On the issue of OPEC behavior: the cartel conjecture under cost asymmetries.

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March 17, 2015

Abstract

It is well known that OPEC was established to preserve stability of oil prices as well as to ensure demand requirements by acting as an expicit cartel. Recently, some papers have investigate whether OPEC still exist as a cartel or not and also the determinants of OPEC production. If the answer to the former question is positive, a rational criteria is to assume that OPEC allocates output quotas between members in order to preserve cartel stability and disuade country members to leave the organization. We first present empirical evidence to check this insight for the period since 1960 to 2011. Second, we tests the robutness of the empirical observations by modelling cartel behavior as an infinite repeated oligopoly game. We argue that OPEC allocates production quotas attending the country members' cost heterogeneity, such that countries find more profitable to follow cartel rules instead to leave the cartel discipline. Moreover, it is argued that asymmetries (maybe jointly with others non-economic reasons) can be behind OPEC decisions to adhere a new member (also to shut down countries unable to fullfil the production quota assigned).

Keywords: OPEC, Internal stability, Cost asymmetries, Output quotas.

JEL classification: C7, D4, L1, Q40.

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1 Introduction

It is well known that spot prices in energy markets are very volatile. In the case of crude oil the refining capacity, declared reserves, socks of demand, and the geopolitical situation are on the background of price formation. As a result, oil prices experiment large fluctuations both in the short and long run.

Oil exploitation on a large-scale began in 1928 in the Middle East. Seven large exporting companies called *The seven sisters* emerged as a cartel by fixing a common price. It was downward and without rigidity to avoid competition. In the late 30's producer countries enter the scene as revenues increase. These contries began to demand a huge participation in the profits. After arduous negotiations the Organization of the Petroleum Exporting Countries (*OPEC*) was established in 1960 aimed to control the daily number of crude barrels negotiated in order to manage wholesale oil prices. In the first 20 years of existence OPEC had to overcome different political affairs as well as some geopolitical conflicts .[1]

After the two energy crisis in the 70's, industrialized countries become more dependent of crude oil due to sharp demand increases and the decline in proved reserves. Thus, in order to maintain the control of prices, OPEC countries began to nationalize firms as well as to manage production of private firms.[2] A third great oil shock took place in 1990 when Iraq invaded Kuwait, with a new wave of high prices and production restrictions. More recently, during the summer of 2008, the oil price suffered a price boom in a context of a economic expansion which was suddenly followed by the current economic crisis. The recent collapse of crude oil prices since the end of 2014 has proved that OPEC still behave as a cartel. Indeed, OPEC (and in particular Saudi Arabia) has maintained production quotas no matter the menace of other non-OPEC producers, mainly Russia, to increase

[1] In 1973 the first energy crisis emerged as a consequence of the Libyan Revolution and the War of Yom Kippur. It caused a rapid increases in oil prices which become for the first time in a durable economic crisis. The second oil crisis took place in 1979 and it had its origin in the Shah's White Revolution, the Iranian revolution and the war between Iran and Iraq. The consequence of this crisis was the price increase again. This crisis in the medium run, encouraged the discovery of new oil fields (in non-OPEC countries, mainly).

[2] Meanwhile, *The seven sisters* remain keeping a large share of transportation, refining and distribution.

per day barrels-production.

The issue of how OPEC has influenced oil prices and its capability to maintain internal cohesion thorought more than sixty hazarous years.has motivated many studies. In fact, OPEC members are different in terms of production capacities and thus, its internal stability over time may involves ardous internal negotiations. We argue that diferences in production costs (that yield to different production capacities) may be the main obstacle to preserve OPEC stability from an economic point of view.

Our goal is twofold. First, we want to highlight the dynamics of the production behaviour by OPEC countries and the exted to which it follows a collusive behaviour. Second, we explore if production quotas explain entries and exits of those countries that since 1960 until 2011 were part of the OPEC. In a recent study Brémond et al (2012) determines up to what extend OPEC acts as a cartel by assuming that production quotas by countries are coordinated. We extend that insight by postulating that such a quotas are efficiently assigned in order to preserve cartel stability over time. Thus, as OPEC countries have different cost structures as a result of different extraction capabilities, they are commited to produce (efficient) crude quotas that fulfil cartel requirements as well as to disuade countries to cheat from the cartel agreement.

