Article

Dynamic Commodity Portfolio Management: A Regime-switching VAR Model

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Abstract

This article examines the impact of dynamic economic states on commodity portfolio performance by using Markov regime-switching vector autoregression (MRS-VAR) framework. Temporal behaviour of different assets in portfolio has been studied using weekly dataset. Empirical evidence finds prevalence of regime-switching phenomenon in all assets suggesting their state-dependent behaviour. Results of the study confirm that a pair of asset classes exhibits different levels of correlations under different economic scenarios. Optimal asset allocation under each regime has been investigated and the results provide evidence of differential optimal commodity portfolio composition in distinct economic states. The results of the study provide interesting insights for investors and portfolio managers. By examining the switching points in different asset classes, they can rebalance their portfolio which will help them in better risk management and enhancing risk–return performance.

Keywords

Commodity market, Markov regime-switching model, portfolio management

Introduction

The impact of changing economic states or environment on asset selection and portfolio management process has been widely researched in financial markets (Elliott, Siu, & Badescu, 2010; Wu, Zeng, & Yao, 2014; Zhou & Yin, 2003). Findings of the above studies suggest that asset allocation among bond, stock and cash shows significant impact of state-switching behaviour on portfolio selection process and optimal portfolio weights are dependent on the prevailing regime. Second, optimal asset allocation results are markedly different for regime-switching cases than no regime cases and regime switches described by a two-state Markov chain had significant impacts on the optimal investment strategies.

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However, research on impact of changing economic states on dynamic management of portfolios with commodity as an asset class is scarce.

Prior to the financial crisis of 2008, majority of the commodity portfolio management literature reported that commodities show unique risk and return characteristics (Irwin & Landa, 1987) and provide higher returns (Anson, 1998; Jensen, Johnson, & Mercer, 2000). However, some recent studies state that investments in commodity futures might not always perform better in a portfolio (Cheung & Miu, 2010; Daskalaki & Skiadopoulos, 2011; Silvennoinen & Thorp, 2013). According to them, correlation among assets is different in different market conditions such as bearish and bullish markets (Chong & Miffre, 2010; Erb & Harvey, 2006); restrictive and expansive monetary policy environments; and pre- and post-crises periods (Silvennoinen & Thorp, 2013; Steen & Gjolberg, 2013). Therefore, diversification benefits derived from inclusion of commodity futures vary with time (Bichetti & Maystre, 2012; Delatte & Lopez, 2013; Huang & Zhong, 2013).

This article is making an attempt to examine whether commodity futures act as an investment asset in a portfolio across various macroeconomic states in India. Rest of the article is organized as follows: next section reviews the related literature. The third section presents the objectives and rationale of the study. The fourth section presents the methodology used in the study. The fifth section provides analysis, the sixth section discusses the results and finally the seventh section concludes and discusses managerial implications.

Review of Literature

The literature on state-dependent behaviour of various asset classes could be divided into following three categories: first, the impact of economic environment on commodity markets; second, the impact of economic environment on interaction of commodity and other asset classes; and third, the dynamic portfolio (equity, bond and cash) management in changing economic environment.

Several studies found that individual commodities perform differently in different economic states (Chang, 2012; Chen, 2010) and performance of commodity futures investment is also found to be state dependent (Abdullah, Saiti, & Masih, 2014; Chan, Treepongkaruna, Brooks, & Gray, 2011; Choi & Hammoudeh, 2010). Shiu-Sheng Chen (2010) found evidence that the higher is the oil price, the higher is the probability of switching from a bull market to a bear market. Liang and Yen (2014) applied the spectral analysis to detect cyclical behaviours of bond, stock and commodity markets plus the business cycle and found that the three markets followed regular cyclical patterns that lasted from 3.5 years to 7.5 years. Nomikos and Panos (2011) while forecasting the prices of petroleum futures contract traded on New York Mercantile Exchange (NYMEX) and Intercontinental Exchange Inc. (ICE) also found evidence in favour of persistent of distinct regimes. Chang (2012) also investigated whether volatility regimes and basis affected the behaviour of crude oil futures by using regime-switching EGARCH model and concluded that the regime switches and asymmetric basis effects played decisive roles in forecasting return, volatility and tail distribution.

Interaction between commodity market and other financial asset classes was found to be state dependent (Bhar & Hammoudeh, 2011; Guo, Chen, & Huang, 2011; Lagesh, Kasim, & Paul, 2014; Lee, 2010; Naifar & Al Dohaiman, 2013). Soucek (2013) in his study found that during periods of unstable financial markets, the correlation between equity and energy futures decreased and the correlation of equity and gold futures market turned negative. Chan et al. (2011) examined the relationships between returns over three different asset classes: financial assets (US stocks and treasury bonds), commodities (oil and gold) and real estate assets (US Case–Shiller index) by using the Markov regime-switching (MRS) models and confirmed the existence of two distinct regimes: a 'tranquil' regime with periods of economic expansion and a ‘crisis’ regime with periods of economic decline. Kumar (2014) found that conditional correlation between gold and stock market rose during periods of market turbulence and crisis indicating the scope of portfolio diversification and hedging during these periods. Prior to the financial crisis, stock returns were negatively affected by oil prices and exchange rate; however, post-crises, stock returns were positively affected (Mollick & Assefa, 2013). Charlot and Marimoutou (2014) found that correlation among exchange rate, equity, crude and commodities switches from one regime to another, touching a peak during the period of the subprime crisis in the USA and again during the days following the Tohoku earthquake in Japan. All the above studies examined dynamic movement among various asset classes. However, none of them addressed the state-dependent behaviour of interactions of various asset classes in a portfolio. Recently, a study by Rao and Goyal (2018) establishes the impact of global oil and commodity price on macroeconomic indicators of India; however, reverse is never studied in the Indian context. Hence, there is a need to examine dynamic interaction among various asset classes in a portfolio including optimal portfolio composition in time-varying economic states.

