GLOBAL STOCHASTIC APPROACH OF ENERGY MARKETS DYNAMIC: MODELING FUTURE OPEC-PLUS STACKELBERG MARKET STRUCTURE 2020-2030

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Summary: This paper attempts to analyze and determine future transformation of OPEC-Plus Stackelberg market structure, whether from fractional equilibrium where the OPEC behaves as an arbitrageur player, or where OPEC-Plus act as compatible in a Stackelberg crude oil market conditions. We provided a factual evidence of global energy market structure until 2030 that should ignore suppliers' intentions and the potential of OPEC-Plus members cheating in production quotas. We used global dynamic stochastic optimization model (GDSOM) to test the sensitivity of future OPEC-Plus Stackelberg market behavior due to demand elasticity rating of full market competition conditions, oligopoly and dynamic stochastic market conditions. Empirical results show that future OPEC-Plus Stackelberg market does not presents synergy in dynamic stochastic crude market conditions, which does not comply with the main research rational hypotheses.

Keywords: Oil arbitrageurs, OPEC-Plus, Stackelberg market, Cartel, Oil market.
Jel Classification Codes: D52, E32, P48, Q43.

I- Introduction:

Energy economics literatures had raised and answered the problem which has been frequently asked since the 70th until 2019, which is whether the organization of petroleum exporting countries behaves as a monopoly in oil market and exerts its power to influence prices to its members' behalf. Many researches clearly that perfect competition in oil market structure is hard to obtain in line with the cartel roles of OPEC.

On the other hand, the importance of the organization of petroleum exporting countries cannot be overlook in crude oil market, including Saudi Arabia dominant player within OPEC members and Russia in the cartel. Though some researchers argue both KSA and Russia are likely to ignore Stackelberg market conditions rather than suppliers' decisions-making string and potential of cheating in production quotas.

In addition to the arbitrageurs cartel and the current structure of crude oil market that count in the general equilibrium models, in our study we included an independent international factors which have influence oil prices, such as OPEC-Plus Stackelberg market structure and other external global determinants factors like local consumptions, crude production and prices that jointly plays major role for either crude exporters and importers decision-making globally.

I.1. Research problem and sub-questions:

In this study, we will develop a key question in order to investigate and provide detailed explanations. The main research problem is: **To which extend arbitrageurs in energy markets jointly contribute to the optimization of OPEC-Plus basket profits in a Stackelberg market structure?**

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In order to assess the relation between arbitrageurs and OPEC-Plus basket and crude oil market arbitrageurs, we asked the following sub-questions:

1- Does Arbitrageurs in future global Stackelberg oil market structure play a major role in optimizing revenues for oil producers?
2- To which extend global market stochastic optimize oil producers for the next 2020-2030 and how OPEC-Plus members would behave a line with Stackelberg oil market structure?
3- What is the factual reaction of global suppliers in response to market powers within global dynamic stochastic optimization model?
4- What would be the aim of the organization of petroleum exporting countries and OPEC-Plus in Stackelberg market structure?
5- What is the impact of market leader on crude oil suppliers' in future global Stackelberg energy market?

I.2. Research objectives:

This essay tries to leveling local consumption, crude production and crude pricing in the light of oil exporters and importers strategic decisions. Whereas modeling future global Stackelberg oil market structure in order to demonstrate oil sector shape in the new market conditions of dynamic stochastic optimization equilibrium scope.

I.3. Previous research:

There are numerous of academic centers and economists tried to explain future OPEC member states actions within the general crude oil market equilibrium, we had selected two approaches that seems had important approaches related to our essay:

1- Al-Gudhea and Diboogluin (2019) tried to select different suppliers that may be able to overlook cartel strategy of allocating supplies within global oil market. In particular, OPEC members that intend to cheat in supply quotation in the future. Results show that small over-supply from OPEC member states cannot bear any effect on prices and global equilibrium. Otherwise, large scales of cheating within OPEC strategy is not tolerate, and ignites sever OPEC Stackelberg leader reactions.
2- Huettner and Al-hajji (2015) attempt to understand OPEC members' strategy concern oil industry incomes. Results appear that countries with small supplies within the cartel, intend to keep a certain amount of income generated from oil industry activities to inject it within local economy. Hence, such countries' objectives are to generating a given amount of revenue instead of optimizing total profits. By modeling this approach, results confirmed that the organization of petroleum exporting counties aims to act as keep the cartel up rather than revenue optimizations.

