Reconsidering the scarcity factor in the dynamics of oil markets: An empirical investigation of the (mis)measurement of oil reserves *

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Abstract

This paper sheds light on the importance of the (mis)measurement of oil reserves in the market dynamics. Using proven oil reserves from three different institutional data sources and for two groups of oil-exporting countries (OPEC members and OECD major oil-exporting countries), we demonstrate that estimates of oil reserves from different institutions are likely to be driven by some common factors for the OPEC panel, which is not the case for the non-OPEC panel. The implications of these robust results from panel cointegration analysis can be seen on two levels. First, any discussion on the sources of reserves data seems not to be relevant since OPEC has an influence on the measure of its reserves whatever the energy agency that assesses them. Second, the growing literature on the oil curse should consider oil reserves as an endogenous variable for the resource abundance.

Keywords: Oil exports; Crude oil reserves; Oil prices

JEL classification: C33; F40; Q43

1. Introduction

The effects of oil shocks on economy are source of global concerns. These concerns gave rise to an extensive literature focused on the oil pricing mechanisms of producing countries, particularly those of the Organization of the Petroleum Exporting Countries (OPEC). Several studies have therefore questioned whether OPEC has a market power, or not, over the pricing of oil. Varied answers and different reasoning have been provided so far. Griffin (1985), for instance, argues that the market sharing is the best suitable model for OPEC, but the competitive model better represents the non-OPEC countries. Kaufmann et al. (2004) argue that OPEC can influence real oil prices through decisions concerning production, quotas, and operable capacity, while several other scholars support that OPEC is a cartel at least on a period of time (Gülen, 1996; Loderer, 1985; Bremond et al., 2012). However, some other studies have shown evidence to the contrary, arguing that OPEC does not act as a cartel (e.g., Ramcharran, 2001) and even that oil price fluctuations are mainly demand-driven rather than supply-driven (Kilian, 2009).

Although this literature still provides mixed (even contradictory) results, a common point that can be found in the empirical studies is that different scholars used consistently and systematically production and price variables in econometric tests. They do not appear to be concerned about the oil reserves depletion. This empirical strategy may seem problematic at least in one way. Oil is an exhaustible resource; the scarcity dimension should appear as an important element when analyzing oil market dynamics (Esfahani et al., 2014). The fact that some former oil-exporting countries have become net importers (e.g., the Great Britain) demonstrates that the stock is not renewable at will and that any analysis should consider the exhaustible nature of oil.

Nevertheless, the aforementioned studies, up to date, have ignored this non-renewable characteristic of oil, and studies that try to figure out this point are very sparse (Polasky, 1992; Pickering, 2008). This study attempts to tackle this point.

Indeed, to avoid using the reserve variables when testing oil market dynamics, scholars often mentioned the falsification and the measurement errors associated with data on oil reserves (Pickering, 2008). However, they do not investigate in which way the potential falsification and measurement errors could affect their results? Are they random or systematic? And ultimately, can these errors help to understand the oil market dynamics? This paper precisely investigates these issues. Specifically, we undertook a novel approach based on the quantification of the divergences between proven oil reserves from three major sources of oil reserves data, namely British Petroleum (BP), OPEC and U.S. Energy Information Administration (EIA).

We explore these divergences through two sets of oil-exporting countries, namely the members of OPEC and the net oil-exporting countries of Organization for Economic Co-operation and Development (OECD). This approach to benchmark the behavior of OPEC countries with that of net oil-exporting countries of OECD is relevant in various ways. Indeed, the net oil-exporting countries of OECD are among the key players in the world energy market (e.g., Norway is the third largest energy-exporting country in the world (IEA, 2011)). These countries are shown to be the most democratic ones, among oil countries.[1] Therefore, one might expect that their statement on oil reserves should be more transparent and more reliable than those of the countries of OPEC (see Laherrere, 2001). We study whether this is actually the case.

[1] See polity IV project: http://www.systemicpeace.org/polity/polity4.htm

To sum up, the approach proposed herein should be able to indicate whether the divergences in oil reserves are anecdotic, systematic or random, and whether there is some causality between reserves data. To address these issues, we used panel co-integration and causality analysis on the aforementioned samples of countries (OPEC countries and net exporting countries of the OECD) over the period 1980-2013.

The remainder of the paper is organized as follows. In the next section, a brief literature review on oil market dynamics is given along with both theoretical and empirical aspects. In Section 3, methodological framework is described. In Section 4, the results of the econometric study are presented and their implications discussed. Finally, Section 5 concludes the paper.