In the context of financial markets, numerous studies (Ang & Beakert, 1999; Barberis, 2000; Brennan, Schwartz & Lagnado, 1997; Campbell & Viceira, 1999; Chen & Yang, 2011; Elliott et al., 2010; Khalifa, Hammoudeh, & Otranto, 2014; Wu et al., 2014; Zhou & Yin, 2003) have found significant impact of changing economic states on asset selection and dynamic portfolio allocation. The point worth considering here is that these portfolios under investigation were mostly composed of stocks, bonds and cash. Commodity investments were not included in these portfolios. Therefore, there is a need to study dynamic portfolio management in the presence of state-switching environment by including commodities in the portfolios.

Objectives and Theoretical Framework

Since the risk–return behaviour of commodities and the correlation between commodity futures and various asset classes is state dependent, there must be an impact of state switching on the performance of commodities in the context of portfolio. However, explicit impact of dynamic economic environment on commodity portfolio has not been considered yet. In the literature on portfolio management, there is an inherent assumption of same economic state prevailing throughout the duration of the study. But in real economy keeps on swinging between various states. Also different commodities (energy, metal and agriculture) behave differently under different economic states, and adding commodities to the portfolio will change the entire portfolio risk–return dynamics. Therefore, purpose of this study is to examine dynamic portfolio allocation in the presence of state-switching environment by including commodities in the portfolios which will ultimately lead to convergence of literature on commodity futures, state switching and dynamic portfolio management.

In view of the above, first objective of this study is to examine state-dependent behaviour of commodity and other financial asset classes individually in a univariate framework in India. Although in the context of developed markets, this effect was found to be significant, but in emerging Indian commodity markets, this remains unexplored. Therefore, initially each asset class has been modelled in a univariate state-switching framework by using MRS mean and heteroskedasticity model (Hamilton, 1989) so as to check the impact of changing economic sates. Since this is a univariate framework, these states might not be consistent across all asset classes.

In portfolio, different assets are combined together, and therefore interaction among various assets in a particular economic state becomes more relevant. Moreover, economic state or regime should be consistent across all asset classes. Therefore simultaneous interaction of various asset classes in different economic conditions is estimated using Markov regime-switching vector autoregression (MRS-VAR). The MRS-VAR model developed by Krolzig (1997) is the multivariate version of a univariate regime-switching model proposed by Hamilton (1989). The MRS-VAR model differs from the linear VAR model as the nature of the causal linkages among the model variables can be different in different regimes. The point worth noticing is that in the above model, regime switching happens in each asset class individually. In case of regime-switching model for individual asset classes, we cannot constrain the regime process to be common or consistent across assets. Hence, the regime underlying is not concurrent in nature. In the final step, portfolios comprising all assets were constructed and optimized for time-varying economic states using mean-variance inputs from MRS-VAR across different economic regimes and gap of dynamic portfolio management under state-switching environment has been addressed.

Methodology

Data Source and Preliminary Analysis

Weekly closing prices of five asset classes from 01 January 2006 to 28 February 2015 have been used in this article. NIFTY and Government Securities Index (GSEC) of National Stock Exchange are used for Indian equity market and bond market, respectively. NIFTY is a free-float market capitalization-based index that represents the movement of stocks of the 50 most financially sound and actively traded firms. These 50 stocks belong to the 23 different sectors of the economy and therefore indicate the average movement of equity markets. GSEC Index is a market capitalization-based index of all outstanding sovereign securities—Treasury bills and dated government securities. It reflects the gain/loss on a sovereign securities portfolio on account of movement/change in interest rates. In the context of Indian commodity markets, Multi Commodity Exchange (MCX) is India's first listed commodity futures exchange which has the highest market share of nearly 81 per cent of the total commodity markets and it has a number of passive commodity indices which are fully investible. In the present study, three different sectors of commodity market, namely, agriculture, energy and metal, have been considered. For agriculture sector, energy sector and metal sector, MCX AGRI, MCX ENERGY and MCX METAL indices, respectively, have been taken as a proxy. All the price series have been converted to returns using logarithmic return process, that is, log (p_t/p_{t-1}). RAGRI, RENERGY, RMETAL, RGSEC and RENERGY represent the returns of five asset classes.

As a preliminary analysis to study state-dependent behaviour, we plotted a figure of daily price movements of five assets from India during 2006–2015. Figure 1 depicts that during 2006 and 2007, when the prices of NIFTY almost doubled, the prices of all other assets except MCX ENERGY index remained in the range of ±20 per cent. During 2008, when the price of NIFTY index showed a significant decline, MCX ENERGY index reached their peak. This figure indicates that these asset classes exhibit a time-varying co-movement that necessitates further empirical examination to gauge their state-dependent behaviour.

Table 1 presents the descriptive statistics of return series of all five indices representing three different markets in India. Summary statistics suggest that RNIFTY had the highest mean average daily returns followed by RMETAL and RGSEC. RENERGY has the lowest mean average daily returns. However, during the entire time frame, the maximum daily average return was shown by RAGRI followed by RENERGY and RNIFTY. In terms of volatility, RENERGY displays the highest volatility followed by RNIFTY and RAGRI. RGSEC index exhibits the lowest volatility. In a nutshell, RNIFTY had high

