Modeling Dynamics of Expectations on Global Oil Price

Mohammadhussein Rafieisakhaei[1], Babak Barazandeh[2], Mahdi Boloursaz Mashhadi[3] and Seyed Mohammad Asadzadeh[4]

[1]Department of Electrical and Computer Engineering, Texas A&M University
[2]Department of Industrial & Systems Engineering, Virginia Tech
[3]Advanced Communications Research Institute (ACRI), Sharif University of Technology
[4]Department of Industrial Engineering, University of Tehran
[1]*mrafieis@tamu.edu*

***Abstract*— The global oil price is considered as one of the most significant factors in the global trade market. This is due to the fact that many of the macro and micro-economic variables on both sides of the oil trade are heavily dependent on the global oil price. The stochasticity of the market makes it extremely difficult to predict the exact amount of the price. The main reason is that, unlike many other markets, the unconventional nature of the oil market is not merely determined by the total demand and supply. In this paper, we introduce a novel approach that models the impacts of parameters other than demand and supply on the oil price and we call them as expectational variable and parameters. As observed by simulations and results, some of these parameters can impose sharp and drastic price changes in a rather small time period while the total demand and supply remain unchanged.**

I. Introduction

Price of oil as a commodity is determined by the demand and supply like any other commodity in a free market [Abel et al., 2008]. This correct but inaccurate statement cannot solely explain the drastic changes in the oil price as has happened for several times in its history. Figure 1 shows the West Texas Intermediate (WTI) index oil price history taken from [Company, 2015]. As it is seen in this figure, there are periods of times where the oil price has changed drastically whereas according to the market's data, the supply and demand have either not changed or have not changed so much that could explain the price changes. The reason is that, supply and demand are rather inelastic and cannot change so much in a short period of time. This shows that other than demand and supply forces, there are hidden mechanisms that can affect the oil price usually much faster than the demand and supply themselves [Chevillon and Rifflart, 2009], [Kilian, 2014].

Traditional oil market models have been successful in predicting and explaining the oil price [Sterman et al., 1988]. However, many of them have failed to capture the causes and reasons in unexpected scenarios that the oil market usually faces. This is the main reason for some of the behavior in the oil price which surprise the researchers and people in the market. In fact, this is why each time that there is a big shock in the market, many have failed to predict the market behavior or have described the behavior as unexpected and unpredictable. For instance, whenever there is a case of conflict or upheaval in the Middle-East region,

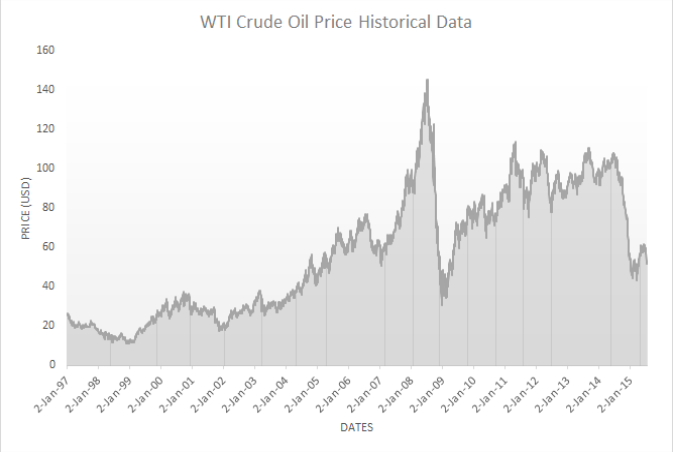

Fig. 1. WTI oil price history.

the oil price usually hikes up due to the expectations on the reduction of the production [Campbell and Laherrère, 1998], [Rafieisakhaei and Jabbari, 2012]. Even though the actual reduction in the production occurs much later or even some times it does not occur at all. This means that those kinds of events can increase the oil price volatility and therefore making it more difficult to predict the market through the conventional models [Askari and Krichene, 2008], [Krichene, 2006].

