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David Roubaud , Mohamed Arouri

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Highlights

- We study interactions between oil prices, exchange rates and stock markets
- We consider the effects of economic policy uncertainty (EUP)
- We use a VAR and an MS-VAR models
- We show non-linear interrelations between currency, oil and stock markets

Oil Prices, Exchange Rates and Stock Markets under Uncertainty and Regime-Switching

David Roubaud, Montpellier Business School, Montpellier Research in Management, FRANCE

Mohamed Arouri, Université Côte d'Azur, GRM, France

Abstract

We contribute to the ongoing literature on the interactions between oil prices, exchange rates and stock markets by considering the effects of economic policy uncertainty (EUP). Based on a VAR and a multivariate Markov switching vector autoregressive (MS-VAR) models, we show (i) significant interrelations between currency, oil and stock markets; (ii) relationships between the variables are rather non-linear; (iii) links between the variables change from one regime to the next, but they are stronger during volatile periods; and (iv) oil plays an active role in the transmission of price shocks to both the exchange rate and stock markets.

JEL Classification: E3 prices, business fluctuations

Keywords: oil price, US effective exchange rate, stock markets, uncertainty

1. Introduction

We contribute to the literature by investigating the relationships between Brent crude oil prices, the US dollar exchange rate and US stock markets. We think that addressing this investigation contributes to several areas covered in recent macroeconomic and finance research. For example, it helps better understand how changes in major US exchange rate and stock markets are transmitted to oil prices and vice versa (Hamilton, 1983, 2003). Moreover, the findings from such research can help better forecast changes in currencies, stock markets and oil prices and create profitable investment and hedging strategies for oil, currencies and stocks (Arouri et al., 2011). Theoretically, these three markets should be linked for several reasons. For instance, oil price changes affect numerous economic variables, such as production costs, inflation, interest rates, investment, economic growth, terms of trade, and consumer and investor confidence. These economic variables affect both the exchange rate market and the stock market (Amano and van Norden, 1995; Hamilton, 1983). Moreover, in international markets, oil prices are expressed in US dollars; thus, the dollar exchange rate may affect the price perceived by consumers and producers of oil and oil-related products.

In the available literature, several empirical studies investigate the interactions between the oil, stock and exchange rate markets. However, previous studies have examined only bivariate links and/or have not considered the effect of uncertainty and changes in market conditions on the relationships between these variables. Their main findings are rather heterogeneous and do not allow researchers to reach definitive conclusions. For instance, Li et al. (2016) use multifractal detrended cross-correlation analysis to study the interactions between the oil and exchange rate markets and report strong correlations in the short and the long run. Ding and Vo (2012) and Aloui et al. (2013) establish that oil price increases are associated with the appreciation of the US dollar, but Narayan et al. (2008) and Zhang et al. (2008) report a negative association between oil prices and US dollar exchange rates. Apergis and Miller (2009) study the case of eight developed economies and show that stock market returns do not respond significantly to oil price changes. By contrast, Kang et al. (2016) use structural vector autoregressive (VAR) models to investigate links between oil price shocks and US stock markets and report evidence of strong links between these two markets. Chkili et al. (2014) use DCC-FIAPARCH models to reveal instabilities in the relationships between oil price changes and US stock market returns.

Our paper contributes to this ongoing literature. Compared with previous research, our study uses an integrated dynamic approach to jointly investigate the three markets. More importantly, we consider the effect of economic policy uncertainty (EPU) on the relationships between those markets and study these relationships under different market conditions. Indeed, numerous studies have recently established that policy shocks significantly affect the relationships between economic variables and that they may introduce nonlinearities into their dynamics (Arouri et al., 2016). Methodologically, we propose using both linear VAR models and Markov switching VAR (MS-VAR) models.

The remainder of the paper is organized as follows. Section 2 introduces the data and presents our preliminary analysis. Section 3 discusses our main empirical findings. Finally, section 4 concludes the paper.

2. Data and preliminary analysis

The data consist of monthly statistics on the US real stock price (S&P 500), the real effective exchange rate of the US dollar, the real Brent oil price in US dollars, and an index of economic policy uncertainty. Covering the 1979M5 to 2015M1 period, these data are sourced from the St. Louis Fed Database and International DataStream. The choice of this period enables us to investigate the relationships between the variables over different periods of stability and instability. We use the index proposed by Baker et al. (2015) as a proxy for economic policy uncertainty. This index is based on three equally weighted components: (i) media coverage of policy-related economic uncertainty; (ii) the number of federal tax code provisions set to expire in the coming years, and (iii) a measure of disagreement among forecasters as a proxy for economic uncertainty.