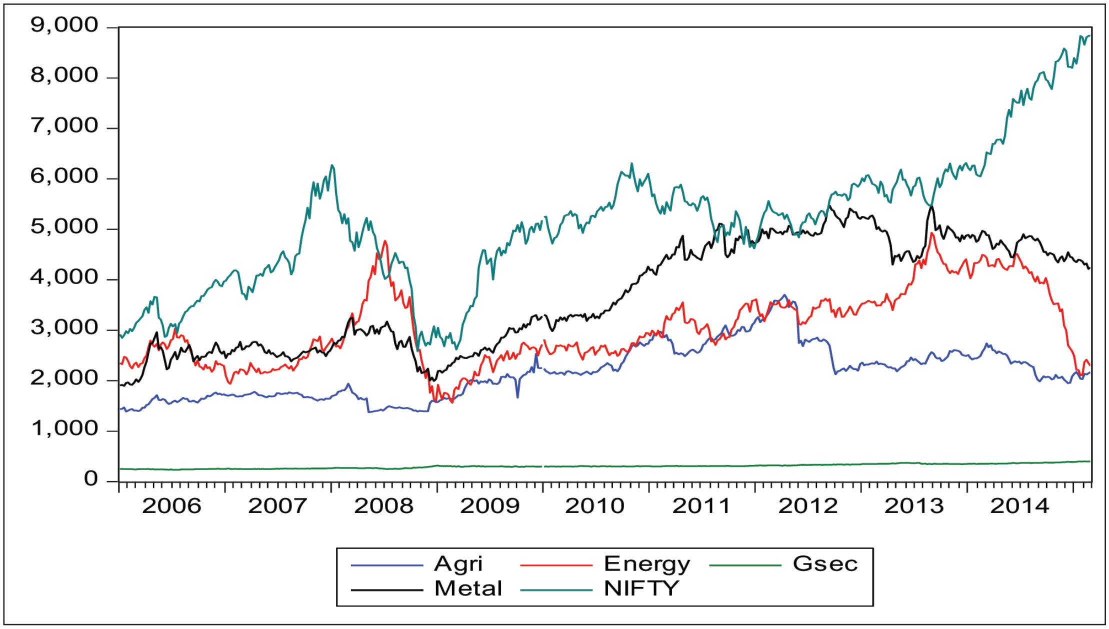


Figure 1. Daily Price Movements of Commodity and Other Financial Assets Index

Source: Authors' calculations.

returns and high volatility, whereas RENERGY had low returns and highest volatility; RGSEC gave moderate returns with lowest volatility.

Returns of all the series are negatively skewed and the kurtosis is much higher than 3 for all the cases. This shows the deviation of the series from the normal distribution which is then supported by the Jarque–Bera (JB) statistics. The JB statistics show that all the series are not normally distributed. Further, the order of integration of the data series is examined by using the augmented Dickey–Fuller (ADF) unit root test. The null hypothesis of unit root was accepted for all the series at the price levels while it was rejected for all the return series. This indicates that all the series were integrated of the first order .

Empirical Models

Regime-switching Mean and Heteroskedasticity Model

To check whether time-varying behaviour is persistent in all asset classes or not, the regime-switching mean and heteroskedasticity model proposed by Hamilton (1989) is used. At this stage, the objective is to identify whether regime-switching phenomenon is prevalent in Indian equity, commodity and bond markets or not. In the context of Indian markets, there is no study which establishes the regime-switching behaviour among these asset classes. Therefore, each asset class is first modelled in a univariate framework and MRS mean and heteroskedasticity is applied.

This model has the capability of capturing temporal asymmetries and nonlinear dynamics of error term in addition to the mean return. The major advantage of regime-switching model is that there is no

Table 1. Descriptive Statistics for Asset Market Index Returns

Parameter	RAGRI	RENERGY	RGSEC	RMETAL	RNIFTY
Mean (%)	0.08	−0.04	0.10	0.16	0.23
Median (%)	0.26	0.28	0.15	0.37	0.38
Maximum (%)	20.04	18.28	3.69	10.18	14.35
Minimum (%)	−22.84	−23.53	−4.20	−11.74	−17.37
Std. Dev. (%)	02.95	04.05	1.18	02.76	03.30
Skewness	−1.30	−0.45	−0.39	−0.87	−0.48
Kurtosis	4.10	6.59	4.70	6.17	6.26
JB *p*-value	0.00*	0.00*	0.00*	0.00*	0.00*
ADF test (price)	−1.552935	−1.148059	−2.274035	−1.569215	−1.842833
p-value	0.8110	0.9193	0.4475	0.8049	0.6835
ADF test (returns)	−45.78131	−46.68740	−29.18221	−50.42759	−44.97935
p-value	0.0001	0.0001	0.0000	0.0001	0.0001

Source: Authors' calculations.

Notes: The statistics are for the first differences of the log of the variables on a daily basis. The table presents author's calculations. *Denotes the rejection of the null hypotheses of normality and unit root at 5% significance level.

need to explicitly specify when the shift in economic states occurs. In this model, the switching mechanism is controlled by an unobservable state mechanism which follows the first-order Markov chain and the current value of the state S_t depends only on the immediate past value, that is, S_{t-1}. The following equations describe the Markov switching in mean and error term, so that regime-specific mean returns and standard deviation can be obtained.

$$[R_{St}] = [\mu_{St}] + [\beta][R_{st-1}] + [e_{St}] \tag{1}$$

$$e_t \mid S_t \sim iidN(0, \sigma^2_{St}) \tag{2}$$

$$\sigma^2_{St} = \sigma^2_0(1 - S_t) + \sigma^2_1 S_t\,, \sigma^2_0 < \sigma^2_1 \tag{3}$$

where R_{St}: rate of return of commodity price or CNX NIFTY or G-SEC index

μ_{St}: regime-specific intercepts term
β: regime-independent autoregressive coefficient
$\sigma_0{}^2$ and $\sigma_1{}^2$: low and high volatilities
S_t: latent state-dependent parameter which follows an irreducible ergodic M-state Markov process with transition probabilities given by

$$P[S_t = 0 \text{ given } S_{t-1} = 0] = q$$
$$P[S_t = 1 \text{ given } S_{t-1} = 1] = p$$

where $S_t = 0$ refers to low volatility regime at time t;

$S_t = 1$ refers to high volatility regime at time t;
p and q are the transition probabilities.

The point worth noticing is that in the above analysis, regime switching happens in each asset class individually. In case of regime-switching model for individual asset classes, we cannot constrain the regime process S_t to be common or consistent across assets. Hence, the regime underlying is not concurrent in nature.

Markov Regime-switching Vector Autoregression

In portfolio when different asset classes are combined together simultaneously, risk–return interactions of these assets in a particular state become important. In case of regime-switching model for individual asset classes (MRS mean and heteroskedasticity model), we cannot constrain the regime process S_t to be common or consistent across assets.

