

# A MODEL FOR THE GLOBAL OIL MARKET: OPTIMAL OIL PRODUCTION LEVELS FOR SAUDI ARABIA

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## Overview

Saudi Arabia, the world's largest crude oil producer and exporter, spends billions of dollars annually to optimize technical efficiencies for producing its five crude grades. However, it is unclear whether this production maximizes economic profits. Although numerous optimization models have been built for the world oil market, none maximizes economic profit for these five crudes. Our contribution is to build a model that allows Saudi Arabia to match its technical excellence with an economic optimum. Because this complex capital-intensive global market is subject to numerous constraints and is nonlinear, we use a non linear programming spatial equilibrium model. We maximize Saudi profits subject to non-Saudi production, crude and refined products supply and demand balances, production and transportation capacities and costs, and refineries yields and capacities. Model flexibility also allows examination of other market structures. By changing the objective function, we model OPEC as a profit-maximizing cartel. By reformulating to a mixed-complementarity model, we also solve for a competitive oil market. Model outputs include market clearing prices and quantities for all crude grades and products for each region. The most interesting result is that both Saudi Arabia and OPEC could have realized higher economic profits in 2004 by producing less and driving up crude prices.

The paper is organised as follows: After the introduction, we include in the second section a brief literature review on both oil market modeling and the behavior of OPEC. In the third section, we mathematically describe and present the proposed NLP model. After presenting our data inputs and validation in the fourth section, we present the model's results for our four cases: (1) Saudi Arabia optimizing given markups for other OPEC countries and supply functions for non-OPEC players, (2) OPEC as a profit-maximizing cartel, (3) Saudi Arabia optimizing unilaterally given a competitive fringe, and (4) a competitive world crude oil market. We also examine the model's sensitivity and robustness by examining the model's output sensitivity to changes in supply and demand elasticities, transportation costs and production capacities. The paper ends with a brief conclusion and suggestions for further future research.

## Methods

Our spatial equilibrium model uses the non linear programming method for optimization.

## Results

First, Saudi Arabia did not fully exercise its market power in 2004, but the deviations for unilateral profit maximization were not great.

Second, OPEC (both Saudi and rest of OPEC) could have increased the joint profits in 2004 if all regions restricted output. This suggests that OPEC is less than fully effective as a cartel.

Third, in a competitive market environment, the world's total crude production increased by 2.5%, crude prices fell by only about 3.8% on average.

Fourth, the model is most sensitive to changes in production capacities but not so sensitive to changes in other parameters.

## Conclusions

The direct measurement of the market conditions suggests that Saudi Arabia is not fully exercising its market power, but the deviations for unilateral profit maximization are not great. Profit maximization suggests a 3.85% decrease in Saudi Arabia's output. This translates into \$1.9 billion of unrealized profits in 2004. This implies that Saudi Arabia may not fully exercise its market power and may have objectives other than pure profit maximization.

We also find that OPEC (both Saudi and rest of OPEC) could increase the joint profits if all regions restrict output. This suggests that OPEC is less than fully effective as a cartel. In addition, our direct measurements

suggests that in a competitive market environment, the world's total crude production increases by 2.5%, crude prices fall by about 3.8% on average, total Saudi profit falls by 118 billion dollars a year while the rest of OPEC's total profit falls by 286 billion dollars a year.

As the model results for the first three configurations show, neither Saudi Arabia nor OPEC fully exercises market power. Reasons behind the deviation from the optimal production levels (4-6%) may include an array of social and political objectives.

To test the model's sensitivities to changes in parameters, we assessed the impact of changing transportation costs, crude price elasticities of supply, product price elasticities of demand and production capacities on the Saudi profits in the case when Saudis maximize profits unilaterally. We found the model to be most sensitive to changes in production capacities but not so sensitive to changes in other parameters.

