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**EXCHANGE MARKET VERSUS OIL AND GOLD PRICES:
AN EUROPEAN APPROACH**

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Abstract

Considering the few studies about the coupled relation between oil and gold prices and the exchange market, the purpose of this article is to explore this line of investigation.

So, combining different approaches on oil and gold prices, stock indexes and exchange market (among others, Dooley, Isard and Taylor (1992), Sadorsky (1999), Park and Ratti (2007), Afshar (2008), Miller and Ratti (2008), Abdelaziz, Chortareas and Cipollini (2008) studies), our model, an unrestricted VAR and a VECM model, mixed all these variables applied to the European market, in order to explain the exchange market variation, from 1999:01 to 2010:05. We innovate by considering both gold and crude prices as explaining variables, differently from the above-mentioned authors, who only consider either gold or crude prices.

Our results suggested that the model explains the long-run relationship between usd/eur and the mentioned variables, being consistent with the results previously found. Differently from the authors mentioned, in our model unrestricted VAR works better than VECM, with a R^2 of 45,66% faces to 34,34%.

Key Words: Exchange rate, crude price, gold price, stock index, and inflation rate.

I - INTRODUCTION

The link between the variables which determines the oil and gold prices variation, and both relation with economic activity, has been investigated in many articles. But, the relation between oil and gold prices and the exchange market has few studies. And this last point is the purpose of this article.

¹In a literature perspective review about modulation applied to oil prices studies, there are a few investigators who received recognition for their work, so being, Hamilton (1983), Jones and Kaul (1996), Huang et al (1996), Sadorsky (1999), and Cinfer (2001).

In particular, Sadorsky (1999) estimated a VAR model and defined several specifications of oil prices: the linear (symmetric) and the non-linear. The non-linear specification is subdivided in other two: the asymmetric and the net oil price increase specifications.

Specifying *linear methodology*, which measures the impact of oil price changes, it is assumed that the increases and decreases effects in oil prices are symmetrical. So, it is expected that oil price increases have a negative impact on economic activity level, and that the decreases have a positive one.

In *asymmetric methodology*, oil price percentage change is decomposed into one variable that represents the positive change (positive impact), and one variable that represents the negative change (negative impact). This specification assumes that an increase in oil prices has a negative impact, but a decrease has a positive impact².

The *net oil price increases approach* measures the difference's impact between current oil price and past period's maximum oil prices, proposed by Hamilton (1996). It is defined as the value by which oil prices exceed its maximum over the previous periods: if the current oil price is higher than the previous periods maximum price, then the percentage change between the two is calculated; if the current oil price is lower than the previous periods maximum price so the difference between both is zero.

¹ See Afshar (2008), "*Oil prices shocks and the US stock market*", and Park and Ratti (2007), "*Oil price shocks and stock markets in the US and 13 European Countries*", for literature review.

² Mork (1989) measure positive and negative impacts in oil price changes while Lee *et al.* (1995) measure positive and negative impacts in oil price volatility.

Afshar (2008), differently from Sadorsky's VAR model specification³, included the variable, net oil price increase. He also extended the Sadorsky's VAR model by incorporating additional variables that can impact the stock market: USD and the consumption spending. These last two variables, coupled with oil prices shocks, reflect many of the concerns and anxieties of the stock market.

⁴ Following oil price volatility methodology studies, Park and Ratti (2007) estimates the effects of oil price shocks and oil price volatility on the real stock returns of the U.S. and 13 European countries. So, they conducted a multivariate VAR analysis, with linear and non-linear specification of oil price shocks.

Generally, linear and nonlinear real oil prices shocks measures, when calculated as the real world oil price, has a greater statistical impact on real return of the real oil price shocks, than measured as the oil national real price. Following this, Park and Ratti (2007) desegregated oil prices variables into several considerations.

They proposed a *VAR model*. The basic model is an unrestricted VAR with four variables: short-term interest rate first log difference (r), oil price shock (op), industrial production first log difference (ip) and real stock returns (rsr) – *VAR* (r, op, ip, rsr). In this model, country suffices are suppressed, and the oil price variable in different VAR systems will be either first log difference of world real or national real oil prices or non-linear transformations of real oil price changes defined as either scaled (*SOP*) or net (*NOPI*) real oil price variables. The ordering of the variables in the basic VAR implies that monetary policy shocks are independent of contemporaneous disturbances to the other variables. This is the ordering in Sadorsky (1999). VAR systems with different ordering and additional variables including oil price volatility and inflation were also estimated.

They also proposed an *alternative VAR specification*⁵. Alternative VAR model specifications must be investigated to check the robustness of the model. So, on the one hand Park and Ratti (2007) places oil price shock ahead of the interest rate in order of the variables. On the other hand, introduced

³ Sardorsky (2006) in his work so called "*Modelling and forecasting petroleum futures volatility*", uses oil prices volatility to address a number of research questions. In this paper he concluded that there is no model that fits the best for each series considered. The TGARCH model fits well for heating oil and natural gas volatility and the GARCH model fits well for crude oil and unleaded gasoline volatility. Simple moving average models seem to fit well in some cases provided the correct order is chosen. Despite the increased complexity, models like state space, VAR and bivariate GARCH do not perform as well as the single equation GARCH model. Parametric and non-parametric value at risk measures were calculated. The results suggest that the non-parametric models outperform the parametric models. In *Appendix* it's possible to find all estimation modulation suggested by Sardorsky (2006).

⁴ See Park e Ratti (2007), "*Oil price shocks and stock markets in the US and 13 European Countries*".

⁵ See in *Appendix* all estimation modulation suggested by Park and Ratti (2007).

inflation (*infl*) as an additional variable into the basic model – VAR (*r, op, ip, rsr, infl*). Park e Ratti (2007) concludes that the finding of statistically significant impact on real stock returns of oil price shocks is not sensitive to reasonable changes in the VAR model.

They also defined *oil price volatility*. To check out the impact of oil price volatility, Park and Ratti (2007) tested VAR models, with and without this variable (Vol_t). On the one hand, Vol_t replaced oil price shock (*op*) in the basic VAR model. They conclude that oil price volatility has a significantly negative impact on the real stock in the most of the countries studied but not for the U.S.. On the other hand, they included Vol_t in the basic model along with oil price shocks. The results were similar to the model estimated without Vol_t .

Summarising, Park and Ratti (2007) suggested that, considering VAR model specifications, it is important to do the following analyses: world real oil price shock, national real oil price shock, alternative VAR specifications, price shock asymmetric effects, oil price volatility, oil price volatility effect, oil price and interest rate shocks, and oil price shocks impact on interest rate.