Continuous monthly return series on the four variables are computed by taking the differences in logarithm of two successive values of the series in levels. The evolution of return series is plotted in Figure 1 while Table 1 reports descriptive statistics and standard tests on those return series.

Panel A in Table 1 suggests that, over the period covered by our empirical investigation, economic policy uncertainty shows the highest volatility, whereas the dollar exchange rate shows the lowest one. Stock market returns show the highest mean returns. Stock market returns show also some negative asymmetry in their dynamics (skewness) and all the four studied return series show excess kurtosis. Not surprisingly, the Jarque-Bera (JB) test rejects the hypothesis of normal distribution. The Ljung-Box test shows the presence of some serial autocorrelation in the return series suggesting that lagged variables should be included in the model estimations. Finally, the Augmented Dickey-Fuller (ADF) test shows that return series are stationary.

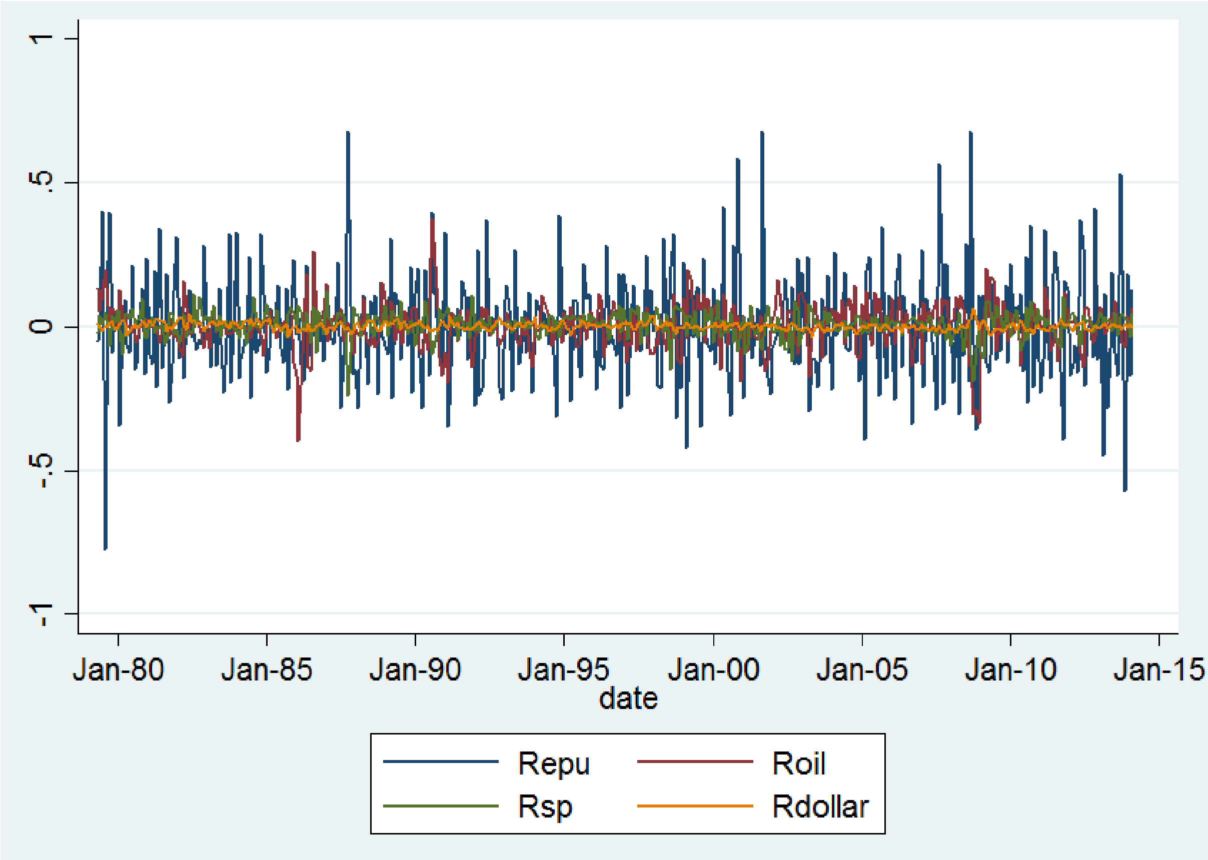

Figure 1. Evolution of US stock market returns (Rsp), dollar exchange rate returns (Rdollar), economic policy uncertainty changes (Repu) and oil price returns (Roil)

From Panel B in Table 1, we learn that oil returns are negatively associated with the US dollar exchange rate returns, and the latter is negatively correlated with stock market returns. More interestingly, a negative correlation exists between the US stock market returns and economic policy uncertainty. However, Figure 1 suggests that these correlations are seemingly unstable and that some alternation in the correlation signs occurs from one period to the next.

