factors variance decomposition and predictability of technical indicators and macro variables. We find that financialization is still a dominated character in commodity market and recent commodity prices fluctuation can be significantly and robustly forecasted by technical analysis in terms of commodity index investment. Moreover, the co-movement of commodities is demonstrated by variance decomposition and explained as commodity index investment, which also provides the evidence of financialization. The overall empirical analysis reveals that technical indicators and macro variables can statistically and economically forecast the indexed investment and off-index trading, respectively, which manifests that they are the suitable predictors of commodity market.

Keywords: Commodity financialization; Commodity co-movement; Technical indicators; Macro variables; Predictability

1. Introduction

For a long time, commodities have dominated as specialized hedge tools for investors (Hirshleifer, 1988; Erb and Harvey, 2006; Gorton and Rouwenhorst, 2006). Starting about 2004, however, flowing into commodity investments began to grow at an unprecedented rate attributed to the institutional investors (Irwin et al., 2009), resulting in "commodity financialization", a process of integration of commodity futures markets with other financial markets in which portfolio rebalancing of index investors can cause volatility spillovers from outside to commodity markets (Tang and Xiong, 2012). Since then, the view that financialization has been a dominated character in commodity market seems generally emphasized and accepted by scholars and practitioners (Basak and Pavlova 2014; Cheng and Xiong, 2014; Henderson et al., 2015) although some opposition views still exist (Adams and Glück, 2015).

However, there is a controversy when explaining the reason of the commodity price fluctuation in recent 10 years. Some work indicates that it could be partly responsible for the surge in

commodity index investment (Tang and Xiong, 2012, Singleton, 2013; Hamilton and Wu, 2015) while there are still some oppositions criticizing the data and methods of above-mentioned studies, which a limit the confidence and can be placed in their results. (Irwin et al., 2009; Sanders et al., 2009, 2010; Stoll and Whaley, 2010; Sanders and Irwin, 2010a, 2010b, 2010c; Kim, 2015). Instead, a number of market analysts and economists who attribute the boom-and-bust cycle to a matter of supply and demand express skepticism about the flucuation argument, citing logical inconsistencies and contrary facts (e.g., Büyüksahin and Harris, 2011; Capelle and Coulibaly, 2011; Bohl and Stephan, 2013; Morana, 2013). Popular explanations are provided regularly like: strong global growth (especially from emerging economies such as China and India) (Krugman, 2008; Hamilton, 2009; Kilian and Murphy, 2012, 2014), global liquidity or easy monetary policy (as reflected in low real interest rates) (Caballero et al., 2008; Belke et al., 2014; Beckmann et al., 2014; Hammoudeh et al., 2015; Ratti et al., 2015), and risk (possibly resulting from geopolitical uncertainties) (Yin and Han, 2014). These opposite statements illustrate the acrimonious and heated nature of the public policy debate surrounding the role of index funds in commodity futures markets.

At the same time, scholars and analysts studying commodity price fluctuations find increasing correlations between the returns on different classes of commodities (Büyükşahin and Robe, 2014; Nicola et al., 2016) as substantial literatures regard co-movements as a central and distinctive characteristic of commodity, which mainly examine the co-movement in terms of types of commodities (See, Alquist and Coibion, 2013; Byrne et al., 2013; West and Wong, 2014). The co-movement in commodity market after 2004 is also argued whether it is resulted from commodity financialization (Tang and Xiong, 2012; Hamilton and Wu, 2015) or economics factor like fundamental supply and demand (Krugman, 2008; Irwin et al., 2009). Recently, a factor structural model for commodity prices in which the common factor can capture the combined contribution of all aggregate shocks that affect commodity markets (Byrne et al., 2013; Alquist and Coibion, 2014) but the results seem not steady (Daskalaki et al., 2014).

When considering of observation even prediction to commodity market, numerous macroeconomics variables have been explored as referred above. However, relative to macro variables or economic fundamentals, technical analysis has received less attention in the literatures. Nowadays, technical analysis is found to reveal significantly and directly predictability in stock market (Neely et al., 2014) and several specified commodities like oil (Yin and Yang,

2016), but still not covering the whole commodity market. Besides, one important find is to demonstrate the economics value of technical analysis both in theoretical and empirical instead of forecast by technical analysis just belonging to data mining.

Based on those debates above, this paper aims to provide the further evidences for the financialization and structural co-movement among 26 commodities futures covering the energy, metal, agriculture, industrial, livestock and softs through the analysis of a Bayesian dynamic latent factor model and prediction by technical indicators and macroeconomics variables.

This paper contributes to the literatures in following aspects. For the character of commodity market, we provide a new evidence of financialization based on distinguishing index investment and off index investment in commodity market both for intuition and in empirical. According to the Bayesian dynamic latent factor model based on commodity return, we differentiate the one global factor and two sectoral factors representing indexed investment and off-index investment, and compare them by figures. The empirical estimates further also display the significance of predictors among 3 factors. Besides, as an important replenishment for previous literatures, we construct the factors above by commodity volatility and discuss the commodity financialization in volatility level.

For the reason the fluctuation in commodity market in recent years, we analyze the problem through predictability of different kinds of predictors, technical indicators and macro variables, providing the evidence of commodity index investment. In theoretically, commodity index investment mainly connects tightly with the index fund and speculation while off- index investment reveals the hedge for specialized investors who would earn a risk premium by providing insurance. Thus, we investigate the forecast capacity of technical indicators based on both returns and trading activity and macroeconomics variables to directly predict the 3 factors by commodity return and take the other as a benchmark. We therefore able to provide direct and systematic evidence of a relationship between index-based trading and commodity return fluctuation statistically or economically. Besides, the robustness check is also investigated that forecast factors in volatility level by technical indicators and macro variables, respectively.

For the co-movement among commodities, we provide the steady confirmation by a new thought. Firstly we fit a factor model to characterize the co-movements in commodity prices. By using a Bayesian dynamic latent factor model, we decompose commodity returns into one global, two sectoral (indexed and off-index sector), and 26 idiosyncratic factors. Then, the variance

decomposition will measure the extent to which global, sectoral, and commodity-specific factors, explaining new insights into the genesis of commodity price fluctuations in terms of the structure of the common dynamic properties of price fluctuations. Secondly, we try to provide a robustness check and explanation of co-movement in terms of indexed trading. For market participates, the co-movement of commodity market means the similar movement/ trend of commodities, suggesting that one of commodity is able to explain even forecast other commodities. In line with this thought, we pick up the "crude oil" as an example to construct technical indicators and forecast the global factor and two sectoral factors, comparing with the 26 commodities results in Section 5.2.3. If the technical indicators constructed by one commodity display the same prediction significance for the global factor as the technical indicators based on 26 commodities and exceeding the macro variables, the co-movement can be explained as commodity index investment.

At last, we demonstrate that technical indicators are significantly and robustly predictors for commodity index investment. We explore both in-sample and out-of-sample predictability for crude oil price over the 30-year period 1984-2013 to address the over-fitting issue (Welch and Goyal, 2008). Moreover, we consider the two specifications for robust analysis. First, many previous work notices the tightly relationship between predictability and economics cycle (Nitschka, 2014; Pierdzioch et al., 2014), so we consider the forecast capacity of technical indicators under the business cycle. Secondly, to parsimoniously incorporate information from many predictors, we also estimate predictive regressions based on a small number of principal components extracted from the entire set of technical indicators or macroeconomic variables.

The remainder of the paper is organized as follows. Section 2 discusses the related literatures. Section 3 describes the data. Section 4 presents the dynamic latent factor model, and outlines how we estimate it and presents factor model estimation results. Section 5 reports the regression results. Section 6 concludes.

2. Related literatures

We investigate the predictability of technical indicators and macro variables for financialization and co-movement of 26 commodities. The evidence of financialization has been studied within various theories and models, which can be categorized as 3 aspects: firstly

Silvennoinen and Thorp (2013), Tang and Xiong (2012) and Bonato and Taschini (2015) find and demonstrate the correlation or co-movement of commodities after 2000s and little co-movement due to a risk premium for idiosyncratic commodity price risk is provided by commodity prices. Secondly, Masters (2008), Gilbert (2010), Singleton (2013) and Hamilton and Wu (2015) show that purchases by non-commercial traders have causal impacts on commodity futures prices or expected returns. Thirdly, Mou (2011) indicates Index rolling affects futures prices. Recently, Hammoudeh et al. (2015) provide the new evidence of commodity financialization in terms of commodity-linked notes (CLN) on commodity prices and Babalos et al. (2015) explain the financialization by demonstrating the "herd effects" among commodity investors.

Conversely, some work rejects the state. Harris and Büyüksahin (2009) argue that position changes computed from CFTC data do not "Granger cause" futures prices, and Büyüksahin and Harris (2011) state that hedge fund positions rather than index investment explain the recent increase in correlations between stock and commodity returns. For the "co-movement" theory, Krugman (2008) and Irwin et al. (2009) believe that co-movement of commodities resulted from the economic factor like supply or demand. For the "rolling" theory above, Stoll and Whaley (2013) state that "Rolling" of positions cannot significantly impact commodities prices. Adams and Glück (2015) find that commodity financialization is just a passing trend rather than new normal.

The technical analysis has not frequently used in commodity market, but it is generally focused in financial market. To do so, in empirical, Moskowitz et al. (2012) indicate that pervasive price trend exist across commonly traded stock index, currency, and bond futures. Neely et al. (2014) demonstrate the technical indicators can significantly forecast equity risk premium. Goh et al. (2012) find that technical indicators can predict bond risk premia. In theoretical, technical analysis owns important economic values in inferences about price information (Treynor and Ferguson, 1985), different responses by heterogeneous investors (Cespa and Vives, 2012), reflecting under- or over-reaction to information (Edmans et al., 2012) and asset allocation (Neely et al., 2014).

3. Data and indicators

3.1 Commodities

The initial commodity data consisting of 26 daily first-month futures spanning 24 years (January 1991–December 2014) are categorized into six groups:

（1）Energy futures: Brent crude oil, WTI crude oil, heating oil, natural gas and gasoil;

（2）Metals futures: Gold, silver, palladium, platinum and copper;

（3）Agricultural futures: Corn, oat, rough rice, soybean meal, soybean oil, soybean and wheat;

（4）Industrial futures: Lumber and cotton;

（5）Livestock futures: Feeder cattle, leans hogs and live cattle;

（6）Softs futures: Cocoa, coffee, orange juice and sugar;

All of data are collected from DataStream for return and volatility. These commodities are widely referred, especially when plenty of previous researches pick up a basket of commodities recently like Yin and Han (2015a), Hua and Wei (2014) and Zheng (2014), which use commodities covering agriculture, livestock, energy, metal, etc. and we follow them and select 26 commodities.

Monthly commodity futures return is calculated as the change of the log commodity futures price, and monthly commodity futures volatility is calculated based on weekly volatilities' average, which is estimated by weekly high, low, opening and closing prices obtained from underlying daily close. It needs to assume that the volatility is fixed within periods but variable across periods. According to Garman and Klass (1980) and Alizadeh et al. (2002):

$$\sigma_t^2 = 0.511\left(H_t - L_t\right)^2 - 0.019\left[\left(C_t - O_t\right)\left(H_t + L_t - 2O_t\right) - 2\left(H_t - O_t\right)\left(L_t - O_t\right)\right] - 0.383\left(C_t - O_t\right)^2, \quad (1)$$

where H_t is the Monday-Friday high price, L_t is the Monday-Friday low price, O_t is the Monday open price and C_t is the Friday close (all in natural logarithms) price. Stationary analysis by unit root tests (both Augmented DF test and Phillips-Perron test) for commodity futures return and volatility is provided in Table 1. The *p*-value of in third and fifth columns highlights the significant results that the commodity return and volatility in Panel A and B are stationary in 1% confidence level.

[Insert Table 1 Here]

3.2 Technical indicators

To directly investigate the predictive ability of technical analysis, 22 technical indicators based on three trading rules are employed, namely, moving-average rule, momentum rule, and on-balance volume rule. These indicators are representative of trending strategies popularly in the academic work (Sullivan et al., 1999; Miffre and Rallis, 2007; Szakmary et al., 2010; Fuertes et al., 2010) and

established from the U.S. Commodity Futures Trading Commission (CFTC).

The moving-average (MA) rule is a mechanical trading rule that attempts to capture trends. It generates a buy or sell signal ($S_{i,t}=1$ or $S_{i,t}=0$, respectively) at the end of t by comparing two moving averages:

$$S_{i,t}=\begin{cases}1 & if \quad MA_{s,t}\geq MA_{l,t}\\ 0 & if \quad MA_{s,t}<MA_{l,t}\end{cases},(2)$$

where

$$MA_{j,t}=(1/\ j)\sum_{i=0}^{j-1}P_{t-i}\ \text{for}\ j=s,l\ ,(3)$$

P_t is denoted as the level of commodity return/ volatility, and s or l is the length of the short or long MA ($s<l$), respectively. We set the MA indicator with short and long lengths s and l by MA(s,l). The MA rule is sensitive about changes in return/ volatility trends through the formulas intuitively. Once return/ volatility have recently been falling, the short MA will get lower quickly than the long MA; conversely, when return/ volatility begin to trend upward, the short MA responds faster than the long MA, eventually exceeding the long MA and generating a buy signal. In empirical analysis, we study monthly MA rules with s= 1, 2, 3, 6 and l = 9, 12[1], which includes MA(1,9), MA(2,9), MA(3,9), MA(6,9), MA(1,12), MA(2,12), MA(3,12), MA(6,12) and MA(9,12).

The second strategy is based on momentum (MOM), which generates a buy or sell signal ($S_{i,t}=1$ or $S_{i,t}=0$, respectively) at the end of t by comparing the current commodity return/ volatility and its level m periods ago:

$$S_{i,t}=\begin{cases}1 & if \quad P_t\geq P_{t-m}\\ 0 & if \quad P_t<P_{t-m}\end{cases},(4)$$

Intuitively, if the commodity return/ volatility is higher than its level m periods ago, it indicates "positive" momentum and relatively high expected excess returns, thereby generating a buy signal; and vice versa. We denote the momentum indicator that compares P_t to P_{t-m} by MOM(m), and we use monthly signals for m= 1, 2, 3, 6, 9 and 12, which includes MOM(1), MOM(2), MOM(3),

[1] The choices of the values considered for the parameters of the three technical indicators are referred to existing studies, see in Miffre and Rallis (2007), Marshall et al. (2008), Szakmary et al. (2010), Fuertes et al. (2010), Shynkevich (2012), Neely et al. (2014) and Narayan et al. (2015).

MOM(6), MOM(9) and MOM(12).

The third strategy is on-balance volume averages (VOL), which is combined with past commodity return/ volatility to identify market trends. It involves the entire amount of volume subtracting from the indicator when the closing return/ volatility increases (decreases). It forms a trading signal ($S_{i,t}=1$ or $S_{i,t}=0$, respectively) at the end of t by comparing two moving averages based on OBV_t as:

$$S_{i,t}=\begin{cases}1 & if \quad MA_{s,t}^{OBV} \geq MA_{l,t}^{OBV} \\ 0 & if \quad MA_{s,t}^{OBV} < MA_{l,t}^{OBV}\end{cases}, \quad (5)$$

where

$$MA_{j,t}^{OBV}=(1/j)\sum_{i=0}^{j-1}OBV_{t-i}\ , \quad (6)$$

$$OBV_t=\sum_{k=1}^{t}VOL_k D_k\ , \quad (7)$$

VOL_k is a measure of trading volume during period k, and D_k is a binary variable that takes a value of 1if $P_k-P_{k-1}\geq 0$ and -1 otherwise. As the formula indicates, relatively high recent volume together with recent return/ volatility increasing illustrates a strong positive market trend and generates a buy signal. Similar to the moving-average strategy, we set monthly signals for $s=1, 2, 3$ and $l=9, 12$, which includes VOL(1,9), VOL(2,9), VOL(3,9), VOL(6,9), VOL(1,12), VOL(2,12), VOL(3,12), VOL(6,12) and VOL(9,12).

3.3 Macroeconomic variables

As for macroeconomic predictors, we consider a set of twenty-two macro variables in three bundles:

1. Stock return predictability variables (Welch and Goyal, 2008), including:

   1) Book-to-market ratio, BM: book-to-market value ratio for the Dow Jones Industrial Average;

   2) Treasury bill rate, TB: interest rate on a three-month Treasury bill (secondary market);

   3) Long-term yield, GB: ten-year government bond yield;

   4) Term spread, TS: long-term yield minus the Treasury bill rate;

   5) Inflation, CPI (log): calculated from the Consumer Price Index (CPI) for all urban consumers;

   6) Dividend-price ratio (log), DP: log of a twelve-month moving sum of dividends paid on the S&P 500 index minus the log of the S&P 500 index;

7) Dividend yield (log), DY: log of a twelve-month moving sum of dividends minus the log of lagged stock prices;

8) Earnings-price ratio (log), EP: log of a twelve-month moving sum of earnings on the S&P 500 index minus the log of stock prices.

9) Lettau-Ludvigson Consumption-wealth ratio, CAY, a successful predictor of forecasting long-term income growth and stock returns;

10) Stock variance, SVAR: the sum of squared daily returns on the S&P 500;

11) Net equity expansion, NTIS: the ratio of 12-monthmoving sums of net issues by NYSE listed stocks divided by the total end-of-year market capitalization of NYSE stocks;

12) Default yield spread, DFY: the difference between BAA and AAA-rated corporate bond yields;

13) Investment to capital ratio, IK: the ratio of aggregate (private nonresidential fixed) investment to aggregate capital for the whole economy.

The variables (1) - (13) are constructed by Gargano and Timmermann (2014), Welch and Goyal (2008), and these data are available on the authors' website.