The hypotesis of OPEC acting as a cartel was assumed in some studies (see for instance Loderer (1985) and Gülen (1996)) whereas others reject the cartel hypothesis (see for instance Dahl and Yücel (1989)). These papers follow econometric and empirical approaches. Other group of studies have investigated OPEC from a more theoretical-oriented perspective. In an early study by Hnyilicza and Pyndick (1976) OPEC was divided in two groups in order to investigate the bargaining power between them. Aperjis (1982) put forward that conflicts between OPEC countries may exist when stablish output quotas. Griffin (1985) concluded that a partial market sharing rule is apropiate to represent OPEC countries behavior. Böckem (2004) concludes that by applying the ideas of New Empirical Industrial Organization, OPEC and the market for crude oil is best described by a price-leader model. Finally, there are some papers which focus in case studies. For instance, Reynolds and Pippenger (2010) conduct a test to see if Venezuela's production Granger cause its OPEC quota or whether the OPEC quota Granger cause Venezuela's production. Their results shown both occur at different times.

In this paper it is argued that OPEC members behave as a cartel by asumming different production quotas depending on their production capacities. This idea is supported by previous studies on OPEC bahaviour. In a study of the characteristics of commodity cartels Alhajji and Huettner (2000) conclude that OPEC is composed of Saudi Arabia, the dominant world producer, plus several distinct sub-groups. They attribute the recent OPEC success to political, natural, and technical capacity limitations in the oil fields that prevented countries from cheating on their quota. Kauffman et al. (2008) estimate models that identify the economic and organizational determinants of crude oil production by individual OPEC nations. Results indicate that quotas are an important determinant of total OPEC production and their effects generally are symmetric, which implies that OPEC is an organization that influences production and ultimately prices. Moreover, it is argued that all nations other than Saudi Arabia show some form of production sharing behavior, which may imply that OPEC shares mismatches between the call for OPEC production and OPEC quotas.

In the present study we procced as follows. First, we perform a cluster analysis aimed to determine the extend to which production of OPEC countries can be divided in homogenous groups. To do so, we use the World Energy Statistics database by British Petroleum (2012 edition). Second, we present a dynamic oligopoly model to test the insight from the cluster analysis. We focus in the static as well as in the dynamic behavior of OPEC country members. Besides, it is studied the reasons of those countries who adhere the organization and abandoned it at any time. Overall, we can argue that OPEC countries behave as a cartel where country members are clusterized attending to different production capacities. This conclusion does not exclude that geopolitical reasons and other speculative actions play a non negligible role in OPEC organization. However, it seems that economic reasons are in the core of OPEC stability along time.

The rest of the paper is organized as follows. Section 2 describes our intra-group OPEC's hypothesis and the cluster analysis is presented. Section 3 describes and solves the dynamic oligopoly model with the main insights follows. Section 4 concludes.

2 Data and OPEC's country member classification hypothesis

In this section we conduct a cluster analysis aimed to classify OPEC country members in homogeneous groups attending their production quotas during the period 1960-2011. We use the World Energy Statistics performed by Bristish Petroleum (BP) 2012 edition. It is considered countries that during that period joined OPEC at any time. According to OPEC country members' production quotas in the period studied we argue that they behave as a cartel where profits are split according to these production quotas observed. Thus, our hypothesis is that oil production capacities determines OPEC's cartel behaviour. That means that geopolitical reasons do not prevail when the time horizon is large enough.

We employ a cluster analysis where data are production quotas by country at each year under review. It is adopted the Wald method. We proceed in two steps.

