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**On the Economic
Determinants of Oil
Production.
Theoretical Analysis and
Empirical Evidence
for Small Exporting
Countries**

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Summary

In this paper, decisions regarding production in oil exporting countries are studied by means of theoretical analysis and empirical investigation. Under the assumptions of exogenous oil prices and world oil demand, we are able to describe the relationship between oil production levels and changes in the conditions in world oil markets. Intertemporal production decisions by a representative oil producer are modelled by means of a partial equilibrium model. In this theoretical model, oil producers are subject to exogenous shocks in world oil demand and prices. Oil companies can change output levels only by incurring a fixed cost. Results from the simulation of this model show a strong relationship between oil production and changes in world oil consumption. On the contrary, the effects of changes in real oil prices on oil production decisions seem to be much lower. Results from the simulation of the theoretical model are then empirically investigated using time-series econometric techniques. The empirical evidence supports the hypothesis that several oil producing countries are characterized by different responses to changes in world oil demand and in real oil prices. For many countries production rapidly adjusts to changes in consumption whereas responses of oil production to innovations in real oil prices are found to be not statistically significant. In addition, when non-linearities in the relationship between exogenous variables and output levels are allowed for, evidence of asymmetric effects of output levels to shocks in demand levels and oil prices is found.

Keywords: Oil Production, Exogenous Shocks, Theoretical Modelling, Time Series Analysis

JEL Classification: C22, D21, D22, Q41

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Abstract

In this paper, decisions regarding production in oil exporting countries are studied by means of theoretical analysis and empirical investigation. Under the assumptions of exogenous oil prices and world oil demand, we are able to describe the relationship between oil production levels and changes in the conditions in world oil markets.

Intertemporal production decisions by a representative oil producer are modeled by means of a partial equilibrium model. In this theoretical model, oil producers are subject to exogenous shocks in world oil demand and prices. Oil companies can change output levels only by incurring a fixed cost. Results from the simulation of this model show a strong relationship between oil production and changes in world oil consumption. On the contrary, the effects of changes in real oil prices on oil production decisions seem to be much lower.

Results from the simulation of the theoretical model are then empirically investigated using time-series econometric techniques. The empirical evidence supports the hypothesis that several oil producing countries are characterized by different responses to changes in world oil demand and in real oil prices. For many countries production rapidly adjusts to changes in consumption whereas responses of oil production to innovations in real oil prices are found to be not statistically significant. In addition, when non-linearities in the relationship between exogenous variables and output levels are allowed for, evidence of asymmetric effects of output levels to shocks in demand levels and oil prices is found.

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1. Introduction and Related Literature

Developments in international oil markets are studied in various fields of economics. In particular, the structure of world oil markets, as well as the determinants of oil production levels, is examined by both theoretical and empirical studies.

Many authors study the pattern of oil production, drawing conclusions on the structure of international oil markets. For instance, in Griffin [1] various assumptions on the structure of world oil markets are tested. The validity of four alternative models for OPEC (Organization of Petroleum Exporting Countries) production¹ is examined using data on oil production for the 1983-1988 period. According to his results, the behavior of OPEC can be described by means of a partial market-share model. Conversely, for non-OPEC countries the hypothesis of a competitive model cannot be rejected by the data.

The empirical results obtained by Griffin [1] are examined, among others, by Ramcharran [2], Kaufmann et al. [3] and Kaufmann et al. [4]. In particular, in Ramcharran [2], a supply function is estimated using data from 1973 to 1997. His study aims at determining how oil supply of both OPEC and non-OPEC countries respond to oil price changes. Results suggest a negative and significant elasticity of production of OPEC countries to prices. On the contrary, for many non-OPEC countries, positive and significant coefficients are obtained.

Similarly, Gulen [5] concludes that the world oil market is dominated by a cartel of oil producers.² In fact, OPEC is able to affect prices by restricting or expanding its output through a system of quotas assigned to each of its members. On the other hand, there is a set of producing countries which

¹That is, a) the competitive model; b) the cartel model; c) the target revenue model and d) the property rights model.

²Nevertheless, the assumption that OPEC represents a “dominant producer” is rejected by, among others, Alhajji and Huettner [6] and Smith [7]. In particular, the empirical analysis of Alhajji and Huettner [6] emphasizes the role in the Organization of producing countries of Saudi Arabia. This country is argued to act as the “swing producer” of the Organization, varying its own output according to demand and supply shocks in order to defend oil prices (see, also, Griffin and Xiong [8] and Gately [9]).

represent the “competitive fringe” of the market³.

Oil production changes since 1960 are examined by, among others, Gately [9] and Pirog [11]. Gately [9] argues that, in spite of rapid increases in world oil demand, since the late 1960s production by non-OPEC countries has not changed significantly, while, on the contrary, OPEC output increased noticeably. A likely explanation of this evidence lies in rising extraction costs faced by oil producers.

After the first oil shock, despite the quadrupling of oil prices (1974-1978), production by non-OPEC countries remained stable. Viceversa, since 1976, oil production in these countries expanded significantly. New major discoveries in Mexico and a huge increase of production from new fields in the North-Sea and Alaska allowed non-OPEC countries to increase oil output by about 6 per cent between 1976 and 1983.

Differently from Gately [9], Pirog [11] examines the role of national oil companies in international oil markets. According to his analysis, rising world oil demand and higher prices are among the main factors determining the increase of production of oil companies since 2003.

In order to assess the responses of oil production to demand and price changes, other authors propose to consider factors behind investment decisions. For instance, Kesicki [12] shows that huge oil price increases often lead to investments in oil exploration.⁴ As a consequence, past investments are argued to be one of the main factors determining current oil production levels.

As far as the responses of producing countries to the development of global economy are concerned, De Santis [13] considers a computational general equilibrium model to evaluate the effects of shocks to crude oil demand and supply on prices and production levels for Saudi Arabia. De Santis [13] suggests that, with the notable exception of this country, OPEC members tend to adjust output levels to changes in the stance of world economy. On the contrary, because of the high share of capital input in the production function, output levels of Saudi Arabia show a low degree of correlation with

³For an analysis of the stability of collusive behavior in the presence of producers which take the price as exogenously given see, for instance, D’Aspremont et al. [10].

⁴According to the author, recent examples are represented by exploration in Alaska, Siberia and the North Sea.

demand shocks. Nevertheless, output levels adjust differently to increases and decreases in world oil demand. In fact, in the case of a negative shock to demand, production levels are reduced rapidly to prevent prices from falling too rapidly. On the contrary, output levels are not expanded accordingly following a positive innovation on the demand side.

Numerical simulations of theoretical models (mainly, general equilibrium models) suggest weak or negligible effects of demand and oil price shocks on output also for non-OPEC countries. In particular, in Choucri et al. [14] the domestic oil sector of a small oil producer such as Egypt is modeled by means of a dynamic simulation model. The authors suggest that the possibility to adjust production on the basis of developments in world oil prices is constrained by the fact that, in Egypt, the oil sector often operates near full capacity.

In Kaufmann [15] the effects of geological, economic and political factors on total oil supply in the U.S. are examined. Econometric techniques are employed to model extraction levels for the continental US. Results suggest that, because of high extraction costs, negative oil price shocks adversely affect production levels.

Finally, in its mid-term outlooks, the U.S. Department of Energy (see, for instance, EIA [16])⁵ reports that oil production increases are projected to be less than those in world oil demand.

In this paper we focus on small producing countries. The importance of these countries in the world oil industry is rapidly increasing. According to data from the Energy Information Administration between 1995 and 2010 production levels of countries with a share of world oil production of not more than 5 per cent have increased from 42 to approximately 56 million barrels per day (B/d). During the same period, the number of countries producing at least 200 thousand B/d has increased from 33 to 40.

Although the oil sector is important for these economies, changes in the output levels are not able to affect significantly prices in international oil markets. In other words, these actors of the world oil market are assumed to take prices as exogenously given. This assumption is explicitly considered, *inter alia* by Choucri et al. [14], Pindyck [18] and [19]. In particular, Pindyck describes how decisions on optimal production levels vary when different as-

⁵See, also, Horn [17].

sumptions on marginal extraction costs are taken into consideration.

Our study concentrates on the economic determinants of oil production for these countries. One of the purposes of this paper is to fill the gap in our understanding of the relationship between oil production levels, international oil prices and world oil demand. Although previous research has already studied the determinants of decisions on oil production levels for both OPEC and non-OPEC countries (see, for instance, the article by Ramcharran [2]), to our knowledge no study has previously tried to measure the degree of flexibility of decisions on oil production levels, that is the possibility by these nations to rapidly modify production levels as conditions in the world oil markets change. In addition, our paper contributes to the existing literature by offering a competing alternative empirical framework to describe and test the *target revenue model* for oil producers (see Griffin [1]).

In order to establish how production levels respond to changes in world oil demand and prices, results from both theoretical and empirical perspectives are presented. The implications of our results for the theory of the structure of oil markets are also discussed. Our analysis also differs from the study by Ramcharran because of the empirical methodology here adopted. While Ramcharran [2] focuses on a simple supply function estimated by using annual observations, we employ monthly data and, thus, more appropriate AutoRegressive Distributed Lag or Error Correction Models.

In this paper, a partial equilibrium model is designed to describe decisions over oil production levels for a representative small producing country. In our model, oil producers are subject to exogenous shocks in world oil demand and prices. Producing countries can react to these shocks by changing output levels. However, they can adjust production only by incurring a fixed cost. Results from numerical simulation suggest that production levels tend to adjust rapidly to changes in the conditions of the world oil market. Moreover, these responses seem to be strongly linked to the cost structure of the oil producer. In addition, decisions on output levels are argued to be characterized by different responses to changes in world oil demand and real oil prices. While output levels react significantly to increases in the world oil demand, responses of oil producing countries to changes in real oil prices are less statistically significant. Finally, an upward sloping Kaplan-Meier hazard function is shown to well describe oil production levels for many countries. Predictions based on our theoretical model are, then, tested using empirical analysis. An econometric framework is employed to describe data regarding oil production levels for a significant sample of oil producing countries. To

check whether small and large oil producing countries have different sensitivities to economic variables, our sample includes also the largest member countries of OPEC (i.e. Saudi Arabia, Iran and Kuwait), the U.S. and Russia.

The statistical relationships between oil production, world oil demand and real oil prices are examined by means of time-series econometric techniques. The methodology here adopted allows us to analyze both short and long-term dynamics of oil production as well as to introduce asymmetric effects of exogenous variables. At this regard, our paper is different from the works of Gulen [5] and Dibooglu and AlGudhea [20] who employ cointegration and causality tests to test a different assumption (that is, output coordination between OPEC member countries).

As a first step of the analysis, the order of integration of these variables is tested. The long- and short-run relationships existing between the series are estimated by using both univariate and multivariate regression techniques. Empirical evidence shows different responses to variations in world oil demand and prices for the countries considered in the analysis. In general, the effects of world oil demand changes on oil production levels are statistical not different from zero. Conversely, the hypothesis of no effects from oil price changes to oil output cannot be rejected.

Finally, the hypothesis of asymmetric effects of increases and decreases of world oil demand and real oil prices on oil production levels is examined and discussed. According to this textable assumption, adjustments of production are less frequent in the presence of negative shocks because of downward rigidities of production levels.

The paper is organized as follows. In Section 2, our theoretical model is presented. In Section 2.1 the main assumptions of our framework are reported. The procedure aimed at simulating the model is outlined in Section 2.2. Results of how oil production levels reacts to changes in world oil demand and oil prices are examined in Section 2.3. In Section 3 the empirical framework employed to assess the economic determinants of oil production is presented. In particular, in Section 3.1 data regarding oil production for a significant set of producing countries are presented. Section 3.2 describes the time-series econometric techniques employed to test the relationships between oil production, total demand and real oil prices. Econometric results are examined and discussed in Section 3.3. Section 4 concludes.

2. The Theoretical Model

2.1. The Model

We focus on the production decisions of an oil exporting country.⁶ Our approach is to use a partial equilibrium model in which the preferences of economic agents (oil producers) and production levels are determined endogenously in equilibrium while oil prices and the pattern of world oil demand are specified exogenously.

According to our framework, producers are assumed to behave as price-taking profit maximizers. In addition, they set output levels without considering other producers' behaviors. They are *small producers* in the sense that each producer would adjust his production so as to obtain maximum net profits regarding the oil price as fixed beyond his control. Moreover, expansions of world demand are important for these oil producers since they may embody a better economic environment and, thus, the possibility of larger capital inflows by foreign investors.

At this regard, our model can be seen as a competing alternative description of the *target revenue model* for oil producers (see Griffin [1]).^{7, 8, 9}

Single-period profits are given by:

$$\Pi_t = q_t (P_t - c_t) \quad (1)$$

where c_t and q_t denote marginal costs and *effective* oil production at time t while P_t represents real oil prices.

Unit costs, c_t , are a function of both the current level of production, q_t and of world oil demand, that is:

$$c_t = c(q_t, D_t) \quad (2)$$

⁶For the purposes of this analysis, the terms *oil company* and *(small) oil producer* are used interchangeably.

⁷Nevertheless, Kaufmann et al. [3] suggest that OPEC is able to affect market prices by means of decisions over production quotas and capacity utilization.

⁸This assumption is also considered by, among others, Gilbert [21], Pindyck [19], Choucri et al. [14] and Horn [17]. In particular, Choucri et al. [14] argue that, for an exporting country like Egypt, "oil prices are clearly significant exogenous".

⁹Notice also that, in many non-OPEC countries, oil is often extracted by a set of international oil companies that take prices as exogenously given.

Marginal costs are an increasing function of oil production, i.e. $c_{q_t} > 0$.¹⁰ In other words, we are assuming that, because of finite reserves, as production increases and oil becomes more difficult to extract, unit costs increase as well.^{11, 12} In addition, marginal costs are an inverse function of world oil demand, D_t , i.e. $c_{D_t} < 0$.¹³

The following expression for unit costs is, for simplicity, employed for simulation purposes:

$$c_t = \gamma \left(\frac{q_t}{D_t} \right)^\theta \quad (3)$$

where γ and θ are scale parameters. If we substitute the expression (3) for c_t into equation (1) we obtain that net profits can be expressed as:

$$\Pi_t^* = \frac{q_t}{D_t} \left(P_t - \gamma \left(\frac{q_t}{D_t} \right)^\theta \right)$$

here, $\frac{q_t}{D_t}$ denotes *relative* oil production (i.e. the share of demand satisfied by domestic production).¹⁴

Since production is not fully flexible, we assume that, in order to change output, oil company's costs increase by a factor ψ .¹⁵ This implies that,

¹⁰ c_X denotes the first derivative of function $c(X)$ with respect to X .

¹¹This assumption indirectly implies that the level of reserves and production costs are related through an inverse relationship.

¹²Modelling marginal costs as a function of the rate of production is quite common. See, for instance, Livernois and Uhler [22] and Moel [23].