2. The board state of the economy variables, including:

14) The unemployment rate in USA, UER (Doğrul and Soytas, 2010);

15) The growth of the monthly US money supply, M2;

16) The monthly growth in the US Industrial Production Index, GIP;

17) The capacity utilization in manufactory index, CUM;

18) The monthly Purchasing Managers' Index in USA, PMI: an indicator of the economic health of the manufacturing sector;

19) Chicago Fed's National Activity Index, NAI: one of the key gauge of economic activity.

The variables (14) - (18) can be obtained from the Federal Reserve Bank of St. Louis.

3. Fluctuations in demand and supply pressures in commodity markets related variables, taking crude oil as example, including:

19) The Kilian's real global economic activity index, KI, which is found significantly influence crude oil prices (Kilian, 2009);

20) Log of the U.S. field production of crude oil, FPO, which is widely used as the supply variable in reports like International Energy Agency (IEA);

21) Returns and excess returns on oil company stocks, OI: log of NYSE Arca oil index to capture information from financial markets;

22) Real U.S. trade-weighted real exchange rate, TWI because the trading of oil is dominated in the US dollars.

The variables (19) - (22) are published by U.S. Energy Information Administration (EIA).

The Table 2 displays the unit root analysis of 22 macroeconomics variables with significant *t*-statistic, demonstrating the stationary of macro variables.

[Insert Table 2 Here]

4. The dynamic factors construction

4.1 Methodology

We extract factors by applying a dynamic latent factor model proposed by Kose et al. (2003, 2008) and modified by Yin and Han (2015b). This approach models co-variation among many variables in a unified framework, as a function of a small number of latent factors rather than using pair-wise correlations and related techniques that are difficult to summarize. The factors are obtained by following steps:

First, we suppose that there are three types of factors: the single global factor (f_t^w)[2], J sectoral factors ($f_{j,t}^s$, one each for each sector) and N commodity-specific factors ($f_{n,t}^c$, one per commodity). Thus, the model is given by:

$$y_{i,t} = \beta_i^w f_t^w + \beta_i^s f_{j,t}^s + \beta_i^c f_{n,t}^c + \varepsilon_{i,t}, \quad (8)$$

where $y_{i,t}$ is the demeaned log returns/ volatilities for commodity i ($i = 1,...,N$) from month $t-1$ to t ($t = 1,...,T$). The global factor, f_t^w, is common across all of the $N = 26$ commodity return/ volatility. The sectoral factors, $f_{j,t}^s$ $(j = 1,2,\cdots,J)$, are common to the commodities in each of $J = 2$ specific sectors, namely the commodity indexed factor and commodity off-index factor.

[2] To attempt to discover whether there are really two global factors or more, we study a variety of dynamic systems with multiple global factors. However, we find no significant evidence of a second global factor. Therefore, we choose a simplified model which employs one global factor that all commodities share.

The $f_{n,t}^{c}$ is the specific component of commodity i 's return/ volatility, which captures purely specific influences on return/ volatility. The loadings, β_i^w, β_i^s and β_i^c, measure the responses of an individual commodity's return/ volatility to change in the global, sectoral and commodity-specific factors, respectively.[3]

For $\varepsilon_{i,t}$, we assume it follows an AR(p) process:

$$\varepsilon_{i,t} = \rho_{i,1}\varepsilon_{i,t-1} + \cdots + \rho_{i,p}\varepsilon_{i,t-p} + u_{i,t}, \quad (9)$$

where $u_{i,t} \sim \left(0, \sigma_i^2\right)$, and $E\left(u_{i,t}u_{i,t-s}\right) = 0$ for $s \neq 0$.

Next, we assume that the evolution of each factor follows an AR (q) process, respectively, of order q with normal errors:

$$f_t^w = \rho_1^w f_{t-1}^w + \cdots + \rho_q^w f_{t-q}^w + u_t^w, \quad (10)$$

$$f_{j,t}^s = \rho_{j,1}^s f_{j,t-1}^s + \cdots + \rho_{j,q}^s f_{j,t-q}^s + u_{j,t}^s, \quad (j = 1,2,\cdots,J), \quad (11)$$

$$f_{n,t}^c = \rho_{n,1}^c f_{n,t-1}^c + \cdots + \rho_{n,q}^c f_{n,t-q}^c + u_{n,t}^c, \quad (n = 1,2,\cdots,N), \quad (12)$$

where $u_t^w \sim \left(0, \sigma_w^2\right)$, $u_{j,t}^s \sim \left(0, \sigma_{j,s}^2\right)$, $u_{n,t}^c \sim \left(0, \sigma_{n,c}^2\right)$ and $E\left(u_t^w u_{t-s}^w\right) = E\left(u_{j,t}^s u_{j,t-s}^s\right) = E\left(u_{n,t}^c u_{n,t-s}^c\right) = 0$ for $s \neq 0$. We set the orders of the AR processes, p and q, equal to two when estimating the dynamic factor model. Other non-zero values for p and q produce similar results. Then, Eq. (8) is a dynamic latent factor model.

We reiterate that the dynamic factor model attributes all of the co-movements in commodity returns/ volatilities to the global and sectoral factors via the factor loadings. In the extreme, a commodity with $\beta_i^w = \beta_i^s = 0$ will have return/ volatility that is completely idiosyncratic ($y_{i,t} = \beta_i^c f_{n,t}^c + \varepsilon_{i,t}$), displaying no co-variation with other commodities' returns/ volatilities. To normalize the signs of the factors/loadings, we follow a strategy similar to Kose et al. (2003) and restrict the loading on the global factor for Corn and the loadings on the sectoral factors for Corn

[3] To ensure that β_i^w, β_i^s and β_i^c sum to one, we follow Kose et al. (2003) and orthogonalize the factors (using the global, sectoral, commodity-specific factor ordering) when computing the variance decompositions at each replication. Since the sample correlations are small, this has little influence on the results. The idiosyncratic errors $\varepsilon_{i,t}$ are assumed to be normally distributed, but may be serially correlated.

and Oatto be positive. To normalize the scales, we also assume that each of the factor shock variances, σ_w^2 and $\sigma_{j,s}^2$ $(j=1,2,\cdots,J)$, is equal to one. The sign and scale normalizations do not have any economic content and do not affect any economic inference.

Then, we use the following conjugate priors to implement Bayesian analysis, which are similar to those used in Kose et al. (2003):

$$\left(\beta_i^w,\beta_i^s,\beta_i^c\right)' \sim N\left(0,I_3\right),\ (i=1,2,\cdots,N), \quad (13)$$

$$\left(\rho_{i,1},\cdots,\rho_{i,p}\right)' \sim N\left[0,diag\left(1,0.5,\cdots,0.5^{p-1}\right)\right],\ (i=1,2,\cdots,N), \quad (14)$$

$$\left(\rho_1^w,\cdots,\rho_q^w\right)' \sim N\left[0,diag\left(1,0.5,\cdots,0.5^{q-1}\right)\right], \quad (15)$$

$$\left(\rho_{j,1}^s,\cdots,\rho_{j,q}^s\right)' \sim N\left[0,diag\left(1,0.5,\cdots,0.5^{q-1}\right)\right],(j=1,2,\cdots,J), \quad (16)$$

$$\left(\rho_{n,1}^c,\cdots,\rho_{n,q}^c\right)' \sim N\left[0,diag\left(1,0.5,\cdots,0.5^{q-1}\right)\right],\ (n=1,2,\cdots,N), \quad (17)$$

$$\sigma_i^2 \sim IG\left(6,0.001\right),\ (i=1,2,\cdots,N), \quad (18)$$

where $IG(\ )$ denotes the inverse-gamma distribution, and the prior on the innovation variances is quite diffuse. Experimentation with tighter and looser priors for both the factor loadings and the autoregressive parameters does not produce qualitatively important changes in the results. As noted in Otrok and Whiteman (1998), Equations (14)-(18) imply that the prior distributions for the AR parameters become more tightly centered on zero as the lag length increases.

In particular, taking starting values of the parameters and factors as given, we *firstly* sample from the posterior distribution of the parameters conditional on the factors; *next* we sample from the distribution of the global factor conditional on the parameters and the commodity-specific and sectoral factors; *secondly* we sample each sectoral factor conditional on the global factor and the commodity-specific factors in that sector; *thirdly*, we complete one step of the Markov chain by sampling each commodity-specific factor conditioning on the global factor and the appropriate sectoral factor. This sequential sampling of the full set of conditional distributions is known as "Gibbs sampling". Under regularity conditions (Eqs.(13)-(18)), the Markov chain produces converges, and yields a sample from the joint posterior distribution of the parameters and the unobserved factors, conditioned on the data. The sampling order within each step is irrelevant. We in fact experimented with changing the order, and the results obtained are robustness.

Further, we measure the extent of global influences on each commodity by computing the global factor's contribution to the total variability in a commodity's return. This variance decomposition is straightforward to compute for orthogonal factors:

$$\theta_i^w = \left(\beta_i^w\right)^2 \operatorname{var}\left(f_t^w\right) \Big/ \operatorname{var}\left(y_{i,t}\right), \quad (19)$$

where

$$\operatorname{var}\left(y_{i,t}\right) = \left(\beta_i^w\right)^2 \operatorname{var}\left(f_t^w\right) + \left(\beta_i^s\right)^2 \operatorname{var}\left(f_{j,t}^r\right) + \left(\beta_i^c\right)^2 \operatorname{var}\left(f_{n,t}^c\right) + \operatorname{var}\left(\varepsilon_{i,t}\right), i = 1, 2, \cdots, N \ , \quad (20)$$

and θ_i^w is the proportion of the total variability in commodity i's return attributable to the global factor. The relative magnitudes of θ_i^w and θ_j^w depend on both the factor loadings and relative volatility of return in commodities i and j. θ_i^s and θ_i^c (the proportions of the total variability in commodity i's return attributable to the sectoral factors and specific factors, respectively) are defined similarly.

4.2 Properties of the dynamic factors

The global factor and sectoral factors reflect the comprehensive or part characters of commodity market. Figure 1 depicts means of the posterior distributions for the global, indexed and off-index factors in term of price level.

[Insert Figure 1 Here]

The trend of global factor seems to correlate to commodity index investment and business cycle. Before 2004, the global factor is relatively steady. After commodity index investment emergence in 2005, it increases substantially with a notable uptick. It also drops sharply during late 2008 financial crisis, clearly supporting a synchronized fall in prices of a broad set of commodities. As the US economy recovered from the recession in 2012, the global factor increases again, at the same time commodity index investment also surges.

2004 can be regard as an interval for global factor. Before 2004, the off-indexed factor suggests the same tendency with the global factor and the indexed factor shows less similarity. After 2004, the fluctuation of estimated indexed factor displays the much more same trend as the global factor with severe alteration and some portending change while the off-indexed factor suggests little correlation.

As a simple robustness check, means of the posterior distributions for the global, indexed and

off-index factors in the return level are depicted in Figure 2. Panel A shows the global factors and two sectoral factors are in Panel B.

[Insert Figure 2 Here]

The movements in the indexed returns are much more abrupt, whereas the off-index return displays a relatively smooth pattern, further illustrating the complementary roles of these two types of factors, which is same as results above. In accord with those preliminary results, it can be supported that the commodity prices may be driven by commodity index investment intuitively, especially after 2004.

4.3 Variance decompositions

It has been accepted that variance decompositions can assess the degree of co-movements in commodity returns (Engsted and Tanggaard, 2001). Averages across various commodity sectors of the means, as well as 0.05 and 0.95 quantiles for the posterior distributions are reported in the Table 3.

[Insert Table 3 Here]

Basically, the global factor explains a significant fraction of the commodity prices fluctuations[4]. The global and sectoral shocks together account for more than one third (35.21%) of commodity prices fluctuations, indicating significant co-movements characteristic of commodities. However, these effects exhibit significance varied sectors. Notably, the global and sectoral factors of indexed sector edge out their pairs of off-index sectoral as dominant, which explains about half (44.09%) of commodity prices fluctuations, though both play important roles. The high explanatory power for the global factors of indexed sector (22.04%) contrasts with the low explanatory power of global factor of off-index sector (4.61%). Similar to global factors, the sectoral factors also account for 22.05% of price variability for indexed sector, whereas it plays a relatively minor role in off-index sector, with the value of only 10.63%.

5. The dynamic factors forecast

There is an acrimonious debate last nearly 10 years surrounding the role of index funds in

[4] Furthermore, we demonstrate that the co-movement in the volatility level is robust by variance decomposition.

commodity market (Krugman, 2008; Hamilton, 2009; Kilian and Murphy, 2010; Bos and Molen, 2012; Rouwenhorst and Tang, 2012; Cheng and Xiong, 2014) and we will investigate this field by demonstrating the technical strategies are efficient predictors. The Section 4 has reported the co-movement among commodities, so we attempt to provide the further robustness check and explanation by using just one commodity (crude oil) constructing technical indicators to find whether they can significantly forecast commodities factors. As the robustness check and comparison, we report the predictability of technical indicators constructed by comprehensive commodities.

5.1 In-sample analysis

5.1.1 Benchmark estimates: bivariate predicative regressions

As benchmark regressions, at first marginal forecast ability is analyzed by OLS:

$$r_{t+1} = \alpha_i + \beta_i S_{t,i} + \varepsilon_{t+1,i}, \quad (21)$$

where r_{t+1}, is the factor constructed by commodity return from period to $t+1$, including the global factor (Glo_R), indexed sectoral factor ($Index_R$) and off-indexed sectoral factor ($Offdex_R$); $S_{t,i}$ performs as a predictor (e.g., MA(1,9)/ TBL) that is available at period t; and $\varepsilon_{t,i}$ is a zero-mean disturbance term. When the null hypothesis of no predictability is $\beta_i = 0$, Eq. (20) reduces to the constant expected factors model[5].

[Insert Table 4 Here]

Panels A and B in Table 4 report estimates of β_i for the bivariate predictive regressions given by Eqs. (20), together with heteroskedasticity-consistent *t*-statistics, and the R^2 statistic. Generally speaking, there are clearly different predictability between technical indicators and macroeconomics variables. Technical indicators can forecast significantly for Glo_R and $Index_R$ by *t* and R^2 statistics, especially for MOM strategy. The predictability for $Offdex_R$ is relatively weaker, but 9 of 22 predictors are still significant. The macroeconomics variables are intuitively less

[5] Econometrically, here we use a one-sided alternative hypothesis to increase the power of in-sample predictability tests in line with Inoue and Kilian (2005), and a wild bootstrap procedure to compute *p*-values in order to address the well-known Stambaugh (1999) bias.

significant forecast than technical indicators, but it is noted that macro variables seem to "prefer" *Offdex*$_R$ rather than *Glo*$_R$ and *Index*$_R$: 7 predictors are significant for former, while only no more than 5 in latter.

The different performances between two groups of predictors suggest that technical indicators reveal better predictability but are more sensitive to commodity index investment, and the macro variables are less significance to predict that but sensitive to off index investment in commodity market.

5.1.2 Predictive regressions near cyclical peaks and troughs: a specification with business cycle

Many studies repute that the predictive ability is related to the economic cycle, we also consider to gauge the relative strength of factors' predictive ability during different states of the economy as a specification. Here, we refer the NBER-based expansions and recessions (Nyberg, 2013). It is noticed that the nature of the R^2 statistics has no clean decomposition of the full-sample R^2 statistic into subsample R^2 statistics based on the full-sample estimates although it seems feasible to compute R^2 statistics separately for cyclical expansions (recessions) intuitively. Thus, we modify the R^2 statistic:

$$R_c^2 = 1 - \frac{\sum_{t=1}^{T} I_t^c \hat{\varepsilon}_{i,t}^2}{\sum_{t=1}^{T} I_t^c (r_t - \bar{r})^2}, \text{ for } c = EXP(REC), \quad (22)$$

where I_t^c, $c = EXP(REC)$ is a dummy variable that takes a value of 1 when month *t* is during an expansion (or recession) period and zero otherwise; $\hat{\varepsilon}_{i,t}^2$ is the fitted residual based on the full-sample estimates of the predictive regression model; $\bar{r}$ is the full-sample average of r_t; and T is the number of usable observations for the full sample.

[Insert Table 5 Here]

The results in Table 5 display the distinct forecast between technical indicators and macroeconomics variables: The R_c^2 (*c=EXP/REC*) statistics of former are much larger than latter for *Glo*$_R$ and *Index*$_R$ but the R_c^2 (*c=EXP/REC*) of *Offdex*$_R$ for macro variables are dramatically large even 76.47%, yet no more than 10% for technical indicators. Besides, the forecast ability for expansion (or recession) period varies different predictors: short period MA, short period MOM,

DY, SVAR and USDX evaluate the larger R_c^2 during the recession period; middle, long term MA and MOM indicators, TBL, LGB, TermS, DFY, BM, CPI, CUM, OI, KI and FPO perform better during the expansion period. Thus, the forecast is substantial under the business cycle.

5.1.3 Predictive regressions based on principal components: a specification with multivariate information

So far, we have analyzed the effects of individual predictors on predictability but what if the performance by multivariate information? We incorporate information from all of the technical indicators by estimating a predictive regression based on principal component analysis, which filters out much of the noise in individual predictors, thereby guarding against in-sample over-fitting.