Table 1. Descriptive statistics and basic tests on return series

Panel A: Statistical proprieties of return series

	Mean	**Std. dev.**	**Skewness**	**Kurtosis**	**JB normality test**	**Auto-correlation test**	**ADF unit root test**
Roil	0.0044	0.0809	-0.395	6.406	94.036***	82.115***	-12.61***
Rdollar	0.0025	0.0131	0.284	3.998	15.640***	99.889***	-12.17***
Repu	0.0007	0.1891	0.329	4.312	50.147***	13.660	-14.38***
Rsp	0.0092	0.0444	-0.901	6.012	22.767***	65.427***	-20.580***

Panel B: Matrix of correlations of return series

	Roil	Rdollar	Rsp	*Repu*
Roil	1.00	-0.2282***	0.0135	0.0409
Rdollar		1.00	-0.175***	0.0204
Rsp			1.00	-0.1923***
Repu				1.00

Notes. Roil, Rdollar, Rsp and Repu denote changes in Brent crude oil prices, the US dollar exchange rate, the S&P 500 stock market index and the economic policy uncertainty index, respectively. **, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.*

3. Empirical results

To investigate the relationships between the variables, we first estimate a VAR model. Given the aims of our paper, VAR models, generalizations of the univariate autoregressive model, are very suitable here as they allow a multivariate representation that helps reproduce interrelations between the variables in the system.

The optimal lag length for the VAR model estimation was determined based on the minimum Schwarz information criterion (SC), Akaike Information Criterion (AIC) and Hannan-Quinn information criterion (HQ) through the VAR estimation. Results showed in Table 2 suggest to retain a lag equal to 1.

Table 2. VAR Lag Order Selection Criteria

Lag	SC	AIC	HQ
0	-12.01597	-12.05494	-12.03953
1	-12.20278*	-12.39762	-12.32056*
2	-12.08926	-12.43997*	-12.30126
3	-11.93023	-12.43681	-12.23645
4	-11.73333	-12.39578	-12.13378
5	-11.57889	-12.39722	-12.07356

Notes. SC is the Schwarz information criterion, AIC is the Akaike Information Criterion and HQ is the Hannan-Quinn information criterion. * indicates lag order selected by the criterion

The results of the estimation of the VAR(1) model are summarized in Table 3 where we also report diagnostic tests of the model residuals.

Table 3. Linear VAR(1) estimation results

	$Roil_t$	$R\$_t$	Rsp_t	$Repu_t$
Const.	0.004	0.0016***	0.009***	0.010
	(0.003)	(0.001)	(0.002)	(0.009)
$Roil_{t-1}$	0.289***	-0.009	-0.020	0.198*
	(0.047)	(0.007)	(0.027)	(0.111)
$R\$_{t-1}$	-0.351	0.369***	-0.141	-0.498
	(0.296)	(0.047)	(0.172)	(0.689)
Rsp_{t-1}	-0.031	-0.003	0.049	-0.946***
	(0.087)	(0.013)	(0.050)	(0.203)
$Repu_{t-1}$	-0.070***	0.001	-0.009	-0.321
	(0.020)	(0.003)	(0.011)	(0.046)
Std Error	0.076	0.012	0.044	0.177

Residual diagnostics

Log-likelihood = 2596.192

Vector Normality Test: Chi^2 (8) = 136.76 [0.0000]**

Vector Portmanteau (12): Chi^2 (176) = 224.71 [0.0077]**

R^2 (LR) = 0.3463

Notes. $Roil_t$, $R\$_t$, Rsp_t and $Repu_t$ denote changes in Brent crude oil prices, the US dollar exchange rate, the S&P stock market index and the economic policy uncertainty index, respectively. *, ** *and* *** *denote statistical significance at the 10%, 5% and 1% levels.*

From Table 3, we learn that the coefficient relating the current return series to the one-lag returns is significant for changes in the oil price and the dollar exchange rate, suggesting some predictability in these markets based on previous returns. More interestingly, the EPU coefficient is significantly negative for oil return series.

However, the findings discussed above show a weakness as they are obtained from the estimation of linear model where parameters are supposed to be constant and thus they do not take into account possible structural breaks and regime changes that may create varying states of uncertainty in a regime-switching environment and affect the studied variables relationships.