¹³We are assuming that, as demand of oil increases, investments in research and development lower unit costs of oil extraction. In fact, according to a "learning-curve" cost decline on the production side, unit cost decreases as more and more experience is gained. Marginal costs are modeled as function of *experience* by, among others, Spence [24].

¹⁴The ratio of production over total demand is considered on the basis of the assumption that producers monitor their market share.

¹⁵This assumption implies that, in response to idiosyncratic shocks, economic agents can only occasionally modify their decisions, see, for instance, Golosov and Lucas [25] and Nakamura and Steinsson [26] who develop a model in which firms have to pay a "menu" cost (that is, a fixed cost) in order to modify nominal prices. This theoretical framework

according to changes in world oil demand from D_t to \widehat{D}_t , net (relative) profits vary from Π_t^* to $\widehat{\Pi}_t$, where:

$$\widehat{\Pi}_t = \begin{cases} \frac{q_t}{D_t} \left(P_t - \gamma \left(\frac{q_t}{D_t} \right)^\theta \right) & \text{if production does not vary,} \\ \frac{\widehat{q}_t}{\widehat{D}_t} \left(P_t - \gamma \left(\frac{\widehat{q}_t}{\widehat{D}_t} \right)^\theta \right) - \Psi & \text{if production changes} \end{cases} \quad (4)$$

where $\Psi \equiv \psi\gamma$.¹⁶

Moreover, the natural logarithm of oil prices is assumed to evolve according to a random walk process, that is:

$$\ln P_t = \ln P_{t-1} + \epsilon_t$$

where $\ln X_t$ denotes the natural logarithm of variable X_t .

Finally, the process for world oil demand (expressed in natural logarithms of relative units) is given by:

$$\Delta \ln D_t = \mu + \eta_t$$

where $\Delta \ln D_t = \ln D_t - \ln D_{t-1}$. ϵ_t and η_t are distributed according to $N(0, \sigma_\epsilon^2)$ and $N(0, \sigma_\eta^2)$ processes, respectively. In other words, the series is stationary around a trend.¹⁷

2.2. Solution of the Model

The theoretical model described in Section 2.1 is simulated for the actual evolution of oil production values. In doing that, values have to be assigned

allows authors to explicitly introduce some form of price rigidities.

¹⁶Similarly, when real oil prices vary from P_t to \widehat{P}_t , net profits change from Π_t^* to $\widehat{\Pi}_t^*$ where:

$$\widehat{\Pi}_t^* = \frac{q_t}{D_t} \left(\widehat{P}_t - \gamma \left(\frac{q_t}{D_t} \right)^\theta \right) \text{ if production remains stable or,}$$

$$\widehat{\Pi}_t^* = \frac{\widehat{q}_t}{\widehat{D}_t} \left(\widehat{P}_t - \gamma \left(\frac{\widehat{q}_t}{\widehat{D}_t} \right)^\theta \right) - \Psi \text{ if production changes from } q_t \text{ to } \widehat{q}_t.$$

¹⁷These results are confirmed by simple regression analysis (see Section 2.2). Moreover, data strongly reject the possibility to introduce the world oil demand as an additional explanatory variable of oil prices. Similarly, in a regression of oil demand the coefficient on real oil prices is not statistically different from zero. These results are not shown to save space but are available from the authors upon request

to the parameters of the model (that is, $\beta, \theta, \psi, \mu, \gamma, \sigma_\epsilon^2$ and σ_η^2).

According to Stockman and Tesar [27] the rate of time preference (β) is set to be equal to 0.96. From simple regression analysis based on Energy Information Administration data,¹⁸ parameters μ and σ_η^2 are estimated to be equal to 0.00161 and 0.0084, respectively. On the basis of an econometric analysis of oil prices behavior, a parameter value of 0.0923 is assigned to σ_ϵ^2 . Because of the unavailability of data and measurement errors, we are not able to calibrate or estimate parameters θ, ψ and γ on the basis of empirical data. On the contrary, the qualitative behavior of the model is discussed by assigning different values to these parameters (see Section 2.3). In fact, the world oil market is characterized by an heterogenous set of countries as far as the structure of their costs is concerned. In response to demand and supply conditions, countries that have lower extraction costs tend to adjust rapidly production levels. Viceversa, producers with low levels of spare capacity face more rigid extraction decisions.

The model is solved by value function iteration on the Bellman equation. Our iteration procedure produces the value and policy functions (respectively, $V(\frac{q}{D}, P)$ and $\left\{ \left(\frac{q}{D}\right)', P' \right\} = h(\left\{ \frac{q}{D}, P \right\})$) after taking a random draw from the distribution of ϵ and η for each period. A procedure based on a grid of values for q_t and the exogenous variables, D_t and P_t , is then used until a maximum for the profit function is found.

The model is simulated for 60,000 time periods. The first 100 observations are dropped in order not to consider a possibly sub-optimal starting point for our oil producer. To make computation feasible, the state space for $\left\{ \frac{q}{D}, P \right\}$ is assumed to be discrete. While the relative production, $rq = \frac{q}{D}$ lies in the set:

$$\left[rq_{min}, rq_{min} + \frac{rq_{max} - rq_{min}}{N_{rprod} - 1}, rq_{min} + 2 \cdot \frac{rq_{max} - rq_{min}}{N_{rprod} - 1}, \dots, rq_{max} \right]$$

the state space for P is given by:

$$\left[P_{min}, P_{min} + \frac{P_{max} - P_{min}}{N_P - 1}, P_{min} + 2 \cdot \frac{P_{max} - P_{min}}{N_P - 1}, \dots, P_{max} \right]$$

¹⁸The period considered for this analysis extends from January 1994 to January 2010 for a total of 193 monthly observations.

Values for rq_{min} , rq_{max} , P_{min} and P_{max} are chosen to avoid that the optimal production level is higher (lower) with respect to the upper (lower) endpoint of the state space of q .¹⁹

In Figures 1 and 2 the profit function is depicted together the value and policy functions of our oil producer.

[INSERT FIGURES 1 AND 2 ABOUT HERE]

As it can be seen in Figure 1, profits are a strictly concave function with respect to both relative production and oil prices. On the other hand, the value function is given by:

$$V\left(\frac{q_{t-1}}{D_t}, P_t\right) = \max_{q_t} \left[\Pi_t + \beta E_t V\left(\frac{q_t}{D_{t+1}}, P_{t+1}\right) \right]$$

and takes into account the decision by the oil producer to modify its production level once conditions in the world oil market have changed. Figure 2 illustrates the particular pattern of the policy function for a representative oil producer. As the Figure shows, if oil producers decide to vary their output levels, profits do not change linearly (see equation 4).

2.3. Results

The properties of the simulated policy function are investigated to determine how oil production reacts to changes in demand and price levels. In this Section, the relationship between *effective* production and relevant exogenous variable (i.e. world oil demand and prices) is examined using artificial data. A Kaplan-Meier plot of hazard function is, thus, computed and curves representing the probability of changes in production levels due to developments in the exogenous variables plotted.

The Effects of Economic Variables on Oil Production Levels

The degree of correlation between production levels and the pattern of world oil demand (respectively, oil prices) is reported in Table 1 (respectively, Table 2). Since the oil market is characterized by countries with varying

¹⁹Values we chose for rq_{min} , rq_{max} , P_{min} and P_{max} are equal to -3, 0, 0, 0.35, respectively. On the other hand, N_{rprod} and N_P are equal to 200 and 40, respectively.

extraction costs,²⁰ statistics are obtained by considering different values assigned to parameters θ , ψ and γ . As it can be observed from these Tables, oil output displays a higher correlation with demand than with respect to prices. In addition, although correlation decreases when first-differences of the series are employed, it still remains particularly high. A strong correlation of oil production with world demand behavior is also shown in the first panel of Figure 3. On the contrary, oil producing countries do not modify significantly output levels in response to oil price shocks (see Figure 3 second panel).

[INSERT TABLES 1 AND 2 AND FIGURE 3 ABOUT HERE]

In order to obtain additional evidence on the importance of the economic determinants of oil production levels, the following supply functions are estimated by employing simulated data:²¹

$$\ln q_t = \beta_0 + \beta_1 \ln D_t + \beta_2 \ln P_t + \epsilon_t \quad (5)$$

and

$$\Delta \ln q_t = \tilde{\beta}_0 + \tilde{\beta}_1 \Delta \ln D_t + \tilde{\beta}_2 \Delta \ln P_t + \tilde{\epsilon}_t \quad (6)$$

Here, $\Delta \ln Y_t = \ln Y_t - \ln Y_{t-1}$ represents the log-first difference of variable $Y_t = \{q_t, D_t, P_t\}$. As already outlined, q_t , D_t and P_t denote, respectively, the *effective* production, total world oil demand and the real price of oil at time t . β_i ($\tilde{\beta}_i$, $i = 0, 1, 2$), are the parameters to estimate while ϵ_t ($\tilde{\epsilon}_t$) denotes the error term of the regressions.

Different assumptions on parameters ψ , γ and θ allow us to generate patterns that can be used to describe output levels of oil producers with varying extraction costs.

[INSERT TABLES 3 AND 4 ABOUT HERE]

Results reported in Table 3 demonstrate that the elasticity of production to world oil demand is positive and statistically different from zero. This result

²⁰In fact, extraction costs depend on several factors, like for instance, the stock of oil remaining and the features of oil reservoirs. See also Section 2.2.

²¹These equations are simply an extension of the models employed by Griffin to test several assumptions on the structure of the world oil market (see Griffin [1]).

is confirmed when variables are specified as log-first differences (see Table 4). Viceversa, the relationship between oil production and oil prices is argued to be much weaker. Estimates obtained by employing variables expressed as log-levels (equation 5) are significantly different from zero in six out of nine cases. Nevertheless, when first differences of the series are used (equation 6), in no case results support statistically significant effects of oil prices on production levels.

On the Frequency of Oil Production Changes

As far as the frequency of production changes is concerned, in Tables 5 to 7 is reported the percentage of production increases and decreases together with the average size of production changes. Even in this case, results are shown as assumptions on the parameters of the model²² (that is, θ , ψ and γ) are changed.

[INSERT TABLES 5 TO 7 ABOUT HERE]

Results suggests that, as θ increases, the frequency of production changes decreases. The frequency of production changes tends to vary also with oil producers' costs. As unit costs (denoted by parameter γ) or the multiplier associated to costs (ψ) increase, the frequency of decisions on production levels decreases, that is, production becomes more rigid.

Tables 5 to 7 show that a similar relationship exists between the percentage of production increases and the values assumed by the different parameters. In particular, higher values of key parameters imply a larger fraction of upward adjustments of production rates, i.e., a higher percentage of output increases with respect to production decreases suggests that asymmetric effects probably affect output levels.^{23, 24}

In addition, the possibility to change output levels seems to be characterized by some asymmetries. In fact, producers tend to adjust output levels in the

²²In the framework of our theoretical model, these parameters are employed to represent the cost structure of our representative oil producing country.

²³Of course, part of this effect is due to the positive trend that characterizes simulated data of total world oil demand.

²⁴The hypothesis of asymmetric effects of positive and negative changes in D_t and P_t is tested by means of an empirical analysis in Section 3.

presence of increasing world oil demand. On the contrary, according to theoretical evidence, when oil demand drops, producing countries tend to reduce output more slowly. Finally, there is no evidence of a relationship between the cost structure that characterizes oil producing countries and the average size of production changes.

To characterize the probability of adjustments in production levels a hazard model that relates the intensity of changes in output rates for a representative oil producer is specified. A function which is often used to denote the probability that *effective* production will change at time t given that it has remained stable for t periods is represented by the Kaplan-Meier hazard function.^{25, 26} Figure 4 depicts the probability of adjustments in production levels as a consequence of changes in conditions on the oil market.

[INSERT FIGURE 4 ABOUT HERE]

The Kaplan Meier plot of hazard function demonstrates that production adjusts almost instantaneously to changes in the stance of world oil market. However, the possibility that output levels are modified according to changes in oil demand and prices depends on parameters representing the relative cost of extraction of oil. In other words, responses of oil producing countries shocks are affected by the relative importance of marginal costs. Moreover, according to the cost of adjustments oil producing countries have to face when they decide to change production levels, the hazard function is assumed to take different forms. In the presence of low costs of adjustment, the hazard function is upward slopping. For some countries, the probability that production levels increase tends to be higher the longer the output has remained stable.

²⁵Let us denote the duration of a production increase by the random variable D . The *hazard* of the decision by oil producers to increase output is given by $\lambda(t) = P(D = t | D \geq t)$.

²⁶The possibility to use duration models in economics is discussed in, *inter alia*, Efron [28] and Kiefer [29].

3. An Empirical Analysis of Oil Production

3.1. A Preliminary Analysis of Data

In this Section, according to the theoretical framework outlined earlier, we concentrate on the effects of world oil demand and prices on output levels of relevant oil producers. The data set underlying the empirical analysis presented is constructed with monthly data on oil output levels for 19 countries: Algeria, Angola, Ecuador, Iran, Kuwait, Libya, Nigeria, Saudi Arabia, Venezuela, Brazil, Canada, Colombia, Egypt, Indonesia, Malaysia, Mexico, Norway, Russia and the U.S.. Both the oil production and world oil demand variables are expressed as thousand barrels per day and are taken from the U.S. Department of Energy's database (*Energy Information Administration*). Information on the sample period considered for each country is given in Table 8.

[INSERT TABLE 8 ABOUT HERE]

As already outlined, the countries we focus on in this paper are relevant small oil producers. Although oil production is important for the economy of these countries, changes in their production levels have small effects on oil prices in international markets. For these nations, adjustments in production levels are difficult to implement, since they often involve relevant investments by foreign companies. Supply functions are estimated also for major producing nations (e.g. Saudi Arabia, Iran, Kuwait, the U.S. and Russia). This allows us to compare the responses by large producers to demand and price shocks with producers which are assumed to behave independently.

Oil prices in national currencies are obtained by multiplying the nominal oil price by the exchange rate of the US dollar for each country. The measure of nominal oil prices is the average oil price from the *International Monetary Fund's* database (*International Financial Statistics*). Real oil price levels are calculated by deflating the oil prices measured in national currencies using the inflation indicator of the country. Both the exchange rate (average monthly value for the period considered) and the inflation indicator are taken from the *International Financial Statistics* database.

Other explanatory variables are introduced to account for institutional and geological factors that affect oil production. Results reported in this work are obtained by including the State Fragility Index developed by the Center

for Systemic Peace (see Marshall and Goldstone [30]) in all regressions.²⁷ In addition, a variable representing the amount of proven oil reserves in each country is included in each equation. All data on oil reserves are from the British Petroleum Statistical Review of World Energy (2010).