We define $S_t = (S_{i,t},...,S_{N,t})'$, denoting the N-vector $(N = 22)$ of the entire set of predictors (technical indicators or macro variables) and with $\hat{F}_t^T = (\hat{F}_{i,t}^T,...,\hat{F}_{k,t}^T)'$ representing the first K principal components extracted from S_t where $K \square N$. Therefore, the principal component predictive regression for predictors (technical indicators or macro variables) can be given by:

$$r_{t+1} = \alpha + \sum_{k=1}^{K} \beta_k \hat{F}_{k,t}^{T(E)} + \varepsilon_{t+1}, (23)$$

. In line with the estimates above, we estimate Eqs. (23) via OLS, and compute heteroskedasticity-consistent *t*-statistics, and base inferences on wild bootstrapped *p*-values, respectively. Panel A to C in Table 6 report the estimation results for Eqs. (23) for Glo_R, $Index_R$ and $Offdex_R$, respectively. The estimates are intuitive that technical and macro principle components are significant for Glo_R, and technical principle components forecast much better in terms of R_c^2. All of technical principle components are significant for $Index_R$, but it is relatively weaker when forecasting $Offdex_R$, which macro principle components reveal efficient prediction. In short, forecast under multi-information is still robust.

[Insert Table 6 Here]

To depict the much more intuitive results, Figure 3 illustrates in-sample forecasts of the 3 factors for the technical or macro principle components models, which represent in-sample estimates of the expected factors with real factors for comparison. Technical principle components can both mimic the trend and fluctuation of Glo_R and $Index_R$, whereas macroeconomics variables

seem to perform better prediction. Macroeconomics principle components only depict the trend, and describe the volatility relatively weakly.

[Insert Figure 3 Here]

In sum, technical indicators exploit the information in each set of predictors to produce expected commodity index investment that significantly track Glo_R and $Index_R$, and macro variables reveal powerful forecast in $Offdex_R$, which represents off-indexed investment.

5.2 Out-of-sample analysis

5.2.1 out-of-sample forecast: return level

It is necessary to notice the in-sample over-fitting issue and emphasize the importance of out-of-sample analysis appearing to be more relevant for assessing genuine factors predictability in real time (Welch and Goyal, 2008). In addition, out-of-sample tests are much less affected by small-sample size distortions such as the Stambaugh bias (Busetti and Marcucci, 2013) and the look-ahead bias concern with the PLS approach (Kelly and Pruitt, 2013).

Thus, our out-of-sample regression for the 22 technical indicators (macroeconomic variables) based on month $(t+1)$ out-of-sample factors forecasts is given by:

$$\hat{r}_{t+1}=\hat{\alpha}_{t+1}+\hat{\beta}_{t,i}S_{t,i}, \quad (24)$$

where $S_{t,i}$ represents the individual predictor and $\hat{\alpha}_{t+1}$ and $\hat{\beta}_{t,i}$ are OLS estimates from regressing $\{r_s\}_{s=2}^{t}$ on a constant and $\{S_{i,s}\}_{s=1}^{t-1}$. As out-of-sample tests of predictive ability have better size properties when the forecast evaluation period is a relatively large proportion of the available sample (Hansen and Timmermann, 2012), Dec2004 is set as an interval, using 13 years as the out-of-sample period and 8 years as the in-sample period.

In addition, we also generate the out-of-sample forecasts based on principal components:

$$\hat{r}_{t+1}^{j}=\hat{\alpha}_t+\sum_{k=1}^{k}\hat{\beta}_{t,k}\hat{F}_{1:t,k,t} \text{ for } j=TECH, ECON, \quad (25)$$

where $\hat{F}_{1:t,k,t}$ is the *k*-th principal components extracted from the 22 technical indicators, 22 macroeconomic variables through period *t*. Additionally, the definitions of $\hat{\alpha}_t$ and $\hat{\beta}_{t,k}$ are the OLS estimations.

Relatively, we generate historical average forecast as a benchmark based on Welch and Goyal (2008), Campbell and Thompson (2008) and Ferreira and Santa-Clara (2011):

$$\hat{r}_{t+1}^{HA} = (1/t)\sum_{k=1}^{k} r_s \ ,(26)$$

The assumption of Eq. (28) is a constant expected log factors, and it is very strict (Welch and Goyal, 2008) for predictive regression forecasts based on individual macroeconomic variables that typically fail to outperform the historical averages.

In line with Campbell and Thompson (2008) and Clark and West (2007), we measure the R_{os}^{2} and $MSFE-adjusted$ statistics to analysis forecasts performance. The R^2 statistic measures the proportional reduction in mean squared forecast errors (*MSFE*) for the predictive regression forecasts relative to the historical averages. Thus, a positive value indicates that the predictive regression forecast outperforms the historical average in terms of *MSFE*, whereas a negative value signals the opposite. The $MSFE-adjusted$ statistic tests the null hypothesis that the historical average *MSFE* is less than or equal to the predictive regression *MSFE* against the one-sided (upper-tail) alternative hypothesis that the historical average *MSFE* is greater than the predictive regression *MSFE*.

[Insert Table 7 Here]

Table 7 reports the out-of-sample results for the bivariate predictive regression forecasts for three factors in Section 3. There are 13 technical indicators significantly forecast Glo_R， while the macro variables seem much weaker, only 3 variables significant. The values of $R_{c,os}^{2}$ also reflect the results: 18 technical indicators own the $R_{c,os}^{2}$ more than 0.5%, yet the macroeconomics variables only own 5. Technical indicators reveal better predictability for $Index_R$, 18 of which are significant and all $R_{c,os}^{2}$ of 22 indicators are more than 0.5%. The macroeconomics variables are still weak, only 4 of which are significant and 7 $R_{c,os}^{2}$ values are more than 0.5%. However, macro variables manifest the strong prediction for $Offdex_R$ intuitively, 14 of which are significant, 17 of whose $R_{c,os}^{2}$ value is more than 0.5%. Conversely, technical indicators perform relatively weaker with only 2 indicators significant.

[Insert Table 8 Here]

Similarly, the specification with business cycle is also conducted and displayed in Table 8. The $R_{c,os}^2$ (c=EX*P/REC*) statistic of technical indicators is much larger than macroeconomic variables for both *Glo*$_R$ and *Index*$_R$. The VOL indicators seem perform better during the recession period and the $R_{c,os}^2$ (*c=EXP*) of MOM are larger for *Index*$_R$. The value $R_{c,os}^2$ (c=EX*P/REC*) of macroeconomic variables is much smaller for *Glo*$_R$ and *Index*$_R$, while it is much larger on forecast *Offdex*$_R$. The value $R_{c,os}^2$ (c=EX*P/REC*) of technical indicators intuitively is smaller for *Offdex*$_R$, while macroeconomics variables are larger than with maximum to 85.57%.

[Insert Table 9 Here]

The multi-information specification for out-of-sample is reported in the Table 9. All $\hat{F}_{i,t}^T$ are significant at 1% confident level for *Glo*$_R$ and *Index*$_R$, with the R^2 (*c=EXP/REC*) indicating that technical principle components show stronger forecasts while macro principle components show relatively weaker predictability. However, macroeconomics principle components manifest better prediction ability than technical for *Offdex*$_R$, which reveal more significant principle components and higher R^2 and R_c^2 (*c=EXP/REC*).

Figure 4 depicts the intuitively forecast capacity for out-of-sample estimates with real factors during 2004 to 2013. Macroeconomics principle components mainly reflect trend, while technical principle components seem to mimic fluctuation better. For *Glo*$_R$ and *Index*$_R$, technical principles predict relatively better, and weakly for *Offdex*$_R$ comparing the macroeconomic principle components.

[Insert Figure 4 Here]

To sum up, technical indicators constructed by crude oil can significantly forecast the commodity market and commodity index investment in return level both in-sample and out-of-sample estimates with robust performance in business cycle and multi-information specifications, while macro variables reveal efficiently on commodity off index investment. These results do not reveal the index investment and financialization of commodity further, but it also provides the explanation that the co-movement of commodities is significant and robust, resulted from commodity index investment.

5.2.2 out-of-sample forecast: volatility level

The estimates above mainly focus on the forecast in terms of return, but many literatures pay much attention to volatility in financial market (Poon and Granger, 2003; Fernandes et al., 2014). As a specification, we investigate the predicative power of technical indicators in terms of volatility focus on the out-of-sample estimates for predictability.

[Insert Figure 5 Here]

Figure 5 depicts means of the posterior distributions for 3 factors interpreted as a normalized index of corresponding commodity volatility. The global factor (Glo_V) and the indexed factor ($Index_V$) show more broadly fluctuation than the off-index factor ($Offdex_V$), which is much smoother. In volatility level, the overall trend in commodity market is still driven by commodity index investment intuitively.

In line with Section 5.2.1, we analyze the predictability of technical indicators by out-of-sample estimates in volatility level reported in Table 10 first. According to the *MSFE-adjusted* statistic, technical indicators, especially for the MOM strategy, reveal significantly forecast capacity for Glo_V and $Index_V$, while perform weak for $Offdex_V$. Macro variables seem to explain better for $Offdex_V$ rather than Glo_V. $R_{c,os}^2$ and *MSFE* also reflect the same results.

[Insert Table 10 Here]

Next, the specifications with business cycle and multi-information are investigated, which reported in the Table 11 and Table 12, respectively. Under constrain of business cycle or multi-information, the predictability of technical indicators and macro variables is robust. It is noted that the forecast Glo_V by principle component analysis shows that the technical principle components are all significant, whereas none of macro principle components is significant.

[Insert Table 11 Here]

[Insert Table 12 Here]

The estimates in volatility level still reveal the significant and robust predictability of technical indicators constructed by crude oil for Glo_V and $Index_V$, and macro variables for $Offdex_V$, demonstrated the commodity index investment further.

5.2.3 out-of-sample forecast: technical indicators based on the global factor

The estimates above focus on the technical indicators based on the one specified commodity—crude oil as the example and it manifests the co-movement of commodities can be explained as

commodity index investment. However, the technical indicators constructed by one commodity cannot represent the overall commodity market. As the factor estimates in Section 4, we have investigated the global factor, Glo_R to represent the commodity market and also as the comparison with one commodity results. Thus, in this section, we focus on the specification of technical indicators[6].

In line with the out-of-sample estimates above, we still display the out-of-sample bivariate regressions and two specifications with business cycle and multi-information in Table 13, 14 and 15. And the macro variables results are listed in the Table 7, 8 and 9.

[Insert Table 13 Here]

[Insert Table 14 Here]

[Insert Table 15 Here]

Briefly, the technical indicators display significant predictability for both bivariate and specifications estimates, exceeding the macro variables as the caparison. Technical indicators constructed by more commodities seem to improve their forecast capacity for $Offdex_R$, and still predict Glo_R, $Index_R$ significantly and substantially, which is showed that there are 15, 8 and 11 significant indicators for Glo_R, $Index_R$ and $Offdex_R$, respectively.

For the specification with business cycle, technical indicators reveal much preference on Glo_R with the largest R^2 (c=*EXP/REC*) reaching nearly 50%, and R^2 (c=*EXP/REC*) statistics of $Index_R$ and $Offdex_R$ are still robust. For the specification with multi-information, the technical principle components are all significant for Glo_R, $Index_R$ and $Offdex_R$, manifesting the strong predictability. And the technical principle components perform better during the expansion periods rather than recession periods.

The technical indicators constructed by Glo_R still reveal the significant forecast capacity for Glo_R and $Index_R$, which revealing the robust prediction for commodity index investment. And it is noticed that technical indicators seem to perform well for $Offdex_R$, which is different from technical indicators constructed by crude oil. The results are the same as prediction of technical indicators constructed by just one commodity above, demonstrating the co-movement of commodities.

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[6] The volume of Glo_R is the average of 26 commodities futures volumes.

6. Conclusion

This paper provides a new evidence for financialization and co-movement among commodities market according to Kose et al. (2003; 2008) and investigates the predictability of technical analysis and macro variables based on trending to directly forecast the co-movements in commodity return and volatility. By utilizing 22 technical indicators and 22 macroeconomic variables, we explore both in-sample and out-of-sample estimates for commodity index investment and off-index investment in returns and volatilities over the period 1991-2013, and we evaluate the strength of the predictive evidence by specifications with business cycle and principle component analysis further.

As a result, first, the commodity index investment is dominated in commodity market rather, suggesting that commodity financialization is not “a passing trend”. Next, the co-movement of commodities is demonstrated by variance decomposition. The explanation that only using crude oil price constructing technical indicators provides evidence of commodity index trading. Then, technical indicators do exhibit statistically and economically significant in-sample and out-of-sample forecast the co-movement of commodity market both in return and volatility level, clearly exceeding that of well-known macroeconomic variables. At last the results are robust and substantial under the business cycle and multi-information forecast.

The finding that the predictability for co-movement of commodity market has increasing provided implications from several perspectives. Base on commodity market, our results confirm the significance of and co-movement both by theoretical analysis and empirical application. The factors also find that the overall commodity trend is more similar to commodity index investment rather than off indexed trading, suggesting the commodity financialization. It is of particular relevance for recent policy discussions about the potential role of speculation in commodity markets after 2004. From the predictability, it is confirmed the significance and robust of direct effect between index-based trading from the perspective of technical analysis and off index investment for macroeconomics variables. The results prove useful to commodity producers, consumers, and financial investors keen to enhance their understanding and observation of commodity return/ volatility movements.

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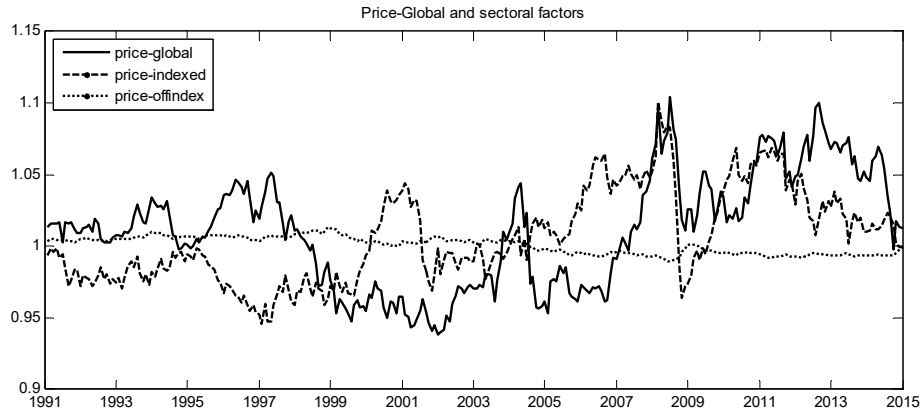


Figure 1 The mean for the posterior distributions for the global and sectoral factors in term of price level, 1991-2014.

Notes: This figure describes the means of the posterior distributions for the global, indexed and off-index factors in term of price level and return in Panel A and B for 1991-2014.

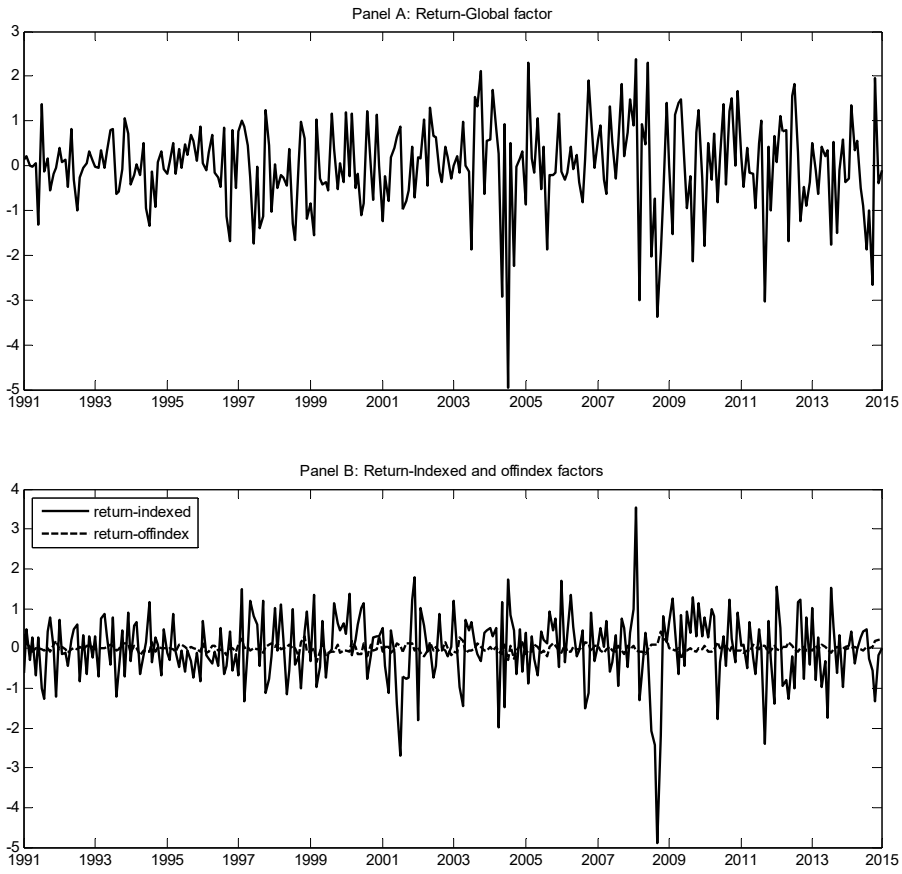
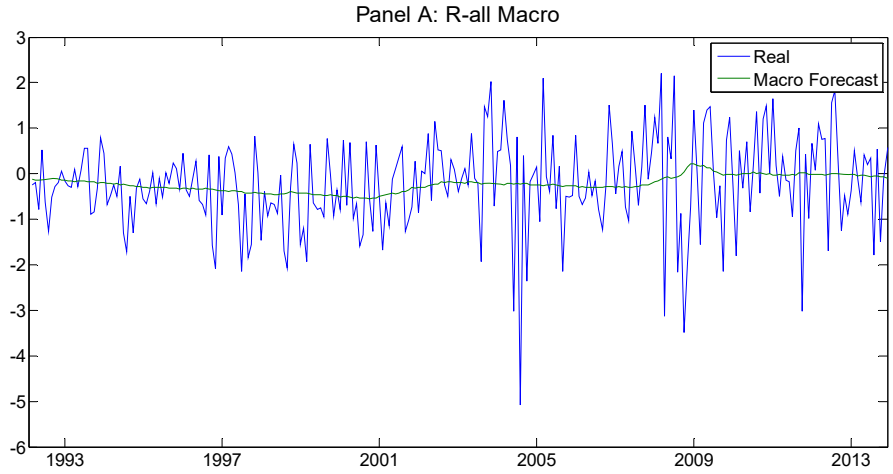
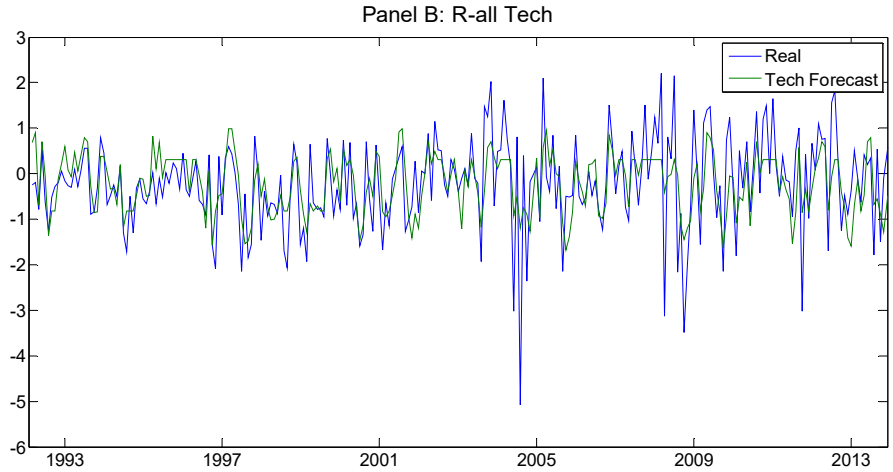
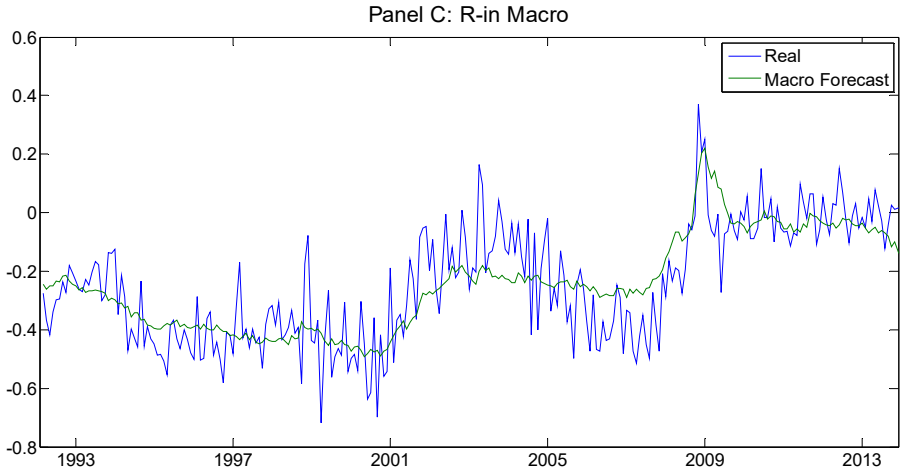