I.4. Hypotheses:

Under the assumption of no-price discrimination of crude oil market organizers (OPEC, IEA and arbitrageurs) which result in full crude oil market conditions we could set the following assumptions for our study:

• Arbitrageurs in future global Stackelberg oil market structure find the key for revenue optimization issue along with oil producers.

• Crude oil suppliers are set to the behavior of market leader in which leader moves first and then the follower suppliers move sequentially (Stackelberg). Also, they can predict market organizers actions that are counted as dependent factors.

• A global market stochastic optimization of oil producers for the next 2020-2030.

I.5. Theoretical framework and literature review:

Since non-conventional oil production seemed to have positive response to changes in global energy markets and affecting crude oil markets equilibrium. It can be obviously remarkable from the period extended from 2010 until 2020; shale revolution and production increases in the last 10 years have helped the United States the largest crude oil producer in the world, overhead Saudi Arabia including OPEC and Russia and other petroleum Cartel (OPEC-Plus). The EIA have reviewed its total U.S. crude oil production growth predictions to 2020 to settle to 12.32 million barrel per day. As seen, U.S. oil production levels were the largest in more than 50 years, certainly attributed to tight oil markets during 2010-2020.

Nevertheless, the dramatic increases in global oil production do not mean that non-conventional oil is not expensive or easy to access comparing with the OPEC-Plus producers. Eventually, many researchers concluded that non-conventional oil cost is as higher as conventional oil, and more risky investment in energy field overall, which requires a lot of high tech gears as fleets of truck mounted with high pressure and high-volume pumps and horizontal drilling[1].

On the other hand, general crude oil markets equilibrium continued its imbalance due to future uncertainty of Stackelberg oil market structure and hydraulic fracturing gears and drilling rigs equipment had been largely used in both non-conventional gas and oil investment, due to the large discovery and expansion of non-natural gas since 2003, which requires such equipment in service. But this reached its end by 2009 after the backward of gas prices in global energy market to $2 MMBtu per million British thermal units after it was 6$ (1 MMBtu = 1.055 GJ). This reflected to downgrading gas drilling rigs from 1600 in 2003 to the level of 700 in 2009. Therefore, plans of non-conventional oil might be recovered quickly after prices boom of West Texas Intermediate crude since 2014 which certainly had impacts on general crude oil markets equilibrium[2].

Since drilling operations and equipment can easily be accessed over time, prices fluctuations are actually the main key for OPEC-Plus and other petroleum Cartel investment in production operations till 2030. The average default for non-conventional oil production and investment is approximately 12 months, similarly with the (14000 wells) default associated with oil fields from the period extended from the first oil crisis to 2017. All Bornstein information set is generally distributed; the widest lags supposed to be associated with oil fields in onshore or deepwater which may be call back for recalculate the whole equilibrium factors of future Stackelberg oil market[3].

I.6. Trading entities in oil field

In oil industry, firms pull out crude oil then they distribute petroleum in downstream operations as derivative oil. In global dynamic stochastic optimization model, we distinguish between trading activities (T) and upstream activities (P). While the trading operation exclusively setup for refine, distribute and trades of crudes in oil markets, the upstream operations exercise oil production $\left(Prod_n^p\right)$. Global dynamic stochastic optimization model enables us to distinguishing between trading and production entities in order to understand both situations of oil market[4], either each entity try to optimize autonomously or by combining revenues optimization through the Organization of Petroleum Exporting Countries monopoly, by finding a single entity which purchase all OPEC-Plus outputs and redistribute it aftermath.

I.7. The downstream entity:

The output entity (P) of oil industry arranges to sell their derivative oil to downstream entities (T) in return for a surplus, which is originated from marginal oil cost $\left(\varphi_{t.n}^T\right)$. Production entity intends to optimize their revenues using the following function regarding the cost of production $\left(\mathrm{Cos}\,t_n^P\right)$, which is the identical production cost function used for non-conventional oil suppliers. As we can see in the production operations, companies are subject of material constraints in terms of production volume. $\left(\alpha_n^{\mathrm{Prod}}\right)$ is considered bilateral factor which influence upstream volume $\left(\overline{Cap_n^P}\right)$ that refers to umbra rating price for production capacity[5]. (See table.3) We can express the entire production function for suppliers in the following equation:

$$Max.prod_n^P.\phi_{t.n}^T - \cos t_n^P\left(prod_n^P\right)$$
$$s.t.prod_n^P \le \overline{Cap_n^P}.\left(\alpha_n^{prod}\right)$$