Table 9 presents some descriptive figures of the oil production variable (considered in levels) for the countries examined in the analysis. In Table 10 the same statistics are computed using the production expressed in log first-difference form. The first moments of the distribution (mean, standard deviation, skewness and kurtosis) of oil production are reported in columns two to five of the tables. The sixth column shows the degree of correlation between oil production and demand. The relationship between oil production and real oil prices is reported in column seven.²⁸

[INSERT TABLES 9 AND 10 ABOUT HERE]

According to Tables 9 and 10, production levels of OPEC countries show, on average, a higher degree of correlation with world oil demand. This result is probably due to larger oil reserves and lower extraction costs. Production levels of Algeria are the most correlated with demand. On the contrary, output levels from Angola and Ecuador show lower levels of correlation. As far as non-OPEC countries are considered, results suggest a high correlation between production levels and oil demand for the U.S., Norway and Russia. Finally, the correlation between production and oil prices tends to be particularly low for all countries considered in the present study.

3.2. Methodology

In this paper we focus on the economic determinants of output levels by oil producing countries. Our purpose is to answer to this question: how do

²⁷The State Fragility Index scores countries according to their capacity to respond effectively to challenges and crises and, consequently, promote economic development. Therefore, to construct this index, performance dimensions on security, political, economic, and social issues are taken into account. The ability of governments to manage conflict by maintaining social cohesion is considered together with an evaluation of their efforts to deliver essential services to the population.

²⁸The relationship between oil production for each country and other nations' output levels is also examined. Results from statistical analysis confirm that the degree of correlation of production levels of non-OPEC countries is particularly low. Statistics are not reported to save space but are available upon request.

oil production responds to changes in the stance of world oil markets? The empirical methodology examined in the present study is based upon time-series econometric techniques. In particular, for each country, the order of integration and cointegration of the variables is examined and a dynamic econometric model is estimated on the basis of the following algorithm.²⁹

1. The order of integration of oil production and real oil prices for country i ($i = 1, \dots, 19$) is considered.³⁰
 - (a) if both series are stationary (that is, they are both $I(0)$) the following equation is estimated:

$$\ln q_{i,t} = \alpha_i + \sum_{k=1}^p \beta_{i,k} \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j} \Delta \ln D_{t-j} + \sum_{s=0}^p \vartheta_{i,s} \ln P_{i,t-s} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t} \quad (7)$$

where $q_{i,t}$ is total production for country i at time t , D_t and $P_{i,t}$ denote, respectively, total world oil demand and the real price of oil. $Z_{i,t}$ represent other explanatory variables (polity index and oil reserves). Parameters α_i , $\beta_{i,k}$ ($k = 1, \dots, p$), $\gamma_{i,j}$ ($j = 0, 1, \dots, p$), $\vartheta_{i,s}$ and Γ_i ($s = 0, 1, \dots, p$) represent the coefficients to estimate while $\epsilon_{i,t}$ denotes the error term of the regression. All variables considered are expressed in natural logarithms.

- (b) if the production level is $I(0)$ while the price level is $I(1)$, the equation (8) is estimated:

$$\ln q_{i,t} = \alpha_i + \sum_{k=1}^p \beta_{i,k} \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j} \Delta \ln D_{t-j} + \sum_{s=0}^p \vartheta_{i,s} \Delta \ln P_{i,t-s} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t} \quad (8)$$

²⁹It is worth noticing that our analysis does not aim at giving a full description of factors that may affect output levels in oil producing countries. Other factors (such as the degree of political instability, the measure of openness of the economy to foreign investments, future expectations on extraction costs, etc.) are able to influence oil production. Nevertheless, in this paper we concentrate on the effects that changes in world oil demand and prices have on output levels. The possibility to extend our analysis in order to include these exogenous variables in a more complete model of oil production is left as a topic for future research.

³⁰Results from unit root tests suggest that world oil demand is not stationary (i.e., $I(1)$).

- (c) if only the price level is $I(0)$, the expression to estimate takes the following form:

$$\begin{aligned} \Delta \ln q_{i,t} = & \alpha_i + \sum_{k=1}^p \beta_{i,k} \Delta \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j} \Delta \ln D_{t-j} + \\ & + \sum_{s=0}^p \vartheta_{i,s} \ln P_{i,t-s} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t} \end{aligned} \quad (9)$$

- (d) if both series are integrated then step 2 has to be considered;

2. Tests for the presence of cointegration are implemented. Let us consider the following equation:

$$\ln q_{i,t} = a_{i,0} + a_{i,1} \ln D_t + a_{i,2} \ln P_{i,t} + \Phi Z_{i,t} + \nu_{i,t} \quad (10)$$

where $a_{i,w}$ between ($w = 0, 1, 2$) and $\nu_{i,t}$ denote parameters to estimate and the error term, respectively. It is worth noticing that OLS regressions of world oil production on total demand and prices yield superconsistent estimates of long-run coefficients. This equation represents the long-run equilibrium relationship between oil production, world oil demand and oil prices. If the long-run disequilibrium world oil production, world oil production and prices ($\nu_{i,t}$) follows a stationary process, it can be said that the three series are cointegrated. According to the results on the stationarity of $\nu_{i,t}$, one of the following two cases has to be considered.

- (a) If series are not cointegrated (that is, the relationship representing the long-run equilibrium between the series is non-stationary), the following AutoRegressive Distributed Lag model ($ARDL(p)$) of order p is estimated:

$$\begin{aligned} \Delta \ln q_{i,t} = & \alpha_i + \sum_{k=1}^p \beta_{i,k} \Delta \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j} \Delta \ln D_{t-j} + \\ & + \sum_{s=0}^p \vartheta_{i,s} \Delta \ln P_{i,t-s} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t} \end{aligned} \quad (11)$$

- (b) if oil production is cointegrated with world oil demand and oil prices, the specification to estimate is represented by an Error Correction Model (ECM):

$$\begin{aligned} \Delta \ln q_{i,t} = & \alpha_i + \sum_{k=1}^p \beta_{i,k} \Delta \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j} \Delta \ln D_{t-j} + \\ & + \sum_{s=0}^p \vartheta_{i,s} \Delta \ln P_{i,t-s} + \theta_i ECT_{i,t-1} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t} \end{aligned} \quad (12)$$

here θ_i represents the long-run equilibrium adjustment parameter while $ECT_{i,t-1} = \nu_{i,t-1}$ denotes the long-run equilibrium relationship between oil production, world oil demand and crude oil prices.

In this paper, the relationship between oil production, world oil demand and prices is investigated country-by-country and at a system level using dynamic Seemingly Unrelated Regression (SUR) techniques. In fact, as proposed by Zellner (Zellner [31] and Zellner [32]), under certain conditions,³¹ regression coefficient estimators obtained by employing generalized least squares to a system of equations are asymptotically more efficient than those that result from estimating single equations by means of least squares techniques. The system of equations, to estimate by means of dynamic SUR techniques, is given by:

I if both the production level and the price level are $I(1)$

$$\begin{aligned} \Delta \ln \mathbf{q}_t &= \alpha + \sum_{k=1}^p \beta_k \Delta \ln \mathbf{q}_{t-k} + \sum_{j=0}^p \gamma_j \Delta \ln D_{t-j} + \\ &+ \sum_{s=0}^p \vartheta_s \Delta \ln \mathbf{P}_{t-s} + \mathbf{D} \cdot \theta \cdot \mathbf{ECT}_{t-1} + \mathbf{\Gamma} \cdot \mathbf{Z}_t + \epsilon_t \end{aligned} \quad (13)$$

where $\mathbf{q}_t = [q_{1,t}, q_{2,t}, \dots, q_{N1,t}]'$, $\mathbf{P}_t = [P_{1,t}, P_{2,t}, \dots, P_{N1,t}]'$, $\mathbf{ECT}_t = [ECT_{1,t}, ECT_{2,t}, \dots, ECT_{N1,t}]'$ and $\mathbf{Z}_t = [Z_{1,t}, Z_{2,t}, \dots, Z_{N1,t}]'$ are, respectively, the endogenous variable and the exogenous regressors, $\alpha = [\alpha_1, \alpha_2, \dots, \alpha_{N1}]'$, $\beta_k = [\beta_{1,k}, \beta_{2,k}, \dots, \beta_{N1,k}]'$, $\vartheta_s = [\vartheta_{1,s}, \vartheta_{2,s}, \dots, \vartheta_{N1,s}]'$, $\theta = [\theta_1, \theta_2, \dots, \theta_{N1}]'$, and $\gamma_j = [\gamma_{1,j}, \gamma_{2,j}, \dots, \gamma_{N1,j}]'$ are parameters to estimate, \mathbf{D} is a $(N1 \times 1)$ ³² vector whose values are equal to one if there exists a long-run relationship between oil production and the explanatory variables and zero otherwise and $\epsilon_t = \{\epsilon_{1,t}, \epsilon_{2,t}, \dots, \epsilon_{N1,t}\}$ is the vector of residuals.

II if the production level is $I(0)$ while the price level is $I(1)$.

$$\begin{aligned} \ln \mathbf{q}_t &= \alpha + \sum_{k=1}^p \beta_k \ln \mathbf{q}_{t-k} + \sum_{j=0}^p \gamma_j \Delta \ln D_{t-j} + \\ &+ \sum_{s=0}^p \vartheta_s \Delta \ln \mathbf{P}_{t-s} + \mathbf{\Gamma} \cdot \mathbf{Z}_t + \epsilon_t \end{aligned} \quad (14)$$

3.3. Results

Introduction

Results obtained from unit root tests for relevant variables considered in the present study are reported in Tables 11 to 12. The problem of testing the

³¹Analysis by Zellner and Huang [33] suggests that a large gain in efficiency can be obtained when contemporaneous disturbance terms in different equations are correlated and variables in different equations are not highly correlated.

³² $N1$ is the number of countries considered.

null hypothesis of non-stationarity versus stationarity is solved by employing the Augmented Dickey Fuller test (see Dickey and Fuller [34]). The test equation is:

$$\Delta \ln Z_{i,t} = \alpha_{i,0}^* + \alpha_{i,1}^* \cdot trend + \alpha_{i,2}^* \ln Z_{i,t-1} + \sum_{j=1}^p \beta_{i,j} \Delta \ln Z_{i,t-j} + u_{i,t} \quad (15)$$

where $Z_{i,t}$ and $u_{i,t}$ are the variable being tested ($Z_{i,t} = \{q_{i,t}, P_{i,t}\}$) and the residuals of the regression, respectively. The test is implemented by determining the t -statistic of $\hat{\alpha}_{i,2}^*$ and comparing the value of this statistic with critical values computed by MacKinnon [35].³³

[INSERT TABLES 11 AND 12 ABOUT HERE]

Results suggest that, in general, oil production is a variable integrated of order one (i.e., $I(1)$). Nevertheless, production levels of Nigeria, Venezuela, Brazil, Canada and the U.S. seem to be stationary around a trend. With the relevant exception of Angola, tests of unit root suggest that real oil prices are not stationary.

Results of tests on the stationarity of the residuals obtained from the estimation of long-run relationships between oil production, world oil demand and real oil prices are presented in Table 13. At this purpose, critical values for the ADF tests are based upon Davidson and MacKinnon [38].

[INSERT TABLE 13 ABOUT HERE]

Stationarity tests implemented on the residuals of long-run relationship suggest that, for several countries³⁴, there exists a cointegrating relationship between oil production, world oil demand and oil prices.

³³If the trend is not significant, equation (15) is re-estimated without trend ($\alpha_1 \equiv 0$). Following Lee and Strazicich [36], the number of lags to include in the regression is chosen by minimizing the Schwarz-Bayesian Information Criterion. For an analysis of the testing procedure adopted in this paper, see Dolado et al. [37].

³⁴Namely, Ecuador, Iran, Kuwait, Saudi Arabia, Egypt, Malaysia, Mexico, Norway and Russia.

The Effects of Economic Variables on Oil Production Levels

Equations representing the short-run dynamics of oil production decisions are estimated by means of least squares techniques and results shown in Tables 14 to 16.^{35, 36} Table 17 shows the statistical significance of the overall impact of world oil demand and prices on total output. Simple statistical tests of the hypothesis that all regression coefficients associated with exogenous variables are zero are reported together with the sign of the relationship between oil production and total demand (or real oil prices). Long-run coefficients $\beta_{i,D} = \frac{\gamma_{i,1} + \gamma_{i,2} + \dots + \gamma_{i,p}}{1 - \beta_{i,1} - \beta_{i,2} - \dots - \beta_{i,p}}$ and $\beta_{i,P_i} = \frac{\vartheta_{i,1} + \vartheta_{i,2} + \dots + \vartheta_{i,p}}{1 - \beta_{i,1} - \beta_{i,2} - \dots - \beta_{i,p}}$ are presented only for countries which are characterized by a statistically meaningful relationship between the two variables.

Estimation of equations (7) to (12) yields important insights as far as the relationship between production decisions and developments in world oil market is concerned. In fact, many countries display a significant relationship between their production levels and world oil demand. This is particularly true for OPEC member countries like Algeria, Iran, Kuwait, Saudi Arabia and Venezuela. This relationship is confirmed for many non-OPEC countries. In particular, a strong positive relationship between oil production and world oil demand exists for Mexico, Norway, Russia and the U.S.. An explanation for this evidence lies in the fact that, in presence of economic growth and, consequently, increasing domestic oil demand, these countries have incentives to expand their production.

Table 17 shows that, for countries like Angola, Libya, Brazil and Canada, coefficients associated to world oil demand are not statistically different from zero. Oil production of these countries tends to adjust more slowly to demand changes. This fact is probably due to a lower spare capacity and, consequently, a lack of flexibility in domestic oil production.

Finally, the relationship between oil production and oil prices is much weaker. Many OPEC nations are characterized by an elasticity to price changes not

³⁵These tables provide coefficients estimates with standard errors. Statistics which describe the goodness of fit of regressions are also reported.

³⁶The preferred number of lags of ARDL and EC Models is selected by examining the autocorrelations of the estimated residuals. The process undertaken to obtain the optimum lag length is to increase the number of lags up to the point where the residuals are not serially correlated.

statistically different from zero. Noticeable exceptions are represented by Kuwait and Saudi Arabia. In these countries, in fact, oil tends to increase in presence of positive oil price shocks. A likely explanation is that, these oil producers may try to coordinate OPEC behavior in an attempt to hold down the pressures on prices.³⁷ However, if non-OPEC countries are taken into account, in no case, the oil production tends to respond significantly to real oil price shocks.³⁸

[INSERT TABLES 14 TO 17 ABOUT HERE]

When dynamic SUR techniques are employed, two different systems of equations are estimated depending on the properties of the time series. While in the first system the endogenous variable is represented by the first differences of oil production, in the second system the natural logarithm of output levels is considered as the dependent variable. For each system of equations, the number of lags is selected by examining the residual autocorrelations. The multivariate portmanteau test (based on the Box-Pierce/Ljung-Box Q -statistics) is used to test whether the null of no residual correlation is rejected by the data (see Tables 18 and 19). Adjusted Q statistics are generally consistent with the absence of serial correlation in the residuals when a number of lags equal to one and three is selected for the first and second group of countries, respectively.

