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Essays on
the Economics and Politics of
Oil Producing Countries

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Preface

Natural resources endowments (and oil, in particular) are often argued to affect in a negative manner both the political and economic stance of a country. According to a wide literature there seems to be also evidence that natural resources affect positively the likelihood of internal conflicts. In addition, natural resources are believed to have negative effects on the democratization process of a country.

This first essay aims at examining several issues concerning the politics of oil producing countries with particular reference to the political transition of authoritarian regimes. In particular, our research tries to explore the impact that rents from natural resources (and, in particular, oil) have on the establishment of a given political system. Based on previous literature, a political economy perspective is employed. A simple game theoretical approach is presented and discussed in order to explain the relationships between oil revenues, political instability and emergence of different political regimes.

The implementation of particular redistributive fiscal policies together with the possibility that paternalistic or "predatory" autocracies emerge are considered. Since a process of full democratization is argued not to represent an optimal choice for the oil-rich authoritarian nations, governments prefer to remain autocratic. However, in order to prevent internal conflicts from occurring, authoritarian countries have either to undertake redistributive activities or allow for a military regime. Under other circumstances, political instability is the likely outcome.

Moreover, results from comparative statics exercises suggest that, ceteris paribus, governments of countries characterized by a low degree of socio-political fragmentation are more likely to adopt military regimes. On the contrary, the probability that redistributive autocracies will be adopted increases when the population of the country presents high levels of heterogeneity. Finally, higher natural resource endowments increase the possibility that policies aimed at redistributing oil rents are implemented.

There is a large body of research which tries to assess how oil shocks influence the business cycle of oil producing countries. According to many empirical papers, countries which are endowed with relevant natural resources are characterized by lower economic growth rates with respect to countries with few natural resources. Previous literature has also suggested that different mechanisms of transmission of exogenous oil shocks are responsible for the negative effects on the economic performances of oil exporting countries (see Alexeev and Conrad, 2009 for a recent review of the literature).

Our second essay aims at providing further evidence on the role of sectoral reallocation between private and public sectors in explaining the impact of shocks to oil revenues on the economic growth rates of oil producing countries. The effects of oil shocks on the business cycle of oil producing countries are examined by distinguishing between various components of public sector spending policy: purchases of consumption goods, investments in productive activities and compensation for public employees.

Simulation results from a simple theoretical model suggest that a large fraction of the negative effects of shocks to oil revenues on the private sector of the economy can be explained by crowding-out effects of public over private investments. Since the growth of the public sector is not able to compensate for the reduction in size of the private sector, an increase in oil revenues has the effect to decrease total output and employment. Finally, numerical results suggest that countries which are characterized by lower levels of private investments in the steady state are less affected by an exogenous oil shock with respect to countries where private investments have the higher share in total output.

In the third essay, decisions behind production levels for oil exporting countries are studied by means of both theoretical and empirical models. Under the assumptions of exogenous oil prices and world oil demand, we are able to describe how decisions on oil production levels vary according to changes of conditions on the world oil market. We argue that an important factor which is able to affect these decisions is represented by the cost structure of oil producing countries.

Results from the simulation of our theoretical model suggest that oil production changes are strongly correlated with changes in world oil demand and real oil price changes. However, although producing countries show a significant relationship between their output levels and total demand, the effect of oil prices on oil production decisions seems to be much lower.

By means of econometric analysis based on cointegration techniques, different responses to world oil demand and real oil prices seem to characterize decisions of relevant oil producting countries. As far as the responses to changes in total demand are concerned, production adjusts with few lags to increases in consumption. On the contrary, responses by oil production levels to innovations in real oil prices are argued to be much lower. In addition, when asymmetric econometric are introduced, evidence of nonlinear effects of output levels to shocks in demand levels and oil prices is found.

Finally, according to our theoretical framework, an upward sloping Kaplan-Meier hazard function is valid for oil producers' decisions on output levels. This result is confirmed when an empirical model is applied to time-series representing oil production levels.

Our research presents several interesting avenues for future analyses. With regards to the political economy of oil producing countries, the model presented in the first essay could be easily generalized in order to introduce a dynamic framework. Similarly, future research on the fiscal policy of oil exporting countries could be aimed at formulating additional guidelines for spending decisions by governments of oil rich countries. The possibility to extend the framework considered here in order to allow for inter-temporal decisions on the accumulation of financial wealth over the period of oil production represents an interesting topic for future studies. Finally, the theoretical model considered in the third essay could be extended in order to describe the behavior of the Organization of exporting countries (in particular, as far as the modeling of the relationship between production decisions and changes in world oil demand is concerned).

Originalities of the Thesis

Our research is argued to contribute significantly to the existing literature. By focusing on relevant topics in the field of political economy, fiscal policy and microeconomic theory, our analysis tries to provide some answers to issues not yet well addressed by researchers and analysts in previous works. The introduction of a theoretical framework which endogenizes the emergence of different political regimes in a context of a rentier state represents the most relevant contribution to the existing literature of the first essay. In this article, the impact of relevant variables (i.e. degree of socio-political fragmentation of the society, size of natural resources endowments, etc.) is also studied in greater detail.

The second essay extends the previous literature on the macroeconomic effects of exogenous oil shocks on the economic stance of oil exporting countries in various directions. The hypothesis that oil price shocks drive large aggregate reallocation of production factor is investigated by several previous studies. However, earlier works lack the sectoral detail on job creation and destruction that we examine.

Although previous research has already considered the determinants of decisions on oil production levels, relatively few studies have examined the elasticity of these decisions to changes in the stance of world oil markets. Our third study aims, in particular, at filling the gap in our understanding of the relationship between oil production levels, international oil prices and world oil demand. At this purpose, results from both a theoretical model and an empirical analysis are presented. The implications of our results with regard to the effects on the overall structure of the markets are, hence, discussed.

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Chapter 1

Management of External Rents and Political Transition of Authoritarian Regimes

Natural resources are generally associated to negative economic effects. This paper explores the impact that rents from natural resources (and, in particular, oil) have on the establishment of a given political system. Based on previous literature, a political economy perspective is employed. A simple game theoretical approach in order to explain the relationships between oil revenues, political instability (*conflicts*) and emergence of different political systems is presented. The implementation of particular redistributive fiscal policies together with the possibility that paternalistic or "predatory" autocracies emerge are considered. Since a process of full democratization is argued not to represent an optimal choice for the oil-rich authoritarian nations, governments prefer to remain autocratic. However, in order to prevent internal conflicts from occurring, authoritarian countries have either to undertake redistributive activities or allow for a military regime. Under other circumstances, political instability is the likely outcome. Moreover, results from comparative statics exercise suggest that, *ceteris paribus*, governments of low fragmented countries are likely to adopt military regimes. On the contrary, the probability that redistributive autocracies will be adopted increases when the population of the country presents high levels of heterogeneity. As natural resource endowments increase, the possibility to implement generous redistribution of oil rents becomes a more interesting solution.

1.1 Introduction

Natural resources endowments (and oil, in particular) are often argued to affect in a negative manner both the economic and political stance of a country ("resource curse"). According to a wide literature (see, among others, [1], [2], [3], [4], [5], [6], [7]) there seems to be evidence that natural resources affect positively the likelihood of internal conflicts.[1] An additional channel by means of which a curse of natural resources endowments may arise is represented by the "oil-impedes-democracy" claim (see [9]): natural resources (and oil, in particular) have negative effects on the democratization process of a country.[2]

[1] According to [8], even a phenomenon with "numerous complex social and historical causes" like the Iranian Revolution (1979) can be interpreted as a social movement directed at a better distribution of oil revenues.

[2] As a partial consequence of these phenomena, several authors (for instance, [10], [11], [12], [13], [14], [15], [16], [17], [18], [19] - for a different viewpoint, see, among others, [20]) argue that there is strong evidence that countries with large natural resources tend to grow slower than countries with small amounts of the natural resource. In particular, recent works (see,

Different works (both theoretical and empirical) have, consequently, attempted to describe the channels by which resource wealth negatively influences the polities of exporting countries.[3] [9] argues that oil affects democracy through, mainly, three main mechanisms of transmission: a "rentier hypothesis", oil revenues are employed by governments in an attempt to reduce grievances by the population; a "repression" mechanism, natural resource wealth is used for military or "internal security spending"[4] and a "modernization" effect: according to this theory, economic development is a key factor in boosting a democratization process. Since a resource boom is not able to "produce cultural and social changes", a democratization process is prevented from occurring.[5]

Econometric evidence seems to confirm these assertions. Empirical results are consistent with a negative and statistically significant impact of oil on the process of democratization of countries ([9]). [27] finds a strongly significant relationship between resource dependence (as measured by the ratio of primary exports to gross domestic product, GDP) and the emergence of authoritarian regimes. [4]'s results support, from an empirical point of view, the linkages between natural resource abundance and the emergence of authoritarian political regimes for African nations. By using as indicator of democracy the thirty-year change in the policy index, [28] shows negative effects of oil discoveries on the levels of democracy of a country, an effect that persists even if large Middle East coun-

inter alia, [21], [18], [17], [19] and [22] have argued that natural resource-rich countries could avoid negative economic effects from a resource boom should they adopt good policies and institutions.

[3] Earlier studies that links natural resources to the emergence of authoritarian regimes are the analyses by [23] and [24].

[4] See also [25].

[5] Similarly, [26] considers as factors that may help to explain the linkages between "oil wealth and regime survival" the "rentier state", the repression and the rent-seeking theses.

tries are included in the analysis.

In an analysis aimed at determining the impact of oil wealth on regime failure, antistate protests and domestic armed conflict, [26] argues that the oil dependence variable (ratio of the value of oil exports to GDP) does affect in a positive manner the durability of a regime. By contrast, the impact on the level of protests and civil wars is suggested to be negative. According to the author, the investment of oil revenues in order to establish good institutions could be able to guarantee the "regime survival".

[29] examines the relationship between "rentierism" (that is, rent revenues as a fraction of total government revenues) and democracy indexes. According to empirical evidence, the net effect of rentierism on democracy is not statistically relevant.[6]

Finally, [31] and [32] describe detrimental effect of oil on democracy and economic growth. According to their analysis, the ownership structure of the national oil industry and how revenues are distributed represent, respectively, the main explanation of the causality link.

Other articles try to categorize exporting nations by specifying different tipologies of political regimes. [33] suggests a classification based on the definitions of "autonomous" (in the two versions of "benevolent" and "predatory" states) and "factional" states (with the two categories of "oligarchic" state and "majoritarian" democracies). Similarly, in an effort directed at extending the classification of the economic policies of oil-exporting nations, [34] compare ("mature" or "factional") democratic systems and autocracies. Hence, while in "predatory" autocracies, the self-seeking of the ruling party is directed at maximizing net rents from the sale of the natural resource, in "reformist" (or "paternalistic")

[6]Similar results are obtained by [30] in an analysis of U.S. data.

autocracies natural resource revenues are employed in order to boost economic growth and raise population's living standards.

In a study aimed at studying the relationship between natural resources rents and the policies implemented by governments, [35] find that governments may reduce the provision of public goods in order to "facilitate patronage politics". According to [14], "predatory" and "factional" governments are the result of dependence of the economy of the country on the export of natural resources. In such a context, repression may emerge as an instrument to ensure political legitimacy.

This paper is aimed at studying with the causal relationship between oil rents and political transition in authoritarian regimes. How do natural resource endowments interact with the emergence of a particular type of political regime? Why do oil rich countries often switch towards paternalistic or "predatory" regimes instead of choosing a democratic regime? In addition, one of the objectives of the present study is to investigate why, despite the possibility to implement a redistributive fiscal policy, political instability may arise under equilibrium.[7]

With regard to the factors that determine the emergence of redistributive or military systems, this research points out that, in order to study how managing natural resources revenues affect the socio-political institutions of country, a researcher has to employ a political economy perspective. Based on previous literature (see, *inter alia* [36], [37], [38] and [39]), this paper considers an intuitive game theoretical model in order to link the onset of internal conflicts to the possibility that alternative political systems emerge. In particular, the transition of an authoritarian regime towards either one of three different political regimes,

[7] As the experience of Congo Brazzaville shows (see, also, footnote 38).

namely, democratic systems, redistributive or military autocracies is modelled by employing a simple framework. The channel by means of which oil affect the emergence of a particular regime I focus on is the so-called "rentier effect".[8] Wealth from the exploitation of natural resources is employed in order to reduce threats of internal conflict.[9] The most relevant contribution of the present work to the existent literature is the introduction of a theoretical framework which endogenizes the emergence of different political regimes in a context of a rentier state.[10]

The main idea of the theoretical model can be better specified as follows: since natural resource-rich countries are characterized by higher levels of grievances by the population (in order to allow for a better redistribution of natural resource) a high degree of political violence may, consequently, arise. The possibility to employ oil wealth in order to offset threats of political conflict is considered by the government's ruler. If some conditions are satisfied, a complete transition through authoritarian to a democratic system may occur. However, this political transition may not represent a first best choice. Rather, in authoritarian political systems, incumbent politicians are able to employ natural resource wealth

[8]According to [9], a rentier state is "a state that derives a large fraction of its revenues from external rents".

[9]In this paper, the terms "conflict", "revolution", "revolt" and "political instability" are used interchangeably.

[10][40] and [41] present formal theories in order to explain why, under some circumstances, resource wealth is able to impede democracy. Even if some conclusions are similar to mine (for instance, the fact that the size of the natural resource represents a relevant factor in determining authoritarian regimes), the present analysis focuses on the emergence of different typologies of political systems. The taxonomy of authoritarian regimes introduced by [34] is, in particular, employed.

in order to maintain support and even consolidate their political power through either a redistributive policy or the adoption of a military regime.

In addition, the theoretical model predicts that factors that affect political changes towards redistributive or "predatory" activities are the size of the natural resource endowment, the number of political groups that compose the country, and, finally, on parameters that represent the warfare technology. In particular, more fragmented countries are likely to implement redistributive policies. On the contrary, countries with low-levels of fragmentation will tend to adopt military regimes. As an additional result, I will be able to prove that, while resource-rich countries will adopt paternalistic autocratic regimes, in countries with relatively low amount of natural resource military regimes could emerge. Finally, a glance at the data for a sample of authoritarian oil exporting countries seems to confirm this theoretical evidence.

The paper is organized as follows. Section 1.2 introduces the theoretical model. Section 1.2.1 illustrates the structure of the game. A sequential three-stage game is introduced. Section 1.2.2 presents the main assumptions of the game. Section 1.2.3 presents the equilibrium outcome of the model. In particular, the actions that can be implemented by the ruling party of an authoritarian regime and, in particular, the possibility to adopt a democratic regime, the implementation of either redistributive or "predatory" policies are considered. Section 1.3.1 offers the final result, concerning the policy undertaken by both democratic and authoritarian governments. Results of comparative statics exercises together with evidence based on data analysis and implications for economic development are presented in Sections 1.3.2 and 1.3.3, respectively. Section 2.4 concludes.[11]

[11]Proofs and mathematical derivations of the main results of the paper are given in the Appendix.

1.2 The theoretical model. Introduction

Consider an economy composed by a government (B) and a set of $N \geq 2$ excluded (socio-political) groups ($i = A_1, A_2, \ldots, A_N$, *peasants*, in short $i = 1, 2, \ldots, N$). For simplicity, the size of the population of a country is normalized to unity. That is to say, all groups are composed by a fraction $\frac{1}{N+1}$ of individuals. In addition, they are assumed to be *ex-ante* homogenous with respect to the total natural resource endowment.

1.2.1 Structure of the game

The model can be described as a three-stage game.[12] In the first stage of the game, an endowment of natural resources ($R > 0$)[13] is discovered. Since this study has the aim to study the relationship between natural resources, conflicts and political regimes, it is assumed that the rent (from abroad) accrues to the *government* of the country (group B, ruling party). As far as the endowments of natural resources, while each excluded agent owns an amount of natural resource R_0 (equal across individuals), after the discovery, the government is endowed with an amount of natural resource equal to $R_B \equiv R_0 + R$.

[12]In the following analysis, I abstract from considering the impact of economic growth on the emergence of different political regimes. However, the extension of the framework in order to account for such relationship is immediate. It suffices to consider a stage (*1bis*) in which a high (or low) economic regime is revealed.

[13]In the analysis of the present paper, I focus on the discovery of oil fields. In fact, as argued by [42] in a survey of articles on natural resources and civil wars, oil discoveries and the onset of conflict are positively correlated. On the contrary, "lootable" commodities (e.g. gemstones and drugs) are associated to the duration of the conflict.

In the second stage, (and assuming an authoritarian regime), the ruling party has to decide between three alternatives: 1) whether to set a fiscal policy which grants a redistribution of the natural resource revenues in favor of the peasants; 2) provide a (direct or indirect, i.e. by means of a program of public spending) redistribution of the natural resource among citizens or 3) accelerate a process of militarization of the country, i.e. to increase spending in the defense sector in order to reduce the likelihood of a successful conflict. Under a democratic rule, in particular, the model is used in order to check whether a fiscal policy program based on a redistribution of the oil wealth is able to prevent an insurrection or whether a "factional" democracy (i.e. a regime where political groups are weak, military role in the administration of the country is not uncommon and the "development of clientelistic networks and rent-seeking behavior" is encouraged by "nontransparent mechanisms of rent distribution", [34]) can emerge.[14]
Simultaneously, the other N excluded agents should decide whether to start a conflict against the government in order to provide a better distribution of the natural resource that has been discovered.[15] In particular, each of the N peasants has to choose the coalition to join, i.e. whether to support the insurrection or to remain neutral. As far as the revenues which derive from a successful conflict, if they accept to join the coalition they agree to share the natural resource ex-

[14]An example of such a political regime is represented by Ecuador during the 1980s (see, also, footnote 31). In this country, the importance of the military in the economy is well documented even after 1979 (re-introduction of a democracy). In fact, despite the expansion of the electorate a large fraction of all petroleum resources continued accrue to the military. In 1989, 14.5 percent of all revenues were perceived by the military sector ([43], cfr. [34]).

[15]In the sense of the present analysis, conflict has to be intended as *a set of actions, strategies, coordination policies among agents aimed at obtaining a better redistribution of resources. The redistribution of resources may be direct or indirect, that is, for instance, through a fiscal policy aimed at providing a non-rival public goods to the citizens*.

propriated to the losing coalition according to a fixed sharing rule ψ (see Section 1.2.3).

Finally, in the third stage rents from the sale of the natural resource accrue to the respective owners. As it will be outlined in the next Section (Assumption III) the unique income source of the country derives from the sale of the natural resource to foreign agents.

The game is solved by backward induction.

1.2.2 Assumptions.

Conflict Decision

The decision by the peasants to provoke an insurrection is modelled by considering the following assumptions:

- **Assumption I.1** The probability that a revolt has to succeed in the next period is given by λ. In particular, λ depends on **(1)** the proportion of agents that decide to oppose to the government ($\xi = \frac{N_A}{N+1}$) and **(2)** on an (exogenous) parameter δ ($\delta_1 = \delta_2 = \ldots = \delta_N = \delta$) that reflects the effort that agents put in the protests. λ is positive for any value $\xi,\ \delta > 0$, $\lambda(0, \delta) = 0$. λ is assumed to be an increasing function of both ξ and δ, i.e. $\frac{\partial \lambda(\cdot)}{\partial \xi},\ \frac{\partial \lambda(\cdot)}{\partial \delta} > 0$, that is, as the percentage of groups who support the protests and effort increase, the probability the peasants have to succeed in the protests increases as well. For simplicity, it is assumed that $\lambda = \lambda\left(\xi, \delta\right) = \xi^{1/\delta}$, where $\delta \geq 0$;

- **Assumption I.2** In equilibrium only two coalitions (A, B) are assumed to form;

- **Assumption I.3** After the conflict, a fraction θ of the total natural resource endowment of the members of the losing coalition is expropriated by the members of the winning coalition and divided in equal parts. The increase of natural resource endowment is assumed to be permanent;

- **Assumption I.4** The whole country is interested by the civil conflict. In addition, it is assumed that after a conflict, a fraction ϵ of natural resource endowments of all group participating to the conflict is destroyed;

- **Assumption I.5** If a coalition wins, its members become the (new) governments' rulers.

The decision of the peasants to enter in a row over resource redistribution is studied in a very simple model of conflict. An individual randomly chosen in the group of peasants (say, $\widehat{i}$) proposes to form a coalition (coalition A) and enter in conflict against the government in order to provide a better redistribution of the natural resource. In turn, the other agents have to decide whether to join the coalition or to remain neutral.[16, 17]

If an agent decides to join a coalition A, she agrees to share the outcome from the expropriation of the natural resource endowment of the rival coalition and to set a fiscal policy that is able to maximize the total post-tax income of the group. It is supposed that entering in a conflict over government's total resource endowments under coalition A implies a binding commitment to a particular sharing

[16]Or, analogously, to join government's coalition (coalition B).

[17]Technically, the (sub)-game under analysis can be structured as follows: each prospective member of coalition A has to respond whether to join coalition A or remain neutral in a predetermined order rule. In this stage, a strategy of agent i ($i \neq \widehat{i} = 1,\ 2,\ \ldots,\ N$) σ_i is, therefore, represented by: $\sigma_i\left(s\right) \in \{Yes,\ No\}$, where s represents the number of the persons that have already agreed to join the coalition.

rule ψ. In the analysis that follows, I make the simplifying assumption that coalition members equally share the amount of natural resource endowment expropriated to the rival coalition.[18] On the contrary, if agent i decides not to join rebels coalition (coalition A) she obtains, in case of success of her coalition (coalition B), a part of coalition A's total resource endowment.

Political Regimes: Definition

In the framework under analysis, each of the major types of government is defined by who controls the government and by the economic and fiscal conditions that best serve their interests. To the purpose of this analysis, an *authoritarian government* is defined as one controlled by a specific autocrat; in particular in these regimes requirements for voting are enhanced.

On the other hand, democratic systems are defined as "those regimes in which governmental offices are filled as a consequence of contested elections" (see, e.g., [45]). In particular, this model of democracy represents an indirect mechanism of social consensus; in other words, governments are ruled according to a majority rule ([46]). The decision by autocrats to introduce such a political regime is defined as *(full) democratization* of the country.[19]

Role of Government

As for the role of the government (agent B) in the economy, it is assumed that:

[18] In this analysis, for simplicity, only conflicts that may take place between the different coalitions are considered. However, as [44] points out, since members of a coalition have to agree on how to distribute the resource between themselves, "within" group conflicts can also arise.

[19] For a definition of redistributive and military ("predatory") authoritarian regimes, see Section 1.2.3.

- **Assumption II.1** All resources available to the government comes from a tax on total income, Y. It is assumed that total income derives from the sale of the natural resource each agent owns (see also Assumption III);

- **Assumption II.2** The government may decide to implement a redistributive fiscal policy by financing lump-sum transfers of income. In particular, it is assumed that they take the form of the provision of public goods. Let t and G denote (1) the percentage of income the worker has to pay to the government as taxes and (2) the aggregate level of government spending on the provision of the public good, respectively. Following [47] it is assumed that $G = \left(t - \frac{t^2}{2}\right) Y$ where Y is the average income of the country;[20]

- **Assumption II.3** In order to describe the differences in tastes existing between the government and other individuals, a parameter γ ($\gamma \in [0, 1]$) is introduced. In particular, this parameter allows me to account for the fact that the public good provided to the citizens may differ from their preferences. Therefore, when $\gamma = 1$, the public good matches perfectly the preferences of the peasants. On the other hand, $\gamma = 0$ ($\gamma_B = 1 - \gamma = 1$) implies that the public good responds to the preferences of government's ruler, i.e. citizens are assumed to receive less utility from the consumption of the public good.[21] Under assumptions II.1 to II.3, post-tax (indirect) utility levels of peasants and ruling party are, respectively, given by:

$$\pi_i^D(t, \gamma) = (1 - t) \cdot Y_i + \gamma \cdot G$$

[20]From this assumption, it follows that the collection of taxes is costly. In particular, at tax rate t there is a deadweight cost of $c(t) = \frac{t^2}{2} Y$.

[21]In other words, peasants and the ruling party may have different tastes as far as the provision of the public good is concerned. This assumption is borrowed from [48] where agents are assumed to differ in "their tastes for the public good".

$$\pi_B^D(t,\gamma) = (1-t)\cdot Y_B + (1-\gamma)\cdot G$$

where Y_i (Y_B) is the income level of the peasants (ruling party);

- **Assumption II.4a** The government can decide to spend a part β of its income in order to grant defense from internal threats. This additional spending by the government can be seen as a form of insurance against political instability (see [49]);

- **Assumption II.4b** The probability of a revolt to succeed depends on the effort of the opponents of the regime relative to the military strength of government, which in turn depends on the level of defense spending (see previous assumption). In order to leave the model simpler, military spending is assumed to accrue to individuals which are external to the country;[22]

- **Assumption II.5** There is no discounting. The game can be defined as static. Finally, financing is not allowed.

Income from the natural resource

The structure of the economy is modelled by assuming that:

Assumption III The natural resource is able to generate income according to the function:

$$Y_i = p_i \cdot R_i \quad i = A_1,\ A_2, \ldots,\ A_N,\ B$$

where p_i is a parameter representing the ability to produce income by selling the natural resource (and investing the oil wealth) and R_i is the amount of natural

[22]This is the case, for instance, when the domestic government obtains support from agents who are external to the country.

resources each agent is endowed with. No other income sources are available. It is assumed that $p_j = p_A$, $\forall j = A_1,\ A_2, \ldots,\ A_N$. On the other hand, $p_B \leq p_A$.

Let me denote by $i \in A$ and $j \in B$ ($i \neq j$) the members of the coalitions A and B, respectively. The coalition structure such that N_A individuals decide to fight whereas $N+1-N_A$ individuals decide to support the government is denoted by $P = \left\{P = \{N_A, N_B\} \,| N_A \in 2^{N+1}, N_B = N+1-N_A\right\}$ or $P = \{P_A,\ P_B\}$. If agent i (or j) belongs to the winning coalition, the increase in natural resource endowment is given by:

$$\Delta R^A_{i\in A} = \theta \frac{\widehat{R} + \widehat{R}_0\,(N+1-N_A)}{N_A}$$

$$\Delta R^B_{j\in B} = \widehat{R}_0 \theta \frac{N_A}{N+1-N_A}$$

On the other hand, in case of defeat, we have:

$$\Delta R^Q_{i\in Z} = -R_0 \cdot [\epsilon + \theta\,(1-\epsilon)]$$

where $Z,\ Q \in \{A,\ B\}$ ($Z \neq Q$), $\widehat{R}_0 = R_0 \cdot (1-\epsilon)$, $\widehat{R} = R \cdot (1-\epsilon)$. Subscripts denote the winning coalition.

The new level of natural resource endowment for each peasant after a conflict is given by:

$$R^W_{i\in Z} = \widehat{R}_{0i} + \Delta R^W_{i\in Z}$$

where $\Delta R^W_{i\in Z} = \Delta R^Z_{i\in Z}$ (in case of success) or $\Delta R^Q_{i\in Z}$ (defeat).

According to Assumption I, the payoff (expected income) of individual i ($i = 1,\ 2,\ \ldots,\ N$) if she decides to enter in the conflict (where coalition A is composed by N_A agents) can be specified as follows:

$$E\left[\pi^W_{i\in Z}(N_A,\ \delta)\right] = p_i\left[\xi^{1/\delta} R^A_{i\in Z} + \left(1-\xi^{1/\delta}\right) R^B_{i\in Z}\right] \tag{1.1}$$

As far as agent B (*government*) is concerned, I have:

$$E\left[\pi_B^W(N_A,\ \delta)\right] = p_B\left[\xi^{1/\delta}R_B^A + \left(1-\xi^{1/\delta}\right)R_B^B\right] \tag{1.2}$$

where $R_B^A = \widehat{R}_B\,(1-\theta)$ and $R_B^B = \widehat{R}_B + \theta\frac{R_0\cdot N_A}{N+1-N_A}$.
On the other hand, let me denote by π_i^P the payoff individual i receives under a regime of peace, i.e. $\pi_i^P = Y_i$.[23]
When the possibility of a military regime is introduced, the model is modified along the lines outlined above (see assumptions II.4a and 4b). With regard to government's total natural resource revenues, in particular, it follows that:

$$\pi_B^M(\beta) = (1-\beta)\left[p_B\cdot(R_0+R)\right]$$

On the contrary, the expected payoff of the peasant i if she decides to enter in the conflict under coalition A is given by:

$$E\left[\pi_{i\in A}^W(N,\ \widehat{\delta})\right] = p_A\left[\xi^{1/\widehat{\delta}}R_i^A + \left(1-\xi^{1/\widehat{\delta}}\right)R_i^B\right] \quad \forall i\in A$$

where

$$\widehat{\delta} = \frac{\delta}{1+\delta_g(\beta)},\ \ \delta_g'(\beta) = \frac{\partial\delta_g(\beta)}{\partial\beta} > 0$$

Without loss of generality, I assume that:

$$\widehat{\delta} = \frac{\delta}{1+\beta\cdot k} \tag{1.3}$$

[23]It can be easily noticed that equations (1.1) and (1.2) are characterized by *spillovers*. In other words, the decision by an agent to join a coalition affects the payoffs of all other agents. These spillovers can be either positive or negative depending on the fact that the change in the payoff associated to the increase in the likelihood of a positive result in the civil war is greater or less than the reduction in the payoff due to the that the natural resource has to be divided among a greater number of agents.

where k is a positive parameter (given exogenously) that represents the relative fighting efficiency of the governmental army with respect to the peasants one. Equation (1.3) is derived by assuming that the military strength of the government is a linear function of the level of defense spending.[24] In other words, the utility that arises from a successful revolt is decreasing in the level of defense spending of the government.

1.2.3 Solution of the game

Conflict decision

In order to analyze the second stage of the game without considering the fiscal policy implications of a (possible) regime change (that is, even if a revolution succeeds, the equilibrium fiscal policy is represented by no taxes, no provision of public goods), the following constraint is added to assumption I:

Assumption I.1bis With regard to parameter θ, it is assumed that:

$$\overline{\theta} \leq \theta \leq 1 \quad where \quad \overline{\theta} = \frac{(1-\epsilon)\left\{[p_B - p_A]\, R_0 + p_B R\right\}}{[p_A + p_B N]\, E\left[\Delta R_i^A(N)\right]}$$

where, as it will be seen later, $E\left[\Delta R_i^A(N)\right] = (1-\epsilon)\left\{[R + R_0(N+1)]\,\lambda\,(N,\ \delta) - N \cdot R_0\right\}/N$ is the expected increase in the amount of the natural resource if the coalition wins the conflict. $\lambda\,(N,\ \delta) = \left(\frac{N}{N+1}\right)^{1/\delta}$ represents the probability that a conflict has to succeed if all peasants decide to fight.

The equilibrium strategy by the peasants results from the following Proposition:

[24] This assumption borrows from [50] and implies that the model does not allow for different productivities of military spending across political regimes.

PROPOSITION 1. *In the present model of coalition formation and conflict, the equilibrium structure satisfies one of the following three cases:*
(i) $P = \{P_N, P_B\} \in$ *NE(G)*[25] *(conflict) if and only if:*

$$\delta < 1 \;\; and \;\; R > \widetilde{R} \quad where \quad \widetilde{R} = N \cdot R_0 \cdot \left[1 + \frac{\epsilon}{\theta\,(1-\epsilon)}\right] \cdot \left[\lambda\,(N,\;\delta)\right]^{-1} - R_0\,(N+1) \tag{1.4}$$

If condition (2.12) is not satisfied, the unique Nash equilibrium coalition structure is given by $P = \{P_0, P_{N+1}\} \in$ *NE(G) (i.e. no agent decides to fight, peace equilibrium).*
(ii) On the contrary, if $1 \le \delta \le \widetilde{\delta}$ *(where*

$$\widetilde{\delta} = \frac{\ln(N+1)}{\ln\{[\theta \cdot (1-\epsilon) \cdot [R + R_0 \cdot (N+1)]]\} - \ln\{R_0 \cdot [\theta \cdot (1-\epsilon) + \epsilon]\}}$$

the coalition structure $P = \{P_0, P_{N+1}\}$ *(peace equilibrium) is the NE(G).*
(iii) Finally, if $\delta > \widetilde{\delta}$ *and* $\delta \ge 1$*, there is no stable coalition structure under equilibrium.*

PROOF. For a proof of this Proposition, see the Appendix.[26]

From the previous Proposition, it follows that, provided that the amount of natural resources endowment is sufficiently high, a collective action by a wide coalition of different social groups aimed at reacting to considerable distortions in the distribution of income and oriented to affect a better redistribution of oil rents can originate.[27] Viceversa, if the increase in the natural resources endowment of the government's ruler is lower than $\widetilde{R}$, the grand coalition where all

[25] Nash equilibrium of the game.

