A Regime-Dependent Assessment of the Information Transmission Dynamics between Oil Prices, Precious Metal Prices and Exchange Rates[1]

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Outline

Introduction

- After 2000, there has been a dramatic rise in commodity prices and precious metal as attractive and safe investment have lured smart investors.
- Noticeably, these commodity prices generally have been known to move in tandem when exposed to similar macroeconomic conditions.
- Given the recent crises over the last few decades and the insecurity of traditional investments (shares, bonds, mortgages etc.), we probe the questions;
- Given the properties of our selected precious metals (Gold, Silver, Platinum, Palladium), can these precious metals mitigate risks in spite the usual oil and exchange rate (ER) shocks?

Motivation & Contribution-I

- We investigate information dynamics between selected precious metals (gold, silver, platinum and palladium) in the presence of oil and exchange rates shocks in a regime changing environment.
- We undermine the potential for information diffusion by using homogeneous rather than heterogeneous commodities like other studies.
- Which of the commodities is most informative in the group when accounting for regime shifts?
- Since commodity prices move in tandem when exposed to similar macroeconomic conditions, do the co-movements differ within a given state of the economy, which could be normal or volatile?
- Is there significant disparity in co-movement in lieu of crises as covered by the sample data?
- Which of these commodities can be an effective hedge asset if their prices move in unison in a multi-state economy?

Motivation & Contribution-II

- Djuric et al. (2012) and Listorti and Esposti (2012) used the MS-VEC technique but studied agricultural and/or industrial commodities and not precious metals.
- The Bayesian MS-VEC and the Bayesian regime dependent impulse response analysis is not used by previous studies on precious metal price transmissions.
- Use of similar commodities unlike heterogeneous commodities like others (Pindyck & Rotemberg, 1990) hence more reliable findings.
- We employ more flexible form of the model that allows both the coefficients and variances to change based on the prevailing regime leading to more reliable results.
- This study uses the Bayesian estimation which is robust to model misspecification and allows for the estimation of the impulse response functions and their confidence intervals based on the Markov-chain Monte Carlo method (MCMC) of Gibbs sampling.

Literature Review-I

- Literature on commodity prices can be categorized under different characteristics including price co-movements, information diffusion in the presence of economic fundamentals and nonlinearity in chaotic environments (Bhar and Hammoudeh, 2011).
- Pindyck and Rotemberg (1990) are the pioneers of the research on excess co-movements who assert that after accounting for similar economic fundamentals, a group of unrelated raw commodity prices tend to move together.
- Cashin et al. (1999) strongly disagree to this contention and label this perception a "myth" after using concordance measures on unrelated commodities under similar macroeconomic conditions.[2]
- On information diffusion under similar economic fundamentals, Ewing and Malik (2012) find significant volatility transmission between gold and oil price returns when structural breaks in variance are considered using univariate and bivariate GARCH models.

[2] See Palaskas and Varangis (1991), Trivedi (1995) and Deb et al. (1996) for more on commodity price co-movements.

Literature Review-II

- Thompson et al. (2002), Goshray (2002), and Barassi & Goshray (2007) amongst others use sophisticated techniques to analyze the world market price transmissions, they neither focus on the selected precious metals nor use the Bayesian MS-VEC.
- Awokuse and Yang (2003) find that the CRB Index carries substantial information that can forecast the future path of interest rates, industrial productivity and inflation.
- Marquis and Cunningham (1990), Cody and Mills (1991), and Hua (1998), among others, share a controversial belief with Awokuse and Yang (2003).
- Regarding nonlinearity and chaotic phenomena, Soni (2013) test the presence of nonlinearity in serial dependence for the Indian commodity market, using the AR(p)-GARCH (1,1) and concludes that the nonlinearities are present in the series.

