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REGRESSION ANALYSIS OF GLOBAL DETERMINANTS AFFECTING CRUDE OIL PRICE DYNAMICS: MODELING MACROECONOMIC VARIABLES - (GFVECM)

DAOUD SADALLAH [1,*]

[1] University of Algiers 03, Faculty of Economics (Algeria).

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SUMMARY:

The purpose of this paper is to identify the underlying global macroeconomic variables of crude oil price dynamics, such as consumer price index, financial variables, money supply, world industrial production and interest rates by using Global Factors Vector Error Correction Model (*GFVEC*). The analysis of the observed result indicates a systematic response of oil prices to global variables; meanwhile augmenting interest rates have a reverse effect on oil price shocks. On the other hand, we found that financial variables could explain about 60% of the expected future supply and demand shocks in the physical market. Finally, we confirmed that the development of non-conventional oil and the disregard of declared oil production quota by some OPEC members are relevant sources of oil price fluctuations which can disrupt OPEC vision as the main dominant producer in oil industry.

Keywords: crude market, structural shock, oil price, oil shocks, financial variables.

Jel Classification Codes: B26, C32, Q43, Q47.

ANALYSE DE REGRESSION DES DETERMINANTS GLOBAUX AFFECTANT LA DYNAMIQUE DES PRIX DE PETROLE BRUT: MODELISATION DES VARIABLES MACROECONOMIQUE - (GFVCEM)

SOMMAIRE:

L'objet de cet article est d'identifier les variables macroéconomiques mondiales sous-jacentes de la dynamique des prix du pétrole brut, telles que l'indice des prix à la consommation, les variables financières, la masse monétaire, la production industrielle mondiale et les taux d'intérêt, à l'aide du modèle de correction d'erreur Global Factors Vector (GFVEC). L'analyse du résultat observé indique une réponse systématique des prix du pétrole aux variables globales; dans le même temps, l'augmentation des taux d'intérêt a un effet inverse sur les chocs pétroliers. D'autre part, nous avons constaté que les variables financières pouvaient expliquer environ 60% des chocs futurs attendus de l'offre et de la demande sur le marché physique. Enfin, nous avons confirmé que le développement du pétrole non conventionnel et le non-respect des quotas de production de pétrole déclarés par certains membres de l'OPEP sont des sources importantes de fluctuations des prix du pétrole susceptibles de perturber la vision de l'OPEP en tant que principal producteur dominant de l'industrie pétrolière.

Jel Classification Codes: B26, C32, Q43, Q47.

Mots-clés: marché du brut, choc structurel, prix du pétrole, chocs pétroliers, variables financières.

* DAOUD SADALLAH, daoudsadallah@yahoo.com

1- INTRODUCTION:

After the global financial crisis, several important transformations have taken place in both worldwide economy and the structure of crude oil markets. The growing rates speed of developing economies such as Russia, China and India, including the G5 are now considered the world driving economy with around 70% of global GDP and industrial production. Eventually, aggregate demand for oil has been driven by so-called the association of five major emerging national economies (BRICS) and the expectation of oil supply and demand levels by the financial investors in future oil market.

On the other hand, important changes have also taken place in the global economy in terms of increasing money supply along with the downturns of industrial production for several major economies which is accompanied with low interest rates, in the hope to overtake oil price fluctuations effect on the real macroeconomic variables and enhance economic growth rates. This is what explains G5 and BRICS tending to give big importance to the monetary policies in order to calibrate crude oil prices fluctuation on the national economic variables.

1-1 RESEARCH OBJECTIVES:

This research tries to give an added value in the theoretical approach by exploring systematic relationships between oil prices and macroeconomic factors such as financial and monetary variables in a single model. Therefore, analysis of data estimated in Global Factor Vector Error Correction Model will allow us to measure and explain the reactions of world industrial production, money supply, interest rates, consumer price index and crude oil prices in the short and long period.