To better assess interrelations between our economic variables, we now authorise for nonlinear interactions between their dynamics to account for possible structural breaks and regime changes. We used the Akaike information criterion (AIC) as well as the value of the log likelihood of the model for lags from 1 to 3 for 4 candidate switching regimes models: the two-regime model with constant variance, the two-regime model with regime dependent variance, the three-regime model with constant variance and the three-regime model with regime dependent variance model. Our results suggest that the one lag two-regime dependent variance model gives better results. This one lag Markov switching vector autoregressive MS-VAR(1) model allows us to represent market states in two regimes, where each regime is associated with different mean returns and variances. Table 4 summarizes the main findings from the model estimation and report residual diagnostics.

The log-likelihood ratio test strongly rejects the hypothesis regarding linearity, suggesting that the relationships between the variables studied here are non-linear. The volatility estimates for Regime 1 and Regime 2 are 0.06 and 0.11 for oil, 0.01 and 0.02 for the effective exchange rate of the US dollar, 0.03 and 0.07 for stock markets and 0.16 and 0.28

for EPU, respectively. Thus, these two regimes clearly result in different estimates of volatilities: volatilities are clearly higher is Regime 2 than in Regime 1. We suggest to qualify Regime 1 as low volatility (calm) regime and Regime 2 as high volatility (instability) regime.

In Figure 2, the transition probabilities between the two regimes suggest strong persistence. The calm (low volatility) regime represents 82% of the observations, and the instability (high volatility) regime represents 18% of the observations. As suggested in Figure 2, the high volatility regime mostly corresponds to crash periods.

Table 4. MS-VAR(1) results

			$Roil_t$	$R\$_t$	Rsp_t	$Repu_t$
Regimes characteristics						
Duration	Regime 1	81.93%				
	Regime 2	18.07%				
Volatility	Regime 1		0.058	0.011	0.034	0.159
	Regime 2		0.113	0.016	0.068	0.227
Coefficient estimates						
Const.	Regime 1		0.006*	0.003***	0.015***	0.009
			(0.004)	(0.001)	(0.004)	(0.011)
	Regime 2		-0.006	-0.001	-0.011	0.023
			(0.013)	(0.002)	(0.009)	(0.035)
$Roil_{t-1}$	Regime 1		0.138**	-0.022**	-0.057*	0.248*
			(0.054)	(0.010)	(0.035)	(0.150)
	Regime 2		0.434***	-0.003	0.008	0.210
			(0.109)	(0.015)	(0.070)	(0.219)
$R\$_{t-1}$	Regime 1		-0.083	0.338***	-0.151	-0.254
			(0.285)	(0.052)	(0.177)	(0.806)
	Regime 2		-2.680**	0.375***	-0.505	-1.446
			(1.131)	(0.145)	(0.689)	(2.366)

Rsp_{t-1}	Regime 1	0.005	-0.015	-0.160*	-0.989***
		(0.097)	(0.018)	(0.089)	(0.280)
	Regime 2	-0.468*	-0.003	0.382**	-1.015*
		(0.255)	(0.034)	(0.172)	(0.564)
$Repu_{t-1}$	Regime 1	-0.032	-0.002	-0.003	-0.283***
		(0.020)	(0.003)	(0.011)	(0.051)
	Regime 2	-0.208***	0.011	-0.005	-0.435***
		(0.064)	(0.009)	(0.041)	(0.162)
Std Error	Regime 1	0.058	0.011	0.034	0.159
	Regime 2	0.113	0.016	0.068	0.227

Transition probabilities p_{i|j} = P(Regime i at t+1 | Regime j at t)

	Regime 1,t	Regime 2,t
Regime 1,t+1	0.953	0.191
Regime 2,t+1	0.046	0.808

Residual diagnostics

Log-likelihood = 2673.012

Linearity LR Test: Chi^2 (32) = 7915.2 [0.0000]** approximate upper bound: [0.0000]**

Vector Normality Test: Chi^2 (8) = 11.760 [0.1622]

Vector Portmanteau (36): Chi^2 (576) = 615.86 [0.1214]

Notes. $Roil_t$, $R\$_t$, Rsp_t and $Repu_t$ denote changes in Brent crude oil prices, the US dollar exchange rate, the S&P stock market index and the economic policy uncertainty index, respectively. *, ** *and* *** *denote statistical significance at the 10%, 5% and 1% levels.*

More importantly, the exchange rate, stock markets and EPU seemingly to be not related to oil prices in the low volatility regime. However, their interrelation is significantly negative in the high volatility regime. Thus, the US dollar exchange rate, US EPU and the stock market can be useful in predicting changes in the price of oil during high volatility periods. The link of the US dollar to oil is not significant in the low volatility regime and is negative in the high volatility regime. Changes in the US dollar exchange rate are predicted based on previous oil price changes and previous stock market returns during low volatility periods and on previous stock market returns during high volatility periods. Stock market returns seem to be interrelated to previous oil price changes in the low volatility regime and by previous stock market returns in both low and high volatility regimes. From Column 4, we learn that US EPU depends on previous changes in oil prices and US stock markets. Moreover, EPU dynamics seemingly persist to a degree, and this persistence is stronger during high volatility periods.