Literature Review-III

- Barkoulas et al. (2012) examine whether crude oil spot prices are determined by stochastic or deterministic endogenous fluctuations, using both metric and topographic diagnostic tools.
- Djuric et al. (2012), and Listorti and Esposti (2012) are some of the few studies that use the MS-VEC model to study commodity prices
- Although Beckmann and Czudaj (2013) do not use all our selected commodities, they apply a non Bayeisan MS-VEC model to investigate the dynamic relationships between the oil price and the dollar exchange rate.
- Compared to Beckmann and Czudaj (2013), our study allows for additional four precious metals prices to be included in the model and performs the Bayesian regime dependent impulse response analysis (RDIRF) based on the Gibbs sampling.
- Apart from Beckmann and Czudaj (2013), all of the other studies consider agricultural commodities in specific countries,

Reasons for Using Nonlinear MS-VEC Model-I

- Adequately captures nonlinearity of price changes in multiple regimes compared to other conventional threshold models (Ihle and von Cramon-Taubadel, 2008)
- Frequently changing equilibrium relationship between these commodity prices renders the parameter constancy assumption of the customary VEC models too restrictive and the model to be misspecified.
- The parameter constancy assumption cannot stand in face of financial crises, demand shocks and supply interruptions and discoveries.
- Unlike others, (Beckmann and Czudaj, 2013), we generate Bayesian regime dependent impulse response analysis (RDIRF) based on the Gibbs sampling to measure the impact of shocks in the system.
- It allows regime classification to depend on parameter switches in the full sample thus possible to detect the changes in dynamic interactions among the variables.

Reasons for Using Nonlinear MS-VEC Model-II

- It allows for multiple changes in the dynamic interactions among the variables at unknown periods.
- It allows to make possible probabilistic inference about the dates of a regime change and evaluation of the extent of whether a change in the regime has actually occurred.
- It facilitates derivation of regime-dependent impulse response functions to summarize how the impact of a shock in one variable on other variables varies with regimes.
- Stock/commodidty returns are well modelled using MS. Researchers who employed the MS model after Hamilton (1989) were Diebold, et al. (1994), Durland & McCurdy (1994), Filardo (1994), Ghysels (1994), Kim & Yoo (1995) while Tyssedal & Tjostheim (1988), Schwert (1989), Pagan & Schwert (1990), Kim, et al. (1998), Kim & Nelson (1998) used the MS models in the context of stock market returns.

Methodolgy-I

Variables:

R_t = spot US dollar/euro exchange rate
F_t = spot crude oil price
G_t = spot price of gold
L_t = spot price of silver
P_t = spot price of platinum
A_t = spot price of palladium

Let $X_t = [R_t, F_t, G_t, L_t, P_t, A_t]'$

MS-VEC

$$\Delta X_t = \mu_{S_t} + \sum_{k=1}^{p-1} \Gamma_{S_t}^{(k)} \Delta X_{t-k} + \Pi_{S_t} X_{t-1} + \varepsilon_t, \qquad t = 1, 2, \ldots, T \qquad (1)$$

where $\varepsilon_t \sim \text{NID}(0, \Omega_{S_t})$ with the regime (state) variable $S_t \in \{1, 2\}$.

Methodolgy-II

The random state or regime variable S_t, conditional on S_{t-1}, is unobserved, independent of past Xs, and is also assumed to follow a q-state Markov process:

Markov Process

$$\Pr[S_t = j\,|S_{t-1} = i\,, S_{t-2} = k_2, \ldots, \Im_{t-1}] = \Pr[S_t = j\,|S_{t-1} = i\,, \Im_{t-1}] = p_{ij}$$

for all t and k_l, regimes $i, j = 1, 2, \ldots, q$, and $l \geq 2$. The transition of probability matrix of S_t is given by

$$P = \begin{bmatrix} p_{11} & p_{12} & \ldots & p_{1q} \\ \vdots & \vdots & & \vdots \\ p_{q1} & p_{q2} & \ldots & p_{qq} \end{bmatrix}, \qquad \sum_{j=1}^{q} p_{ij} = 1 \tag{2}$$

Thus, p_{ij} is the probability of being in regime j at time t, given that the economy was in regime i at time $t-1$, where i and j take possible values in $\{1, 2, \ldots, q\}$.