Global Factor Vector Error Correction Model is characterized by allowing us to collect several variables in an individual vector by keeping factors independency from a country to another. Thus, granting the analysis of particular effects on emerging markets and developed market separately. The main advantage with Global Factor Vector Error Correction Model is allowing us to measure interactions of a wide range of data implicated in several variables through an estimated time period.

1-2 RESEARCH PROBLEM AND SUN-QUESTIONS:

This study seeks to provide accurate answers about the following main question:

What are the dynamic impacts of global variables on crude oil prices in the future market?

In order to inquire the main problematic, we would suggest the following sub-questions:

1. How the macroeconomic variables respond to the oil shocks?
2. What is the effect of financial investors' expectations on future oil prices?
3. What is the type of causality between oil prices and interest rates?
4. What are the major impacts of oil supply and demand shocks on the economy?

1-3 PREVIOUS STUDIES:

Identifying oil price shocks and their consequences: the role of expectations in the crude oil market, BIS working paper No725, by Takuji Fueki, Hiroka Higashi, Naoto Higashio, Jouchi Nakajima, Shinsuke Ohyama and Yoichiro Tamanyu. Monetary and Economic Department, Bank for international settlements, May 2018. This study tried to establish a new model (structural vector autoregression-SVAR) which combines global supply and demand expectations activities in crude oil market besides global macroeconomic factors, in order to determine their effects on future oil prices. The model results illustrates more than 30% of oil prices changes could be explained by aggregate supply and demand expectations, while oil markets are familiar to be more influenced by supply expectations.

1-4 HYPOTHESES:

In order to study the relationship between selected variables above, we are going to establish the following hypotheses:

1. Tight conjunction between crude oil prices, industrial production and supply of money on an international level.
2. Positive default causality between crude oil prices and worldwide interest rate average, therefore energy prices impact international interest rate.
3. Empirical finding tends to adapt the persuasion of long term high crude oil prices strongly connected to the international supply of money.

1-5- METHODS AND MATERIALS:

The theoretical context of our analysis often attempt to find links between official interest rates declared by the central banks for each country and oil prices. Nevertheless, in the actual approach we presume that official rates of interest at international level and also aggregate demand and supply of money globally might be taking into account in line with oil prices, particularly given the surge in the BRICS economies and the current tends of central banks to influence the economy using monetary tools[1].

In this research we assume that we could contribute to the theoretical context by extending the realities on the strong interaction between international macroeconomic variables and crude oil prices, through different monetary policies of world driving economies as well as declared interest rates, by using Global Factors Vector Error Correction Model $(GFAVEC)$ prediction. This model will attempt to measure interactions between global macroeconomic variables to give us the necessary materials in order to analyze global oil prices tends in the short and long term period.

In our model international agents such as global inflation, industrial production and declared interest rates are forecasted by using techniques of the principal component. Since Brent crude oil prices have been standing up above West Texas Intermediate for a long term in the international oil markets, we consider the use of agent analysis technique for crude oil prices is accurate in our research.

2- FINANCIAL VARIABLES AND FUTURE CRUDE OIL PRICES

Although to crude market forces which often give reasonable descriptions about oil prices dynamics. Financial factor usually plays a key role in exploring our analysis concern sources behind price fluctuations in energy markets. According to different variables in Global Factor Vector Error Correction Model, analysts found that the development of the financial capitalism in oil markets related to oil products is significant[2]. Non-commercial investor activities for oil future delivery manipulate final prices dynamics.

In oil aggregate demand crisis such as the shock of 2008, financial investors have magnified the reaction of oil prices to the changes occurred in global oil demand. Although, financial investors often speculate crude oil in future market, but their shift to the spot markets in 2008 due to their expectations mechanisms, made oil prices uncontrollable during the prices[3]. *GFVECM* model suggests investigating the impact of financial investors' expectations changes on crude prices in order to better understanding the mechanisms in oil markets. See table.1 financial factors and market forces covariance.