Table 20 gives F -statistics for the test of the joint significance of coefficients of the contemporaneous and lagged values of variables D_t and P_{it} .³⁹

Estimates derived by employing dynamic SUR techniques yield similar insights with regard to the important effects that demand changes have on oil production levels. Results obtained from the estimation of systems (13) and (14) confirm that the impact of oil prices on output is limited to a few

³⁷Remember that these countries are characterized by high levels of spare capacity.

³⁸This relationship is valid only for Canada, Mexico and Norway but only at a 10 per cent significance level.

³⁹According to these tests, the null hypothesis $H_0 : \gamma_{i,1} = \gamma_{i,2} = \dots = \gamma_{i,p} = 0$ (respectively, $H_0 : \vartheta_{i,1} = \vartheta_{i,2} = \dots = \vartheta_{i,p} = 0$) is considered in order to evaluate the joint significance of parameters on world oil demand (resp., real oil prices).

countries (namely, Saudi Arabia, Kuwait and Norway).⁴⁰

[INSERT TABLES 18 TO 20 ABOUT HERE]

Finally, tests are introduced to examine the hypothesis of asymmetric responses as indicated by different coefficients on positive and negative changes in D_t and $P_{i,t}$. In fact, for instance, Kaufmann et al. [4] demonstrate that, among the OPEC countries, short-run effects of price changes on production tend to be asymmetric.⁴¹ The obvious motivation for distinguishing between positive and negative demand (respectively, price) changes is due to the assumption that the curve is upward sloping when demand is (resp. prices are) above the expected demand (resp. price) level but completely vertical when demand is (resp. prices are) below that level.

The Asymmetric Effects on Oil Production of World Oil Demand and Price Changes

The modified versions of equations (8) to (12) employed in order to test the assumption of asymmetric effects are given in Table 21. In this Table, $\Delta \ln Y_{t-j}^+$ and $\Delta \ln Y_{t-j}^-$ denote, respectively, increases and decreases of variable Y_{t-j} ($j = 1, 2, \dots, p$) where $Y_t = \{D_t, P_{i,t}\}$. Similarly, $ECT_{i,t-1}^{(+)}$ (respectively, $ECT_{i,t-1}^{(-)}$) indicates the positive (respectively, negative) component of the error correction term.

[INSERT TABLE 21 ABOUT HERE]

Tables 22 to 27 examine whether (positive or negative) shocks to demand and prices have symmetric effects on oil production. Equations are estimated by adopting both univariate and multivariate SUR techniques.⁴²

⁴⁰The regression analysis also suggests that oil production in countries like Russia, Colombia, Venezuela and Libya is affected also by the political environment. To save space, these results are not presented here but they are available upon request from the authors.

⁴¹According to these authors, for instance, in Saudi Arabia “price reductions lower production faster than price increases raise production”.

⁴²The test procedure presented here is similar to those employed, among others, by Galeotti et al. [39] and Grasso and Manera [40]. Their analysis are, however, concerned with the asymmetric relationship between gasoline and crude oil prices.

Table 22 (resp. Table 23) shows Wald statistics for the hypothesis that the coefficients on positive and negative oil demand (resp. oil price) changes are jointly not statistically different from zero. In order to gain further insights on asymmetric effects of demand and prices, the results of formal statistical tests for the equality of the effects of positive and negative shocks to demand and prices are presented. Table 24 presents Wald statistics from testing the null hypothesis that the sum of the coefficients on positive changes equals the sum of the coefficients on negative changes. Similarly, Tables 25 to 27 show results when dynamic SUR techniques are employed to test asymmetric effects of demand and oil prices on oil production levels.

[INSERT TABLES 22 TO 27 ABOUT HERE]

Results suggest that, for Saudi Arabia and Norway, responses of national output are stronger in the presence of increases in demand levels. Using Wald test statistics, the hypothesis that the coefficients on positive changes in world oil demand equal those on negative changes is rejected at any significance level only for the former country. In Colombia responses of oil production are found to respond significantly to increases in world oil demand whereas, the relationship between oil production changes and declines in demand is not statistically meaningful. With regard to the effects of real oil price changes, Table 24 shows that, for Libya, output levels respond in a non-linear way to oil price changes. For this country, the null hypothesis of symmetric effects is rejected by the data when both least squares and SUR techniques are used. Finally, Table 28 (and Table 29 when dynamic SUR models are employed) shows that for Ecuador, Iran, Malaysia and Norway, there exist nonlinear responses of oil production levels to disequilibrium in the supply function as represented by the long-run relationship (equation 10).

[INSERT TABLES 28 TO 29 ABOUT HERE]

4. Concluding Remarks

This paper focuses on the decisions on production levels faced by *small* exporting countries. The importance in the world oil industry of these market players is, in fact, rapidly growing. A relatively large number of small oil producers has recently recorded a relevant increase in revenues from oil extraction. Between 1995 and 2010, production levels of countries with production levels of not more than 5 per cent of world oil output have increased

from 59.4 to 65.1 per cent of world oil output.

This paper aims at studying the behavior of small oil producers under exogeneity assumptions on variables that describe the economic conditions in the world oil market. Because of the size of their oil reserves, these actors of the world oil market are characterized by relatively low production levels. Consequently, they are assumed to take prices as exogenously given. In many countries the productivity of the oil sector has recently risen. However, these producing countries are still not able to affect world oil prices by modifying production levels.

In particular, our analysis aims at establishing how oil production levels react to changes in world oil demand and real prices. Although previous research has already considered the determinants of decisions on oil production levels, relatively few studies have examined the degree of flexibility of decisions on oil production levels (that is, the possibility by both OPEC and non-OPEC countries to rapidly modify production levels as conditions in the world oil markets change). This paper tries to fill the gap in our understanding of the relationship between oil production levels, world oil demand and real oil prices. At this purpose, both theoretical analysis and empirical investigation are designed to describe the decisions on production levels of these actors of the world oil market. The implications of our results with regard to the effects on the overall structure of the markets are, then, discussed.

Oil production adjustments are investigated through a partial equilibrium model. In this model, oil companies are subject to exogenous shocks in world oil demand and prices. Oil producers can change output levels only by incurring a fixed cost. Results from the simulation of this theoretical model demonstrate that decisions on output levels depend on factors that affect the cost structure of oil producers. As a consequence, output reacts significantly to changes in the stance of international oil markets. However, different responses to exogenous variables are argued to characterize production levels. In fact, on the one hand, the pattern of simulated series suggests that changes in the world oil demand affect significantly output. On the contrary, responses of oil exporting countries to oil price shocks are much weaker. Finally, output levels for a representative oil producing country are well described by an upward sloping Kaplan-Meier hazard function.

Empirical models based on time-series econometric techniques are introduced to describe data regarding output levels for a significant sample of oil producers. Results from the estimation of AutoRegressive Distributive Lag (ARDL) and, when cointegration is present, Error Correction (EC) models suggest

that production levels tend to adjust significantly to variations in total oil demand. On the contrary, the hypothesis of no effects of price changes on oil output is not rejected by the data. This latter result underlines the possibility that, in many small oil producing countries, the oil sector is characterized by low levels of spare capacity. As a consequence, adjustments of production levels are constrained and output reaction to oil price changes is weaker.

Finally, the hypothesis of asymmetric effects of increases and decreases of exogenous variables on oil production levels is examined and discussed. Empirical evidence illustrates that, for some countries (namely, Saudi Arabia, Norway and Colombia), positive oil demand shocks have larger effects than negative demand shocks.

An important direction for future research is to extend the theoretical and empirical models presented in this paper. For instance, additional research is required to investigate the interactions between production quotas adopted by OPEC and world oil prices. Finally, further empirical research should be addressed in order to take into account how political and economic institutions affect investments and production in oil exporting countries.

Figure 1: Profit function of a representative oil producing country

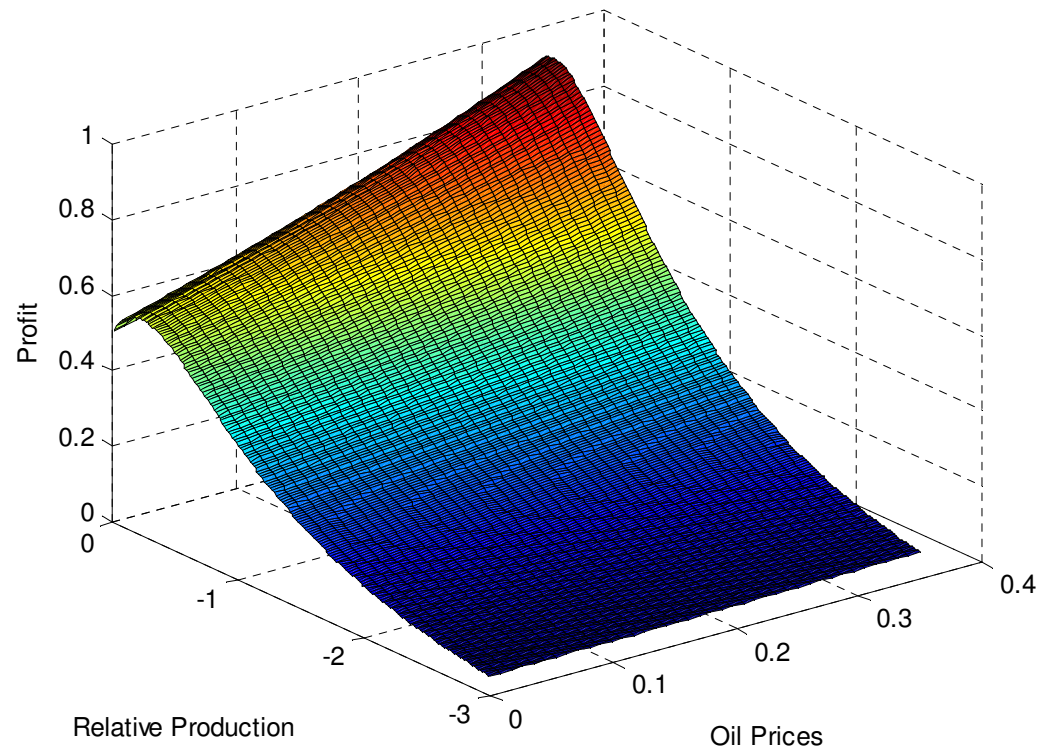


Figure 2: Value and policy function

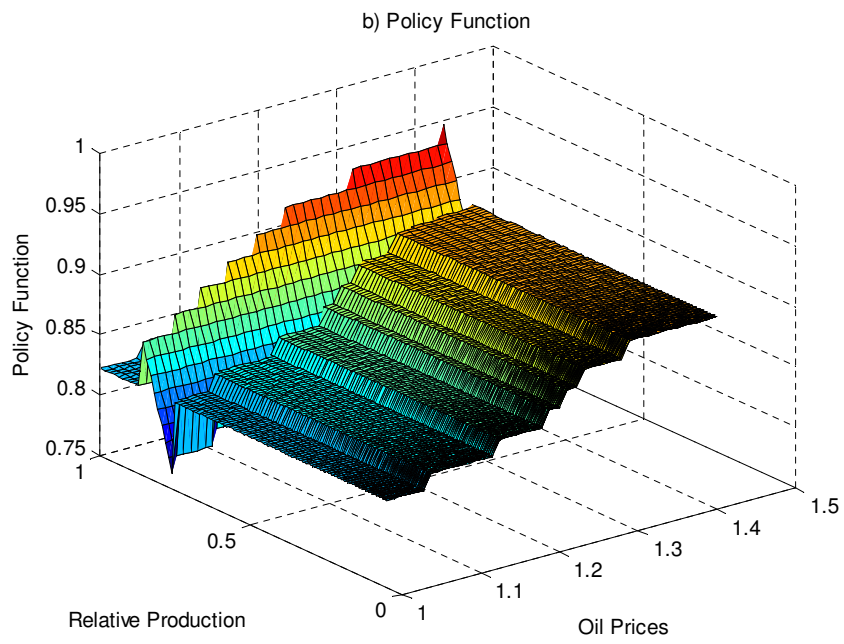
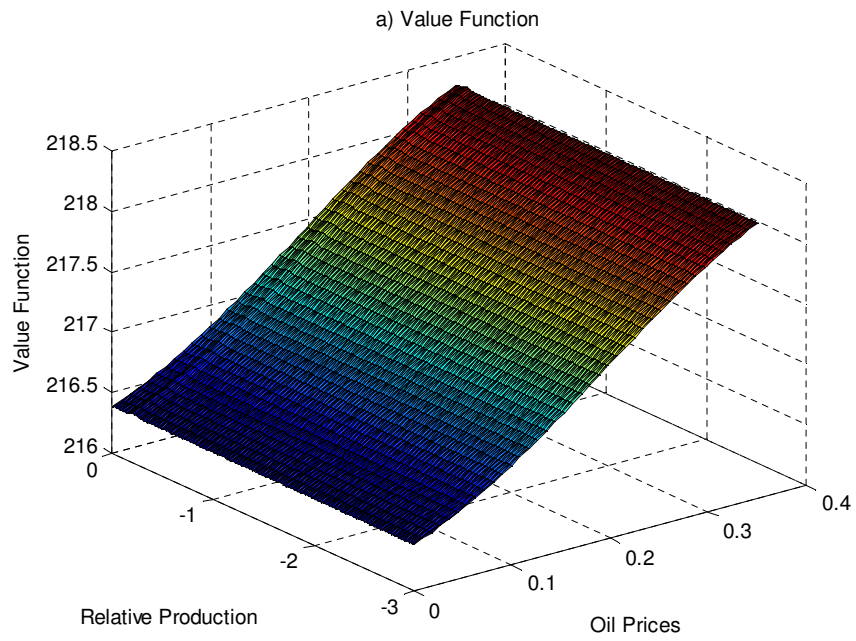