Methodolgy-III

Asymmetric Adjustment to Equilibrium

$$\Pi_{S_t} = \alpha_{S_t}\beta' \quad (3)$$

where the equilibrium error is given by

$$z_t = \beta' X_t$$

MCMC Estimation

Our MCMC implementation is based on the following steps:

MCMC

1. Draw the model parameters given the regimes. In our case, the transition probabilities do not enter this step.
2. Draw the regimes given the transition probabilities and the model parameters.
3. Draw the transition probabilities given the regimes. In our case, the model parameters do not enter this step.

Methodolgy-IV

- Initially introduced by Sims (1980), IRF analysis examines how a given magnitude of a shock in one of the variables propagates to all variables in the system over time, say for $h = 1, 2, \ldots, H$ steps after a shock.
- Of the two approaches that arose to solve the historical dependency problem of IRF:
  1. Ehrmann et al. (2003) suggests that regimes do not switch beyond the shock horizon while
  2. Krolzig (2006) acknowledges history dependence and allows the regime process to influence the propagation of the shocks for the period of interest.

Methodolgy-V

The path taken by an endogenous variable at time $t + h$ after a k-th initial sock at time t conditioned on regime i is expressed as:

RDIRF

$$\psi_{k,i,h} = \frac{\partial E_t[X_{t+h}]}{\partial u_{k,t}}\bigg|_{S_t = \cdots = S_{t+h} = i}$$

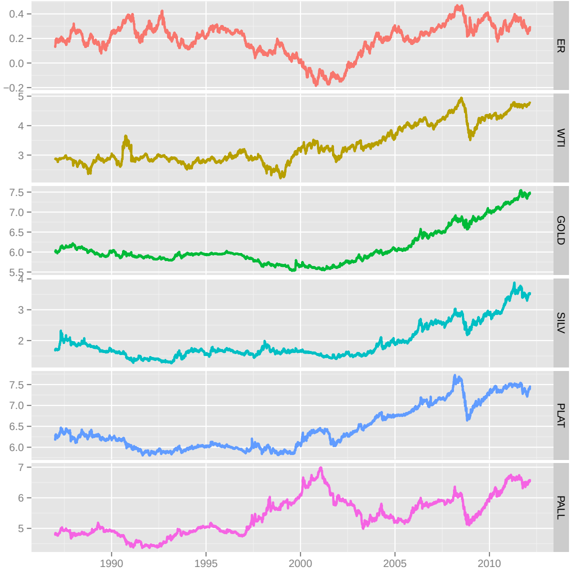
$u_{k,t}$ is the structural shock to the k-th variable.

- The reduced form shocks ε_t will be correlated across the equations and $\varepsilon_{k,t}$ will not correspond to$u_{k,t}$.
- We assume $\varepsilon_t = F_{S_t} u_t$ where F_{S_t} is a (6×6) matrix relating the reduced form shocks to the structural shocks.
- The recursive identification scheme based on the Cholesky decomposition of the covariance matrix as $\Omega_{S_t} = L_{S_t} L'_{S_t}$ and the identifying structural shocks from $u_t = F_{S_t}^{-1} \varepsilon_t$ with $F_{S_t} = L_{S_t}$

Data

- Daily spot prices of the four precious metals (gold, silver, platinum and palladium), the oil spot price and the dollar/euro exchange rate.
- We use a five-working day week from January 1987 to February 2012 (25-year period) with 6560 observations.
- All commodities are traded in the COMEX and data is obtained from DataStream International.
- The entire data series are expressed in natural logarithms and the price returns used are defined as $\ln(P_t/P_{t-1}) \times 100$.