Table 1: Financial factor and market forces covariance matrix (%)

year	Financial Factor	Future Demand	Future Supply	Realized Demand shock	Realized Supply Shock	Oil Prices
1	20.7	6.1	10.7	3	0.9	58.7
2	9.9	9.1	26	6.1	0.2	48.6
3	10.7	7.7	26.1	5.9	0.3	48.9
4	12	5.1	27.2	5.5	0.5	49.7

Source: A Pavlova and Basak, S (2017): "A model of financialization of commodities", Journal of Finance, vol 62, p 85.

3- SENSITIVITY ANALYSIS

In order to better analyze structural shocks in oil markets, we consider Global Factor Vector Error Correction Model which take into account a wide range of both structural and external variables in oil markets.

$$y_t = \alpha + \sum_{i=1}^{2} B_i y_{t-j} + e_t$$

In this model:

$$y_t = \left[\Delta rea_t, \Delta rpe_t, \Delta prod_t\right]$$

Shows annual information on crude production ($prod_t$), $\left(e_t\right)$ a residual crude, and the real economic activity of the business cycle is indicated by $\left(rea_t\right)$ and the fluctuation of oil prices in percentage is $\left(rpe_t\right)$. The symbol Ω modeling the variance of $\left(e_t\right)$, in order to measure the range of oil market variable changes and its interactions between themselves[4].

To identify variation average in our model, we employ a long term moving average instead of single matrix which is largely used in specific time period analysis, in order to find a set of orthogonal vector that span in particular subspace Ω and determine the shock modeling $\left(P_k\right)$ as[5]:

$$\Omega_k = P_k{}' P_k$$
$$e_{t+n} = P_k \varepsilon_{t+n}$$

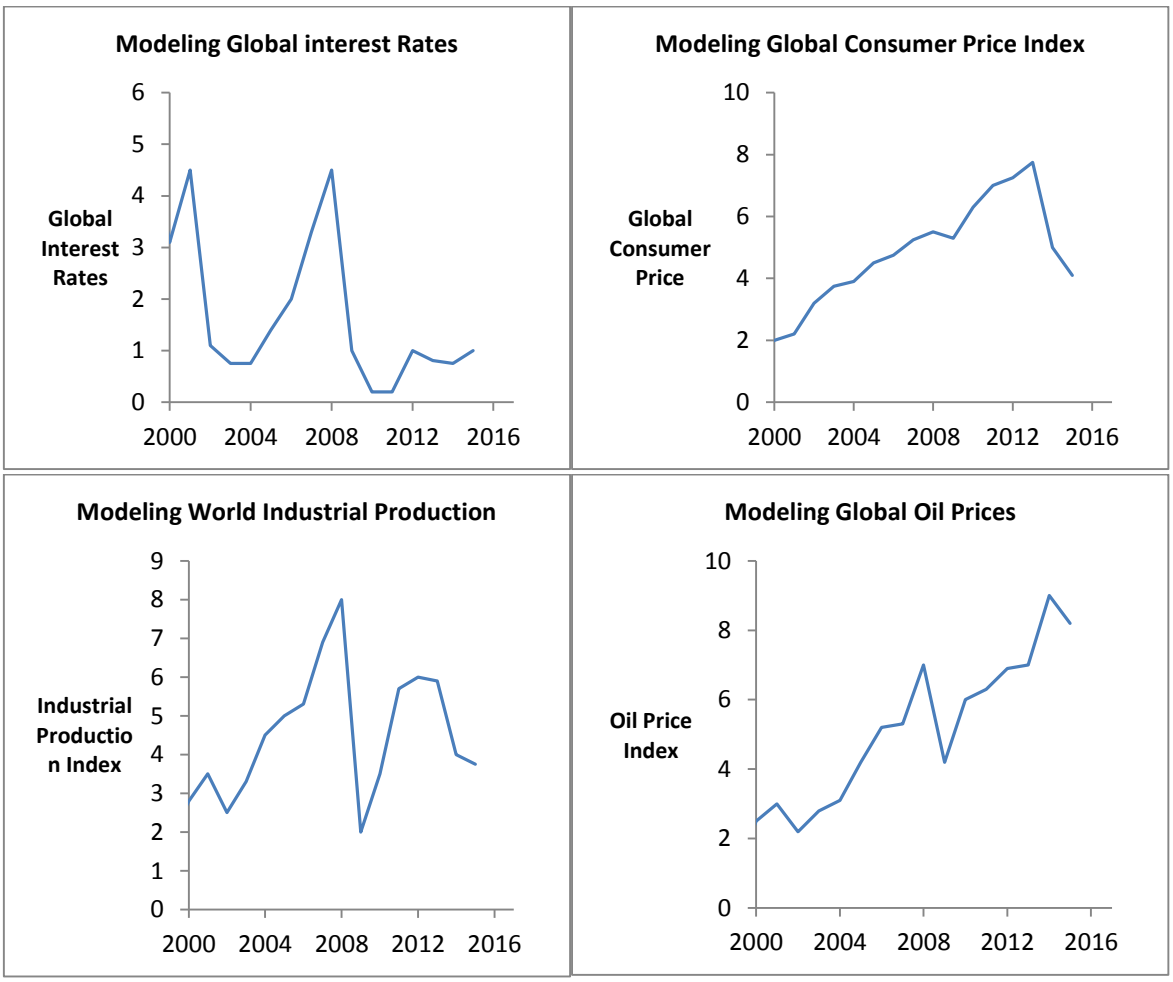
As longer as time period of shocks is too long, we need to admit that relationships between structural variables, such as the residual crude, real economic activity, crude oil production, and energy prices in Global Factor Vector Error Correction Model has been evolved over the long run.