The other important notion is that variety of resources in the oil production both regionally and in time [Nehring, 1978]. For instance, US oil production has increased by 70% since 2008, which has caused a significant reduction on their imports form the Organization of Petroleum Exporting Countries (OPEC) [Krauss, 2015]. According to the International Energy Agency (IEA), the OPEC data show that the average production has increased from 29.81 to 30.52 mb/d since the forth quarter of 2014 till the first quarter of 2015, whereas the total world oil supply has increased from 91.89 mb/d to 94.34 mb/d [IEA, 2015].

On the demand side, we categorize the importers into two main sides. In one hand, the emerging markets like Russia, India, Brazil, and China (RIBC) and their highly growing economies are heavily dependent on oil consumption [Chazan, 2015]. On the other hand, in the European

Union and United States (EUS) the oil dependency has not increased significantly relative to the RIBC countries. More important, there have been policies on limiting the pollution and air emission which has prevented the uncontrolled increase of fossil fuel consumptions [Roe et al., 2001].

Therefore, the factors enforcing the oil price are more than just the aggregated demand and supply. In this paper, we propose a system dynamic model [Sterman, 2000] that tries to capture some of the parameters and variables that are specially involved in determining the oil price other than just the aggregated demand and supply. We separate the Total Oil Demand into three different categories of the demand by EUS, RIBC and the other countries. Moreover, the supply resources are categorized as OPEC, US, spare oil supply, smuggled oil production, and the production by other countries. The model structure significantly captures the new parameters. Particularly, we introduce two variables named as "Expectation on The Demand Side" and "Expectation on The Supply Side" to capture the unconventional factors. These variables act as amplifier or suppressor of the demand and supply in our model. We propose the model and its causal loops in section II, and proceed to simulation scenarios in section III. Finally, section IV brings the concluding remarks and future works.

II. Causal Loops

In this section, we provide the main causal loops. Figure 2 provides the main causal loops of the model that involves the main variables in determining the oil price.

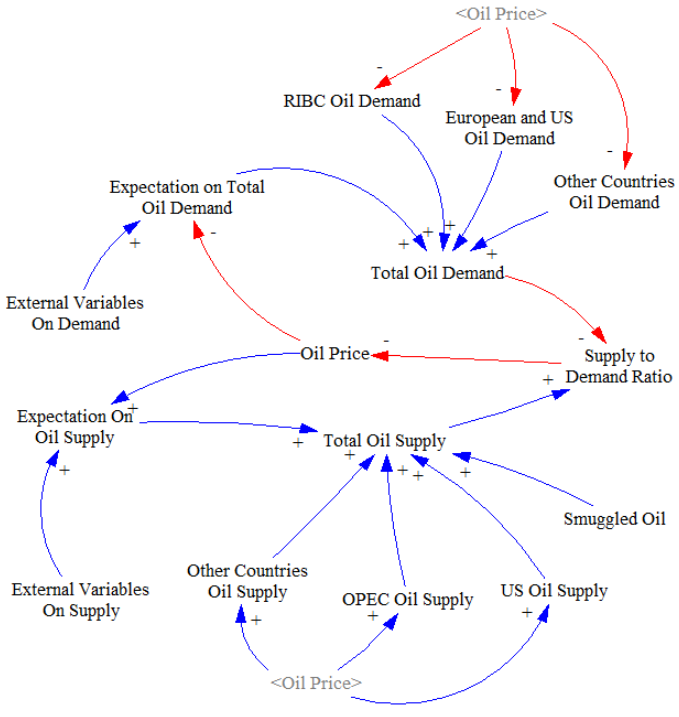

Fig. 2. The main loop and the sign of its arrows.

Main causal loop: The main components of the core structure consists of 'Total Oil Supply', 'Total Oil Demand', 'Supply to Demand Ratio', 'Expectation on Oil Supply' and 'Expectation on Oil Demand' that determine the 'Oil Price' in interaction with other variables. Note that the External Variables that are indicated in the figure, reflect many other variables specially those related to the expectational variables that are explained more in the next parts of the paper.