Plot of Data in Logarithms



Descriptive Statistics

	ER	WTI	GOLD	SILV	PLAT	PALL
Panel A: log levels						
Mean	0.193	3.338	6.116	1.939	6.442	5.413
S.D.	0.134	0.660	0.475	0.574	0.526	0.632
Min	-0.188	2.212	5.533	1.266	5.801	4.360
Max	0.469	4.947	7.549	3.883	7.729	6.994
Skewness	-0.787	0.739	1.301	1.379	0.746	0.405
Kurtosis	0.297	-0.701	0.748	1.039	-0.776	-0.794
JB	700.992***	730.717***	2006.279***	2377.588***	772.544***	351.652***
$Q(1)$	6547.694***	6551.660***	6551.921***	6548.551***	6554.303***	6551.957***
$Q(5)$	32571.343***	32642.789***	32659.843***	32610.113***	32699.968***	32658.485***
ARCH(1)	6531.685***	6544.571***	6552.933***	6546.271***	6541.866***	6538.564***
ARCH(5)	6519.303***	6540.970***	6548.939***	6542.488***	6537.895***	6534.640***
Panel B: log returns						
Mean	0.002%	0.030%	0.023%	0.029%	0.020%	0.027%
S.D.	0.632%	1.958%	0.967%	1.761%	1.417%	2.014%
Min	-3.844%	-42.986%	-7.218%	-23.672%	-17.277%	-17.859%
Max	4.617%	17.267%	7.382%	13.665%	11.728%	15.841%
Skewness	0.072%	-1.736%	-0.266%	-0.797%	-0.704%	-0.174%
Kurtosis	2.384%	41.323%	7.104%	11.090%	9.595%	7.074%
JB	1560.7640***	470270.5990***	13880.5480***	34333.9760***	25719.9350***	13718.8920***
$Q(1)$	3.1293*	150.4286***	0.1315	2.4898	2.554	9.7048***
$Q(5)$	56.2889***	170.1901***	7.339	5.882	18.0124***	28.9476***
ARCH(1)	35.0174***	85.8749***	173.4158***	197.1089***	199.0196***	187.1028***
ARCH(5)	140.2771***	177.8160***	413.4662***	337.5270***	428.8704***	466.8582***
n	6560	6560	6560	6560	6560	6560

Properties of Data

- Gold and platinum have the lowest historical price volatility as viewed by their standard deviations (0.475 and 0.526 respectively)
- Oil and palladium have the highest standard deviations (0.660 vs 0.632) which may be due to oil being a major energy source and being heavily used as a production input for the other commodities.
- Oil has the highest historical daily mean return (0.030%), followed by silver, palladium, gold, and platinum, respectively.
- Ljung-Box autocorrelation tests indicate strong autocorrelation in the series except gold and silver returns which are weakly correlated.
- The ARCH tests for all series indicate strong ARCH effects while normality is rejected at 1% level thus suggesting the appropriateness of dynamic nonlinear models for the analysis.

Correlation Matrix

	ER	WTI	GOLD	SILV	PLAT	PALL
Panel A: log levels						
ER	1.000					
WTI	0.419	1.000				
GOLD	0.639	0.831	1.000			
SILV	0.498	0.853	0.953	1.000		
PLAT	0.412	0.941	0.865	0.905	1.000	
PALL	-0.294	0.595	0.384	0.575	0.609	1.000
Panel B: log returns						
ER	1.000					
WTI	0.064	1.000				
GOLD	0.289	0.167	1.000			
SILV	0.239	0.162	0.625	1.000		
PLAT	0.184	0.143	0.437	0.400	1.000	
PALL	0.169	0.097	0.318	0.307	0.566	1.000