[26] It is assumed that, if the payoffs agents receive under the two scenarios (revolution or peace) are the same, the equilibrium outcome is *no war*.

[27] This is the point of [8] as far as the Iran revolution is concerned (see also footnote 1).

agents decide not to fight (*peace equilibrium*) represents the NE(G): the possibility of internal conflicts (or political instability) does not represent a threat for both authoritarian and democratic systems.
According to a political economy approach to internal instability, civil conflict is an activity which could have a low probability of success and high potential costs. Problems due to the organization of revolts may also arise (according to this model negative spillovers arise when $\delta > 1$). These results are consistent with a theory of rebel motivation ([51]) based on the argument that, despite the presence of grievances by the population, a coalition may form only if appropriate effective conditions (in the present analysis, the existence of abundant natural resources) are satisfied. Hence, groups of individuals can mount effective revolts (aimed at a better redistribution of natural resources) only under predetermined conditions which could prove difficult to achieve.

From straightforward calculations it results that:
REMARK 1. $\widetilde{R}$ (*threshold* value of R such that if $R > \widetilde{R}$ all *peasants* have an incentive to fight the government) is an increasing function of R_0, ϵ and N and a decreasing function of θ and δ.

According to the previous remark, a result that is worth noticing is that, as the number of political groups increases, the level of the mimimum amount of the resource endowment such that all peasants have an incentive to fight increases. On the contrary, $\widetilde{R}$ is a decreasing function of the parameter θ. Finally, in addition, $\widetilde{R}$ and R_0 (ϵ) are positively correlated. As the natural resource endowment of the peasants (or the fraction of the resource that is expected to be destroyed) increases, the level of $\widetilde{R}$ increases as well.

From an authoritarian regime to . . .

The different strategies that can be undertaken by the (authoritarian) government in order to prevent revolts are here separately considered and discussed. The first action that can be implemented is the introduction of a redistributive fiscal policy. In order to provide a better description of the fiscal policy of the government aimed at preventing revolution, the decisions over the fiscal policy is assumed to embody the choice of the type of public good to provide to the population (see assumption II). Revenues that come from the sale of natural resources are employed to provide a non-rival public good to the citizens. Under some circumstances, a process of *(full) democratization* is shown to be the equilibrium outcome. In this case, according to Corollary 1.1, the tax rate and the quality of the public good are those preferred by the country's median income voter. To the other extreme, if other conditions are satisfied, the commitment by the ruling party to implement a redistributive fiscal policy is not able to prevent an internal conflict. Consequently, a military sector emerges according to Proposition 3.

Other political regimes that can emerge are *redistributive* authoritarian regimes. The political group which rules the country, in order to avoid an insurrection, may embark on important investment programs often directed at building basic infrastructure or at providing essential public services to the population. An often cited example is that of the Persian Gulf countries which, thanks to oil revenues, have been able to raise living standards of the whole population. In other words, latent pressures for democratization are eliminated by a spending policy carried out by the authoritarian regime.[28]

[28]This is the point of, for instance, [52] and [53] which consider the process of democratization for Saudi Arabia and Libya, respectively. [54] documented the capacity of large oil producers

To the purpose of the present analysis, a direct redistribution of the natural resources is considered as an alternative to a redistribution of the revenues that accrues to the government. The possibility that "paternalistic" or "reformist" autocracies ([34]) arise is, therefore, considered by analyzing a specific feature of the model.[29]

Finally, governments could decide to increase the military spending such that the reduction in the probability of a successful protest suffices to reduce any threats of revolution (military regime or "predatory" autocracy). Natural resource wealth may allow governments to spend more in order to grant internal security. The permanence of the status quo is guaranteed by the use of natural resources with the aim to preserve the power from internal threats. Natural resources revenues are not employed in order to finance productive activities but they are rather used as a repression instrument. Consequently, the level of revenues inequality tends not to decrease.

Examples of this type of political regime are Iran during the 1970s (see [55]), Nigeria, country which has experienced a succession of military dictatorships ([34]), Ecuador during the 1970s, as well as Angola, after oil and diamonds were discovered (early 1990s, see, [56]). For all these countries, as a consequence of

to prevent social unrest by employing oil revenues in order to finance the provision of public goods and services.

[29]Two cases will be considered: while according to the first option (our *benchmark* case), the government decides to redistribute directly part of the natural resource R (see Proposition 2.2), according to the second possibility the ruling party engages in a program of public spending financed by using part of the income generated by the sale of the natural resource (see Corollary 2.1). Finally, Corollary 2.2 presents the condition to be satisfied in order for a program of public spending to be the equilibrium strategy of the ruling party.

the oil boom, military spending was increased considerably.[30, 31]

The following Proposition can now be proved:[32]

PROPOSITION 2.

2.1 Implementation of a redistributive fiscal policy. *Under the assumption:*

$$\theta < \widehat{\theta} \quad where \quad \widehat{\theta} = \frac{Y^2 + p_A \cdot R_0 \cdot [p_A \cdot R_0 - 2Y \cdot (1-\epsilon)]}{2 \cdot p_A \cdot E\left[\Delta R_i^A(N)\right] Y}$$

(1.5)

the fiscal policy implemented by the ruling government is able to prevent an insurrection when the fiscal policy allows for a public good that responds to the preferences of the peasants (i.e., $\gamma^* = 1$) and for a tax rate t^* such that:

(1.6) $$t^* = 1 - \frac{p_A \cdot R_0 + \left[Y\left(Y - 2 \cdot E\left[\Delta Y_i^W\right] - 2 \cdot p_A \cdot R_0\right) + (p_A R_0)^2\right]^{1/2}}{Y}$$

and

$$t^* \leq t_B^* = \frac{-E\left[\Delta Y_B^W\right]}{p_B \cdot (R_0 + R)}$$

[30] In Nigeria, regimes of military dictatorships employed oil rents in order to boost programs of public capital spending. However, resources were appropriated mainly by a corrupt elite or fuelled distorted and wasteful economic sectors ([57]). As a consequence, the general welfare of the population did not increase.

[31] As for Ecuador, the prospect of vast oil reserves expected to transform country's feable economy was a fundamental factor in determining the military coup that overthrew president Ibarra's government in 1972. General Lara's government decided to employ oil resources to implement social policies and an economic agenda directed at modernizing agriculture and introduce a program of industrial development in order to foster growth and reduce national economy's dependence from abroad. However, since it was not able to include the powerful business elite into any of the governmental structures and decision-making processes, in 1976 it was removed.

[32] To notice that in Sections 1.2.3 and 1.3.1, only the case $\delta < 1$, condition that (provided that $R > \widetilde{R}$) ensures that a grand coalition of peasants forms under equilibrium, will be considered.

where $E\left[\Delta Y_i^W\right] = p_A\left[\theta \cdot E\left[\Delta R_i^A(N)\right] - R_0\epsilon\right]$ *and* $E\left[\Delta Y_B^W\right] = -p_B\left\{\epsilon\left(R_0 + R\right) + \theta \cdot N \cdot E\left[\Delta R_i^A(N)\right]\right\}$ *denote the expected change in revenues the peasants and the ruling party, respectively, have if a conflict has to start.*

2.2 Case of a redistributive authoritarian regime. *In order to prevent a revolution from occurring, the government's ruler has to redistribute a fraction of the resource endowment equal to* $\widetilde{\alpha}$ *where:*

$$\widetilde{\alpha} = \frac{E\left[\Delta Y_i^W\right] \cdot N}{R \cdot p_A} \tag{1.7}$$

2.3 Emergence of a "predatory" autocracy. *Provided that* $\widetilde{\widetilde{R}} \leq R \leq \widetilde{\widetilde{R}}^{(2)}$*, in order to avoid a revolution the ruling party has to spend in defense spending an amount of resource equal to:*

$$\widetilde{\beta} = \frac{\delta \cdot [\ln(\varphi) - \ln(\vartheta)] - \ln(N+1) + \ln(N)}{[\ln(N+1) - \ln(N)] \cdot k} \tag{1.8}$$

where $\ln(x)$ *is the natural logarithm of* x, $\vartheta = R_0 \cdot N \cdot [\epsilon + \theta \cdot (1-\epsilon)]$ *and* $\varphi = \theta \cdot (1-\epsilon) \cdot [R + R_0 \cdot (N+1)]$.

PROOF. The complete proof of Proposition 2 is given in the Appendix. However, here it should observed that Proposition 2 is obtained by considering whether two conditions are satisfied: 1) peasants get an increase of their expected income with respect to the likely income under a regime of conflict; 2) even the government's ruler is better off relative to a situation of conflict.

Let me now extend Proposition 2.1 by considering the case of a *full democratization* of the country. The following corollary is argued to hold.

COROLLARY 1.

1.1 The fiscal policy. *In the case of a process of (full) democratization of the country the fiscal policy implemented by the government implies that:*

$$t^* = \widehat{t}_m \ \ and \ \ G^* = \left(\widehat{t}_m - \frac{\widehat{t}_m^2}{2}\right) Y$$

where $\widehat{t}_m = \frac{Y - p_A \cdot R_0}{Y}$ *and* $Y = \frac{p_A \cdot R_0 \cdot N + p_B (R_0 + R)}{N+1}$ *represent the tax rate preferred by median income voter (agent* i*) and the average income of the country, respectively. Finally, in equilibrium,* $\gamma = \gamma_A = 1$.

1.2 Case of a (full) democracy. Equilibrium. *In order to prevent a revolution from occurring, a (full) democratic system is set if and only if* $\theta = \widehat{\theta} < 1$ *where* $\widehat{\theta}$ *is given in equation (1.5) (**condition 1**) and* $\widehat{\theta} \geq \widetilde{\theta}$ *(**condition 2**) where*

$$\widetilde{\theta} = \frac{(R_0+R)[(1-\epsilon)Y - p_A R_0]}{N \cdot E\left[\Delta R_i^A(N)\right] Y} \tag{1.9}$$

PROOF. Corollary 1.1 derives from a direct application of the median income voter's theorem.[33] For a formal proof of Corollary 1.2, refer to the Appendix. Here, it is worth observing that, While **condition 1** states the assumption under which the optimal tax rate for the peasant is the equilibrium tax rate, **condition 2** guarantees that the post-tax income of the government's rulers is higher with respect to the expected post-tax income in case of conflict.

All in all, results outlined by Proposition 2.1 and Corollary 1 are summarized in Table 1.1.

[33] See [58] for a presentation of this fundamental concept of political economy.

[INSERT TABLE 1.1 ABOUT HERE]

If, on the one hand, the introduction of a fiscal policy characterized by a tax rate equal to $t^* < \widehat{t}_m$) is a feasible possibility when $\theta < \widehat{\theta}$ and $t^* \leq \frac{-E\left[\Delta Y_B^W\right]}{p_B \cdot (R_0+R)}$, on the other hand, a (full) democracy may emerge when $\theta = \widehat{\theta}$ and $\widehat{\theta} \geq \widetilde{\theta}$.

Finally, Table 1.1 shows that, under certain circumstances (and namely when: **1)** $\theta = \widehat{\theta}$ and $\widehat{\theta} < \widetilde{\theta}$, **2)** $\theta > \widehat{\theta}$ or **3)** $\theta < \widehat{\theta}$ and $t^* > \frac{-E\left[\Delta Y_B^W\right]}{p_B \cdot (R_0+R)}$) political instability can not be avoided: for either the peasants or the ruling party, conflict is a more profitable option with respect to accepting a redistributive fiscal policy.

Stability of the process of democratization. The issue relative to the stability of equilibrium under a redistributive fiscal policy can now be addressed in more detail. Can political instability arise after the authoritarian government redistribute oil revenues through the provision of a public good? At this regard, the following Proposition is argued to be valid:

PROPOSITION 3.

3.1 Stability of a democratic regime. *A full democracy is stable if and only if:*

$$\theta = \widehat{\theta} \ \ and \ \ \widehat{\theta} \geq \widetilde{\theta}$$

where $\widetilde{\theta}$ and $\widehat{\theta}$ are, respectively, given in equations (1.5) and (1.9).

3.2 Emergence of a military sector. *Assuming that $\theta > \widehat{\theta}$ and $k \geq \widetilde{k}$ where*

$$\widetilde{k} = \frac{\ln(N) - \ln(N+1) - \delta \cdot [\ln(\eta) - \ln(\chi)]}{\ln(N+1) - \ln(N)} \tag{1.10}$$

here $\chi = 2 \cdot p_A \cdot \theta \cdot [R + R_0 \cdot (N+1)] \cdot (1-\epsilon)$ *and* $\eta = N \cdot \{t_m \cdot Y \cdot (2 - t_m) - 2 \cdot p_A \cdot R_0 \cdot [t_m - \epsilon - \theta \cdot (1-\epsilon)]\}$, *the government has to spend in military spending a fraction* $\widetilde{\widetilde{\beta}}$ *of revenues equal to:*

$$\widetilde{\widetilde{\beta}} = \frac{\widetilde{k}}{k}$$

where $\widetilde{k}$ *is given in equation (1.10). Another condition to be satisfied for a "factional" democracy*[34] *to emerge is:*

$$\widetilde{\widetilde{\beta}} \leq \widetilde{\widetilde{\beta}}^{(2)} \quad where$$

$$\widetilde{\widetilde{\beta}}^{(2)} = \frac{\delta \cdot L_W \cdot (1-t_m) \cdot (R+R_0) - \varepsilon \cdot k \cdot \{R_0 \cdot [\theta \cdot N \cdot (1-\epsilon)] + (R+R_0) \cdot (t_m - \epsilon)\}}{\varpi \cdot \varepsilon \cdot k}$$

here $\varepsilon = \ln(N+1) - \ln(N)$, $\varsigma = (R+R_0) \cdot (1 - t_m + k \cdot (\epsilon - t_m)) - k \cdot \theta \cdot n \cdot R_0 \cdot (1-\epsilon)$, $\varpi = (R+R_0) \cdot (1-t_m)$ *and* $L_W = L_W \left(\frac{-\varepsilon \cdot k \cdot \theta \cdot (1-\epsilon) \cdot [R+R_0 \cdot (n+1)] \cdot \exp^{-\varepsilon \cdot \varsigma / (\delta \cdot \varpi)}}{\delta \cdot (-\varpi)} \right)$.[35]

3.3 Political instability. *When* $k < \widetilde{k}$, $\widetilde{\widetilde{\beta}} > \widetilde{\widetilde{\beta}}^{(2)}$ *or* $\theta < \widetilde{\theta}$, *a regime of political instability is the likely outcome.*

PROOF. While Proposition 3.1 derives directly from Proposition 2.1, proofs of Proposition 3.2 and 3.3 are obtained by considering the solution of the following problem by the (democratic) government:

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[34] For a definition of "factional" democracy see Section 1.2.1.

[35] L_W denotes, in particular, a Lambert's W function, i.e, a function that solves the equation $w \cdot \exp^w = x$ where w represents a function of x.

Problem 2

$$
\begin{gathered}
min_{\beta} E\left[\pi_B^W\left(N,\ \tilde{\tilde{\delta}}\right)\right] - \pi_B^{FD}\left(t_m,\ 1,\ \beta\right) \\
such\ that \\
\pi_i^D\left(t_m,\ 1\right) < E\left[\pi_i^{W,D}\left(N,\ \tilde{\tilde{\delta}}\right)\right],\ \ \forall i = A_1,\ A_2,\ \ldots,\ A_N \\
\beta \in [0,1]\ \ and \\
E\left[\pi_B^W\left(N,\ \tilde{\tilde{\delta}}\right)\right] < \pi_B^{FD}\left(t_m,\ 1,\ \beta\right)
\end{gathered}
$$

where $\pi_B^{FD}\left(t_m,\ 1,\ \beta\right) = (1-\beta) \cdot \pi_B^D\left(t_m,\ 1\right)$ (income that the government gets under a regime of "factional" democracy).

As a solution of Problem 2, a fraction $\tilde{\tilde{\beta}}$ of the post-tax income of the rich group (group with the natural resource endowment) is spent in military. In particular, $\tilde{\tilde{\beta}}$ is decided in order to reduce the incentive of the peasants to undertake protests, i.e. $\tilde{\tilde{\beta}}|E\left[\pi_i^D(\cdot)\right] = E\left[\pi_i^{W,D}(\cdot)\right]$. The implementation of such a policy is constrained by two orders of conditions. Firstly, cases under which the introduction of a regime of "factional" democracy is a convenient option for the ruling party have to be determined. According to my notation, $E\left[\pi_B^W(\cdot)\right] < \pi_B^{FD}(\cdot)$. This condition is true when $\tilde{\tilde{\beta}} \leq \tilde{\tilde{\beta}}^{(2)}$. On the contrary, when $\tilde{\tilde{\beta}} > \tilde{\tilde{\beta}}^{(2)}$ the military sector is so expensive that the government does not care if political instability arises after the natural resource endowment is discovered.[36] The second constraint that should be satisfied is that $\beta \in [0,\ 1]$. In fact, financing is not allowed in the present model (see Assumption II.5). This condition holds when $k \geq \widetilde{k}$. This completes the proof.

[36]Political instability poses a limited burden on the government even when $\theta = \widehat{\theta}$ and $\widehat{\theta} < \widetilde{\theta}$.

According to Proposition 3, under certain conditions (namely, $\theta = \widehat{\theta} \geq \widetilde{\theta}$), the new equilibrium can be defined to be stable. On the contrary, under other assumptions (i.e., $\theta > \widehat{\theta}$, see Table 1.1), a military sector emerges following lines that are similar to those outlined above for a pure authoritarian regime (case of a "factional" regime, [34]).

Finally, when significant amount of revenues accrues to governments, neither mature nor "factional" democracies are able to emerge. In other words, democracies tend to be characterized by political instability.[37, 38].

Notes on the implementation of redistributive policies. If the attempt by the government to prevent a revolution by means of a direct redistribution of part of the natural resource discovered is considered, the following Corollary is shown to hold.

COROLLARY 2.

2.1 Direct redistribution of the natural resource. *In order to prevent a revolution from occurring, (and assuming that $E\left[\Delta Y_i^W\right] \cdot N \leq -E\left[\Delta Y_B^W\right]$) governments' rulers*

[37] To notice that, in the framework under analysis, peasants may undermine democratic institutions when redistributive fiscal policies are perceived as inequal (in light of the natural resource rents the owner of oil endowment gets).

[38] An example of this situation is represented by Congo Brazzaville ([59]) during the early 1990s. In this country, because of the pressures for a better redistribution of oil revenues, democracy under Lissouba proved incapable to consolidate and a civil war represented the "end of Congo's democratic experiment" ([60]). A military regime was able to regain control over state (and, hence, oil) revenues. President Sassou reintegrated a form of "neo-patrimonial state" ([51]) in which resources have been deployed (in an effort to build up a political support base) through military employment benefits, investments in the civil sector and inefficient spending programs in education.

have to redistribute a fraction of the income generated from the sale of the resource equal to $\widetilde{\widetilde{\alpha}}$ where:

$$\widetilde{\widetilde{\alpha}} = \frac{E\left[\Delta Y_i^W\right] \cdot N}{R \cdot p_B} = \frac{p_A}{p_B}\widetilde{\alpha} \tag{1.11}$$

2.2 Equilibrium strategy. *A program of public spending where a fraction $\widetilde{\alpha}$ of total natural resource rent is spent is a possible policy that can be implemented by the ruling party if and only if p_B is equal to p_A.*
A direct redistribution of the natural resource is a more profitable option relatively to a program of public spending provided that $p_B < p_A$.

PROOF. The complete proof of Corollary 2.1 is given in the Appendix. The equilibrium outlined by Corollary 2.2 can be derived by calculating the level of p_B such that revolution is not a profitable option for both the peasants and the ruling party. At this regard, from Proposition 2.3 and Corollary 2.1 it follows that, if $\alpha = \widetilde{\alpha}$ (or $\alpha = \widetilde{\widetilde{\alpha}}$), the redistribution of a fraction of the natural resource directly (or the implementation of a program of public spending) and no conflict is, respectively, the NE(G). As a second step, the level of p_B such that a program of public spending is (at least) as profitable as a direct redistribution of the natural resource has to be determined. It is straightforward to show that:

$$\pi_B^R(\widetilde{\alpha}) \geq \pi_B^R(\widetilde{\widetilde{\alpha}}) \Longleftrightarrow \widetilde{\alpha} \leq \widetilde{\widetilde{\alpha}}$$

Hence, from equations (1.7) and (1.11):

$$\widetilde{\alpha} \leq \widetilde{\widetilde{\alpha}} \Longleftrightarrow p_B \leq p_A$$

That is, the condition for p_B such that a program of public spending can be an equilibrium outcome is given by $p_B = p_A$ (see Assumption III). On the other hand, if $p_B \leq p_A$ the government will obtain a higher payoff if it *directly* redistributes the natural resource. This completes the proof.

1.3 Discussion

1.3.1 Final equilibrium outcome.

While in the Section 1.2.3 the issue of the emergence of particular regimes is solved separately, this Section concludes the analysis of the equilibrium outcome of the game by dealing with the choice of a particular political regime by the government's ruler. Main determinant of the decision by the ruling party is the objective to maximize its (expected) income. From the previous analysis, the government has to take into account the necessity to reduce the threats of internal conflict.

According to Proposition 2, where natural resource revenues accrue to an authoritarian ruler, either a process of (full) democratization of the country or redistributive or "predatory" policies are likely to be implemented,

From the previous discussion, the overall equilibrium outcome in an authoritarian regime will satisfy the following proposition:

PROPOSITION 4. *A military regime will be adopted by the ruling party if and only if $k > k^*$ where:*

$$k^* = \frac{\{\ln(N) - \ln(N+1) - \delta \cdot [\ln(\varrho) - \ln(\nu)]\} \cdot (R + R_0)}{E\left[\Delta Y_i^W\right] \cdot N \cdot [\ln(N+1) - \ln(N)]} \tag{1.12}$$

where $\varrho = R_0 \cdot N \cdot [\epsilon + \theta \cdot (1-\epsilon)]$ and $\nu = \theta \cdot (1-\epsilon) \cdot (R + R_0 \cdot (N+1))$.

On the other hand, when $k < k^*$ a redistributive authoritarian regime will be adopted.

PROOF. Proposition 4 indicates the conditions under which the ruling party will choose either to move to a redistributive policy or to adopt a military authoritarian regime. The ruling party has to choose the policy that maximizes its (expected) total revenue. In particular, the government's ruler will decide to adopt a military regime (redistributive autocracy) if and only if:

$$\pi_B^M\left(\widetilde{\beta}\right) > (<)\pi_B^R\left(\widetilde{\alpha}\right) \tag{1.13}$$

where $\pi_B^M\left(\widetilde{\beta}\right) = (1-\widetilde{\beta})\left[p_B \cdot (R_0 + R)\right]$ and $\pi_B^R\left(\alpha^*\right) = p_B\left\{R_0 + R\left(1-\alpha^*\right)\right\}$ [$\widetilde{\beta}$ and $\alpha^* = \widetilde{\alpha}$ $(or\ \widetilde{\widetilde{\alpha}})$ are given in equation (1.8) and (1.7) (or (1.11)), respectively]. Equation (1.13) is satisfied when $k > (<)k^*$ where k^* is given in equation (1.12). According to Proposition 3, as parameter k increases, the equilibrium response by the authoritarian leaders will switch from redistributive policies to military practices.

The proof is complete by considering that Proposition 4 rules out the possibility that a democratic regime emerges. In fact, given the assumptions of the model (see Section 1.2.2) condition $\pi_B^R(\widetilde{\alpha}) > \pi_B^D\left(t^*\right)$ is always satisfied. In other words, even if it is a feasible alternative ($\pi_B^D(t^*) > 0$ where $t^* = t|\pi_i^D(t^*) = 0$), the introduction of a redistributive fiscal policy does not represent a first best choice. From a technical viewpoint, a likely explanation is the possibility that, because of the deadweight losses associated to the tax collection and provision of public goods, inefficiencies arise from the introduction of a fiscal sector with respect to the other two alternatives. In addition, it is worth noticing that the ruling party receives less utility from the public good. If a mathematical point of view is taken into account, $\pi_B^R(\widetilde{\alpha}) < \pi_B^D\left(t^*\right)$ if and only if $R \in \left(\overline{\overline{R}}, \widetilde{R}\right)$.[39] But since $R > \widetilde{R}$

[39]Where: $\overline{\overline{R}} = \frac{R_0 \cdot \{p_A \cdot N \cdot [\theta \cdot (N - \lambda(N,\ \delta) \cdot (N+1)) \cdot (1-\epsilon) + N \cdot \epsilon] - 2 \cdot p_B\}}{p_A \cdot \lambda(N,\ \delta) \cdot \theta \cdot N \cdot (1-\epsilon) + 2 \cdot p_B}$.

(condition such that all peasants decide to fight, see Proposition 1) it follows that $\pi_B^R(\widetilde{\alpha}) > \pi_B^D(t^*)$ for all values of R.

1.3.2 Comparative statics.

With regard to the emergence of a redistributive or a military regime in authoritarian countries, evidence on the adoption of a given policy by the authoritarian govenment, is obtained by simulating the decision process making of the authoritarian leader. Results are reported in Tables 1.2 to 1.7.[40]
In particular, from Table 1.2 the following observations result: as the number of (socio-political) groups increases, governments can move from military regimes to redistributive autocracies. This is due to the fact that the higher the fragmentation of a country, the lower the level of public (redistributive or military) expenses to sustain. Furthermore, the reduction of redistributive expenses by the government is higher with respect to the reduction in military spending.[41] An interesting evidence that results from Table 1.2 is that for high levels of fragmentation even the introduction of a fiscal policy can be employed in order to avoid an insurrection. However, the adoption of a redistributive policy or a military regime is a more profitable option available to the ruling party (see Proposition 3). Finally, as seen previously (Remark 1), an increase in N has the effect to increase $\widetilde{R}$, so that in some instances,[42] threat of conflict does not represent, any longer, a feasible strategy that can implemented by the peasants.

[40]The payoff of the optimal strategy for the ruling party is reported in **bold** letters.

[41]Remember that, while the military spending of a country affects the total income of the ruling party only indirectly (i.e. in a probabilistic way), the redistribution of income represents a direct disincentive to the conflict.

[42]For example, for $N = 7$ in the simulation exercise.

[INSERT TABLE 1.2 ABOUT HERE]

Table 1.3 shows how the response of the government changes as the endowment of the natural resource which is discovered increases. Results suggest that natural resources poor-countries will tend to adopt military regimes. However, as the amount of the natural resource increases, the authoritarian leader will be better off by introducing redistributive autocracy regime. This is the case of, for instance, Saudi Arabia, by definition the classic "rentier state" ([61]). Because of its huge oil reserves (approximately, 25 percent of world's proven oil reserves), this country was able to establish an important welfare state. The possibility to employ natural resources revenues in order to finance investment programs and, contemporaneously, reduce the level of taxation enables this country to avoid extensions of political rights to large shares of the population (such as representiveness in institutions).

Other important conclusions that arise from Table 1.3 are: 1) as R increases, the equilibrium level of $\widetilde{\alpha}$ increases as well; 2) for relatively low values of R the introduction of a democratic regime is also a feasible alternative (even though not a first best choice).

[INSERT TABLE 1.3 ABOUT HERE]

Another evidence of the model is that, as θ increases (see Table 1.4), the likely response strategies of the ruling party shifts from the adoption of redistributive to "predatory" policies. In addition, notice that redistributive fiscal policies are possible strategies only for low values of θ. Furthermore, Table 1.5 shows how the equilibrium strategy changes as the level of parameter δ changes. According to this model, as the effort each agent puts in the protest increases, the incentive by the ruling party to undertake redistributive policies increases as well.

With regard to the change in the percentage that is destroyed after a conflict, Table 1.6 suggests that, the more violent the conflict, the more likely is the government to implement redistributive policies. Finally, as the efficiency of the military effort (represented by the parameter k) by the ruling party increases, the incentive to redistribute part of the resource (income) to the peasants decreases (Table 1.7).

[INSERT TABLES 1.4 TO 1.7 ABOUT HERE]

How are results from the theoretical model consistent with data provided by widely acknowledged institutions? Figures 1.1 and 1.2 illustrate the main relationships of interest described by the theoretical model.[43]

In Figure 1.1 the relationship between the military/government final consumption ratio[44] and the log of population (or the crude oil production) is examined by controlling for different ranges of the ethno-linguistic fractionalization (ELF) index.[45, 46] Even in this case, as the theoretical model correctly predicts (Table 1.2), as the level of fractionalization increases, the incentive to implement redistributive policies increases as well: *ceteris paribus* the average ratio of military ex-

[43]These figures have been obtained by employing data for 27 countries (Algeria, Angola, Azerbaijan, Cameroon, China, Egypt, Indonesia, Iran, Kazakhstan, Kuwait, Libya, Malaysia, Mexico, Nigeria, Oman, Pakistan, Peru, Russia, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Vietnam) over the 1988-2002 sample. Results do not change if, for relevant variables, averages on ten-year periods are considered.

[44]Source of data: World Development Indicators, World Bank, 2007.

[45]A Herfindahl-based index defined as: $ELF = 1 - \sum_i s_i^2$ (here, s_i is the share of group i over the total of the population) is, in particular, employed in order to represent the probability that two persons which are selected randomly from a given country will belong to different social groups (see [62]).

[46]Countries are classified as either high or low fractionalized according to their value of the ELF index (higher or less than 0.5) (Source: [63]).

penditure to total government consumption expenses will tend to be higher for low social fragmented (*solid line*) relative to high-fragmented countries (*dashed line*).

[INSERT FIGURE 1.1 ABOUT HERE]

Finally, Figure 1.2 illustrates the validity of another property of the theoretical model: as oil endowments increase, the implementation of redistributive policies is preferred to military expenditure programs.[47, 48] In average small oil exporting countries (*solid line*) are more likely to have a higher military spending/government final consumption ratio with respect to large oil producers (*dashed line*).

[INSERT FIGURE 1.2 ABOUT HERE]

1.3.3 Implications for economic development

According to common wisdom, mature democracies (such as Norway) have been able to afford the socio-economic issues raised by oil booms. In these countries, stable party systems, high degrees of social consensus, competent and well-functioning bureaucracies and a good rule of law have all allowed policy stability and transparency. Consequently, high levels of competitiveness as well

[47] Countries are classified as small or large producers depending on the fact that their annual production is less or more than 1 million barrels per day (bpd, Source: U.S. Department of Energy, Energy Information Administration).

[48] Figure 1.2 plots the ratio of military to government final consumption expenditure on the level of population (and on the fractionalization index) by accounting for the relative size of crude oil production.

as policies aimed at economic stabilization have been introduced.

Other political systems that have been argued to perform well in facing socio-economic pressures associated to oil booms are reformist autocracies. By employing natural resource revenues in productive investments aimed at diversifying the economic activities of these countries, reformist autocracies have been able to foster economic development. In addition, political stability together with stabilization and fiscal restraint measures implemented by technocratic elites have been associated to good economic performances (see [64] for an analysis of reforms in Indonesia).

Indonesia during the Suharto period is an interesting case study of the emergence of a reformist political regime. The agricultural sector was protected in an efficient way, while an attempt was made to reduce the role of the oil sector in the economy. Finally, an equilibrated budget law was introduced to avoid expansions of unproductive programs of social spending ([10]).

On the contrary, bad economic performances are usually associated to "factional" democracies or paternalistic autocracies. In fact, in these political regimes public expenditure is often directed towards protected and low inefficient economic sectors (often, public enterprises). As already outlined, examples of paternalistic autocracies are given by the Persian Gulf monarchies. For these countries, a large share of the rents from oil exports was allocated in order to raise population's standard livings. Consequently, programs of public spending aimed at raising the education and health levels of the population were implemented. However, while massive programs of investments in infrastructure were undertaken, they were quite inefficient. Since the quality of the services remained low, a significant self-sustained economic growth of the private sector was not able to start.