Figure 3: Responses of oil production to changes in the world oil market

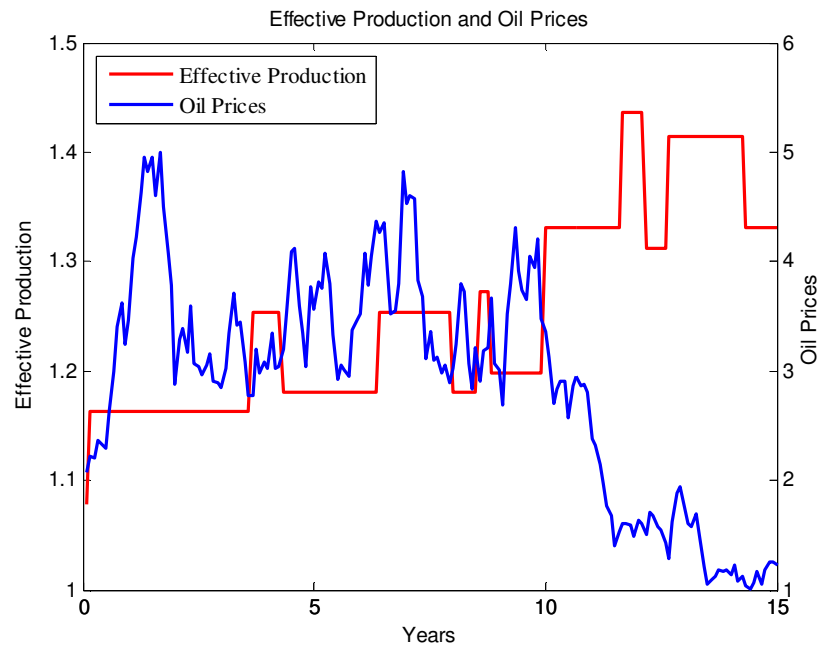
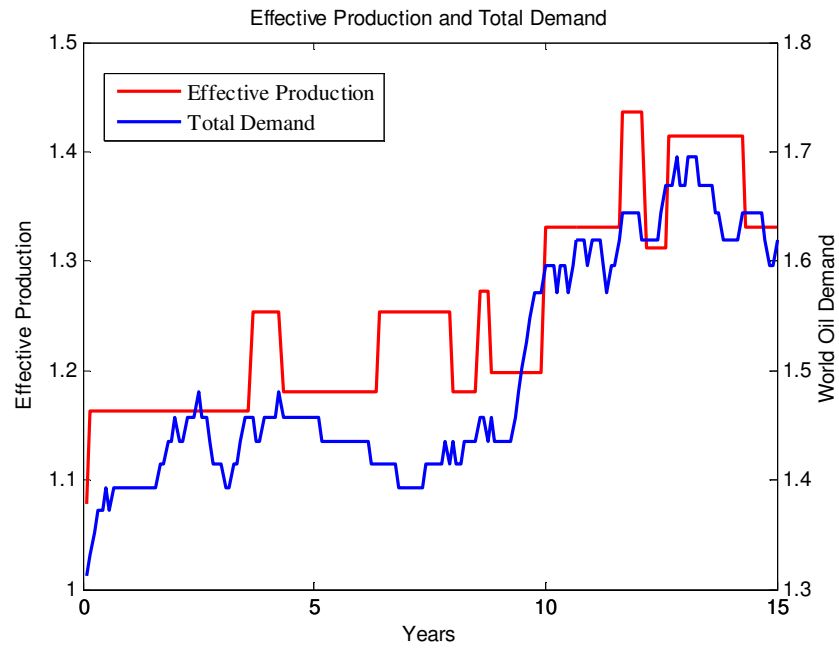


Figure 4: Hazard function of oil production changes (simulated data)

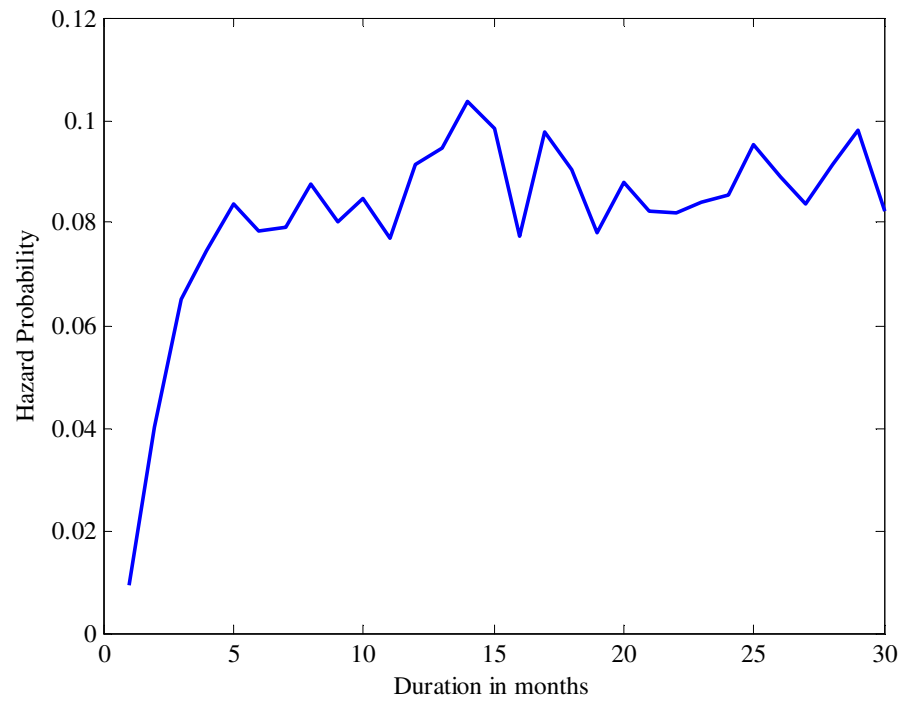


Table 1: Correlation between production levels and world oil demand. Simulation data.

θ_i	Levels	First Differences
2.5	79.1%	17.9%
3	79.9%	1.4%
3.5	95.9%	20.0%
γ	Levels	First Differences
0.4	79.8%	36.8%
0.5	95.3%	26.9%
0.6	88.4%	15.1%
ψ	Levels	First Differences
0.025	92.2%	20.1%
0.03	92.7%	25.3%
0.035	22.7%	16.2%

Table 2: Correlation between production levels and oil prices. Simulation data.

θ_i	Levels	First Differences
2.5	41.9%	1.2%
3	50.1%	-14.2%
3.5	1.4%	-10.0%
γ	Levels	First Differences
0.4	26.9%	-8.6%
0.5	23.9%	9.6%
0.6	-58.2%	-16.0%
ψ	Levels	First Differences
0.025	-60.7%	7.4%
0.03	21.5%	1.3%
0.035	14.2%	-3.6%

Table 3: Statistical relationship between production levels, world oil demand and oil prices.
 Simulated data - Levels.

θ_i	Demand			Prices		
	Coeff.	Std. Error		Coeff.	Std. Error	
2.5	1.114	0.071	***	0.004	0.008	
3	0.385	0.027	***	0.021	0.006	***
3.5	0.972	0.021	***	0.004	0.010	
γ	Coeff.	Std. Error		Coeff.	Std. Error	
0.4	1.016	0.056	***	-0.017	0.007	
0.5	0.969	0.021	***	0.029	0.007	***
0.6	1.121	0.049	***	0.113	0.015	***
ψ	Coeff.	Std. Error		Coeff.	Std. Error	
0.025	1.548	0.075	***	0.042	0.006	***
0.03	1.078	0.030	***	0.016	0.006	***
0.035	0.281	0.085	***	0.019	0.010	*

Notes.

Reported are the results obtained by estimating the following model
 $\ln q_t = \beta_0 + \beta_1 \ln D_t + \beta_2 \ln P_t + \epsilon_t$ on the basis of simulated data.
 *** (**, *) denote rejection of the null hypothesis that coefficients $\hat{\beta}_1$
 and $\hat{\beta}_2$ are statistically not different from zero at 1% (5%, 10%)
 significance level.

Table 4: Statistical relationship between production levels, world oil demand and oil prices. Simulated data - First Differences.

θ_i	Demand			Prices	
	Coeff.	Std. Error		Coeff.	Std. Error
2.5	0.410	0.164	***	0.003	0.015
3	0.002	0.068		-0.028	0.014
3.5	0.391	0.149	***	-0.014	0.014
γ	Coeff.	Std. Error		Coeff.	Std. Error
0.4	0.926	0.169	***	-0.023	0.017
0.5	0.608	0.160	***	0.018	0.016
0.6	0.140	0.069	**	-0.015	0.007
ψ	Coeff.	Std. Error		Coeff.	Std. Error
0.025	0.394	0.134	***	0.016	0.013
0.03	0.561	0.155	***	0.005	0.015
0.04	0.36	0.16	**	-0.009	0.019

Notes.

Reported are the results obtained by estimating the following model $\Delta \ln q_t = \beta_0 + \beta_1 \Delta \ln D_t + \beta_2 \Delta \ln P_t + \epsilon_t$ using simulated data. *** (**, *) denote rejection of the null pothesis that the coefficients $\hat{\beta}_1$ and $\hat{\beta}_2$ are statistically not different from zero at 1% (5%, 10%) significance level.

Table 5: Simulation results. Statistics on oil production changes. Sensitivity to θ .

θ	Frequency	Fraction up	Fraction down	Average size
2.75	8.371	60.992%	40.008 %	7.100
3.00	7.808	62.489%	37.511 %	7.123
3.25	7.664	65.615 %	34.385 %	6.574

Notes.

Frequency and *fraction up* (resp. *down*) denote the average frequency of oil production changes expressed in months and the fraction of oil production increases (resp. decreases), respectively. *Average size* denotes the mean size of oil production changes.

Table 6: Simulation results. Statistics on oil production changes. Sensitivity to γ .

γ	Frequency	Fraction up	Fraction down	Average size
0.4	9.583	58.810%	41.190%	6.851
0.5	7.765	62.503%	37.497%	7.102
0.6	6.948	64.060%	35.940%	6.658

Notes.

See notes to Table 5.

Table 7: Simulation results. Statistics on oil production changes. Sensitivity to ψ .

ψ	Frequency	Fraction up	Fraction down	Average size
0.025	8.394	60.723%	39.277%	7.054
0.03	7.766	62.052%	37.948%	7.163
0.035	7.386	62.740 %	37.260%	7.214

Notes.

See notes to Table 5.

Table 8: Countries considered in the empirical analysis

Country	Start Date	End Date	N. Observations
Algeria	January 1995	December 2009	180
Angola	November 1995	December 2009	170
Ecuador	January 1995	December 2009	180
Iran	January 1995	December 2009	180
Kuwait	January 1995	February 2009	170
Libya	January 2001	November 2009	107
Nigeria	January 1995	October 2009	178
Saudi Arabia	January 1995	December 2009	180
Venezuela	January 1995	December 2009	180
Brazil	January 1996	December 2009	168
Canada	January 1995	December 2009	180
Colombia	January 1995	December 2009	180
Egypt	January 1995	January 2009	169
Indonesia	January 1995	December 2009	180
Malaysia	January 1995	December 2009	180
Mexico	January 1995	December 2009	180
Norway	January 1995	December 2009	180
Russia	January 1998	December 2009	144
U.S.	January 1995	December 2009	180

Table 9: Oil production. Descriptive statistics, levels.

Country	Mean	St. Dev.	Skewness	Kurtosis	Correlation with:	
					a) demand	b) prices
Algeria	1718.7	336.2	0.25	-1.71	94.3%	87.9%
Angola	1058.2	478.6	0.99	-0.47	83.8%	21.9%
Ecuador	438.7	65.4	0.41	-1.45	85.2%	-36.1%
Iran	3875.5	240.1	0.11	-1.24	81.8%	73.3%
Kuwait	2317.7	248.3	0.40	-1.32	84.7%	86.1%
Libya	1564.3	177.4	0.67	-1.14	83.4%	88.4%
Nigeria	2210.5	190.5	0.40	0.53	74.1%	56.1%
Saudi Arabia	9745.5	752.1	0.45	-0.94	78.1%	75.7%
Venezuela	2971.1	398.1	-1.46	7.15	-38.3%	-45.8%
Brazil	1673.4	529.2	0.08	-1.11	94.0%	82.2%
Canada	2904.6	347.3	0.04	-1.15	93.6%	78.4%
Colombia	619.1	94.7	0.61	0.03	-14.2%	-36.4%
Egypt	769.9	108.9	0.03	-1.21	-93.2%	-78.4%
Indonesia	1354.2	233.3	-0.16	-1.64	-91.2%	-81.1%
Malaysia	758.2	54.9	0.27	-0.64	8.6%	-22.0%
Mexico	3452.1	277.7	-0.37	0.32	35.7%	-7.9%
Norway	3007.2	369.42	-0.50	-0.80	-34.5%	-55.2%
Russia	7831.0	1590.2	0.17	-1.74	92.6%	69.4%
U.S.	8950.7	452.2	-1.04	2.31	-71.5%	-58.4%

Table 10: Oil production. Descriptive statistics, log-first differences.

Country	Mean	St. Dev.	Skewness	Kurtosis	Correlation with:	
					a) demand	b) prices
Algeria	0.26%	1.10%	0.83	4.02	18.5%	-7.85%
Angola	0.74%	2.68%	0.83	4.37	2.2%	-0.72%
Ecuador	0.14%	3.72%	0.78	10.94	5.4%	0.30%
Iran	0.07%	2.17%	-0.35	2.73	25.9%	-0.76%
Kuwait	0.10%	1.99%	-0.71	11.63	24.0%	-12.50%
Libya	0.12%	1.12%	-0.15	5.37	21.6%	-7.43%
Nigeria	0.09%	4.10%	-0.18	6.17	16.4%	3.18%
Saudi Arabia	0.05%	1.95%	0.60	8.12	50.5%	5.92%
Venezuela	-0.09%	11.22%	-2.85	66.75	28.5%	-12.32%
Brazil	0.56%	5.94%	-0.04	57.40	-6.4%	-4.74%
Canada	0.20%	2.79%	0.15	0.03	15.4%	-0.11%
Colombia	0.25%	4.13%	-0.76	9.44	-3.7%	4.30%
Egypt	-0.23%	1.96%	-1.89	9.58	-3.5%	9.93%
Indonesia	-0.23%	1.09%	0.51	4.27	3.1%	-5.85%
Malaysia	0.01%	2.66%	-0.10	4.26	-3.0%	-1.08%
Mexico	-0.03%	4.37%	-1.18	29.45	15.1%	6.01%
Norway	-0.05%	6.34%	-0.12	1.16	43.9%	-10.43%
Russia	0.21%	1.00%	-0.58	2.03	17.1%	7.67%
U.S.	-0.01%	2.82%	-2.06	22.88	28.5%	-3.23%

Table 11: Results of unit root tests. Production and world oil demand.

Country	Levels			First Differences		
	N. Lags	T-Stat.	Prob.	N. Lags	T-Stat.	Prob.
Algeria	0	-0.29	0.922	0	-11.609	0.000***
Angola	1 ^t	-1.58	0.797	0	-11.718	0.000 ***
Ecuador	1	-1.71	0.423	0	-17.780	0.000***
Iran	1 ^t	-2.93	0.156	0	-18.107	0.000***
Kuwait	1 ^t	-2.45	0.353	0	-11.584	0.000***
Libya	0	-0.41	0.905	0	-11.965	0.000***
Nigeria	0 ^t	-4.49	0.002***	1	-13.398	0.000***
Saudi Arabia	1	-2.21	0.205	0	-11.694	0.000***
Venezuela	4 ^t	-4.03	0.009***	3	-10.626	0.000***
Brazil	1 ^t	-4.63	0.001***	2	-11.838	0.000***
Canada	0 ^t	-5.62	0.000***	1	-13.815	0.000***
Colombia	0	-2.11	0.241	0	-15.722	0.000***
Egypt	0	-0.24	0.930	0	-14.269	0.000***
Indonesia	0 ^t	-2.40	0.378	0	-14.974	0.000***
Malaysia	0	-2.68	0.080*	0	-14.815	0.000***
Mexico	2	-1.70	0.429	2	-12.251	0.000***
Norway	12 ^t	-1.63	0.778	11 ^t	-5.927	0.000***
Russia	0 ^t	-2.97	0.144	0	-15.954	0.000***
U.S.	0 ^t	-5.11	0.000***	1	-13.637	0.000***
Oil Demand	0 ^t	-2.86	0.178	1	-12.220	0.000***

Notes.