Unit Root Tests

	ADF	DF-GLS	PP	KPSS	NP- Z_a
Panel A: Level					
Deterministic regressors in the test equation: Constant					
ER	-1.849 [0]	-1.598 [0]	-1.903	1.501***	-5.645 [0]
WTI	1.668 [0]	2.094** [0]	1.667	5.212***	3.345 [0]
GOLD	-0.896 [1]	0.110 [1]	-0.886	6.069***	0.209 [1]
SILV	-0.318 [0]	0.230 [0]	-0.238	7.609***	0.446 [0]
PLAT	0.340 [0]	0.844 [0]	0.312	6.049***	1.922 [0]
PALL	-0.476 [2]	0.296 [2]	-0.452	7.913***	0.623 [2]
Deterministic regressors in the test equation: Constant and linear trend					
ER	-1.882 [0]	-1.889* [0]	-1.936	1.443***	-7.203[0]
WTI	-0.099 [0]	0.137 [0]	-0.112	2.289***	0.249 [0]
GOLD	-1.969 [1]	-1.886* [1]	-1.944	0.510***	-7.417 [1]
SILV	-2.024 [0]	-1.291 [0]	-1.944	2.042***	-3.798 [0]
PLAT	-1.223 [0]	-0.868 [0]	-1.247	1.929***	-2.598 [0]
PALL	-2.452 [2]	-1.788* [2]	-2.418	1.673***	-7.264 [2]
Panel B: First differences					
Deterministic regressors in the test equation: Constant					
ER	-79.202*** [0]	-6.011*** [23]	-79.200***	0.0705	-21.626*** [23]
WTI	-81.333*** [0]	-8.085*** [19]	-81.333***	0.874*	-37.534*** [19]
GOLD	-77.916*** [0]	-2.860*** [30]	-77.881***	0.0876	-7.261* [30]
SILV	-60.178*** [1]	-2.544** [20]	-82.669***	0.1936	-7.901* [20]
PLAT	-79.466*** [0]	-10.366*** [19]	-79.456***	0.313	-54.519*** [19]
PALL	-56.070*** [1]	-14.786*** [14]	-68.956***	0.123	-166.649*** [14]
Deterministic regressors in the test equation: Constant and linear trend					
ER	-79.196*** [0]	-10.736*** [16]	-79.195***	0.063	-66.858*** [16]
WTI	-81.421*** [0]	-21.044*** [8]	-81.421***	0.068	-518.245*** [8]
GOLD	-77.914*** [0]	-8.379*** [17]	-77.878***	0.070	-43.221*** [17]
SILV	-60.192 *** [1]	-5.240*** [18]	-82.681***	0.034	-21.474** [18]
PLAT	-79.493*** [0]	-77.224*** [0]	-79.481***	0.027	-3271.640*** [0]
PALL	-56.079*** [1]	-54.780*** [1]	-68.950***	0.020	-3503.940*** [1]

Cointegration Tests

Panel A: VAR order selection criteria

Lag (p)	1	2	3	4	6	7	8
AIC	-52.957	-53.031	**-53.034**	-53.032	-53.031	-53.031	-53.029
HQ	-52.942	**-53.003**	-52.993	-52.979	-52.964	-52.951	-52.937
BIC	-52.913	**-52.950**	-52.916	-52.877	-52.838	-52.801	-52.762

Panel B: Johansen cointegration tests

Eigenvalues	0.0067	0.0034	0.0032	0.0018	0.0005	0.0001

		Critical values		
H_0	λ_{max}	10%	5%	1%
$r = 5$	0.720	6.500	8.180	11.650
$r = 4$	3.530	12.910	14.900	19.190
$r = 3$	11.960	18.900	21.070	25.750
$r = 2$	21.340	24.780	27.140	32.140
$r = 1$	22.410	30.840	33.320	38.780
$r = 0$	44.040**	36.250	39.430	44.590

H_0	λ_{trace}	10%	5%	1%
$r \leq 5$	0.720	6.500	8.180	11.650
$r \leq 4$	4.260	15.660	17.950	23.520
$r \leq 3$	16.220	28.710	31.520	37.220
$r \leq 2$	37.560	45.230	48.280	55.430
$r \leq 1$	59.980	66.490	70.600	78.870
$r = 0$	104.020**	85.180	90.390	104.200

Cointegration vector	
ER	1.0000
WTI	-0.3985
GOLD	0.2720
SILV	-0.4656
PLAT	0.4030
PALL	0.2839
ER	1.0000

Loadings	
ER	-0.0020
WTI	0.0120
GOLD	-0.0030
SILV	-0.0001
PLAT	-0.0029
PALL	-0.0063