2.1 Global analysis

First, it is analysed the whole time period under review. Within this period we distinguish two panel data. On one hand, we report a *global syntetic panel* data which includes those countries that have ever joined the OPEC organization, regardless they already remain as OPEC member countries or joined the organization for a limited period of time. On the other hand, we report a *global real panel* data which includes only OPEC country members at each year under review. Figure 1 reports dendograms as a result of the cluster analysis. It is observed that regardless the panel used member countries can be divided in three groups: Saudi Arabia as cartel leader; a second groups characterised by those countries with stable production quotas including Arabia Emirates, Nigeria, Algeria, Indonesia, Lybia, Kuwait, Iraq, Venezuela and Iran; and a group formed with countries with reduced and unstable production quotas including Angola, Qatar, Ecuador and Gabon. It seems that the organization preserve an internal production rule in which countries are classified acording with its production capacities. Thus, it is argued that the *core country members* (those that remain as OPEC country members during the whole

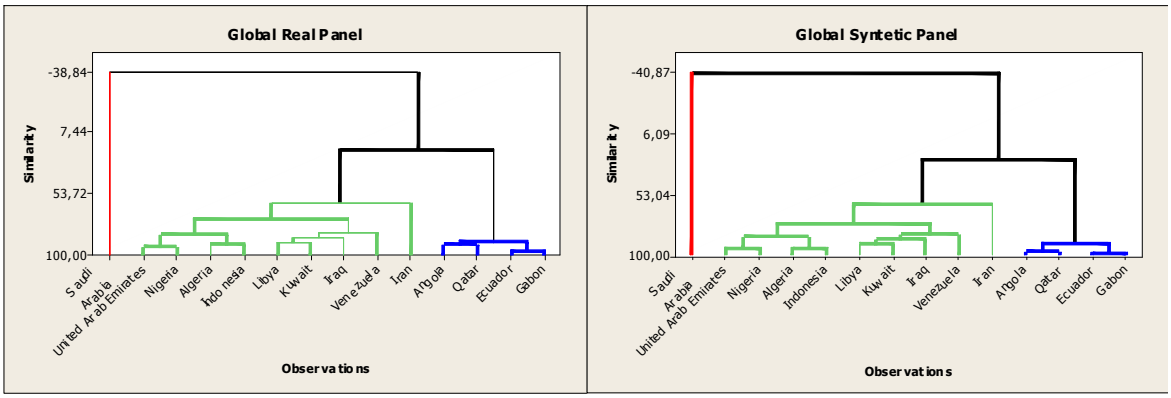

Figure 1: Global and Synthetic Panel.

period) do not significative change behaviour over time as a result of particular in-and-out country movements. For instance, Qatar produce at moderate quotas but its production increase at a symmilar rates that the total OPEC production.

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Table 1 reports information about mean and standard deviation differences by groups. It is observed that clusters B and C differs in the grade of heterogeneity. Indeed, cluster B presents lower deviations respect to the mean; however, production quotas of cluster C are more erratic around the mean.

Table 1. Mean and st. deviation by cluster.		
Cluster	Mean	St. deviation
Cluster A	7695	2665
Saudi Arabia	7695	2665
Cluster B	2032	751
United Arab Emirates	1968	821
Libya	1630, 80	544, 30
Iran	3646	1182
Iraq	1802	764
Kuwait	2096	712
Venezuela	2762, 80	579, 10
Algeria	1325, 50	357, 80
Nigeria	1787, 10	622, 20
Indonesia	1265, 90	342, 10
Cluster C	419, 2	198, 5
Angola	563, 9	556, 2
Ecuador	284, 5	165, 9
Qatar	613, 1	355, 9
Gabon	215, 3	86, 1

2.2 By-period analysis

Here it is highlighted why certain countries adhere or abandon the OPEC organization. We motivate the analysis taking into acount production reasons.

First, we observe the case of Ecuador, Nigeria and Gabon. All of them joint OPEC during the period 1971-1975 (during the years 1973, 1971, and 1975, respectively). In order to study if production quotas are a relevant reason to adhere OPEC we take the period 1965-1974 and perform the cluster analysis including these countries and those that already were OPEC country members (see Figure 2). It is found that all of them are classified in the low-productive group. Moreover, due Yom Kippur war Lybia's production decrease which favors that Iran arise as a leader production country joinly with Saudi