Model expansions for future research include: expanding to four refining configurations in each region, splitting Saudi Arabia to east and west regions, disaggregating gas plants and petrochemicals from the refining sector, including a pipeline transportation sector, including more sophisticated supply and demand functions, making the model dynamic and include reserves, integrating the model backwards to include by field and by well production levels, developing a mechanism to keep the trading and transportation matrices updated, incorporating production subsidies and taxes on refined products, adding crude and refined product stocks, and including product specification limitations on imports for the various regions.

## References

- Armington, P. S. (1969). "A Theory of Demand for Products Distinguished by Place of Production." *European Economic Review* 1:7-73.
- Ben-Shahar, H. (1976). *Oil: Prices and Capital*. Lexington, MA, D.C. Heath and Company.
- Blackwell Energy Research (2005). *World Oil Trade*. Oxford, UK, Blackwell Energy Research Publishers.
- Bohi D. R. and Russel, M. (1975). *US Energy Policy: Resources for the Future*. Baltimore, MD, John Hopkins University Press.
- Cremer, J., and Weitzman, M.L. (1976). "OPEC and the Monopoly Price of World Oil." *European Economic Review* 8: 155-164.
- Celta, D. J. (1998). *OPEC as a Social Welfare Maximizer*. Doctoral Thesis. Minerals Economics, Colorado School of Mines, CO.
- Deam R.J. et al. (1973). "World Energy Modeling: the Development of the Western European Oil Prices." *Energy Policy* 1(1): 21-34.
- Energy Information Administration (EIA), International Petroleum (Oil) Production Tables, Total Oil Supplies: <http://www.eia.doe.gov/emeu/international/oilproduction.html>
- Energy Information Administration (EIA), International Petroleum (Oil) Consumption Tables, Petroleum Consumption by Type of Refined Petroleum Product: <http://www.eia.doe.gov/emeu/international/oilconsumption.html>
- Energy Intelligence Research (2006). *The international Crude Oil Market Handbook, 2006*. New York, USA, Energy Intelligence Publishers.
- Ente Nazionale Idrocarburi (ENI). *World Oil and Gas Review 2005*. Rome, Italy, Marchesi Grafiche Editoriale SpA.
- Ezzati, A. (1976). "Future OPEC Price and Production Strategies as Affected by its Capacity to Absorb Oil Revenues." *European Economic Review* 8:107-138.
- Hnyilicza, E. and Pindyck, R. S. (1976). "Pricing Policies for a Two-part Exhaustible Resource Cartel, the Case of OPEC." *European Economic Review* 8: 139-154.
- International Energy Agency (IEA). *Oil Information (2006)*. Paris, France, Head of Publication Services.**
- Kalymon, B. A. (1975). "Economic Incentives in OPEC Oil Pricing." *Journal of Development Economics* 2: 337-362.**
- Kennedy M. (1974). "An Economic Model for the World Oil Market." *Bell Journal of Economics and Management Science* 5(2): 540-577.
- Manne, A. S. (1976). "ETA: A Model for Energy Technology Assessment." *Bell Journal of Economics* 7(2): 379-406.
- Marshall R. A. and Nesbitt D. M. (1984). *The Decision Focus Incorporated World Oil Model: Model Structure and Methodology*. Los Altos, CA, Decision Focus.
- Nordhaus, W. B. (1973). "The Allocation of Energy Resources." *Brookings Papers of Economic Activity* 3: 529-576.
- Organization of Petroleum Exporting Countries (OPEC). *OPEC Annual Statistical Bulletin 2005*. Vienna, Austria, Ueberreuter Print and Digimedia.

Purvin and Gertz (2006). *Global Petroleum Market Outlook: Petroleum Balances*. Houston, USA, Purvin and Gertz Inc.

Salant, S. (1976). "Exhaustible Resources and Industrial Structure: A Nash Cournot Approach to the World Oil Market." *Journal of Political Economy* 84(5): 1079-1093.

Worldscale Association Limited (2005). *New worldwide Tanker Nominal Freight Scale "Worldscale"*. Exeter, UK, Polstar Wheatons Ltd.