Panel C: Stock-Watson cointegration test

H_0: $q(k,k\text{-}r)$	Statistic
$q(6,0)$	2.181
$q(6,1)$	-4.193
$q(6,2)$	-4.193
$q(6,3)$	-30.848
$q(6,4)$	-30.848*
$q(6,5)$	-74.689***

Critical values:	$q(6,5)$	$q(6,4)$
1%	-60.20	-38.20
5%	-49.80	-31.50
10%	-44.80	-28.30

MS-VEC Estimates

Model selection criteria

	MS(2)-VEC	Linear VEC(2)
Log likelihood	122534.760	118130.404
AIC criterion	-37.309	-35.996
HQ criterion	-37.237	-35.961
BIC criterion	-37.102	-35.894

LR linearity test	Statistic	*p*-value
	8808.712	$\chi^2(100)$ =[0.0000]***
		$\chi^2(101)$=[0.0000]***
		Davies=[0.0000]***

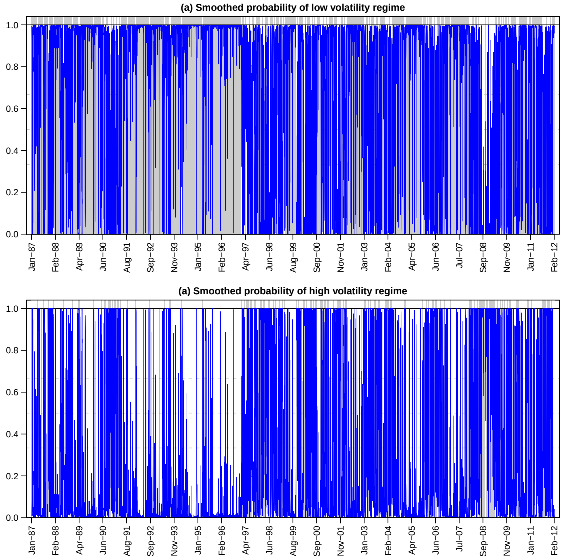
Transition probability matrix

$$P = \begin{bmatrix} 0.856 & 0.144 \\ 0.370 & 0.631 \end{bmatrix}$$

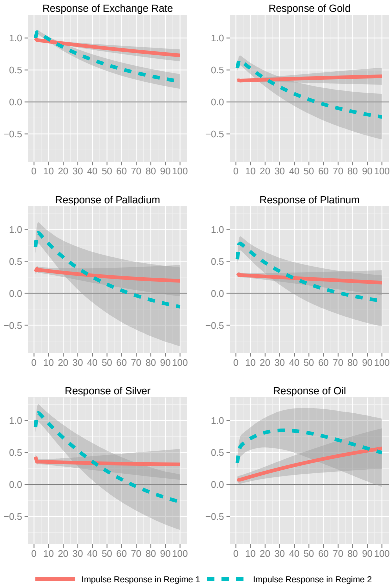
Regime properties

	Probability	Observations	Duration (months)
Regime 1	0.720	4718	6.960
Regime 2	0.280	1840	2.710