I.8. Crude oil merchandising materials:

The role of merchandising materials in oil markets is narrowing distance which may occur between production operations and final consumption. By transferring oil derivatives from original wells through ship$\left(Ship^{T}\right)$ or pipelines$\left(Flow^{T}\right)$to clients point in order to delivering crude oil to the definitive demand $R\left(Sales_{R}^{T}\right)$. It is obviously that merchandising materials in oil markets aim to optimize their revenues during trading activities. By assuming global dynamic stochastic optimization model enables non-perfect market conditions, if the dealer is called global dynamic stochastic optimization agent. Hence, he can overwork market forces of supply and demand to affect equilibrium prices by forgo intentionally stocks. To build up our model, we added a coefficient$\left(\delta^{T}\right)$ time intended crude price of global dynamic stochastic optimization players'. Therefore, a rate of $\left(\delta^{T}\right)$ equal to zero refers that the agent behaves in perfect complete market conditions. Otherwise, a rate of $\left(\delta^{T}\right)$ equal to (1) indicates that the dealer is global dynamic stochastic optimization player. Hence, global dynamic stochastic optimization model price at point N is calculated by cost of transportation plus pool price of balance $\left(\pi_{i}^{Pool}+TC_{i\to n}\right)$ we can demonstrate the above variables in global dynamic stochastic optimization pricing model in the following equation[6]:

$$\left(\begin{array}{l} Max_{Flow_{t,n,m}^{T}Ship_{t,n.m}^{T}}^{Sales_{t,n}^{T\to R}} \sum_{n\in N}\left[\begin{array}{l} Sales_{t,n}^{T\to R}.\left[\partial_{t,n}^{T}.\Pi_{n}^{R}+(1-\delta_{t,n}^{T}).\sum_{i}\vartheta_{n,i}.\left(\pi_{i}^{Pool}+TC_{i\to n}\right)\right] \\ -\sum_{m\in A(n)} Flow_{t,n\to m}^{T}.TC_{n\to m}^{Pipe}-\sum_{k\in Pt} Ship_{t,n\to k}^{T}-prod_{n}^{P}.\phi_{t,n}^{T} \end{array}\right] \\ s.t.Sales_{t,n}^{T\to R}-prod_{n}^{p}+\sum_{m\in A(n)} Flow_{t,n\to m}^{T}+\sum_{k\in Sea} Ship_{n\to k}^{T}-\sum_{n\in(1)} Flow_{l\to n}^{T}-\sum_{h\in Pt} Shop_{h\to n}^{T}=0,\left(\phi_{t,n}^{T}\right)\forall_{t} \end{array}\right)$$

Where (n)indicates states that could be achieved by pipelines$\left(TC_{n\to m}^{Pipe}\right)$, and$\left(TC_{n\to k}^{Ship}\right)$ refers to oil harbors in all countries. The attitude mathematical value of oil transportation cost is linear mileages for both oil producers and exporters at the same time (See tables 1, 2).

I.9. Future crude oil linear dynamic stochastic optimizations inverse demand function

In oil markets producers transfer oil derivatives to the domestic users via supply chain economics, often through refinery gates(R). As long as our objectives to analyze the effect of crude oil producers market forces and standardize global selling operations of oil, we will exclude upstream activities from our model. Crude oil demand for a given state is standardized as inverse linear demand equation from category of$(DemInt-DemSlp.q)$. In this equation, crude oil demand elements are originated from root market data$(P.Q)$ and suggestions market price changing rates. By formulating price changes $\left(\varepsilon=\frac{y-y^{ref}}{P-P^{ref}}.\frac{P}{Y}\right)$ and including linear inverse demand$\left(DemInt=P^{ref}-b.y^{ref} \text{ while } DemSlp=\frac{P^{ref}}{Y^{ref}}.\frac{1}{\varepsilon}\right)$, the demand functional price could be demonstrated and a price of nearest pool plus transportation cost (pipeline or ship) to the domestic demand$\left(\sum_{i\in I}\vartheta_{n,i}.(\pi_{i}^{Pool}+TC_{i\to n})\right)$.