Finally, "predatory" autocracies have not been socially committed to economic development. As pointed out by [64], while between 1950 and the late 1990s, Indonesia has been able to manage well oil resources, during the same period, Nigeria's ruling elite had no similar concern about economic liberalization and poverty reduction.

Other countries where military regimes have not been able to introduce a significant process of economic development despite important oil revenues are Syria and Angola. In the former country, primary oil production started in 1967 (Source: Syrian Petroleum Company). Revenues from the sale of the natural resource were employed in order to enhance government autonomy from the other social classes. A large fraction of government revenues from aid and oil rent was absorbed by military and military-related activities. The large coalition that formed between the ruling Baath party, the army and the bureacracy had the effect to confine the productive industrial bourgeoisie ([65]) to the periphery of the society with detrimental economic effects.

Angola represents another example of how in a relatively small and rich oil exporter, state revenues have been redistributed in a clientelist way. In particular, a large fraction of oil rents (in 1999, 41 percent of total government expenditure accrued to the military sector, [56]) has been employed in order to serve security interests or to "sustain a clientele beyond the military apparatus, building a degree of legitimacy among those rewarded and allowing support or resistance to reforms, according to a short-term expediency".[49]

[49]However, it should be noted that, following robust stabilization policies aimed, *inter alia* at reducing the inflation rate (see, for instance, [66]) Angola has recently recorded very high levels of economic growth.

1.4 Concluding remarks

Does natural resources (and oil, in particular) affect the process of political transition of authoritarian regimes? Why do either paternalistic or "predatory" regimes often emerge? In this paper, a simple game-theoretical model aimed at assessing the impact of natural resource discoveries on the set-up of a particular political regime has been introduced. The possibility that a coalition forms in order to allow for a better redistribution of the natural resource is argued to be the main channel through which natural resources affects political regimes changes. This analysis relies on the conclusions by [1], [2] and [4] (among others) according to which natural resource wealth has a positive impact on civil war. Consequently, the study focuses on the relationships between natural resources and the emergence of different political systems. The channel by means of which oil affect the transition towards a particular regime I have focused on is the so-called *rentier effect*, i.e. wealth from the exploitation of natural resources is used in order to reduce threats of internal conflict.

A first result that emerges from this study is that the commitment by a democratic government to employ the natural resource revenues by means of a redistributive fiscal policy can not be able to avoid political instability. This result is consistent with the analyses by [38], according to which "in societies where a large fraction of GDP is generated from natural resources - democracies may be harder to consolidate", and [34] which, similarly, argue that, in oil exporting countries, the emergence of a "factional" democracy is a possible outcome.

Another point stressed by this work is that, as revenues from the sale of natural resources accrues to authoritarian governments, political leaders are better off (rather than by introducing a fiscal sector) by implementing a redistributive program or by introducing a military regime. The likely explanation is the hope for the ruling party to gain "legitimacy" ([61]). Evidence is, therefore, consistent with the existence of a positive and strongly statistically significant relationship between the wealth from natural resources and the "tenure of leaders" (see [67]. In other words, my point of view is that, provided that some conditions are satisfied, a process of (full) democratization may occur. However, as this political transition proves not to represent a first best choice, incumbent authoritarian rulers may prefer to maintain support by deploying natural resources rents in order to consolidate their political power through either a redistributive policy or adopting a military regime (see, also, [9] and [34]).

Finally, according to the result of the theoretical model it follows that the choice between implementing redistributive or "predatory" activities depends on factors such as the size of the natural resource endowment, the number of political groups that compose the country and on parameters that describe the technology of warfare. While more fragmented countries - as well as countries with higher natural resources endowments - will tend to implement redistributive policies, low-fragmented countries - and resource-poor nations - will tend to adopt military regimes. In addition, as the level of heterogeneity that exists among the different groups increases, the possibility that the ruling party will implement "predatory" autocracies increases as well. Evidence from data analysis seems to confirm all the conclusions drawn on the basis of the theoretical model.

Tables and Figures

Table 1.1: Implementation of redistributive fiscal policies by natural-resource rich countries, overall results

Case	Value of parameter θ	Fiscal Policy	Conflict	Final outcome
1	$\theta < \widehat{\theta}$ and $t^* \leq \frac{-E\left[\Delta Y_B^W\right]}{p_B \cdot (R_0+R)}$	tax rate=$t^* < \widehat{t}_m$	No	redistributive fiscal policy;
2	$\theta \equiv \widehat{\theta}$ and $\widehat{\theta} \geq \widetilde{\theta}$	tax rate=$\widehat{t}_m$	No	Full democratization;
3	$\theta \equiv \widehat{\theta}$ and $\widehat{\theta} < \widetilde{\theta}$	—	Yes	Political instability;
4	$\theta < \widehat{\theta}$ and $t^* > \frac{-E\left[\Delta Y_B^W\right]}{p_B \cdot (R_0+R)}$	—	Yes	Political instability;
5	$\theta > \widehat{\theta}$	—	Yes	Political instability.

Table 1.2: Simulation results ($\delta = 0.99$, R_0=3, R=21, ϵ=0.33, θ=0.51, p_B=0.3, $p_A = 1$, k=12).

N	$\overline{\theta}$	$\widetilde{R}$	$\widehat{\theta}$	t^*	t_B^*	$\widetilde{\beta}$	$\widetilde{\widetilde{R}}$	$\widetilde{\widetilde{R}}^{(2)}$	$\widetilde{\alpha}$ ($\widetilde{\widetilde{\alpha}}$)	$\widetilde{\alpha}_B$
2	0.38	8.76	0.26	—	0.53	0.11	0.48	2.41e+003	0.13	0.60
3	0.42	11.66	0.32	—	0.55	0.10	0.41	761.4	0.11	0.63
4	0.46	14.55	0.39	—	0.57	0.07	-0.06	426.8	0.08	0.65
5	0.48	17.45	0.45	—	0.58	0.04	-0.71	305.1	0.05	0.66
6	0.50	20.34	0.52	0.07	0.59	0.01	-1.41	246.9	0.01	0.67
7	0.50	23.24	—	—	—	—	—	—	—	—

N	π_i^P	π_B^P	$E\left[\pi_i^W(\cdot)\right]$	$E\left[\pi_B^W(\cdot)\right]$	$\pi_A^D(t^*,\ 1)$	$\pi_B^D(t^*,\ 1)$	$\pi_B^M(\widetilde{\beta})$	$\pi_i^R(\widetilde{\alpha})$	$\pi_B^R(\widetilde{\alpha})$
2	3.00	7.20	4.39	3.40	—	—	**6.43**	4.39	6.37
3	3.00	7.20	3.80	3.22	—	—	**6.51**	3.80	6.48
4	3.00	7.20	3.44	3.11	—	—	**6.67**	3.44	6.67
5	3.00	7.20	3.20	3.04	—	—	6.89	3.20	**6.89**
6	3.00	7.20	3.03	2.99	3.03	6.72	7.14	3.03	**7.14**
7	3.00	7.20	—	—	—	—	—	—	—

Table 1.3: Simulation results ($\delta = 0.99$, R_0=3, N=4, ϵ=0.33, θ=0.51, p_B=0.3, p_A=1, k=12).

R	$\overline{\theta}$	$\widetilde{R}$	$\widehat{\theta}$	t^*	t_B^*	$\widetilde{\beta}$	$\widetilde{\widetilde{R}}$	$\widetilde{\widetilde{R}}^{(2)}$	$\widetilde{\alpha}\ (\widetilde{\widetilde{\alpha}})$	$\widetilde{\alpha}_B$
14.56	0.36	14.55	0.53	0.001	0.56	8.84e-005	-1.63	426.8	1.32e-004	0.47
18.20	0.42	14.55	0.43	—	0.56	0.04	-0.76	426.8	0.05	0.45
21.84	0.47	14.55	0.37	—	0.57	0.08	0.16	426.8	0.09	0.44
25.48	0.50	14.55	0.33	—	0.57	0.11	1.14	426.8	0.12	0.44

R	π_i^P	π_B^P	$E\left[\pi_i^W(\cdot)\right]$	$E\left[\pi_B^W(\cdot)\right]$	$\pi_A^D(t^*,\ 1)$	$\pi_B^D(t^*,\ 1)$	$\pi_B^M(\widetilde{\beta})$	$\pi_i^R(\widetilde{\alpha})$	$\pi_B^R(\widetilde{\alpha})$
14.56	3.00	5.27	3.00	2.34	3.00	5.26	<u>**5.27**</u>	3.00	5.27
18.20	3.00	6.36	3.25	2.77	—	—	<u>**6.09**</u>	3.25	6.06
21.84	3.00	7.45	3.50	3.21	—	—	6.84	3.50	<u>**6.86**</u>
25.48	3.00	8.54	3.75	3.64	—	—	7.55	3.75	<u>**7.65**</u>

Table 1.4: Simulation results ($\delta = 0.99$, R_0=3, N=6, ϵ=0.33, R=21, p_B=0.3, p_A=1, k=12).

θ	$\overline{\theta}$	$\widetilde{R}$	$\widehat{\theta}$	t^*	t^*_B	$\widetilde{\beta}$	$\widetilde{\widetilde{R}}$	$\widetilde{\widetilde{R}}^{(2)}$	$\widetilde{\alpha}$ ($\widetilde{\widetilde{\alpha}}$)	$\widetilde{\alpha}_B$
0.50	0.50	20.65	0.52	0.03	0.58	0.00	-1.50	248.8	0.00	0.43
0.53	0.50	19.47	0.52	—	0.60	0.02	-1.14	241.2	0.02	0.43
0.56	0.50	18.42	0.52	—	0.61	0.03	-0.77	234.4	0.04	0.43
0.59	0.50	17.48	0.52	—	0.63	0.05	-0.40	228.3	0.06	0.43

θ	π_i^P	π_B^P	$E\left[\pi_i^W(\cdot)\right]$	$E\left[\pi_B^W(\cdot)\right]$	$\pi_A^D(t^*,\ 1)$	$\pi_B^D(t^*,\ 1)$	$\pi_B^M(\widetilde{\beta})$	$\pi_i^R(\widetilde{\alpha})$	$\pi_B^R(\widetilde{\alpha})$
0.50	3.00	7.20	3.02	3.01	3.02	6.98	7.17	3.02	**7.17**
0.53	3.00	7.20	3.08	2.90	—	—	7.06	3.08	**7.06**
0.56	3.00	7.20	3.14	2.79	—	—	**6.96**	3.14	6.95
0.59	3.00	7.20	3.20	2.68	—	—	**6.86**	3.20	6.84

Table 1.5: Simulation results (θ=0.51, R_0=3, N=4, ϵ=0.33, R=21, p_B=0.3, p_A=1, k=12).

δ	$\overline{\theta}$	$\widetilde{R}$	$\widehat{\theta}$	t^*	t_B^*	$\widetilde{\beta}$	$\widetilde{\widetilde{R}}$	$\widetilde{\widetilde{R}}^{(2)}$	$\widetilde{\alpha}$ ($\widetilde{\widetilde{\alpha}}$)	$\widetilde{\alpha}_B$
0.85	0.49	15.67	0.41	—	0.55	0.05	-0.19	700.9	0.07	0.44
0.95	0.46	14.83	0.39	—	0.56	0.07	-0.10	484.9	0.08	0.44
1.05	0.45	14.17	0.38	—	0.57	0.08	-0.00	358.7	0.09	0.45
1.15	0.43	13.64	0.37	—	0.58	0.10	0.10	278.9	0.10	0.45

δ	π_i^P	π_B^P	$E\left[\pi_i^W(\cdot)\right]$	$E\left[\pi_B^W(\cdot)\right]$	$\pi_A^D(t^*,\ 1)$	$\pi_B^D(t^*,\ 1)$	$\pi_B^M(\widetilde{\beta})$	$\pi_i^R(\widetilde{\alpha})$	$\pi_B^R(\widetilde{\alpha})$
0.85	3.00	7.20	3.35	3.22	—	—	**6.83**	3.35	6.77
0.95	3.00	7.20	3.42	3.14	—	—	**6.72**	3.41	6.70
1.05	3.00	7.20	3.47	3.07	—	—	6.61	3.47	**6.63**
1.15	3.00	7.20	3.52	3.01	—	—	6.49	3.52	**6.58**

Table 1.6: Simulation results ($\delta = 0.99$, R_0=3, N=4, R=0.21, θ=0.51, p_B=0.3, p_A=1, k=12).

ϵ	$\overline{\theta}$	$\widetilde{R}$	$\widehat{\theta}$	t^*	t_B^*	$\widetilde{\beta}$	$\widetilde{\widetilde{R}}$	$\widetilde{\widetilde{R}}^{(2)}$	$\widetilde{\alpha}$ ($\widetilde{\widetilde{\alpha}}$)	$\widetilde{\alpha}_B$
0.28	0.46	11.53	0.31	—	0.54	0.11	1.73	381.6	0.13	0.39
0.31	0.46	13.50	0.36	—	0.56	0.09	0.45	411.0	0.10	0.43
0.35	0.46	15.66	0.41	—	0.58	0.06	-0.51	443.4	0.06	0.46
0.38	0.46	18.06	0.47	—	0.60	0.03	-1.25	479.3	0.04	0.50

ϵ	π_i^P	π_B^P	$E\left[\pi_i^W(\cdot)\right]$	$E\left[\pi_B^W(\cdot)\right]$	$\pi_A^D(t^*,\ 1)$	$\pi_B^D(t^*,\ 1)$	$\pi_B^M(\widetilde{\beta})$	$\pi_i^R(\widetilde{\alpha})$	$\pi_B^R(\widetilde{\alpha})$
0.28	3.00	7.20	3.69	3.34	—	—	**6.39**	3.69	6.37
0.31	3.00	7.20	3.52	3.18	—	—	**6.58**	3.52	6.57
0.35	3.00	7.20	3.35	3.03	—	—	6.77	3.35	**6.77**
0.38	3.00	7.20	3.19	2.88	—	—	6.97	3.19	**6.98**

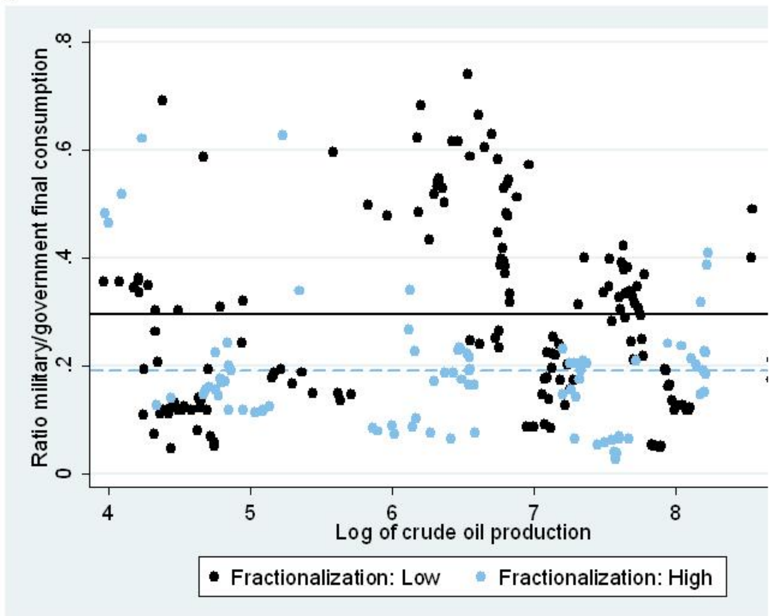
Table 1.7: Simulation results ($\delta = 0.99$, R_0=3, N=4, R=0.21, θ=0.51, p_B=0.3, p_A=1, ϵ=0.33).

k	$\overline{\theta}$	$\widetilde{R}$	$\widehat{\theta}$	t^*	t^*_B	$\widetilde{\beta}$	$\widetilde{\widetilde{R}}$	$\widetilde{\widetilde{R}}^{(2)}$	$\widetilde{\alpha}$ ($\widetilde{\widetilde{\alpha}}$)	$\widetilde{\alpha}_B$
10.20	0.46	14.55	0.39	—	0.57	0.09	0.02	279.5	0.08	0.45
11.40	0.46	14.55	0.39	—	0.57	0.08	-0.04	371.0	0.08	0.45
12.60	0.46	14.55	0.39	—	0.57	0.07	-0.08	490.8	0.08	0.45
13.80	0.46	14.55	0.39	—	0.57	0.06	-0.12	647.9	0.08	0.45

k	π_i^P	π_B^P	$E\left[\pi_i^W(\cdot)\right]$	$E\left[\pi_B^W(\cdot)\right]$	$\pi_A^D(t^*,\ 1)$	$\pi_B^D(t^*,\ 1)$	$\pi_B^M(\widetilde{\beta})$	$\pi_i^R(\widetilde{\alpha})$	$\pi_B^R(\widetilde{\alpha})$
10.20	3.00	7.20	3.44	3.11	—	—	6.58	3.44	$\underline{\textbf{6.67}}$
11.40	3.00	7.20	3.44	3.11	—	—	6.65	3.44	$\underline{\textbf{6.67}}$
12.60	3.00	7.20	3.44	3.11	—	—	$\underline{\textbf{6.70}}$	3.44	6.67
13.80	3.00	7.20	3.44	3.11	—	—	$\underline{\textbf{6.74}}$	3.44	6.67

Figure 1.1: Oil production and emergence of a redistributive or military autocratic regime. Social fractionalization

a)



b)

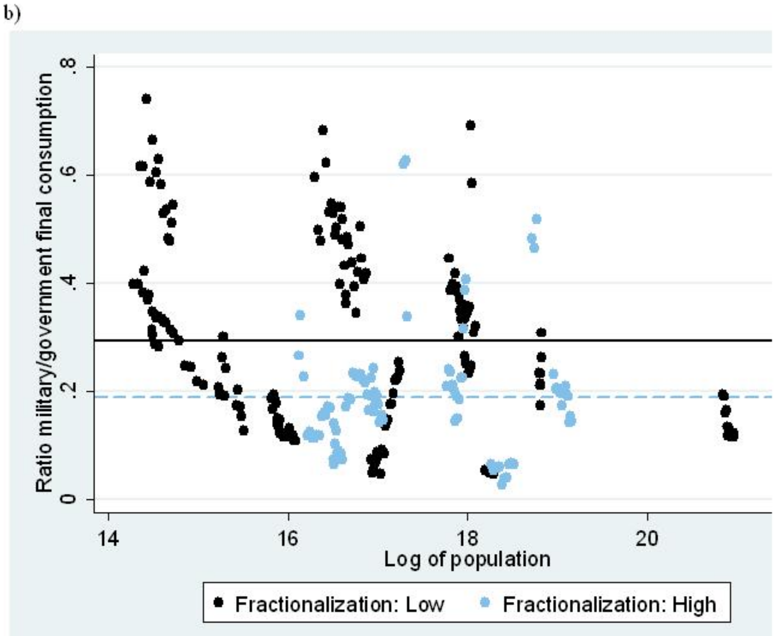
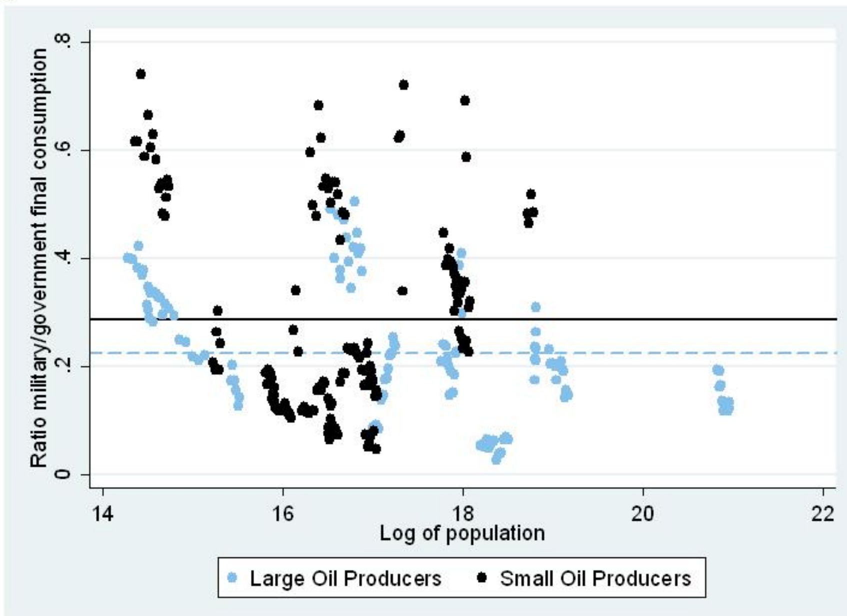
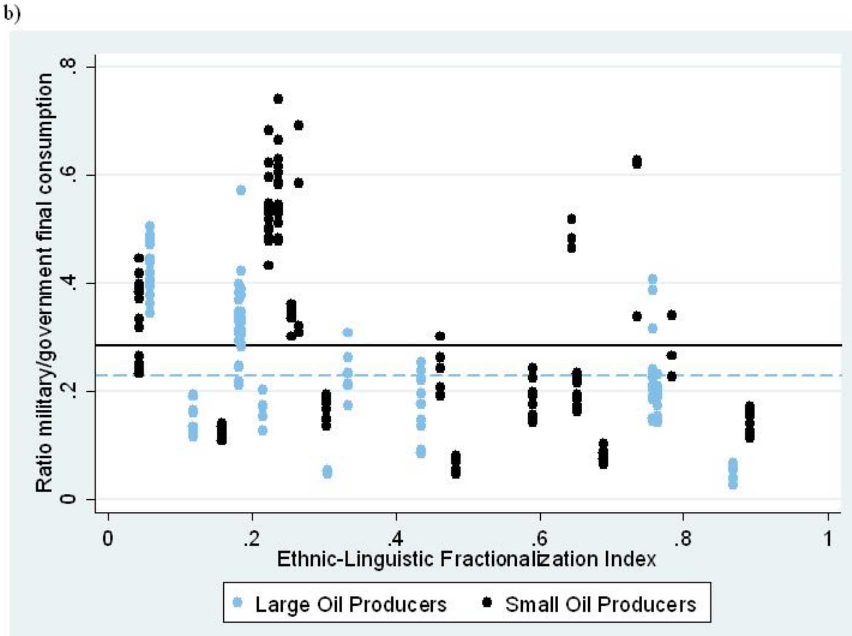


Figure 1.2: Oil production and emergence of a redistributive or military autocratic regime. Crude Oil Production

a)



b)



Appendix to Chapter 1. Proof of Propositions 1 and 2, Corollaries 1.2 and 2.1

Proof of Proposition 1

From a formal point of view, the proof of Proposition 1 relies on the following theorem (see [68], [69], [70], [71] and [72]):

Theorem. Existence of the Nash Equilibrium.

If the payoff function of the agents satisfies the *anonimity* as well as the *monotonicity* and the *single crossing* properties, then, the set of the Nash equilibrium structures of the game G (*NE(G)*) is nonempty (*NE(G)*$\neq \emptyset$).[50]

This theorem refers to stability concepts associated to *individual* agents deviations. Strictly speaking, if (1) an agent's incentive to switch unilaterally from a coalition to another one is related only to the size of the two coalitions (it does not depend on agents' identities), (2) this incentive is a monotonic function of the number of members of a coalition and (3) it is possible to determine critical values of some parameters (say $\widehat{\mu}$, "intensity of preference" for that coalition) such that the incentive to switch uniterally from one coalition to the other depends on these parameters, then, there exists at least a (Nash equilibrium) coalition structure in the game such that individual deviations are never profitable.

[50] In addition, the validity of these conditions guarantees that even the set of Coalition-Proof Nash Equilibria (*CPNE(G)*) is nonempty (*CPNE(G)*$\neq \emptyset$) ([68]).

Characterization of the equilibrium.

In order to characterize the NE(G), let me consider the differences in payoffs an agent will get by joining a different coalition. Let me denote by $E\left[\pi_i^A(k)\right] = \overline{\pi}_i^A(k)$ the expected payoff a representative peasant (say, i) gets if she joins coalition A, coalition which is composed by k agents. In particular, let me consider the change of the expected income agent i obtains if she decides to fight when the number of coalition A members increase from $k-1$ to k. The conditions under which $\overline{\pi}_i^A(k) \geq \overline{\pi}_i^A(k-1)$ have to be determined. Then, three possible cases arise:

1. Provided that $\delta < 1$ the fact that an agent joins the coalition has a positive effects on other agents' expected payoffs (case of *positive* spillovers). Therefore, positive externalities arise if the members of the fighting coalition increases. Since:

$$\overline{\pi}_i^A(0) \leq \ldots \leq \overline{\pi}_i^A(k-1) \leq \overline{\pi}_i^A(k) \leq \overline{\pi}_i^A(k+1) \leq \ldots \leq \overline{\pi}_i^A(N)$$

   the grand coalition will form when the difference in the expected income with respect to the *status quo* are positive. However, for a revolution to be convenient, condition (2.12) should hold: when $R \leq \widetilde{R}$ where $\widetilde{R}$ is given in equation (2.12), the NE(G) is given by the partition $\{P_N, P_B\}$. On the contrary, provided that condition (2.12) is not satisfied (such that $\pi_i^A(N) \leq W_i^P, \forall i = 1,\ 2, \ldots,\ N$) the grand coalition where all N peasants decide not to fight represents the final outcome of the game (*peace equilibrium*).[51]

[51]The proof of this part of Proposition 1 derives also from the definitions of *superadditive* and *convex* games. As argued, for instance, by [73], if a game is convex and, hence, superadditive, the grand coalition emerges in equilibrium.

Finally, it is easy to check that the fact that individuals have no incentive to leave the coalition once it has been decided to start a revolt implies that the coalition is stable.

2. On the contrary, if it is assumed that $1 \leq \delta \leq \widetilde{\delta}$ where

$$\widetilde{\delta} = \frac{\ln(N+1)}{\ln\{[\theta \cdot (1-\epsilon) \cdot [R + R_0 \cdot (N+1)]]\} - \ln\{R_0 \cdot [\theta \cdot (1-\epsilon) + \epsilon]\}}$$

it follows that:

$$\overline{\pi}_i^A(0) > \overline{\pi}_i^A(1) \ldots > \overline{\pi}_i^A(k-1) > \overline{\pi}_i^A(k) > \overline{\pi}_i^A(k+1) > \ldots > \overline{\pi}_i^A(N)$$

In other words, the decision by an agent to join coalition A does not have the effect to raise other agents' expected payoff, i.e. the increase of the probability of a successful revolution is not able to compensate the reduction of the expected payoff due to the necessity to divide the natural resource expropriated among a higher number of individuals. Therefore, under assumption I.2, the alternative to join coalition B is taken into account. In addition, since it can be proved that $E\left[\pi_i^A(k)\right] < Y_i^P$, for $k = 1, \ldots, N$ it follows that the *status quo* (no conflict) is the NE(G);

3. Finally, under the assumption that $\delta > \widetilde{\delta}$ and $\delta \geq 1$, although *negative* spillovers continue to arise from the decision of an excluded individual to join coalition A, since $\overline{\pi}_i^A(0) < \overline{\pi}_i^A(1)$, the *monotonicity* property is no longer valid. Hence, according to the theorem outlined above, there do not exist any (Nash) equilibria in the game that guarantee that deviations by single individuals are never profitable.

These observations complete the proof.

Proof of Proposition 2.1

The problem that the government has to face can be expressed as follows:[52]

Problem A.1

$$max_{t,\gamma}\pi_B^D\left(t,\gamma\right)$$

$$such\ that$$

$$E\left[\pi_i^W\left(N,\ \delta\right)\right] \leq \pi_i^D\left(t,\gamma\right),\quad \forall i = A_1,\ A_2,\ldots,\ A_N$$

$$E\left[\pi_B^W\left(N,\ \delta\right)\right] \leq \pi_B^D\left(t,\gamma\right),$$

$$t \in [0,1] \tag{1.14}$$

where $E\left[\pi_i^W\left(N,\ \delta\right)\right] = \widehat{R}_0 + \theta \cdot E\left[\Delta R_i^A(N)\right]$ ($E\left[\Delta R_i^A(N)\right] = (1-\epsilon)\left\{\left[R + R_0(N+1)\right]\lambda\left(N,\ \delta\right) - N\cdot R_0\right\}/N$ and $\lambda\left(N,\ \delta\right) = \left(\frac{N}{N+1}\right)^{1/\delta}$, $i = A_1,\ A_2,\ldots,\ A_N$), $\pi_i^D(t,\gamma) = (1-t)\,p_A{\cdot}R_0 + \gamma{\cdot}\left(t - \frac{t^2}{2}\right)Y$, $E\left[\pi_B^W\left(N,\ \delta\right)\right] = p_B\left\{\left(\widehat{R}_0 + \widehat{R}\right) - \theta\cdot N\cdot E\left[\Delta R_i^A(N)\right]\right\}$ ($Y = \frac{p_A R_0\cdot N + p_B(R_0+R)}{N+1}$) and $\pi_B^D(t,\gamma) = (1-t)\,p_B\left(R_0+R\right) + (1-\gamma)\cdot\left(t - \frac{t^2}{2}\right)Y$.

That is, governments have to maximize the post-tax income after the introduction of a fiscal policy (defined by means of the parameters t and γ) under the constraint that all peasants are better off in case of a redistributive fiscal policy. The Lagrangean function associated to the problem A.1 can be specified as follows:

$$\widetilde{L}(t,\ \gamma) = L(t,\ \gamma) + \mu_1 t + \mu_2\gamma$$

$$L(t,\ \gamma) = \pi_B^D\left(t,\gamma\right) - \widehat{\lambda}_1\left[E\left[\pi_i^W\left(N,\ \delta\right)\right] - \pi_i^D\left(t,\gamma\right)\right] +$$

$$-\widehat{\lambda}_2\left(t-1\right) \tag{1.15}$$

[52]As outlined in the text, I focus on the case $\delta < 1$, condition that (ensured that $R > \widetilde{R}$) guarantees the formation of a grand coalition.