Figure 2 The mean for the posterior distributions for the global and sectoral factors in term of return, 1991-2014.

Notes: This figure describes the means of the posterior distributions for the global, indexed and off-index factors in term of price return in Panel A and B for 1991-2014. The estimated factor series is naturally interpreted as a normalized index of corresponding commodity returns.


Panel A: R-all Macro
Real
Macro Forecast
3
2
1
0
-1
-2
-3
-4
-5
-6
1993
1997
2001
2005
2009
2013


Panel B: R-all Tech
Real
Tech Forecast
3
2
1
0
-1
-2
-3
-4
-5
-6
1993
1997
2001
2005
2009
2013


Panel C: R-in Macro
Real
Macro Forecast
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1993
1997
2001
2005
2009
2013

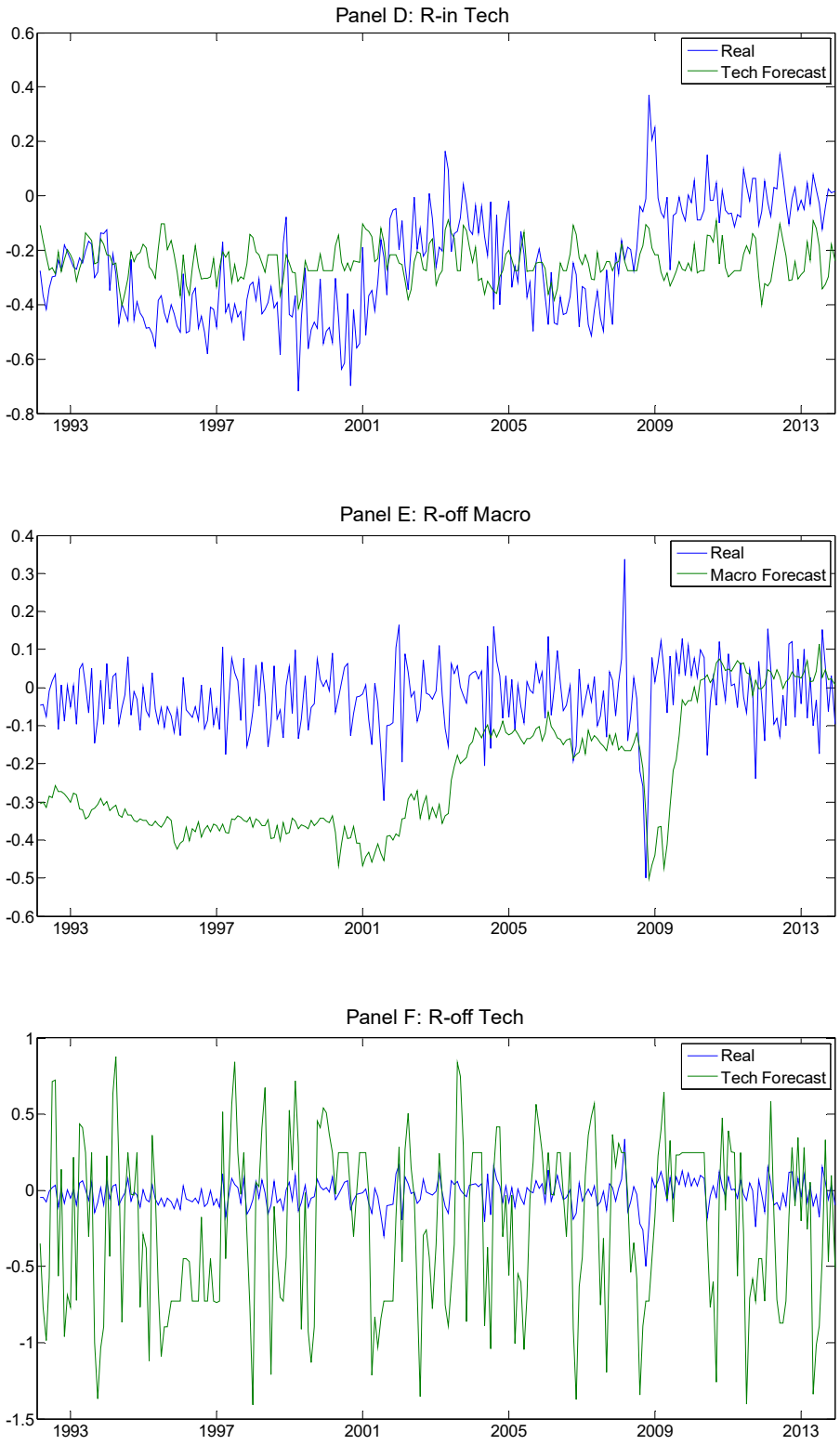
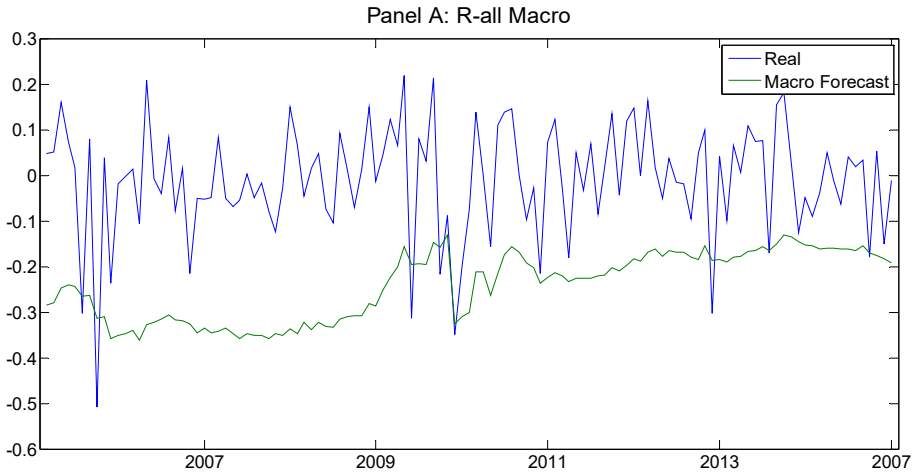
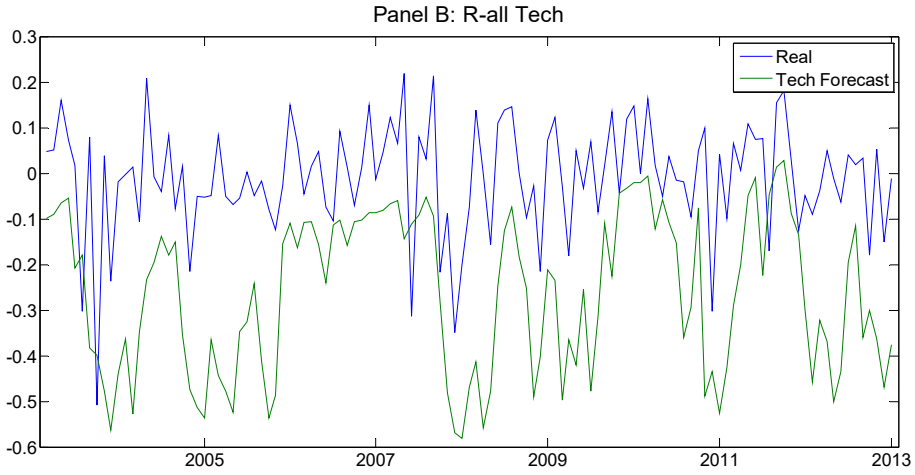


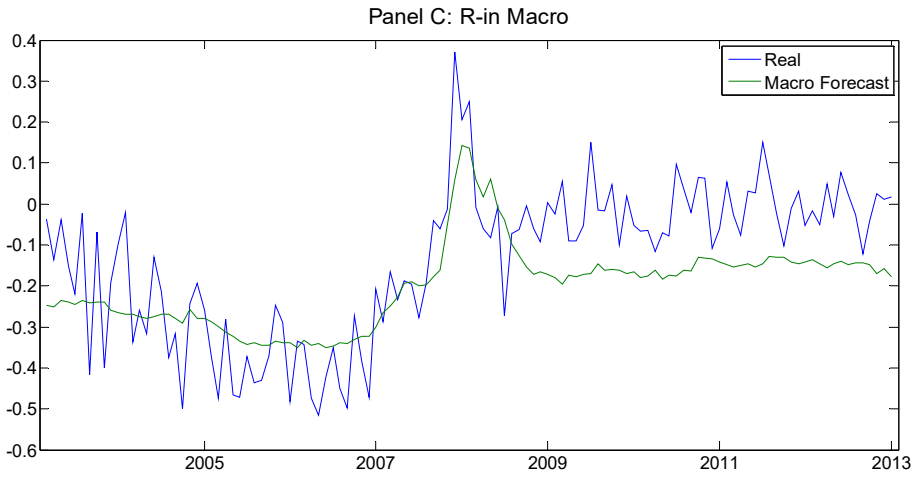
Figure 3 In-Sample return factors forecasts

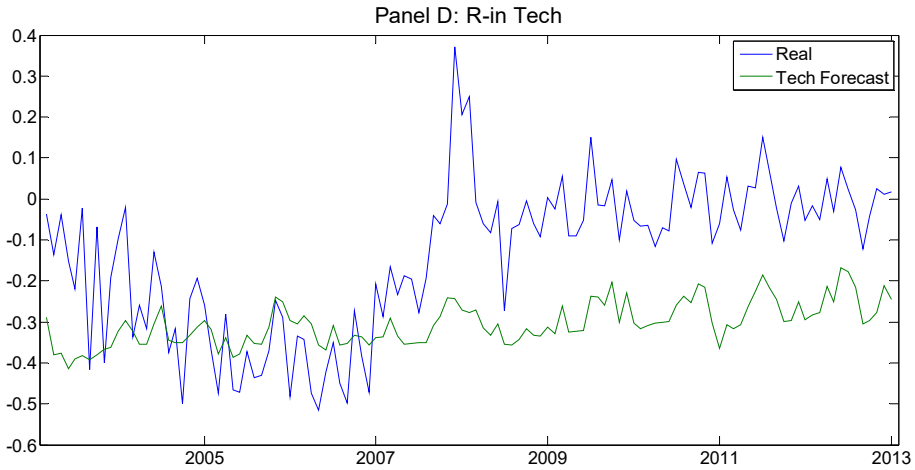
Notes: This figure summarizes the in-sample results of principle components, consisting of 6 panels for the technical indicators defined in Section 3.2, the macroeconomic variables descried in Section 3.3 from 1992:01 to 2014:12, respectively. The principal components for the technical indicators

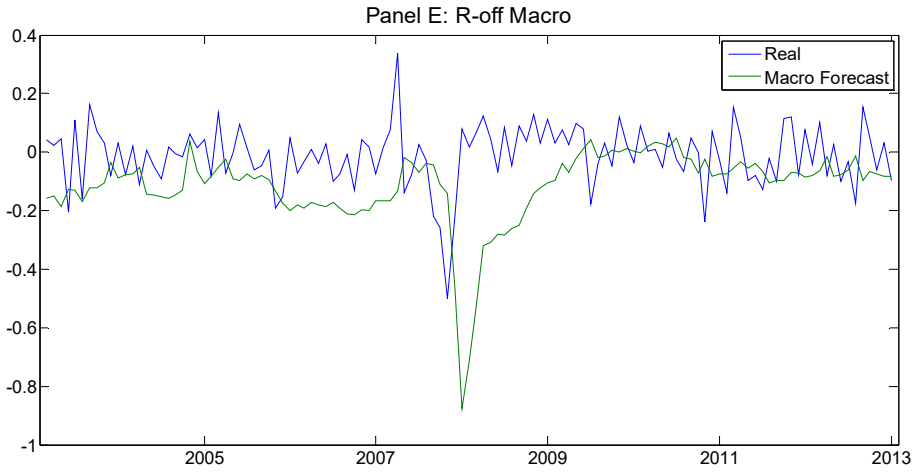
($\hat{F}^{T}_{c,t} = (\hat{F}^{T}_{c,1,t},...,\hat{F}^{T}_{c,3,t})'$) and the macroeconomic variables ($\hat{F}^{E}_{c,t} = (\hat{F}^{E}_{c,1,t},...,\hat{F}^{E}_{c,3,t})'$). Each Panel includes real factors (Real) and expected factors estimated by technical or macroeconomics principle components. R-all (in/off) represents the global (indexed/ off-index) factor and tech/macro represents the technical (macro) principle component.


Panel A: R-all Macro
Real
Macro Forecast
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
2007
2009
2011
2013
2007


Panel B: R-all Tech
Real
Tech Forecast
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
2005
2007
2009
2011
2013


Panel C: R-in Macro
Real
Macro Forecast
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
2005
2007
2009
2011
2013


Panel D: R-in Tech
Real
Tech Forecast
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
2005
2007
2009
2011
2013


Panel E: R-off Macro
Real
Macro Forecast
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
2005
2007
2009
2011
2013

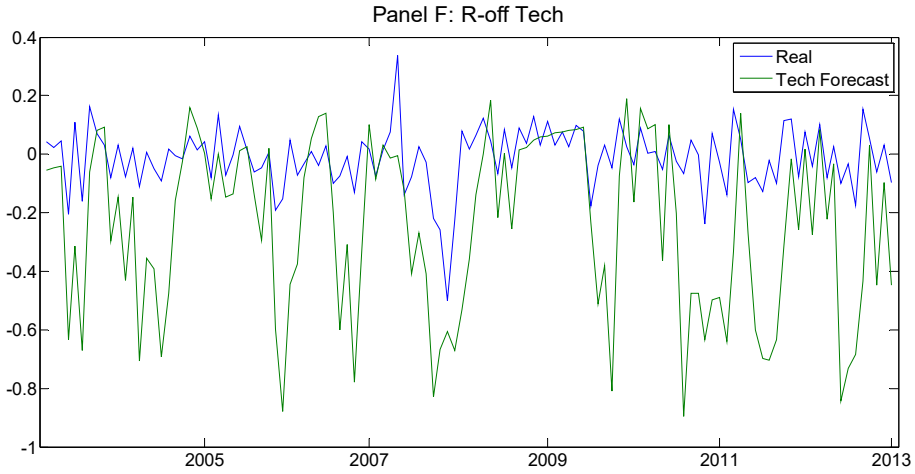
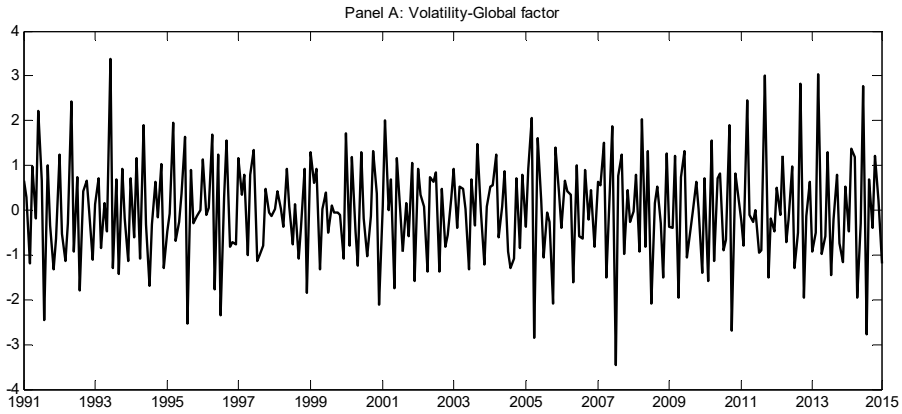


Figure 4 Out-of--sample return factors forecasts

Notes: This figure summarizes the out-of-sample results of principle components, consisting of 6 panels for the technical indicators defined in Section 2.2, the macroeconomic variables descried in Section 2.3 from 1992:01 to 2014:12 with 2004:01 as an interval, respectively. The principal components for the technical indicators ($\hat{F}^{T}_{c,t} = (\hat{F}^{T}_{c,1,t},...,\hat{F}^{T}_{c,3,t})'$) and the macroeconomic variables ($\hat{F}^{E}_{c,t} = (\hat{F}^{E}_{c,1,t},...,\hat{F}^{E}_{c,3,t})'$) defined in Section 4. Each Panel includes real factor(Real) and expected factor for 2004:02-2013:12 estimated by technical or macroeconomics principle components. R-all (in/off) represents the global (indexed/ off-index) factor and tech/macro represents the technical (macro) principle component.