Presented are the t -values of $\widehat{\alpha}_{i,2}^*$ in the following equations:

$$\Delta \ln Z_{i,t} = \alpha_{i,0}^* + \alpha_{i,1}^* \cdot trend + \alpha_{i,2}^* \ln Z_{i,t-1} + \sum_{j=1}^p \beta_{i,j} \Delta \ln Z_{i,t-j} + u_{i,t} \text{ (variables in levels)}$$

$$\Delta^2 \ln Z_{i,t} = \alpha_{i,0}^* + \alpha_{i,1}^* \cdot trend + \alpha_{i,2}^* \ln \Delta Z_{i,t-1} + \sum_{j=1}^p \beta_{i,j} \Delta^2 \ln Z_{i,t-j} + u_{i,t} \text{ (variables in}$$

log-first differences). The procedure proposed by Dolado et al. [37] is adopted. t denotes that a linear trend is included in the above equations. The number of lags to include in the regressions is chosen by minimizing the Schwarz-Bayesian Information Criterion. *** (**, *) denote that the null hypothesis $H_0 : \widehat{\alpha}_{i,2}^* = 0$ is rejected given 1% (5%, 10%) significance levels. Critical values computed by MacKinnon [35] are employed.

Table 12: Results of unit root tests. Real oil prices.

Country	Levels			First Differences		
	N. Lags	T-Stat.	Prob.	N. Lags	T-Stat.	Prob.
Algeria	1 ^t	-3.174	0.093*	0	-10.881	0.000***
Angola	2	-3.310	0.016**	0	-11.213	0.000***
Ecuador	1	-1.781	0.389	0	-10.447	0.000***
Iran	0 ^t	-2.201	0.486	0	-12.218	0.000***
Kuwait	1 ^t	-2.393	0.382	0	-10.407	0.000***
Libya	1	-2.208	0.205	0	-8.339	0.000***
Nigeria	0 ^t	-2.229	0.471	0	-13.428	0.000***
Saudi Arabia	1 ^t	-2.850	0.181	0	-10.691	0.000***
Venezuela	1	-1.936	0.316	0	-10.379	0.000***
Brazil	1	-1.682	0.439	0	-10.788	0.000***
Canada	1 ^t	-3.278	0.073*	0	-11.447	0.000***
Colombia	1 ^t	-2.898	0.166	0	-11.478	0.000***
Egypt	1 ^t	-2.469	0.343	0	-10.370	0.000***
Indonesia	0	-2.979	0.141	0	-12.317	0.000***
Malaysia	1 ^t	-3.427	0.051*	0	-11.060	0.000***
Mexico	1 ^t	-2.761	0.214	0	-11.391	0.000***
Norway	1 ^t	-3.025	0.128	0	-11.418	0.000***
Russia	1 ^t	-2.781	0.207	0	-11.083	0.000***
U.S.	1 ^t	-2.825	0.190	0	-10.828	0.000***

Notes.

See notes to Table 11.

Table 13: Stationary analysis of residuals of long-run relationship.

Country	N. Lags	T-Stat.
Algeria	3	-2.449
Ecuador	0	-3.405 ***
Iran	2	-3.793 **
Kuwait	0	-4.904 ***
Libya	0	-3.392 *
Saudi Arabia	5	-3.959 **
Colombia	1	-3.241
Egypt	0	-3.813 **
Indonesia	2	-2.822
Malaysia	2	-3.677 **
Mexico	0	-4.970 ***
Norway	1	-5.673 ***
Russia	0	-5.042 ***

Notes.

Reported are the results from ADF tests on the residuals of long-run equations (10). The number of lags to include in the regression is chosen by minimizing the Schwarz-Bayesian Information Criterion. *** (**, *) denote rejection of the null hypothesis that coefficient $\alpha_{i,2}^*$ (see equation 15) is not statistically different from zero at 1% (5%, 10%) significance level. We employ critical values computed by Davidson and MacKinnon [38].

Table 14: Estimation of oil production levels. Short-run dynamics.

	Algeria	Ecuador	Iran	Kuwait	Libya	Saudi Arabia
C	-0.001	-0.009	0.012	-0.026	-0.167 0.041	
$\Delta \ln q_{i,t-1}$	0.037	0.028	0.050	0.089	0.067 ** 0.326	
	0.157	-0.190	-0.239	0.181	-0.023 0.121	
$\Delta \ln q_{i,t-2}$	0.075 **	0.077 **	0.084 ***	0.068 ***	0.105 0.077	
	-0.005		-0.192		-0.063 -0.022	
$\Delta \ln q_{i,t-3}$	0.075		0.082 **		0.099 0.077	
			-0.068		-0.073	
$\Delta \ln q_{i,t-4}$			0.080		0.076	
			-0.221			
$\Delta \ln q_{i,t-5}$			0.073 ***			
$\Delta \ln D_t$	0.232	0.488	0.600	0.478	0.119 1.085	
	0.099 **	0.323	0.176 ***	0.160 ***	0.155 0.154 ***	
$\Delta \ln D_{t-1}$	-0.012	0.088	0.304	0.234	-0.168 -0.008	
	0.098	0.324	0.193	0.165	0.149	0.176
$\Delta \ln D_{t-2}$	0.208		0.294		-0.027	0.136
	0.099 **		0.197		0.147	0.176
$\Delta \ln D_{t-3}$			0.311			0.231
			0.189			0.174
$\Delta \ln D_{t-4}$			0.340			
			0.187 *			
$\Delta \ln D_{t-5}$						
$\Delta \ln P_{i,t}$	-0.013	0.005	-0.003	-0.045	-0.014	-0.004
	0.010	0.032	0.010	0.016 ***	0.010	0.015
$\Delta \ln P_{i,t-1}$	-0.005	0.066	-0.004	0.001	0.013	0.029
	0.010	0.032 **	0.010	0.018	0.011	0.015 *
$\Delta \ln P_{i,t-2}$	0.031		-0.007		0.020	0.035
	0.010 ***		0.010		0.010 *	0.015 **
$\Delta \ln P_{i,t-3}$			-0.010			0.029
			0.010			0.015 *
$\Delta \ln P_{i,t-4}$			-0.002			
			0.010			
$\Delta \ln P_{i,t-5}$						
$ECT_{i,t-1}$		-0.153	-0.201	-0.288		-0.098
		0.052 ***	0.064 ***	0.044 ***		0.036 ***
$polity_{i,t}$	0.000	0.001	-0.001	0.000	0.010	0.000
	0.001	0.003	0.002	0.002	0.004 ***	0.001
$reserves_{i,t}$	0.000	-0.001	0.000	0.000	0.002	0.000
	0.002	0.003	0.000	0.001	0.001 **	0.001
R^2	0.149	0.145	0.305	0.341	0.174	0.402
ln-likelihood	566.4	345.2	464.6	447.5	318.3	491.9
F-statistic	2.951	3.610	4.148	10.335	1.958	7.873
Prob(F-statistic)	0.002 ***	0.001 ***	0.000 ***	0.000 ***	0.047 **	0.000 ***

Notes.

Presented are the results from the estimation of short-run dynamic of oil production (see equations 7 to 12). For each country the final specification is chosen according to the algorithm presented in Section 3.2. *** (**, *) denote rejection of the null hypothesis that the coefficient is not statistically different from zero at 1% (5%, 10%) significance level. The optimal lag-length of ARDL and EC Models is chosen by computing the autocorrelations of the estimated residuals and selecting the minimum number of lags that ensure not serially autocorrelated error series. Dynamic models are estimated by employing least squares techniques.

Table 15: Estimation of oil production levels. Short-run dynamics (Ctd.)

	Colombia	Egypt	Indonesia	Malaysia	Mexico	Norway	Russia
C	0.076	-0.017	0.005	0.004	-0.002	0.010	-0.022
	0.034 **	0.036	0.010	0.046	0.009	0.037	0.010 **
$\Delta \ln q_{i,t-1}$	-0.070	0.025	-0.102	-0.003	-0.487	-0.356	-0.045
	0.075	0.080	0.077	0.078	0.086 ***	0.089 ***	0.090
$\Delta \ln q_{i,t-2}$		-0.055	-0.074		-0.377	-0.229	
		0.079	0.077		0.085 ***	0.078 ***	
$\Delta \ln q_{i,t-3}$					-0.177		
					0.076 **		
$\Delta \ln q_{i,t-4}$							
$\Delta \ln q_{i,t-5}$							
$\Delta \ln D_t$	-0.114	-0.182	0.037 0.046	1.071	2.582	0.174	
	0.311	0.188	0.104	0.241	0.356 ***	0.467 ***	0.077 **
$\Delta \ln D_{t-1}$	0.514	-0.241	-0.040	0.199	-0.097	0.262	-0.127
	0.308 *	0.184	0.101	0.237	0.366	0.499	0.074 *
$\Delta \ln D_{t-2}$		0.240	-0.077		0.160	0.627	
		0.188	0.102		0.360	0.502	
$\Delta \ln D_{t-3}$					-0.465		
					0.353		
$\Delta \ln D_{t-4}$							
$\Delta \ln D_{t-5}$							
$\Delta \ln P_{i,t}$	0.042	0.020	-0.007	0.001	0.022	-0.129	0.005
	0.030	0.018	0.008	0.024	0.035	0.049 ***	0.007
$\Delta \ln P_{i,t-1}$	0.009	-0.004	0.005	0.008	-0.074	-0.007	0.002
	0.030	0.018	0.008	0.024	0.035 **	0.049	0.007
$\Delta \ln P_{i,t-2}$		0.038	0.012		-0.024	0.029	
		0.018 **	0.008		0.035	0.048	
$\Delta \ln P_{i,t-3}$					0.063		
					0.035 *		
$\Delta \ln P_{i,t-4}$							
$\Delta \ln P_{i,t-5}$							
$ECT_{i,t-1}$		-0.104		-0.134	-0.076	-0.225	-0.048
		0.042 **		0.042 ***	0.053	0.076 ***	0.031
$polity_{i,t}$	-0.008	0.001	0.001	0.001	-0.002	-0.011	0.002
	0.003	0.002	0.001	0.002	0.002	0.010	0.000
$reserves_{i,t}$	0.014	0.002	-0.003	-0.002	0.001	0.000	0.000
	0.006	0.007	0.003	0.007	0.000	0.003	0.000
R^2	0.070	0.107	0.045	0.075	0.335	0.432	0.140
ln-likelihood	353.2	437.6	558.5	397.7	337.4	287.6	500.0
F-statistic	1.838	1.753	0.803	1.717	5.903	11.543	2.737
Prob(F-statistic)	0.083 *	0.066 *	0.626	0.098 *	0.000 ***	0.000 ***	0.008 ***

Notes.

See notes to Table 14.

Table 16: Estimation of oil production levels. Short-run dynamics (Ctd.)

	Angola		Nigeria	Venezuela	Brazil	Canada	U.S.
C	-0.018	C	1.000	2.197	0.442	0.349	2.896
	0.067		0.335 ***	0.521 ***	0.220 **	0.234	0.509 ***
$\Delta \ln q_{i,t-1}$	0.183	$\ln q_{i,t-1}$	0.802	1.280	0.798	0.848	0.695
	0.078 **		0.076 ***	0.078 ***	0.081 ***	0.076 ***	0.053 ***
$\Delta \ln q_{i,t-2}$		$\ln q_{i,t-2}$	-0.121	-0.933	0.135	-0.159	
			0.098	0.124 ***	0.082	0.099	
$\Delta \ln q_{i,t-3}$		$\ln q_{i,t-3}$	0.177	0.618		0.157	
			0.076 **	0.134 ***		0.099	
$\Delta \ln q_{i,t-4}$		$\ln q_{i,t-4}$		-0.410		0.110	
				0.122 ***		0.076	
$\Delta \ln q_{i,t-5}$		$\ln q_{i,t-5}$		0.192			
				0.077 **			
$\Delta \ln D_t$	0.209	$\Delta \ln D_t$	0.690	2.658	0.161	0.463	0.901
	0.250		0.311 **	0.796 ***	0.274	0.242 *	0.229 ***
$\Delta \ln D_{t-1}$	-0.078	$\Delta \ln D_{t-1}$	0.175	0.288	-0.058	0.062	0.488
	0.251		0.314	0.822	0.261	0.241	0.230 **
$\Delta \ln D_{t-2}$		$\Delta \ln D_{t-2}$	0.323	-1.493	-0.116	-0.178	
			0.313	0.828 *	0.266	0.246	
$\Delta \ln D_{t-3}$		$\Delta \ln D_{t-3}$	0.546	-0.155		-0.153	
			0.306 *	0.830		0.239	
$\Delta \ln D_{t-4}$		$\Delta \ln D_{t-4}$		0.261		0.332	
				0.812		0.238	
$\Delta \ln D_{t-5}$		$\Delta \ln D_{t-5}$		-0.097			
				0.800			
$\ln P_{i,t}$	0.000	$\Delta \ln P_{i,t}$	0.001	-0.111	-0.018	-0.017	0.000
	0.013		0.019	0.069	0.025	0.025	0.024
$\ln P_{i,t-1}$	0.001	$\Delta \ln P_{i,t-1}$	-0.025	0.131	-0.001	0.009	0.013
	0.013		0.018	0.071 *	0.025	0.025	0.024
$\ln P_{i,t-2}$		$\Delta \ln P_{i,t-2}$	0.011	0.028	-0.020	-0.055	
			0.019	0.071	0.025	0.025 **	
$\ln P_{i,t-3}$		$\Delta \ln P_{i,t-3}$	-0.009	-0.095		0.040	
			0.019	0.072		0.025	
$\ln P_{i,t-4}$		$\Delta \ln P_{i,t-4}$		0.026		0.035	
				0.072		0.025	
$\ln P_{i,t-5}$		$\Delta \ln P_{i,t-5}$		-0.079			
				0.069			
$ECT_{i,t-1}$		$ECT_{i,t-1}$					
$polity_{i,t}$	0.001	$polity_{i,t}$	0.003	-0.014	-0.001		-0.012
	0.003		0.004	0.006 **	0.007		0.003 ***
$reserves_{i,t}$	0.001	$reserves_{i,t}$	0.001	-0.001	0.007	0.000	-0.004
	0.002		0.001 *	0.000 **	0.004 *	0.000	0.003
R^2	0.048	R^2	0.827	0.790	0.990	0.953	0.762
ln-likelihood	373.4	ln-likelihood	356.7	198.5	360.2	424.8	406.3
F-statistic	1.168	F-statistic	60.198	31.727	1498.086	232.934	78.616
Prob(F-statistic)	0.324	Prob(F-statistic)	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***

Notes.