⁶ In a more recent work, Miller and Ratti (2008) analyze a long-run relationship contribution between crude oil price and international stock markets, using a cointegrated vector error correction model (VECM).

Their basic model includes additional regressors (first-differenced log of interest rates and of industrial production) to control for short-run dynamics between stock market prices and a single international crude oil price and other macroeconomic series. Also Sadorsky (1999), for the U.S., and Park and Ratti (2007), for the U.S. and European countries, consider the influence of industrial production and interest rates first-differences (for each country separately), but do not allow oil and stock market prices long-run interaction.

These authors concluded that a clear negative long-run relationship exists between real stock prices and world oil price until 1998. After this period, this negative relationship is eroded. Such an empirical finding supports a controversial change in the relationship between real oil price and real stock prices in the last decade compared to earlier years, and the presence of several stock market bubbles and/or oil prices bubbles since the turn of the century.

⁶ See Miller and Ratti (2008), “*Crude Oil and Stock Markets: Stability, Instability, and Bubbles*”. In appendix is possible to see all modulation suggested by this authors.

Abdelaziz, Chortareas and Cipollini (2008)⁷, consider the linkage between stock prices, exchange rates, and oil. So, in their paper they analyse the long-run interaction among stock prices and the real exchange rate in four oil exporting Middle East countries using cointegration analysis. They applied the reduced rank regression technique (equivalent to FIML) to estimate a VECM for the whole sample period. This exercise has not produced any evidence of cointegration between stock prices and real exchange rate in the countries under investigation. In line with Phylaktis and Ravazzolo (2005) they argued that this result may be due to the omission of an important variable, which acts as a conduit through which the two markets are linked. Therefore they incorporated additional variables to the system such as oil prices and a global market index (using the US stock prices as a proxy). Again the analysis that focuses on the full sample does not point to any evidence of cointegration. They therefore, shift attention to the possible existence of a regime shift and divide the sample into two sub periods according to the major oil price shock in March 1999 consequent to an OPEC meeting.

Both the reduced rank regression technique and the Quasi Maximum Likelihood approach (robust to non normality and heteroscedasticity in the residuals of the VECM) suggest the existence, in the second sub period, of a long-run equilibrium relationship among the stock prices, the real exchange rates and oil prices for three countries: Egypt, Oman and Saudi Arabia. As for Kuwait both econometric techniques (employed to estimate the VECM coefficients) suggest the existence of a long-run equilibrium relationship between stock and oil prices. They find that, in each country, oil prices have a long-run positive effect on stock prices. They also found that, in Egypt and Oman the real exchange rates are positively related to stock price, while in Saudi Arabia it is negatively related.

Their results indicate that, firstly, the oil price is an important variable, which acts as a conduit through which the real exchange rates and domestic stock prices are linked, so that the oil exporting countries as policy makers in OPEC should keep an eye on the effects of changes in oil prices levels on their own economies and stock markets. Secondly, government policy makers may play a role in influencing real exchange rates and stock prices through the use of oil prices, as the countries in our sample are among the biggest oil producers in the world. Thirdly, the relationship between real exchange rates and stock prices may be useful for portfolio managers interested in global asset allocation or investors trying to hedge against foreign exchange risk. Also the no cointegration among real exchange rates, stock prices and US stock market give the foreign

⁷ M. Abdelaziz, G. Chortareas and A. Cipollini (2008), "Stock Prices, Exchange Rates, and Oil: Evidence from Middle East Oil-Exporting Countries",

investors an opportunity to benefit from that in diversifying their portfolio between the major stock markets like US stock exchange and the emerging markets in the Middle East region.

⁸*In the gold price study field*, Dooley, Isard and Taylor (1992), stood out for its innovation by explaining the financial markets through exchange rates study. Basically, they argued that countries preferences changes should be systematically reflected into the gold price (asset without frontiers, not belonging to any country). Thus, if the monetary shock effects can be isolated, so evidence of gold price residual changes will be able to explain the exchange rates residual changes. These residual evidences can be viewed as indirect evidence that exchange rate changes behaviour reflects the countries preferences.

Dooley, Isard and Taylor (1992) assume the assumption that gold is an asset that does not belong to any country. It can be held outside the tax authority's jurisdiction, and gold return is not considered in country specific uncertainty, which is incorporated in outputs. Any kind of shock that reduces the attractiveness of a particular good A, while the others remaining equal, will increase other assets supply (another B and gold) leading to changes in price market equilibrium. This adjustment will result in a higher price of currency A, face to gold and face to currency B (currency A depreciation face to currency B). The currency B price face to the gold groundedness will increase, or not, depending of the substitution effect impact.

The same authors consider monetary shocks as a shock that have no effect on the relative attractiveness of owning assets in different countries. This includes both inflationary shocks, global and specific, accompanied by a monetary policy response which, essentially, takes constant real expectations of A and B earnings. Such shocks typically lead to nominal interest rate changes and, consequently, the nominal cost of owning gold leads, in turn, to jumps in gold nominal price. Since its purpose is to extract, from the gold price, information that reflects countries preferences changes, the econometric methodology must be able to isolate movements in the gold price that can not be attributed to monetary shocks.

Following the studies of Meese and Rogoff (1983a, 1983b, 1988), Dooley *et al.* (1992) investigated how the exchange rate general specifications remain, when the gold price is added to the set of explanatory variables. They believe that the gold is the most significant explanatory variable for explaining an equation based on the exchange rate logarithmic variation.

⁸ See Dooley, Isard e Taylor (1992), "*Exchange rate, country preferences and gold*".

Following a third line research, Dooley *et al.* (1992) recommend the use of a VAR model. Its research uses VAR modulation to examine the relationship between a long-term exchange rate, the gold price and other variables. They found that, the long-term relationship between the exchange rate and gold price is highly significant, obtaining the expected signal. The estimated cointegrating relationship founded is used to find an error correction equation, and once again, apply forecasting ability tests.

⁹ Differently from Dooley *et al.* (1992), Faugère and Van Erlach (2005) take the gold as a richness source.

Historically, the literature shows a relationship between the gold price and macroeconomic variables, such as inflation and exchange rates. However, little evidence has been achieved between the gold price and other classes of assets. Basically, there is not an appreciation gold theory that shows how inflation, exchange rates or other assets classes affects the gold price; or how gold and other assets classes may be affected by common factors.