However, in order to combine different assets, regime/economic state must be consistent across all assets because at one point of time, only one economic state can be prevalent, and we have to check combinations of different portfolio in a particular regime.

MRS-VAR Framework, in which the state of variable *Xcom, t* can be made to depend on the lagged states of the other variable *Xstock*, *t* & *Xbond*, *t* and vice versa has been used. In this we study the dynamics involving commodities and the financial markets in a VAR setting where we allow the model parameters to be dependent on an unobservable regime variable whose evolution is governed by a specific probability law. The transition probability of a certain market to switch from a regime to another depends not only on its own state at the previous time, but also on the state of the other markets. Thus, the model is piecewise linear within each regime but non-linear across regimes. The model used in our study is similar to Bhar and Hammoudeh (2011)

Consider a multivariate autoregressive process in which S_t represents the particular regime prevailing at a point of time.

$$\begin{bmatrix} Xcom, t \\ Xstock, t \\ Xbond, t \end{bmatrix} = \begin{bmatrix} \mu com, st \\ \mu stock, st \\ \mu bond, st \end{bmatrix} + \begin{bmatrix} \beta cc, st & \beta cs, st & \beta cb, st \\ \beta sc, st & \beta ss, st & \beta sb, st \\ \beta bc, st & \beta bs, st & \beta bb, st \end{bmatrix} \begin{bmatrix} Xcom, t-1 \\ Xstock, t-1 \\ Xbond, t-1 \end{bmatrix} + \begin{bmatrix} \varepsilon com, st \\ \varepsilon stock, st \\ \varepsilon bond, st \end{bmatrix} \tag{4}$$

Where

$$\begin{bmatrix} \varepsilon com, st \\ \varepsilon stock, st \\ \varepsilon bond, st \end{bmatrix} \sim N \left\{ \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2_{com,st} & \sigma_{com} \sigma_{stock,st} & \sigma_{com} \sigma_{bond,st} \\ \sigma_{stock} \sigma_{com,st} & \sigma^2_{stock,st} & \sigma_{stock} \sigma_{bond,st} \\ \sigma_{bond} \sigma_{com,st} & \sigma_{bond} \sigma_{stock,st} & \sigma^2_{bond,st} \end{bmatrix} \right\} \tag{5}$$

where $\sigma^2_{,st}$ is the state-dependent variance–covariance matrix.

Further, we assume that the unobservable state-dependent parameter S_t follows an irreducible ergodic M-state Markov process with transition matrix

$$P = \begin{bmatrix} P_{11} & P_{12} \cdots\cdots\cdots & P_{1m} \\ P_{21} & P_{22} \cdots\cdots\cdots & P_{2m} \\ P_{m1} & P_{m2} \cdots\cdots\cdots & P_{mm} \end{bmatrix} \tag{6}$$

where P_{ij} = probability of moving from state *i* to state *j*.

Markowitz Model of Portfolio Selection and Optimization in Different Regimes

In order to examine the impact of regime switching on optimal portfolio allocation, portfolios are constructed by including all assets for each regime.

Initially, equal weight of 20 per cent is allotted to each asset class and with these weights, portfolio risk, return and Sharpe ratio are calculated.

After this, portfolio optimization is done in the context of maximizing Sharpe ratio by reallocating the weights in each asset class. This optimization is also done on weekly basis, as a result of which, for every week in our dataset, we obtain portfolio combination having maximum Sharpe ratio and weight allocated in each asset class is now the optimal weight. This process is repeated across both regimes.

$$\text{Max } u(st)\,(\mu(st)_p\,(w_i), \sigma_p^2(st)\,(w_i)) \tag{7}$$

$$\text{s.t.} \sum_{i=1}^{N} Wi\,(st) = 1 \tag{8}$$

$$0 \leq w_i \leq 1$$

where

σ^2_p = portfolio variance, μ_p = portfolio returns
i = proportion of investment in a particular asset class (commodity, stock and bond)
u = utility of the investor
st = 1, 2, …, m depending on the state of the regime

Objective function is a utility function defined as

$$u = \mu_p(st)\,(w_i) - \gamma\,\sigma_p(st)(w_i) \tag{9}$$

Here, γ = investors risk aversion coefficient.

Finally, in each regime for a particular week, the asset which has got the maximum weight is selected. This is done for the entire duration of study and then the number of times an asset gets the maximum weight in optimal portfolio in a particular regime is calculated.

Analysis

Markov Regime-switching Mean and Heteroskedasticity Model Results

Table 2 lists the parameter estimates of two state MRS models with p-value associated with each parameter in parenthesis. It also reports the ergodic probability and duration of the system in each regime. In the present study, returns are modelled as Autoregressive (AR) (1) process with regime switching in both mean and variances. From the output, it is evident that the regime-switching model bifurcates the returns and volatility behaviour of returns of the asset class under consideration into two distinct regimes—one with positive mean returns and the other with negative mean returns. RAGRI exhibits positive returns of 0.20 per cent in Regime 1 and negative returns of −2.6 per cent in Regime 2. On the contrary, RENERGY exhibits negative returns of −1.2 per cent in Regime 1 and positive returns of 0.22 per cent in Regime 2. Similarly to RAGRI and RENERGY, RMETAL and RNIFTY also exhibit positive returns