Panel A: Volatility-Global factor
4
3
2
1
0
-1
-2
-3
-4
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015

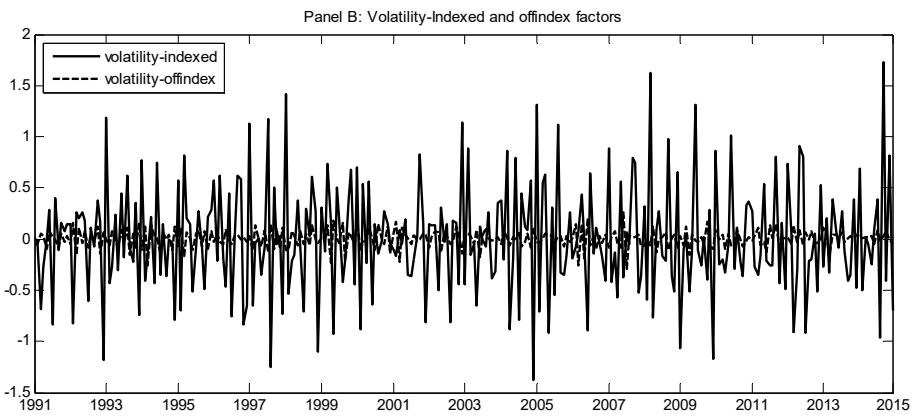


Figure 5 The Mean for the Posterior Distributions for the Global and Sectoral Factors in term of Volatility, 1991-2014.

Notes: This figure describes the means of the posterior distributions for the global, indexed and off-index factors in term of price volatility in Panel A and B for 1991-2014. The estimated factor series is naturally interpreted as a normalized index of corresponding commodity volatility.

Table 1 Unit root tests for 26 commodities (in level).

	ADF test		Philips-Perron test	
	t-stat	*p*-value	*t*-stat	*p*-value
Panel A: Returns				
Energy				
Brent oil	-14.6447	0.0000***	-14.6190	0.0000***
Crude oil	-14.8447	0.0000***	-14.8566	0.0000***
Heating oil	-16.3788	0.0000***	-16.3721	0.0000***
Natural gas	-14.4776	0.0000***	-17.2804	0.0000***
Gasoil	-14.7549	0.0000***	-14.7546	0.0000***
Metals				
Gold	-19.2021	0.0000***	-19.1862	0.0000***
Silver	-18.4082	0.0000***	-18.4662	0.0000***
Palladium	-16.3696	0.0000***	-16.6411	0.0000***
Platinum	-15.1959	0.0000***	-15.2529	0.0000***
Copper	-15.1114	0.0000***	-15.2807	0.0000***
Agriculture				
Corn	-10.0351	0.0000***	-17.5020	0.0000***
Oat	-18.6512	0.0000***	-18.6530	0.0000***
Rough rice	-10.2478	0.0000***	-18.7848	0.0000***
Soybean meal	-19.1363	0.0000***	-19.1132	0.0000***
Soybean oil	-18.7385	0.0000***	-18.6464	0.0000***
Soybean	-17.2760	0.0000***	-17.2727	0.0000***
Wheat	-18.4303	0.0000***	-18.4620	0.0000***
Industrials				

Lumber	-18.6583	0.0000***	-20.4762	0.0000***
Cotton	-18.1597	0.0000***	-18.1161	0.0000***
Livestocks				
Feeder cattle	-15.0395	0.0000***	-14.9921	0.0000***
Lean hogs	-19.7378	0.0000***	-20.4555	0.0000***
Live cattle	-11.4686	0.0000***	-17.3181	0.0000***
Softs				
Cocoa	-21.5907	0.0000***	-21.6624	0.0000***
Coffee	-18.1817	0.0000***	-18.1377	0.0000***
Orange juice	-19.7845	0.0000***	-19.7594	0.0000***
Sugar	-14.5858	0.0000***	-14.4623	0.0000***
Panel B: Volatilities				
Energy				
Brent oil	-13.9434	0.0000***	-57.4811	0.0000***
Crude oil	-13.4507	0.0000***	-43.9598	0.0001***
Heating oil	-16.8734	0.0000***	-57.5249	0.0000***
Natural gas	-17.8977	0.0000***	-49.3398	0.0000***
Gasoil	-15.1897	0.0000***	-51.7811	0.0000***
Metals				
Gold	-13.9321	0.0000***	-57.8533	0.0001***
Silver	-12.9971	0.0000***	-84.1330	0.0000***
Palladium	-18.5970	0.0000***	-76.7672	0.0000***
Platinum	-17.0230	0.0000***	-33.9556	0.0001***
Copper	-12.1845	0.0000***	-88.6161	0.0000***
Agriculture				
Corn	-18.2323	0.0000***	-63.6530	0.0001***

Oat	-17.1675	0.0000***	-59.0559	0.0000***
Rough rice	-14.3238	0.0000***	-39.9219	0.0001***
Soybean meal	-14.7636	0.0000***	-85.5456	0.0000***
Soybean oil	-12.3580	0.0000***	-112.5990	0.0000***
Soybean	-10.2296	0.0000***	-89.2197	0.0000***
Wheat	-11.0847	0.0000***	-127.5564	0.0000***
Industrials				
Lumber	-13.1407	0.0000***	-82.6118	0.0000***
Cotton	-10.7551	0.0000***	-47.3309	0.0001***
Livestocks				
Feeder cattle	-11.7325	0.0000***	-80.6253	0.0001***
Lean hogs	-13.1665	0.0000***	-86.2189	0.0000***
Live cattle	-14.0954	0.0000***	-169.6053	0.0000***
Softs				
Cocoa	-9.3177	0.0000***	-135.6623	0.0000***
Coffee	-13.3662	0.0000***	-77.4484	0.0000***
Orange juice	-11.1685	0.0000***	-50.9724	0.0001***
Sugar	-10.2356	0.0000***	-49.2887	0.0001***

Notes*:** This table shows unit root test of returns and volatilities for 26 commodities defined in Section 2.1. The second to fifth columns report the *t*-stat and *p*-value of augmented DF and Philips Perron test, respectively. and ** indicates rejection of the normality at the 1% and 5% level, respectively.

Table 2 The unit root test for macroeconomic variables (In level).

	Abbr.	ADF test		Philips-Perron test	
		t-stat	p-value	t-stat	p-value
Book-to-market ratio	BM	-17.2187	0.0000***	-16.3971	0.0000***
Treasury bill rate	TB	-3.10149	0.0321**	-1.29638	0.0783*
Long-term yield	GB	-4.02418	0.0367**	-3.2382	0.0449**
Term spread	TS	-20.7128	0.0000***	-20.5748	0.0000***
Inflation	CPI	-9.20874	0.0023***	-7.75643	0.0073***
Dividend-price ratio	DP	-16.7744	0.0000***	-15.8864	0.0000***
Dividend yield	DY	-17.2107	0.0000***	-17.2636	0.0000***
Earnings-price ratio	EP	-12.3651	0.0007***	-12.9626	0.0007***
Consumption-wealth ratio	CAY	-18.9773	0.0000***	-19.8190	0.0000***
Stock variance	SVAR	-18.3672	0.0000***	-17.8713	0.0000***
Net equity expansion	NTIS	-13.0309	0.0008***	-12.7259	0.0008***
Default yield spread	DFY	-17.8037	0.0000***	-19.4020	0.0000***
Investment to capital ratio	IK	-1.86076	0.0736*	-1.91709	0.0627*
The unemployment rate	UER	-15.2283	0.0000***	-15.4693	0.0000***
Money supply growth	MS2	-3.30265	0.0096***	-3.81133	0.0097***
Growth in industrial production	OI	-14.4711	0.0003***	-13.9866	0.0003***
Capacity utilization in manufactory	USDX	-15.2197	0.0000***	-15.6051	0.0000***
Purchasing Managers' Index	PMI	-35.5417	0.0000***	-17.2562	0.0000***
Real global activity	KI	-10.9720	0.0000***	-10.0247	0.0000***
U.S. trade-weighted real exchange rate	IIP	-8.4808	0.0034***	-6.83879	0.0074***
U.S. Production of crude oil	CUM	-15.0831	0.0000***	-14.6404	0.0000***
Excess returns on oil company stocks	FPO	-7.74633	0.0021***	-7.73525	0.0021***

Notes*:** This table shows unit root test of returns and volatilities for 26 commodities defined in Section 2.1. The second to fifth columns report the *t*-stat and *p*-value of augmented DF and Philips Perron test, respectively. and ** indicates rejection of the normality at the 1% and 5% level, respectively.

Table 3 Averages across commodity groups, variance decompositions for commodity returns.

	Global factor			Sectoral factor			Commodity-specific factor		
	Mean	0.05	0.95	Mean	0.05	0.95	Mean	0.05	0.95
All	16.68%	14.87%	18.68%	18.53%	16.38%	20.89%	64.79%	61.21%	68.19%
Indexed	22.04%	20.09%	24.21%	22.05%	20.41%	23.89%	55.91%	52.93%	58.67%
Off-index	4.61%	3.11%	6.22%	10.63%	7.31%	14.14%	84.76%	79.84%	89.62%
Brent oil	40.66%	40.07%	41.43%	19.12%	18.85%	19.45%	40.22%	39.48%	40.84%
Crude oil	54.62%	52.04%	56.96%	10.79%	9.48%	12.83%	34.59%	29.79%	39.90%
Heating oil	22.17%	21.08%	23.42%	21.18%	19.42%	23.65%	56.65%	54.03%	58.63%
Natural gas	12.48%	11.27%	13.91%	13.32%	9.96%	17.89%	74.20%	69.66%	77.67%
Gasoil	18.61%	14.73%	23.20%	11.54%	9.50%	14.32%	69.86%	65.24%	73.86%
Gold	19.69%	17.25%	22.42%	20.61%	20.00%	21.34%	59.70%	57.08%	62.04%
Silver	11.77%	9.65%	14.36%	70.52%	66.63%	74.26%	17.71%	14.66%	20.69%
Palladium	3.68%	2.76%	4.79%	40.05%	32.48%	50.64%	56.27%	45.84%	63.79%
Platinum	7.61%	5.99%	9.59%	38.29%	22.35%	51.81%	54.11%	40.35%	70.09%
Copper	23.92%	22.27%	25.93%	10.01%	9.99%	10.09%	66.07%	64.06%	67.72%
Corn	44.80%	39.22%	51.33%	10.05%	9.95%	10.31%	45.15%	38.61%	50.73%
Oat	6.51%	3.53%	8.78%	1.09%	0.91%	1.58%	92.39%	87.89%	98.36%
Rough rice	5.18%	3.07%	7.68%	1.40%	0.83%	2.15%	93.42%	88.53%	97.53%
Soybean meal	0.87%	0.15%	1.75%	0.84%	0.28%	1.47%	98.29%	97.19%	99.27%
Soybean oil	1.05%	0.95%	1.26%	1.40%	0.72%	2.14%	97.55%	96.82%	98.22%
Soybean	20.26%	19.92%	20.69%	10.02%	9.98%	10.12%	69.72%	69.26%	70.08%
Wheat	35.37%	32.89%	38.22%	11.36%	8.88%	13.92%	53.26%	50.76%	55.64%
Lumber	1.60%	0.56%	2.89%	1.71%	0.89%	2.60%	96.68%	95.41%	97.80%
Cotton	4.65%	3.91%	5.57%	11.84%	9.69%	14.04%	83.51%	81.34%	85.55%
Feeder cattle	3.26%	2.30%	4.46%	4.69%	3.95%	5.47%	92.06%	89.82%	93.96%

Lean hogs	3.58%	2.56%	4.86%	4.95%	4.17%	5.75%	91.46%	89.19%	93.43%
Live cattle	1.75%	0.64%	3.13%	3.56%	1.78%	5.12%	94.69%	92.63%	96.92%
Cocoa	1.27%	0.36%	2.44%	92.36%	89.17%	95.23%	6.37%	4.30%	8.48%
Coffee	1.94%	0.88%	3.22%	69.92%	65.65%	74.17%	28.14%	24.53%	31.65%
Orange juice	10.40%	7.90%	13.02%	0.23%	0.00%	0.74%	89.38%	86.67%	91.93%
Sugar	75.86%	70.64%	80.33%	1.05%	0.33%	2.07%	23.09%	18.29%	28.27%

Notes: This table reports averages across various commodities of the means and 0.05and 0.95 quantiles for the posterior distributions. The second (fifth, eighth) to fourth (seventh, tenth) columns report the mean, 0.05 and 0.95 quantiles for global, sectoral and commodity-specific factors, respectively.

Table 4 Averages across commodity groups, variance decompositions for commodity volatility (%).

	Global factor			Sectoral factor			Commodity-specific factor		
	Mean	0.05	0.95	Mean	0.05	0.95	Mean	0.05	0.95
All									
Indexed									
Off-index									
Brent oil	1.05%	0.11%	2.54%	0.34%	0.00%	1.05%	98.62%	97.12%	99.65%
Crude oil	28.99%	23.13%	34.77%	3.32%	0.01%	12.07%	67.69%	59.21%	74.51%
Heating oil	1.30%	0.22%	2.82%	4.60%	0.01%	19.48%	94.10%	79.25%	99.26%
Natural gas	1.24%	0.27%	2.60%	3.28%	0.01%	11.88%	95.48%	86.76%	99.31%
Gasoil	2.93%	1.11%	5.42%	5.02%	0.01%	18.18%	92.05%	77.92%	98.33%
Gold	0.56%	0.01%	1.56%	0.37%	0.01%	1.07%	99.07%	97.99%	99.80%
Silver	0.65%	0.00%	2.40%	49.26%	43.31%	55.15%	50.09%	44.43%	55.82%
Palladium	0.16%	0.00%	0.64%	4.45%	0.01%	17.43%	95.39%	82.36%	99.93%
Platinum	0.31%	0.00%	1.02%	4.98%	0.01%	17.81%	94.71%	81.85%	99.83%
Copper	0.35%	0.00%	1.17%	0.98%	0.14%	2.20%	98.67%	97.37%	99.62%
Corn	30.71%	25.14%	36.54%	0.78%	0.01%	2.28%	68.52%	62.86%	73.88%
Oat	59.19%	51.67%	66.19%	0.35%	0.00%	1.36%	40.47%	33.54%	47.87%
Rough rice	18.60%	14.26%	23.30%	0.67%	0.01%	1.95%	80.73%	76.06%	85.00%
Soybean meal	3.08%	1.32%	5.25%	0.39%	0.01%	1.16%	96.53%	94.35%	98.31%
Soybean oil	0.19%	0.00%	0.71%	1.82%	0.66%	3.30%	97.99%	96.50%	99.18%
Soybean	0.15%	0.00%	0.57%	0.31%	0.00%	0.98%	99.54%	98.78%	99.97%
Wheat	1.10%	0.11%	2.61%	0.87%	0.08%	2.08%	98.03%	96.34%	99.31%
Lumber	1.70%	0.37%	3.49%	0.30%	0.00%	1.02%	98.00%	96.02%	99.48%
Cotton	0.94%	0.09%	2.22%	4.74%	2.77%	7.04%	94.33%	91.72%	96.57%
Feeder cattle	0.24%	0.00%	0.89%	5.66%	3.45%	8.20%	94.10%	91.44%	96.36%

Lean hogs	1.37%	0.25%	2.99%	0.83%	0.10%	1.96%	97.80%	96.10%	99.15%
Live cattle	0.84%	0.01%	3.06%	56.48%	50.51%	62.16%	42.68%	37.22%	48.30%
Cocoa	0.75%	0.00%	2.74%	55.72%	49.95%	61.32%	43.52%	38.11%	49.07%
Coffee	0.65%	0.00%	2.18%	33.72%	28.60%	38.97%	65.63%	60.45%	70.67%
Orange juice	1.95%	0.51%	4.01%	3.42%	0.01%	11.49%	94.64%	85.78%	98.99%
Sugar	45.09%	37.26%	52.50%	1.57%	0.01%	5.95%	53.34%	45.98%	61.01%

Notes: This table reports averages across various commodities of the means and 0.05and 0.95 quantiles for the posterior distributions. The second (fifth, eighth) to fourth (seventh, tenth) columns report the mean, 0.05 and 0.95 quantiles for global, sectoral and commodity-specific factors, respectively.