$$e_{t+n} = \begin{pmatrix} e_{t+n}^{\Delta rpe} \\ e_{t+n}^{\Delta prod} \\ e_{t+n}^{\Delta rea} \end{pmatrix} = \begin{bmatrix} P_{k31} & \mathrm{P}_{k32} & \mathrm{P}_{k33} \\ P_{k11} & \mathrm{P}_{k12} & \mathrm{P}_{k13} \\ P_{k21} & \mathrm{P}_{k22} & \mathrm{P}_{k23} \end{bmatrix} \begin{pmatrix} \varepsilon_{t+n}^{residual-shock} \\ \varepsilon_{t+n}^{\mathrm{sup}\,ply-shock} \\ \varepsilon_{t+n}^{demand-shock} \end{pmatrix}$$

Where $\left(n\right)$ indicates time period in years of moving average, $\left(k\right)$ determines number of years in which oil shocks modeling $\left(P_k\right)$ is characterize. Also, $\left(\varepsilon_t\right)$ vector composed of several data such as[6]: demand shock, oil crisis related to global supply, and unexplained oil prices variation of demand or supply shock which is named residual crude oil shock.

Kilian, in his first attempting model version has fixed the value of (b) to the level of zero, and proposed a new short term curve for crude oil supply[7]. Nevertheless, Kilian suggests crude oil supply respond negatively to prices fluctuation and the change of global demand, and assumed that real economic activity has no tangible reaction to changes in oil prices for the short run. Although these hypothesizes seemed logically accepted on short term basis, but they are not reasonable for long term period data. For this reason we utilized Murphy sign-identification method, meaning, instead of fixing the precedent values to zero we determine each of these market variables on basis of economic reasoning: residual shocks, oil demand and supply. For analytical reasons, Murphy has moderate elasticity limits on crude oil supply in order to outlines resulting available models.

Figure.1. Modeling global macroeconomic variables



Source: authers' estimations, data has been collected from bloomberg database, last visit 19 August, 2019 01:30 am.

As economic globalization go on with a high speed during the current decade, including energy markets, might resulting in downward crude oil markets vulnerability to external factors along with the development of large natural gas reserves around the world[8]. Otherwise, such situation could augment of each individual economy's vulnerability to global macroeconomic factors as well as the world record economic growth rates registered during the period extending from 2002-2008, which bring crude oil prices to rise at around 149$ per barrel. We need to argue the positive impact of new energy sources such as renewable energy on stabilizing oil markets. The development of such energy sources should integrate individual economies in order to put out oil markets vulnerability fears and guarantee energy sources diversification and avoid economic demolition.