Table 2. Markov Regime-switching Mean and Heteroskedasticity Parameter Estimates

Parameter	RAGRI	RENERGY	RGSEC	RMETAL	RNIFTY
			REGIME 1		
μ_0	0.20%	−1.2%	0.01%	−0.22 %	0.40%
	(0.00)*	(0.07)	(0.90)	(0.62)	(0.00)*
Log σ_0	−4.01*	−2.65*	−4.08*	−3.07*	−3.85*
$P[S_t = 0]$	0.96	0.97	0.94	0.90	0.98
Duration $S_t = 0$	30.85	42.01	17.13	10.23	72.34
			REGIME 2		
μ_1	−2.6%	0.22%	0.15%	0.29%	−0.15%
	(0.19)	(0.19)	(0.00)*	(0.00)*	(0.76)
Log σ_1	−2.33*	−3.45*	−4.96*	−3.99*	−3.01*
$P[S_t = 1]$	0.44	0.99	0.96	0.97	0.96
Duration $S_t = 1$	1.81	184.31	27.64	34.32	72.34
			DIAGNOSTICS		
AIC	−4.80	−3.74	−6.24	−4.55	−4.20
HQ	4.78	−3.72	−6.22	−4.53	−4.18
SIC	−4.75	−3.69	−6.19	−4.49	−4.15
Log likelihood	1151.389	899.62	1495.22	1091.62	1009.71

Source: Authors' calculations.
Note: *Denotes rejection of null hypothesis at 5% level.

in one regime and negative returns in another Regime 2. RGEC exhibits positive returns in both the states, which is quite logical as the returns on government securities can never be negative. The important point here is that all these assets were modelled in univariate framework as mentioned earlier. This was done to confirm whether regime-switching phenomenon is prevalent in asset classes under study in India or not. Therefore, regime of one asset class has no correspondence with the regime of another asset class.

Also, it is apparent that regime with positive mean return has lower standard deviation (log sigma value) in all the asset classes as compared to volatility in negative mean return regime. Regime switching incorporating three and four states is also modelled for all the assets. In all cases, the optimization process failed. This confirms that the nature of data is such that only two dominant states are prevalent.

The transition probabilities in Table 2 also reveal both these states are highly stable and once the returns enter into one state, they tend to remain in the same state. However, in the context of agri-markets, the tranquil regime is more stable (transition probability to same state 0.96) than crises regime (transition probability to same state 0.44). Duration in Table 2 represents regime persistence. Duration of tranquil state is higher in all the cases with maximum of 184 weeks for energy, followed by 72 weeks in NIFTY and average of around 30 weeks in energy, G-SEC and agri indices, respectively. Crisis regime tends to be of shorter durations.

Figure 2 represents the smoothed probability diagram of equity, G-SEC and three commodity market returns in positive return regimes. These figures display visually the persistence of high return and low volatility regime and also capture the timing of shift from tranquil regime to crises regime.

The smoothed probability diagram of ENERGY indicates that high return regime is very persistent and it tends to remain in the regime most of the time. However, from 2008 to 2009, negative return regime was prevalent, which is justified due to the onset of financial crisis at the global level. In case of

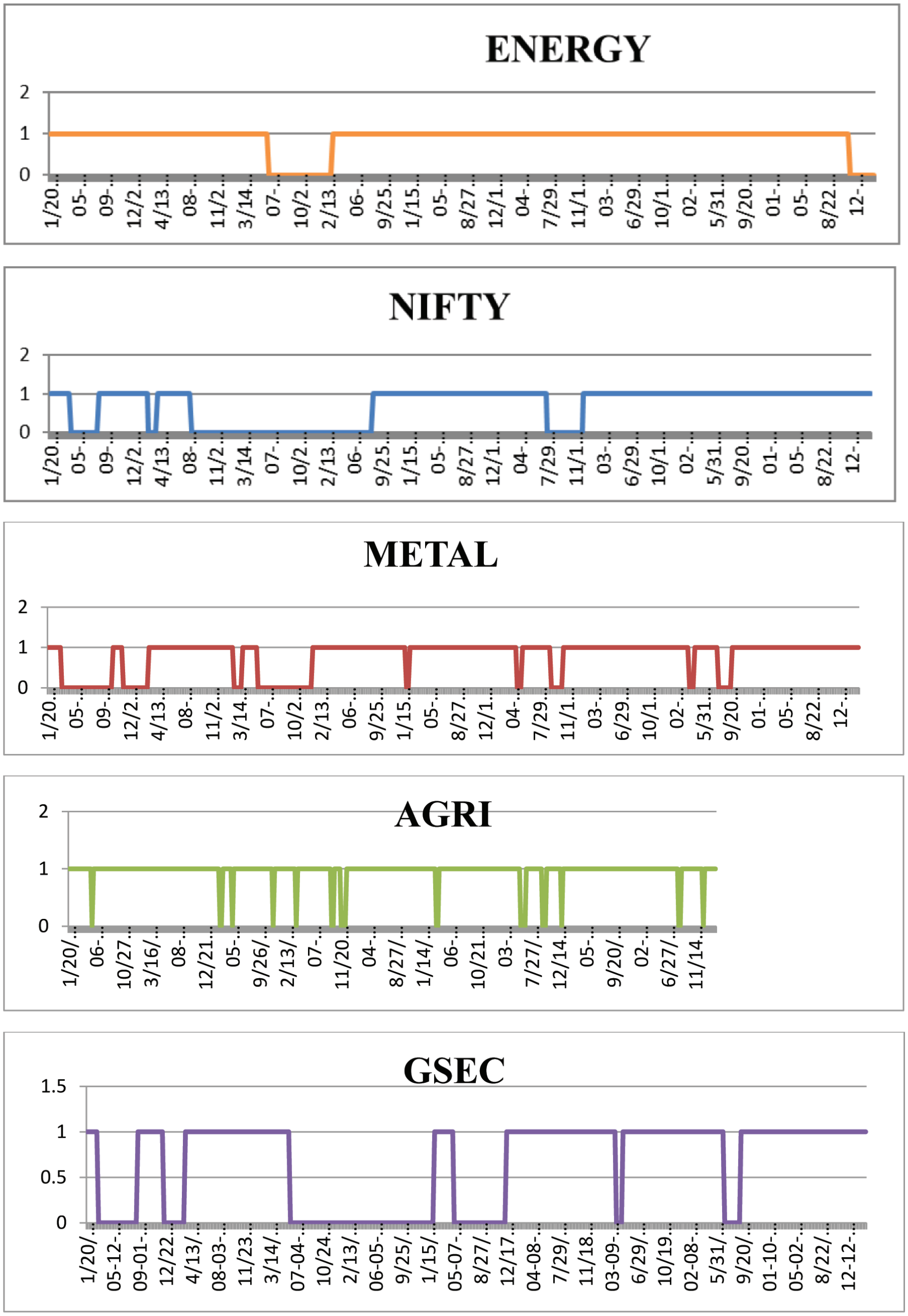


Figure 2. Smoothed Probability Diagram of Different Assets in Positive Returns Regime

Source: Authors' calculations.