Faugère and Van Erlach (2005) demonstrated an empirical and practical connection between gold price, inflation and foreign exchange rate, and the general market assets appreciation. Their approach is based on a generalization of Required Yield Theory (Faugère-Van Erlach (2003)). This theory explains that financial assets valuation, required by general investors to earn a minimum expected, is equal to PIB/GDP per capital growth in the long term. They consider that, since the gold acts as a value store, its income should vary inversely to the yield required for any class of financial asset, providing a roof, if assets where losing value.

The relationship between the gold price and the global macroeconomic variables, such as inflation and exchange rates, are well documented in the literature. However, there are no empirical records sufficiently robust to support the theory that the gold price is related to GDP growth or with other classes, either with inflation or interest rate. (Lawrence (2003)), Coyne (1976), and Sherman (1983), proved the opposite, finding evidence of this relationship.

Following the Barsky and Summers (1988) study, who found an inverse relationship between the gold price log and real interest rate at the time of the gold standard, Faugère and Van Erlach (2005) extended this methodology by taking the gold as a value source (instrument against inflation and loss of value of other assets classes).

⁹ Faugère and Van Erlach (2005), "*The price of gold: A global required yield theory*".

So, considering Park and Ratti (2007), Miller and Ratti (2008), Abdelaziz, Chortareas and Cipollini (2008), Dooley *et al* (1992) and Faugère and Van Erlach (2005) studies, we formulated a model, mixing all the relevant variables pointed out by these authors. We applied this same model to the European market, from 1999:01 to 2010:05, in order to explain the exchange market variation. Differently from the mentioned authors, that just applied or gold or crude prices, we consider both variables in our model. That is our innovation.

We also tested four indexes: NASDAQ, Dow Jones, Standard and Poor's and EuroStoxx 50 indexes. Analysing model's variables correlation, the only index with significant correlation is the Standard and Poor's. In model formulation we only consider this index.

The model was tested following an unrestricted VAR and a VECM modelling.

So being, the model is formulated as follows,

$$\Delta\text{USD/EUR}_t = \Delta C_t + \Delta G_t + \Delta I_H_t + \Delta I_R_t + \Delta I_P_t + \Delta S_P_t + \varepsilon_t \quad [1]$$

where,

USD/EUR_t , where USD is the base currency and EUR is the quote currency. To purchase one USD is need x EUR.

C_t , represents crude price.

G_t , is the gold price.

I_H_t , reflects the homologue inflation rate.

I_R_t , is the European short-term interest rate (three months treasury bill).

I_P_t , reflects the European industrial production.

S_P_t , is the Standard and Poor's index real price.

ε_t , represents an error term.

II –SAMPLE AND DATA

This paper studies the coupled relation between oil and gold prices and the exchange market.

The model was tested using monthly data for euro zone, from 1999:01 to 2010:05.

We also tested four indexes: NASDAQ, Dow Jones, Standard and Poor's and EuroStoxx 50 indexes. Analysing model's variables correlation, the only index with significant correlation is the Standard and Poor's. In model formulation we only consider this index.

The model was tested following an unrestricted VAR and a VECM modelling.

All the variables were calculated by using following equation:

$$\Delta t = \ln(P_t / P_{t-1}) \quad [2]$$

where,

P_t , represents the value on month "t";

P_{t-1} , represents the value on month "t-1".

The methodology initially analysis the Pearson correlations between the model variables, followed by the correlations analysis using the Akaike Information criterion (1974). The methodology also involves the Augmented Dickey-Fuller (1979, 1981) and Phillips-Perron (1988) stationary testing.

If a time series is non stationary, but it becomes stationary after differencing than is said to be integrated of order one, this is, I(1). So, if they are integrated of order one, there may have a linear combination that is stationary without requiring differencing. If such linear combination exists, those variables are called to be cointegrated. During this study, we apply Johansen and Juselius (1990) tests to determine the presence of cointegration vectors in a set of non stationary time series. In order to apply this procedure, Lag length is selected on basis of the Akaike Information Criterium (AIC). This assumes that all variables in the model are endogenous.

This empirical study is based on the economic time series collected from the European Central Bank for: the usd/eur exchange rate, the gold price face to USD, the crude price face to USD, the homologue inflation rate, the european short-term interest rate (three month treasury bill), the european industrial production, and the Standard and Poor's real price stock indexes.

All modelling was carried out using the Eviews 5.0 software.

III – RESULTS

III.1. Model’s variables correlation analyse

The Pearson correlation model’s variables analyse, conclude the results expressed in Table 1.

Correlations coefficients between usd/eur and crude price, oil price, homologue inflation rate, European short-term interest rate (three months treasury bill), and Standard and Poor’s index real price, are significant. However, the correlation coefficient between usd/eur and European industrial production, Nasdaq, Dow Jones and EuroStoxx 50 indexes is statistically insignificant. The results are consistent with Park and Ratti (2007) findings. As already mentioned, these authors applied these variables in the studding of the relation between oil price shocks and real stock returns. Abdelaziz, Chortareas and Cipollini (2008) found strong evidence between stock prices, exchange rates and oil prices. In the same way, Dooley *et al.* (1992) also found a long term relationship between exchange rate and gold price.

Table 1: Model’s variables correlation analyse

	VAR_USDEUR
VAR_USDEUR	1,0000
VAR_CRUDE_USD	-0.207758
VAR_GOLD_USD	-0.430151
VAR_INF_HOMOL	-0.154992
VAR_3M_TBILL	0.174516
VAR_IPROD	0.007342
VAR_NASD_DEF	-0.113200
VAR_DJ_DEF	-0.021015
VAR_SP_DEF	-0.202398
VAR_EUROSTOXX_DEF	-0.010938

Source: Own elaboration, July 2010

III.2. Data stationarity analyse (unit root test)

Correlation analysis, besides being a very useful technique isn’t enough. Therefore, causal nexus among the variables and their direction has been explored by employing bivariate cointegration analysis. Cointegration analysis tells us about the long term relationship between usd/eur and the model’s independents variables, already mentioned.

Cointegration tests involve two steps. In first stage, each time series is examined to determine its order of integration. In second stage, time series is examined for cointegration by using trace statistics and maximum Eigen value statistics.

Therefore our first step is to test the stationarity of variables. For this purpose, we apply the ADF (1979) and Phillips-Perron (1988) at level and at first difference.

Table 2 displays the results, which clearly provide that for some variables, time series are not stationary at level, but the first difference of series variation transformation is stationary. So, series are integrated of order one I (1).