Under the assumption of no-price discrimination final demand for crude oil is[7]**:**

$$DemInt_n^R - DemSlp_n^R.\left[\sum_{t\in T} Sales_{t,n}^{T\to R} + \sum_{i\in I} \vartheta n_{n,i}.Arbit_{i,n}^{Pool}\right] - \sum_{i\in I} \vartheta_{n,i}.\left(\pi_i^{Pool} + TC_{i\to n}\right) = 0$$
$$\left(\beta_n^{\mathrm{Price}}\right) \forall n \in N$$

Suppliers' price for crude oil is $\left(\pi^{Pool}\right)$ Pool is defined as bilateral to the restrictions $\left(\sum_n \beta_n^{\mathrm{Price}} = 0\right)$ and $\left(Arbit_{i,n}^{Pool}\right)$ is the arbitrageur (see table 4).

I.10. OPEC-Plus's influence on oil market equilibrium

Since the early stages of oil market shocks, several research centers and experts attempts to determine market forces in oil industry which lead to better understanding oil prices. For instance they arrived to results which fall into admitting the prevalent of the OPEC-Plus on oil market segments. The global dynamic stochastic optimization model provides results which are of some importance to industrial economics. It can be shown those prices will not in most cases equal marginal costs. The uses of concept of global dynamic stochastic optimization model in oil markets shown that some producers ignored the other producer's reactions, as a result, dominant producers in OPEC-Plus took the path of oil prices and influence marginal producers (non-OPEC)[8]. In (2010) Hamilton argued that some players in OPEC-Plus cannot be matter of trust in terms of declared oil production, over 7 years OPEC-Plus members were wrong information on their quota which did not complied with their production ceiling.

The major model underlines the Organization of petroleum Exporting Countries as the main structure of monopoly in oil markets. It suggests Saudi Arabia as the key player which fixes oil prices, and warrants other members of the cartel organization to supply additional quantity of oil they desire to sell, in order to balance oil market. Thus, Saudi Arabia plays swing role attempting to absorb short term fluctuations in market demand, in the hope to build up and protect OPEC-Plus interests and build up oil prices monopoly. By using this strategy, OPEC-Plus could monitor energy companies' monopoly on the industry. On the other hand, such approach may give hands to producers outside of OPEC-Plus to take control in oil markets[9]. Therefore, ruin OPEC-Plus strategy as the main dominant producer in oil industry.

$$\left(\left(\frac{OP^{Pro}}{OP^{Cap}} \times OP^{Quo}\right) \div \left(\frac{OP_t^{Che}}{Aggregate}\right)\right)$$
$$OP_t^{Che} = OP^{\mathrm{Pro}} - OP^{Quo}$$
$$PROD^{OPEC} = DEM^{World} + \Delta Stocks - NEGLS^{Natural} - PROD^{Non-OPEC} - PG^{\mathrm{Process}}$$

Where: OP^{Cap} OPEC-Plus Capacity utilization or upstream operation capacity for refining, OP_t^{Che} OPEC-Plus variance meaning difference between OPEC-Plus real market supplies and quotas (cheat rate), OP^{Quo} market production for OPEC-Plus in million barrel per day, OP^{Pro} OPEC-Plus production, while total oil rigs count drilling activity.

In this case, OPEC-Plus cartel interfere a dilemma of how to set a fair price which maximize its profits over the short and long terms. OPEC-Plus can set low prices in order to suspend any inputs or expansion by rivals according to discounts levels. Alternatively it choose to set high prices encourage new rivals to take place in oil market, though, must admit future decline in their profits and market shares to new competitors.

In fact, the decline and non-stable oil supply in several regions in the world, made the swing role of OPEC-Plus overall very important in order to maintain market equilibrium. It is necessary to keep prices stability in the short and long run, which can be asserted by the positive impact of

OPEC-Plus. OPEC-Plus was managing to realize market equilibrium with fair prices and maintain its position as the dominant force in global oil market.

I.11. Future prices and external factors

In this part we are going to measure and analyze the global factors affecting oil markets for the five world leading economies. We could distinguish global factors to: aggregate global monetary supply ($GM2_t$)[10], which indicates liquidity impacts in U.S. dollar, world industrial production (GIP_t), consumer price index ($GCPI_t$), and global interest rate (GIR_t). Where average crude oil prices (GOP) are acquired from data collected based on Brent, West Texas Intermediate and Dubai oil markets. All indexes data are calculated in U.S. dollar.