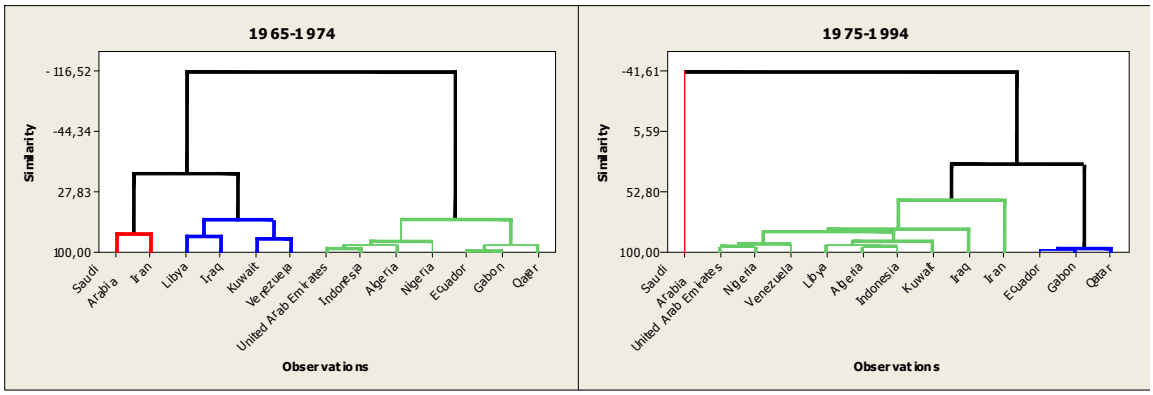

Figure 2: Cluster analysis, 1965-1974, and 1975-1994.

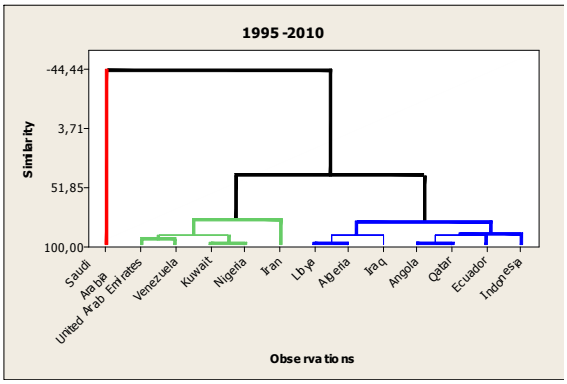

Figure 3: Cluster analysis 1995-2010.

Arabia.

Second, it is studied the sub-period 1975 to 1994 in order to analyse why Ecuador and Gabon abandon OPEC organization (see Figure 3). It is observed that Ecuador increase production lower than the OPEC average total production. Moreover, Gabon diminish its production. Figure 4 reports production dynamics by Ecuador and Gabon during the period studied.

Third, we analyse why Indonesia leaves OPEC in 1997 and Angola join OPEC in 2007. To do so, we perform the cluster analysis for the period 1995-2011 (see Figure 5). In viewing the dendogram it is obsrved that Indonesia locate at the end of the chain, which means that its production decrease at a higher rate. Finally, Angola enter the organisation as a result of continous production increases.

In what follows we present a cartel model aimed to model the empirical evidence

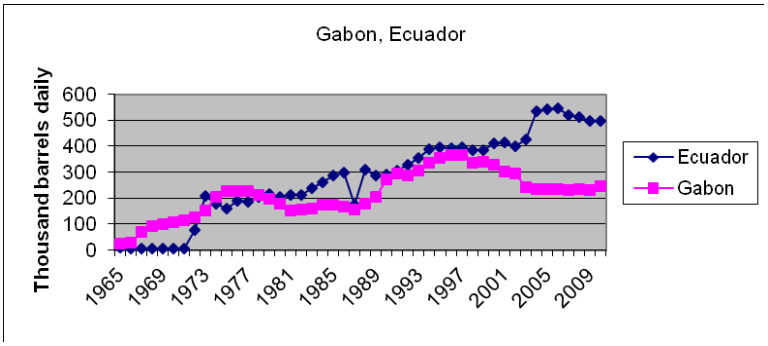

Figure 4: Ecuador and Gabon production during the period 1965-2010.