Expectational variables and the Oil Price: In our model, it is only Supply to Demand Ratio that can directly affect the Oil Price. In other words, in our model, it is only through the supply to demand ratio that all the other factors can affect the oil price. As shown in Fig. 2, the Expectational variables either boost or suppress the total demand or supply. That is, they are two coefficients that amplify the effects of the supply or demand changes on the price. These coefficients are determined in the model in their corresponding loops. The main concept behind this simple idea is that in any case that there is a change in the Expectation on Demand, if such a change is a positive expectation, the oil price increases. In other words, it is as if the demand has already increased (although it might be very small). On the contrary, in a case that there is a negative expectation on the demand growth, the oil price decreases. The oil price response is similar to the situation where the demand itself has slightly decreased. Even though, due to the inelasticity, the actual demand might not change for a while, these expectations change the price much faster than the actual changes. In fact, in some cases, the actual change never occurs, and the expectations prove to be wrong. In such a case, the oil price adjusts itself after the actual data arrives or source of expectations disappear. Moreover, the changes in the expectations affect the oil price in the same direction that the demand affects the price. The same line of reasoning applies for the supply, as well. Therefore, we model all these variables as the expectational variables and aggregate their interacting effects on the 'Expectation on the Oil demand' and 'Expectation on the Oil Supply' variables, which are multiplied in the demand and supply, respectively, to amplify or suppress the effects of the actual demand and supply on the oil price.

Main factors in the Supply side: The 'Total Oil Supply' consists of the 'OPEC Oil Supply', 'US Oil Supply', 'Other Countries Oil Supply', 'Smuggled Oil Supply', and 'Spare Oil Supply'. The Smuggled Oil Supply [Africaecon, 2015] reflects the oil production oil in the regions with political conflicts or regional upheavals where the central governments of the producing countries have lost their political authority over those oil producing regions of the country. For instance, in 2014, the smuggled oil production in Syrian and Iraqi regions, where their governments had no control, was approximately 600,000 barrels a day [Taştekin, 2015], [Herbert, 2014].

Main factors in the Demand side: The 'Total Oil Demand' includes the 'EU and US Oil Demand', 'Russia, India, Brazil, China Oil Demand' and the 'Other Countries Oil Demand'. As we mentioned in the introduction, we have separated the RIBC oil demand from the EU and US demand because of the different nature of their economic growths including

their dependencies on the oil consumption, which is higher and increasing in the RIBC side [Birol, 2010]. One important factors that had many adverse effects in the demand side was the Economic Depression that occurred in the 2008. Other than the actual demand, the economic depression affected the expectation on demand for many months after it occurred. Our model includes a factor that captures these effects, as well.

Now that we have elaborated the main causal loops in the model, we are ready to bring the results corresponding to some scenarios. The next section talks about these scenarios in detail.

III. Simulations and Scenarios

In this section we simulate some scenarios using Vensim PLE 6.3 [Vensim, 2013] and bring their corresponding results to support our model. In each of the scenarios, some specific circumstance that can happen in the oil market have been investigated and the corresponding oil price changes have been reflected. Our simulations involve the cases where the parameters on the expectation on either demand or the supply side changes and the results are reflected in the oil price.

A. Low RIBC Economic Growth

In this subsection, we investigate a case where the economic growth of the RIBC countries has dropped and those countries are not productive as expected.

RIBC Low Economic Growth: In the late 2014, the economic growth of China was less than predicted. This causes an speculation on the future oil demand. Consequently, the oil price reduces due to the expectation that the demand will be less than that of previous prediction. We have investigated such a case in this scenario and the Fig. 3 reflects the result.