Table 2: Unit Root Analysis

Variables	ADF - Level	ADF - 1st Diff.	PP - Level	PP - 1st Diff.
VAR_USDEUR	-8.290.847	-7.300.713	-8.242.386	-3.803.015
VAR_CRUDE_USD	-9.089.332	-4.842.401	-9.089.332	-4.624.664
VAR_GOLD_USD	-9.385.347	-7.375.867	-1.166.938	-2.602.280
VAR_INF_HOMOL	-4.656.288	-5.753.500	-1.029.133	-3.781.369
VAR_3M_TBILL	-1.020.043	-7.890.658	-9.100.975	-7.006.438
VAR_IPROD	-3.592.695	-5.271.465	-1.061.700	-3.403.715
VAR_SP_DEF	-4.752.880	-7.754.366	-1.048.243	-2.779.456
1% Critical Value	-3.474.874	-3.477.144	-3.474.874	-3.475.184
5% Critical Value	-2.880.987	-2.881.978	-2.880.987	-2.881.123
10% Critical Value	-2.577.219	-2.577.747	-2.577.219	-2.577.291

Source: Own elaboration, July 2010

A Dickey–Fuller test requires that error terms are stationarity independent, and data is homocedastic. Seeing this may be the case with some of the data, we also perform Phillips Perron tests to test stationarity. Table 2 also displays the Phillips Perron results, which confirm the ADF tests results. So, we can conclude that time series are I (1).

III.3. Johansen Cointegration Test

Engle and Granger (1987) pointed out that a linear combination of two or more nonstationary series may be stationary. In this case, the linear combination is called the cointegration equation and may be interpreted as a long-run equilibrium relationship among the variables.

Table 3 exhibits the results of the cointegration tests for sample period.

Table 3: Bivariate Cointegration Analysis

Hypothesized - No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**	Remarks
VAR_USDEUR_ & VAR_CRUDE_USD_					2
None *	0.157300	4.160.201	1.549.471	0.0000	cointegrating eqn(s) at the 0.05 level
At most 1 *	0.111090	1.695.727	3.841.466	0.0000	
VAR_USDEUR_ & VAR_GOLD_USD_					2
None *	0.216925	5.529.119	1.549.471	0.0000	cointegrating eqn(s) at the 0.05 level
At most 1 *	0.130154	2.007.927	3.841.466	0.0000	
VAR_USDEUR_ & VAR_INF_HOMOL_					2
None *	0.291546	6.734.824	1.549.471	0.0000	cointegrating eqn(s) at the 0.05 level
At most 1 *	0.115759	1.771.571	3.841.466	0.0000	
VAR_USDEUR_ & VAR_3M_TBILL_					2
None *	0.214449	5.056.713	1.549.471	0.0000	cointegrating eqn(s) at the 0.05 level
At most 1 *	0.103978	1.580.982	3.841.466	0.0001	
VAR_USDEUR_ & VAR_IPROD_					2
None *	0.128906	2.718.365	1.549.471	0.0006	cointegrating eqn(s) at the 0.05 level
At most 1 *	0.049502	7.310.793	3.841.466	0.0069	
VAR_USDEUR_ & VAR_SP_DEF_					2
None *	0.149720	4.014.538	1.549.471	0.0000	cointegrating eqn(s) at the 0.05 level
At most 1 *	0.110056	1.679.000	3.841.466	0.0000	
* Denotes rejection of the hypothesis at the 0.05 level					
** MacKinnon-Haug-Michelis (1999) p-values					

Source: Own elaboration, July 2010

Table 3 fails to reject the null hypothesis of no cointegration between usd/eur and all the other model's variables for the period from 1999:01 to 2010:05. Trace tests indicates the presence of 2 cointegration equations at 0,05 level between usd/eur and all the other variables individually considered.

III.4. Model estimation results

We tested the model in accordance with the theoretical specification set out in the introductory paragraph of this article, for European market.

While Table 4 compiled the results using an unrestricted VAR estimate, Table 5, show the results obtained with modelling methodology based on VECM.

III.4.1. Unrestricted VAR

Because economic theory is often not rich enough to provide a dynamic specification that identifies all relations between variables, unrestricted VAR approach treats every endogenous variables in the system, as a function of the lagged values of all of the endogenous variables in the system.

Applying our model, the mathematical representation of unrestricted VAR is:

$$\begin{aligned} \Delta USDEUR_t = & \alpha_1 \Delta_{USDEUR}_{t-1} + \alpha_2 \Delta_{USDEUR}_{t-2} + \alpha_3 \Delta_{USDEUR}_{t-3} + \alpha_1 \Delta_{CRUDE_USD}_{t-1} + \\ & \alpha_2 \Delta_{CRUDE_USD}_{t-2} + \alpha_3 \Delta_{CRUDE_USD}_{t-3} + \alpha_1 \Delta_{GOLD_USD}_{t-1} + \alpha_2 \Delta_{GOLD_USD}_{t-2} + \\ & \alpha_3 \Delta_{GOLD_USD}_{t-3} + \alpha_1 \Delta_{INF_HOMOL}_{t-1} + \alpha_2 \Delta_{INF_HOMOL}_{t-2} + \alpha_3 \Delta_{INF_HOMOL}_{t-3} + \\ & \alpha_1 \Delta_{3M_TBILL}_{t-1} + \alpha_2 \Delta_{3M_TBILL}_{t-2} + \alpha_3 \Delta_{3M_TBILL}_{t-3} + \alpha_1 \Delta_{IPROD}_{t-1} + \alpha_2 \Delta_{IPROD}_{t-2} + \\ & \alpha_3 \Delta_{IPROD}_{t-3} + \alpha_1 \Delta_{SP_DEF}_{t-1} + \alpha_2 \Delta_{SP_DEF}_{t-2} + \alpha_3 \Delta_{SP_DEF}_{t-3} + C + \varepsilon_t \end{aligned}$$

[3]

where,

Δ_t is the $\ln(P_t/P_{t-1})$, where P represents the variable's value on month "t", and on month "t-1", **USDEUR, CRUDE_USD, GOLD_USD, INF_HOMOL, 3M_TBILL_, IPROD, SP_DEF** represents the variables (already defined above). Furthermore, the coefficients α_i 's capture the variables coefficients; and ε_t is stationary residuals.