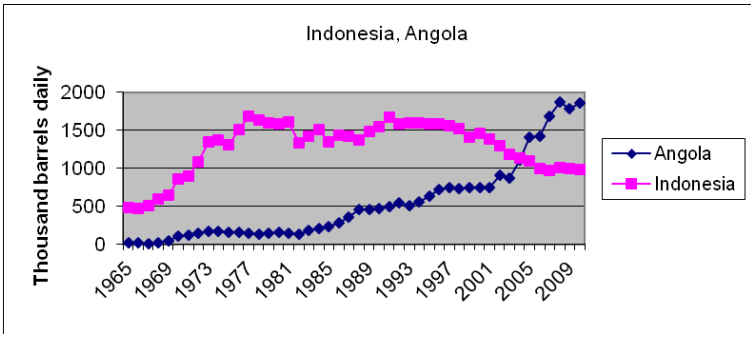

Figure 5: Indonesia and Angola production during the period 1965-2010.

discussed above. Our main assuption is that economic reasons, mainly production cost, drive OPEC's behaviour, so cost asymmetries should be included to explain the cartel dynamic behaviour of the organization.

3 OPEC as a cartel: The Model

First, we study the incentives to joint the OPEC cartel by asumming that countries have different cost structures which yield to different production quotas. Regarding the formation of asymmetric cartels, Patinkin (1947) determined the rule of asymmetrical distribution of cartel quotas at one with the marginal costs of production. The conceptual analysis was completed by Bain (1948) whoargued that if a firm was relative sufficently inefficient it may got less profits under a collusive agreement than by maximizing firm's profits. Second, the issue of OPEC stability is studied by using the well known assumption of a constant tension between fidelity to the cartel agreement and the incentives to deviate in order to raise profits in the short run.[3] Hence, we argue that as a country member does not fulfill the require production quota within its group, it abandon the OPEC discipline. Similarly, a country that enter the OPEC discipline is asigned to a group depending on its capabilities of production (determined by its cost structure). Taking into acount cost asymmetries we follow Friedman's (1971) strategies profile: countries collude as long as cooperation has been observed in the past, otherwise the punishment is to revert to the asymmetric Nash-Cournot equilibrium one period after the violation has been detected.

According with the results obtained in the above section we consider three country groups which behave as an explicit cartel, namely OPEC. As it is suggested by data analysis, that classification is according to production capabilities. Thus, countries follows 3 different profiles: (i) efficient country or production-aggressive, E, (ii) weakly efficient country or production-neutral, N, and (iii) low efficient country or production-residual, I. Production capacities are approximated by assuming quadratic cost functions in order to internalize capacity limits in a continuous and smoot (differentiable) way. The cost function of each country is $C_h(q_h) = (1 + \varrho_h(c))q_h^2/2$. Thus, the larger the capacity of a

[3]Folk theorem states that any agreement lead to the long run equilibrium if it is sufficiently credible (Fundenberg and Maskin, 1986).

country to produce crude oil, the lower the marginal costs are. The function $\varrho(c)$ specifies differences in costs,

$$\varrho_h(c) = \begin{cases} -c \text{ if } h = E \\ 0 \text{ if } \ h = N. \quad c \in (0,1). \\ c \text{ if } h = I. \end{cases}$$

where c represents efficiency differences by country group. Moreover, c can be used to represent changes in group's production capacity and, therefore, changes in their relative efficiency within the cartel. Thus, we can check how c affects the internal stability of the cartel.

The inverse demand function is linear $p(Q) = \alpha - Q$, where p is the market price and Q is the total quantity produced, $Q = q_E + \sum_{i=1}^{n} q_{Ni} + \sum_{j=1}^{m} q_{Ij}$. Although the cartel maximizes the joint profits, we need a profit sharing rule according to the efficiency level of each country group.

Assumption 1: each country group $h = E, N, I$ behave efficiently so that they contribute to the total OPEC production by following the efficient production quota rule,

$$CMg_E(q_E) = CMg_{Ni}(q_{Ni}) = CMg_{Ij}(q_{Ij}).$$

This rule was suggested by Patinkin (1947). He stated that an efficient allocation rule is one that equates marginal costs of each player.[4]

Thus, OPEC maximizes joint profits,

$$\max_{q_E, q_{Ni}, q_{Ij}} \sum_{h=E,N,I} \pi_h(q_h, q_{-h}), \quad \text{where} \quad \pi_h(q_h, q_{-h}) = P(q_h, q_{-h})q_h - C_h(q_h),$$

where $-h$ is a vector comprising the rest of countries' strategy.