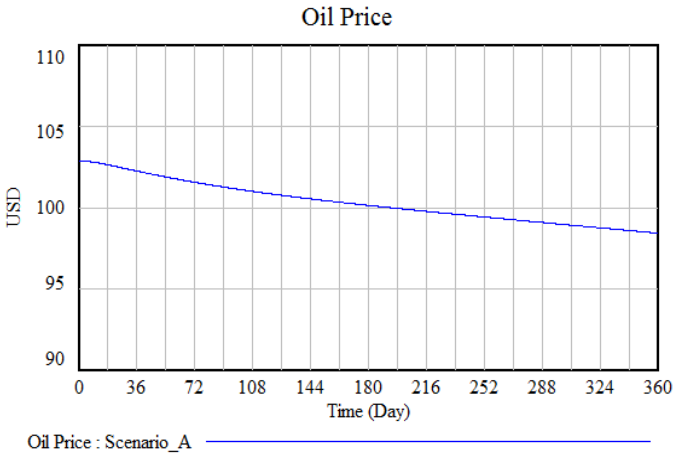

Fig. 3. The Oil Price changes in Scenario A, outputs shown from Vensim.

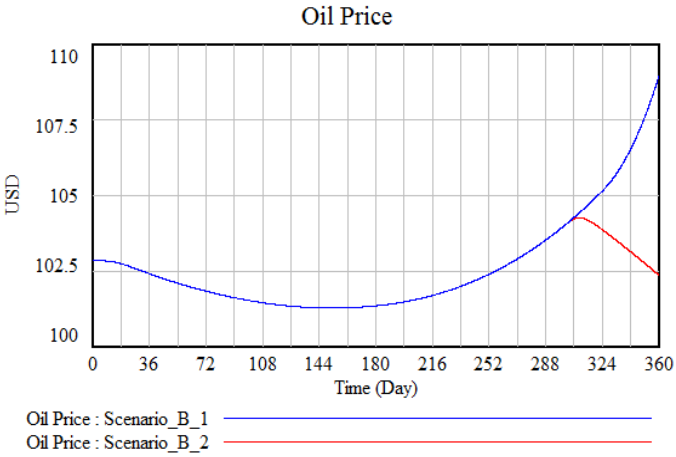

Fig. 4. The Oil Price changes in Scenario B, outputs shown form Vensim.

B. Sanctions on the Production and OPEC's Decision

In this subsection, we simulate a scenario where the sanctions on the oil producers has caused a reduction in their production.

International Sanctions: The international community can decide to establish economic sanctions on oil producing countries. There are many instances of those cases in the history of oil production. For instance, as mentioned before in the 90s, there were heavy economical sanctions on Iraq which had infected their economies with lots of problems. Over the past two years, there has also been many economical sanctions on Iran (as an OPEC member), which has limited their oil sales and production. These kinds of sanctions have many adverse effects on the economies of the under sanctioned countries. However, in all of these cases, the effect of sanctions is clear. We have reflected the results of sudden introduction of a sanction on one of the OPEC producers in Fig. 4. In the simulation, we have assumed a sudden placement of sanctions on one of the producers (at time 10) whose effects leads to a shortage in the supply with a reasonable delay, consequently giving an increasing rate to the oil price. Moreover, the OPEC's Decision (which reflects the OPEC's Decision on keeping the oil production unchanged or not) is still zero which simulates a case that the OPEC countries have not yet decided on compensating the supply shortage. If they continue their policy, the price will keep on growing as shown in the Scenario B_1. This is mainly due to the fact that the sudden reduction in the oil production of one the countries cannot be compensated by the usual growth of the oil supply, and it only needs the introduction of spare oil reserves. Therefore, if the OPEC countries decide to compensate for the supply shortage (using their spare reserves after some bigger delay at time 300) the oil price will start to reduce as shown in Scenario B_2. The mechanism for these reduction and growth are as explained in the previous section through the supply and its corresponding expectation loops.