Table 5 Bivariate predictive regression estimation results

Predictor	Glo_R			$Index_R$			$Offdex_R$		
	Coeff.	t-stat.	R^2	Coeff.	t-stat	R^2	Coeff.	t-stat.	R^2
Panel A: Technical Indicators									
MA(1,9)	0.8164	7.0869***	16.36%	0.7998	7.8792***	19.59%	0.0632	2.5940***	2.51%
MA(1,12)	0.7228	6.2204***	12.87%	0.6642	6.2767***	13.48%	0.0530	2.1727**	1.76%
MA(2,9)	0.5022	4.1385***	6.20%	0.3091	2.7503***	2.92%	0.0239	0.9719	0.36%
MA(2,12)	0.4247	3.4780***	4.44%	0.2828	2.5037***	2.43%	0.0289	1.1827	0.53%
MA(3,9)	0.2447	1.9605**	1.47%	0.2461	2.1836**	1.85%	0.0272	1.1109	0.47%
MA(3,12)	0.2516	2.0368**	1.56%	0.2360	2.0610**	1.68%	0.0056	0.2270	0.02%
MA(6,9)	0.1927	1.5656*	0.91%	0.1111	0.9796	0.38%	-0.0046	-0.1898	0.01%
MA(6,12)	0.1323	1.0707	0.43%	0.1365	1.1861	0.56%	0.0127	0.5212	0.10%
MOM(1)	1.4901	17.6198***	54.64%	1.3874	19.3790***	59.14%	0.1396	6.0966***	12.41%
MOM(2)	1.0568	9.7657***	27.41%	0.8607	8.7294***	22.74%	0.0888	3.6970***	5.01%
MOM(3)	0.8030	6.8183***	15.67%	0.6943	6.6516***	14.75%	0.0738	3.0181***	3.43%
MOM(6)	0.5730	4.7268***	8.02%	0.4720	4.2689***	6.78%	0.0498	2.0414**	1.57%
MOM(9)	0.5991	5.0353***	8.84%	0.4674	4.1436***	6.57%	0.0301	1.2354*	0.57%
MOM(12)	0.4499	3.7133***	4.98%	0.4273	3.8178***	5.52%	0.0369	1.5226*	0.87%
VOL(1,9)	0.6518	5.5993***	10.44%	0.5826	5.3295***	10.30%	0.0441	1.8057**	1.22%
VOL(1,12)	0.6413	5.5292***	10.06%	0.5068	4.6081***	7.82%	0.0161	0.6449	0.16%
VOL (2,9)	0.4246	3.5178***	4.43%	0.3090	2.7536***	2.92%	-0.0163	-0.6618	0.17%
VOL (2,12)	0.3856	3.2104***	3.64%	0.3163	2.8046***	3.05%	-0.0268	-1.0818	0.45%
VOL (3,9)	0.2936	2.4158***	2.10%	0.2329	2.0434**	1.65%	-0.0226	-0.8951	0.31%
VOL (3,12)	0.2345	1.9394**	1.34%	0.2493	2.1910**	1.89%	-0.0402	-1.6254	0.96%
VOL (6,9)	0.0401	0.3284	0.04%	0.1694	1.4935*	0.87%	-0.0425	-1.7183	1.09%
VOL (6,12)	0.0480	0.3911	0.06%	0.2023	1.7534**	1.23%	-0.0569	-2.3418	1.91%
Panel B: Macroeconomic Variables									

TBL	-8.4524	-2.8355	2.93%	-6.9614	-2.7102	2.48%	-8.3434	-28.3137	74.36%
LGB	-11.2569	-2.8039	2.51%	-6.6897	-1.8305	1.11%	-9.2019	-18.3500	43.72%
TermS	6.8022	1.5513*	0.84%	8.4224	2.3628***	1.61%	8.8010	14.2244***	36.61%
DFY	31.0299	1.8119**	1.77%	19.4518	1.3183	0.87%	23.8565	8.1441***	27.24%
DP	-0.1064	-0.5191	0.08%	0.0478	0.2421	0.02%	-0.1915	-4.3197	6.64%
DY	-0.2501	-1.2560	0.44%	-0.0541	-0.2952	0.03%	-0.1787	-4.1682	5.80%
EP	0.0468	0.2702	0.03%	0.2349	1.7864**	1.04%	0.0367	1.2287	0.53%
BM	0.3483	2.0680**	1.14%	0.1809	0.9697	0.39%	0.2817	7.8423***	19.48%
SVAR	-18.1358	-1.2977	0.86%	-27.5611	-1.6035	2.48%	12.3588	8.9618***	10.40%
NTIS	0.0250	0.3482	0.06%	-0.0986	-1.4273	1.10%	0.0110	0.8002	0.28%
CPI	-1.6668	-0.0671	0.00%	37.8922	1.3858	1.26%	-18.6276	-3.9421	6.33%
IK	-42.6430	-3.2578	3.25%	-29.8236	-2.5979	1.99%	-31.8485	-17.0388	47.24%
CAY	-6.3902	-2.5734	1.57%	-6.4437	-2.8826	2.00%	-3.7478	-8.0457	14.09%
UER	0.5971	2.6120***	2.37%	0.5044	2.6090***	2.11%	0.5224	19.2006***	47.21%
MS2	0.3499	0.0365	0.00%	-5.4916	-0.6887	0.15%	2.6471	1.1937	0.72%
IIP	-8.0167	-0.4821	0.27%	18.8150	1.0493	1.86%	-4.7116	-2.6203	2.43%
CUM	-1.4532	-1.0773	0.76%	-0.5549	-0.4039	0.14%	-1.2011	-6.1272	13.44%
PMI	-0.2915	-0.4008	0.08%	1.0928	1.5380*	1.46%	-0.2152	-1.4920	1.18%
OI	0.2014	1.9338**	1.37%	0.0868	0.8179	0.32%	0.1589	8.9760***	22.11%
KI	0.0374	0.6913	0.18%	0.0617	1.4331	0.63%	0.0242	1.9618**	2.00%
USDX	-0.8251	-1.2248	0.51%	-0.0762	-0.1138	0.01%	-0.5288	-3.8478	5.40%
FPO	-0.3499	-0.5919	0.17%	-0.1310	-0.1901	0.03%	-0.1616	-1.6133	0.96%

Notes: This table summarizes the in-sample results, consisting of two panels for the technical indicators defined in Section 3.2, the macroeconomic variables descried in Section 3.3 from 1992:01 to 2014:12. Every three columns list the results of three return factors, respectively. The second (fifth, eighth) and fourth (seventh, tenth) columns show slope coefficient with heteroskedasticity-consistent *t*-statistic. ***, ** and * indicating the rejection of normality at the 1%, 5% and 10% levels, respectively, and the R^2 statistics.

Table 6 Business cycle specification**:** bivariate predictive regression estimation with NBER business cycle

Predictor	Glo_R		$Index_R$		$Offdex_R$	
	R^2_{exp}	R^2_{rec}	R^2_{exp}	R^2_{rec}	R^2_{exp}	R^2_{rec}
Panel A: Technical Indicators						
MA(1,9)	17.45%	12.49%	21.25%	16.33%	1.47%	9.75%
MA(1,12)	13.98%	8.96%	14.66%	11.15%	0.89%	7.75%
MA(2,9)	6.31%	5.81%	0.91%	6.88%	-0.14%	3.79%
MA(2,12)	4.45%	4.39%	1.94%	3.41%	0.09%	3.53%
MA(3,9)	1.21%	2.38%	1.03%	3.46%	0.04%	3.39%
MA(3,12)	1.71%	1.02%	0.86%	3.30%	-0.09%	0.77%
MA(6,9)	0.74%	1.52%	-0.42%	1.95%	0.06%	-0.29%
MA(6,12)	0.64%	-0.30%	0.23%	1.20%	0.02%	0.64%
MOM(1)	53.32%	59.28%	65.65%	46.31%	10.80%	23.62%
MOM(2)	26.28%	31.39%	23.08%	22.07%	3.49%	15.52%
MOM(3)	16.91%	11.32%	13.24%	17.72%	2.11%	12.61%
MOM(6)	8.11%	7.70%	4.43%	11.42%	0.85%	6.52%
MOM(9)	10.32%	3.64%	6.23%	7.25%	0.04%	4.29%
MOM(12)	6.81%	-1.45%	5.80%	4.96%	0.13%	5.97%
VOL(1,9)	10.24%	11.16%	6.33%	18.12%	0.13%	8.74%
VOL(1,12)	10.63%	8.06%	5.18%	13.01%	-0.27%	3.15%
VOL (2,9)	3.86%	6.44%	0.53%	7.61%	0.60%	-2.83%
VOL (2,12)	4.18%	1.75%	0.41%	8.23%	1.28%	-5.32%
VOL (3,9)	1.62%	3.77%	-0.55%	5.99%	1.05%	-4.84%
VOL (3,12)	1.92%	-0.71%	-0.01%	5.63%	1.99%	-6.15%
VOL (6,9)	0.16%	-0.39%	-0.13%	2.85%	2.18%	-6.40%
VOL (6,12)	0.26%	-0.65%	0.65%	2.39%	2.96%	-5.35%
Panel B: Macroeconomic Variables						
TBL	3.81%	-0.17%	3.86%	-0.22%	76.47%	59.72%

LGB	2.71%	1.83%	1.43%	0.48%	43.90%	42.49%
TermS	1.37%	-1.01%	2.77%	-0.68%	36.72%	35.85%
DFY	2.37%	-0.35%	1.47%	-0.31%	24.71%	44.79%
DP	0.04%	0.21%	0.24%	-0.42%	2.82%	33.04%
DY	0.23%	1.18%	-0.25%	0.56%	2.87%	26.05%
EP	-0.23%	0.97%	1.72%	-0.30%	-0.82%	9.90%
BM	1.68%	-0.73%	-0.86%	2.85%	21.13%	8.08%
SVAR	-0.52%	5.70%	0.78%	5.83%	1.86%	69.55%
NTIS	0.06%	0.05%	0.89%	1.51%	-0.56%	6.14%
CPI	0.05%	-0.16%	1.91%	-0.03%	2.01%	36.22%
IK	3.74%	1.53%	1.50%	2.94%	50.33%	25.83%
CAY	1.20%	2.91%	2.59%	0.83%	15.66%	3.23%
UER	2.74%	1.08%	1.65%	3.03%	52.16%	12.95%
MS2	0.02%	-0.06%	-0.11%	0.65%	-0.22%	7.20%
IIP	0.84%	-1.72%	-1.44%	8.36%	-0.60%	23.46%
CUM	1.22%	-0.89%	1.19%	-1.95%	11.06%	29.89%
PMI	0.04%	0.23%	1.99%	0.42%	-2.15%	24.27%
OI	1.68%	0.25%	1.01%	-1.05%	19.78%	38.26%
KI	0.23%	0.04%	0.95%	-0.01%	3.02%	-5.03%
USDX	0.45%	0.72%	-0.09%	0.19%	6.42%	-1.60%
FPO	0.45%	-0.80%	0.39%	-0.68%	-0.72%	12.63%

Notes: This table summarizes the in-sample results, consisting of two panels for the technical indicators defined in Section 3.2, the macroeconomic variables descried in Section 3.3 from 1992:01 to 2014:12. Every two columns list the results of three factors constructed by commodity return—Glo_R, $Index_R$ and $Offdex_R$, respectively. The second (fourth, sixth) and third (fifth, seventh) columns report R^2_{exp} and R^2_{rec} during expansion and recession periods, respectively.

Table 7 Multi-information specification: bivariate predictive regression estimations by principle components analysis

Predictor	Coeff.	t-stat.	R^2	R^2_{exp}	R^2_{rec}
Panel A: Glo$_R$					
$\hat{F}^T_{c,1,t}$	-0.0915	-6.8979***	40.27%	39.88%	41.65%
$\hat{F}^T_{c,2,t}$	-0.0191	-0.6377			
$\hat{F}^T_{c,3,t}$	-0.3792	-10.2508***			
$\hat{F}^E_{c,1,t}$	0.0694	2.5946***	2.81%	4.20%	0.44%
Panel B: Index$_R$					
$\hat{F}^T_{c,1,t}$	0.0808	5.3253***	35.87%	37.67%	32.33%
$\hat{F}^T_{c,2,t}$	0.1836	7.7265***			
$\hat{F}^T_{c,3,t}$	-0.2563	-10.8445***			
$\hat{F}^E_{c,1,t}$	0.0392	1.5296***	40.27%	39.88%	41.65%
$\hat{F}^E_{c,2,t}$	0.0046	0.1618			
$\hat{F}^E_{c,3,t}$	-0.0740	-1.7612			
Panel C: Offdex$_R$					

$\hat{F}^{T}_{c,1,t}$	-0.0036	-1.0464	11.33%	11.04%	13.33%
$\hat{F}^{T}_{c,2,t}$	0.0267	3.7416***			
$\hat{F}^{T}_{c,3,t}$	-0.0320	-4.2065			
$\hat{F}^{E}_{c,1,t}$	0.0624	20.3499***	63.92%	65.36%	53.96%
$\hat{F}^{E}_{c,2,t}$	0.0186	5.8083***			
$\hat{F}^{E}_{c,3,t}$	-0.0071	-1.4148			

Notes: This table summarizes the in-sample results of principle components, consisting of 3 panels for the technical indicators defined in Section 3.2, the macroeconomic variables descried in Section 3.3 from 1992:01 to 2014:12, respectively. The principal components for the technical indicators ($\hat{F}^{T}_{c,t} = (\hat{F}^{T}_{c,1,t},...,\hat{F}^{T}_{c,3,t})'$) and the macroeconomic variables ($\hat{F}^{E}_{c,t} = (\hat{F}^{E}_{c,1,t},...,\hat{F}^{E}_{c,3,t})'$) defined in Section 5.1.3. The second and third columns show slope coefficient and its heteroskedasticity-consistent *t*-statistic. ***, ** and * indicate the rejection of normality at the 1%, 5% and 10% levels, respectively. The fourth to sixth columns report R^2, R^2_{exp} and R^2_{rec} overall and during expansion and recession periods, also, respectively.

Table 8 Out-of-Sample forecast results.

Predictor	Glo_R			$Index_R$			$Offdex_R$		
	MSFE	$R_{c,os}^2$ (%)	*MSFE-adj*	*MSFE*	$R_{c,os}^2$ (%)	*MSFE-adj*	*MSFE*	$R_{c,os}^2$ (%)	*MSFE-adj*
Panel A: Technical Indicators									
HA	1.5342			1.1429			0.0544		
MA(1,9)	1.3174	14.1343	4.4822***	0.9677	15.3290	4.5171***	0.0564	-3.7278	-0.2815
MA(1,12)	1.4063	8.3399	3.2720***	1.0143	11.2490	3.6907***	0.0568	-4.5029	-0.8792
MA(2,9)	1.4725	4.0285	2.2100**	1.1178	2.1937	1.5497*	0.0553	-1.7334	-1.0930
MA(2,12)	1.4827	3.3655	2.0211**	1.1190	2.0952	1.5455*	0.0557	-2.4707	-1.0990
MA(3,9)	1.5238	0.6863	0.9107	1.1254	1.5343	1.3351*	0.0554	-1.9068	-1.0945
MA(3,12)	1.5293	0.3230	0.7619	1.1239	1.6591	1.4161*	0.0551	-1.2436	-1.7310
MA(6,9)	1.5380	-0.2445	0.2927	1.1432	-0.0235	0.1984	0.0550	-1.1687	-1.5686
MA(6,12)	1.5464	-0.7880	-0.3178	1.1417	0.1023	0.4433	0.0555	-1.9715	-1.9019
MOM(1)	0.7287	52.5041	12.8533***	0.5095	55.4189	13.0410***	0.0503	7.4237	3.0262***
MOM(2)	1.1572	24.5783	6.3682***	0.9095	20.4245	5.7210***	0.0539	0.8730	1.2410
MOM(3)	1.2948	15.6103	4.9258***	0.9629	15.7501	4.8841***	0.0544	0.0124	0.8323
MOM(6)	1.4290	6.8610	2.9899***	1.0825	5.2813	2.4556***	0.0558	-2.6699	-0.2894
MOM(9)	1.4639	4.5879	2.3852***	1.0663	6.7056	2.7865***	0.0559	-2.7684	-1.2402
MOM(12)	1.5260	0.5386	1.1817	1.1139	2.5339	1.7275**	0.0565	-3.9710	-0.9291
VOL(1,9)	1.4049	8.4341	3.3096***	1.0213	10.6430	3.7350***	0.0543	0.1535	0.7303
VOL(1,12)	1.4149	7.7799	3.1381***	1.0440	8.6554	3.4324***	0.0549	-0.9234	-0.0670
VOL (2,9)	1.4955	2.5256	1.6757**	1.1061	3.2231	2.0341**	0.0544	-0.1034	-0.0808
VOL (2,12)	1.5130	1.3859	1.2249	1.1069	3.1498	1.9260**	0.0542	0.3357	0.5759
VOL (3,9)	1.5090	1.6494	1.4298*	1.1223	1.8058	1.4988*	0.0543	0.0646	0.2654
VOL (3,12)	1.5411	-0.4430	0.3128	1.1182	2.1599	1.6354*	0.0538	1.0799	1.2188
VOL (6,9)	1.5430	-0.5661	-1.3018	1.1356	0.6376	0.8559	0.0537	1.2107	1.2759
VOL (6,12)	1.5433	-0.5865	-1.2918	1.1298	1.1442	1.1379	0.0529	2.7453	2.4450***
Panel B: Macroeconomic Variables									

