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Examining the Asymmetric Effects of Oil Price Changes on Global Commodity Prices

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Abstract

The effect of oil price changes on macroeconomy is evident through many studies. The results, however, could be heterogenous using different time frames, countries and estimation approaches. In this study, we seek to further examine the effect of oil price changes on the global commodity prices by applying a Markov switching (MS) regression with particular emphasis on three main sector that are energy, non-energy and precious metal sector. We attempt to study the asymmetric effect of oil price change on commodity prices by modifying the non-linear MS regression to include the asymmetric component of oil price change. Our results reveal the asymmetric effect of oil price change to be significant in energy and non-energy sectors and both increase and decrease lead to higher commodity inflation. The effect of oil price change is strongest in energy sector and weakest in the precious metal sector. The world effective exchange rate variable is the main determinant to commodity price inflation across sectors.

1 Introduction

The surge of oil price and the series of oil price crises have caused to economic fluctuations in the globe. Historical records and empirical findings showed ev-

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idence on the significant influences of oil price shocks on the global economy. In particular, the effects of oil price shocks were transmitted into commodity prices. The co-movement between crude oil price and commodities were observed, for instance, during the 2007-2008 global food crisis, commodity boom and commodity bust period. Previous studies affirmed that the 2007-2008 global food crisis was among others, caused by increased oil price that transmitted into food price through input cost and that the start of biofuel production had strengthened the relationship between oil and agricultural commodities [1]-[5].

Despite the evidence observed, previous studies are constraint by some limitations. The main limitation is the application of the linear models to estimate the oil-comodity relationship which limits the relationship to be linear and time-invariant. In the real situation, the relationship could be time-varying due to shocks/ crisis, the change in market demand and policy. These factors may cause to regime swift and changes in the structure of time series variables [6]. Besides, linear regression is not able to capture the asymmetric effect of oil price changes. Theoretically, oil price changes might lead to indirect effect on an economy and such effect is asymmetric [6]. Ignoring the asymmetric effect in its presence may cause to bias and inaccurate results. Apart from the estimation aspect, other limitation could be the sample or data used. Previous studies mainly used the aggregated data, i.e. the total commodity price index in examining the oil-commodity relationship. This leaves the effect of oil price change on sectoral commodities less examined and hence the discussions on the effect of oil on sectoral commodities less elaborated.

Considering the two limitations discussed above, this study seeks to fill the gaps by focusing on the nonlinear effects of oil price on global commodity prices by modifying the Markov switching autoregressive model with asymmetric oil price effect. This study contributes to the research of oil effects in two ways: first, in terms of estimation approach by considering two aspects that are regimes switching in commodity prices and the asymmetric effect of oil price. Second, this study provides insightful new findings and information by comparing three sectoral commodity prices (energy, non-energy and precious metals).

2 Literature review

Theoretically, the oil effect can be explained through three main channels: aggregate demand (input cost channel), aggregate supply or real income shift channel and the policy responses channel [6]. These channels are applicable in explaining the transmission of oil effect on commodity prices. In terms of input cost channel, oil price is directly transmitted to commodity prices through input cost as crude oil is used as fuels for transporting commodities as well as raw materials for processing the production of commodities. Besides, the aggregate demand channel is also relevant in explaining the inflation in precious metals that is transmitted from oil price indirectly as the outcome of the increase in global economic activities. Precious metals are invested as a store of wealth [7]. When oil price increases, the demand for gold and silver also increases as consumers purchase them to hedge against inflation caused by hike in oil price [8], [9]. Besides, oil price could be transmitted to commodity prices through changes in the level of disposable income. According to [1], as oil price hikes, the disposable income of consumers in the oil-exporting countries increases. Consumers with higher purchasing power increases the purchase of luxury goods such as gold, silver or imported commodities that eventually lead to hike in the price for such commodities. The opposite condition will be experienced by consumers in the oil-importing countries. Finally the policy channel is relevant with the application of biofuels in agriculture sector. The start of biofuel production is also an initiative to reduce dependence of foreign oil imports and hence reduce the transmission of imported oil price cost into United States, according to [5], in line with the policy responses changes explained by [6].