Table 4: Unrestricted VAR Modelling

Vector Autoregression Estimates			
Sample (adjusted): 1999M04 - 2010M05			
Included observations: 134 after adjustments			
Variables	VAR USDEUR		
	Coefficient	Standard errors in ()	t-statistics in []
VAR USDEUR (-1)	0.373851	(0.07387)	[5.06088]
VAR USDEUR (-2)	-0.086101	(0.07780)	[-1.10665]
VAR USDEUR (-3)	0.006343	(0.07504)	[0.08453]
C	0.003018	(0.00177)	[1.70337]
VAR CRUDE USD	-0.053426	(0.02087)	[-2.56015]
VAR GOLD USD	-0.263174	(0.04278)	[-6.15202]
VAR INF HOMOL	-0.006346	(0.00752)	[-0.84326]
VAR 3M TBILL	0.028716	(0.00719)	[3.99576]
VAR IPROD	0.191239	(0.24245)	[0.78878]
VAR SP DEF	-0.122008	(0.03718)	[-3.28183]
R-squared	0.456579	Log likelihood	3.425.971
Adj. R-squared	0.417137	Akaike AIC	-4.964.135
Sum sq. resids	0.047197	Schwarz SC	-4.747.879
S.E. equation	0.019509	Mean dependent	-0.001069
F-statistic	1.157.601	S.D. dependent	0.025554

Source: Own elaboration, July 2010

Analysing the results from unrestricted VAR modelling, the only variables that are statistically significant is the crude (-2,56), gold (-6,15), treasury bill (3,99) and Standard and Poor's index (-3,28). Besides treasury bill, all the significant variables are negatively related with usd/eur. These results reveal that a rise in crude and gold prices leads to a depreciation of usd/eur, on one hand. On the other hand, this fall in real exchange rate affect the economic activity, so a decrease in stock prices is expected. Considering model's robustness, the R^2 found is strong with a value of 45,66%. So, we can conclude that model formulation enplanes usd/eur variation throw crude, gold, inflation, treasury bill, industrial production and standard and Poor's independent variables.

III.4.2. VECM

The VECM is a restricted VAR designed for use with nonstationary series that are known to be cointegrated. The VECM has cointegration relations, built into the specification, so that it restricts the long-run behaviour of the endogenous variables to converge to their cointegration relationships, while

allowing for short run adjustment dynamic. The cointegration term is known as the error correction term, since the deviation from long-run equilibrium is correct gradually through a series of partial short run adjustments.

Applying our model, the equation of VECM is:

$$\begin{aligned} \Delta \text{USDEUR}_t = & \omega_1 \Delta \text{USDEUR}_{t-1} + \eta_1 \Delta \text{CRUDE_USD}_{t-1} + \eta_2 \Delta \text{GOLD_USD}_{t-1} + \eta_3 \Delta \text{INF_HOMOL}_{t-1} \\ & + \eta_4 \Delta \text{3M_TBILL}_{t-1} + \eta_5 \Delta \text{IPROD}_{t-1} + \eta_6 \Delta \text{SP_DEF}_{t-1} + \alpha_{11} (\text{USDEUR}_{t-1} - \delta - \mu_1 \text{CRUDE_USD}_{t-1} - \\ & \mu_2 \text{GOLD_USD}_{t-1} - \mu_3 \text{INF_HOMOL}_{t-1} - \mu_4 \text{3M_TBILL}_{t-1} - \mu_5 \text{IPROD}_{t-1} - \mu_6 \text{SP_DEF}_{t-1}) + \varepsilon_t \end{aligned} \quad [4]$$

where,

Δ_t is the $\ln(P_t/P_{t-1})$, where P represents the variable's value on month "t", and on month "t-1", **USDEUR, CRUDE_USD, GOLD_USD, INF_HOMOL, 3M_TBILL_, IPROD, SP_DEF** represents the variables (already defined above). Furthermore, the coefficients α_{1i} 's capture the speed of adjustment towards to the long-run relationship usd/eur , μ_i capture the cointegrating vector coefficients; and ε_t is stationary residuals.

Table 5: VECM Modelling

Vector Error Correction Estimates			
Sample (adjusted): 1999M05 2010M05			
Included observations: 133 after adjustments			
Cointegrating Eq:	Coefficient	Standard errors in ()	t-statistics in []
VAR_USDEUR_(-1)	1000000		
VAR_CRUDE_USD_(-1)	2927003	(0.69325)	[4.22212]
VAR_GOLD_USD_(-1)	3061424	-139782	[2.19014]
VAR_INF_HOMOL_(-1)	-0.999136	(0.29587)	[-3.37690]
VAR_3M_TBILL_(-1)	1898942	(0.27860)	[6.81607]
VAR_IPROD_(-1)	-4891006	-772461	[-6.33172]
VAR_SP_DEF_(-1)	-0.517169	-126388	[-0.40919]
Error Correction:	Coefficient	Standard errors in ()	t-statistics in []
CointEq1	-0.008517	(0.00985)	[-0.86423]
D(VAR_USDEUR_(-1))	-0.304489	(0.11446)	[-2.66023]
D(VAR_USDEUR_(-2))	-0.236515	(0.11469)	[-2.06221]
D(VAR_USDEUR_(-3))	-0.235688	(0.11285)	[-2.08844]
D(VAR_CRUDE_USD_(-1))	0.014930	(0.03669)	[0.40689]
D(VAR_CRUDE_USD_(-2))	0.009932	(0.03661)	[0.27130]
D(VAR_CRUDE_USD_(-3))	0.032626	(0.02962)	[1.10157]
D(VAR_GOLD_USD_(-1))	0.090008	(0.06511)	[1.38250]
D(VAR_GOLD_USD_(-2))	0.124493	(0.06681)	[1.86348]
D(VAR_GOLD_USD_(-3))	0.064793	(0.06095)	[1.06308]
D(VAR_INF_HOMOL_(-1))	0.006929	(0.01154)	[0.60051]
D(VAR_INF_HOMOL_(-2))	0.012597	(0.01108)	[1.13705]
D(VAR_INF_HOMOL_(-3))	0.010794	(0.00969)	[1.11396]
D(VAR_3M_TBILL_(-1))	7.40E-05	(0.01538)	[0.00481]
D(VAR_3M_TBILL_(-2))	-0.009385	(0.01335)	[-0.70283]
D(VAR_3M_TBILL_(-3))	0.012880	(0.01069)	[1.20473]
D(VAR_IPROD_(-1))	-0.697389	(0.47514)	[-1.46774]
D(VAR_IPROD_(-2))	-1145735	(0.48522)	[-2.36127]
D(VAR_IPROD_(-3))	-0.433937	(0.41129)	[-1.05506]
D(VAR_SP_DEF_(-1))	-0.008556	(0.05270)	[-0.16234]
D(VAR_SP_DEF_(-2))	0.059617	(0.05615)	[1.06176]
D(VAR_SP_DEF_(-3))	0.032678	(0.05068)	[0.64483]
C	0.000277	(0.00228)	[0.12151]
R-squared	0.343456	Log likelihood	3079566
Adj. R-squared	0.212148	Akaike AIC	-4285062
Sum sq. resids	0.075891	Schwarz SC	-3785227
S.E. equation	0.026266	Mean dependent	0.000366
F-statistic	2615641	S.D. dependent	0.029592

Source: Own elaboration, July 2010

In this modelling, the results are not so robust, comparing with the results achieved in the unrestricted VAR modelling.