By imposing simmetry intra groups and taking first order conditions we obtain reaction functions $q_h(q_{-h}) = (\alpha - \sum q_{-h})/(3 + \varrho_h(c))$. The equilibrium output for each country h,

[4]There are differerent possibilities to assign production quotas or profit sharing rules. For example, it is possible to allow side payments to encourage less eficient countries do not leave the cartel. However, it implies different negotiation power by goups and, accordingly, take into account another non-economic motivations. As we want to study in the economic perspective we focus on the above efficient production rule.

and the collusive price are, respectively

$$q_h^c = \prod_{k \neq h} \frac{(2+\varrho_k(c))\alpha}{4(3+n+m)-2c(m-1)-c^2(n+2)}, \qquad Q^c = \frac{\left[4(m+n+1)-2c(m-1)-nc^2\right]\alpha}{4(3+n+m)-2c(m-1)-c^2(n+2)} \qquad P^c(Q^c) = 2q_h^c.$$

In the case that a given country abandone the OPEC discipline, that country act unilaterally by choosing q_h (and q_{-h} represents the production of the other competitors). Explicitly, each country maximizes,

$$\max \ (\alpha - q_h - q_{-h})q_h - (1 + \varrho_h(c))q_h^2/2.$$

In following subsections we discuss the membership of the cartel and its sustainability over time.

3.1 Formation of the cartel

A first observation is extracted from above expressions. Both the quantity allocated for each country as the total quantity and the equilibrium price depend on the relative efficiency. These results are complied in the following

Proposition 1: *Profits of a country i in the collusive equilibrium is a linear combination of the production quota allocated according to their efficiency,*

$$\pi_i^c = q_i^c/2.$$

Proof: *It is immediate, simply replacing the price and equilibrium quantities for each profit function for each firm $i = E, N, I$, and simplifying appropriately.*■

Once we've defined the rule of distribution within the cartel and profits to which results have to approach the main problem faced by a cartel where all partners are different in terms of costs: is there a possibility that some cartel member prefer to leave their discipline because differences in efficiency are large enough? Clearly, the answer is not trivial. Indeed, the parameter c determines the extent to which the cartel members are willing to be part of t.he organization. Hence, we have to confront profits earned under the cartel discipline and those earned when firms behave as Cournot competitors. The static Nash equilibrium is straightforward obtained by

$$q_i^* \arg\max_{q_i} \pi_i(q_i, q_{-i}).$$

The first order condition for each firm yields to the reaction function $q_i(q_{-i}) = (1 - q_{-i})/(3 + \varrho_{-i}(c))$. The equilibrium quantity for each country i, the total quantity transacted and the price are, respectively,

$$q_i^* = \frac{1}{(20-3c^2)} \left[\prod_{i=E,I,N} (2 + \varrho_{-i}(c)) \right], \qquad Q^* = \frac{(12-c^2)}{(20-3c^2)}, \qquad P^* = \frac{2(4-c^2)}{(20-3c^2)}.$$

As in the collusive equilibrium, both the quantities produced by each country as the total quantity and the equilibrium price depend on the relative efficiency.

Proposition 2: *The profit for each country i when competing in the international market is a function of the Nash-Cournot q_i^* which, in turn, depends on its efficiency,*

$$\pi_i^* = \frac{(3 + \varrho_i(c))}{2} (q_i^*)^2.$$

Proof: *It is immediate, simply replacing the price and equilibrium quantities for each profit function for each firm $i = E, N, I$, and simplifying appropriately.*■

Now, once the Nash-Cournot equilibrium and the cartel outcome are characterized, the following result holds.

Proposition 3: *In the static game, the decision to adhere the cartel discipline decrease as c increase. Specifically, (i) if $c > 0,41$ the I-group does not adhere the cartel, (ii) if $c > 0,57$ I and N-group does not adehere the cartel and, therefore,it ceases to exist.*

Proof: *We will proceed in two parts: (i) bearing in mind expressions π_I^c and $\pi_I^* \Longrightarrow$ to ensure compliance $\pi_I^c \geq \pi_I^* \Longrightarrow$ we need that $c^* \geq 0,41$. So if we take a $c = c^* + \varepsilon$, where $\varepsilon > 0 \Longrightarrow \pi_I^c < \pi_I^*$; (ii) if we know π_N^c and $\pi_N^* \Longrightarrow$ to ensure compliance $\pi_N^c \geq \pi_N^* \Longrightarrow$ we need that $\hat{c} \geq 0,57$. So if we take a $c = \hat{c} + \varepsilon$, where $\varepsilon > 0 \Longrightarrow \pi_N^c < \pi_N^*$, which also includes the condition (i). This concludes the proof.*■