NIFTY, positive return regime was prevalent majority of the time except for a dip in 2007–2009 and a small period of time in 2011. The results of smoothed probability for ENERGY and NIFTY are in line with the macro-economic events happening in Indian economy due to which regime shift occurs. Probability diagram for METAL indicates that during 2006 METAL was in low returns regime for a very short span of time followed by high return regime till 2008. During 2008, METAL index again reverts to the crisis regime and eventually begins to recover, thereby shifting to high return and low volatility regime. G-SEC index also reveals the high persistence of tranquil regime interrupted by the crises regime for a short span of time during 2008. This contagion effect in various asset classes during crises regime can be explained by the onset of global crises due to which there is herding behaviour among the investors, which in turn, pushes the market into bearish phase.

Contrary to the above smoothed probability diagram of MCX AGRI reveals that there is a frequent swing in returns from one regime to another regime. The justification for the rapid movement of AGRI index from one regime to another is that most of the agricultural commodities are seasonal and exhibit a cyclical pattern of sowing and harvesting within a year and provide higher returns (tranquil regime) during sowing season which falls significantly during harvesting season (supply rises vis-à-vis demand), thereby entering into low return regime. Prevalent weather conditions, rainfall patterns and El Nino effect are some of the factors that directly impacting agricultural produce, which in turn, impacts the agriculture index (domino effect). Thus, it can be seen that the AGRI index is susceptible to volatilities of various types resulting in a frequent regime-switching behaviour.

Markov Regime-switching VAR Results

Table 3 presents the estimated results of MRS-VAR. The output of MRS-VAR provides very interesting results. In the MRS-VAR model, two regimes are found to be prevalent among all asset classes. The important point here is that the regime in this case represents a particular economic state which is consistent across all asset classes.

The important point worth noticing is that in Regime 1 (refer to Table 3), when NIFTY and ENERGY are in a state of positive mean return (3.6% and 2.7%), AGRI, METAL and G-SEC are in state of negative returns (−32.5%, −3.9% and −0.01%). Similarly, in Regime 2, when ENERGY and NIFTY exhibit negative returns (−30.4% and −1.25%), METAL and AGRI exhibit positive returns of 2.1 per cent and 2.8 per cent, respectively.

Also if we look closely at Table 3, we can see that current regime in RMETAL depends on the lagged value of RENERGY. This relationship can be justified on the basis that when there is a volatility in ENERGY commodity market (crude oil), investors prefer investing in safe metals like gold. Therefore, current regime in RMETAL depends on the lagged value of RENERGY. However, reverse is not true for ENERGY market regime. Current regime in ENERGY does not depend on lagged values of any other asset class. However, lagged state of RMETAL is significant in determining current state in RGEC.

Figure 3 represents the smoothed probability diagram of MRS-VAR. In this case, unlike the univariate MRS model, we cannot specify regime as tranquil and crises regime. In this case, regime just represents a particular economic state which drives the movement of these assets and is consistent across all asset classes. Most importantly, tranquil and crises state do not happen simultaneously in all assets. At a particular point of time, while one asset is in tranquil or in positive return state, some other assets are in crises state.

The regime-dependent correlation matrix (refer to Table 4) also provides interesting results. The upper half of the table corresponds to correlations between asset classes in Regime 1 while the lower half

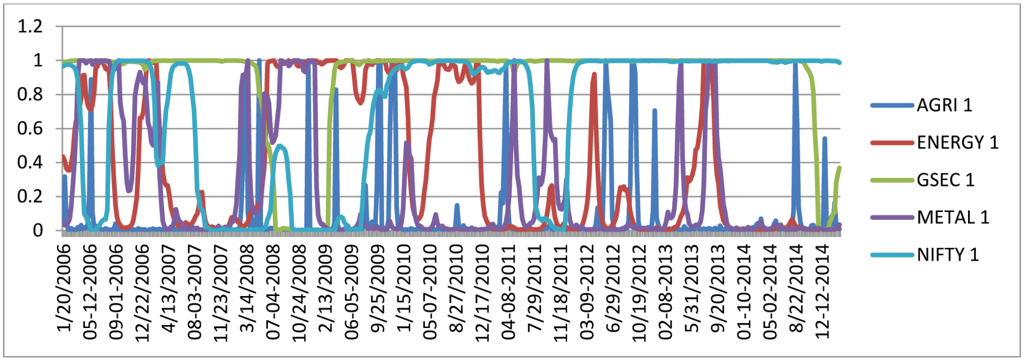
Table 3. Markov Regime-switching VAR Parameter Estimates