Industrial production has a negative relation with the usd/eur (- 2,36), and gold has a weak positive relation with usd/eur (1,86). These are the only variables statistically significant.

Concerning R^2 , just like the coefficients found in the previous modelling, this result is also less robust: the R^2 found in this model is 34,34%.

IV – CONCLUDING REMARKS

Considering the few studies about the coupled relation between oil and gold prices and the exchange market, the purpose of this article is to explore this line of investigation.

So, combining different approaches on oil and gold prices, stock indexes and exchange market (among others, Dooley, Isard and Taylor (1992), Sadorsky (1999), Park and Ratti (2007), Afshar (2008), Miller and Ratti (2008), Abdelaziz, Chortareas and Cipollini (2008) studies), our model, an unrestricted VAR and a VECM model, mixed all these variables applied to the European market, in order to explain the exchange market variation, from 1999:01 to 2010:05, differently from the above-mentioned authors, that just applied or gold or crude prices. That is our innovation.

This study shows the existence of correlation between usd/eur and crude price, gold price, homologue inflation rate, European short-term interest rate (three months treasury bill), European industrial production, and Standard and Poor's index real price. But, usd/eur and Nasdaq, Dow Jones and EuroStoxx 50 indexes, although being cointegrated, are poorly correlated.

The results from the unit root procedures indicate that the usd/eur and all the model's variables, mentioned above, are first difference stationary, which is a necessary condition for cointegration analysis. So, performing Johansen cointegration test, it fails to reject the null hypothesis of no cointegration between usd/eur and all other variables for the period 1999:01 to 2010:05.

Both modelling results shows that model is robust and explains long-run relationship between usd/eur and crude, gold, inflation, treasury bill, industrial production and standard and Poor's index. This results are consistent with Park and Ratti (2007), who studied the relation between oil price shocks and real stock returns, Abdelaziz, Chortareas and Cipollini (2008), who found a long-run equilibrium relationship among stock prices, real exchange rates and oil prices for Egypt, Oman and Saudi Arabia, Dooley *et al.* (1992) also found a long term relationship between exchange rate and gold price, and

Miller and Ratti (2008), who found that a negative long-run relationship between crude oil and stock market, after 1998, to six OECD countries was eroded.

Comparing both modelling results, unrestricted VAR has a strong performance, with a R^2 of 45,66% comparing with the 34,34% found in VECM modelling. Differently from Abdelaziz, Chortareas and Cipollini (2008) and Miller and Ratti (2008) which found long-run relationship using a VECM model, in our study, this long-run relationship was found using an unrestricted VAR.

APPENDIX

I - SARDORSKY'S (2006) SUMARIZE ESTIMATION MODELS:

1) Random walk model

From a random walk (RW) model, the best forecast of next period's volatility is this period's actual volatility. The random walk model is used as the benchmark.

$$\delta^2_{t,1} \text{ (RW)} = r^2_t \quad (1)$$

2) Historical mean model

From an historical mean model, the best forecast of next period's volatility is the average of the previous volatilities. This approach assumes a stationary volatility series.

$$\delta^2_{t,1} \text{ (HW)} = (1/1250) \sum_{j=0}^{1249} \delta^2_{t-j} \text{ and } \delta^2_t = r^2_t \quad (2)$$

3) Moving average model

Moving average (MA) methods are widely used in time series forecasting. In this study a moving average of length m where $m = 20, 60, 180$ days is used to generate volatility forecasts. These values of m correspond to one month, three months and six months of trading days respectively. The expression for the m day moving average is shown below.

$$\delta^2_{t,1} \text{ (MA (m))} = (1/m) \sum_{j=0}^{m-1} \delta^2_{t-j} \quad (3)$$

4) Exponential smoothing

Exponential smoothing (ES) models are also very widely used in applied forecasting. In ES models the current forecast of volatility is calculated as the weighted average of the one period past

value of volatility and the one period past forecast of volatility. This specification is appropriate provided the underlying volatility series has no trend.

$$\delta^2_{t,1}(\text{ES}) = \alpha \delta^2_t(\text{ES}) + (1-\alpha) \delta^2_t \quad (4)$$

The smoothing parameter, α , lies between zero and unity. If α is zero then the ES model is the same as a random walk. If α is one then the ES model places all of the weight on the past forecast. In the estimation process the optimal value of α was chosen based on the root mean squared error. The ES model and smoothing parameter are estimated for each forecast horizon using a 20 day, 60 day, 180, and 1250 day rolling window. Exponential smoothing is used to model volatility in Morgan's (1996) Risk Metrics methodology.

5) *Least squares linear regression model*

This model uses an ordinary least squares (OLS) regression model to model volatility by using a one period lagged value of past volatility as a driver.

$$\delta^2_{t,1}(\text{LS}) = \beta_0 + \beta_1 \delta^2_t \quad (5)$$

6) *AR model*

This model uses an autoregressive process to model volatility. Five lagged values of past volatility, corresponding to the average number of trading days in a week, are used as drivers.

$$\delta^2_{t,1}(\text{AR5}) = \beta_0 + \beta_1 \delta^2_t + \beta_2 \delta^2_{t-1} + \beta_3 \delta^2_{t-1} + \beta_4 \delta^2_{t-3} + \beta_5 \delta^2_{t-4} \quad (6)$$

7) *GARCH(1,1) model*

There is now an extensive literature on the use of autoregressive conditional heteroscedasticity (ARCH) (Engle, 1982) and generalized autoregressive conditional heteroscedasticity (GARCH) (Bollerslev, 1986) models applied to financial data (Harris and Sollis, 2003). GARCH models jointly estimate a conditional mean and a conditional variance equation. GARCH models are very useful when analyzing data that appears to exhibit volatility clustering

(which is particularly the case in futures data). The GARCH(1,1) model works well in most applied situations (Bollerslev et al., 1992). The conditional mean equation for the GARCH(1,1) is:

$$r_t = \Pi + \varepsilon_t, \quad \varepsilon_t \sim N(0, h_t) \quad (7)$$

and the conditional variance equation is,

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} \quad (8)$$

The one day forward variance forecast is,

$$h_{t+1} = \omega + \alpha \varepsilon_t^2 + \beta h_t \quad (9)$$

Volatility forecasts are computed using a five-year rolling window. Five years of daily trading data are used to estimate the GARCH(1,1) model and then a daily volatility forecast is made. The process is then rolled forward until all of the data is exhausted. Starting coefficients for the GARCH models are obtained from the Yule-Walker equations. The log-likelihood function was maximized using the Marquardt optimization algorithm.