The economic intuition behind this proposition is immediate. OPEC designs its criteria of production quota bearing in mind the following objective: that any country has not incentives to withdraw from the cartel. So, when a country or group of countries have problems keeping their quotas, it makes a reallocation of quotas with the aim of maintaining price and any country does not suffer a larger decrease in their profits, even when there are periods where its share has been diminished as a result of greater inefficiency.[5]

[5]For a detailed discussion of this fact we need consider the side payments. However, the qualitative results remain unchanged even if it does the complexity of the model.

3.2 Intertemporal stability of the cartel

In this subsection we analyze to what extent countries have incentives to leave the cartel discipline when differences in costs are large enough. To do so, we will analyze the infinitely repeated stage game assuming that countries collude explicitly. We will take a discount factor δ $(0 < \delta < 1)$ to assess the current present value of future profits for each country. Thus, each country will be faithful to the collusive agreement when profits el discipline are higher or equal than present profits of betraying the other cartel members plus the subsequent punishment (to compete in quantities forever after). If a member acts unilaterally, the cartel would enter in a war of market shares (quotas), expanding production in response to decision of any member to offer in the market a higher quota than that (ex-ante) agreed. That is, any country of the cartel compete à la Cournot and thus, they get those profits at Proposition 2. The intertemporal strategy profile, following Friedman (1971) is,

$$q_i^t = \begin{cases} q_i^1 = q_i^c \\ q_i^t = q_i^c \quad \text{si} \quad q_i^\tau = q_i^c \text{ para } \tau < t \quad \tau, t = 2, ..., \infty, \\ q_i^\tau = q_i^* \quad \text{si} \quad q_i^\tau \neq q_i^c \text{ para } \tau < t \end{cases}$$

where q_i^t specifies the strategy played by each country i in each stage $t = 1, 2, ..., \infty$. Because countries differ in their level of efficiency, we have to study intertemporal incentives to break the agreement by each country. Use the concept of subgame perfect Nash equilibrium to define the δ minimum necessary to preserve the structure of the cartel with all its members. Obviously, the value of δ depends on c.

Explicitly, the condition for which each member belongs to the cartel over time is

$$\pi_i^c \geq \pi_i^d - \delta_i(\pi_i^d - \pi_i^*).$$

Moreover, although discount factors are common to all countries, each country will need to weigh more the future in relation to present when its inefficiency is growing. Then, the sufficient condition for the maintenance of the cartel over time,

$$\widehat{\delta} = \max\{\delta_E, \delta_N, \delta_I\}$$

The country that chooses to deviate takes quotas of the other countries at the collusive strategy (keeping its production quotas) so that $q_i(q_{-i}^C) = (1 - q_{-i}^C)/(3 + \varrho_{-i}(c))$. It yield

an output q_i^d and a new equilibrium price,

$$q_i^d = \left[\frac{1}{(7-3c^2)(3+\varrho_i(c))}\right] \cdot \prod_{i=E,I,N} (1+\varrho_{-i}(c)) \qquad P_i^d = (2+\varrho_i(c))q_i^d$$

This allows us to state the following,

Proposition 4: *The profit of each country i, in case it decides to leave the cartel discipline, depends on q_i^d, which, in turn, depends on its efficiency,*

$$\pi_i^d = \left[\frac{(3+\varrho_i(c))}{2}\right] \cdot q_i^d.$$

Proof: *It is immediate, simply replacing the price and equilibrium quantity q_i^d for each profit function for each firm $i = E, N, I$, and simplifying appropriately.*■

Therefore, the discount factor δ expresses the extend to which any country remain under OPEC cartel. Indeed, an inefficient player will need a higher δ to remain in the cartel agreement. Now we can state the second result of the paper.