The solution to problem A.1 satisfies the following Karush-Kuhn-Tucker (KKT) (necessary and sufficient) optimality conditions:

$$\frac{\partial L}{\partial t} = -\mu_1 \leq 0, \quad t \geq 0, \quad t\frac{\partial L}{\partial t} = 0;$$

$$\frac{\partial L}{\partial \gamma} = -\mu_2 \leq 0, \quad \gamma \geq 0, \quad \gamma\frac{\partial L}{\partial \gamma} = 0;$$

$$\frac{\partial L}{\partial \widehat{\lambda}_i} \geq 0, \quad \widehat{\lambda}_i \geq 0, \quad \widehat{\lambda}_i\frac{\partial L}{\partial \widehat{\lambda}_i} = 0$$

here $\widehat{\lambda}_i$ ($i = 1, 2$), μ_1 and μ_2 are the Lagrange multipliers associated to the inequality constraints of problem A.1 (see equation 1.20) and the Lagrangean function L is given by equation (1.15).

$$\begin{gathered} L(t,\ \gamma) = (1-\gamma)\, Y \cdot \tfrac{t^2}{2} - \{(1-\gamma)\, Y - p_B\,(R_0 + R)\} \cdot t + E\left[Y_B^W\right] + \\ -\widehat{\lambda}_1 \left\{ \left[\tfrac{\gamma Y}{2}\right] \cdot t^2 - \left[\gamma Y - p_A R_0\right] t + E\left[Y_i^W\right] \right\} + \\ -\widehat{\lambda}_2\,(t-1) \end{gathered} \tag{1.16}$$

These conditions imply that:

$$\begin{gathered} \tfrac{\partial L}{\partial t} = (1-\gamma) \cdot Y \cdot t - (1-\gamma) \cdot Y + p_B\,(R_0 + R) + \\ +\widehat{\lambda}_1 \cdot (\gamma \cdot Y(1-t) - p_A R_0) - \widehat{\lambda}_2 \leq 0, \quad t \geq 0 \quad t\tfrac{\partial L}{\partial t} = 0 \end{gathered}$$

$$\begin{gathered} \tfrac{\partial L}{\partial \gamma} = Y \cdot t\,(1 - 1/2 \cdot t) + \widehat{\lambda}_1 \cdot \left[Y \cdot t\,(1 - 1/2t)\right] \leq 0, \\ \gamma \geq 0 \quad \gamma\tfrac{\partial L}{\partial \gamma} = 0 \end{gathered}$$

$$\frac{\partial L}{\partial \lambda_1} = -1/2 \cdot \gamma \cdot Y \cdot t^2 + (\gamma \cdot Y - p_A R_0) \cdot t - E\left[Y_i^W\right] \geq 0, \quad \lambda_1 \geq 0 \quad \lambda_1\frac{\partial L}{\partial \lambda_1} = 0$$

$$\frac{\partial L}{\partial \lambda_2} = 1 - t \geq 0, \quad \lambda_2 \geq 0 \quad \lambda_2\frac{\partial L}{\partial \lambda_2} = 0$$

By solving this optimization problem by following an intuitive reasoning, I obtain as a first result that the optimal fiscal policy set by the government implies that:

$$\gamma^* = 1$$

in fact, as γ^* decreases, the government has to increase the redistribution of income aimed at leaving the peasant indifferent between fighting and working. If the post-tax income of the ruling party is compared under the two alternatives: **1)** $\gamma_1^* = 1,\ t_1^*$ and **2)** $\gamma_2^* < 1,\ t_2^* > t_1^*$) it can be observed that, for any values of γ_2^*, her income is lower with respect to the case where $\gamma^* = 1$.
By means of simple substitution, the equilibrium tax rate can be determined:

$$t^* = 1 - \frac{p_A R_0 + \left[Y\left(Y - 2 \cdot E\left[Y_i^W\right] - 2 \cdot p_A \cdot R_0\right) + (p_A R_0)^2\right]^{1/2}}{Y} \tag{1.17}$$

Let me now derive the conditions under which fiscal policy is not able to prevent a revolution. Conditions under which $\pi_i^D(t,\gamma) < E\left[\pi_i^W(N,\ \delta)\right]$ $\forall t \in [0,1]$ (i.e., the expected income from insurrection is higher with respect to the post-tax income in case of the country's democratization is satisfied for all values of the tax rate) have to be determined:

$$\pi_i^D(t,\gamma) < E\left[\pi_i^W(N,\ \delta)\right] \quad \forall t \Longleftrightarrow$$
$$-\left\{\tfrac{\gamma Y}{2}\right\} \cdot t^{*2} + \left\{\gamma Y - p_A R_0\right\} t^* - E\left[Y_i^W\right] \leq 0 \tag{1.18}$$

where $\gamma = 1$ and t^* represents the tax rate for which equation (1.18) is maximized (i.e., $t^* = \frac{Y - p_A R_0}{Y}$).[53] By substituting $E\left[Y_i^W\right]$ in equation (1.18) and solving for θ, it follows:

$$\widehat{\theta} = \frac{Y^2 + p_A R_0 \cdot [p_A \cdot R_0 - 2Y \cdot (1-\epsilon)]}{2 \cdot p_A E\left[\Delta R_i^A(N)\right] Y}$$

[53] Remember that $\pi_i^D(t,\gamma) - E\left[\pi_i^W(N,\ \delta)\right]$ is a concave function of t that has its maximum at $t^* = t_m = \frac{Y - p_A R_0}{Y}$.

the threshold level of θ such that, if $\theta > \widehat{\theta}$, joining coalition A and starting a conflict is always the best strategy for each peasant.

A last condition to check is that, when $t = t^*$, the difference between the total income of ruling party in case of peace (after redistributive fiscal policy at tax rate t^*) and the expected payoff in case of conflict is positive, i.e.:

$$\pi_B^D(t,\gamma) \geq E\left[\pi_B^W\left(N,\ \delta\right)\right] \Longleftrightarrow$$

$$-\gamma_B Y \cdot \frac{t^{*2}}{2} + \left\{\gamma_B Y - p_B\left(R_0 + R\right)\right\} \cdot t^* - E\left[Y_B^W\right] \geq 0$$

where $\gamma_B = 1-\gamma = 0$, $E\left[Y_B^W\right] = -p_B\left\{\epsilon\left(R_0 + R\right) + \theta \cdot \widehat{R}_0 \cdot N - \theta\lambda\left(N,\ \delta\right) \cdot \left[\widehat{R}_0 \cdot (N+1) + \widehat{R}\right]\right\}$
or:

$$\pi_B^D(t^*,\ 1) - E\left[\pi_B^W\left(N,\ \delta\right)\right] = -p_B \cdot \left(R_0 + R\right) \cdot t^* - E\left[Y_B^W\right] \qquad (1.19)$$

where t^* is given in equation (1.17).

By solving equation (1.19) for t^* it follows:

$$\pi_B^D(t,\gamma) \geq E\left[\pi_B^W\left(N,\ \delta\right)\right] \Longleftrightarrow t^* \leq t_B^* = \frac{-E\left[Y_B^W\right]}{p_B \cdot \left(R_0 + R\right)}$$

This completes the proof.

Proof of Proposition 2.2

The problem the government has to face is the following:

Problem A.2

$$max_\alpha \pi_B^R\left(\alpha\right)$$

$$such\ that$$

$$E\left[\pi_i^W\left(N,\ \delta\right)\right] \leq \pi_i^R\left(\alpha\right),\ \ \forall i = A_1,\ A_2,\ \ldots,\ A_N$$

$$\alpha \in [0,1]\ \ and$$

$$E\left[\pi_B^W\left(N,\ \delta\right)\right] \leq \pi_B^R\left(\alpha\right)$$

Even in this case, the expected payoff from insurrection an agent gets when all peasant individuals decide to join coalition A, $E\left[\pi_i^W(N,\ \delta)\right]$ has to be compared with the income a peasant obtains in case of a redistribution of the natural resource among citizens, $\pi_i^R(\alpha)$.
A second condition to check is the following:

$$\alpha_A^* = \widetilde{\alpha} \leq \alpha_B^*$$

where α_B^* is the maximum percentage of the natural resource that has to be distributed to the peasants such that $\pi_B^R(\alpha) > E\left[\pi_B^W(N,\ \delta)\right]$. That means that, for the authoritarian regime, the reduction of total income due to the redistribution of natural resource among citizens is less than the reduction of expected income she obtains in the case the peasants decide to fight. Let me consider the possibility of a direct redistribution of the natural resource among citizens. The expected payoff from insurrection an agent gets when all peasants decide to join coalition A is concerned and the income that a peasant obtains in case of a redistribution of the natural resource among citizens are, respectively, given by:

$$E\left[\pi_i^W(N,\ \delta)\right] = \widehat{R}_0 + \theta \cdot E\left[\Delta R_i^A(N)\right]$$

$$\pi_i^R(\alpha) = p_A\left(R_0 + \frac{\alpha R}{N}\right)$$

Hence, the condition under which the redistribution policy implemented by democratic regime is able to prevent an insurrection is the following:

$$\pi_i^R(\alpha) \geq E\left[\pi_i^W(N,\ \delta)\right] \Longleftrightarrow$$
$$\widehat{R}_0 + \theta \cdot E\left[\Delta R_i^A(N)\right] \leq R_0 + \tfrac{\alpha R}{N}$$

$$\pi_i^R(\alpha) \geq E\left[\pi_i^W(N,\ \delta)\right] \Longleftrightarrow \alpha \geq \widetilde{\alpha}$$
$$where\ \ \widetilde{\alpha} = \tfrac{E\left[Y_i^W\right]\cdot N}{R\cdot p_A}$$

As a second step, I have to prove that, after the redistribution of a fraction $\widetilde{\alpha}$ of the natural resource, even the total income of the ruling party is higher with respect to the expected payoff it gets in case of revolts.
In particular, the expected payoff from insurrection the government gets when all peasants decide to join coalition A, i.e.:

$$E\left[\pi_B^W\left(N,\ \delta\right)\right] = p_B\left\{\left(\widehat{R}_0 + \widehat{R}\right) - \theta \cdot N \cdot E\left[\Delta R_i^A(N)\right]\right\}$$

has to compared with the net income the government gets after redistributing the natural resource, i.e.:

$$\pi_B^R(\alpha) = p_B\left\{R_0 + R \cdot (1-\alpha)\right\}$$

Therefore, the ruling party is better off after a redistributive policy provided that:

$$E\left[\pi_B^W\left(N,\ \delta\right)\right] \leq \pi_B^R(\alpha) \Longleftrightarrow$$
$$\left(\widehat{R}_0 + \widehat{R}\right) - \theta \cdot N \cdot E\left[\Delta R_i^A(N)\right] \leq (R_0 + R) - R \cdot \alpha$$

$$E\left[\pi_B^W\left(N,\ \delta\right)\right] \leq \pi_B^R(\alpha) \Longleftrightarrow \alpha \geq \widetilde{\alpha}_B$$
$$where\ \ \widetilde{\alpha}_B = \tfrac{\epsilon(R_0+R)+\theta\cdot N\cdot E\left[\Delta R_i^A(N)\right]}{R}$$

As the inequality $\widetilde{\alpha}_B < \widetilde{\alpha}$ is satisfied for all $R > 0$.[54], it can be concluded that the equilibrium fraction of the natural resource endowment to redistribute should be equal to $\widetilde{\alpha}$.

[54]In fact, $\widetilde{\alpha} > \widetilde{\alpha}_B$ if and only if $R > -R_0 \cdot (N+1)$ and $R < 0$, but this is not possible under the assumption of strictly positive parameters.

Proof of Proposition 2.3

The problem the ruling party has to face is now given by: **Problem A.3**

$$min_{\beta} E\left[\pi_B^W\left(N,\ \widehat{\delta}\right)\right] - \pi_B^M\left(\beta\right)$$
$$such\ that$$
$$E\left[\pi_i^W\left(N,\ \widehat{\delta}\right)\right] \leq \pi_i^P, \quad \forall i = A_1,\ A_2, \ldots,\ A_N$$
$$E\left[\pi_B^W\left(N,\ \widehat{\delta}\right)\right] \leq \pi_B^M\left(\beta\right),$$
$$\beta \in [0, 1]$$

where:

$$\pi_B^M = (1-\beta)\cdot p_B\left(R_0 + R\right)$$

This problem can be solved by considering that the aim of governments' rulers is to reduce the incentive compatibility of all agents to start a conflict by spending the minimum amount β in the process of militarization of the country. This condition holds when β corresponds to the quantity $\widetilde{\beta}$ where $\widetilde{\beta}$ satisfies $E\left[\Delta Y_i^W\right]\left(\widehat{\delta}\right) = 0$. Accordingly, if we denote by $\widetilde{R}^{(2)}$ the threshold value of the resource endowment such that if $R > \widetilde{R}^{(2)}$ peasants can decide to start a conflict despite the military spending by the government, condition $R \leq \widetilde{R}^{(2)}$ should hold.

Another assumption that has to be satisfied is that total income after military spending is higher with respect to the expected payoff that derives to the government from a civil conflict. This is true when:

$$\pi_B^M\left(\beta\right) \geq E\left[\pi_B^W(N,\ \widehat{\delta})\right] \Longleftrightarrow R \geq \widetilde{\widetilde{R}} \quad where \quad \widetilde{\widetilde{R}} = \frac{R_0\cdot\left\{\widetilde{\beta}-\epsilon-\theta(1-\epsilon)\left[\lambda\left(N,\ \widehat{\delta}\right)\cdot(N+1)-N\right]\right\}}{(1-\epsilon)\cdot\theta\cdot\lambda\left(N,\ \widehat{\delta}\right)+\epsilon-\widetilde{\beta}}$$

where $\left(\lambda\left(N,\ \widehat{\delta}\right) = \left(\frac{N}{N+1}\right)^{1/\widehat{\delta}}\right)$ and $E\left[\pi_B^W(N,\ \widehat{\delta})\right]$ are obtained by replacing in equation (1.2) N_A with N and δ with $\widehat{\delta}$.

Finally, extreme cases arise when the government is not able to prevent a revolution even if the total amount of natural resource revenues is spent in order to militarize the country. This is the case when condition:

$$R \geq \widetilde{\widetilde{R}}^{(2)} \quad where \quad \widetilde{\widetilde{R}}^{(2)} = NR_0 \cdot \left[1 + \frac{\epsilon}{\theta\,(1-\epsilon)}\right] \cdot \left[\lambda\,(N,\ \delta/(1+k))\right]^{-1} - R_0\,(N+1) \tag{1.20}$$

is satisfied.[55] Even in the hypothetical case where all government's income is spent in order to defend the country from internal threats (i.e. $\beta = 1$), the reduction of the expected income is not sufficient to prevent all peasants from starting a conflict. This completes the proof.

Proof of Corollary 1.2

Starting point is to consider the equilibrium tax rate t^* (see Proposition 2.1, equation 1.6) and the fiscal policy that maximizes median voter's post-tax income (see Corollary 1.1). The fiscal policy set is equivalent to that of a (full) democratic regime when $\theta = \widehat{\theta}$ **(condition 1)** where

$$\widehat{\theta} = \frac{Y^2 + p_A \cdot R_0 \cdot [p_A \cdot R_0 - 2Y \cdot (1-\epsilon)]}{2 \cdot p_A E\left[\Delta R_i^A(N)\right] Y}$$

and $\widehat{\theta}$ is θ such that $\pi_i^D(t,1) = E\left[\pi_i^W\,(N,\ \delta)\right]$ (see proof of Proposition 2.1).[56]
In order for democracy to be achieved, a condition that has to be satisfied is that,

[55] For a mathematical derivation of equation (1.20) it suffices to replace $\beta = 1$ in equation (1.3) and, then, consider equation (2.12).

[56] If $\theta < \widehat{\theta}$ it follows that $t^* \leq t_m$. On the other hand, if $\theta > \widehat{\theta}$ the peasants will be better off if they decide to form a coalition and enter in a conflict over resource redistribution.

when $\theta = \widehat{\theta}$, $\pi_B^D(t^*, \gamma) \geq E\left[\pi_B^W(N,\ \delta)\right]$. This condition holds when:

$$\pi_B^D(t, \gamma) \geq E\left[\pi_B^W(N,\ \delta)\right] \Longleftrightarrow$$
$$\{-p_B(R_0 + R)\} \cdot \left(\tfrac{Y - p_A \cdot R_0}{Y}\right) - E\left[Y_B^W\right] \geq 0$$

where $t^* = \frac{Y - p_A \cdot R_0}{Y}$. This is the case when $\theta > \widetilde{\theta}$ where

$$\widetilde{\theta} = \tfrac{(R_0 + R)[(1-\epsilon)Y - p_A R_0]}{N \cdot E\left[\Delta R_i^A(N)\right] Y}$$

(condition 2).

By considering **condition 1** and **condition 2**, it follows that under a full democratic system, we should have $\theta = \widehat{\theta}$ and $\widehat{\theta} \geq \widetilde{\theta}$. This completes the proof.

Proof of Corollary 2.1

If the expected payoff from insurrection an agent gets when all peasants decide to join coalition A (i.e, $E\left[\pi_i^W(N,\ \delta)\right] = \widehat{R}_0 + \theta \cdot E\left[\Delta R_i^A(N)\right]$) is compared with the income that a peasant obtains in case of a redistribution among citizens of the income generated from the sale of the natural resource, i.e.,

$$\pi_i^R(\alpha)^{(2)} = p_A R_0 + p_B\left(\frac{\alpha R}{N}\right)$$

it follows that:

$$E\left[\pi_i^W(N,\ \delta)\right] \leq \pi_i^R(\alpha)^{(2)} \Longleftrightarrow \alpha > \widetilde{\widetilde{\alpha}}$$

where

$$\widetilde{\widetilde{\alpha}} = \frac{E\left[Y_i^W\right] \cdot N}{R \cdot p_B} = \frac{p_A}{p_B}\widetilde{\alpha}$$

On the contrary, if the government's (expected) payoff is considered, it can be proved that redistribution is a better solution with respect to conflict when:

$$E\left[\pi_B^W(N,\ \delta)\right] \leq \pi_B^R(\alpha)^{(2)}$$

where

$$E\left[\pi_B^W(N,\ \delta)\right] = p_B\left\{\left(\widehat{R}_0 + \widehat{R}\right) - \theta \cdot N \cdot E\left[\Delta R_i^A(N)\right]\right\}$$

and

$$\pi_B^R(\alpha)^{(2)} = [R_0 + R \cdot (1-\alpha)] \cdot p_B$$

The equilibrium condition for the ruling party is, therefore, given by:

$$E\left[\pi_B^W(N,\ \delta)\right] \leq \pi_B^R(\alpha)^{(2)} \Longleftrightarrow \alpha \leq \widetilde{\widetilde{\alpha}}_B \ \ where$$
$$\widetilde{\widetilde{\alpha}}_B = \frac{\epsilon(R_0+R)+\theta\cdot N\cdot E\left[\Delta R_i^A(N)\right]}{R}$$

The proof is complete by verifying that $\widetilde{\widetilde{\alpha}} \leq \widetilde{\widetilde{\alpha}}_B$ is always satisfied for $E\left[Y_i^W\right] \cdot N \leq -E\left[Y_B^W\right]$.[57]

[57] This condition is satisfied for any values of $R \geq \overline{R}$, where $\overline{R} = \frac{R_0\cdot\{\rho\cdot(N+1)-\theta(1-\epsilon)[p_A-p_B]\cdot N-\epsilon[p_A N+p_B]\}}{p_B\cdot\epsilon-\rho}$ [here, $\rho = (p_A - p_B)\cdot\theta\cdot\lambda(N,\ \delta)\cdot(1-\epsilon)$].

Chapter 2

Exogenous Oil Shocks, Fiscal policy and Sector Reallocations in Oil Producing Countries

Previous literature has suggested that different mechanisms of transmission of exogenous oil shocks are responsible for the negative effects on the economic performances of oil exporting countries.

This paper aims at providing further evidence on the role of sectoral reallocation between private and public sectors in explaining the impact of shocks to oil revenues on the economic growth rates of oil producing countries. The effects of oil shocks on the business cycle of oil producing countries are examined by distinguishing between various components of public sector spending policy: purchases of consumption goods, investments in productive activities and compensation for public employees.

Simulation results from a simple theoretical model suggest that the possibility

that crowding-out effects of public over private investments can explain a large fraction of the negative effects of shocks to oil revenues on the private sector of the economy. Since the growth in size of the public sector is not able to compensate for the reduction in size of the private sector, an increase in oil revenues has the effect to decrease total output and employment.
Finally, numerical results suggest that countries which are characterized by lower levels of private investments in the steady state are the least affected by an exogenous oil shock with respect to countries where private investments have the higher share in total output.

2.1 Introduction and literature review

There is a large body of research which tries to assess how oil shocks influence the business cycle of oil producing countries. According to many empirical papers, countries which are endowed with relevant natural resources are characterized by lower economic growth rates with respect to countries with few natural resources. Important studies on the failures of resource-led development include, for instance, [57], [11], [12], [18], [74]. In particular, [12] find a strong inverse relationship between the log of the export contribution to growth during the period 1970-1990 and the log of natural resource abundance in 1970. [11] briefly surveyed the Dutch disease explanation for the natural resource curse. According to this mechanism, export windfalls may have adverse effects on the real exchange rate of these countries. This, in turn, may render most other exports uncompetitive. Thus a rapid and, often distorted, growth of the non-tradeable sector may occur. In turn, the industrialization process of the country, as well as the traditional economic sectors (i.e. agriculture), may be negatively affected. As noted by [18], countries that depend heavily on the export of natural resources tend to suffer from a variety of problems, including authoritarian governance, antistate protests and/or civil wars, high corruption levels, high poverty rates, etc.[1, 2] In this work, we aim at studying a different, but by no means less important, mechanism of transmission of oil shocks to the overall economy of oil producing countries, which is represented by the reallocation effects associated to the fiscal policy implemented by the government.

Starting from the pioneristic works of [75], [76], [77], the effects of domestic resource discoveries on tradeable and non-tradeable sectors of open economies have been assessed by many theoretical and empirical studies. According to this branch of literature, oil discoveries prompts huge booms in investments, especially in the non-traded goods sectors of the economy. In contrast, investments and profits in the traded sectors are squeezed by the oil boom. As the non-traded goods sectors expand, the traded goods sectors of these countries tend to shrink.

On the other hand, [78] emphasises the issues related to the effects of the spending policy implemented by the public sector. According to this author, poor management of oil wealth and, in particular, inefficient spending by the public sector induces significant imbalances in the internal market.

[1] For a review of the literature on the effects of oil endowments on oil producing countries see [20].

[2] Other authors find a positive effect of a large endowment of oil and other mineral resources on long-term economic growth. According to [20], although large endowments of oil and other mineral resources do not affect significantly political institutions, positive effects on long-term economic growth may nevertheless occur.

[79] argue that distorted allocations of spending over time by the public sector are enhanced in the presence of common-pool problems or uncertainty over property rights over the resource income. This fact, in turn, may further enhance low economic performances. [80], in an analysis of how to improve economic performance of the Gulf Council Countries, argue that oil wealth should be reallocated in such a way to improve economic incentives directed in boosting the growth of the private sector.

More recently, studies by [81], [34], [82], among others, were interested in the operational aspects of fiscal policy in oil producing countries. These works are interested in offering indications on fiscal policy adjustments in order to reduce the negative effects on sustainable economic growth arising from high volatile and uncertain flow of oil revenues from abroad.

The reallocation effects of booms in resource revenues affect also oil importing countries. Several papers argue that oil price shocks often require an unusual amount of labour to be reallocated across industries of developed economies, thereby increasing the unemployment rate in those periods. [83] contends that reallocative shocks significantly affect aggregate unemployment by increasing the amount of labour reallocation required. According to [84], macroeconomic models typically assign primary importance to aggregate demand shocks in the determination of the unemployment rate. This reflects the belief that shocks to the composition of demand merely lead to a reallocation of labour resources across industries. This evidence finds empirical support in [85], who shows that oil prices Granger-cause unemployment. [86] argue that factor specialization and reallocation frictions led to reduced output and employment in the US economy in the wake of the first OPEC oil price shock. The car industry was particularly hit, as its actual features of factor inputs did not closely match the desired characteristics.[3]

In [87] Vector Autoregression models are used to investigate how different sectors of the US economy have been affected by oil shocks. Results of impulse response functions indicate that oil price increases mainly reduce supply for high energy-intensive industries. On the other hand, oil price shocks affect many other industries (such as the car industry) by reducing demand for their products. According to [88], oil prices shocks are associated with variations in employment shares and relative wages across industries. Results suggest that, while real wages declines for all workers, wages for skilled workers increase.

This paper aims at providing further evidence on the effects of exogenous oil shocks on the macroeconomic performances of oil exporting countries. It does so by means of a simple theoretical framework based on the real business cycle modelling of macroeconomic activity in oil producing countries. The questions we would like to answer can be summarized as follows. How are oil shocks likely to affect the economic activity of oil exporting countries? More specifically, what are the effects of oil shocks on consumption, investments and labour markets? Do oil shocks increase the role of the public sector in the economy[4]? How important are changes in the allocation of production inputs across sectors in determining the economic consequences to exogenous oil shocks?

This paper extends the previous literature on the macroeconomic effects of ex-

[3]For instance, the auto industry and the network of dealership were specialized, respectively, in the production and sale of large cars. Similarly, skills of workers in the auto industry and research and design activities were directed in producing and engineering large cars. However, the demand of this type of cars dropped as oil prices increased after the oil shocks.

[4]In the present paper, the word *government* and *public sector* are used interchangeably.

ogenous oil shocks on the economic stance of oil exporting countries in various directions. The hypothesis that oil price shocks drive large aggregate reallocation of production factor is investigated by several previous studies. However, earlier work lacks the sectoral detail on job creation and destruction that we examine. Shifts in demand across sectors induced by changes in public spending is well documented in literature. For instance, [89] examine the effects of changes in public spending on the reallocation of production factor in a two-sector dynamic general equilibrium model. Under the assumption that changes in public spending are ofthen sector-specific, shifts in the allocation of factors across industries can lead to declines in employment and changes in the wages paid across sectors. Differently from this literature, our analysis focuses on the sectoral reallocation adjustment process that follows a negative wealth effect induced by an exogenous oil shock. In particular, a two-sector economy in which the public sector role is separately considered from the role of private firms is considered.

Many assumptions of our analysis are similar to those considered in the work by [90] on the cyclical effects of fiscal policy. Nevertheless, the focus is quite different.[5] We concentrate on the mechanism of transmission of exogenous oil shocks on producing countries, whereas [90] considers the different effects of government fiscal policy on both private and public sectors for the US economy. A calibrated version of the model is simulated and sensitivity analysis over key parameters and steady state values is implemented. A particular feature of our

[5]Several assumptions of the theoretical model also differ significantly with respect to this paper. The main differences involves the source of exogenous growth, the functional form taken by government budget constraint, the role of the public sector in the economy as far as productive activities are concerned.

model is that intervention of fiscal policy in the economic system is assumed to take several forms: purchases of consumption goods, investments in productive activities and compensation for public employees.

In this paper, we derive the analytical conditions under which the possibility that a positive effect of oil shocks on the economic performances of exporting countries arises. Implications of fiscal policies aimed at reducing the so-called natural resource curse are, hence, presented.

One of the main results we obtain is that oil shocks cause a reallocation of economic activities between the private and public sectors of the economy. Higher spending and investments by the public sector reduces private wealth. Although the estimated impact on demand for labour supply in the public sector is positive, supply for private labour decreases. As the effect on the private sector outpaces that on the public sector, the overall demand for leisure increases. In addition, higher oil revenues seems to cause a crowding-out effects on both private consumption and investment. All in all, while the role of the public sector in the economy increases, the importance of the private sector lessens out. Since this second effect tends to be larger with respect to the first one, the impact of exogenous oil shocks on total output is negative.

The paper is organized as follows. Section 2.2 presents the theoretical model employed in order to examine the macroeconomic effects of oil shocks in oil exporting countries. In particular, Section 2.2.1 outlines the assumptions of the framework employed in our analysis, while Section 2.2.2 considers the set-up of our theoretical model. Section 2.3 investigates the consequences of disturbances to oil revenues to key macroeconomic variables. Section 2.3.1 describes the framework implemented in order to calibrate model. While section 2.3.2 outlines the main results of one percent oil shock on both relevant variables public and private sectors. Section 2.3.3 discusses how results varies if different assumptions on key parameters are made. Section 2.4 concludes.

2.2 The theoretical model

2.2.1 Assumptions

The effects of exogenous oil shocks on the economic performance of oil exporting countries are studied by means of a simple neoclassical growth model where preferences, technology and resource constraints for both private and public agents are considered together with rules governing public finance. Households, firms and the government interact in a variety of ways within a perfectly competitive market structure.

Households

There is a representative household which aims at maximizing a discounted sum of period utilities over an infinite planning horizon. The household has preferences over sequences of consumption and leisure and maximizes its expected lifetime utility. The lifetime utiliy function is, in particular, given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t u_t \left(C_t,\ L_t,\ G_t\right) \tag{2.1}$$

where E_0 represents the expected value operator. C_t and G_t represent, respectively, private and public consumption, while L_t denotes leisure.

According to this equation, future momentary utilities, u_t, are discounted using the subjective discount factor β, $\beta \in (0,\ 1)$. The fully parameterized momentary utility function employed for simulation purposes is given by:

$$u_t\left(C_t,\ G_t,\ L_t\right) = \frac{\left(C_t^{\psi} G_t^{1-\psi}\right)^{1-\sigma} L_t^{1+\vartheta}}{1-\sigma} \tag{2.2}$$

where σ and ϑ denote preference parameters. In particular, $\sigma > 0$ is the inverse of intertemporal elasticity of substitution in consumption whereas, ψ is a parameter denoting the degree of substitutability between private and public consumption expenditure. According to this period utility function, government consumption expenditure provides utility for the household, as it represents a substitute for private consumption.[6] It can be easily verified that utility depends positively on consumption services and leisure. Furthermore, it can be observed that $v_L > 0$ and $v_{LL} > 0$[7] where $v(L_t) = L_t^{1+\vartheta}$, $\vartheta > 0$. In other words, $v(.)$ is an increasing and convex function of leisure. Assuming constant leisure, these features of the momentary utility function are compatible with steady state growth in consumption. Thus, the specification of the period utility function we employ ensures positive first and negative second derivatives of the utility function with respect to consumption levels, i.e. $u_C > 0$, $u_{CC} < 0$, $u_G > 0$, $u_{GG} < 0$, that is utility is an increasing and concave function in both private and public consumption.

The household has a time endowment which is normalized to one. The sum of time devoted to work and leisure cannot exceed its endowment of time. Consequently, labour supply N_t and leisure L_t are related through the following time

[6] This assumption follows [90].

[7] v_X and v_{XX} denote, respectively, first and negative second derivatives of function $v(X)$ with respect to X.

constraint:[8]

$$L_t + N_t = 1 \tag{2.3}$$

In addition, in each period the representative household faces a flow budget constraint setting its total income equal to its total spending, that is:

$$W_t N_t + R_t K_t^P = C_t + I_t \tag{2.4}$$

where W_t is the real wage rate, R_t is the real rental rate on capital, I_t is gross private investment.

Firms

Taking market prices as given, the firm maximizes profit Π_t from the production of goods:

$$\Pi_t = Y_t^P - W_t N_t^P - R_t K_t^P$$

where Y_t^P denotes total private output at date t obtained through the following Cobb-Douglas production function:

$$Y_t^P = F_t^P(N_t^P,\ K_t^P) = A_t \left(K_t^P\right)^{\theta} \left(N_t^P\right)^{1-\theta} \quad \theta \in (0,1) \tag{2.5}$$

where K_t^P is the private capital stock and N_t^P is the quantity of labour input. The Cobb-Douglas production function (2.5) is characterized by constant returns to scale with respect to N^P and K^P.

The household owns a stock of capital (K_t) which is rented to the representative firm each period. The rule governing the process of capital accumulation is

[8]For simplicity, we assume that the time-endowment constraint of the household always binds with equality.

given by:

$$K_{t+1}^{P} = \left(1 - \delta^{P}\right) K_t^{P} + I_t \tag{2.6}$$

where δ^P is the rate of depreciation of private capital. In addition, K_0 is assumed to be constant.

The government

Finally, there is a government which hires labour from households, N_t^G and invests a fraction of its revenues in order to produce government output. In addition, it purchases consumption goods from the market. The government has only one sources of revenues: it owns a flow endowment of a natural resource commodity (in our case, oil), whose value in each period t is given by Z_t.[9]

In addition, public output is produced according to the following production function:

$$Y_t^G = F_t^G(N_t^G,\ K_t^G) = A_t \left(K_t^G\right)^{\gamma} \left(N_t^G\right)^{1-\gamma} \quad \gamma \in (0,1) \tag{2.7}$$

where N_t^G and K_G^t are the stock, of labour and capital employed by the government for production purposes and A_t denotes total production augmenting technological progress.[10] In equation (2.7), constant returns to scale over (pub-

[9]Although this seems to be a strong assumption, we need to remember that for high-indebted poor countries oil often accounts for a very high percentage of government's revenues and exports earnings.For instance, in Angola oil accounts for approximately 80% of the government's revenues and 90% of export earnings.

[10]This assumption allows us to differentiate the framework employed from that, for instance, used by [90]. In this article, K_t^G enters directly in the private production function.

lic) capital and labour are assumed.[11]

Government's investment increases the capital stock K^G subject to the following law of motion:

$$K^G_{t+1} = \left(1 - \delta^G\right) K^G_t + X_t \tag{2.8}$$

where X_t denotes (exogenous) gross public investment and δ^P is the rate of depreciation of public capital.

In each period, the government faces the following budget constraint:

$$Z_t = G_t + X_t + W_t N^G_t \tag{2.9}$$

where Z_t denotes the flow of exogenous oil revenues the government obtains from abroad. According to equation (2.9), the total amount of resources used by the government for purchases of consumption goods, investments and compensation for public employees can not exceed total external revenues. The possibility to differentiate between government's purchases of consumption and investment goods enable us to assess the relative importance of the different mechanisms of transmission of the fiscal policy. In particular, we are able to distinguish between the utility effects which arise from government's purchases and the effects on sectoral reallocation of employment and capital determined by the productive decisions by the public sector .

Government's fiscal policy responds to the stance of world's economy summarized by changes in oil prices. Consequently, a quantitative analysis of the response of fiscal policy decisions (in particular, government investments and employment) to exogenous oil fluctuations has to be employed. Thus, we will be

[11]Please notice that, since in our analysis we focus on innovation caused by shocks in exogenous oil revenues we abstract from the effects of the technical progress on the trend growth in the economy. Therefore, A_t is assumed constant and equal to one.

able to evaluate whether these components are positively or negatively related to the business cycle of oil producing countries.