Estimate of Smoothed Regime Probabilities

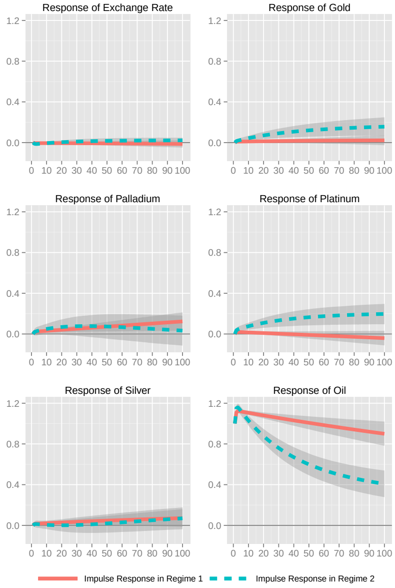


Responses to an Exchange Rate Shock



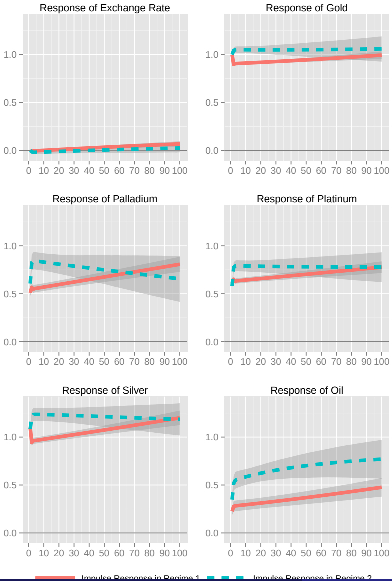
- The fluctuating U.S. dollar/euro exchange rate significantly affects the price returns of all other commodities, especially when the system is in the high volatility regime (regime 2).
- This may be due to the use of both currencies in international trade for global exchanges.
- The co-integrated relationship between the oil price and the dollar exchange rate could explain why a shock in the exchange rate has the most impact on the oil price.

Responses to an Oil Price Shock



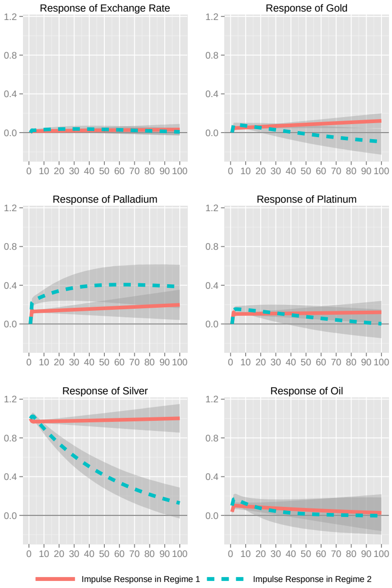
- The impacts of the oil price shocks in regime 2 are more significant than in regime 1 as expected.
- Coupled with oil's use as a major energy source traded in US dollars, changes in the oil shocks caused specifically by economic events, geopolitical factors, wars, etc., thereby making the oil to have significant impacts on all other commodities.
- The initial impact of an oil price shock is positive on all other variables in regime 2, except for the exchange rate which gets initially depressed
- The response of the exchange rate to oil price shock is radically asymmetric, the response rising from negative to positive in the high volatility regime

Responses to a Gold Price Shock



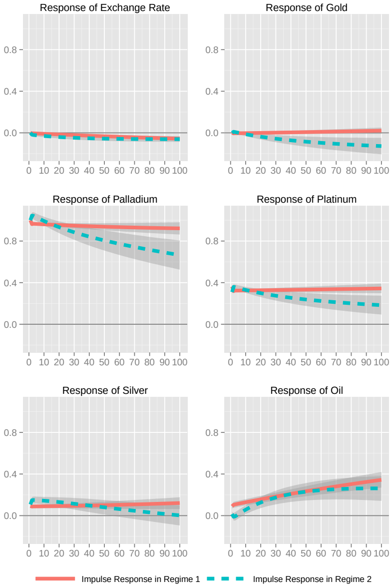
- In spite its low volatility, changes in gold price however transmit the most significant effect on all other commodity prices.
- In regime 1, the impact of fluctuating gold prices is a steady rise in all other commodity prices.
- In the highly volatile regime 2, a gold price shock unlike the shocks in the other commodity prices initially depresses the dollar/euro (appreciating the US dollar) exchange within the first five days before this exchange rate starts to gradually rise.
- Within the first 5 days the initial impact is the highest on the silver price returns (about 1.25%), while it is lowest on oil (0.50%)