Parameter	RAGRI	Probability	RENERGY	Probability	RGSEC	Probability	RMETAL	Probability	RNIFTY	Probability
					REGIME 1					
μ_0	−32.5%	0.10	2.7%	0.11	−0.01	0.98	−3.9%	0.43	3.66%	0.00*
Log σ_0	−2.60	0.00*	−3.42	0.00*	−4.19	0.00*	−3.10	0.00*	−3.84	0.00*
RAGRI(−1)	−0.53	0.02*	−0.00	0.94	0.06	0.10	0.04	0.86	0.01	0.68
RENERGY(−1)	0.96	0.07	0.04	0.37	−0.07	0.01*	−0.30	0.02*	−0.04	0.30
RGSEC(−1)	−2.33	0.11	−0.02	0.89	−0.42	0.00*	−0.25	0.43	0.11	0.37
RMETAL(−1)	−0.03	0.96	−0.05	0.43	0.00	0.91	0.35	0.04*	0.00	0.96
RNIFTY(−1)	−0.04	0.92	0.06	0.21	0.00	0.98	−0.02	0.80	0.061	0.33
$P[S_t = 0]$	0.47		0.95		0.99		0.89		0.99	
Duration $S_t = 0$	1.90		19.40		186.32		9.19		68.95	
					REGIME 2					
μ_1	2.1%	0.01*	−30.4%	0.05*	1.79%	0.00*	2.88%	0.00*	−1.25%	0.77
Log σ_1	−4.06	0.00*	−2.64	0.00*	−4.97	0.00*	−4.02	0.00*	−3.00	0.00*
RAGRI(−1)	0.09	0.01*	0.03	0.94	−0.00	0.65	−0.04	0.19	−0.03	0.84
RENERGY(−1)	0.01	0.68	−0.20	0.36	−0.03	0.01*	0.07	0.02*	0.07	0.49
RGSEC(−1)	0.08	0.26	−0.14	0.85	−0.23	0.00*	0.14	0.15	−0.20	0.50
RMETAL(−1)	0.09	0.01*	0.12	0.77	0.00	0.86	−0.10	0.06*	−0.09	0.53
RNIFTY(−1)	−0.04	0.13	−0.34	0.11	0.00	0.84	0.01	0.61	0.00	0.94
$P[S_t = 1]$	0.96		0.97		0.96		0.97		0.96	
Duration $S_t = 1$	27.33		33.01		28.40		31.07		27.82	

Source: Authors' calculations.

Note: *Denotes rejection of null hypothesis of no regime switching at 5% level.

Smoothed Probability Regime 1 VAR



Smoothed Probability Regime 2 VAR

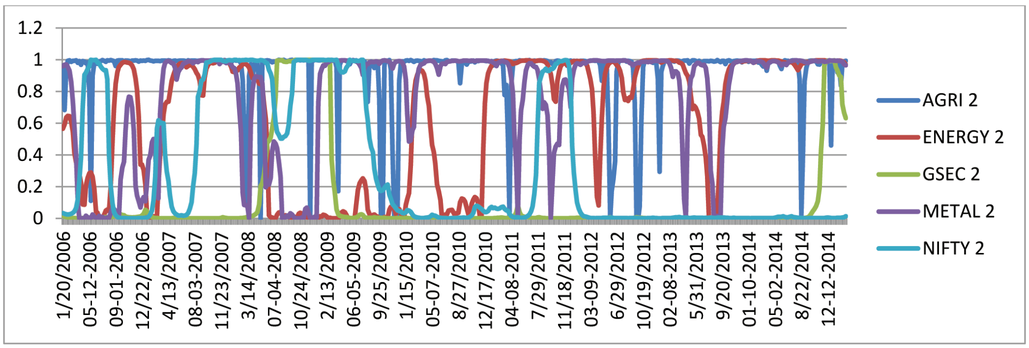


Figure 3. Smoothed Probability Diagrams of MRS-VAR Regime 1 and Regime 2

Source: Authors' calculations.

corresponds to the correlations between asset classes in Regime 2. If observed keenly, it is interesting to note that the correlations between a pair of asset classes do not hold the same relationship in both the regimes.

All assets (except AGRI) are negatively related to bond index in state 1 and positively related in state 2. AGRI, however, exhibits positive correlation in state 1 and negative correlation in state 2. All commodities relate positively with equity index in both the states. However, the degree of correlation is lower in state 1 as compared to state 2. This means that when NIFTY is in state of positive mean returns, it has low correlation with commodity futures, thereby implying that commodity provides the diversification benefits to equity in positive return state. In state 2, when NIFTY moves in negative return state, its correlation with ENERGY index increases significantly (from 7% to 14%). The possible reason for this could be the contagion effect among these markets which usually happens during crises. However, MCX METAL and MCX AGRI still possess low degree of correlation (only 1% and 2%) with NIFTY in state 2, which implies that these two asset classes provide the best diversification benefit in state 2.

The above results clearly indicate that assets behave differently in different economic states. In fact, among commodities only, when ENERGY market is in positive return state, METAL and AGRI markets are in negative return state and vice versa. Similarly, all assets are positively related to bond index in one

Table 4. Correlation Among Asset Classes in Regime 1 and Regime 2

Correlation	AGRI	ENERGY	GSEC	METAL	NIFTY
AGRI	**1.0000**	0.0335	0.0551	−0.0201	0.0188
ENERGY	0.0695	**1.0000**	−0.0706	0.2782	0.0733
GSEC	−0.0273	0.0096	**1.0000**	−0.1415	−0.0294
METAL	0.0574	0.0576	0.0408	**1.0000**	0.0255
NIFTY	0.0277	0.1436	0.0414	0.0203	**1.0**

Source: Authors' calculations.

Notes: 1. Upper half of diagonal in the table displays correlation in Regime 1 and lower half displays correlation in Regime 2.
2. All correlation coefficients are statistically significant at 5% level of significance.

state and negative in another. These observations provide key inputs for portfolio managers and investors to design their portfolio under varied economic conditions. While a negative correlation between G-SEC and other indices can be used for hedging under state 1, these might not help hedge in state 2. Thus, it is clear that a pair of asset classes may exhibit different levels of correlations under different economic scenarios and might not necessarily assume a static or linear relationship at all points in time. It is, therefore, imperative for portfolio managers to clearly understand the dynamics of the economy and take into consideration time-varying correlations between asset classes while designing their portfolios.

Markowitz Optimal Portfolio Composition in Different Regimes

Optimal portfolio combination on weekly basis for each regime is presented in Table 5. The important point worth remembering is that the output of MRS-VAR has been used as input for portfolio construction in the next step. The output of MRS-VAR confirms the presence of two states. In state 1, equity and ENERGY provide the positive returns, whereas in state 2, AGRI and METAL exhibit positive returns.