Moving to the empirical studies, the effect of oil price changes on commodity prices is evident but results might vary using different sample periods, countries, commodity sectors and estimation approaches. For instance, [4] found no evidence of relationship between oil price and food prices during the pre-commodity boom (1990-2006) but evidenced a positive impact of oil price on the commodities during the post boom period (2007-2015). Similarly, [10] reported a positive impact of oil price on agricultural commodities only after the 2006-2008 commodity crisis. On the other hand, [11] observed a change in the relationship between oil price and precious metals before and after the 2008-2009 global financial crisis.

Results might also differ according to commodity sectors. For instance, while [1] found strong positive impact of oil price change on raw materials such as cotton and rubber, [12] found a weak oil effect on cotton. Both [13] and [5] found natural gas to be very responsive to oil price change while [14] found crude oil and natural gas market to be totally independent to one another. On precious metals, [1], [8] and [15] similarly found that an increase in oil price is followed by an increase in the price of gold, both in the short and long run. On the contrary, [16] found increase in oil price to cause decrease in the price of gold and silver (cooling effect) since oil then become more attractive to investors than precious metals. [17] found Brent crude oil price to have no correlation with precious metal in India since the influence of oil price on price of silver, gold and platinum were found not significant.

In terms of estimation approach, previous studies mainly relied on linear modeling approaches to examine the effect of oil price. Only more recently, there are attempts to apply nonlinear modeling to study the topic. Among them include [19], [9], [15] and [18]. [19] found that while linear Granger causality approach of Toda–Yamamoto failed to capture the effect of oil price change on agricultural commodities, the use of Diks–Panchenko nonlinear Granger causality model proved the presence of a persistent unidirectional causality from oil price to price of corns and soybeans.

3 Data

This study uses monthly data from February 1994 to December 2019. There are three main commodity sectors examined in this study: energy, non-energy and precious metals. The data is classified as dependent variable and independent variable. Dependent variables are the inflation of commodities measured as the difference of logarithm of the commodity prices (*DLENE, DLNONE, DLMETAL*) and the independent variables are the inflation of oil price and global commodity price (*DLOIL, DLTOTAL*) and the non-oil variables in the growth of exchange rate and world GDP and world inflation (*DLREER, WGDP, WINF*), see Table 1. All data are obtained from the World Bank, except the oil price data is obtained from the U.S. Energy Inflation Administration (EIA).

To examine the asymmetric effect of oil price, the oil price series is decomposed into increases and decreases series. The equations are as shown in (3.1) and (3.2) respectively. $LOIL_t^+$ is the cumulative of oil price increases

Table 1: Summaries of variables

Variables			Description	Unit of measurement
Dependent	Commodity price inflation	*DLENE*	Commodity price index for energy sector	Nominal U.S. dollar
		DLNONE	Commodity price index for non-energy sector	Nominal U.S. dollar
		DLMETAL	Commodity price index for precious metal sector	Nominal U.S. dollar
Independent	Oil price	*DLOIL*	Europe Brent Spot Price FOB	Dollars per barrel
	Global non-oil variables	*DLTOTAL*	All Commodity Price Index, includes both fuel and non-fuel price indices	Index
		DLREER	World real effective exchange rate	Index
		WGDP	World GDP Growth	Annual (%)
		WINF	World Inflation, consumer price	Annual (%)

Note: All the variables are in log differenced form of original data that indicates measure of growth or inflation rate, except *WGDP* and *WINF* that are collected as percentage of growth.

while $LOIL_t^-$ is the cumulative of oil price decreases.

$$LOIL_t^+ = \sum_{j=1}^{t} DLOIL_j^+ = \sum_{j=1}^{t} \max(DLOIL_j, 0) \tag{3.1}$$

$$LOIL_t^- = \sum_{j=1}^{t} DLOIL_j^- = \sum_{j=1}^{t} \min(DLOIL_j, 0) \tag{3.2}$$

4 Methodology

A standard MS equation is as shown in equation (4.3). In this study, the standard MS equation is extended to include the independent regressors as shown in Model 1. The extended MS regression, Model 1, is then modified to include the asymmetric component of oil price change, as shown in Model 2.

$$y_t = \mu_{S_t} + \phi_1(y_{t-1} - \mu_{S_{t-1}}) + \epsilon_t \tag{4.3}$$

where $S_t = 1 \ldots k$ is the latent state that indicates the regime at time t and there could be k number of states; y_t is the dependent variables; μ_{S_t} is state or regime dependent mean coefficient; ϵ_t is the error term and ϕ_1 is the coefficient of AR(1) which is state dependent.