The quantitative analysis considered in this paper necessarily requires the specification of the process followed by the exogenous variable Z_t. The stochastic processes for prices and production levels are combined into a single process which is described by the following formula:[12]

$$Z_t = (1 - \rho_Z)logZ + \rho_Z logZ_{t-1} + \epsilon_t \tag{2.10}$$

where $\rho_Z < 1$ and ϵ_t denotes shocks to Z_t. In other words, variable Z_t evolve according to AR(1) processes (autoregressive processes of order 1). Similarly, in order to introduce persistence in the investment decisions by the government[13] we assume that $X_t = (1 - \rho_X)logX + \rho_X logX_{t-1}$.

Finally, by combining the government budget constraint (2.9) with the household budget constraint (2.4), the following economy-wide constraint is obtained:

$$C_t + I_t + Z_t \leq Y_t \tag{2.11}$$

According to equations (2.9) and (2.11), consumption and investments by private and public agents and compensation for public employees by the public sector completely absorb the economy's resources.

[12]This assumption is similar to that adopted by [91] which considered for oil revenues the following process: $dx(t) = \mu_x x(t)dt + \sigma_x x(t)dz_x(t)$ where $dz_x(t)$ are increments of a standard Brownian motion process.

[13]See, for instance, [92].

2.2.2 The Ramsey equilibrium

The equilibrium of the economy is obtained when the representative firm and representative household solve their optimization problems, the public sector satisfies its budget constraint and all markets clear. The rational expectations equilibrium consists of the sequences of endogenous variables which satisfy the following set of first order equations and accounting identities:

$$W_t = \frac{\partial F^P(N_t^P,\ K_t^P)}{\partial N_t^P} = \frac{\partial F^G(N_t^G,\ K_t^G)}{\partial N_t^G} \tag{2.12}$$

$$R_t = \frac{\partial F^P(N_t^P,\ K_t^P)}{\partial K_t^P} \tag{2.13}$$

$$-\frac{\partial U(C_t,\ N_t)}{\partial N_t} = \frac{\partial U(C_t,\ N_t)}{\partial C_t} W_t \tag{2.14}$$

$$\frac{\partial U(C_t,\ N_t)}{\partial C_t} = \beta E_t \left[\frac{\partial U(C_{t+1},\ N_{t+1})}{\partial C_{t+1}} \left(R_{t+1} + 1 - \delta^P \right) \right] \tag{2.15}$$

$$N_t \equiv N_t^P + N_t^G \tag{2.16}$$

$$Y_t \equiv Y_t^P + Y_t^G \tag{2.17}$$

Equations (2.12) and (2.13) give the outcome of the maximizing behaviour by firms. According to these expressions, equilibrium is guaranteed when the marginal productivities of labour and capital equals their marginal costs. Equation (2.14) represents the household *intratemporal* efficiency condition governing its labour supply and investment. This equation tells us that the marginal rate of substitution between labour and consumption must be equal to the marginal product of labour. On the other hand, equation (2.15) establishes the *intertemporal* efficiency condition, that is the Euler equation first-order condition. At equilibrium, the marginal cost, in terms of utility, of investing in more capital should be equal to the expected marginal utility gain. Finally, equations (2.16) and (2.17) show that labour and output markets clear when the sum of private and public labour and production equals total supply.

Other conditions to be satisfied are given by the laws of motion for K^P and K^G (equations 2.6 and 2.8), production functions by the private and public sectors (equations 2.5 and 2.7), the government budget constraint (equation 2.9), the process representing the behavior of exogenous oil shocks (equation 2.10), and the economy-wide constraint (equation 2.11).

2.3 Solution of the model

2.3.1 Calibration

In this section the transmission mechanism of exogenous oil shocks to the economy's structure of producing countries is analyzed in detail. In order to examine the effects of exogenous oil shocks on our simplified economy, the effects of one positive percent shock to exogenous oil revenues on relevant variables are here examined and discussed. The model's cyclical implications are explorated by means of a quantitative analysis based on simulation and calibration of the economic model. For this purpose, equations which represent the competitive equilibrium of the economy have to be log-linearized around the nonstochastic steady state of the model.[14] The next step consists in solving the resulting system of linear difference equations. The details of the log-linear system are presented in the Appendix.

The calibration procedure proposed by [93] is adopted. According to this methodology, the values of model's parameters and steady state variables have to be chosen to fit information on oil producing countries. In the present study, values for preference parameters β, σ, ψ, θ, γ, δ^P and δ^G coincides with those used in previous quantitative studies (for instance, [94], [93] and [95]). Values of steady-state variables $\frac{C}{Y}$, $\frac{G}{Y}$, $\frac{I}{Y}$ and $\frac{X}{Y}$ (average shares of - private and public - consumption and investments on total output) and between government's and private employment and output ($\frac{N^G}{N^P}$ and $\frac{Y^G}{Y}$) are chosen to match the characteristics of a high number of oil exporting countries. At this purpose, data from widely recognized database (World Bank, World Development Indicators, 2008, [96] and International Monetary Fund, International Financial Statistics, 2010, [97]) are employed.

Consequently, impulse response functions of a one percent oil shock in period one are shown using $\rho_Z = 0.95$ for the autocorrelation of the shock process. All parameters and steady state values for the relevant variables used in the simulation exercise are reported in Table 2.1.

[INSERT TABLE 2.1 ABOUT HERE]

[14] In what follows, constant steady state values of relevant variables are denoted by employing symbols without the time subscript. On the other hand, lower-case letters with time subscript are used to denote logarithm deviations of variables from their steady state value.

The behaviour of relevant variables over 1000 samples of 200 observations[15] is simulated over quarterly data by using the system of linear equations presented in the Appendix (equations 2.22 to 2.36) At this purpose, the recursive method proposed by [98] and the Hodrick-Prescott technique are employed, respectively, to simulate the model and to filter the model's samples. The sample means and standard deviations of the statistics over the full set of data set generated are, thus, calculated and shown in Table 2.2.

2.3.2 Effects of exogenous oil shocks

In this Section, the impulse responses induced by an exogenous oil shock on relevant variables obtained by our model are examined. Figures 2.1 to 2.3 show the impulse response to a one percent change in oil revenues.

A positive innovation shock to oil revenues is shown to cause an increase in consumption goods expenditure by the government. As a result of the increase in oil revenues, both public employment and demand of capital by the government strongly increase. Higher production factors raise public output. In contrast, an oil shock is associated with decreases of private consumption. This latter effect can be explained by observing that a rise in government spending tends to crowde-out private demand for consumption goods (see [99], for further details on this mechanism)[16].

[15] In order to match the sample size often considered in macroeconometric time-series analysis.

[16] These authors argue that the crowding-out effects of consumption in response to a rise in government spending is due to the full-flexibility of prices and (or) the intertemporal optimization problem faced by households.

With regard to the impact of the shock on the labour market, while employment in the public sector increases, demand in the private sector falls significantly. In other words, the exogenous increase in external revenues received by the government induces a sectoral reallocation between the private and public sector. In particular, the oil shock causes a transfer of productive factors (labour and capital) from the private to the government sector. As the sensitivity exercise will show, the magnitude of reallocation is strongly related to the size of marginal productivity of factors in the two sectors. The diminishing marginal product of labour (or capital) in the public production function could limit the reallocation of factor across sector.

In other words, while an oil shock increases the role of the government in the economy, it reduces resources available to the private sector. This fact implies that the link between public employment and the marginal utility of consumption is not strong enough to compensate for the negative wealth effect due to the increase in government expenditure on private consumption.

In addition, as far as the effects of the oil shock on the private investments are concerned, it can be noticed that, because of the combined effect of consumption decreases and interest rates increases, total investments by the private sector fall significantly. Due to the strong slump of the process of accumulation of capital, private employment responds negatively to the oil shock. Private labour market dynamics over the business cycle are, in this case, mainly explained by the opposite effects of oil shocks on the supply of labour and its average productivity. The overall negative effect on private capital and employment induces a contraction in private output.

As demand for leisure increases, total employment decreases despite the positive effect of the oil shock on public employment. Consequently, since the negative effects on the private sector tends to outpace the positive impact that characterizes the public sector, higher oil revenues usually decreases total output. Therefore, the combined effects on public and private sectors prompts total output to fall significantly. In other words, under our assumptions, the components of government fiscal policy are countercyclical since they move in opposite direction with respect to the fluctuations of output generated by the exogenous oil shock.

[INSERT FIGURES 2.1 TO 2.3 ABOUT HERE]

2.3.3 Sensitivity analysis

In this section the sensitivities of the results to overall oil shocks on our economy to changes in key parameters with respect to those presented in Table 2.1 are explored. In particular, several simulation exercises are considered. In the first exercise, the importance of the size of private consumption is examined in order to assess the overall effects of oil shocks on our model economy. In the second exercise, different assumptions over the production function of Y^P are considered. In particular, parameter γ is assumed to take different values. Assumptions on the different role of oil resources in the economy and on the size of governments are also considered. Results are displayed by simulating our model under the assumption of different steady state values for $\frac{Z}{Y}$ and $\frac{N^P}{N}$.
Finally, the simulation exercise is repeated by modifying the model in order to evaluate how results changes as parameter ψ varies , that is, by considering different positive effects arising to households from different type of fiscal policy.

All the parameters employed for our sensitivity analysis are reported in Table 2.3.[17]

[INSERT TABLE 2.3 ABOUT HERE]

Figure 2.4 shows the impulse response functions of both the public and private sectors to a one percent oil shock by considering different assumptions on the characteristics of the economy. Simulation results are obtained by employing varying values for the ratios between consumption and private investments in steady state. In Figure 2.4, the black and blue lines correspond to the case of a ratio between private consumption and investments equal to five and four, respectively. Other scenarios involve a significantly higher investment levels by the representative agent. In case three (green line), the ratio between private consumption and investments ($\frac{C}{I}$) is assumed to equal three, whereas, under case four (red line), the ratio between consumption and investment is set to be equal to two.

Results suggest that private investments continue to be crowded-out by the expansion of government role in the economy induced by an exogenous oil shock. However, it can be observed that the negative effects of the oil shock on private investment decrease as the steady state value of the ratio between private investment and consumption increases.

The responses of both public employment and output seem not to be related to the percentage of private investments on the total size of the private sector in steady state. Viceversa, it is apparent from Figure 2.4 that, as the ratio C/I falls,

[17]For all the exercises presented in this section, the equilibrium we find is characterized by saddle path stability.

the negative impact on private consumption, employment and output decreases. The explanation behind this result is that the fiscal policy through a negative effect on private wealth may, under certain circumstances, causes expansions in employment (see case four). Under the assumption of a lower ratio between consumption and investment in steady state, numerical results suggest that an oil shock has initially a negative effect on total output and employment. However, as the contraction of private labour decreases, the effect on real interest rates becomes negative and private consumption starts increasing, the percentage change of total output and employment becomes positive.

[INSERT FIGURE 2.4 ABOUT HERE]

Figures 2.5 and 2.6 show how results vary if changes on the assumptions on the importance of oil resources and of the size public sector are made. Results from numerical simulations suggest that the negative effects on the private sector widen as the percentages of oil revenues on total output and the ratio of total public employment on total employment increase. Another interesting result is that the positive impact on public labour and output tends to be lower for the economies that in steady state are more dependent on oil revenues and for those in which the size of the government is bigger.

[INSERT FIGURES 2.5 AND 2.6 ABOUT HERE]

In Figure 2.7 impulse response functions of relevant variables to a one percent oil shock are examined by taking into account several assumptions on the characteristics of the production function. In particular, scenarios are constructed by considering various values of parameter γ. For public employment and output, Figure 2.7 shows that quite similar qualitative predictions are obtained by varying the assumptions of the model. In particular, according to all model specifications, a positive oil shock continues to have important negative effects on private wealth as well as consequences on the process of sectoral reallocation of production factors between the private and public sectors of the economy. As a result of these mechanisms of transmission of fluctuations to the oil revenues, significant decreases in private consumption and increases in compensation for public employees occur after a few quarters from the shock. However, the impact on these variables tends to be lower when production by the public sector becomes more capital-intensive. This result implies that the reduction in total output and employment following an oil shock is negatively correlated with parameter γ.

[INSERT FIGURE 2.7 ABOUT HERE]

How does the economy responds to a positive oil shocks if household's utility function is assumed to depend on government consumption? How do these responses depend on the values assumed by parameter ψ? [18] As we have seen from equation (2.2), the utility function parameter ψ represents the degree of substitutability between private and public consumption in the utility function of the representative agent.

Figure 2.8 displays the impact response of relevant variables for given values of this parameter. In particular, as ψ takes higher values, the negative wealth effect associated with the oil shock increases. On the one hand, the effect of the exogenous oil shocks on demand for private labour, consumption and output tends

[18] All results examined in Section 2.3.2 are obtained by considering a parameter ψ set equal to zero.

to be damped (see, for instance, case four). Under these assumptions, a positive oil shock results in a reduction in the size of the private sector and an increase of both public employment and labour.

On the contrary, as ψ decreases, the direct intervention by the government on the economy diminishes. As a consequence, the positive impact of the exogenous oil shock on public employment and output falls as well. Similarly, the negative effect on private investment decreases with parameter ψ. This fact implies that, in case of a relatively high preference rate for the public provided consumption good by the representative agents (case one) a mechanism similar to the Keynesian multiplier works. According to this mechanism, accumulation of private capital causes further expansions of employment and output.

[INSERT FIGURE 2.8 ABOUT HERE]

To summarize the main results we have obtained in this Section, a positive impact of the exogenous oil shock on the economic growth of oil exporting countries is guaranteed under certain assumptions on key parameters. In fact, our exercise of simulation suggests that, after an exogenous oil shock, countries which are characterized by higher levels of private investment in steady state tend to have higher rate of growth for both private and public sectors.

Moreover, our results do support the possibility to reduce the negative economic effects from an oil shock by reducing the direct (i.e. productive) intervention of government in the productive activities of the country. The negative effects increase proportionally with the importance of oil revenues and of the size of the public sector in the economy.

Finally, as the degree of substitutability between public and private consumption increases, the wealth and reallocation effects associated to a higher level of government consumption decrease. As a result, the negative effect of the oil shock on the economy also lessens out.

2.4 Concluding remarks

Exogenous oil shocks have been argued to negatively affect the economic stance of producing countries. The main thesis we present in this paper is that, in order to evaluate the impact on the economic performances of an oil producing country, a researcher must address the negative wealth effects and the reallocation process causes by the fiscal policy implemented by the government.

Through a simple economic model we have assessed that changes in the spending decisions by the government can imply a strong negative wealth effect on the private sector. Because of the shift of productive factors from the households and firms to the government sector, private consumption, employment and output can show strong negative changes after the shock. Under these assumptions, a crowding-out effect on private investment may also arise. In addition, since the negative effect on private output, employment and private investment due to from increases in government goods purchases is only in part compensated by the positive impact which derives from the employment policy by the government, positive fluctuations of oil revenues are associated with a decrease in total employment and output.

For several assumptions on key parameters and steady-state values of variables of interest, numerical simulations of the our theoretical model show results which are consistent with negative response of total employment and labour to exogenous oil shocks. However, results from sensitivity analysis suggest that positive effects on the economic growth of oil exporting countries are guaranteed under certain assumptions concerning the decisions on the fiscal policy implemented by governments. In particular, countries which are characterized by higher levels of private investment in steady state are able to receive significant economic benefits in terms of growth of both goods and labour market from an exogenous oil shock. Finally, if substitutability between government and private consumption is allowed for, the possibility of oil shock to negatively affect the business cycle of producing countries may be seriously reduced.

According to the overall results of our analysis, producing countries could be able to manage oil booms well by not allowing the public sector to increase significantly after the oil shock. The possibility to avoid wasteful and inefficient spending policy by the goverments of these countries could reduce the negative effects which arise from the exogenous increase in wealth.

This paper faces several questions with regard to the implementation of fiscal policy in oil exporting countries. However, our analysis could be enriched along several directions. In particular, future research could be aimed in formulating additional guidelines for government spending decisions which arise from the flow of oil revenues. In order for producing nations to reduce the negative effects arising from the high volatility and uncertainty of oil revenues, according to [81], the government should target the non-oil balance. The accumulation of financial wealth over the period of oil production could enable producing countries to face in a proper manner the challenges arising from oil shocks. The introduction of these aspects in a more complete theoretical framework represents an interesting topic for future studies.

Table 2.1: Parameter values and steady state variable

a) Parameter	
Preferences	$\beta = 0.99$
	$\sigma = 0.32$
	$\psi = 0.00$
	$\vartheta = 0.25$
	$\rho_X = 0.735$
Production	$\theta = 0.30$
	$\gamma = 0.30$
	$\delta_P = 0.025$
	$\delta_G = 0.010$
Exogenous oil revenues	$\rho_Z = 0.95$
b) Steady State Variables	
Private Sector	$Y = 1.00$
	$C/Y = 0.66$
	$I/Y = 0.17$
Government	$G/Y = 0.10$
	$(WN^P)/Y = 0.03$
	$X/Y = 0.04$
Oil Sector	$Z/Y = 0.17$
Market Clearing Condition	$N = 0.20$
	$N^P/N = 0.10$
	$Y^G/Y^P = 0.10$

Notes. This table shows the values of parameter values and steady state variables used in the simulation exercise.

Table 2.2: Results of the calibration exercise

Series	(a)	(b)
Private capital	0.11	0.42
Public capital	0.25	-0.42
Total output	0.08	1.00
Private output	0.13	0.86
Public output	0.27	-0.08
Consumption	0.15	1.00
Private investment	1.27	0.98
Public investment	7.09	-0.97
Government Consumption	2.91	1.00
Labour	0.12	1.00
Private labour	0.15	0.94
Public labour	0.28	0.02
Wages	0.03	0.88
Interest rate	0.07	-0.88
Oil revenues	0.93	-0.99

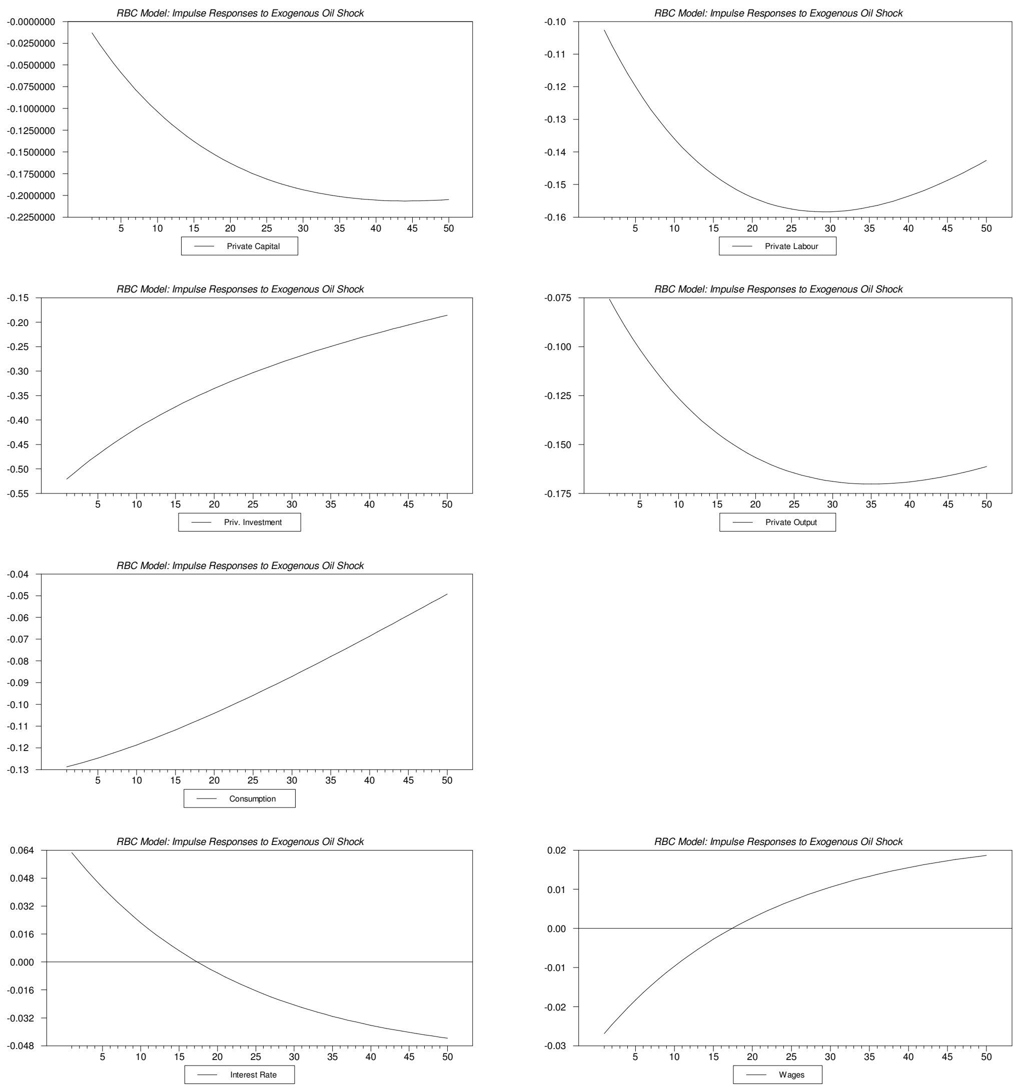
Notes. a) Standard deviations in percent.
b) Correlations with output.

Table 2.3: Sensitivity analysis: parameter and steady state values

a) Different size of the private sector*	
Case 1 (C1)	$C/I = 5$
Case 2 (C2)	$C/I = 4$
Case 3 (C3)	$C/I = 3$
Case 4 (C4)	$C/I = 2$
b) Different role of oil revenues in the economy	
Case 1 (C1)	$Z/Y = 0.10$
Case 2 (C2)	$Z/Y = 0.15$
Case 3 (C3)	$Z/Y = 0.20$
Case 4 (C4)	$Z/Y = 0.25$
c) Different structure of the economy	
Case 1 (C1)	$N^P/N = 0.80$
Case 2 (C2)	$N^P/N = 0.70$
Case 3 (C3)	$N^P/N = 0.60$
Case 4 (C4)	$N^P/N = 0.50$
d) Different assumptions over γ	
Case 1 (C1)	$\gamma = 0.3$
Case 2 (C2)	$\gamma = 0.5$
Case 3 (C3)	$\gamma = 0.7$
Case 4 (C4)	$\gamma = 0.9$
e) Government consumption expenditure in the households utility function	
Case 1 (C1)	$\psi = 0.40$
Case 2 (C2)	$\psi = 0.60$
Case 3 (C3)	$\psi = 0.80$
Case 4 (C4)	$\psi = 0.99$

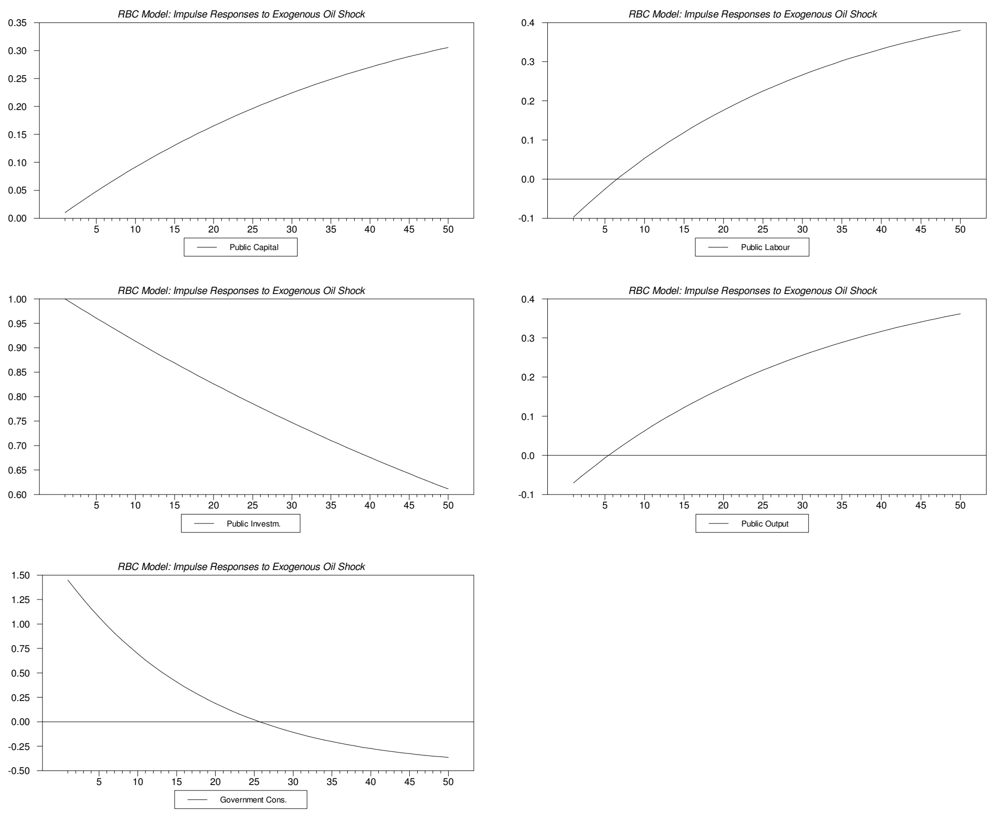
Notes. * In all cases considered, it is assumed that $(C + I)/Y = 0.90$.

Figure 2.1: The effect on the private sector



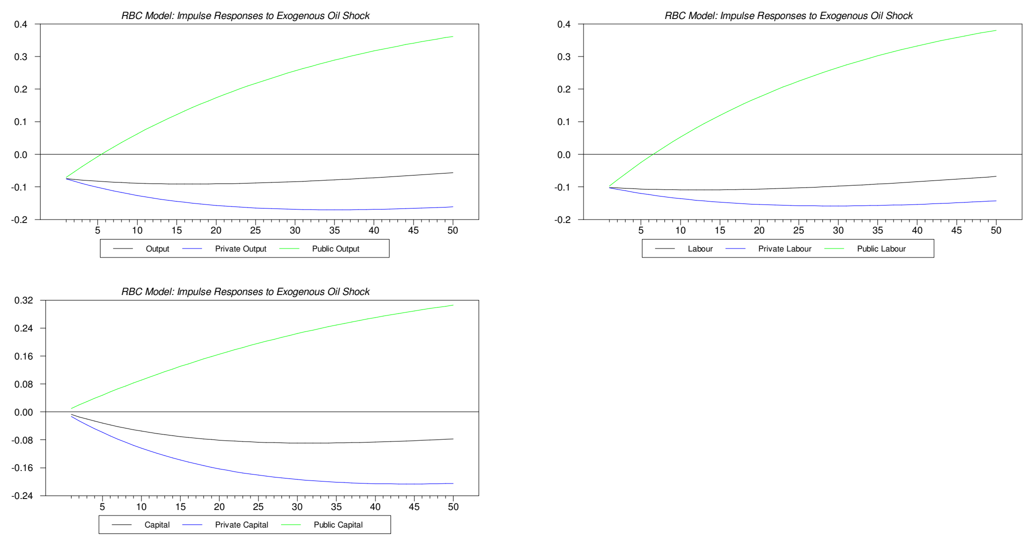
Notes. Figures show the percentage impulse responses of private sector variables to one per cent shock to oil revenues in period 1.

Figure 2.2: The effect on the public sector



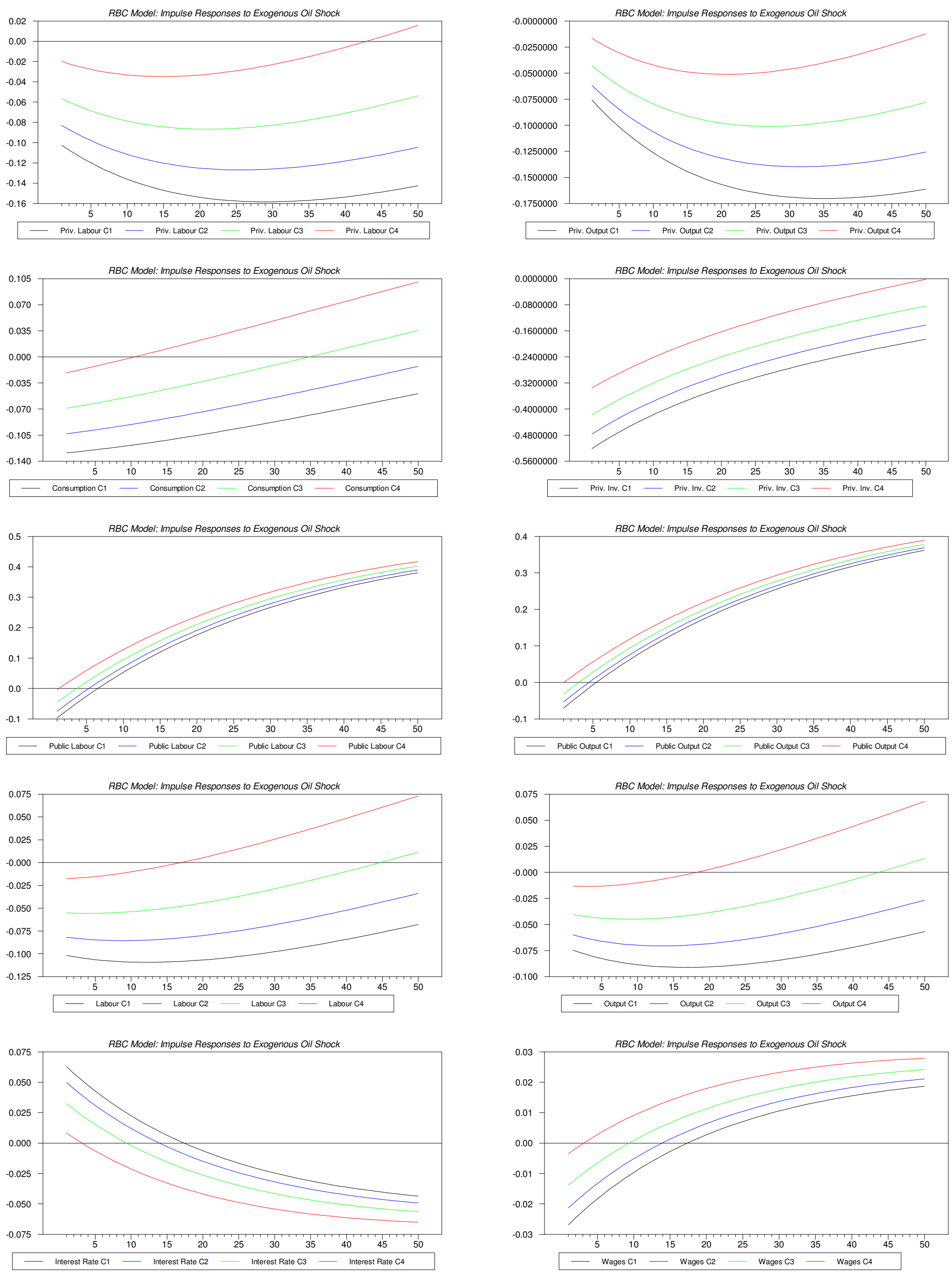
Notes. Figures show the percentage impulse responses of public sector variables to one per cent shock to oil revenues in period 1.