8) GARCH(1,1) in mean model with variance

In financial markets it is desirable to model expected returns with an explanatory variable that captures risk. Time varying risk premium can be modelled by including some function of the variance as an additional regressor in the conditional mean Eq. (8). This model is the GARCH in mean model with the conditional variance included in the mean equation (Engle et al., 1987).

$$r_t = \Pi + \delta h_t + \varepsilon_t, \quad \varepsilon_t \sim N(0, h_t) \quad (10)$$

9) TGARCH(1,1) model

In financial markets it is often the case that downward movements in the market are followed by higher volatilities than upward movements of the same magnitude (Engle and Ng, 1993). This

asymmetry can be modelled using the Threshold GARCH or TGARCH model of Glosten et al. (1993) and Zakoian (1994). The variance equation is:

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} + \gamma \varepsilon_{t-1}^2 D_{t-1}, \quad (11)$$

where D_{t-1} is equal to unity if $\varepsilon_{t-1} < 0$ and zero otherwise.

10) State space model

State space (SS) models are very useful for modelling and forecasting volatility that is stochastic rather than deterministic (So et al., 1999; Dunis et al., 2001; Yu, 2002). In this paper a fairly simple state space model is specified for volatility and a one period ahead forecast constructed from the estimated model.

$$(r_t)^2 = c_1 z_{1t} + z_{2t} \quad (12)$$

where,

$$z_{2t} = \text{var}(\exp(c_2))$$

$$z_{1t} = z_{1t-1}$$

where r_t is the petroleum futures price return. This model describes an unobserved term with an AR(1) process. This model is similar to a rational expectations model. The variables z_1 and z_2 are the two state variables. Eq. (13) is the signal equation and Eqs. (14) and (15) are the state equations. This model is certainly plausible given the high degree of persistence at the short lags in the squared returns of petroleum futures prices. The log-likelihood function was maximized using the Marquardt optimization algorithm.

11) Bivariate GARCH (BIGARCH)

In a multivariate GARCH model, y_t is a $N \times 1$ vector of dependent variables, μ_t is a $N \times 1$ vector of the conditional means of y_t and H_t is a $N \times N$ matrix of the conditional variance of y_t . The diagonal elements of H_t are the variances and the off diagonal terms are the covariances.

There are a number of different representations of the multivariate GARCH model. The BEKK representation is particularly useful and easy to implement (Engle and Kroner, 1995). In the BEKK representation H_t is almost always positive definite and in the case of $N=2$ and a GARCH (1,1) specification, requires only 11 parameters be estimated. The H_t matrix takes the following form for a multivariate GARCH(p,q) model.

$$H_t = A_0 + \sum_{i=1}^q A^*_{i} \varepsilon_{t-i} \varepsilon'_{t-i} A^{*'}_{i} + \sum_{j=1}^p B^*_{j} H_{t-j} B^{*'}_{j} \quad (13)$$

The matrices A and B are dimension $N \times N$ and contain parameters that need to be estimated by maximum likelihood.

II - PARK AND RATTI (2007) SUMMARIZE ESTIMATION MODELS:

The VAR (r, op, ip, rsr) is given by,

$$Z_t = A_0 + \sum_{i=1}^k A_i Z_{t-i} + u_i \quad (1)$$

Where,

$Z_t = (r, op, ip, rsr)'$.

A_i is a 4x4 matrix of unknown coefficients.

A_0 is a column vector of constant terms.

u_t is a column vector of errors with properties $E(u_t) = 0$, all t, $E(u_t u'_s) = \omega$, s=t, and $E(u_t) = 0$, s \neq t. k will be taken to be 6 for all VAR over the full sample.

The definition of volatility is given by,

$$Vol_t = \sum_{d=1}^{st} (\text{Log}(P_{t,d+1} / P_{t,d}) / \sqrt{st})^2, \quad (2)$$

Where,

$P_{t,d}$ is the spot price crude oil on day d of month t (obtained by NYMEX).

s_t is the number of trading days in month t . An alternative measure of oil price volatility could be given by the sum of squared first log differences in daily futures (1 month) crude oil price.

$$\text{Vol}_t = \sum_{d=1}^{st} (\text{Log} (F_{t, d+1} / F_{t,d}) / \sqrt{st})^2, \quad (3)$$

Where, $F_{t,d}$ is the futures crude oil price in day d of month t (obtained by NYMEX).

III - MILLER AND RATTI (2008) SUMMARIZE ESTIMATION MODELS:

Miller and Ratti (2008) assume the existence of a stock market prices for N countries and a single international crude oil price.

So, z_t denote the $(N + 1) \times 1$ vector of these random variables observed over $t = 1, \dots, T$. The family of VECMs based on those studied by Johansen (1998, 1995) may be written as,

$$\Delta z_t = \Gamma A' z_{t-1} + \sum_{k=1}^{q-1} \Gamma_k \Delta z_{t-k} + Bx_t + \mu d_t + \varepsilon_t \quad (1)$$

Where,

A in an $(N+1) \times r$ matrix of cointegration vectors.

Γ is an $(N+1) \times r$ matrix of error correction coefficients.

Γ_k are $(N+1) \times (N+1)$ parameter matrices.

x_t is a $2N \times 1$ vector containing first difference log interest rates and industrial production for N countries.

B is an $(N+1) \times 2N$ parameter matrix.

μd_t is a generic deterministic term.

ε_t is a normally distributed error term.