See notes to Table 14.

Table 17: Estimation of oil production levels.

Country	Lags	Demand			Prices		
		F-Stat.	Prob.	Sign	F-Stat.	Prob.	Sign
Algeria	2	2.85	0.04 **	(+)	3.88	0.01 **	(+)
Angola	1	0.42	0.66		0.01	0.99	
Ecuador	1	1.15	0.32		2.41	0.09 *	
Iran	4	3.56	0.00 ***	(+)	0.36	0.87	
Kuwait	1	5.00	0.01 ***	(+)	4.02	0.02 **	(-)
Libya	2	0.77	0.51		2.40	0.07 *	(+)
Nigeria	3	2.02	0.09 *	(+)	0.64	0.64	
Saudi Arabia	3	14.00	0.00 ***	(+)	4.24	0.00 ***	(+)
Venezuela	5	2.91	0.01 **	(+)	1.37	0.23	
Brazil	2	0.25	0.86		0.43	0.73	
Canada	4	1.75	0.13		1.96	0.09 *	(+)
Colombia	1	1.54	0.22		1.17	0.31	
Egypt	2	1.73	0.16		1.94	0.12	
Indonesia	2	0.33	0.80		1.21	0.31	
Malaysia	1	0.36	0.70		0.06	0.94	
Mexico	3	2.79	0.03 **	(+)	2.15	0.08 *	(-)
Norway	2	10.24	0.00 ***	(+)	2.46	0.06 *	(-)
Russia	1	4.18	0.02 **	(+)	0.40	0.67	
U.S.	1	9.45	0.00 ***	(+)	0.16	0.85	

Notes.

Presented are the F -statistic tests that all regression coefficients associated with world oil demand and real oil prices are zero. *** (**, *) indicate that: $H_0 : \gamma_{i,1} = \gamma_{i,2} = \dots = \gamma_{i,p} = 0$ and $H_0 : \vartheta_{i,1} = \vartheta_{i,2} = \dots = \vartheta_{i,p} = 0$ can be rejected given a 1% (5%, 10%) significance level. These tests are based on the estimates presented in Tables 14 to 16. In columns five and eight the sign of the relationship between oil production and total demand (or real oil prices) based on long-run coefficients $\beta_{i,D} = \frac{\gamma_{i,1} + \gamma_{i,2} + \dots + \gamma_{i,p}}{1 - \beta_{i,1} - \beta_{i,2} - \dots - \beta_{i,p}}$ and $\beta_{i,P_i} = \frac{\vartheta_{i,1} + \vartheta_{i,2} + \dots + \vartheta_{i,p}}{1 - \beta_{i,1} - \beta_{i,2} - \dots - \beta_{i,p}}$ is reported. ARDL and EC models are estimated by employing least squares techniques. See also notes to Table 14.

Table 18: System Residual Portmanteau Tests for Autocorrelations. First group of countries.

Lags (h)		$Q - Stat$			$Adj Q - Stat$		
		$m = 1$ Lag	2 Lags	3 Lags	$m = 1$ Lag	2 Lags	3 Lags
1	Value	195.57	226.49	239.14	197.63	228.90	241.71
	Prob	0.08	0.00	0.00	0.07	0.00	0.00
2	Value	366.33	411.52	437.48	372.02	417.91	444.36
	Prob	0.14	0.00	0.00	0.10	0.00	0.00
3	Value	542.47	578.27	609.67	553.84	590.09	622.23
	Prob	0.13	0.02	0.00	0.07	0.01	0.00
4	Value	702.84	734.33	773.53	721.18	753.02	793.38
	Prob	0.23	0.06	0.01	0.11	0.02	0.00
5	Value	834.70	882.49	931.44	860.29	909.41	960.15
	Prob	0.59	0.18	0.02	0.35	0.06	0.00
6	Value	1019.36	1082.85	1136.07	1057.27	1123.27	1178.73
	Prob	0.45	0.07	0.00	0.17	0.01	0.00

Notes. The first group of countries comprises Algeria, Ecuador, Iran, Kuwait, Libya, Saudi Arabia, Colombia, Egypt, Indonesia, Malaysia, Mexico, Norway and Russia. The null hypothesis considered by the multivariate Box-Pierce/Ljung-Box Q -statistics is that there is no residual autocorrelations up to lag h . Notice that the test is valid only for h larger than the lag order of the system ($m = 1, 2, 3$).

Table 19: System Residual Portmanteau Tests for Autocorrelations. Second group of countries.

Lags (h)		$Q - Stat$			$Adj Q - Stat$		
		$m = 1$ Lag	2 Lags	3 Lags	$m = 1$ Lag	2 Lags	3 Lags
1	Value	47.67	31.14	24.62	47.96	31.33	24.78
	Prob	0.00	0.18	0.48	0.00	0.18	0.48
2	Value	85.94	72.93	46.99	86.71	73.64	47.43
	Prob	0.00	0.02	0.59	0.00	0.02	0.58
3	Value	127.08	107.49	82.28	128.62	108.85	83.37
	Prob	0.00	0.01	0.26	0.00	0.01	0.24
4	Value	146.71	127.99	106.37	148.73	129.87	108.08
	Prob	0.00	0.03	0.31	0.00	0.02	0.27
5	Value	157.88	138.49	120.71	160.26	140.70	122.88
	Prob	0.02	0.19	0.59	0.02	0.16	0.54
6	Value	191.62	169.60	147.54	195.28	173.00	150.74
	Prob	0.01	0.13	0.54	0.01	0.10	0.47

Notes. The second group of countries comprises Nigeria, Venezuela, Brazil, Canada and the U.S.. See also notes to Table 18.

Table 20: Estimation of Dynamic SURs. Results on the statistical significance of world oil demand and prices.

Country	Lags	Demand			Prices		
		$\chi^2(2)$	Prob.	Sign	$\chi^2(2)$	Prob.	Sign
Algeria	1	6.26	0.04 **	(+)	1.94	0.38	
Ecuador	1	8.88	0.01 **	(+)	2.27	0.32	
Iran	1	31.48	0.00 ***	(+)	4.32	0.12	
Kuwait	1	23.25	0.00 ***	(+)	9.49	0.01 ***	(-)
Libya	1	3.57	0.17		1.18	0.55	
Saudi Arabia	1	69.61	0.00 ***	(+)	12.80	0.00 ***	(+)
Colombia	1	3.11	0.21		1.91	0.39	
Egypt	1	8.07	0.02 **	(+)	1.47	0.48	
Indonesia	1	0.33	0.85		1.31	0.52	
Malaysia	1	0.74	0.69		1.21	0.55	
Mexico	1	5.58	0.06 *	(+)	6.21	0.04 **	(-)
Norway	1	36.74	0.00 ***	(+)	9.90	0.01 ***	(-)
Russia	1	11.03	0.00 ***	(+)	1.03	0.60	
Nigeria	3	8.87	0.06 *	(+)	2.70	0.61	
Venezuela	3	19.48	0.00 ***	(+)	6.68	0.15	
Brazil	3	1.31	0.86		2.63	0.62	
Canada	3	5.91	0.21		7.82	0.10 *	(+)
U.S.	3	23.29	0.00 ***	(+)	6.85	0.14	

Notes.

Presented are the statistic tests that all regression coefficients associated with world oil demand and oil prices are zero. *** (**, *) indicate that: $H_0 : \gamma_{i,1} = \gamma_{i,2} = \dots = \gamma_{i,p} = 0$ and $H_0 : \vartheta_{i,1} = \vartheta_{i,2} = \dots = \vartheta_{i,p} = 0$ can be rejected given a 1% (5%, 10%) significance level. Dynamic models are estimated by employing Seemingly Unrelated Regression techniques. In columns five and eight the sign of the relationship between oil production and total demand (or real oil prices) based on long-run coefficients $\beta_{i,D} = \frac{\gamma_{i,1} + \gamma_{i,2} + \dots + \gamma_{i,p}}{1 - \beta_{i,1} - \beta_{i,2} - \dots - \beta_{i,p}}$ and $\beta_{i,P_i} = \frac{\vartheta_{i,1} + \vartheta_{i,2} + \dots + \vartheta_{i,p}}{1 - \beta_{i,1} - \beta_{i,2} - \dots - \beta_{i,p}}$ is reported.

Table 21: Models employed to test asymmetric effects of exogenous variables on oil production levels.

Model	Symmetric Effects
1b	$\ln q_{i,t} = \alpha_i + \sum_{k=1}^p \beta_{i,k} \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j} \Delta \ln D_{t-j} + \sum_{s=0}^p \vartheta_{i,s} \Delta \ln P_{i,t-s} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t}$
1c	$\Delta \ln q_{i,t} = \alpha_i + \sum_{k=1}^p \beta_{i,k} \Delta \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j} \Delta \ln D_{t-j} + \sum_{s=0}^p \vartheta_{i,s} \ln P_{i,t-s} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t}$
2a	$\Delta \ln q_{i,t} = \alpha_i + \sum_{k=1}^p \beta_{i,k} \Delta \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j} \Delta \ln D_{t-j} + \sum_{s=0}^p \vartheta_{i,s} \Delta \ln P_{i,t-s} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t}$
2b	$\Delta \ln q_{i,t} = \alpha_i + \sum_{k=1}^p \beta_{i,k} \Delta \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j} \Delta \ln D_{t-j} + \sum_{s=0}^p \vartheta_{i,s} \Delta \ln P_{i,t-s} + \theta_i ECT_{i,t-1} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t}$
I	$\Delta \ln \mathbf{q}_t = \alpha + \sum_{k=1}^p \beta_k \Delta \ln \mathbf{q}_{t-k} + \sum_{j=0}^p \gamma_j \Delta \ln D_{t-j} + \sum_{s=0}^p \vartheta_s \Delta \ln \mathbf{P}_{t-s} + \mathbf{D} \cdot \theta \cdot \mathbf{ECT}_{t-1} + \mathbf{\Gamma} \cdot \mathbf{Z}_t + \epsilon_t$
II	$\ln \mathbf{q}_t = \alpha + \sum_{k=1}^p \beta_k \ln \mathbf{q}_{t-k} + \sum_{j=0}^p \gamma_j \Delta \ln D_{t-j} + \sum_{s=0}^p \vartheta_s \Delta \ln \mathbf{P}_{t-s} + \mathbf{\Gamma} \cdot \mathbf{Z}_t + \epsilon_t$
Model	Asymmetric Effects
1b	$\ln q_{i,t} = \alpha_i + \sum_{k=1}^p \beta_{i,k} \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j}^{(+)} \Delta \ln D_{t-j}^{(+)} + \sum_{s=0}^p \vartheta_{i,s}^{(+)} \Delta \ln P_{i,t-s}^{(+)} + \sum_{j=0}^p \gamma_{i,j}^{(-)} \Delta \ln D_{t-j}^{(-)} + \sum_{s=0}^p \vartheta_{i,s}^{(-)} \Delta \ln P_{i,t-s}^{(-)} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t}$
1c	$\Delta \ln q_{i,t} = \alpha_i + \sum_{k=1}^p \beta_{i,k} \Delta \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j}^{(+)} \Delta \ln D_{t-j}^{(+)} + \sum_{s=0}^p \vartheta_{i,s} \ln P_{i,t-s} + \sum_{j=0}^p \gamma_{i,j}^{(-)} \Delta \ln D_{t-j}^{(-)} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t}$
2a	$\Delta \ln q_{i,t} = \alpha_i + \sum_{k=1}^p \beta_{i,k} \Delta \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j}^{(+)} \Delta \ln D_{t-j}^{(+)} + \sum_{s=0}^p \vartheta_{i,s}^{(+)} \Delta \ln P_{i,t-s}^{(+)} + \sum_{j=0}^p \gamma_{i,j}^{(-)} \Delta \ln D_{t-j}^{(-)} + \sum_{s=0}^p \vartheta_{i,s}^{(-)} \Delta \ln P_{i,t-s}^{(-)} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t}$
2b	$\Delta \ln q_{i,t} = \alpha_i + \sum_{k=1}^p \beta_{i,k} \Delta \ln q_{i,t-k} + \sum_{j=0}^p \gamma_{i,j}^{(+)} \Delta \ln D_{t-j}^{(+)} + \sum_{s=0}^p \vartheta_{i,s}^{(+)} \Delta \ln P_{i,t-s}^{(+)} + \theta_i^{(+)} ECT_{i,t-1}^{(+)} + \sum_{j=0}^p \gamma_{i,j}^{(-)} \Delta \ln D_{t-j}^{(-)} + \sum_{s=0}^p \vartheta_{i,s}^{(-)} \Delta \ln P_{i,t-s}^{(-)} + \theta_i^{(-)} ECT_{i,t-1}^{(-)} + \Gamma_i \cdot Z_{i,t} + \epsilon_{i,t}$
I	$\Delta \ln \mathbf{q}_t = \alpha + \sum_{k=1}^p \beta_k \Delta \ln \mathbf{q}_{t-k} + \sum_{j=0}^p \gamma_j^{(+)} \Delta \ln D_{t-j}^{(+)} + \sum_{j=0}^p \gamma_j^{(-)} \Delta \ln D_{t-j}^{(-)} + \sum_{s=0}^p \vartheta_s^{(+)} \Delta \ln \mathbf{P}_{t-s}^{(+)} + \sum_{s=0}^p \vartheta_s^{(-)} \Delta \ln \mathbf{P}_{t-s}^{(-)} + \mathbf{D} \cdot \theta^{(-)} \cdot \mathbf{ECT}_{t-1}^{(-)} + \mathbf{D} \cdot \theta^{(+)} \cdot \mathbf{ECT}_{t-1}^{(+)} + \mathbf{\Gamma} \cdot \mathbf{Z}_t + \epsilon_t$
II	$\ln \mathbf{q}_t = \alpha + \sum_{k=1}^p \beta_k \ln \mathbf{q}_{t-k} + \sum_{j=0}^p \gamma_j^{(+)} \Delta \ln D_{t-j}^{(+)} + \sum_{j=0}^p \gamma_j^{(-)} \Delta \ln D_{t-j}^{(-)} + \sum_{s=0}^p \vartheta_s^{(+)} \Delta \ln \mathbf{P}_{t-s}^{(+)} + \sum_{s=0}^p \vartheta_s^{(-)} \Delta \ln \mathbf{P}_{t-s}^{(-)} + \mathbf{\Gamma} \cdot \mathbf{Z}_t + \epsilon_t$

Table 22: Asymmetric effects of world oil demand on oil production.