Model 1: MS Regression Model (symmetric model)

$$COMO_t = \begin{cases} \mu_1 + a_1 DLOIL_t + a_2 DLTOTAL_t + a_3 DLREER_t \\ +a_4 WGDP_t + a_5 WINF_t + \phi_1(COMO_{t-1} - \mu_{1_{t-1}}) + \epsilon_t & S_t = 1 \\ \mu_2 + a_1 DLOIL_t + a_2 DLTOTAL_t + a_3 DLREER_t \\ +a_4 WGDP_t + a_5 WINF_t + \phi_1(COMO_{t-1} - \mu_{2_{t-1}}) + \epsilon_t & S_t = 2 \end{cases} \tag{4.4}$$

where S_t refers to the regimes and the number of regimes is two. $COMO_t$ is the sectoral commodity price inflation, $COMO_t = DLENE$, $DLNONE$, $DLMETAL$. The independent variables consist of oil price, *DLOIL* and four non-oil variables, *DLTOTAL, DLREER, WGDP, WINF*. μ_1 is mean price inflation for regime 1 while μ_2 is the mean price inflation for regime 2. The a_1, a_2, a_3, a_4 and a_5 are the coefficient of independent variables and ϕ is the coefficient of the autoregressive term with lag order (1). Both the coefficient of independent variables and autoregressive term are state-invariant since these variables are treated as non-switching regressor. This model only allows for the net effect of oil price on the dependent variable and hence explain the symmetric effect of oil price.

Model 2: MS Regression Model (asymmetric model)

$$COMO_t = \begin{cases} \mu_1 + b_1 DLOIL_t^+ + b_2 DLOIL_t^- + b_3 DLTOTAL_t + b_4 DLREER_t \\ +b_5 WGDP_t + b_6 WINF_t + \phi_1(COMO_{t-1} - \mu_{1_{t-1}}) + \epsilon_t & S_t = 1 \\ \mu_2 + b_1 DLOIL_t^+ + b_2 DLOIL_t^- + b_3 DLTOTAL_t + b_4 DLREER_t \\ +b_5 WGDP_t + b_6 WINF_t + \phi_1(COMO_{t-1} - \mu_{2_{t-1}}) + \epsilon_t & S_t = 2 \end{cases} \tag{4.5}$$

where similar to Model 1, non-oil price variables include *DLTOTAL, DLREER, WGDP* and *WINF* but the oil price is replaced with decomposed series that are oil price increase, $DLOIL_t^+$ and oil price decrease, $DLOIL_t^-$.

5 Results

Before the main estimation, all the variables are tested for stationarity by using Augmented Dickey Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Philips-Schmidt-Shin (KPSS) unit-root tests. From the result obtained, all the variables except WGDP and WINF will enter the regression analysis at first difference form, I(1). WGDP and WINF are stationary series by itself, I(0) and will enter the regression analysis at level.

The analysis in this study involves several steps. First, the MS regression (symmetric oil effect (Model 1)) with time-varying (MS-TV) and time-invariant (MS-TI) transition function is performed for three commodity sectors. Second, the results of MS-TV and MS-TI are compared based on goodness of fits (maximum loglikelihood value, minimum AIC and SC) and forecast performance (minimum RMSE, MAPE and MAE). Third, the best results of Model 1 for each sector is then modified by replacing the symmetric oil effect with the asymmetric oil effect (Model 2) and the results of Model 1 and Model 2 are compared with the baseline results of OLS regression for each sector (as summarized in Table 2).

From Table 2, it is observed that MS-TI is the best model that suits for energy and non-energy sector while MS-TV is best suits for precious metals sector. The behavior of commodity price inflation can be represented by a two-regime specification with low inflation regime (Regime 1) and high inflation regime (Regime 2). The average inflation for each regime is captured by μ. The negative value indicates to deflation while the positive value indicates to inflation. Energy sector has the largest mean rate compared to other sectors for both regimes under symmetric and asymmetric models. The commodity price inflation is also determined by some non-regime switching regressors. It is also observed that an autoregressive pattern, dominantly up to first order of autoregression is evident in energy, non-energy and precious metal sector. This exhibits the gradual or partial adjustment behavior in which the mean commodity price inflation (low inflation or high inflation) is persistent up to one month period.