4- RESULTS AND DISCUSSION:

In the first part of result's discussion, we need to test hypotheses suggested in the main introduction:

1) Tight conjunction between crude oil prices, industrial production and supply of money on an international level.

Empirical findings of the global factors mainly affected by structural oil shocks, using Global Factor Vector Error Correction Model show tight conjunctions between industrial production, global consumer prices index, interest rates and crude oil prices in different world leading economies. These dynamic interactions of oil shocks and global factors are obviously explained by:

$$GIR_t = \left[IR_t^{Euro}, IR_t^{US}, IR_t^{China}, IR_t^{Japan}, IR_t^{India} \right]$$
$$GCPI_t = \left[CPI_t^{Euro}, CPI_t^{US}, CPI_t^{China}, CPI_t^{Japan}, CPI_t^{India} \right]$$
$$GIP_t = \left[IP_t^{Euro}, IP_t^{US}, IP_t^{China}, IP_t^{Japan}, IP_t^{India} \right]$$

Otherwise, the initial principal component for each factor refers to much diversity in each factor though the world leading economies as the following: world industrial production 65%, consumer price index 91%, interest rates 40% and aggregate oil price over 100%.

2) Positive default causality between crude oil prices and worldwide interest rate average, therefore energy prices impact international interest rate.

In addition to conjunctions fact, causality in *GFVEC* model moves from global money supply to crude oil prices, while positive causality goes from global oil prices to interest rates. Which explain the tight integration of global factors (money supply, oil prices and industrial production) therefore energy prices affect international interest rates.

3) Empirical finding tends to adapt the persuasion of long term high crude oil prices strongly connected to the international supply of money.

Weak money supply $M2$ followed with high interest rates can cause significant crude oil price lowering in markets. On the other hand, statistical findings show dramatic increases in oil prices due to augmenting global money supply and industrial production level in the long run.

$$ECT_t = \log\left(GCPI_t\right) - \alpha - \theta \log\left(GIP_t\right) - \delta \log\left(GM2_t\right) \square\ I\left(0\right)$$

The correlation test discloses that frequent synchronism victors equal or under $\left(r,\ \text{error}\right)$ is rejected when $\left(r\right)$ equal to zero at 0.99%, whereas when $\left(r \le 2 \text{ and } \mathrm{r} \le 1\right)$ hypothesis is hard to be rejected until 19% scale. Otherwise the null hypothesis of frequent synchronism victors test in eigenvalue merely be rejected when $\left(r = 0\right)$ meanwhile each suggestions of $\left(r = 1 \text{ or } r = 2\right)$ could not be rejected until 14% scale[9].

Table 1: Modeling global factors (Null hypothesis-Alternative hypothesis)

Field	Rooted Factor (Null hypothesis)	Fixed Factor (Null hypothesis)	Initial Variance	Rooted Factor (Alternative hypothesis)	Not Steady Factor (Alternative hypothesis)
USM2	0.21	1.62*	USM2	-10.08	0.094
EUROM2	-0.49	1.54*	EUROM2	-12.37	0.16
CHM2	0.37	1.62*	CHM2	9.3555	0.74
JM2	-0.12	1.40*	JM2	-11.29	0.12
INM2	-0.98	1.61*	INM2	-8.9	0.2
USPI	-1.08	1.63*	USPI	3.32	0.13
EUROPI	-0.41	1.63*	EUROPI	2.58	0.24
CHPI	-0.17	1.55*	CHPI	2.75	0.3
JPI	-2.25	0.94*	JPI	2.58	0.1
INPI	4.63	1.57*	INPI	3.09	0.72*
USIP	-2.42	0.40*	USIP	3.95	0.07
EUROIP	-2.3	0.43*	EUROIP	2.62	0.11
CHIP	-2.52	1.61*	CHIP	10.35	1.11
JIP	-2.53	0.35*	JIP	18.03	0.06
INIP	-0.75	1.62*	INIP	9.52	0.15
OPD	-2.19	1.54*	OPD	9.81	0.08
OPW	-2.43	1.48*	OPW	9.35	0.1
OPB	-2.29	1.52*	OPB	9.33	0.09

Source: Data and information have been collected from World Bank website, https://data.worldbank.org visited: August 18th 2019 at 19:00 *at the levels of 1.5 to 10% null hypothesis is rejected.