Country	Lags	$\Delta \ln D_t^{(+)}$		$\Delta \ln D_t^{(-)}$	
		F-Stat.	Prob. (Sign)	F-Stat.	Prob. (Sign)
Algeria	2	2.28	0.08 * (+)	0.77	0.51
Angola	6	0.66	0.70	0.80	0.59
Ecuador	1	0.10	0.90	0.69	0.50
Iran	3	0.68	0.61	1.32	0.26
Kuwait	1	1.40	0.25	1.17	0.31
Libya	2	0.43	0.73	1.68	0.18
Nigeria	1	0.32	0.73	1.35	0.26
Saudi Arabia	1	13.53	0.00 *** (+)	3.23	0.04 ** (+)
Venezuela	5	1.16	0.33	3.37	0.00 *** (+)
Brazil	2	1.59	0.19	0.91	0.44
Canada	4	0.26	0.93	0.65	0.66
Colombia	1	2.66	0.07 * (+)	1.60	0.21
Egypt	4	0.37	0.87	0.76	0.58
Indonesia	1	1.03	0.36	1.06	0.35
Malaysia	1	0.63	0.53	0.39	0.68
Mexico	2	1.84	0.14	0.34	0.79
Norway	2	4.51	0.00 *** (+)	2.58	0.06 * (+)
Russia	1	2.33	0.10	1.98	0.14
U.S.	2	0.11	0.95	8.75	0.00 *** (+)

Notes.

Presented are the F -statistic tests that all regression coefficients associated with world oil demand increases and decreases are zero. *** (**, *) indicate that the null hypotheses $H_0 : \gamma_{i,1}^{(+)} = \gamma_{i,2}^{(+)} = \dots = \gamma_{i,p}^{(+)} = 0$ and $H_0 : \gamma_{i,1}^{(-)} = \gamma_{i,2}^{(-)} = \dots = \gamma_{i,p}^{(-)} = 0$ are rejected given a 1% (5%, 10%) significance level. The optimal lag-length of ARDL and EC Models is chosen by computing the autocorrelations of the estimated residuals and selecting the minimum number of lags that ensure not serially autocorrelated error series. Dynamic models are estimated by employing least squares techniques.

Table 23: Asymmetric effects of real oil prices on oil production.

Country	Lags	$\Delta \ln P_{i,t}^{(+)}$		$\Delta \ln P_{i,t}^{(-)}$	
		F-Stat.	Prob. (Sign)	F-Stat.	Prob. (Sign)
Algeria	2	0.41	0.75	2.91	0.04 ** (+)
Angola	6	-	-	-	-
Ecuador	1	0.26	0.77	1.20	0.30
Iran	3	0.10	0.98	0.97	0.42
Kuwait	1	2.06	0.13	0.55	0.58
Libya	2	2.24	0.09 * (+)	3.16	0.03 ** (+)
Nigeria	1	1.01	0.37	0.19	0.82
Saudi Arabia	1	0.89	0.41	1.02	0.36
Venezuela	5	0.27	0.95	1.38	0.23
Brazil	2	0.58	0.63	1.66	0.18
Canada	4	1.89	0.10 * (+)	0.48	0.79
Colombia	1	0.20	0.82	2.56	0.08 * (+)
Egypt	4	0.18	0.97	0.66	0.66
Indonesia	1	0.65	0.52	2.58	0.08 * (-)
Malaysia	1	0.61	0.55	0.94	0.39
Mexico	2	1.02	0.39	0.45	0.72
Norway	2	1.02	0.39	1.49	0.22
Russia	1	0.20	0.82	0.40	0.67
U.S.	2	1.86	0.14	4.02	0.01 *** (-)

Notes.

Presented are the F -statistic tests that all regression coefficients associated with real oil price increases and decreases are zero. *** (**, *) indicate that the null hypotheses $H_0 : \vartheta_{i,1}^{(+)} = \vartheta_{i,2}^{(+)} = \dots = \vartheta_{i,p}^{(+)} = 0$ and $H_0 : \vartheta_{i,1}^{(-)} = \vartheta_{i,2}^{(-)} = \dots = \vartheta_{i,p}^{(-)} = 0$ is rejected given a 1% (5%, 10%) significance level. See also notes to Table 22.

Table 24: Asymmetric effects of world oil demand and real oil prices on oil production.

Country	$\gamma_i^{(+)} =$ $\gamma_i^{(-)}$	Prob.	$\vartheta_i^{(+)} =$ $\vartheta_i^{(-)}$	Prob.
Algeria	2.18	0.14	0.15	0.69
Angola	0.10	0.75	-	-
Ecuador	0.39	0.53	0.28	0.60
Iran	0.04	0.85	0.77	0.38
Kuwait	0.00	0.99	1.34	0.25
Libya	4.42	0.04 **	5.52	0.02 **
Nigeria	0.91	0.34	0.26	0.61
Saudi Arabia	3.35	0.07 *	0.07	0.80
Venezuela	0.08	0.78	0.04	0.85
Brazil	0.08	0.78	3.20	0.08 *
Canada	0.07	0.79	0.07	0.80
Colombia	4.16	0.04 **	1.33	0.25
Egypt	0.28	0.60	0.18	0.67
Indonesia	2.58	0.11	1.94	0.17
Malaysia	0.90	0.35	1.56	0.21
Mexico	0.44	0.51	0.15	0.70
Norway	0.03	0.86	1.59	0.21
Russia	3.65	0.06 *	0.02	0.88
U.S.	3.87	0.05 *	5.59	0.02 **

Notes.

In columns two and three the results of F -test over the null hypothesis that: $\sum_j \gamma_{i,j}^{(+)} = \sum_j \gamma_{i,j}^{(-)}$ are presented. In columns four and five we report the results of F -test over the null hypothesis that: $\sum_s \vartheta_{i,s}^{(+)} = \sum_s \vartheta_{i,s}^{(-)}$.

Table 25: Asymmetric effects of world oil demand on oil production. Estimation of dynamic SURs.

Country	Lags	$\ln \Delta D_t^{(+)}$		$\ln \Delta D_t^{(-)}$	
		F-Stat.	Prob. (Sign)	F-Stat.	Prob. (Sign)
Algeria	1	6.56	0.04 ** (+)	0.56	0.76
Ecuador	1	0.23	0.89	1.02	0.60
Iran	1	1.07	0.59	6.70	0.04 ** (+)
Kuwait	1	5.99	0.05 * (+)	3.58	0.17
Libya	1	1.70	0.43	2.79	0.25
Saudi Arabia	1	38.54	0.00 *** (+)	4.88	0.09 * (+)
Colombia	1	6.24	0.04 ** (+)	3.26	0.20
Egypt	1	1.83	0.40	0.58	0.75
Indonesia	1	2.20	0.33	1.85	0.40
Malaysia	1	0.95	0.62	0.99	0.61
Mexico	1	6.76	0.03 ** (+)	0.08	0.96
Norway	1	15.06	0.00 *** (+)	5.17	0.08 * (+)
Russia	1	4.13	0.13	3.43	0.18
Nigeria	3	2.65	0.62	6.36	0.17
Venezuela	3	1.64	0.80	20.57	0.00 *** (+)
Brazil	3	6.15	0.19	3.19	0.53
Canada	3	1.08	0.90	3.10	0.54
U.S.	3	3.41	0.49	25.94	0.00 *** (+)

Notes. Presented are the F -statistic tests that all regression coefficients associated with world oil demand increases and decreases are zero. Dynamic models are estimated by employing Seemingly Unrelated Regression techniques. *** (**, *) indicate that the null hypotheses $H_0 : \gamma_{i,1}^{(+)} = \gamma_{i,2}^{(+)} = \dots = \gamma_{i,p}^{(+)} = 0$ and $H_0 : \gamma_{i,1}^{(-)} = \gamma_{i,2}^{(-)} = \dots = \gamma_{i,p}^{(-)} = 0$ are rejected given a 1% (5%, 10%) significance level. The number of lags to include in the system of equations is chosen by considering the Box-Pierce/Ljung-Box adjusted Q -statistics. The minimum lag length that ensures not serially autocorrelated residuals is selected.

Table 26: Asymmetric effects of real oil prices on oil production. Estimation of dynamic SURs.

Country	Lags	$\ln \Delta P_{i,t}^{(+)}$		$\ln \Delta P_{i,t}^{(-)}$	
		F-Stat.	Prob. (Sign)	F-Stat.	Prob. (Sign)
Algeria	1	0.67	0.72	1.97	0.37
Ecuador	1	1.09	0.58	1.83	0.40
Iran	1	0.31	0.86	0.22	0.90
Kuwait	1	4.14	0.13	1.27	0.53
Libya	1	5.79	0.06 * (-)	4.94	0.08 * (+)
Saudi Arabia	1	2.61	0.27	1.91	0.38
Colombia	1	0.87	0.65	3.04	0.22
Egypt	1	0.24	0.89	0.85	0.65
Indonesia	1	0.52	0.77	3.18	0.20
Malaysia	1	1.32	0.52	1.40	0.50
Mexico	1	3.90	0.14	0.20	0.91
Norway	1	3.11	0.21	2.14	0.34
Russia	1	0.33	0.85	0.63	0.73
Nigeria	3	5.16	0.27	2.92	0.57
Venezuela	3	4.07	0.40	5.17	0.27
Brazil	3	2.06	0.72	7.65	0.11
Canada	3	9.53	0.05 ** (-)	2.29	0.68
U.S.	3	8.47	0.08 * (+)	13.08	0.01 ** (-)

Notes. Presented are the F -statistic tests that all regression coefficients associated with real oil price increases and decreases are zero. Dynamic models are estimated by employing Seemingly Unrelated Regression techniques. *** (**, *) indicate that the null hypotheses $H_0 : \vartheta_{i,1}^{(+)} = \vartheta_{i,2}^{(+)} = \dots = \vartheta_{i,p}^{(+)} = 0$ and $H_0 : \vartheta_{i,1}^{(-)} = \vartheta_{i,2}^{(-)} = \dots = \vartheta_{i,p}^{(-)} = 0$ are rejected given a 1% (5%, 10%) significance level. See also notes to Table 25.

Table 27: Asymmetric effects of world oil demand and real oil prices on oil production. Estimation of dynamic SURs.

Country	$\gamma_i^{(+)} =$	Prob.	$\vartheta_i^{(+)} =$	Prob.
	$\gamma_i^{(-)}$		$\vartheta_i^{(-)}$	
Algeria	2.04	0.15	1.31	0.25
Ecuador	0.39	0.53	0.06	0.81
Iran	0.01	0.93	0.00	0.96
Kuwait	0.01	0.91	1.45	0.23
Libya	2.50	0.11	4.13	0.04 **
Saudi Arabia	5.06	0.02 **	0.02	0.89
Colombia	4.79	0.03 **	0.46	0.50
Egypt	0.03	0.87	0.14	0.71
Indonesia	2.35	0.13	1.28	0.26
Malaysia	0.71	0.40	1.31	0.25
Mexico	0.33	0.57	0.29	0.59
Norway	0.07	0.79	1.18	0.28
Russia	3.11	0.08 *	0.01	0.91
Nigeria	0.39	0.53	0.74	0.39
Venezuela	4.11	0.04 **	0.10	0.75
Brazil	0.43	0.51	1.78	0.18
Canada	0.02	0.89	0.11	0.74
U.S.	1.22	0.27	4.35	0.04 **

Notes.

In columns two and three (resp. four and five) we report the results of F -tests over the null hypothesis that the sums of positive and negative coefficients on world oil demand (resp. real oil prices) are equal. Dynamic models are estimated by employing Seemingly Unrelated Regressions techniques.

Table 28: Estimation of asymmetric Error Correction Models for oil production.

Country	$ECT_{i,t-1}^{(+)}$		$ECT_{i,t-1}^{(-)}$	
	F-Stat.	Prob. (Sign)	F-Stat.	Prob. (Sign)
Ecuador	1.65	0.20	18.40	0.00 ***
Iran	12.85	0.00 ***	0.14	0.71
Kuwait	11.03	0.00 ***	9.96	0.00 ***
Saudi Arabia	5.30	0.02 **	2.29	0.13
Egypt	1.22	0.27	0.90	0.35
Malaysia	0.03	0.86	12.24	0.00 ***
Mexico	0.01	0.94	2.78	0.10 *
Norway	0.17	0.68	10.13	0.00 ***
Russia	1.36	0.25	0.19	0.67

Country	$\theta_i^{(+)} = \theta_i^{(-)}$	Prob.
Ecuador	9.96	0.00 ***
Iran	5.00	0.03 **
Kuwait	0.05	0.82
Saudi Arabia	0.21	0.65
Egypt	0.02	0.90
Malaysia	4.55	0.03 **
Mexico	0.85	0.36
Norway	3.33	0.07 *
Russia	0.22	0.64

Notes.

Reported are the F -statistics for the null hypothesis that equilibrium adjustment parameters associated to positive and negative components of the long-run equilibrium relationship are zero. *** (**, *) indicate that the null hypotheses $H_0 : \theta_i^{(+)} = 0$ and $H_0 : \theta_i^{(-)} = 0$ are rejected given a 1% (5%, 10%) significance level. Columns seven and eight present the results of F -test over the hypothesis that: $H_0 : \theta_i^{(+)} = \theta_i^{(-)}$. Dynamic models are estimated by employing least squares techniques.

Table 29: Asymmetric Error Correction Models for oil production. Estimation of dynamic SURs.

Country	$ECT_{i,t-1}^{(+)}$		$ECT_{i,t-1}^{(-)}$	
	F-Stat.	Prob. (Sign)	F-Stat.	Prob. (Sign)
Ecuador	1.91	0.17	23.97	0.00 ***
Iran	28.09	0.00 ***	0.01	0.91
Kuwait	7.10	0.01 ***	8.42	0.00 ***
Saudi Arabia	3.26	0.07 *	1.02	0.31
Egypt	3.74	0.05 *	0.44	0.50
Malaysia	0.06	0.81	3.98	0.05 **
Mexico	0.08	0.78	7.82	0.01 ***
Norway	0.00	0.99	15.64	0.00 ***
Russia	0.68	0.41	0.51	0.48

Country	$\theta_i^{(+)} = \theta_i^{(-)}$	Prob.
Ecuador	13.47	0.00 ***
Iran	11.84	0.00 ***
Kuwait	0.05	0.83
Saudi Arabia	0.10	0.75
Egypt	0.80	0.37
Malaysia	3.50	0.06 *
Mexico	3.59	0.06 *
Norway	10.65	0.00 ***
Russia	0.01	0.90

Notes.

Reported are the F -statistics for the null hypothesis that equilibrium adjustment parameters associated to positive and negative components of the long-run equilibrium relationship are zero. *** (**, *) indicate that the null hypotheses $H_0 : \theta_i^{(+)} = 0$ and $H_0 : \theta_i^{(-)} = 0$ are rejected given a 1% (5%, 10%) significance level. Columns seven and eight present the results of F -test over the hypothesis that: $H_0 : \theta_i^{(+)} = \theta_i^{(-)}$. Dynamic models are estimated by employing SUR techniques.

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