The precedent global factors world industrial production, global consumer price index and interest rates are the relevant principle leading components for oil prices in energy markets[11] (world largest oil consumption economies: Eurozone, U.S. China, Japan and India), which are given by the following equation:

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

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

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

First equation describes central bank interest rates reductions, the second and third equations describe vectors for the global consumer price index and world industrial production for the previous countries respectively. On the other hand, aggregate crude oil prices average is calculated based on Brent, Dubai and West Texas Intermediate crude oil markets, which is demonstrated as:

$$GOP_t = \left[OP_t^{Brent}, OP_t^{WTI}, OP_t^{Dubai} \right]$$

The global factor concern crude oil price seems to be very clear and appropriate in showing oil prices for the world leading economies than particular Dubai, West Texas Intermediate and Brent prices. Typically crude prices disparity of West Texas Intermediate and Brent were very weak prior the global financial crisis, naturally West Texas Intermediate outstands from Brent. But since 2020 West Texas Intermediate has been trading at a considerable spread to Brent, which reached over 20$ per barrel.

While crude price differentiation for Dubai and Brent have also changed during that period. Basically Brent prices outstand above Dubai crude at 2$ per barrel, but prices spread at the end of 2019 achieved the level of 8.01$ per premium per barrel and settled later in 2020 approximately at 6.60$ premium per barrel.

Changes in crude oil prices premium indicate modifications in crude oil market conditions based on market forces and non-economic components. In order to minimize variables estimation numbers we utilize the global factor for each of the world leading economies presciently cited, which demonstrates changes occurred in aggregate crude oil price, world industrial production, global consumer price index and average interest rates[12].

II– Methods and Materials:

Global dynamic stochastic optimization model (GDSOM) approach for future global Stackelberg oil market structure employs two different oil importing areas and one oil exporting: in which countries use crude oil to produce ultimate goods and services and the remaining balance consumed locally, while exporting the surplus amounts to other regions.

Areas concerned with second hand oil importation also employ it to fulfill domestic consumption instead for ultimate production. Kilian in 2017 assumed in his general equilibrium estimation that negative oil price shocks transmit to economies through active demand of individuals for final merchandises and services instead of crude demand for factories.

Global dynamic stochastic optimization model for future Stackelberg oil market structure has been eventually process to inquire the impact of oil spot market liquidity, market power of organization of petroleum exporting countries and its ultimate decisions on oil production within OPEC-Plus.

III- Results and discussion:

III.1 Hypotheses testing:

Along with the existing explanations of market economics and literatures related to energy economics our study brought a new approach for future Stackelberg oil market structure described by the following tested hypotheses:

• Crude oil market Arbitrageurs jointly contribute to the optimization of OPEC-Plus basket revenues by overtaking market forces, which result in monopoly behavior, meanwhile the rest of suppliers constitute edge market competition.

• All members of the organization of petroleum exporting countries are considered a dominant in future Stackelberg oil market structure that can result various forms of collusion which reduce competition and lead to a dramatic crude oil price elasticity for the next 10 years.

• Most OPEC-Plus producers overtake market forces at global stochastic optimization dynamic model until 2030.

III.2. Result discussion:

According to the empirical findings, it is remarkable that there are an important and sensitive outlines about global dynamic stochastic optimization of future Stackelberg crude oil market structure for the period extended from 2020-2030 that we can highlights as following:

- The model investigates crude oil as systematic merchandise, while disregard features differentiations of supplies on a global level and from a region to another. This appears in empirical results for global stochastic optimization dynamic of OPEC-Plus of 113.16 for demand elasticity of 0.01, comparing to 54.43 results for maximum demand elasticity 0.2 in Stackelberg market future market, with the over identification test $J \sim x^2(dof)$ for 1.281 (3 stages value). In contrast to other structural models that fractioning energy markets future components.
- On the other hand, global dynamic stochastic optimization of future Stackelberg crude oil market structure merely investigates long terms market forces, while neglect demand for crude oil for non-commercial speculations and spot markets, which could never mirror the fact in short run analysis. The annual crude oil demand elasticity rating (0.05 to 0.2) look steadier than average demand sensitivity changes in the short run, considering arbitrageur restrictions $\left(\sum_n \beta_n^{\text{Price}} = 0\right)$ when investigating oil markets turmoil.
- Global dynamic stochastic optimization of future Stackelberg crude oil market structure model might not highlighting an accurate data concern oil market conditions in future Stackelberg components, as it does not consider elements such as future OPEC-Plus arbitrageur effects $s.t. prod_n^P \leq \overline{Cap_n^P}.\left(\alpha_n^{prod}\right)$ and excludes partnership process within the organization of petroleum exporting countries in terms of market power and oil price discriminations $V_t^{OPEC-Plus} = \left[\Delta InW_t^{OPEC-Plus} .... \Delta InW_{t-q}^{OPEC-Plus} .... \Delta InCap_{t-2}^{OPEC-Plus} .... \Delta InCap_{t-q-1}^{OPEC-Plus}\right]$ while arbitrageur restrictions in oligopoly SB of production rating sensitivity is 177.6 comparing to future total Stackelberg market rate of 3025.2.

III.3. Conclusion and future directions:

Nearly all OPEC-Plus suppliers except KSA and Russia pump out close to their full power range, apart in the situation where participants in OPEC-Plus collude with each other in order to improve their profits and dominate Stackelberg market. This goes along with the assumption that members of the OPEC and arbitrageurs in Stackelberg market have high intentions to move away from an appropriated market shares quotation.

Empirical findings assert that KSA and Russia can show different roles with its joint moves, in Stackelberg oil market structure, KSA produces with full market power while Russia often act as global Stackelberg dominant in the future. Hence, it takes advantages from joint integration of supplies and oil price leverages (benefiting from withholding stocks by oil joint cartel). In

Stackelberg market structure leader with the lowest cost in oil market might suspend equilibrium in prefect competition conditions.

Due to Stackelberg market structure in 2020-2030, the cartel are forced to lower future production rates, which is caused mainly where OPEC-Plus strategy are forced by highest cost suppliers (joint cartel) that are definitely non OPEC-Plus members.

However, future global dynamic stochastic optimization decisions in OPEC-Plus enable Russia and Saudi Arabia to supply up to 70% from allocated quotation within future OPEC-Plus basket and produce up to 30% range in oligopoly market conditions. Hence, this empirical analysis confirms that arbitrageurs in future Stackelberg oil market structure still in a predominant spot player in global crude oil marketplace, which can give initiative for further researches concerning future Stackelberg decisions in energy markets and their effects on renewable energy outbreak.

IV- Appendices:

Table (1): Sensitivity test for various elasticity rates: ultimate demand in USD per barrel for OPEC-Plus and OPEC 2020-2030

Demand elasticity		0.05		0.10		0.20	
Demand type		OPEC	OPEC-Plus	OPEC	OPEC-Plus	OPEC	OPEC-Plus
Stackelberg Market Structure	Competition SB	28.45	28.69	25.76	31.06	30.81	35.86
	Competition	28.26	28.96	30.40	31.09	35.10	35.79
	Oligopoly SB	50.90	50.39	36.36	36.13	35.55	34.91
	Oligopoly	84.97	85.45	54.24	54.71	44.56	45.03
	Reference	65.00	59.15	65.00	59.15	65.00	59.15
	stochastic optimization SB	113.16	110.08	73.62	70.67	54.43	55.67
	stochastic optimization	143.25	136.16	88.18	84.75	61.11	59.46
	Cartel	318.31	318.78	157.29	175.76	10.396	104.43

Source: Data collected mainly from: https://www.iea.org/data-and-statistics/data-tables/?country=WORLD&year=2017&energy=Oil, last visit: 19-01-2020 at 23:20.

Table (2): Sensitivity evaluation for various elasticity rates: production of oil in million metric tons 2020-2030

Demand elasticity		0.05			0.10			0.20		
Production type		Russia & KSA	Total OPEC	Total OPEC-Plus	Russia & KSA	Total OPEC	Total OPEC-Plus	Russia & KSA	Total OPEC	Total OPEC-Plus
Stackelberg Market Structure	Competition	541.7	1816.1	3168.5	541.7	1820.2	3240.4	541.7	1820.8	3347.9
	stochastic optimization	266.8	1546.0	2887.5	325.0	1604.2	2957.4	437.1	1716.3	3093.5
	Oligopoly	177.6	1401.1	3025.2	220.4	1494.3	3118.3	344.5	1623.7	3247.7
	Cartel	210.6	817.4	2441.4	23.8	888.6	2512.6	271.3	1029.2	2653.3
	Competition SB	541.7	1817.0	3167.9	541.7	1820.8	3245.6	541.7	1820.8	3356.0
	stochastic optimization	541.7	1798.2	2957.4	541.7	1820.8	3028.2	541.7	1820.8	3137.9
	Oligopoly SB	541.7	1484.6	3108.6	541.7	1633.1	3206.8	541.7	1807.4	3342.1
	Cartel	514.6	1729.8	3272.7	514.6	1729.8	3272.7	514.6	1729.8	3272.7