The OLS regression is a linear model, which is not able to capture the behavior of commodity price inflation due to regime shifts. Ignoring such effect might lead to inaccurate estimates. On the other hand, the standard MS regression (symmetric) only captures the symmetric or net oil price effect on commodity price inflation while the proposed MS regression (asymmetric) enables estimation on the asymmetric (increases versus decreases) of oil price inflation. Comparing both version of MS regressions, we observed the presence of asymmetric oil effect with larger impact due to oil price decreases in energy and non-energy sectors and both oil increases and decreases lead

Table 2: Results for the best MS regressions (symmetric versus asymmetric oil effect)

Model/Sector	Energy sector					
	MS-TI -symmetric		MS-TI -asymmetric		OLS-symmetric	OLS-asymmetric
μ:	Regime 1	Regime 2	Regime 1	Regime 2		
	-0.0058	0.0844***	-0.0041	0.0904***	-0.0040	-0.0044
Independent Variables:						
DLOIL	0.7526***				0.7369***	
$DLOIL^+$			0.7262***			0.7432***
$DLOIL^-$			0.7744***			0.7319***
DLTOTAL	0.0944***		0.0958***		0.0700**	0.0701**
DLREER	-0.5763*		-0.5422*		-0.7352**	-0.7358**
WGDP	0.0018*		0.0017*		0.0017*	0.0017*
WINF	0.0002		0.0002		0	0
AR(1)	0.0003		-0.0093		0.0530***	0.0542***
Model/Sector	**Non-energy sector**					
	MS-TI -symmetric		MS-TI -asymmetric		OLS-symmetric	OLS-asymmetric
μ:	Regime 1	Regime 2	Regime 1	Regime 2		
	-0.0846***	0.002	0.0026	0.0552***	0.0014	0.0043
Independent Variables:						
DLOIL	0.0794***				0.0940***	
$DLOIL^+$			0.0462*			0.0549*
$DLOIL^-$			0.1393***			0.1247***
DLTOTAL	0.0305		0.0457		0.1059***	0.1062***
DLREER	-1.5200***		-1.4617***		-1.0739***	-1.0690***
WGDP	0.0008		0.0022		0.0008	0.0007
WINF	-0.0001		-0.0011		-0.0005	-0.0005
AR(1)	0.3953***		0.3887		0.2826***	0.2662***
Model/Sector	**Precious metals sector**					
	MS-TI -symmetric		MS-TI -asymmetric		OLS-symmetric	OLS-asymmetric
μ:	Regime 1	Regime 2	Regime 1	Regime 2		
	-0.0087	0.0614***	-0.0091	0.0608***	0.0115*	0.0107
Independent Variables:						
DLOIL	0.0427*				0.0397	
$DLOIL^+$			0.0463			0.0506
$DLOIL^-$			0.0417			0.0314
DLTOTAL	0.0624		0.0642		0.1082*	0.1087*
DLREER	-1.9690***		-1.9621***		-1.6949***	-1.6960***
WGDP	0.0050**		0.0049**		-0.0007	-0.0007
WINF	-0.0012		-0.0011		-0.001	-0.001
AR(1)	0.0712		0.0707		0.0980*	0.0997*

Note: *, ** and *** indicate the significance levels at 10%, 5% and 1% respectively.

to the same outcome of higher commodity prices. The asymmetric effects of oil are much large in energy sector than non-energy sector but are not significant in precious metals sector. The consistent results also obtained from the MS symmetric and OLS which only capture the net oil effect. The relatively stronger impact of oil price in the energy sector may be caused by the wide use of crude oil in the energy industry besides natural gas and coal [6], [20].