Figure 2.3: Reallocation effects of exogenous shocks on total output, employment and capital



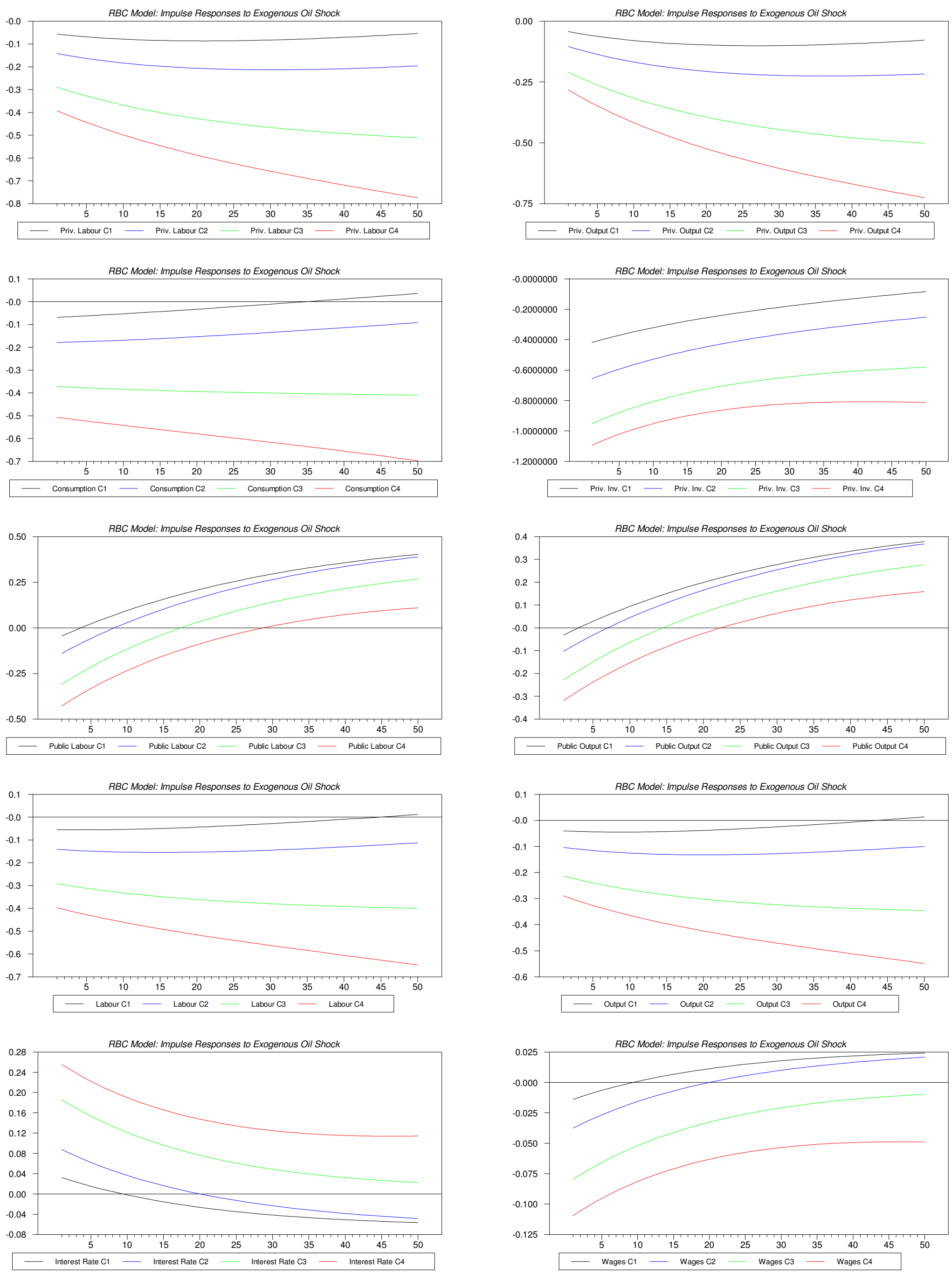
Notes. Figures show the percentage impulse responses of output, labour and capital to one per cent shock to oil revenues in period 1.

Figure 2.4: Does the composition of the private sector matter?



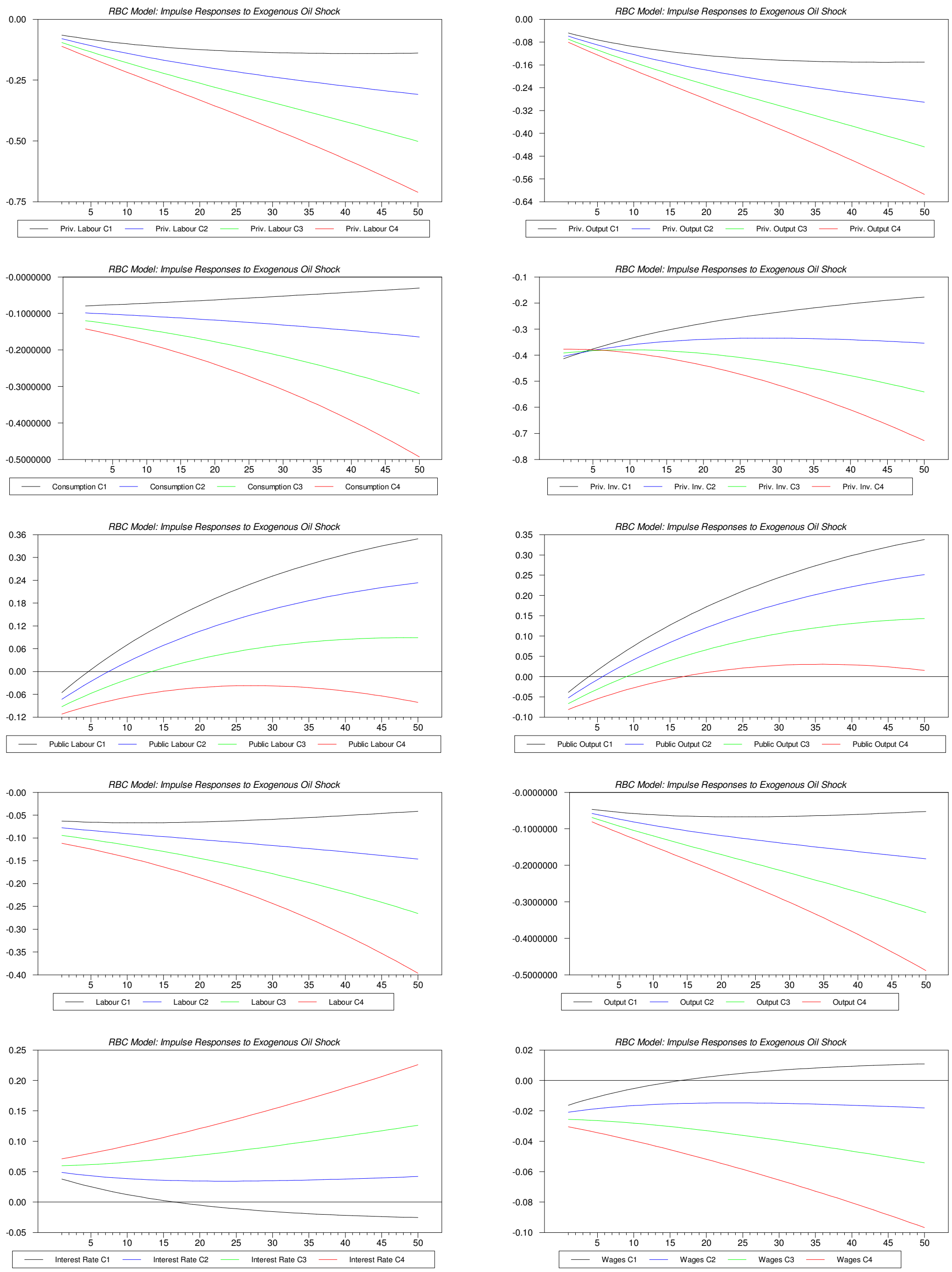
Notes. Figures show the percentage impulse responses to one per cent shock to oil revenues in period 1 under different assumptions on the C/I ratio.

Figure 2.5: Different role of oil revenues in the economy



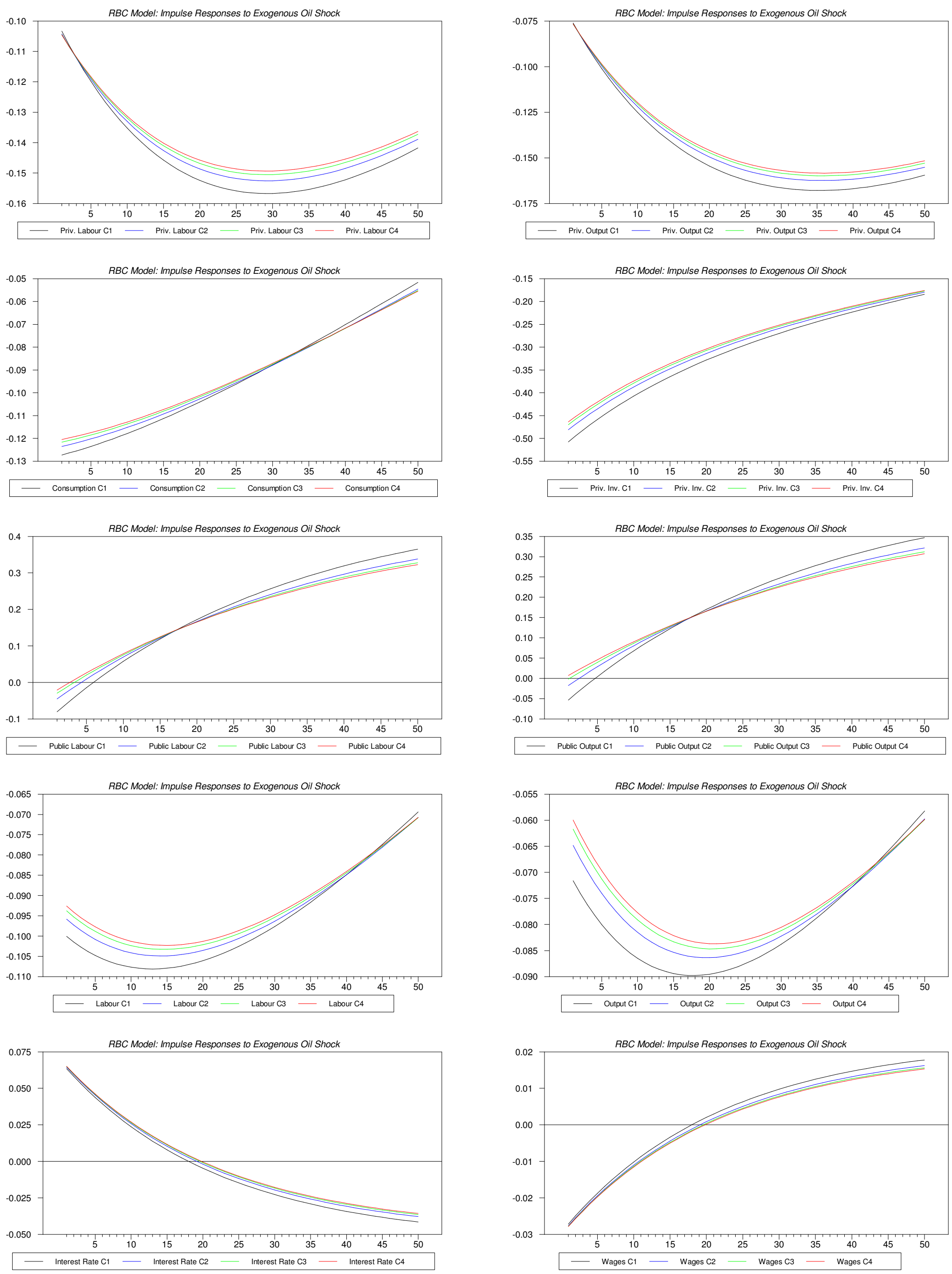
Notes. Figures show the percentage impulse responses to one per cent shock to oil revenues in period 1 under different assumptions on the ratio Z/Y.

Figure 2.6: Different size of public sector



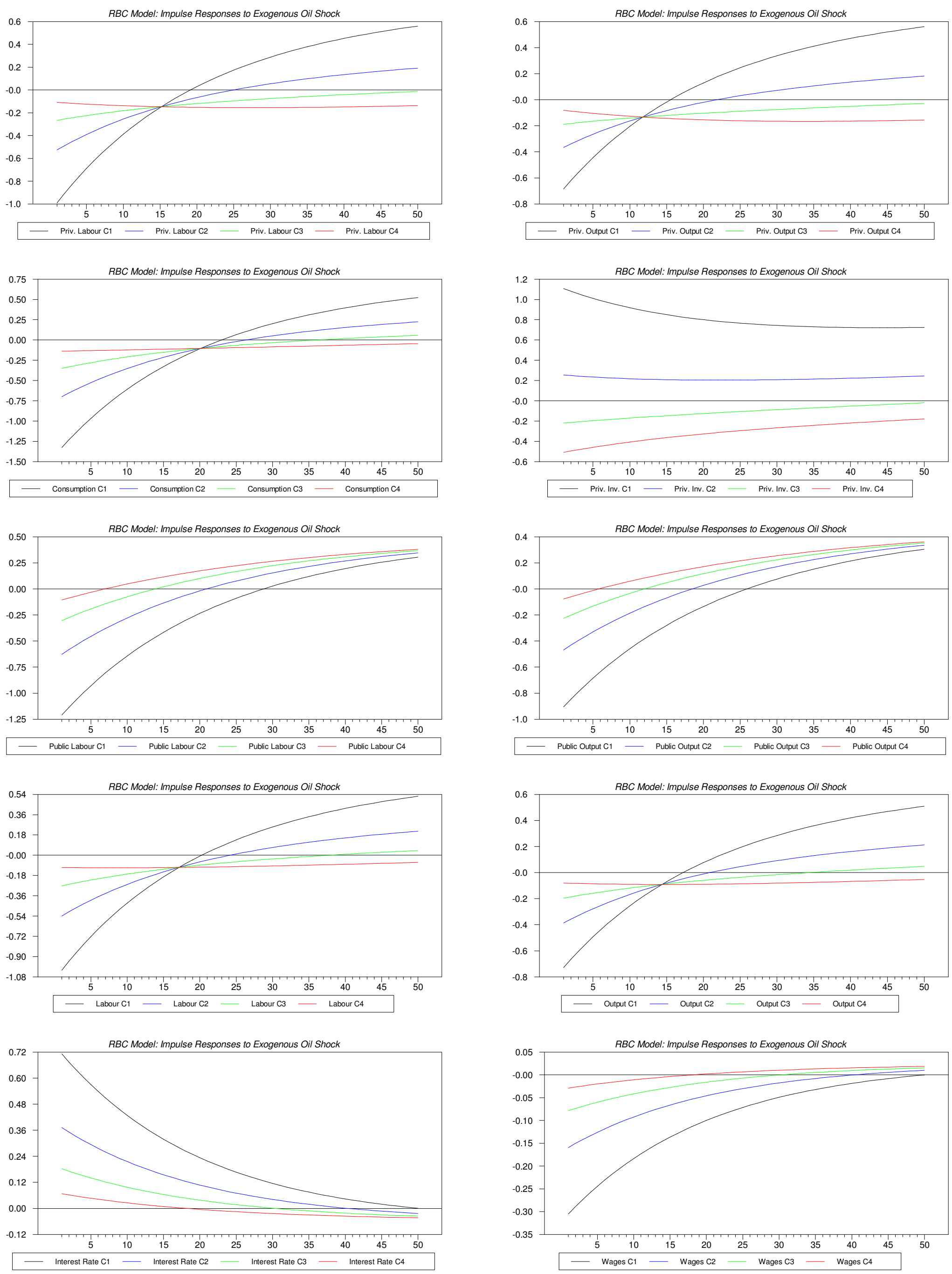
Notes. Figures show the percentage impulse responses to one per cent shock to oil revenues in period 1 under different assumptions on the ratio N^P/N.

Figure 2.7: Different assumptions over γ



Notes. Figures show the percentage impulse responses to one per cent shock to oil revenues in period 1 under different assumptions on parameter γ.

Figure 2.8: Case of government consumption which enters households' utility



Notes. Figures show the percentage impulse responses to one per cent shock to oil revenues in period 1 under different assumptions on parameter ψ.

Appendix to Chapter 2

A1. Equilibrium conditions

In this appendix we reproduce the optimization problem faced by the household and by the firms.

The household chooses sequences $\{C_t,\ N_t,\ K_{t+1}\}_{t=0}^{\infty}$ to maximize the intertemporal utility function (2.1) subject to the flow budget constraint (2.4) and to equation (2.3). Let us set the Lagrangian for the household maximization problem:

$$L_H = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{\left(C_t^{\psi} G_t^{1-\psi}\right)^{1-\sigma} L_t^{1+\vartheta}}{1-\sigma} + \lambda_t \left\{ W_t N_t + R_t K_t^P - C_t - \left[K_{t+1}^P - (1-\delta) K_t^P\right] \right\} \right\}$$

where λ_t is the Lagrange multiplier associated to equation (2.4).

The first-order conditions for an interior solution to the household's problem are represented by:

$$\frac{\partial L_H}{\partial C_t} : \psi C_t^{[\psi(1-\sigma)]-1} G_t^{(1-\psi)(1-\sigma)} (1-N_t)^{1+\vartheta} = \lambda_t \tag{2.18}$$

$$\frac{\partial L_H}{\partial N_t} : \frac{1}{1-\sigma} \left[C_t^{\psi} G_t^{1-\psi}\right]^{1-\sigma} (1+\vartheta)(1-N_t)^{\vartheta} = \lambda_t W_t \tag{2.19}$$

$$\frac{\partial L_H}{\partial K_{t+1}^P} : \lambda_t = \beta E_t \left[(R_{t+1} + 1 - \delta) \lambda_{t+1}\right]$$

$$\frac{\partial L_H}{\partial \lambda} : K_{t+1}^P = Y^d - C_t + (1-\delta) K_t^P = 0$$

or, if we consider, equation (2.6):

$$\frac{\partial L_H}{\partial \lambda} : I_t = Y^d - C_t$$

where $Y^d = W_t N_t + R_t K_t^P$.

Other conditions to consider are given by equations (2.3), (2.6) and by the transversality condition $lim_{t\to\infty} \lambda_t K_{t+1}^P = 0$.

By combining equations (2.18) and (2.19) we get:

$$\frac{1}{1-\sigma}\left[C_t^{\psi} G_t^{1-\psi}\right]^{1-\sigma}(1+\vartheta)(1-N_t)^{\vartheta} = W_t \psi C_t^{[\psi(1-\sigma)]-1} G_t^{(1-\psi)(1-\sigma)}(1-N_t)^{1+\vartheta}$$

or

$$\frac{1+\vartheta}{(1-\sigma)\psi}\cdot\frac{C_t}{1-N_t} = W_t \tag{2.20}$$

On the other hand, the Euler equation first order condition can be written as:

$$\psi C_t^{[\psi(1-\sigma)]-1} G_t^{(1-\psi)(1-\sigma)}(1-N_t)^{1+\vartheta} =$$
$$\beta E_t\left[\left(R_{t+1}+1-\delta\right)\psi C_{t+1}^{[\psi(1-\sigma)]-1} G_{t+1}^{(1-\psi)(1-\sigma)}(1-N_{t+1})^{1+\vartheta}\right] \tag{2.21}$$

Equations (2.20) and (2.21) represent, respectively, the *intratemporal* and *intertemporal* equilibrium conditions for the households.

As far as the decisions on production levels faced by firms and the government, behaviour aimed at profit maximization implies that the marginal product of each factor has to be set equal to its user cost. Hence, equilibrium conditions for the firm are represented by:

$$\frac{\partial Y_t^P}{\partial N_t^P} : A_t(1-\theta)\left(\frac{K_t^P}{N_t^P}\right)^{\theta} = W_t$$

$$\frac{\partial Y_t^P}{\partial K_t^P} : A_t\theta\left(\frac{K_t^P}{N_t^P}\right)^{1-\theta} = R_t$$

or, if we consider equation (2.5):

$$W_t = (1-\theta)\left(\frac{Y_t^P}{N_t^P}\right)$$

$$R_t = \theta \left(\frac{Y_t^P}{K_t^P} \right)$$

Similarly, with regard to the productive decisions on public output by the government we have:

$$\frac{\partial Y_t^G}{\partial N_t^G} : A_t(1-\gamma) \left(\frac{K_t^G}{N_t^G} \right)^{\gamma} = W_t$$

A2. Log-linearization of the economic model

Since we have a set of both linear and nonlinear equations, in order to solve for the system we need to approximate it by a corresponding set of linear equations. Consequently, the following steps have to be followed. First, we need to solve for the nonstochastic steady state. In that case, since no trend growth in exogenous variable is assumed, all variables take constant values. This implies the absence of uncertainty. In addition, in our representation of the economy variables tend to fluctuate around the values given by this path. Second, we have to log-linearize all the equations. According to our model and employing the specification for the momentary utility function of the household given by equation (2.2), the economy is well approximated by the following system of linear equations:

- equilibrium conditions for wages:

$$w_t = \theta \left(n_t^P - k_t^P \right) \tag{2.22}$$

$$w_t = \gamma \left(n_t^G - k_t^G \right) \tag{2.23}$$

- equilibrium condition for interest rates:

$$r_t = (\theta - 1) \left(n_t^P - k_t^P \right) \tag{2.24}$$

- intratemporal constraint for the households:

$$w_t = c_t - n_t \tag{2.25}$$

- intertemporal constraint for the households:

$$\{[\psi(1-\sigma)] - 1\} c_t + [(1-\psi)(1-\sigma)] g_t + (1+\vartheta) n_t = \tag{2.26}$$

$$E_t [\{[\psi(1-\sigma)] - 1\} c_{t+1} + [(1-\psi)(1-\sigma)] g_{t+1} + (1+\vartheta) n_{t+1} + \mu \cdot r_{t+1}]$$

where $\mu = 1 - \beta(1-\delta^P)$.

- production function of the private-sector firms:

$$y_t^P = \theta k_t^P + (1-\theta) n_t^P \tag{2.27}$$

- production function of the government:

$$y_t^G = \gamma k_t^G + (1-\gamma) n_t^G \tag{2.28}$$

- law of motion for private and public capital:

$$k_t^P = \delta^P i_t + (1-\delta^P) k_{t-1}^P \tag{2.29}$$

$$k_t^G = \delta^G x_t + (1-\delta^G) k_{t-1}^G \tag{2.30}$$

- the aggregate resource constraint:

$$y_t = \frac{C}{Y} c_t + \frac{I}{Y} i_t + \frac{Z}{Y} z_t \tag{2.31}$$

- market-clearing condition for total output:

$$y_t = \frac{Y^P}{Y} y_t^P + \frac{Y^G}{Y} y_t^G \tag{2.32}$$

- labour market-clearing condition:

$$n_t = \frac{N^P}{N} n_t^P + \frac{N^G}{N} n_t^G \tag{2.33}$$

- government budget constraint:

$$z_t = \frac{G}{Z} g_t + \frac{X}{Z} x_t + \frac{WN^G}{Z} (n_t + w_t) \tag{2.34}$$

- evolution of other variables (Z_t and X_t):

$$z_t = \rho_z z_{t-1} + \epsilon_{t-1} \tag{2.35}$$

$$x_t = \rho_x x_{t-1} \tag{2.36}$$

Chapter 3

How Oil Production Responds to World Oil Demand and Price Changes: Theoretical and Empirical Evidence.

In this paper, decisions behind production levels for oil exporting countries are studied by means of both theoretical and empirical models. Under the assumptions of exogenous oil prices and world oil demand, we are able to describe how decisions on oil production levels vary according to changes of conditions on the world oil market. We argue that an important factor which is able to affect these decisions is represented by the cost structure of oil producing countries.
Results from the simulation of our theoretical model suggest that oil production changes are strongly correlated with changes in world oil demand and real oil price changes. However, although producing countries show a significant rela-

tionship between their output levels and total demand, the effect of oil prices on oil production decisions seems to be much lower.

By means of econometric analysis based on cointegration techniques, different responses to world oil demand and real oil prices seem to characterize decisions of relevant oil producting countries. As far as the responses to changes in total demand are concerned, production adjusts with few lags to increases in consumption. On the contrary, responses by oil production levels to innovations in real oil prices are argued to be much lower. In addition, when asymmetric econometric are introduced, evidence of nonlinear effects of output levels to shocks in demand levels and oil prices is found.

Finally, according to our theoretical framework, an upward sloping Kaplan-Meier hazard function is valid for oil producers' decisions on output levels. This result is confirmed when an empirical model is applied to time-series representing oil production levels.

3.1 Introduction

Developments in the world oil market have been studied in various fields of economics. In many articles, the structure of the world oil market as well as the determinants of oil production decisions are considered and examined by means of both empirical and theoretical models. From a microeconomic point of view, the world oil market is said to be dominated by a cartel of oil producers (OPEC, Organization of Petroleum Exporting Countries, see, *inter alia*, [100]).[1]

[1] Nevertheless, [101] and [102] reject the assumption that OPEC represents a "dominant producer". According to the empirical analysis of [101], in particular, the structure of the Organization of producing countries is said to be dominated by Saudi Arabia who is argued to act like a

This organization is able to affect prices by restricting or expanding its output through a system of quotas assigned to each of Organization's member countries. On the other hand, there is a set of producing countries which represent the "competitive fringe" of the market[2].

Oil production changes related to developments in international markets since the foundation in 1960 of the Organization of Petroleum Exporting countries are examined in [105] and [106]. [105] argue 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 other hand, OPEC countries saw their production levels increase. A likely explanation of this evidence lies in the fact that these countries were facing rising extraction costs.

Similarly, after the first oil shock, despite the quadrupling of oil prices (1974-1978), production by non-OPEC countries have remained stable. Viceversa, since 1976, oil production in these countries have 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 production to increase by about 6 percent between 1976 and 1983.

Differently from [105], [106] examines the role of national oil companies in world oil markets. According to his analysis, rising world oil demand and higher prices are among the main factors responsible for the increase of oil production of many oil companies since 2003.

In order to assess the responsiveness of oil production to demand and prices,

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"swing producer" (see [103]).

[2]For an analysis of the stability of collusive behavior in the presence of producers which take the price as given by the Organization of producing countries see, for instance, [104].

other authors propose to consider the importance of investment's decision. For instance, [107] argue that huge oil price increases often lead to investments in oil exploration.[3] As a consequence, investments decisions implemented in the previous years are argued to be one of the main determinant of current oil production.

Oil production is also modelled by several authors in order to test various assumptions on the structure of the world oil market. For instance, [108] considered different models for OPEC countries (a) the competitive model; b) the cartel model; c) the target revenue model and d) the property rights model) using data on oil production for the 1983-1988 period.

The possibility to test the model introduced by Griffin has recently been examined by, among others, [109], [110] and [111]. In [109], in particular, a supply function is estimated using data from 1973 to 1997. The aim of his study is to determine 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.

[112] consider a computational general equilibrium model with the aim of evaluating the effects of shocks to crude oil demand and supply on prices and production levels for Saudi Arabia. As far as the responses of production of producing countries to the global economy are concerned , [112] suggests that OPEC countries with the notable exception of Saudi Arabia tend to adjust output levels to changes in the stance of world economy. On the contrary, because of the high

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

share of capital input in the production function of this country, output levels show a low degree of correlation with demand shocks. Nevertheless, output levels responds differently to increases and decreases of world oil demand. In fact, in the case of a negative demand shock, production levels are reduced rapidly in order to sustain prices. On the contrary, following a positive innovation on the demand side, production levels tend not to be expanded accordingly.

Simulations of theoretical models suggest a low responsiveness of oil production to changes in world oil demand and prices also for non-OPEC countries. In particular, according to [113][4] between 1999 and 2020 oil production increases are projected to be only half as much of changes in world oil demand.

In [115] the domestic oil sector of a small oil producer like Egypt is modelled by means of a dynamic computer 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 this country, the oil sector often operates near full capacity.

Finally, in [116] the effects of geological, economic and political factors on total oil supply in the United States are examined. Econometric techniques are employed to model extraction levels for the lower 48 states. Results suggest that, because of high costs associated to the extraction of oil, negative oil price shocks affect negatively production levels.

Our analysis focuses on the countries which, because of their size or that of their oil reserves, are characterized by production levels which are not able to affect prices. That is, these actors of the world oil market are assumed to take prices as exogenously given. This assumption is explicitly considered by [117] which

[4] See also [114].

describe how decisions on optimal production levels vary when different assumptions on marginal extraction costs are made. In other words, although oil production is important for the economy of these countries, it is not able to affect international oil prices. Our study aims, in particular, at examining the behavior of these countries under assumptions regarding the stance of world oil markets. One of our purposes is to establish how production levels respond to changes in world oil demand and prices.

Although previous research has already considered the determinants of decisions on oil production levels (see, for instance, the article by [109]), relatively few studies have examined the rigidity of these decisions to changes in the stance of world oil markets. This paper aims, in particular, at filling the gap in our understanding of the relationship between oil production levels, international oil prices and world oil demand. At this purpose, results from both a theoretical model and an empirical analysis are presented. The implications of our results with regard to the effects on the overall structure of the markets are also discussed.[5]

In this paper, a simple theoretical model is designed in order to describe the behaviour over oil production levels for a representative small producing country. Results from numerical simulation of our theoretical model suggest that production levels tend to adjust rapidly to changes in the stance of world oil market. These decisions are likely to depend on the cost structure of these oil producers. In addition, different responses to changes in world oil demand and real oil

[5]Our analysis also differs from the study by Ramcharran because of the empirical methodology adopted. While [109] focuses on a simple supply function specified as $\ln Q_t = \alpha + \gamma \ln P_t$ estimated by using annual observations, we employ monthly data and, thus, more appropriate AutoRegressive Distributed Lag or Error Correction Models.

prices are argued to characterize the decisions on production levels. On the one hand, decisions on output levels by several producing countries are proved to depend significantly from increases in world oil demand. On the contrary, on the basis of simulation exercises, we can argue that the response of oil producing countries to changes in real oil prices is lower. Finally, an upward sloping Kaplan-Meier hazard function is argued to well describe oil production decisions for many countries.

Empirical models are, hence, employed to describe data regarding oil production levels for a significant sample of oil producing countries. The implications of our theoretical model are consequently directly tested. In particular, the statistical relationship which characterizes oil production, world oil demand and real oil prices is examined by means of standard time-series econometric techniques.[6] As a first step of the analysis, the order of integration of these variables is tested. Following Engle and Granger ([119]) both the long-run and short-run relationships existing between the series are estimated. According to the results obtained we are able to confirm different responses to variations in world oil demand and prices. While the effect of world oil demand changes on oil production levels is statistical significant, the hypothesis of no effects from oil price changes to oil output can not 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.

The paper is organized as follows. In Section 3.2, our theoretical model is presented. In Subsection 3.2.1 the main assumptions of the the our framework are

[6] Previously, [100] and [118] have employed cointegration and causality tests in order to test the assumption of output coordination between OPEC member countries. At this regard, our paper is different from these works.

presented. The procedure directed at calibrating and simulating the model in order to match actual data for oil producers is given in Subsection 3.2.2. Results of how oil production levels reacts to changes in world oil demand and oil prices are examined in Subsection 3.2.3. In Section 3.3 econometric techniques are introduced to evaluate the relationship between output levels, total demand and real oil prices. In particular, in Subsection 3.3.1 data regarding oil production for a significant set of producing countries are presented. Subsection 3.3.2 describes the empirical framework employed to test the relationships existing between oil production, total demand and real oil prices. Econometric results are examined and discussed in Subsection 3.2.3. Section 3.4 presents our concluding remarks.

3.2 The Theoretical Model

3.2.1 The Model

Consider the production decisions of an oil exporting country. Producers are assumed to behave as price takers. In other words, we consider a partial equilibrium model in which producers set output levels by ignoring other producers' levels (that is, decisions by single producers are not correlated). They are "small" producers in the sense that they are not able to affect price levels. Our assumption is that, while OPEC strategy is able to affect equilibrium conditions on world oil markets,[7] these oil exporting countries adjust their production to

[7] According to [110], because of decisions over production quotas and capacity utilization, OPEC is able to affect market prices.

changes in world oil demand and oil prices.[8, 9]

Single-period profits are given by:

$$\Pi_t = q_t \left(P_t - c_t \right)$$

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

In that follows, we will assume that unit costs are given by:

$$c_t = \gamma \left(\frac{q_t}{D_t} \right)^{\theta} \tag{3.1}$$

where D_t denotes world oil demand; hence, $\frac{q_t}{D_t}$ denotes relative oil production (i.e. the share of demand satisfied by the production of the oil company).[10] γ is a scale parameter. Equation 3.1 embodies the fact that production costs and the level of reserves are related through an inverse relationship.[11]. The ratio of production over total demand is considered on the basis of the assumption that producers monitor their market share. According to equation (3.1) marginal costs are an increasing function of oil production. We are assuming that, because of finite reserves, as production levels of previous years increase and oil becomes

[8]This assumption has previously been considered by, among others, [120], [117], [115]and [114]. In particular, [115] argue that for an exporting country, like Egypt, "oil prices are clearly significant exogenous".