Responses to a Silver Price Shock



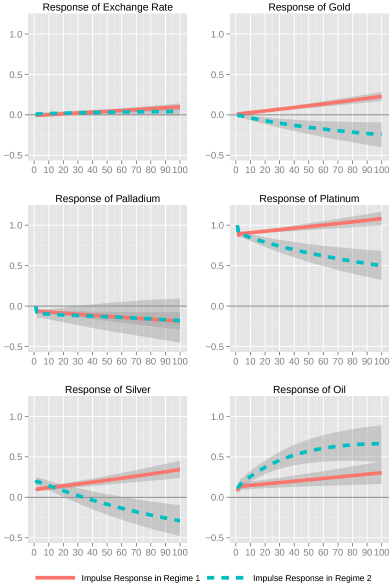
- The changes in silver prices affect the gold price returns by only about 0.07% in regime 2, while the impact of changes of the gold price on silver is about 1.25%. This shows that changes in the gold price affect the silver price return about 17 times more than the other way around. (Compare to Sari et al. (2010) who finds symmetric impacts).
- The asymmetry in impulse responses to silver shocks illustrates how misleading might be the analysis based on linear models.

Responses to a Palladium Price Shock



- Although changing palladium price in regime 1 affect the exchange rate and oil prices significantly, the impact is rather weak on the other commodities.
- Rising palladium price depress the dollar/euro exchange rate (appreciate the U.S. dollar) by about 2% in the first few days and the effect gets much significant over the horizon.
- The impact of a positive palladium price shock on the other commodities in regime 2 causes a fall in all price returns except for the oil return which rises.
- In addition to its low correlation with the other commodities, this makes palladium a good portfolio diversifier for investors in precious metals.

Responses to a Platinum Price Shock



- Changes in platinum prices impact the other commodity prices similarly to the impact of the changes in the palladium price on those commodities.
- Like palladium, a platinum price shock causes a rise in oil prices but depresses the palladium price returns, regardless of the state of the market.

Concluding Remarks & Recommedations-I

- Gold as an inflationary hedge and platinum as an investment asset diversifier which recently moves in a lock-up with gold.
- Gold and silver have the highest historical correlation (95%), closely followed by oil and platinum (94%), thus suggesting the former pair as close monetary and investment assets, while the latter pair as close industrial neighbors.
- Gold has the lowest volatility amongst all variables in the group, which makes it an attractive hedge asset for diversifying investors' portfolios.
- The MS-VEC model supports the presence of two regimes (low volatility and high volatility) with substantial information asymmetries.
- Increases in the gold price on the other variables is positive and significant in the both regimes, but the effect dampens in the high volatility regime.

Concluding Remarks & Recommedations-II

- The results posit that changes in gold prices affect silver price returns about 25 times more than silver prices affect gold price returns. Hence gold amongst the group of precious metals apparently has the highest information content in this group.
- Although we find that the effects of changes in gold price on platinum and palladium price returns to be similar, we notice significant asymmetries regarding the effects of fluctuations in both commodity prices on each other.
- The platinum price increases affect palladium prices negatively, while the palladium price changes convey a positive effect on the platinum prices. This goes against the claim that the palladium prices play “catch-up” in their price returns with platinum.
- Increases in the palladium price which is expressed in U.S. dollar, however, depress exchange rate (appreciating US dollar and depreciating the euro) in both regimes and the gold price in regime 2.
- Changes in the exchange rate in the past since 2000 result from the weakening dollar, thus causing spiking in commodity prices.

Concluding Remarks & Recommedations-III

- Based on our findings, we recommend that international investors consider including palladium in their precious metal portfolios since its low correlation makes it a good hedge asset.
- Investors of precious metal, central banks and other stakeholders should watch gold and oil prices carefully especially during high volatility regimes since they carry sufficient information that can determine the direction of change in the other commodity prices.
- Changes in the gold and oil prices can determine the direction of exchange rates hence central banks and governments can implement better policies to serve as a cushion especially during periods of high volatility.
- Investors and speculators should watch the changes in the gold price carefully as a change in direction may suggest whether or not to invest in silver.
- For the oil-importing and -exporting countries, monitoring oil prices especially in the high volatile regime is vital since it can guide governments on how to implement effective policies to stabilize their exchange rates, inflation and balancing the budget.

Thank You.