However, oil price is not the main determinant factor. All regressions reported that exchange rate changes is the main factor contributing to commodity price changes with negative sign and in the largest absolute coefficient value. The possible reason that exchange rate appears to have the main influence might due to dominant of US$ and Euro as the medium of transaction in the international trades. Hence, depreciation of real exchange rate leads to higher commodity price inflation as observed in this study. On the other hand, the world GDP and inflation have a limited or non-significant effect on commodity price inflation of all sectors as observed in all regression results.

Table 3: Results for the best MS regressions (symmetric versus asymmetric oil effect)

Model/Sector	Energy sector			
	MS-TI -symmetric		MS-TI -asymmetric	
μ:	Regime 1	Regime 2	Regime 1	Regime 2
	-0.0058	0.0844***	-0.0041	0.0904***
Transition Probability:				
Regime 1	0.9921	0.0079	0.9928	0.0072
Regime 2	1	0	1.0000	0.0000
Expected Duration:				
Mean	127.2147	1	138.0110	1.0000
Model/Sector	Non-energy sector			
	MS-TI -symmetric		MS-TI -asymmetric	
μ:	Regime 1	Regime 2	Regime 1	Regime 2
	-0.0846***	0.002	0.0026	0.0552***
Transition Probability:				
Regime 1	0.4647	0.5353	0.9787	0.0213
Regime 2	0.0075	0.9925	0.7727	0.2273
Expected Duration:				
Mean	1.8682	133.1805	46.9246	1.2942
Model/Sector	Precious metals sector			
	MS-TI -symmetric		MS-TI -asymmetric	
μ:	Regime 1	Regime 2	Regime 1	Regime 2
	-0.0087	0.0614***	-0.0091	0.0608***
Transition Probability:				
Regime 1	0.9469	0.0531	0.9470	0.0530
Regime 2	0.6382	0.3618	0.6406	0.3594
Expected Duration:				
Mean	36.292	1.6023	36.4036	1.5969

Note: *, ** and *** indicate the significance levels at 10%, 5% and 1% respectively.

Table 3 reports the transition probability and expected duration for each regime in the energy, non-energy and precious metal sectors for the best MS regression that captures the symmetric and asymmetric effect of oil price change respectively. The results show that both symmetric and asymmetric models for energy and precious metals sectors are consistent where there is a high probability that commodity price inflation will stay in the low regime (Regime 1) as well as the transition probability from high (Regime 2) to low (Regime 1) inflation is high. Also, the expected duration to remain in the low regime is long compared to the high regime. The mean durations to remain in low regime are 127.2 months and 39.3 months respectively for energy and precious metals as reported by the symmetric model. On the other hand, the result is quite inconsistent for non-energy sector.

The results imply that commodity price of energy and precious metal sectors are stable or with low fluctuation while commodity price of non-energy sector is more volatile and exhibits an increasing trend or is expected to increase over time. Non-energy commodities are very broad covering agricultural, beverages, metals, food, timber and raw materials, fertilizers, cereals, fats and oils and other foods which might be affected by other factors such as weather or climate, global demand, natural disaster and other unpredictable factors. Therefore, the prices of these non-energy commodities are highly fluctuated.

6 Conclusion

In this study, MS regression is applied to examine the asymmetric effects of oil price changes on commodity price inflation at disaggregated level (oil, non-oil and precious metals). The main contribution of the study is to innovate the standard MS model by incorporating the asymmetric elements of oil price changes into a 2-regime MS model. Our results reveal that both oil price increase and oil price decrease are significant in energy and non-energy sector and both the effects lead to higher commodity price inflation. The effect of oil price is heterogenous across sector and is found strongest in energy sector and weakest in precious metal sector. Global non-oil factor (world effective exchange rate) is found to be the main factor that contributes to commodity price inflation across the three sectors examined.

The influence of oil price change on commodity price inflation in the energy and non-energy sector suggest that observing oil price fluctuations could help predict price movements of commodities in energy and non-energy sector. This would be helpful to monetary authorities and policymakers in monitoring the prices of major commodities, especially essentials such as agricultural, food commodities and raw materials and to ensure that the economic policies implemented are on course to hedge against the negative effects of oil price transmission.

Since price of commodities in the non-energy sector have higher tendency to show upward trend in price, policy implementation such as price caps and price ceilings or subsidies to control the price of food essentials and monetary policies to target on low inflation could help alleviate the burden of the poor.

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