TBL	1.5510	-1.0855	0.6483	1.1272	1.3724	1.4057*	0.0100	81.5546	12.8025***
LGB	1.5098	1.5972	1.4520*	1.1396	0.2902	0.8590	0.0224	58.8271	10.2671***
TermS	1.5714	-2.4192	-0.6748	1.1345	0.7358	1.1015	0.0353	35.1465	9.3031***
DFY	1.5761	-2.7230	-0.1392	1.1856	-3.7377	-0.6918	0.0410	24.6879	3.3433***
DP	1.5390	-0.3053	-1.3829	1.1490	-0.5362	-0.5475	0.0492	9.5388	5.4215***
DY	1.5320	0.1507	0.5003	1.1471	-0.3636	-0.5946	0.0498	8.3480	5.6506***
EP	1.5545	-1.3164	-0.3376	1.1420	0.0808	0.8068	0.0577	-6.1056	1.1320
BM	1.5280	0.4087	0.7164	1.1417	0.1025	0.3826	0.0395	27.4413	8.6606***
SVAR	1.5564	-1.4384	0.7346	1.2081	-5.7005	0.9902	0.0461	15.2814	1.8163**
NTIS	1.5439	-0.6262	-1.0548	1.1368	0.5359	0.6319	0.0552	-1.4760	0.0512
CPI	1.5605	-1.7084	-1.0007	1.1630	-1.7574	0.7405	0.0503	7.4516	2.0315**
IK	1.5084	1.6865	1.5308*	1.1152	2.4258	2.1664**	0.0219	59.7841	10.9412***
CAY	1.5125	1.4227	1.6445**	1.1265	1.4377	1.6597**	0.0430	20.8523	7.7109***
UER	1.5202	0.9200	1.2718	1.1170	2.2688	1.9337**	0.0202	62.9414	10.7449***
MS2	1.5457	-0.7457	-1.2060	1.1510	-0.7098	-0.2603	0.0542	0.3494	0.4646
IIP	1.5836	-3.2153	-0.6066	1.1612	-1.6022	0.1104	0.0533	2.0418	1.1679
CUM	1.5443	-0.6515	0.1263	1.1666	-2.0776	-0.6804	0.0447	17.8692	4.5734
PMI	1.5513	-1.1070	-1.4710	1.1622	-1.6867	0.4486	0.0551	-1.3022	0.4501
OI	1.5287	0.3669	0.6223	1.1590	-1.4119	-0.4998	0.0359	34.0428	9.7295***
KI	1.5429	-0.5633	-0.7748	1.1384	0.3936	0.9149	0.0538	1.1074	0.9523
USDX	1.5340	0.0216	0.2900	1.1523	-0.8189	-1.1119	0.0523	3.7592	2.5830***
FPO	1.5559	-1.4050	-0.4901	1.1711	-2.4677	-0.5873	0.0548	-0.7317	1.1704

Notes: This table summarizes the out of-sample results, consisting of 2 panels for the technical indicators defined in Section 3.2, the macroeconomic variables in Section3.3 for the 22 years from 1992:01 to 2013:12 with 2004:01 as an interval. Every three columns list the results of three Return factors—Glo_R, $Index_R$ and $Offdex_R$, respectively. The $R_{c,os}^2$ in the third(sixth, ninth) columns measure the percent reductions in mean squared forecast error (*MSFE*) in the second(fifth, eighth) columns for the predictive regression forecasts based on the predictors relative to the historical average benchmark forecasts. The fourth (seventh, tenth)

columns report the *MSFE-adjusted* statistics for testing the null hypothesis that the historical average *MSFE* is less than or equal to the predictive regression *MSFE* against the one-sided (upper-tail) alternative hypothesis that the historical average *MSFE* is greater than the predictive regression *MSFE*.

Table 9 Business cycle specification**:** out-of-sample estimations with NBER business cycle

Predictor	Ret_g		Ret_i		Ret_o	
	R^2_{exp} (%)	R^2_{rec} (%)	R^2_{exp} (%)	R^2_{rec} (%)	R^2_{exp} (%)	R^2_{rec} (%)
Panel A: Technical Indicators						
MA(1,9)	15.0988	11.9312	17.6624	12.2215	-8.2082	8.9244
MA(1,12)	9.6460	5.3561	14.9387	6.3354	-9.2437	8.8845
MA(2,9)	3.5098	5.2133	0.9769	3.8142	-3.9253	4.4561
MA(2,12)	3.1421	3.8759	2.7722	1.1935	-4.6975	3.8174
MA(3,9)	-0.1331	2.5582	1.5267	1.5443	-3.8089	3.4642
MA(3,12)	0.0222	1.0100	2.2692	0.8467	-2.3461	1.8697
MA(6,9)	-1.2496	2.0516	0.2726	-0.4178	-1.5316	-0.1439
MA(6,12)	-0.6060	-1.2036	0.5290	-0.4660	-2.6660	-0.0104
MOM(1)	51.5198	54.7527	66.1294	41.1556	3.8112	17.6251
MOM(2)	23.5355	26.9606	21.9724	18.3631	-2.1598	9.4372
MOM(3)	18.0281	10.0872	17.1862	13.8376	-2.6465	7.5205
MOM(6)	5.8964	9.0646	2.9242	8.4204	-6.1394	7.1275
MOM(9)	6.0927	1.1503	9.7390	2.6660	-5.0166	3.5804
MOM(12)	2.6219	-4.2204	2.9691	1.9542	-6.8023	4.0244
VOL(1,9)	7.3117	10.9981	8.1212	14.0012	-2.9965	9.0488
VOL(1,12)	7.6381	8.1039	7.7386	9.8764	-3.1594	5.3909
VOL (2,9)	1.0948	5.7942	1.5663	5.4295	-0.5110	1.0476
VOL (2,12)	1.3079	1.5641	0.5935	6.5542	0.4678	-0.0372
VOL (3,9)	0.6181	4.0054	0.2617	3.8620	0.4328	-0.9754
VOL (3,12)	-0.4676	-0.3870	1.4712	3.0770	1.7386	-0.7801
VOL (6,9)	-0.6702	-0.3284	0.3345	1.0412	1.9414	-0.8527
VOL (6,12)	-0.9001	0.1301	1.1860	1.0887	3.8225	-0.2963
Panel B: Macroeconomic Variables						
TBL	-1.1748	-0.8815	4.7331	-3.1032	84.5719	73.0341
LGB	1.4221	1.9973	1.3281	-1.0919	63.1301	46.6760

TermS	-2.9828	-1.1317	2.3154	-1.3679	35.5219	34.0863
DFY	0.7508	-10.6586	1.0743	-10.1459	10.5583	64.5875
DP	-0.2493	-0.4334	-0.2383	-0.9328	6.4766	18.1862
DY	0.0367	0.4111	-0.1069	-0.7054	6.1476	14.5618
EP	-3.4622	3.5857	-1.2929	1.9102	-18.2259	28.1200
BM	0.8150	-0.5195	0.1359	0.0581	30.9602	17.5045
SVAR	-0.2375	-4.1818	2.0537	-16.0270	-4.7899	71.9596
NTIS	-0.5900	-0.7089	0.5961	0.4558	-7.6372	15.9220
CPI	-0.3068	-4.9102	3.3290	-8.5310	2.2471	22.1482
IK	1.7803	1.4720	4.3758	-0.1710	66.1819	41.7178
CAY	1.0967	2.1674	2.1255	0.5218	26.3339	5.3730
UER	0.8805	1.0102	4.2316	-0.3450	72.0787	37.1391
MS2	-0.6489	-0.9668	-0.9773	-0.3535	-0.9217	3.9388
IIP	0.6257	-11.9899	0.4063	-4.2769	-8.5637	31.9901
CUM	0.6583	-3.6437	0.3131	-5.2613	6.8434	49.0044
PMI	-1.1602	-0.9856	4.2006	-9.5270	-13.6372	33.5300
OI	1.0083	-1.0983	-0.3330	-2.8486	40.7066	15.2253
KI	-0.3496	-1.0514	1.0581	-0.4913	2.9845	-4.1931
USDX	0.3700	-0.7744	-1.8012	0.4893	9.9919	-13.8412
FPO	-0.6490	-3.1321	-0.2404	-5.4340	-8.4443	21.0475

Notes: This table summarizes the out-of-sample results, consisting of 2 panels for the technical indicators defined in Section 2, the macroeconomic variables in Table 1 for the 22 years from 1992:01 to 2013:12 with 2004:01 as an interval. Every two columns list the results of three Return factors—Return all, Return_in and Return_off, respectively. The second (fourth, sixth) and third (fifth, seventh) columns report R^2_{exp} and R^2_{rec} during expansion and recession periods, respectively.

Table 10 Multi-information specification: out-of-sample estimations by principle components analysis

Predictor	*MSFE*	$R_{c,os}{}^2$ (%)	*MSFE-adj*	R^2_{exp} (%)	R^2_{rec} (%)
Panel A: Ret_g					
$\hat{F}^T_{c,1,t}$	1.3695	10.7408	5.5015***	11.5666	8.8541
$\hat{F}^T_{c,2,t}$	0.9796	36.1558	6.9438***	33.9942	41.0940
$\hat{F}^E_{c,1,t}$	1.5283	0.3881	0.5746	0.6675	-0.2501
$\hat{F}^E_{c,2,t}$	1.6127	-5.1110	-0.2359	-1.4845	-13.3953
Panel B: Ret_i					
$\hat{F}^T_{c,1,t}$	-0.1564	-0.1564	-0.1564***	13.8749	8.5884
$\hat{F}^T_{c,2,t}$	-17.1335	-17.1335	-17.1335***	38.7499	27.8306
$\hat{F}^E_{c,1,t}$	1.1282	1.2875	1.3070*	2.3717	-0.1564
$\hat{F}^E_{c,2,t}$	1.2125	-6.0880	0.5517	2.2062	-17.1335
Panel C: Ret_o					
$\hat{F}^T_{c,1,t}$	0.0542	0.4175	0.7230	-1.1847	4.9418
$\hat{F}^T_{c,2,t}$	0.0527	3.0948	1.9510**	-2.2573	18.2084
$\hat{F}^E_{c,1,t}$	0.0368	32.3523	8.6952***	29.4831	40.4544

$\hat{F}^{E}_{c,2,t}$	0.0157	71.1815	6.7743***	75.8826	57.9063

Notes: This table summarizes the out-of-sample results of principle components, consisting of 3 panels for the technical indicators defined in Section 2, the macroeconomic variables in Table 1 for the 22 years from 1992:01 to 2013:12 with 2004:01 as an interval, respectively. The principal components for the technical indicators ($\hat{F}^{T}_{c,t} = (\hat{F}^{T}_{c,1,t},...,\hat{F}^{T}_{c,3,t})'$) and the macroeconomic variables ($\hat{F}^{E}_{c,t} = (\hat{F}^{E}_{c,1,t},...,\hat{F}^{E}_{c,3,t})'$).The second and third columns show slope coefficient and its heteroskedasticity-consistent *t*-statistic. ***, ** and * indicate the rejection of normality at the 1%, 5% and 10% levels, respectively. The fourth to sixth columns report R^2, R^2_{exp} and R^2_{rec} overall and during expansion and recession periods, also, respectively.

Table 11 Indicators specification: Out-of-Sample forecasting results in volatility level

Predictor	Glo_V			$Index_V$			$Offdex_V$		
	MSFE	$R_{c,os}^2$	*MSFE-adj*	*MSFE*	$R_{c,os}^2$	*MSFE-adj*	*MSFE*	$R_{c,os}^2$	*MSFE-adj*
Panel A: Technical Indicators									
HA	1.4582			0.3487			0.0524		
MA(1,9)	1.0575	27.4750	6.5106***	0.2491	28.5603	6.7548***	0.0490	6.5414	3.2203***
MA(1,12)	1.1339	22.2342	5.6684***	0.2595	25.5869	6.3802***	0.0511	2.5411	2.4361***
MA(2,9)	1.4679	-0.6657	-2.5850	0.3507	-0.5801	-1.0792	0.0529	-1.0015	-0.5807
MA(2,12)	1.4629	-0.3283	-1.0302	0.3503	-0.4480	-0.7894	0.0536	-2.2604	-0.6117
MA(3,9)	1.4717	-0.9260	-0.8099	0.3510	-0.6445	-1.0614	0.0536	-2.1923	-0.2778
MA(3,12)	1.4675	-0.6380	-1.3872	0.3509	-0.6189	-1.6573	0.0538	-2.6581	-0.1116
MA(6,9)	1.4638	-0.3896	-0.3620	0.3508	-0.5884	-1.1935	0.0544	-3.7091	-0.7488
MA(6,12)	1.4664	-0.5632	-0.6006	0.3538	-1.4686	-0.8593	0.0541	-3.1634	0.2742
MOM(1)	0.6173	57.6649	12.8153***	0.1651	52.6630	10.9203***	0.0498	4.9357	2.8261***
MOM(2)	1.2133	16.7933	4.8589***	0.3081	11.6568	3.9398***	0.0494	5.7170	2.9988***
MOM(3)	1.3083	10.2769	3.6549***	0.3059	12.2643	3.9310***	0.0518	1.1829	1.3301*
MOM(6)	1.3217	9.3599	3.4954***	0.3002	13.9178	4.5171***	0.0516	1.6587	1.8189**
MOM(9)	1.3674	6.2247	2.8330***	0.3272	6.1696	2.8770***	0.0524	-0.0223	1.5818*
MOM(12)	1.3261	9.0535	3.4689***	0.3367	3.4518	2.2040**	0.0518	1.1911	1.6583**
VOL(1,9)	1.4630	-0.3308	1.4029*	0.3385	2.9209	2.0851**	0.0550	-4.8899	-0.2590
VOL(1,12)	1.4422	1.0950	1.6026*	0.3449	1.0831	1.5000*	0.0558	-6.4386	-0.8113
VOL (2,9)	1.4811	-1.5720	-0.8651	0.3500	-0.3558	0.1435	0.0534	-1.7836	-1.0584
VOL (2,12)	1.4799	-1.4931	-1.0907	0.3507	-0.5816	-0.4621	0.0542	-3.3916	-1.5655
VOL (3,9)	1.4631	-0.3371	-0.7134	0.3514	-0.7842	-0.2684	0.0544	-3.7702	-1.5599
VOL (3,12)	1.4785	-1.3960	-1.4717	0.3506	-0.5472	-0.5074	0.0556	-6.0157	-1.8385
VOL (6,9)	1.4663	-0.5613	-1.6450	0.3508	-0.6017	-0.5601	0.0538	-2.5800	-1.3213
VOL (6,12)	1.4678	-0.6629	-1.6963	0.3494	-0.1991	-0.3338	0.0545	-3.8751	-1.1245
Panel B: Macroeconomic Variables									

TBL	1.4329	1.7289	1.5504*	0.3103	11.0030	3.8198***	0.0071	86.5104	14.6201***
LGB	1.4459	0.8426	1.0237	0.3199	8.2689	3.2324***	0.0210	60.0259	10.6493***
TermS	1.4535	0.3216	0.8084	0.3352	3.8802	2.4619***	0.0317	39.4328	9.5962***
DFY	1.4796	-1.4688	-0.2292	0.3566	-2.2584	0.8301	0.0468	10.7651	4.1930***
DP	1.4603	-0.1447	-1.1309	0.3470	0.4948	1.7345**	0.0492	6.1462	5.9654***
DY	1.4608	-0.1812	-1.3561	0.3474	0.3658	1.4796*	0.0494	5.7098	6.1810***
EP	1.4799	-1.4911	-0.6471	0.3570	-2.3714	-0.3923	0.0566	-7.9056	0.9353
BM	1.4495	0.5953	0.9380	0.3367	3.4525	2.9184***	0.0387	26.2403	8.8098***
SVAR	1.4711	-0.8890	-2.3870	0.3672	-5.3088	0.3105	0.0505	3.5966	1.8125**
NTIS	1.4651	-0.4782	-3.8170	0.3506	-0.5410	-0.9827	0.0528	-0.8039	-0.2190
CPI	1.4773	-1.3129	-0.9530	0.3521	-0.9744	-0.0751	0.0522	0.4702	0.8498
IK	1.4389	1.3213	1.3055*	0.3247	6.8769	3.4414***	0.0196	62.6181	10.9626***
CAY	1.4545	0.2521	0.5706	0.3357	3.7450	2.6968***	0.0392	25.2451	7.8608***
UER	1.4479	0.7008	0.9407	0.3239	7.1114	3.3991***	0.0178	66.0757	10.3950***
MS2	1.4718	-0.9360	-1.0674	0.3510	-0.6448	-0.1793	0.0525	-0.0583	0.0298
IIP	1.4661	-0.5473	-0.2605	0.3406	2.3205	1.2622	0.0522	0.4404	0.7747
CUM	1.4609	-0.1884	0.0495	0.3419	1.9649	1.5645*	0.0445	15.0361	5.2140***
PMI	1.4695	-0.7804	-1.9601	0.3521	-0.9597	-2.0119	0.0530	-1.1505	-0.3619
OI	1.4656	-0.5129	-0.2203	0.3373	3.2707	2.4475***	0.0349	33.3533	9.4163***
KI	1.4583	-0.0088	0.1030	0.3494	-0.2009	-0.3161	0.0509	2.8855	2.1762***
USDX	1.4652	-0.4839	-0.9814	0.3504	-0.4829	-0.2426	0.0514	2.0265	1.6275***
FPO	1.4736	-1.0571	-0.4223	0.3520	-0.9325	-0.0379	0.0536	-2.3174	1.4197***

Notes: This table summarizes the indicators specification for out of-sample results, consisting of 2 panels for the technical indicators defined in Section 3.2, the macroeconomic variables in Section 3.3 for the 22 years from 1992:01 to 2013:12 with 2004:01 as an interval. Every three columns list the results of three volatility factors—*Glov*, *Indexv* and *Offdexv*, respectively. The $R_{c,os}^2$ in the third (sixth, ninth) columns measure the percent reductions in mean squared forecast error (*MSFE*) in the second(fifth, eighth) columns for the predictive regression forecasts based on the predictors relative to the historical average benchmark

forecasts. The fourth (seventh, tenth) columns report the *MSFE-adjusted* statistics for testing the null hypothesis that the historical average *MSFE* is less than or equal to the predictive regression *MSFE* against the one-sided (upper-tail) alternative hypothesis that the historical average *MSFE* is greater than the predictive regression *MSFE*.