If we look closely to the results in Table 5, we can notice sharp differences in the percentage of an asset getting the maximum weight in a particular regime. In Regime 1, NIFTY has the maximum weight in optimal portfolio for 124 weeks while in Regime 2, AGRI index has the maximum weight in the optimal portfolio for 186 weeks. ENERGY, which performs better (86 weeks) than METAL (73 weeks) in Regime 1, declines to just 32 weeks as compared to METAL which performs better for 91 weeks in Regime 2. The optimal portfolio composition in both regimes is also presented graphically in Figure 4.

Table 5. Optimal Portfolio Composition in Different Regimes

REGIME 1			REGIME 2		
Asset	Number	Percentage	Asset	Number	Percentage
AGRI 1	76	16	**AGRI 2**	186	39
ENERGY 1	86	18	**ENERGY 2**	32	7
GSEC 1	120	25	**GSEC 2**	106	22
METAL 1	73	15	**METAL 2**	91	19
NIFTY 1	124	26	**NIFTY 2**	64	13

Source: Authors' calculations.

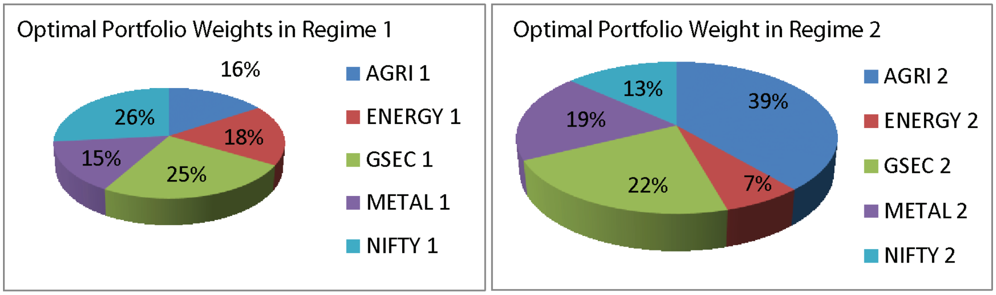


Figure 4. Optimal Portfolio Compositions in Regime 1 and Regime 2

Source: Authors' calculations.

AGRI gets the maximum weight in optimal portfolio in Regime 2. Contrary to the above, ENERGY performs better in Regime 1, that is, 18 per cent in Regime 1 as compared to 7 per cent in Regime 2. In line with the expectations, G-SEC performs almost equally in both the regimes. METAL and ENERGY have the shares of 15 per cent and 26 per cent in Regime 1, and 19 per cent and 13 per cent in Regime 2, respectively, indicating that NIFTY performs better in Regime 1 and METAL performs better in Regime 2.

Results and Discussion

Empirical results confirm the impact of economic environment on Indian commodity and stock markets on standalone basis. It validates the presence of two distinct regimes: *Regime 1*—representing the state of positive return and low volatility; and *Regime 2*—representing the state of negative return and high volatility. At this stage, regime is not consistent across all assets. Therefore, MRS-VAR has been applied and results of regime-switching VAR also validated the presence of two regimes in all asset classes. Interestingly, tranquil and crises regimes do not occur simultaneously in all asset classes; that is, while there is tranquil regime in some asset class, another asset class exhibits crisis regime and vice versa. This implies asset classes exhibit different levels of risk, return and correlations under different economic scenarios. Therefore, assuming a static or linear relationship at all points in time is completely misleading and masks the diversification benefits of commodities.

The above finding has an important implication for portfolio allocation and rebalancing. Therefore, impact of time-varying dynamic economic states on commodity optimal portfolio composition has been evaluated. The result indicates that optimal portfolio compositions were significantly different across two regimes. In Regime 1, NIFTY and energy index obtained the highest allocation for maximum number of times while agriculture index obtained the least weights. However, in Regime 2, agriculture and metal index obtained the highest allocation for maximum number of times while NIFTY and G-SEC index obtained the least weights. This implies that in both the regimes, commodities provide significant diversification benefit and by detecting the switching points in the economic states and rebalancing the portfolio, returns from commodity investment can be enhanced significantly.

Overall, from the result of this study, we can conclude that commodities perform better in the context of portfolio and provide significant diversification benefits at all points of time. These diversification benefits might be time varying in the context of individual commodities, but overall returns of the portfolio have been enhanced by adding commodities. Additionally, as the performance of commodities is consistently better in both economic states, this adds more robustness to our conclusion. These findings have important implications for academicians and practitioners.

Conclusion

This article examines the impact of dynamic economic states on commodity portfolio management in India. This study employs non-linear framework and provides evidence of differential commodity portfolio composition in distinct economic states. In the literature, there is an inherent assumption of the same economic state prevailing throughout the time of study. But in fact economic states keep on swinging from one state to another. Therefore, this segregation of portfolio composition on the basis of time-varying economic states has never been explored in literature. In our study, MRS models are applied to estimate the risk and return dynamics of various assets. Empirical evidence finds prevalence of regime-switching phenomenon in all assets, suggesting their state-dependent behaviour. The existing two regimes could be termed as 'low return and high volatility' and 'high return and low volatility' as defined by Balcilar, Hammoudeh, and Asaba (2015). Optimal asset allocation under each regime has been investigated and the result confirms that the optimal commodity portfolio composition is significantly different in both regimes. This is useful as it suggests optimal portfolio composition should be dependent on dynamic economic states.

Findings of this article will be very much useful to investors and fund managers in portfolio management. This will also be useful in managing risks as different commodities show differential diversification benefits in different economic states. Same set of commodities behave differently in different economic states. As the results reveal that in state 1, NIFTY and energy perform better, while in state 2, metal and agri indices perform better. Therefore, optimal weight of a commodity in optimal portfolio also varies. Hence, a portfolio manager assuming a constant state of economy and rebalancing his portfolio solely on the basis of historical returns may not receive optimal return. This implies that a portfolio manager while allocating assets to his portfolio must consider this state-switching behaviour of asset classes. Regime-switching models used in the study also provide the probability and expected duration of each state/regime. Therefore, this information can be used by portfolio managers and by examining the switching points in different asset classes; they can rebalance their portfolio which will help them in better risk management and capturing higher returns.

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