IV. Conclusion and Future Work

In this paper, we reviewed the parameters and variables that play an important role in determining global oil price. We explained some of the factors that can change the oil price. Some of these variables including the several supply or demand factors affect the oil price directly. On the other

hand, there are many other factors that can drastically change the oil price while the supply to demand ratio is relatively unchanged. This shows that the oil price is not merely determined by the supply to demand ratio. Rather, the expectations on the directions of changes in the demand and supply can actually change the price much earlier and in some cases even sharper than the actual change itself which may not even occur. We proposed a model that mathematically elaborates the effects of these expectations on the oil price. Particularly, we modeled them as amplifying or suppressing the actual demand and supply by some percentage. Moreover, we provided some scenarios in the oil market and simulated the model to reflect the oil price response to any specific factor that was changed in each scenario. Since the oil market still shows new unexpected behavior, there is still a need to provide updated models to reflect the new parameters and variables that might be introduced in future, and we hope that our future works can reflect some of these changes.

REFERENCES

[Abel et al., 2008] Abel, A. B., Bernanke, B. S., and Croushore, D. (2008). *Macroeconomics (6th edn)*. Boston: Pearson Education.

[Africaecon, 2015] Africaecon (2015). Africa economic institute : Nigeria and oil smuggling. *Africa Economic Institute*.

[Askari and Krichene, 2008] Askari, H. and Krichene, N. (2008). Oil price dynamics (2002–2006). *Energy Economics*, 30(5):2134–2153.

[Birol, 2010] Birol, F. (2010). World energy outlook 2010. *International Energy Agency*.

[Campbell and Laherrère, 1998] Campbell, C. J. and Laherrère, J. H. (1998). The end of cheap oil. *Scientific American*, 278(3):60–5.

[Chazan, 2015] Chazan, G. (2015). Oil demand shifts to emerging markets - ft. *Financial Times*.

[Chevillon and Rifflart, 2009] Chevillon, G. and Rifflart, C. (2009). Physical market determinants of the price of crude oil and the market premium. *Energy Economics*, 31(4):537–549.

[Company, 2015] Company, D. J. . (2015). Spot oil price: West texas intermediate (discontinued series) (oilprice). `https://research.stlouisfed.org/fred2/series/OILPRICE/downloaddata`. [Online; accessed 13-July-2015].

[Herbert, 2014] Herbert, M. (2014). Partisans, profiteers, and criminals: Syria's illicit economy. *Fletcher F. World Aff.*, 38:69–213.

[IEA, 2015] IEA (2015). Iea - oil market report public. *Iea.org*.

[Kilian, 2014] Kilian, L. (2014). Oil price shocks: causes and consequences. *CEPR Discussion Paper No. DP9823*.

[Krauss, 2015] Krauss, C. (2015). U.s. oil prices fall below $80 a barrel. *Nytimes*.

[Krichene, 2006] Krichene, N. (2006). *Recent dynamics of crude oil prices*. International Monetary Fund.

[Nehring, 1978] Nehring, R. (1978). Giant oil fields and world oil resources. Technical report, RAND Corp., Santa Monica, CA (USA).

[Rafieisakhaei and Jabbari, 2012] Rafieisakhaei, M. and Jabbari, M. (2012). Modeling the impacts of middle east and north africa unrest on the global oil price. In *The 30th International Conference of the System Dynamics Society*, St. Gallen, Switzerland.

[Roe et al., 2001] Roe, B., Teisl, M. F., Levy, A., and Russell, M. (2001). Us consumers' willingness to pay for green electricity. *Energy policy*, 29(11):917–925.

[Sterman, 2000] Sterman, J. D. (2000). *Business dynamics: systems thinking and modeling for a complex world*, volume 19. Irwin/McGraw-Hill Boston.

[Sterman et al., 1988] Sterman, J. D., Richardson, G. P., and Davidsen, P. (1988). Modeling the estimation of petroleum resources in the united states. *Technological Forecasting and Social Change*, 33(3):219–249.

[Taştekin, 2015] Taştekin, F. (2015). Turkey's syria borders an open door for smugglers, al-monitor: the pulse of the middle east. *Al Monitor*.

[Vensim, 2013] Vensim (2013). Vensim ple. *Ventana Systems, Vensim Simulation Environment, [Software]*.