Table 12 Business cycle specification**:** out-of-sample estimations with NBER business cycle in volatility level

Predictor	Glo_V		$Index_V$		$Offdex_V$	
	R^2_{exp} (%)	R^2_{rec} (%)	R^2_{exp} (%)	.. (%)	R^2_{exp} (%)	R^2_{rec} (%)
Panel A: Technical Indicators						
MA(1,9)	29.0472	17.4918	32.3495	12.3380	14.9157	-40.0072
MA(1,12)	22.2233	22.3029	28.7763	11.9326	13.8994	-60.5938
MA(2,9)	-0.6825	-0.5586	-1.0727	1.5287	-0.0908	-6.0642
MA(2,12)	-0.2521	-0.8117	-0.4817	-0.3037	1.0560	-20.6947
MA(3,9)	-1.0780	0.0390	-1.0537	1.1072	2.4567	-28.0337
MA(3,12)	-0.6475	-0.5775	-0.9115	0.6338	3.4153	-36.4170
MA(6,9)	-0.2689	-1.1558	-0.7610	0.1501	0.9978	-29.8720
MA(6,12)	-0.5714	-0.5108	-2.0856	1.1728	4.2630	-44.4436
MOM(1)	57.0502	61.5683	53.9820	47.0163	5.0718	4.1793
MOM(2)	17.1315	14.6453	12.0523	9.9639	8.1203	-7.6417
MOM(3)	8.8015	19.6459	16.0346	-3.8767	3.5467	-11.9566
MOM(6)	10.6256	1.3222	13.9982	13.5736	7.1577	-28.9079
MOM(9)	5.8882	8.3613	8.5300	-3.9357	7.4371	-41.4855
MOM(12)	7.9795	15.8733	1.5458	11.6118	8.2868	-38.2504
VOL(1,9)	-0.8456	2.9380	2.5132	4.6664	-5.0606	-3.9410
VOL(1,12)	-0.2472	9.6179	1.1286	0.8885	-7.6447	0.2656
VOL (2,9)	-1.3682	-2.8662	0.0425	-2.0613	-2.4592	1.9722
VOL (2,12)	-1.2923	-2.7679	-0.8078	0.3871	-3.7851	-1.2046
VOL (3,9)	-0.3161	-0.4709	-0.4652	-2.1502	-4.7344	1.5891
VOL (3,12)	-1.1827	-2.7508	-0.8066	0.5632	-6.0725	-5.6994
VOL (6,9)	-0.4711	-1.1343	-0.8480	0.4527	-3.8892	4.6969
VOL (6,12)	-0.6309	-0.8661	-0.1762	-0.2968	-4.5280	-0.2460
Panel B: Macroeconomic Variables						
TBL	1.9106	0.5755	12.9564	2.6402	86.3931	87.1624

LGB	0.6959	1.7739	9.2058	4.2576	60.1686	59.2332
TermS	0.4187	-0.2949	4.1583	2.6895	37.3945	50.7630
DFY	0.1929	-12.0205	1.1915	-17.0282	7.8879	26.7578
DP	-0.0331	-0.8531	0.6493	-0.1664	4.6430	14.5018
DY	-0.0654	-0.9163	0.4665	-0.0652	4.6432	11.6385
EP	-1.2756	-2.8589	-2.4163	-2.1793	-18.9559	53.5179
BM	0.7015	-0.0794	4.1210	0.5906	27.2930	20.3893
SVAR	-0.2951	-4.6603	-0.5972	-25.4798	-2.8254	39.2935
NTIS	-0.4352	-0.7510	-0.8545	0.8012	-3.2800	12.9595
CPI	-0.2999	-7.7456	-0.5475	-2.8022	-0.7094	7.0270
IK	1.6138	-0.5360	8.5883	-0.4497	63.2731	58.9775
CAY	0.1604	0.8340	4.4051	0.9188	27.8511	10.7600
UER	0.9854	-1.1062	8.6479	0.5335	68.3711	53.3162
MS2	-0.6656	-2.6535	0.9310	-7.3912	-0.3426	1.5223
IIP	-1.1870	3.5149	0.2441	11.2102	-4.7116	29.0778
CUM	0.0605	-1.7690	2.1099	1.3440	6.9887	59.7674
PMI	-0.3993	-3.2003	-0.4231	-3.2571	-4.0848	15.1600
OI	-0.4374	-0.9925	3.8878	0.6289	35.7273	20.1573
KI	-0.2104	1.2712	-0.2998	0.2224	3.3242	0.4472
USDX	-0.2292	-2.1010	0.3955	-4.2434	7.0553	-25.9258
FPO	-1.4929	1.7102	-1.5063	1.5242	-7.9193	28.8208

Notes: This table summarizes the robust analysis for out-of-sample results, consisting of 2 panels for the technical indicators defined in Section 2, the macroeconomic variables in Table 1 for the 22 years from 1992:01 to 2013:12 with 2004:01 as an interval. Every two columns list the results of three volatility factors—*Glov*, *Indexv* and *Offdexv*, respectively. The second (fourth, sixth) and third (fifth, seventh) columns report. And R^2_{rec} during expansion and recession periods, respectively.

Table 13 Multi-information specification: out-of-sample estimations by principle components analysis in volatility level.

Predictor	*MSFE*	$R_{c,os}{}^2$ (%)	*MSFE-adj*	R^2_{exp} (%)	R^2_{rec} (%)
Panel A: Glo$_V$					
$\hat{F}^T_{c,1,t}$	1.2749	12.5666	7.8946***	12.3137	14.1725
$\hat{F}^T_{c,2,t}$	0.7905	45.7897	8.3977***	44.6083	53.2918
$\hat{F}^E_{c,1,t}$	1.4549	0.2230	0.5641	0.3699	-0.7095
$\hat{F}^E_{c,2,t}$	1.4511	0.4840	1.0798	1.6917	-7.1853
Panel B: Index$_V$					
$\hat{F}^T_{c,1,t}$	0.3029	13.1267	6.8868***	13.8425	10.0624
$\hat{F}^T_{c,2,t}$	0.1924	44.8241	7.8626***	48.4079	29.4812
$\hat{F}^E_{c,1,t}$	0.3355	3.8025	3.1806***	4.1832	2.1725
$\hat{F}^E_{c,2,t}$	0.3280	5.9315	2.8218***	10.4794	-13.5390
Panel C: Offdex$_V$					
$\hat{F}^T_{c,1,t}$	0.0518	1.2506	1.4861*	4.1630	-14.9379
$\hat{F}^T_{c,2,t}$	0.0502	4.1470	2.9442***	11.5092	-36.7757
$\hat{F}^E_{c,1,t}$	0.0363	30.8030	12.0162***	27.9975	46.3973

$\hat{F}^{E}_{c,2,t}$	0.0171	67.3254	11.2243***	76.6816	15.3185

Notes: This table summarizes the out-of-sample results for volatility of principle components, consisting of 3 panels for the technical indicators defined in Section 2, the macroeconomic variables in Table 1 for the 22 years from 1992:01 to 2013:12 with 2004:01 as an interval, respectively. The principal components for the technical indicators ($\hat{F}^{T}_{c,t} = (\hat{F}^{T}_{c,1,t},...,\hat{F}^{T}_{c,3,t})'$) and the macroeconomic variables ($\hat{F}^{E}_{c,t} = (\hat{F}^{E}_{c,1,t},...,\hat{F}^{E}_{c,3,t})'$).The second and third columns show slope coefficient and its heteroskedasticity-consistent *t*-statistic. ***, ** and * indicate the rejection of normality at the 1%, 5% and 10% levels, respectively. The fourth to sixth columns report R^2, R^2_{exp} and R^2_{rec} overall and during expansion and recession periods, also, respectively.

Table 14 Indicators specification: technical indicators constructed by 26 commodities.

Predictor	Glo_R			$Index_R$			$Offdex_R$		
	MSFE	$R_{c,os}^2$	*MSFE-adj*	*MSFE*	$R_{c,os}^2$	*MSFE-adj*	*MSFE*	$R_{c,os}^2$	*MSFE-adj*
Panel A: Technical Indicators									
HA	1.8649			1.2802			1.2405		
MA(1,9)	0.4856	49.2254	11.2672***	1.2142	2.8922	2.0211**	1.1865	4.3607	2.3176**
MA(1,12)	0.3687	50.9291	11.6403***	1.2043	3.3258	2.1740**	1.1941	3.7464	2.1381**
MA(2,9)	1.8801	-0.2217	0.1284	1.2491	1.3598	1.2429	1.2485	-0.6396	-0.2479
MA(2,12)	0.5813	18.6974	5.5441***	1.3088	-1.2548	-1.2414	1.2271	1.0838	1.2660
MA(3,9)	0.7914	6.8966	3.0469***	1.2587	0.9416	1.0597	1.0426	15.9579	4.9115***
MA(3,12)	0.7891	12.7579	4.1224***	1.1850	4.1742	2.2701**	1.1660	6.0104	2.9188***
MA(6,9)	1.5857	4.0669	2.5530***	1.2268	2.3392	1.6813**	1.0994	11.3770	4.0771***
MA(6,12)	1.0180	26.9035	6.7537***	1.2567	1.0293	1.1015	1.2455	-0.3982	-1.3893
MOM(1)	0.9711	27.5861	7.3916***	1.1165	7.1772	3.6276***	1.1096	10.5526	3.6012***
MOM(2)	1.5145	19.6707	5.3413***	1.2656	0.6376	0.9882	1.2332	0.5903	0.9536
MOM(3)	1.7311	3.4061	2.1845**	1.1416	6.0765	3.0225***	1.0402	16.1488	5.0574***
MOM(6)	0.8526	19.1165	5.4105***	1.2538	1.1542	1.1805	1.1930	3.8332	2.2823***
MOM(9)	0.3711	53.8066	11.8469***	1.3028	-0.9913	-2.4059	1.1673	5.9033	2.8063***
MOM(12)	1.7957	1.0073	1.0966	1.2934	-0.5826	-1.0149	1.2444	-0.3104	-0.2639
VOL(1,9)	1.6223	3.5339	2.1316**	1.1703	4.8190	2.7116***	1.0366	16.4436	4.7872***
VOL(1,12)	1.8350	0.4357	0.8956	1.2175	2.7467	1.9313**	1.0763	13.2428	4.2097***
VOL (2,9)	1.7670	1.4262	1.3071*	1.2882	-0.3517	-0.7448	1.2406	-0.0048	0.1271
VOL (2,12)	1.8486	0.2375	0.7708	1.2908	-0.4669	-1.6572	1.2448	-0.3421	-0.2652
VOL (3,9)	1.7642	1.4672	1.2479	1.2737	0.2844	0.5859	1.2371	0.2745	0.5887
VOL (3,12)	1.8693	-0.0637	0.4102	1.2886	-0.3717	-1.2839	1.2395	0.0870	0.5467
VOL (6,9)	1.7219	2.0834	1.6140*	1.2784	0.0766	0.3338	1.2420	-0.1139	0.0253
VOL (6,12)	1.8889	-0.3491	-0.1025	1.2906	-0.4566	-1.9630	1.2414	-0.0718	0.0604

Notes: This table summarizes the robust analysis for out of-sample results, consisting of 2 panels for the technical indicators defined in Section 2, the

macroeconomic variables in Table 1for the 22 years from 1992:01 to 2013:12 with 2004:01 as an interval. Every three columns list the results of three return factors constructed by 26 commodities—Glo_R, $Index_R$ and $Offdex_R$, respectively. The $R_{c,os}^2$ in the third(sixth, ninth) columns measure the percent reductions in mean squared forecast error (*MSFE*) in the second(fifth, eighth) columns for the predictive regression forecasts based on the predictors relative to the historical average benchmark forecasts. The fourth (seventh, tenth) columns report the *MSFE-adjusted* statistics for testing the null hypothesis that the historical average *MSFE* is less than or equal to the predictive regression *MSFE* against the one-sided (upper-tail) alternative hypothesis that the historical average *MSFE* is greater than the predictive regression *MSFE*.

Table 15 Business cycle specification**:** technical indicators constructed by 26 commodities.

Predictor	Glo_R		$Index_R$		$Offdex_R$	
	R^2_{exp} (%)	R^2_{rec} (%)	R^2_{exp} (%)	.. (%)	R^2_{exp} (%)	R^2_{rec} (%)
Panel A: Technical Indicators						
MA(1,9)	49.8682	45.9136	3.8226	-2.6702	4.4637	3.5094
MA(1,12)	51.8551	46.1581	4.3676	-2.9031	3.7575	3.6554
MA(2,9)	0.3754	-3.2985	0.4733	6.6602	-1.0639	2.8665
MA(2,12)	16.4507	30.2737	-1.5107	0.2754	1.6531	-3.6200
MA(3,9)	7.9730	1.3505	1.9841	-5.2913	15.6217	18.7361
MA(3,12)	16.2489	-5.2299	5.0525	-1.0771	6.5722	1.3687
MA(6,9)	4.5582	1.5353	1.0144	10.2593	10.7999	16.1458
MA(6,12)	26.7423	27.7342	0.6701	3.1774	-0.4119	-0.2844
MOM(1)	29.0663	19.9594	7.5652	4.8579	10.5919	10.2275
MOM(2)	19.3652	21.2443	-0.2469	5.9255	1.7446	-8.9483
MOM(3)	5.4586	-7.1693	6.5063	3.5069	16.3602	14.4020
MOM(6)	21.7239	5.6819	-0.1351	8.8624	3.9060	3.2314
MOM(9)	51.9717	63.2608	-0.9205	-1.4144	6.3472	2.2358
MOM(12)	1.8012	-3.0831	0.0163	-4.1630	-0.2570	-0.7514
VOL(1,9)	2.5349	8.6818	5.2268	2.3811	16.5293	15.7355
VOL(1,12)	0.7833	-1.3557	3.6518	-2.6646	14.2688	4.7645
VOL (2,9)	1.6529	0.2581	-0.3799	-0.1831	0.0667	-0.5957
VOL (2,12)	0.2136	0.3605	-0.4803	-0.3866	-0.2890	-0.7812
VOL (3,9)	2.0267	-1.4157	0.4534	-0.7264	0.1439	1.3533
VOL (3,12)	0.0745	-0.7760	-0.3768	-0.3408	-0.1039	1.6645
VOL (6,9)	1.9235	2.9072	-0.0345	0.7413	-0.0947	-0.2729
VOL (6,12)	-0.4414	0.1263	-0.4610	-0.4308	-0.0106	-0.5778

Notes: This table summarizes the robust analysis for out-of-sample results, consisting of 2 panels for the technical indicators defined in Section 3.2, the macroeconomic variables in Section 3.3 for the 22 years from 1992:01 to 2013:12 with 2004:01 as an interval. Every two columns list the results of three

volatility factors—Glo_R, $Index_R$ and $Offdex_R$, respectively. The second (fourth, sixth) and third (fifth, seventh) columns report. And R^2_{rec} during expansion and recession periods, respectively.

Table 16 Multi-information specification: technical indicators constructed by 26 commodities

Predictor	*MSFE*	$R_{c,os}{}^2$ (%)	*MSFE-adj*	R^2_{exp} (%)	R^2_{rec} (%)
Panel A: Glo$_R$					
$\hat{F}^T_{c,1,t}$	5.4359	20.8153	12.3324***	21.3235	18.1965
$\hat{F}^T_{c,2,t}$	2.7838	59.4489	12.2150***	59.8572	57.3453
Panel B: Index$_R$					
$\hat{F}^T_{c,1,t}$	2.2251	2.4153	4.8575***	2.4904	1.9661
$\hat{F}^T_{c,2,t}$	2.2630	3.7528	3.2045***	2.8077	1.4248
Panel C: Offdex$_R$					
$\hat{F}^T_{c,1,t}$	1.1466	7.5721	7.1781***	7.6304	7.0907
$\hat{F}^T_{c,2,t}$	0.9944	19.8439	6.1792***	22.1320	0.9365

Notes: This table summarizes the robust analysis out-of-sample results for return of principle components, consisting of 3 panels for the technical indicators defined in Section 3.2, the macroeconomic variables in Section 3.3 for the 22 years from 1992:01 to 2013:12 with 2004:01 as an interval, respectively. The principal components for the technical indicators ($\hat{F}^T_{c,t} = (\hat{F}^T_{c,1,t},...,\hat{F}^T_{c,3,t})'$) and the macroeconomic variables ($\hat{F}^E_{c,t} = (\hat{F}^E_{c,1,t},...,\hat{F}^E_{c,3,t})'$).The second and third columns show slope coefficient and its heteroskedasticity-consistent *t*-statistic. ***, ** and * indicate the rejection of normality at the 1%, 5% and 10% levels, respectively. The fourth to sixth columns report R^2, R^2_{exp} and R^2_{rec} overall and during expansion and recession periods, also, respectively.