On the other hand, the assessment of OPEC impacts on crude oil prices shows that non-OPEC market suppliers always work to keep moderating real production quotas in line with actual equilibrium prices, while still OPEC reacts as a swing market force to achieve desired equilibrium price. But OPEC capacity to influence crude oil markets and prices is relative to which extend OPEC can play this role respecting members quotas and production capacities. This situation can be determined by so-called cheat equation:

$$\left(\left(\frac{OP^{Pro}}{OP^{Cap}}\times OP^{Quo}\right)\div\left(\frac{OP_t^{Che}}{Aggregate}\right)\right)$$

Empirical analysis illustrates that OPEC role still dominant in oil markets with over 60% of crude oil exports and around 40% of world crude oil production in 2018. We found that some OPEC members were not respecting production quotas roof during the last 7 years. Therefore, we argue that extra crude oil supplies might have negative shock for global oil prices.

Finally, after running Global Factor Vector Error Correction Model on several oil shocks during time period (2000-2018), in order to better estimate future market and financial factors interactions (realized supply and demand, future demand and supply, financial factor and oil price) as this:

$$\begin{pmatrix} e_t^{\Delta prod} \\ e_t^{rea} \\ e_t^{\Delta CF} \\ e_t^{\Delta Stock} \\ e_t^{\Delta Net} \\ e_t^{rpo} \end{pmatrix} = \begin{pmatrix} a_{11} & 0 & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{realized\ \text{supply}} \\ \varepsilon_t^{realized\ demand} \\ \varepsilon_t^{future\ demand} \\ \varepsilon_t^{future\ \text{supply}} \\ \varepsilon_t^{financial\ factor} \\ \varepsilon_t^{oil\ prices} \end{pmatrix}$$

Where (ΔStock) indicates change in crude production capacity, financial factor variations are the net spot in crude futures market and (rpo) real price of oil.

We found that, expected future supply of oil does not positively react to financial factor impacts, although crude oil real price respond to financial factor shocks. Future oil expectations of oil demand and supply could explain 40% of price shocks. Analysis of non-commercial investors in oil market implies that financial variable shocks are structurally connected to the financial investors' activity in future crude oil markets, as well as vulnerability, risks and financial market trends.

5- CONCLUSION:

The results in this paper have clearly shown that official interest rates have played supremacy key role in correlation between global factors and aggregate oil prices. Increases in interest rates are often followed with downward oil prices, while high oil prices put soar pressures on interest rates. Even there are a little official cooperation concern national economic policies due to sovereignty issue; policy makers ought to be full awarded that there is a real link between interest rates and global oil prices.

Macroeconomic factors interact differently depend on the nature of crude oil shock. As far as market conditions forecast plays a major role in determining crude prices levels, it will be very adequate for governments to take into account such harmonies frequency between macroeconomic factors and oil price fluctuations.

Empirical analysis of historical oil shocks determines that oil prices have significant vulnerability upon future market supply predictions. Also, each oil shock affects national economic factors with different intensity based on the nature of the shock and market conditions. Therefore, we recommend being full aware of prices evolution sources in order to better assess their impact on the national economy.

According to our results, it is very useful to policy makers to expand predictions in crude oil markets fluctuations to other financial factors, as well as foreign exchange markets and currency exchange ratios. The actual approaches supplies us with literature evidence on correlation between oil prices and financial variables.

Future researches might implicate future expectations of aggregate demand and supply on different exchange rates and their economic implications.

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