Source: Data collected mainly from:https://www.iea.org/data-and-statistics/data-tables/?country=WORLD&year=2017&energy=Oil, last visit: 19-01-2020 at 23:20

Tables (3): estimated using alternative global stochastic optimization of OPEC-Plus

OPEC-Plus		OPEC-Plus original Benchmark	OPEC-Plus with entry y& exit
World demand			
$\frac{\partial InQ^w}{\partial InP}$	α_1	-0.352(0.018)	-0.344(0.021)
$\frac{\partial InQ^w}{\partial InY}$	α_2	1.154(0.117)	1.140(0.116)
OPEC-Plus supply			
$\frac{\partial InMC^0}{\partial InQ_0}$	π_1^d	1.545(0.904)	0.805(1.217)
$\frac{\partial InMC^0}{\partial InW_0}$	π_2^d	1.516(0.247)	1.410(0.326)
λ		0.655(0.035)	0.642(0.038)
Alternative production			
$\frac{\partial InQ^{at}}{\partial InP}$	β_1	0.322(0.034)	0.564(0.364)
$\frac{\partial InQ^{at}}{\partial InW^{at}}$	β_2	-0.758(0.372)	-0.864(0.364)

Source: The optimization benchmarks standardized errors are shown in parenthesis.

Stochastic optimization		Dominant arbitrageurs Stackelberg NLIV			Competitive arbitrageurs Stackelberg 3SLS
World demand					
$\frac{\partial InQ^w}{\partial InP}$	α_1	-0.352(0.01)			
$\frac{\partial InQ^w}{\partial InY}$	α_2	1.154(0.117)			
OPEC-Plus supply					
$\frac{\partial InMC^0}{\partial InQ_0}$	π_1^d	1.545(0.904)	$\frac{\partial InQ^0}{\partial InP}$	π_1^c	0.194(0.083)
$\frac{\partial InMC^0}{\partial InW_0}$	π_2^d	1.516(0.247)	$\frac{\partial InQ^0}{\partial InW^0}$	π_2^c	-0.183(0.17)
λ		0.655(0.035)			
Alternative production					
$\frac{\partial InQ^{at}}{\partial InP}$	β_1	0.322(0.034)			0.076(0.018)
$\frac{\partial InQ^{at}}{\partial InW^{at}}$	β_2	-0.758(0.37)			0.392(0.107)
Over identification test $J \sim x^2(dof)$					
$J - statistic$		1.281			1.437
Degrees of freedom		31			23

The survey test reports estimates of Stackelberg market forces index λ and elasticity sensitivity for the dominant arbitrageurs using alternative definitions of OPEC-Plus: dynamic status see EIA.(2019) and adjusted for entry and exit see OPEC-Plus.(2019).

Table (4): Estimates for the dominant arbitrageurs' Stackelberg market and stochastic optimization

Source: Using three stages squares (3SLS) evaluation. The predetermined exogenous factors used in stochastic optimization model are $V_t^w = \Delta InY_t....\Delta InY_{t-q}$ the future OPEC-Plus demand equation $V_t^{OPEC-Plus} = \Delta InW_t^{OPEC-Plus}....\Delta InW_{t-q}$ otherwise OPEC-Plus future supplies are $V_t^{OPEC-Plus} = \left[\Delta InW_t^{OPEC-Plus}....\Delta InW_{t-q}^{OPEC-Plus}....\Delta InCap_{t-2}^{OPEC-Plus}....\Delta InCap_{t-q-1}^{OPEC-Plus}\right]$ .In the dominant arbitrageurs shares of Stackelberg market in OPEC-Plus. The distribution critical value of with 31 degrees of freedom at the 73% market Stackelberg shares.

V- Referrals and references:

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