[9]Notice also that, in non-OPEC countries, oil is often extracted by a set of international oil companies.

[10]For the purposes of this analysis, the terms "oil company" and "(small) oil producers" are used interchangeably.

[11]See [121] for an analysis of this assumptions.

more difficult to extract, unit costs increases.

Consequently, given exogenous oil prices, profits can be expressed as follows:

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

Since production is not fully flexible, we assume that, in order to change production, oil company's costs increase by a factor ψ. This implies that, according to changes in world oil demand from D_t to $\widehat{D_t}$, optimal production levels change from q_t to $\widehat{q_t}$. As a consequence, relative profits will be given by:

$$\widehat{\Pi}_t = \frac{\widehat{q_t}}{\widehat{D_t}}\left(P_t - \gamma\left(\frac{\widehat{q_t}}{\widehat{D_t}}\right)^{\theta}\right) - \psi\gamma I_t \tag{3.2}$$

We will assume that the natural logarithm of oil prices evolves according to a random walk:

$$logP_t = logP_{t-1} + \epsilon_t$$

where ϵ_t is distributed according to a $N(0, \sigma_\epsilon^2)$ process. On the other hand, the process for world oil demand (expressed in natural logarithms) is given by:

$$\Delta logD_t = \mu + \eta_t$$

where $\Delta logD_t = logD_t - logD_{t-1}$ and η_t is distributed according to a $N(0, \sigma_\eta^2)$ process. In other words, the series is stationary around a trend.[12]

[12] These results are confirmed by simple regression analysis. Moreover, data strongly reject the possibility to introduce the series denoting the world oil demand as an additional explanatory variable of oil prices. Similarly, in a regression of oil demand the coefficient of oil prices is not statistically different from zero.

3.2.2 Solution of the Model

The theoretical model described in Section 3.2.1 is simulated for the actual evolution of oil production values over the 1980-2009 period. In doing that, we have to choose values to assign to the parameters of the model (that is, β, θ, ψ, μ, γ, σ_ϵ^2 and , σ_η^2). The yearly discount factor is assumed to be equal to $\beta = 0.96$.

From simple regression analysis based on Energy Information Administration data, 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, we assign to σ_ϵ^2 a parameter value of 0.0923.

Finally, values for parameters θ, ψ and γ are chosen to match data for relevant crude oil producers. In fact, the oil market is characterized by countries which are characterized by varying extraction costs due to different values for oil proven reserves, differences in feature of oil reservoirs etc.

This implies that in the world oil market there is an heterogenous set of countries. While, in response to demand and supply conditions, countries that have low extraction costs tend to rapidly adjust production levels, producers characterized by 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 function $V\left(\frac{q}{D},\ P\right)$ and policy function $\left\{\left(\frac{q}{D}\right)',\ P'\right\} = h(\left\{\frac{q}{D},\ P\right\})$ after taking a random draw from the distribution of ϵ and η each period.

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. 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:

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

the state space for P is given by:

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

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.[13]

In Figures 3.1 and 3.2 the profit function is depicted together the value and policy functions of our oil producer.

[INSERT FIGURES 3.1 AND 3.2 ABOUT HERE]

As it can be seen in Figure 3.1, 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 change or not its production once conditions in the world oil market have changed. As Figure 3.2 shows, the particular pattern of the policy function depends on the fact that, if oil producers decide to change their output levels, profits do not change linearly (see equation (3.2)).

[13] Values 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.

3.2.3 Results

The properties of the simulated policy function are employed in order to investigate how oil production decisions are related to changes in demand and price levels in the international oil markets. As a consequence, interesting properties on the behaviour of oil production decisions can be studied. In particular, the correlation of effective production with demand and prices and the rigidity of decisions on extraction levels are examined in the next Subsection. A Kaplan-Meier plot of hazard function is, hence, computed on simulated data and curves representing the probability of increasing production in a given time interval are plotted.

As far as the frequency of production changes is concerned, the percentage of production increases and decreases are here examined together with the average size of production changes. Tables 3.1 to 3.3 show how results vary as assumptions on key parameters (θ, ψ and γ) are changed.

[INSERT TABLES 3.1 TO 3.3 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, production becomes more rigid, that is, the frequency of decisions on production levels decreases.

Tables 3.1 to 3.3 show that a similar relationship exists between the percentage of production increases and the values assumed by the different parameters. In particular, as values of key parameters increase, the fraction of upward adjustment increases as well.

On the contrary, the cost structure that characterizes oil producing countries does not seem to affect the average size of production changes.

A higher percentage of output increases with respect to production decreases suggests that asymmetric effects probably affect oil production decisions.[14, 15] Since the possibility to change output levels is characterized by some rigidity, production adjusts almost instantaneously to increases in world oil demand. On the contrary, numerical simulations suggest that, in case of decreases in demand, oil producing countries tend to reduce production more slowly.

Results on the correlation between production changes and world demand are shown in Table 3.4 whereas the relationship between output levels and oil prices is reported in Table 3.5.

[INSERT TABLES 3.4 AND 3.5 AND FIGURES 3.3 ABOUT HERE]

Statistics obtained by considering different values assigned to parameters θ, ψ and γ suggest that 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 Figure 3.3. On the contrary, oil producing countries do not change significantly output levels as a response to oil price shocks.

By employing simulated data, the following supply function are estimated and

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

[15] This assumption is tested by means of an empirical model in Section 3.3.

results shown in Tables 3.6 and 3.7:[16]

$$lnq_t = \beta_0 + \beta_1 lnD_t + \beta_2 lnP_t + \epsilon_t \tag{3.3}$$

and

$$\Delta lnq_t = \beta_0 + \beta_1 \Delta lnD_t + \beta_2 \Delta lnP_t + \epsilon_t \tag{3.4}$$

where q_t denotes the total production at time t, D_t and P_t are total world oil demand and the real price of oil, respectively. All variables are represented by simulated data. β_i ($i = 0,\ 1,\ 2$) represent the parameters to estimate while ϵ_t denote the error term of the regression. According to equation (3.4) all variables are expressed in log first differences. This would allow us to obtain additional evidence on the importance of the economic determinants of oil production levels.

Even in this case different assumptions on parameters ψ, γ and θ are employed to generate patterns that can be used to describe output levels for different oil producers.

[INSERT TABLES 3.6 AND 3.7 ABOUT HERE]

Results reported in Tables 3.6 and 3.7 suggest that the elasticity of production levels to world oil demand is positive and statistically significant if both equations in levels and in first-differences are considered. Viceversa, the relationship between oil production and oil prices is argued to be much lower. Coefficients obtained by estimating equation (3.5) are significantly different from zero in six

[16] These equations are simply an extension of the models employed by Griffin to test several assumptions on the structure of the world oil market ([108]).

out of nine cases. Nevertheless, when the log-differences of the series are considered, in no case there exists an impact of oil prices on production levels.

Finally, 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.[17] Figure 3.4 depicts the probability of adjustments in production levels as a consequence of changes in conditions on the oil market.

[INSERT FIGURE 3.4 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 adjusted according to changes in world oil demand tends to be affected by parameters representing the relative cost of extraction of oil. In other words, the response of oil producing countries shocks depends on 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.

[17]Let D be a random variable that denotes the duration of a production increase. The hazard of the decision by oil producers to increase output is given by $\lambda(t) = P\left(D = t | D \geq t\right)$.

3.3 An Empirical Analysis of Oil Production

3.3.1 Introduction

The data on oil production levels employed in our analysis are taken from the Energy Information Administration dataset.[18]. Information on the period of time considered for each country are given in Table 3.8. The countries we focus in the present study are represented by relevant non-OPEC oil producers. Although oil production is important for the economy of these countries, changes in their production levels are not able to affect significantly oil prices in international markets. For these countries, adjustments in production levels are often difficult to implement and involves significant investments by foreign companies.

Data on oil production levels are reported also for many OPEC countries, the Organization of Petroleum Exporting Countries.[19] Decisions on output levels for these producers are often motivated by other factors. In fact, OPEC is able to restrict production to take advantage of its market share and determine important

[18] In our analysis, we employ data for the following 19 countries: Algeria, Angola, Ecuador, Iran, Kuwait, Libya, Nigeria, Saudi Arabia, Venezuela, Brazil, Canada, Colombia, Egypt, Indonesia, Malysia, Mexico, Norway, Russia and the United States.

[19] Because of data availability, our dataset does not include oil production levels for Iraq, Qatar and United Arab Emirates.

increases in oil prices.[20, 21]

[INSERT TABLE 3.8 ABOUT HERE]

Simple descriptive statistics on the size of oil production for these countries are shown in Tables 3.9 and 3.10. In Table 3.9 statistics are computed for the levels of the series[22] whereas in Table 3.10, the statistics above are shown for the log first-difference of the variables.[23] 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.[24] The relationship between oil production for the countries considered in this study has been examined. Results from statistical analysis confirm that the degree of correlation of pro-

[20]Nevertheless, a problem OPEC often has to face is related to the cheating behaviour of some members. They often try to benefit of higher prices in order to augment their profits. As a consequnece, issues about the stability of the cartel often arise (see, for instance, [122]) and [109]).

[21]Supply function for OPEC member countries are estimated in order to allow us to compare the responses by these producers to demand and price shocks with those by actors which are assumed to behave indipendently.

[22]Oil production data are expressed in thousand barrels per day.

[23]The first difference of the variable y_t is expressed as Δlny_t, where $\Delta lny_t = lny_t - lny_{t-1}$.

[24]Oil prices in national currencies are obtained by using the exchange rate of the US dollar for each country. Real oil price levels are thus calculated by deflating the oil prices measured in national currencies. At this purpose, the inflation indicator of each of the countries is employed.

duction levels of non-OPEC countries is particularly low and rarely statistically significant.[25]

[INSERT TABLES 3.9 AND 3.10 ABOUT HERE]

Table 3.9 and 3.10 show that production levels of OPEC countries have on average a higher correlation with world oil demand. This result may be due to higher oil reserves and lower extraction costs. Production levels of Algeria are the most correlated with demand whereas correlation of oil output levels from Angola and Ecuador show lower levels of correlation. As far as non-OPEC countries are concerned, results suggest a high correlation between production levels and oil demand for the United States, Norway and Russia. Correlation between production and oil prices tends to be particularly low for all countries considered in the present study.

[25]Statistics are not reported to save space but are available upon request.

3.3.2 The Empirical Analysis

In this Section we focus on the economic determinants of decisions on production levels by oil producing countries. It is worth mentioning that our analysis does not aim at giving a full description of factors that may affect decisions on output levels by producing countries. Although 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.)[26] are able to influence oil production, we have decided to concentrate on the effects that changes in world oil demand and prices have on output levels. In other words, our purpose is to answer to this simple question: how do oil production levels respond to changes in the stance of world oil markets? The empirical methodology examined in the present study is based upon standard 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.

1. The order of integration of oil production and real oil prices is consided.[27]

    (a) if both series are stationary (that is, they are both $I(0)$) the following

[26]Since the aim of this paper is not to study the structure of the world oil market, we do not consider as a determinant of decisions on output levels by OPEC countries the production levels of other countries. The possibility to extend our analysis in order to include this assumption is left as a topic for future research.

[27]Results from unit root tests suggest that world oil demand is not stationary ($I(1)$).

equation is estimated:

$$\text{(3.5)} \quad lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j \Delta lnD_{t-j} + \sum_{s=0}^{n} \vartheta_s lnP_{i,t-s} + \epsilon_t$$

where q_{it} is total production for country i at time t, D_t and $P_{i,t}$ are total world oil demand and the real price of oil, respectively. β_k $(i = 0,\ 1, \ldots,\ n)$, γ_j $(j = 0,\ 1, \ldots,\ n)$ and ϑ_s $(s = 0,\ 1, \ldots,\ n)$ represent the parameters to estimate while ϵ_t denotes the error term of the regression. All variables considered are in natural logarithms.

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

$$\text{(3.6)} \quad lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j \Delta lnD_{t-j} + \sum_{s=0}^{n} \vartheta_s \Delta lnP_{i,t-s} + \epsilon_t$$

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

$$\text{(3.7)} \quad \Delta lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k \Delta lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j \Delta lnD_{t-j} + \sum_{s=0}^{n} \vartheta_s lnP_{i,t-s} + \epsilon_t$$

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

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

$$\text{(3.8)} \qquad lnq_{it} = a_0 + a_1 lnD_t + a_2 lnP_t + \nu_t$$

where a_i $(i = 0,\ 1,\ 2)$ and $\nu_t$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 these coefficients. This equation represents the long-run equilibrium relationship between oil production, world oil demand and oil prices. If the long-run disequilibrium between world oil production, world oil production and prices (ν_t) follows a stationary process, it can be said that the three series are cointegrated. According to the results on the stationary of of ν_t one of the following two results has to be considered.

(a) If series are not cointegrated (that is, the relationship representing the long run equilibrium between the series is no stationary) the following AutoRegressive Distributed Lag model ($ARDL(n)$) of order n has to be estimated:

$$\Delta lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k \Delta lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j \Delta lnD_{t-j} + \sum_{s=0}^{n} \vartheta_s \Delta lnP_{i,t-s} + \epsilon_t \tag{3.9}$$

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

(3.10)
$$\Delta lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k \Delta lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j \Delta lnD_{t-j} + \sum_{s=0}^{n} \vartheta_s \Delta lnP_{i,t-s} + \theta ECT_{t-1} + \epsilon_t$$

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

Finally, tests are introduced to examine the hypothesis of asymmetric effects of increases and decreases of world oil demand and real oil prices on oil production levels. In fact, for instance, [111] suggest that, among the OPEC countries, short-run effects of price changes on production tend to be asymmetric.[28] The modified versions of equations (3.6) to (3.10) employed in order to test the assumption of asymmetric effects are given in Table 3.11.

[INSERT TABLE 3.11 ABOUT HERE]

In this Table, Δlny^{+}_{t-j} and $\Delta lny^{(-)}_{t-j}$ denote, respectively, increases and decreases of variable y_{t-j} ($j = 1,\ 2, \ldots, n$) where $y_t = \{D_t, P_{i,t}\}$ whereas $ECT^{(+)}_{t-1}$ ($ECT^{(-)}_{t-1}$) indicates the positive (negative) component of the error correction term.

3.3.3 The Results

Data for total world oil demand and oil prices are taken from the EIA and International Financial Statistics (International Monetary Fund, IFS, IMF) databases, respectively. The IFS dataset provides us also with the economic data for the nineteen countries examined in this study. The equation chosen between the five alternative specifications is estimated over monthly data. The sample size considered for each country is given in Table 3.8.

Results obtained from unit-root tests for relevant variables considered in the present study are reported in Tables 3.12 to 3.13. The problem of testing the null hypothesis of non-stationarity versus stationary is solved by employing Augmented Dickey Fuller tests (see [123]). The following equation is, thus, estimated:

$$\Delta \ln y_t = \alpha + \alpha_1 \cdot trend + \alpha_2 lny_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln y_{t-i} + \epsilon_t \tag{3.11}$$

[28] According to these authors, for instance, in Saudi Arabia "price reductions lower production faster than price increases raise production".

where y_t and ϵ_t are the variable being tested and the residual, respectively. The test is implemented by determining the t-statistic of $\widehat{\alpha_2}$ and comparing the value of this statistic with critical values computed by [124]. [29]

[INSERT TABLES 3.12 AND 3.13 ABOUT HERE]

Results suggest that, in general, oil production is a variable integrated of order one ($I(1)$). Nevertheless, production levels of Nigeria, Venezuela, Brazil, Canada and the United States seem to be stationary around a trend. With the relevant exception of Angola, tests of unit-root implemented on variables representing real oil prices suggest that these variables are not stationary.

Tables 3.14 shows the results obtained from the estimation of the long-run relationship between oil production, world oil demand and real oil prices. In Table 3.15 results of tests implemented in order to test the stationarity of the residuals of the long-run relationship are presented. At this purpose, critical values for the ADF tests are based upon [127].

[INSERT TABLES 3.14 AND 3.15 ABOUT HERE]

Stationary tests implemented on the residuals of long-run relationship suggest that, only for Malaysia there is a cointegrating relationship between oil production, world oil demand and oil prices.

Equations representing the short-run dynamics of oil production decisions are

[29] If the trend is not significant, equation 3.11 is re-estimated without trend ($\alpha_1 \equiv 0$). Following [125], 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 [126]).

estimated for relevant oil producing countries and results shown in Tables 3.16 to 3.18.[30, 31] Table 3.19 shows the statistical significance of the overall impact of world oil demand and prices on total output. In particular, 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).[32, 33]

[INSERT TABLES 3.16 TO 3.19 ABOUT HERE]

Estimation of equation (3.5) to (3.10 yields important insights as far as the relationship between production decisions and developments in world oil market is concerned. Many countries display a significant relationship between their production levels and world oil demand. This is particularly true for OPEC member countries like Iran, Kuwait and Saudi Arabia. On the contrary for Angola, Ecuador, Libya and Venezuela coefficients associated to world oil demand are not statistically different from zero. This relationship is confirmed for many

[30] These tables report coefficients estimates with standard errors. Statistics which describe the goodness of fit of regressions are also reported.

[31] Following [128] inter alia, the optimal lag-length of ARDL and EC Models is selected on the basis of the Akaike Information Criterion and all models checked for misspecification. All these results are available from the author upon request.

[32] According to these tests, the null hypotheses $H_0 : \gamma_1 = \gamma_2 = \ldots = \gamma_n = 0$ and $H_0 : \vartheta_1 = \vartheta_2 = \ldots = \vartheta_n = 0$ are, respectively, considered in order to evaluate the joint significance of parameters on world oil demand and real oil prices.

[33] This information is reported only when the relationship between the two variables is statistically relevant.

non-OPEC countries. In particular, a strong positive relationship between oil production and world oil demand exists for Norway and the United States. An explanation for this evidence lies in the fact that, in presence of economic growth and, consequently, increases in national demand for oil, these countries have incentive to extract more oil from their oil fields. Finally, according to Tables 3.16 and 3.17 (and, often, because of a lack of flexibility) oil production tend to adjust not instantaneously but after a certain lag.

On the contrary, the effect of oil prices on oil production decisions seems to be much lower. Many OPEC countries are characterized by an elasticity to price changes not statistically different from zero. Noticeable exceptions are represented by Kuwait and Saudi Arabia. In these countries, in fact, oil production tend to increase in presence of positive oil price shocks. A likely explanation is that, these oil producers are likely to increase production in an attempt to reduce pressures of growth in oil demand on prices.[34] However, if non-OPEC countries are considered, only in Russia oil production tend to change in the presence of real oil price shocks.

In Tables 3.20 to3.22 results of statistical evidence aimed at testing the assumption of asymmetric effects of world oil demand and oil prices on output levels are reported.

[INSERT TABLES 3.20 TO 3.22 ABOUT HERE]

According to the results, nonlinear responses of total output to changes in oil demand are valid for Algeria, Russia and Venezuela. For these countries, production responses are more rapid in the presence of increases in total oil demand.

[34]Remember that these countries are characterized by higher levels of spare capacity.

On the contrary, when total oil demand declines, oil production levels either do not change or increase. For Saudi Arabia, Kuwait, Iran and Norway, responses of national output are stronger in the presence of increases in demand levels. However, the hypothesis of symmetric effects to demand changes cannot be rejected at any significance level.

With regard to the effects of real oil price increases and decreases, the most straighforward evidence that results from Table 3.21 is that, for the United States, production increases in response to both price increases and declines. Moreover, Table 3.20 shows that for Malaysia the estimation of Error Correction Models allows us to argue that there exist nonlinear responses of oil production levels to disequilibrium in the supply function as represented by the long-run relationship (3.8).

Finally, the Kaplan-Meier hazard function is determined by employing actual data for both OPEC and non-OPEC countries. According to the results shown in Figure 3.5 a similar pattern of the hazard probability characterizes many oil producing countries.

[INSERT FIGURE 3.5 ABOUT HERE]

The probability of an increase of output levels after they have remained stable for a long period is argued to be particularly high for all producing countries. After it reaches its maximum at the second month, it begins decreasing. Results support the relatively rapid adjustment of production to factors affecting the external environment.

3.4 Concluding Remarks

According to the economic theory, the world oil market can be said to be dominated by a cartel of oil producers (OPEC, Organization of Petroleum Exporting Countries) while a set of non-OPEC producing countries represent the "competitive fringe" of the market (see, *inter alia*, [104]).

Our analysis focuses on the decisions on production levels faced by these latter countries. Because of the size of their oil reserves, these actors of the world oil market are characterized by relatively low production levels. In addition, they are assumed to take prices as exogenously given. In other words, output levels for these producing countries are too low to affect oil prices on international markets.

This paper aims at studying the behavior of these countries under assumptions regarding the stance of world oil markets. In particular, it aims at establishing how oil production levels react to changes in world oil demand and prices. Although previous research has already considered the determinants of decisions on oil production levels, relatively few studies have examined the elasticity of these decisions to changes in the stance of world oil markets. 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 and empirical models are designed to describe the decisions on production levels of these actors of world oil market. The implications of our results with regard to the effects on the overall structure of the markets are, hence, discussed.

According to the calibration and simulation of our theoretical model, decisions on output levels by oil producers are argued to depend on their cost structure. Results from numerical simulation of the model suggest that production levels respond rapidly to changes in the stance of world oil market. In addition, different responses to changes in world oil demand and real oil prices characterize the decisions on production levels. In other words, on the one hand, decisions on output levels by several exporting countries are significantly affected by changes in world oil demand. On the contrary, the behaviour of simulated series suggests that the responses of oil exporting countries to changes in real oil prices are less important. Finally, an upward sloping Kaplan-Meier hazard function is introduced to describe oil production decisions for many countries.

Empirical models based on standard time-series econometric techniques are introduced to describe data regarding output levels for a significant sample of oil producers. Results from the estimation of ARDL (AutoRegresssive Distributive Lag) and EC (Error Correction) models suggest that production levels tend to adjust significantly to changes in world oil demand. On the contrary, statistical tests do not allow us to reject the hypothesis of no effects from oil price changes to oil production levels. This latter result underlines the possibility that adjustments of production levels is constrained by the fact that, in many small oil producing countries, the oil sector is characterized by low levels of spare capacity. As a consequence, production responds to oil price changes only with a certain lag.

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. Nonlinear responses of total output to changes in oil demand for Algeria, Russia and Venezuela suggest that, in these countries, production levels responds more rapidly to increases with respect to decrease of total oil demand. As an interesting avenue for future research the theoretical model considered in this paper can be extended in order to describe the behavior of the Organization of exporting countries. In particular, decisions on production levels and changes in world oil demand could be modelled by introducing the possibility that decisions on production quotas may affect prices in the world oil market.

Figure 3.1: Profit Function of an Oil Producing Country

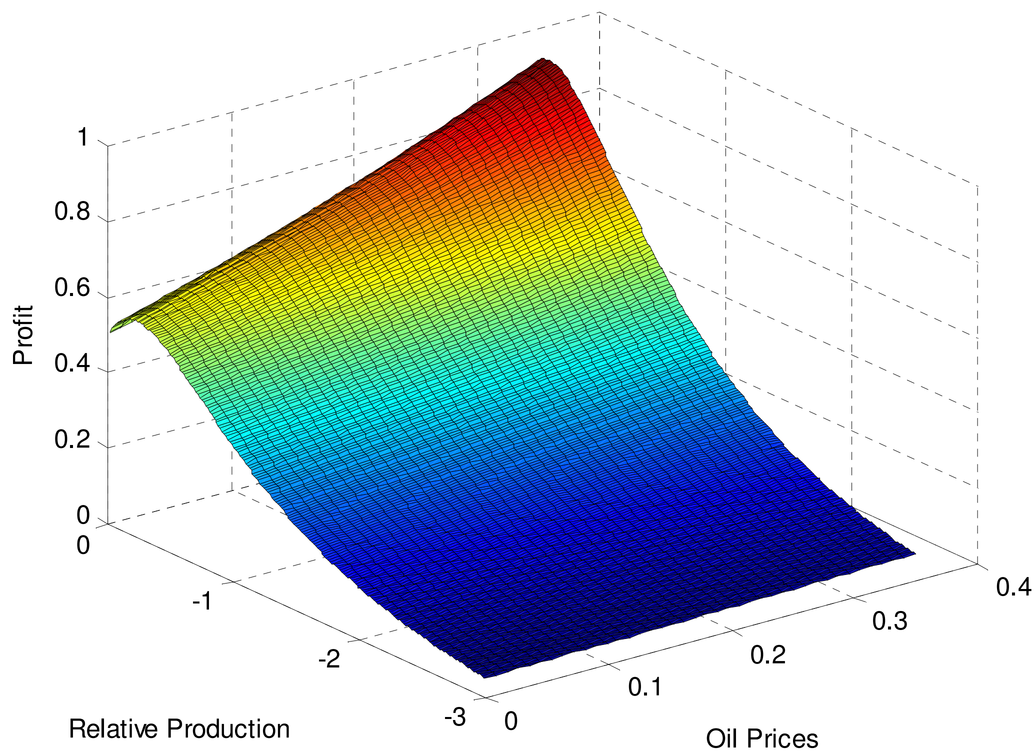


Figure 3.2: Value and Policy Function

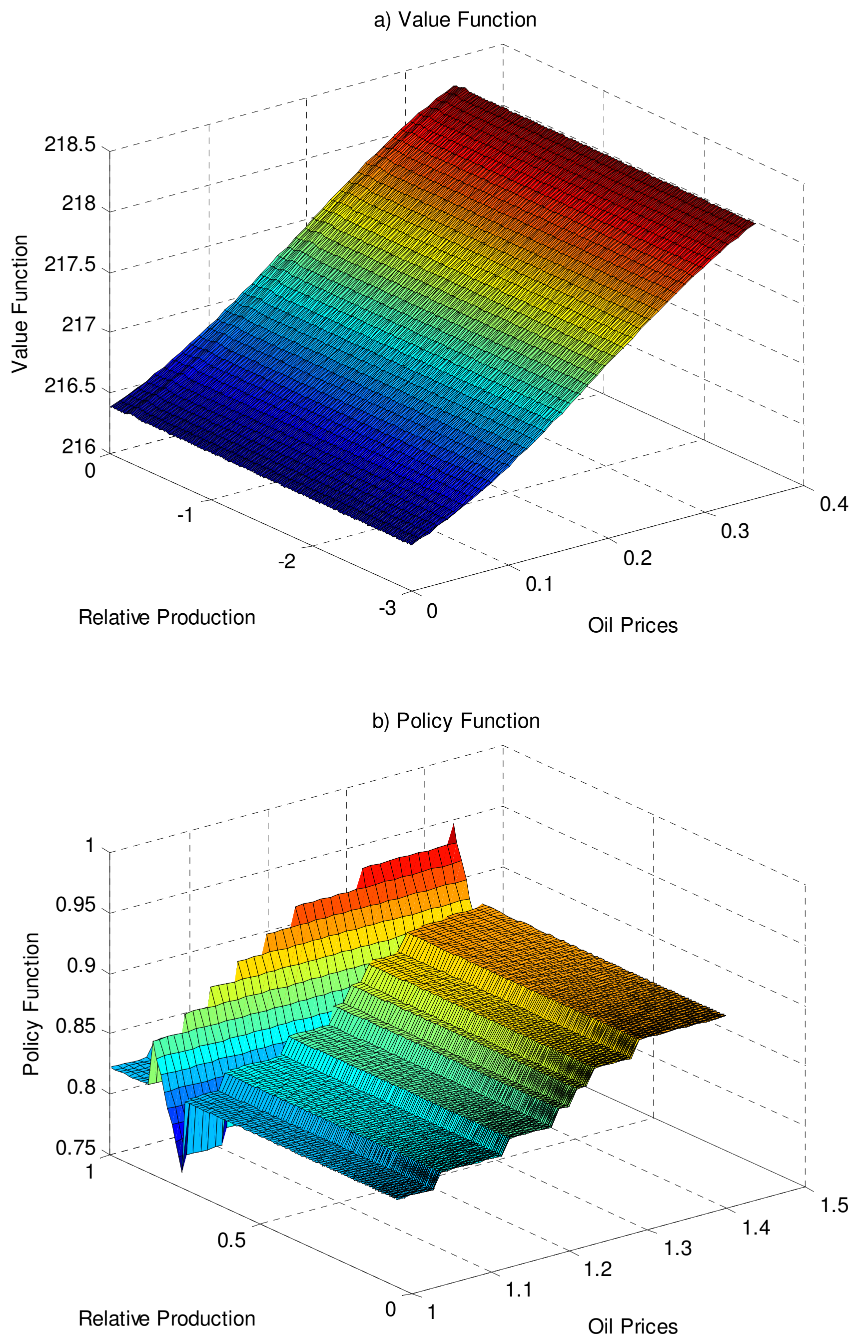


Figure 3.3: Responses of Oil Production to Changes in the World Oil Market

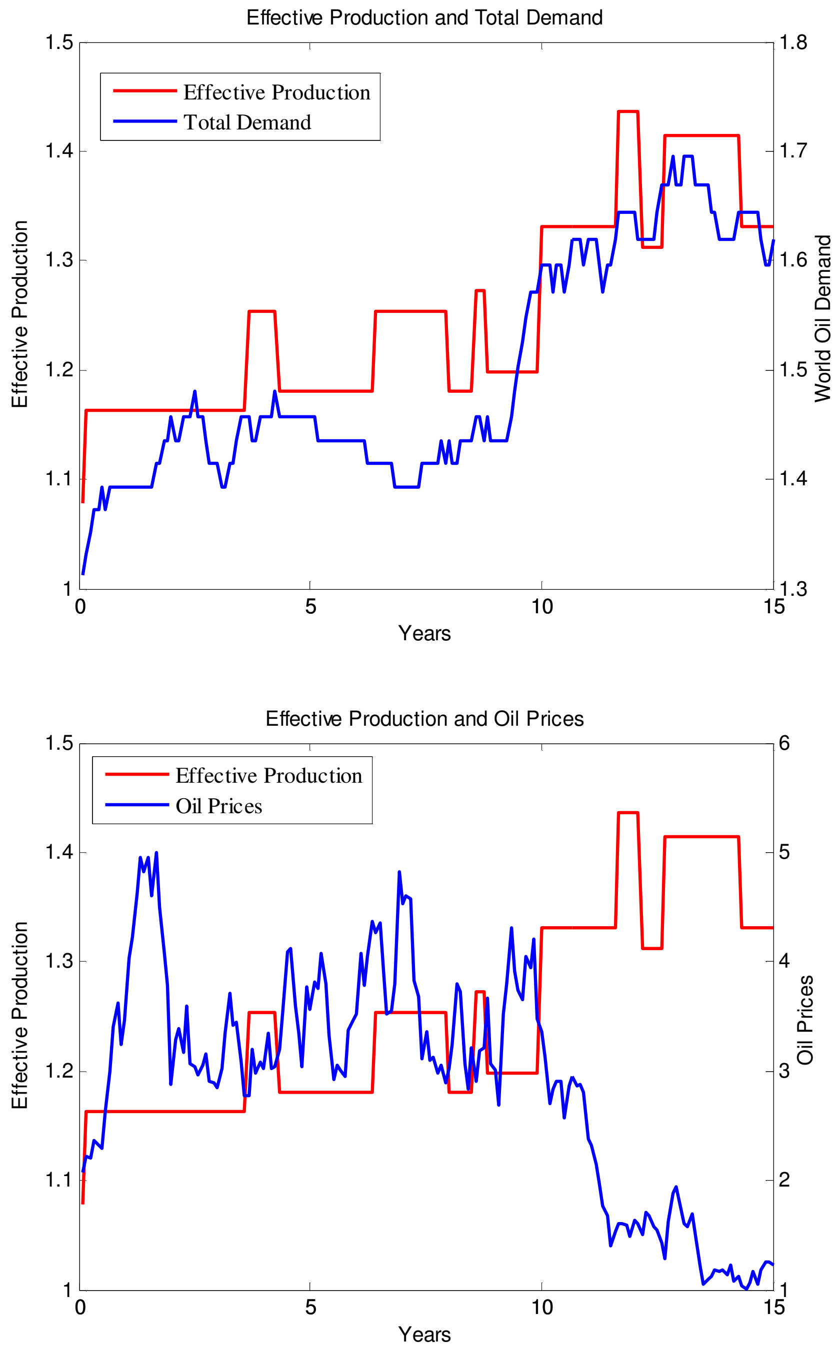


Figure 3.4: Hazard function of Oil Production Changes (Simulated Data)

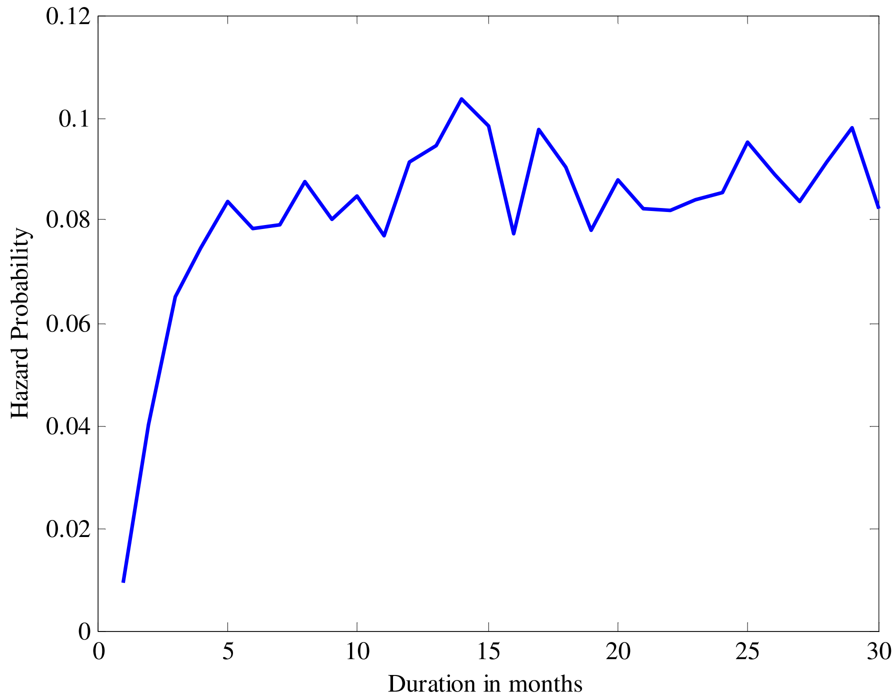
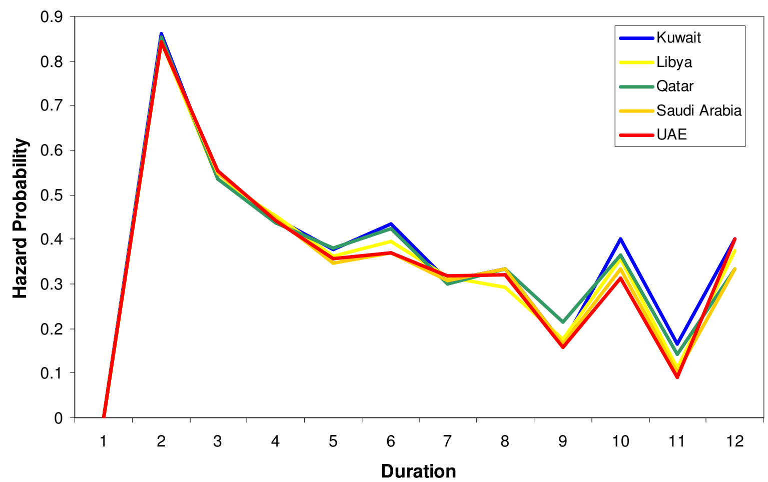


Figure 3.5: Hazard function of Oil Production Changes (estimation)

a) Selected OPEC countries



a) Selected Non-OPEC countries

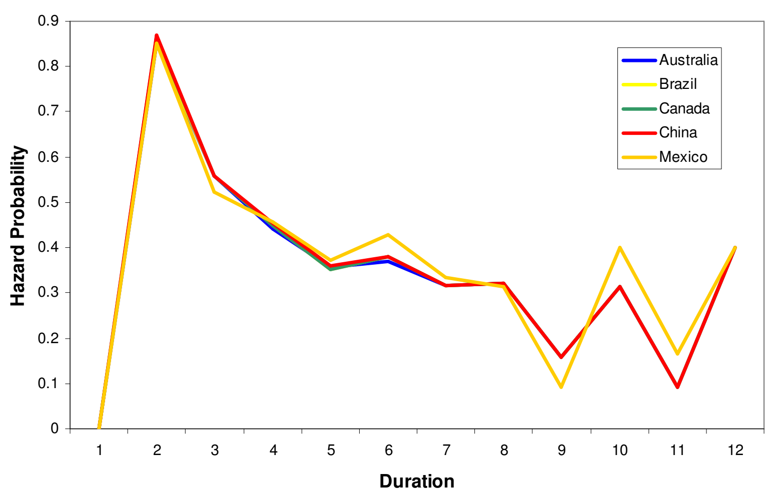


Table 3.1: Simulation results. Statistics on oil production changes. Changes in θ.