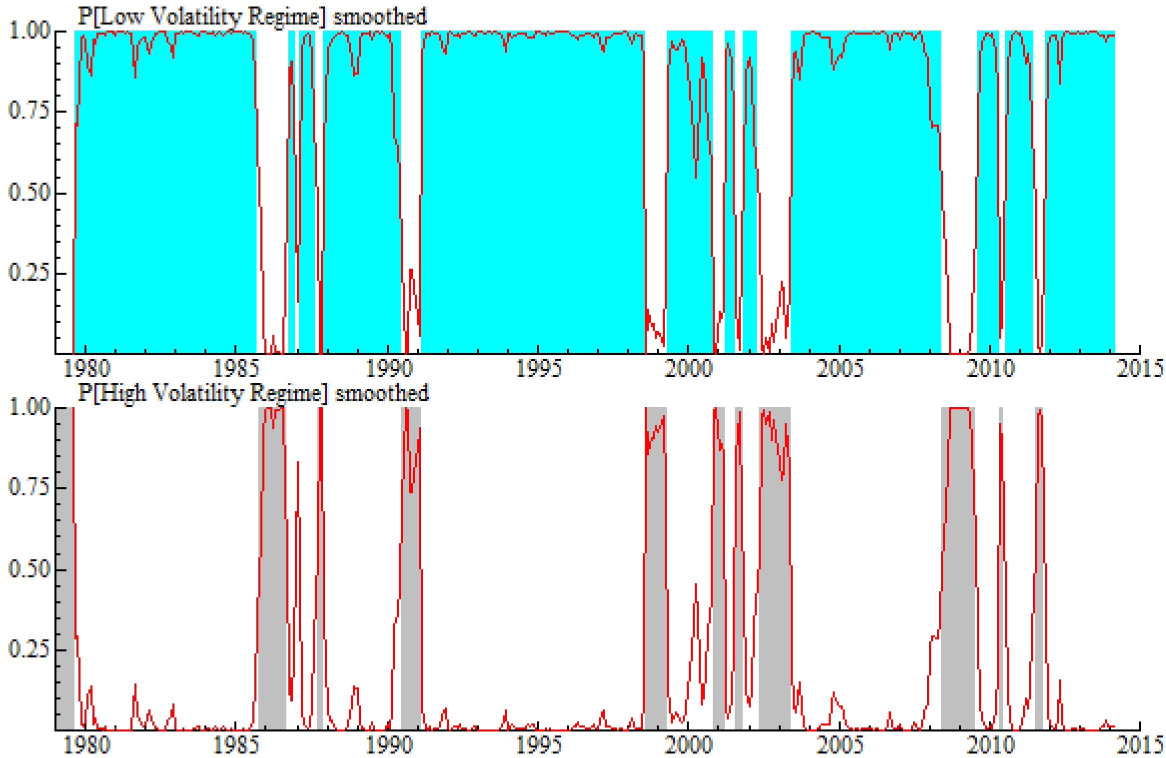

Figure 2. Transition probabilities between the two regimes

4. Conclusion

Theoretically, oil prices, the US dollar exchange rate and the stock markets should be linked. However, the results of previous empirical investigations vary considerably, and drawing a general conclusion regarding their relationships has been difficult. This paper contributes to previous studies on interactions between oil prices, exchange rates and stock markets by considering the effects of economic policy uncertainty. Based on a VAR and a

MS-VAR models, our main findings can be summarized as follows: (i) there are significant interrelations between the studied variables; (ii) the relationships between the variables are rather non-linear; (iii) the links between the variables change from one regime to the next, but they are stronger during high volatility periods; and (iii) oil seems to play an active role in the transmission of price shocks to both the exchange rate and stock markets.

Several future research avenues are possible. First, impulse response functions could be reconstructed by regime to further understand reactions to different shocks across regimes. Second, further empirical investigations should examine whether including EPU and exchange rate changes improves oil price forecasts. Third, this study must be extended to other developed and emerging countries to observe how their stock markets and exchange rates respond to oil price and economic policy shocks. Finally, some linkages can be expected between the US stock market, EPU and exchange rates and the prices of oil-related products and other commodities.

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