Proposition 5: *In the infinitely repeated game, the common discount factor that each country need to maintain the collusive agreement is*

$$\delta_i = \frac{q_i^d(3+\varrho_i(c)) - q_i^c}{q_i^d(3+\varrho_i(c)) - q_i^*(3+\varrho_i(c))}.$$

Particularly, the most inefficient group, I, needs the higher minimum discount factor, and therefore, it fixes δ by,

$$\widehat{\delta} = \frac{q_I^d(3+c) - q_i^c}{q_i^d(3+c) - q_i^*(3+c)}.$$

Finally, when $c \geq 0,41$ the cartel would cease to exist.

Proof: *First two statements are obtained simply replacing each function of profits properly in the necessary and confirming that δ_I is the highest discount factor for all values of $c \in (0,1)$. The last statement is obtained taking the value 1 in the discount factor δ_I verifying that it occurs when $c^* = 0,411883$. Note that although we are considering the total market cartelization, it would be posible the partial cartel with companies E and N if $0,41 \leq c_N^* < 0,571049$. This completes this proof.*■

Summing up, two relevant result from the standpoint of the cooperative perspective are obtained: (i) cartel members may assign production quotas according to the relative efficiency in order to preserve OPEC cohesion with an *efficient profit-sharing rule,* (ii) in the case that a given country experiments production problems, such a country prefers to leave the cartel by cheating rest of memebers (i.e., by producing a quota unilateraly).

4 Concluding remarks

In this paper we investigate the extend to which OPEC behave as a cartel organization. We want to study if asymmetries in production cost may be acomodate by an heterogenous cartel. In particular, our hypothesis is that OPEC country members agree in an output quota such that every contry prefers to adhere the cartel instead of compete unilaterally in the international market.

First, it is conducted a cluster analysis in order to find homogenous groups in terms of output during the period under study. We found that three homogeneous groups can be characterized. We also find that those countries that leave the cartel organization belong to that group with lower quotas; thus, it is argued that they are not able to fulfill the agreement. Contrary to this, countries that adhere the cartel present an increasing (an monotonic) production profile, so the organization is interested in it.

Second, it is presented a cartel model that explicitly assume asymmetries in cost. We study the incentives to adhere the cartel and also the issue of cartel stability. Our results are on the line with the data analysis. Those countries with lower production quotas are more tempted to abandon the cartel, so OPEC stabilty strongly depends of such a countries.

Further research should include more variables in the cluster analysis in order to deteremine up to what extend politic affairs and other variables explain OPEC behaviour.

Acknowledgements

Carlos Gutiérrez-Hita would like to thank financial support from Spanish Department of Science and Technology (through research projects MTM2008-06778-C02-01 and ECO2009-09120), and Basque Government (through research project IT-313-07). The usual disclaimers apply.

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Appendix 1

- Profit-maximizing behaviour of Cournot competitors:

Each group maximize profits,

$$\pi_i(q_i, q_{-i}) = p(q_i, q_{-i})q_i - (1 + \varrho_i(c))q_i^2/2$$

with respect to q_i. By assuming interior solutions $q_i > 0$ first order conditions

$$\frac{\partial \pi_i(q_i, q_{-i})}{\partial q_i} = 1 - q_{-i} - q_i(3 + \varrho_i(c)) = 0,$$

yields a reaction function $q_i(q_{-i}) = (1 - q_{-i})/(3 + \varrho_i(c))\frac{1-q_{-i}}{3+\varrho_i(c)}$, for $i = E, N, I$.

Under our assumptions profit function is strictly concave so first order conditions ar also sufficient.

- Cooperative behaviour (the most collusive outcome):

A cartel maximizes joint profits,

$$\Pi(q_i, q_{-i}) = (1 - q_i - q_{-i})(q_i + q_{-i}) - (1 + \varrho_i(c))q_i^2/2 - (1 + \varrho_{-i}(c))q_{-i}^2/2,$$

yielding a set of first order conditions,

$$\frac{\partial \Pi(q_i, q_{-i})}{\partial q_i} = 1 - 2q_{-i} - q_i(3 + \varrho_i(c)) = 0$$

for $i = E, N, I$.

- Deviation: a firm who cheat from the cartel agreement maximizes own profits so that

$$q_i^D(q_{-i}^*) = \frac{1 - 2q_{-i}^*}{3 + \varrho_i(c)}.$$