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

Table 3.2: Simulation results. Statistics on oil production changes. Changes in 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

Table 3.3: Simulation results. Statistics on oil production changes. Changes in 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

Table 3.4: Correlation between production levels and world oil demand. Simulation data.

θ	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 3.5: Correlation between production levels and oil prices. Simulation data.

θ	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 3.6: Statistical relationship between production levels, world oil demand and oil prices. Simulated data - Levels.

	Demand			Prices		
θ	Coeff	St. Error		Coeff	St.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	St. Error		Coeff	St.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	St. Error		Coeff	St.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	*

Table 3.7: Statistical relationship between production levels, world oil demand and oil prices. Simulated data - First Differences.

	Demand			Prices	
θ	Coeff	St. Error		Coeff	St.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	St. Error		Coeff	St.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	St. Error		Coeff	St.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

Table 3.8: Countries considered in the empirical analysis

Country	Start Date	End Date	N. Observations
Algeria	January 1994	January 2010	193
Angola	November 1995	January 2010	171
Ecuador	January 1994	January 2010	193
Iran	January 1994	January 2010	193
Kuwait	January 1994	February 2009	182
Libya	January 2001	November 2009	107
Nigeria	January 1994	October 2009	190
Saudi Arabia	January 1994	January 2010	193
Venezuela	January 1994	January 2010	193
Brazil	January 1996	January 2010	169
Canada	January 1994	January 2010	193
Colombia	January 1994	January 2010	193
Egypt	January 1994	January 2009	186
Indonesia	January 1994	January 2010	193
Malaysia	January 1994	January 2010	193
Mexico	January 1994	January 2010	193
Norway	January 1994	January 2010	193
Russia	June 1995	January 2010	176
U.S.	January 1994	January 2010	193

Table 3.9: Descriptive Statistics of Oil Producing Countries. Levels.

					Correlation with:	
Country	Mean	St. Dev.	Skewness	Kurtosis	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 3.10: Descriptive Statistics of Oil Producing Countries. First differences.

					Correlation with:	
Country	Mean	St. Dev.	Skewness	Kurtosis	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 3.11: Models employed in order to test asymmetric effects of world oil demand and real oil prices on oil production levels.

Model	Symmetric Effects
1b	$lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j \Delta lnD_{t-j} + \sum_{s=0}^{n} \vartheta_s \Delta lnP_{i,t-s} + \epsilon_t$
1c	$\Delta lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k \Delta lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j \Delta lnD_{t-j} + \sum_{s=0}^{n} \vartheta_s lnP_{i,t-s} + \epsilon_t$
2a	$\Delta lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k \Delta lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j \Delta lnD_{t-j} + \sum_{s=0}^{n} \vartheta_s \Delta lnP_{i,t-s} + \epsilon_t$
2b	$\Delta lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k \Delta lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j \Delta lnD_{t-j} + \sum_{s=0}^{n} \vartheta_s \Delta lnP_{i,t-s} +$ $+\theta ECT_{t-1} + \epsilon_t$
Model	**Asymmetric Effects**
1b	$lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j^{(+)} \Delta lnD_{t-j}^{(+)} + \sum_{s=0}^{n} \vartheta_s^{(+)} \Delta lnP_{i,t-s}^{(+)} +$ $+ \sum_{j=0}^{n} \gamma_j^{(-)} \Delta lnD_{t-j}^{(-)} + \sum_{s=0}^{n} \vartheta_s^{(-)} \Delta lnP_{i,t-s}^{(-)} + \epsilon_t$
1c	$\Delta lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k \Delta lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j^{(+)} \Delta lnD_{t-j}^{(+)} + \sum_{s=0}^{n} \vartheta_s lnP_{i,t-s} +$ $+ \sum_{j=0}^{n} \gamma_j^{(-)} \Delta lnD_{t-j}^{(-)} + \epsilon_t$
2a	$\Delta lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k \Delta lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j^{(+)} \Delta lnD_{t-j}^{(+)} + \sum_{s=0}^{n} \vartheta_s^{(+)} \Delta lnP_{i,t-s}^{(+)} +$ $+ \sum_{j=0}^{n} \gamma_j^{(-)} \Delta lnD_{t-j}^{(-)} + \sum_{s=0}^{n} \vartheta_s^{(-)} \Delta lnP_{i,t-s}^{(-)} + \epsilon_t$
2b	$\Delta lnq_{it} = \alpha + \sum_{k=1}^{n} \beta_k \Delta lnq_{i,t-k} + \sum_{j=0}^{n} \gamma_j^{(+)} \Delta lnD_{t-j}^{(+)} + \sum_{s=0}^{n} \vartheta_s^{(+)} \Delta lnP_{i,t-s}^{(+)} +$ $+\theta^{(+)} ECT_{t-1}^{(+)} + \sum_{j=0}^{n} \gamma_j^{(-)} \Delta lnD_{t-j}^{(-)} + \sum_{s=0}^{n} \vartheta_s^{(-)} \Delta lnP_{i,t-s}^{(-)} + \theta^{(-)} ECT_{t-1}^{(-)} + \epsilon_t$

Table 3.12: Results of unit root tests. Production and world oil demand.

	Levels			First Differences		
Country	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	0.00 ***
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***

Table 3.13: Results of unit root tests. Real oil prices.

	Levels			First Differences		
Country	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***

Table 3.14: Estimates of long-run relationship between oil production, world oil demand and real oil prices.

	Constant		Demand		Prices		
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	R^2
Algeria	-13.964	1.246***	1.824	0.119***	0.110	0.015***	91.48%
Ecuador	-19.119	0.983***	2.206	0.085***	0.080	0.009***	79.49%
Iran	1.927	0.506***	0.538	0.048***	0.022	0.004***	68.60%
Kuwait	0.651	1.118	0.607	0.102***	0.114	0.015***	76.13%
Libya	-16.583	2.159***	2.105	0.194***	0.042	0.012***	87.67%
Saudi Arabia	3.702	1.034***	0.465	0.096***	0.052	0.012***	63.05%
Colombia	-9.607	2.418***	1.732	0.242***	-0.311	0.033***	32.25%
Egypt	23.804	1.038***	-1.505	0.096***	-0.040	0.011***	86.40%
Indonesia	33.551	1.971***	-2.352	0.202***	0.012	0.027	81.29%
Malaysia	-8.696	1.703***	1.435	0.159***	-0.178	0.020***	31.07%
Mexico	-3.836	1.151***	1.139	0.109***	-0.142	0.017***	36.53%
Norway	3.213	2.355	0.523	0.223**	-0.204	0.034***	25.07%
Russia	-24.769	1.258***	2.971	0.120***	0.032	0.019*	89.63%

Table 3.15: Stationary analysis of residuals of long-run relationship.

Country	N. Lags	T-Stat.
Algeria	0	-2.916
Ecuador	1	-3.096
Iran	1	-3.364*
Kuwait	0	-3.077
Libya	0	-3.090
Saudi Arabia	0	-2.601
Colombia	0	-2.952
Egypt	0	-2.768
Indonesia	0	-2.325
Malaysia	0	-3.847**
Mexico	2	-2.210
Norway	2	-2.080
Russia	0	-3.464*

Table 3.16: Estimation of oil production levels. Short-run dynamics.

	Algeria	Ecuador	Iran	Kuwait	Libya	Saudi Arabia
C	0.001	0.001	-0.002	-0.001	0.002	-0.002
	0.001	0.003	0.002	0.001	0.001	0.001 *
$\Delta logq_{i,t-1}$	0.137	-0.265	-0.347	0.060	0.083	0.074
	0.075 *	0.071 ***	0.075 ***	0.073	0.100	0.074
$\Delta logq_{i,t-2}$	-0.019		-0.285	-0.100		-0.071
	0.073		0.077 ***	0.072		0.074
$\Delta logq_{i,t-3}$	0.158		-0.096			-0.119
	0.072 **		0.079			0.073
$\Delta logq_{i,t-4}$			-0.234			
			0.077 ***			
$\Delta logq_{i,t-5}$			0.109			
			0.074			
$\Delta logq_{i,t-6}$						
$\Delta logD_t$	0.234	0.368	0.611	0.589	0.174	1.090
	0.094 **	0.315	0.174 ***	0.171 ***	0.148	0.149 ***
$\Delta logD_{t-1}$	-0.041	0.283	0.435	0.480	-0.111	0.062
	0.096	0.313	0.181 **	0.169 ***	0.142	0.169
$\Delta logD_{t-2}$	0.182		0.428	0.362		0.184
	0.096 *		0.187 **	0.176 **		0.170
$\Delta logD_{t-3}$	-0.043		0.432			0.252
	0.096		0.188 **			0.169
$\Delta logD_{t-4}$			0.420			
			0.186 **			
$\Delta logD_{t-5}$			0.274			
			0.185			
$\Delta logD_{t-6}$						
$\Delta lnP_{i,t}$	-0.012	-0.011	0.000	-0.037	-0.010	-0.003
	0.009	0.031	0.010	0.017 **	0.010	0.014
$\Delta lnP_{i,t-1}$	-0.005	0.064	0.004	0.022	0.018	0.035
	0.009	0.031 **	0.010	0.017	0.010 *	0.014 **
$\Delta lnP_{i,t-2}$	0.022		0.005	0.066		0.038
	0.009 **		0.010	0.017 ***		0.015 **
$\Delta lnP_{i,t-3}$	0.015		0.002			0.031
	0.009 *		0.010			0.015 **
$\Delta lnP_{i,t-4}$			0.009			
			0.010			
$\Delta lnP_{i,t-5}$			0.011			
			0.010			
$\Delta lnP_{i,t-6}$						
ECT_{t-1}						
$trend$						
R^2	17.08%	9.51%	29.01%	25.13%	7.78%	37.33%
Log-Lik.	601.59	367.25	484.51	467.11	315.84	519.55
AIC	-6.24	-3.78	-4.99	-5.12	-5.90	-5.37

Table 3.17: Estimation of oil production levels. Short-run dynamics (Ctd.)

	Colombia	Egypt	Indonesia	Malaysia	Mexico	Norway	Russia
C	0.003	-0.003	-0.003	0.000	-0.003	-0.005	0.002
	0.003	0.002 *	0.001 ***	0.002	0.003	0.004	0.001 **
$\Delta lnq_{i,t-1}$	-0.049	-0.028	-0.087	-0.020	-0.531	-0.485	-0.078
	0.076	0.075	0.074	0.075	0.075 ***	0.072 ***	0.079
$\Delta lnq_{i,t-1}$	-0.029	-0.103			-0.433	-0.298	0.161
	0.074	0.074			0.083 ***	0.072 ***	0.078 **
$\Delta lnq_{i,t-1}$	-0.104				-0.212		0.141
	0.068				0.083 **		0.076 *
$\Delta lnq_{i,t-1}$	-0.054				-0.084		0.141
	0.067				0.073		0.076 *
$\Delta lnq_{i,t-1}$	0.025						0.039
	0.068						0.077
$\Delta lnq_{i,t-1}$	0.180						
	0.067 ***						
ΔlnD_t	0.086	-0.138	0.048	0.040	0.966	2.788	0.095
	0.337	0.181	0.097	0.234	0.341 ***	0.463 ***	0.077
ΔlnD_{t-1}	0.477	-0.302	-0.016	0.213	-0.033	0.465	-0.216
	0.334	0.175 *	0.096	0.230	0.349	0.496	0.077 ***
ΔlnD_{t-2}	0.067	0.200			0.420	0.717	-0.088
	0.342	0.179			0.355	0.500	0.079
ΔlnD_{t-3}	-0.533				-0.363		-0.093
	0.339				0.343		0.079
ΔlnD_{t-4}	-0.185				0.900		0.028
	0.341				0.341 ***		0.077
ΔlnD_{t-5}	0.178						0.090
	0.332						0.074
ΔlnD_{t-6}	-0.353						
	0.326						
$\Delta lnP_{i,t}$	0.029	0.021	-0.007	-0.003	0.015	-0.139	0.006
	0.031	0.017	0.008	0.024	0.032	0.048 ***	0.007
$\Delta lnP_{i,t-1}$	-0.003	-0.005	0.007	0.007	-0.086	-0.020	0.005
	0.031	0.018	0.008	0.024	0.033 ***	0.049	0.007
$\Delta lnP_{i,t-2}$	-0.038	0.037			-0.019	0.006	-0.002
	0.032	0.018 **			0.034	0.048	0.007
$\Delta lnP_{i,t-3}$	0.023				0.045		0.022
	0.032				0.034		0.007 ***
$\Delta lnP_{i,t-4}$	0.000				0.007		-0.004
	0.032				0.033		0.007
$\Delta lnP_{i,t-5}$	-0.034						-0.006
	0.031						0.007
$\Delta lnP_{i,t-6}$	-0.005						
	0.032						
ECT_{t-1}				-0.086			
				0.035 **			
$trend$							
R^2	12.11%	6.98%	1.74%	4.22%	34.46%	38.59%	17.95%
Log-Lik.	368.48	463.09	593.36	426.30	360.25	300.54	593.35
AIC	-3.74	-4.96	-6.15	-4.39	-3.67	-3.07	-6.77

Table 3.18: Estimation of oil production levels. Short-run dynamics (Ctd.)

	Angola		Nigeria	Venezuela	Brazil	Canada	U.S.
C	-0.017	C	1.410	2.681	1.086	2.050	2.358
	0.041		0.328 ***	0.217 ***	0.294 ***	0.470 ***	0.456 ***
$\Delta lnq_{i,t-1}$	0.190	$lnq_{i,t-1}$	0.814	0.596	0.842	0.776	0.742
	0.077 **		0.043 ***	0.044 ***	0.043 ***	0.075 ***	0.050 ***
$\Delta lnq_{i,t-2}$		$lnq_{i,t-2}$		-0.092		-0.210	
				0.066		0.092 **	
$\Delta lnq_{i,t-3}$		$lnq_{i,t-3}$		0.020		0.171	
				0.068		0.073 **	
$\Delta lnq_{i,t-4}$		$lnq_{i,t-4}$		0.083			
				0.066			
$\Delta lnq_{i,t-5}$		$lnq_{i,t-5}$		-0.037			
				0.057			
$\Delta lnq_{i,t-6}$		$lnq_{i,t-6}$		0.102			
				0.035 ***			
ΔlnD_t	0.191	ΔlnD_t	0.772	0.874	0.062	0.521	0.900
	0.248		0.342 **	0.363 **	0.252	0.228 **	0.223 ***
ΔlnD_{t-1}	-0.104	ΔlnD_{t-1}	0.035	0.322	-0.107	0.188	0.437
	0.248		0.342	0.363	0.251	0.232	0.224 *
ΔlnD_{t-2}		ΔlnD_{t-2}		-0.119		-0.090	-0.003
				0.368		0.230	0.023
ΔlnD_{t-3}		ΔlnD_{t-3}		0.395		-0.091	
				0.366		0.227	
ΔlnD_{t-4}		ΔlnD_{t-4}		0.631			
				0.365 *			
ΔlnD_{t-5}		ΔlnD_{t-5}		0.464			
				0.359			
ΔlnD_{t-6}		ΔlnD_{t-6}		0.346			
				0.351			
$lnP_{i,t}$	0.001	$\Delta lnP_{i,t}$	0.010	-0.020	-0.005	-0.019	0.009
	0.012		0.021	0.030	0.024	0.024	0.023
$lnP_{i,t-1}$	0.002	$\Delta lnP_{i,t-1}$	-0.029	-0.007	0.006	0.004	
	0.012		0.021	0.031	0.024	0.024	
$lnP_{i,t-2}$		$\Delta lnP_{i,t-2}$		0.003		-0.064	
				0.031		0.024 ***	
$lnP_{i,t-3}$		$\Delta lnP_{i,t-3}$		-0.018		0.031	
				0.031		0.024	
$lnP_{i,t-4}$		$\Delta lnP_{i,t-4}$		0.020			
				0.031			
$lnP_{i,t-5}$		$\Delta lnP_{i,t-5}$		0.004			
				0.031			
$lnP_{i,t-6}$		$\Delta lnP_{i,t-6}$		0.012			
				0.031			
ECT_{t-1}		ECT_{t-1}					
$trend$		$trend$	0.0002	-0.0005	0.0009	0.0005	-0.0001
			0.0001 ***	0.0001 ***	0.0002 ***	0.0001 ***	0.0000 ***
R^2	4.29%	R^2	79.71%	95.90%	99.04%	95.69%	76.74%
Log-Lik.	375.40	Log Lik.	345.79	358.76	367.00	434.77	432.80
AIC	-4.35	Akaike info criterion	-3.60	-3.61	-4.31	-4.46	-4.46

Table 3.19: Estimation of oil production levels.

		Demand			Prices		
Country	Lags	F-Stat.	Prob.	Sign	F-Stat.	Prob.	Sign
Algeria	3	2.330	0.058 *	(+)	3.115	0.017 **	(+)
Angola	1	0.404	0.668	-	0.152	0.859	-
Ecuador	1	1.015	0.364	-	2.091	0.126	-
Iran	5	4.316	0.000 ***	(+)	0.465	0.833	-
Kuwait	2	6.059	0.001 ***	(+)	7.659	0.000 ***	(+)
Libya	1	1.135	0.325	-	1.697	0.189	-
Nigeria	1	2.350	0.098 *	(+)	0.991	0.373	-
Saudi Arabia	3	14.667	0.000 ***	(+)	5.910	0.000 ***	(+)
Venezuela	6	1.729	0.106	-	0.239	0.975	-
Brazil	1	0.126	0.881	-	0.048	0.953	-
Canada	3	1.672	0.159	-	2.211	0.0696 *	(-)
Colombia	6	1.142	0.340	-	0.605	0.726	-
Egypt	2	1.797	0.150	-	1.998	0.116	-
Indonesia	1	0.144	0.866	-	0.780	0.460	-
Malaysia	1	0.435	0.648	-	0.047	0.954	-
Mexico	4	2.297	0.047 **	(+)	1.930	0.092 *	(-)
Norway	2	12.369	0.000 ***	(+)	2.989	0.032 **	(-)
Russia	5	2.238	0.042 **	(-)	2.172	0.049 **	(+)
U.S.	1	9.546	0.000 ***	(+)	0.079	0.924	-

Table 3.20: Asymmetric effects of world oil demand on oil production.

		$\Delta lnD_t^{(+)}$		$\Delta lnD_t^{(-)}$		$\gamma^{(+)} =$	
Country	Lags	F-Stat.	Prob. (Sign)	F-Stat.	Prob. (Sign)	$\gamma^{(-)}$	Prob.
Algeria	2	2.511	0.060 * (+)	0.834	0.477	2.836	0.094 *
Angola	1	0.764	0.468	0.647	0.525	-	-
Ecuador	1	0.384	0.682	0.320	0.726	-	-
Iran	4	2.752	0.021 ** (+)	2.237	0.053 * (+)	0.104	0.747
Kuwait	2	3.435	0.018 ** (+)	1.238	0.298	0.243	0.623
Libya	1	1.325	0.271	1.790	0.173	-	-
Nigeria	1	1.350	0.262	0.328	0.721	-	-
Saudi Arabia	2	11.258	0.000 *** (+)	3.833	0.011 ** (+)	0.482	0.488
Venezuela	4	4.341	0.001 *** (+)	0.950	0.451	14.575	0.000 ***
Brazil	1	1.904	0.153	0.869	0.421	-	-
Canada	2	0.796	0.498	0.600	0.616	-	-
Colombia	4	1.144	0.339	0.471	0.797	-	-
Egypt	1	0.850	0.429	0.521	0.595	-	-
Indonesia	1	0.879	0.417	1.119	0.329	-	-
Malaysia	1	1.032	0.358	0.786	0.457	-	-
Mexico	3	1.802	0.131	0.650	0.628	-	-
Norway	2	5.636	0.001 *** (+)	3.250	0.023 ** (+)	0.561	0.455
Russia	1	3.594	0.030 ** (+)	2.533	0.083 * (-)	8.517	0.004 ***
U.S.	2	0.175	0.913	8.984	0.000 *** (+)	0.024	0.876

Table 3.21: Asymmetric effects of real oil prices on oil production.

		$\Delta lnP_{i,t}^{(+)}$		$\Delta lnP_{i,t}^{(-)}$		$\vartheta^{(+)} =$	
Country	Lags	F-Stat.	Prob. (Sign)	F-Stat.	Prob. (Sign)	$\vartheta^{(-)}$	Prob.
Algeria	2	0.204	0.894	3.426	0.018 ** (+)	0.014	0.907
Angola	1	-	-	-	-	-	-
Ecuador	1	0.543	0.582	1.483	0.230	-	-
Iran	4	0.141	0.982	0.787	0.561	-	-
Kuwait	2	1.787	0.152	2.178	0.093 * (+)	0.021	0.884
Libya	1	4.253	0.017 ** (-)	3.681	0.029 ** (+)	6.511	0.012 **
Nigeria	1	0.207	0.813	1.497	0.227	-	-
Saudi Arabia	2	1.243	0.296	2.756	0.044 ** (+)	0.003	0.958
Venezuela	4	0.436	0.823	0.200	0.962	-	-
Brazil	1	1.893	0.154	1.449	0.238	-	-
Canada	2	3.819	0.011 ** (-)	1.106	0.348	6.777	0.010 **
Colombia	4	1.266	0.281	1.393	0.229	-	-
Egypt	1	0.077	0.926	0.597	0.552	-	-
Indonesia	1	0.477	0.621	2.591	0.078 * (-)	1.142	0.287
Malaysia	1	0.783	0.459	1.126	0.327	-	-
Mexico	3	0.900	0.465	1.657	0.162	-	-
Norway	2	0.903	0.441	1.747	0.159	-	-
Russia	1	0.270	0.764	0.618	0.540	-	-
U.S.	2	2.400	0.070 * (+)	5.008	0.002 *** (-)	5.354	0.022 **

Table 3.22: Asymmetric effects of real oil prices on oil production.

		$ECT_{t-1}^{(+)}$		$ECT_{t-1}^{(-)}$			
Country	Lags	F-Stat.	Prob. (Sign)	F-Stat.	Prob. (Sign)	$\theta^{(+)} = \theta^{(-)}$	Prob.
Malaysia	1	1.002	0.318	4.036	0.046 ** (+)	4.057	0.019 **

Appendix to Chapter 3

Notes to the Tables of Chapter 3

Table 3.1

Frequency and fraction up (down) denote the mean frequency expressed in months of oil production changes and the fraction of oil production increases (decreases), respectively. Average size denotes the mean size of oil production changes (percentage over previous value).

Table 3.2

See notes to Table 3.1.

Table 3.3

See notes to Table 3.1.

Table 3.6

Reported are the results obtained by estimating the following model on the basis of simulated data: $lnq_t = \beta_0 + \beta_1 lnD_t + \beta_2 lnP_t + \epsilon_t$. *** (**, *) denote rejection of the null hypothesis that the coefficient is statistically not different from zero at 1% (5%, 10%) significance level.

Table 3.7

Reported are the results obtained by estimating the following model on the basis of simulated data: $\Delta lnq_t = \beta_0 + \beta_1 \Delta lnD_t + \beta_2 \Delta lnP_t + \epsilon_t$. *** (**, *) denote rejection of the null hypothesis that the coefficient is statistically not different from zero at 1% (5%, 10%) significance level.

Table 3.12

Presented are the t values of $\widehat{\alpha}_2$ in the following equations:
$\Delta \ln y_t = \alpha + \alpha_1 \cdot trend + \alpha_2 lny_{t-1} + \sum_{t-i}^{p} \beta_i \Delta \ln y_{t-i} + \epsilon_t$ (variables in levels)
$\Delta^2 \ln y_t = \alpha + \alpha_1 \cdot trend + \alpha_2 \Delta lny_{t-1} + \sum_{t-i}^{p} \beta_i \Delta^2 \ln y_{t-i} + \epsilon_t$ (variables in log-first differences). The procedure proposed by [126] is adopted. t denotes that a linear trend is included in the above equations. The number of lags to include in the regression is chosen by minimizing the Schwarz-Bayesian Information Criterion. *** (**, *) denote that the null hypothesis that $H_0 : \widehat{\alpha} = 0$ can be rejected given 1% (5%, 10%) significance levels. Critical values computed by [124] are employed.

Table 3.13

See notes to Table 3.12.

Table 3.14

Least squares estimates of the equation $lnq_{it} = a_0 + a_1 lnD_t + a_2 lnP_t + \nu_t$ are reported. *** (**, *) denote rejection of the null hypothesis that the coefficient is statistically not different from zero at 1% (5%, 10%) significance level.

Table 3.15

Reported are the results from ADF tests on the residuals of long-run equations (see equation 3.8). 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 the coefficient is statistically not different from zero at 1% (5%, 10%) significance level. Critical values computed by [127] are employed.

Table 3.16

Presented are the results from the estimation of short-run dynamics of oil production (see equations 3.5 to 3.10). For each country the final specification is chosen according to the algorithm presented in Section 3.3.2. *** (**, *) denote rejection of the null hypothesis that the coefficient is statistically not different from zero at 1% (5%, 10%) significance level. The number of lags of ARDL and EC Models is selected on the basis of the Akaike Information Criterion (see [128]).

Table 3.17

See notes to Table 3.16.

Table 3.18

See notes to Table 3.16.

Table 3.19

Presented are the $F-$ statistic tests that all regression coefficients associated with world oil demand and real oil prices are zero. *** (**, *) indicate that: $H_0 : \gamma_1 = \gamma_2 = \ldots = \gamma_n = 0$ and $H_0 : \vartheta_1 = \vartheta_2 = \ldots = \vartheta_n = 0$ can be rejected given a 1% (5%, 10%) significance level. These tests are based on the estimates presented in Tables 3.16 to 3.18. In columns five and eight the sign of the relationship between oil production and total demand (or real oil prices) based on coefficients $\beta_D = \frac{\gamma_1+\gamma_2+\ldots+\gamma_n}{1-\beta_1-\beta_2-\ldots-\beta_n}$ and $\beta_{P_i} = \frac{\vartheta_1+\vartheta_2+\ldots+\vartheta_n}{1-\beta_1-\beta_2-\ldots-\beta_n}$ is reported.

Table 3.20

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 $H_0 : \gamma_1^{(+)} = \gamma_2^{(+)} = \ldots = \gamma_n^{(+)} = 0$ and $H_0 : \gamma_1^{(-)} = \gamma_2^{(-)} = \ldots = \gamma_n^{(-)} = 0$ can be rejected given a 1% (5%, 10%) significance level. Columns seven and eight report the results of F-test over the null hypothesis that: $\sum_i \gamma_2^{(+)} = \sum_i \gamma_2^{(-)}$.

Table 3.21

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 $H_0 : \vartheta_1^{(+)} = \vartheta_2^{(+)} = \ldots = \vartheta_n^{(+)} = 0$ and $H_0 : \vartheta_1^{(-)} = \vartheta_2^{(-)} = \ldots = \vartheta_n^{(-)} = 0$ can be rejected given a 1% (5%, 10%) significance level. Columns seven and eight report the results of F-test over the null hypothesis that: $\sum_i \vartheta_2^{(+)} = \sum_i \vartheta_2^{(-)}$.

Table 3.22

Presented are the $F-$ statistic tests that long-run equilibrium adjustment parameters associated to the positive and negative components of the long-run equilibrium relationship are zero. *** (**, *) indicate that the null hypotheses $H_0 : \theta^{(+)} = 0$ and $H_0 : \theta^{(-)}0$ can be rejected given a 1% (5%, 10%) significance level. Columns seven and eight report the results of F-test over the null hypothesis that: $\theta^{(+)} = \theta^{(-)}$.

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