Much of the literature on parameter instability in cointegrated models relies on structurally stable cointegrating and error correction matrices, but focuses on structural breaks in the deterministic components of the cointegrating equations and the error correction equations. Gregory and Hansen (1996) developed early tests for stability of both deterministic and stochastic trends, but in non-autoregressive single-equation cointegrating regressions. Stability of deterministic trends in a cointegrated VAR/VECM such as our model has been analyzed by Johansen, Mosconi, and Nielsen (2000), Saikkonen and Lütkepohl (2000), and Lütkepohl, Saikkonen, and Trenkler (2004).

The authors wish to allow a single structural break in the cointegrating and error correction matrices, but not necessarily in the deterministic components. Allowing such a break at known time, reparameterize the model as,

$$\Delta z_t = \Gamma_0 A' z_{t-1} 1\{1 \leq t \leq r\} + \Gamma_r A' z_{t-1} 1\{r \leq t \leq T\} + \sum_{k=1}^{q-1} \Gamma_k \Delta z_{t-k} + Bx_t + \mu d_t + \varepsilon_t \quad (2)$$

where $1\{-\}$ denotes the standard indicator function, taking a value of one if its argument is true and zero if false.

IV - ABDELAZIZ, CHORTAREAS AND CIPOLLINI (2008) ESTIMATION MODEL:

Abdelaziz, Chortareas and Cipollini (2008) focus on four Middle East countries, namely Egypt, Kuwait, Oman and Saudi Arabia. The sample period is monthly frequency and varies for each country depending on the availability of data. For Egypt the sample period is 1994:12-2006:06; for Kuwait 1992:09-2006:02; for Oman 1996:05-2006:05; and for Saudi Arabia 1994:01-2006:04. The data consist of monthly local stock market index of each country, local bilateral spot exchange rates as domestic currency per US dollar, consumer price index CPI, OPEC basket oil prices and S&P 500 index. All the series are expressed in logarithmic form. The real exchange rate is defined as:

$$\ln RER^{MEC}_t = \ln CPI^{MEC}_t + \ln e^{MEC}_t - \ln CPI^{US}_t, \quad (1)$$

where CPI^{MEC}_t , is the consumer price index for the Middle East Country, e^{MEC}_t is the nominal exchange rate and CPI^{US}_t is the consumer price index for US.

To test the **unit root**, Abdelaziz, Chortareas and Cipollini (2008) employ two procedures, augment Dickey- Fuller (1979) (ADF) test and Kwiatkowski, Phillips, Schmidt, and Shin (1992) (KPSS), to determine whether the univariate time series contain a unit root.

To testify the relationship between real exchange rates and domestic stock prices, they represented it by,

$$SP^{MEC}_t = \beta_0 + \beta_1 RER^{MEC}_t + v_t, \quad (2)$$

where SP^{MEC}_t is the domestic stock price, RER^{MEC}_t is the real exchange rate defined as domestic price level relative to foreign prices multiplied by nominal exchange rate and v_t is a disturbance term. All data are transformed by natural logarithms.

They use the real exchange rate instead of the nominal for two reasons. Firstly, following Chow *et al.* (1997) the real exchange rate reflects better the competitive position of an economy with the rest of the world, and secondly the nominal exchange rate of our sample countries has not varied substantially during the period of study. Although they consider the discussion in nominal terms, it should be noted that due to the short-run rigidity of prices, the effect would be similar in real terms.

In order to test for cointegration, they use the Johansen (1988) and Johansen and Juselius (1990) full information maximum likelihood of a Vector Error Correction Model,

$$\Delta Y_t = \Pi Y_{t-p} + \Gamma_1 \Delta Y_{t-1} + \Gamma_2 \Delta Y_{t-2} + \dots + \Gamma_{p-1} \Delta Y_{t-p+1} + \varepsilon_t \quad (3)$$

where ε_t are white noise Gaussian residuals, Γ 's are the lagged of first differences coefficients which capture the short-run effect, Π is the long-run multiplier matrix of coefficients, and in the case of cointegration, is such that $\Pi = \alpha\beta'$ where α represents the speed of adjustment to disequilibrium, while β is a matrix of cointegrating vectors.

To define the VECM model Abdelaziz, Chortareas and Cipollini (2008) explore the presence of regime shifts in the cointegrating relationship in two ways. Firstly, they spill the sample in two sub periods and apply Johansen cointegration method. Secondly, they use the whole sample and

include slope dummies in the VECM which describes the cointegration relationship among stock prices, real exchange rates and oil prices as follows:

$$\Delta SP_t = \omega_1 \Delta SP_{t-1} + \eta_1 \Delta RER_{t-1} + \eta_2 \Delta OIL_{t-1} + \alpha_{11} (SP_{t-1} - \delta - \mu_1 RER_{t-1} - \mu_2 OIL_{t-1}) + \alpha_{21} D_1 (SP_{t-1} - \delta - \mu_1 RER_{t-1} - \mu_2 OIL_{t-1}) + \varepsilon_t \quad (4)$$

$$\Delta RER_t = \eta_3 \Delta SP_{t-1} + \omega_2 \Delta RER_{t-1} + \eta_4 \Delta OIL_{t-1} + \alpha_{12} (SP_{t-1} - \delta - \mu_1 RER_{t-1} - \mu_2 OIL_{t-1}) + \alpha_{22} D_1 (SP_{t-1} - \delta - \mu_1 RER_{t-1} - \mu_2 OIL_{t-1}) + V_t \quad (5)$$

$$\Delta OIL_t = \eta_5 \Delta SP_{t-1} + \eta_6 \Delta RER_{t-1} + \omega_3 \Delta OIL_{t-1} + \alpha_{13} (SP_{t-1} - \delta - \mu_1 RER_{t-1} - \mu_2 OIL_{t-1}) + \alpha_{23} D_1 (SP_{t-1} - \delta - \mu_1 RER_{t-1} - \mu_2 OIL_{t-1}) + \Psi_t \quad (6)$$

where Δ is the first order difference operator, SP_t is domestic stock prices, RER_t is real exchange rate, OIL_t is oil prices and D_1 is dummy variable takes value 0 before Mar. 1999 and value 1 from Mar. 1999 onwards. This dummy specification allows capturing the regime shift due to the oil prices shock in March 1999 after OPEC meeting. Furthermore, the coefficients α_{1i} 's and α_{2i} 's in each equation capture the speed of adjustment towards to the long-run relationship in the pre oil shock and post oil shock regime, μ_1 and μ_2 capture the cointegrating vector coefficients; and ε_t , V_t and Ψ_t are stationary residuals.

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