2. Literature review and theoretical arguments

Oil is an exhaustible resource, but essential to most contemporary human activities. However, oil wealth is unevenly distributed among different parts of the world. According to OPEC (2009), the 12 countries of OPEC account for over two thirds of oil reserves. In such a context, any disruption of price increase raises some suspicions among many observers and scholars, especially since OPEC itself claims as an organization that can eliminate fluctuations in the oil market.[2]

While economists have been interested by the power of OPEC countries on the oil market, geologists have been concerned about the reliability of the data on which economists base their reasoning in order to derive conclusions on this subject. Thus Laherrere (2001) argues that the data used by economists, including oil production and oil reserves, available from public sources, such as BP, EIA, OPEC, are political data as

[2] For more information see http://www.opec.org/opec_web/en/about_us/23.htm

opposed to technical data held by geologists. Consequently, the analyses of economists fail to account for the exhaustible nature of oil resources (Laherrere, 2001).

The cartel explanations of the behavior of OPEC countries appear to corroborate these views. In the cartel approach, the scarcity factor can be ruled out since, unlike the theory of exhaustible resources, there is no stock depletion in perspective and flows between consumption and supply can be sustained through the discoveries of new oil reserves. Therefore, in the absence of scarcity, if price is above the competitive level, this indicates the existence of monopoly rent (Adelman, 2002; Smith, 2005; Gülen, 1996).[3]

Even those who contradict the cartel approach do not give too much weight to the exhaustible nature of oil. Thus, Kilian (2009) shows that oil price fluctuations are driven by demand shocks rather than supply shocks. More specifically, the author suggests that control on the production of producing countries, including those of OPEC, does not play significant role in the pricing of oil.

In contrast to the aforementioned views, in a recent paper, Esfahani et al. (2014) dispute any strategy that does not account for oil reserves when studying oil market dynamics. The authors claim that if the purpose is to assess whether or not OPEC has power on oil prices, it is necessary to understand the mechanisms underlying the behavior of OPEC countries with respect to their oil reserves. In addition, it has been demonstrated that oil reserves represent the relevant measure of resource abundance as opposed to resource intensity that constitute other measures of oil wealth (Norman, 2009; Van der Ploeg and Poelhekke, 2010).

[3] To be complete, some scholars have also followed the non-cartel approaches. These approaches include a patchwork of theories, the most recurrent ones are: competitive models, backward bending and property rights model.

However, several reasons have been claimed to avoid using oil reserves as a key element of oil market dynamics. A first reason can be drawn from the cartel approach, which has been underlined above. In that framework, technological progress can overcome the depletion of oil, and therefore the issue of scarcity does not arise. On this point, Watkins (2006) argues that remaining oil reserves have increased by 80% over the period 1973-2003, which, according to the author, demonstrates that the stock of oil is sufficient to cope with the growing needs in oil. The author concludes that the only reason that could crowd out oil as a main source of energy is any source much cheaper than oil. Another reason may indicate the fact that oil countries do not use the same convention when declaring their reserves. According to Laherrere (2001), there are at least three oil measurement conventions. The Securities and Exchange Commission (SEC) convention from USA has a market orientation. Within this convention, oil firms might be interested to exaggerate on the quantity of reserves in order to positively impact their assets value in stock markets. Russia has a special classification defined in 1979, which takes the theoretical maximum recovery,[4] the opposite of the US rules, and this may lead to artificially raise the level of reserves. Regarding the OPEC countries, proven reserves determine the quotas. Within this convention, countries have incentives to declare high level of reserves in order to get a high level of quotas (Laherrere, 2001).

Whatever the reason, it seems relevant to investigate on these divergences and to question their relationships with key variables of oil markets. The following sections attempt to address these issues.

[4] See Laherrere (2001) for an extensive review of this point.

3. Empirical Analysis

Our identification strategy is based on three steps. In a first step, we check whether proven oil reserves from the three sources interact differently with the key variables of the oil market, including oil price and exports. According to the results, in a second step we investigate the differences in oil reserves through the two groups of countries, namely OPEC and OECD countries. In a third step, we examine whether some oil-related variables might explain these differences. But before this, it is relevant to describe data and empirical methodology that are used in this study.

3.1. Data and methodology

The annual data used in this study cover the period from 1980 to 2013 for ten OPEC countries: Algeria, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates and Venezuela; and three major non-OPEC oil-exporting countries (or three OECD oil exporters): Canada, Mexico and Norway. We excluded Angola and Ecuador from the OPEC sample since these two countries joined OPEC in 2007 and thus cannot be in accordance with the long-term OPEC behavior. Regarding the OECD countries, we considered only the net oil-exporting countries in order to have a fairly homogeneous group able to serve as a comparison group to OPEC countries that are also net oil-exporting ones. Thus, countries like the United States or the United Kingdom, that are among the important oil producing countries in OECD, are not in the non-OPEC panel as they are currently net oil-importing countries (EIA, 2014). Data for crude oil exports are in thousand barrels per day (Mbbls/d) and obtained from the OPEC's Annual Statistical Bulletin (OPEC, 2014). It is worth noting that oil exports directly determine the country's revenues and have a significant impact on the economy in terms of current account position or fiscal balance. Therefore, the use of oil exports should be prioritized when analyzing the oil market related issues (Esfahani et al., 2014). Data for proven crude oil reserves are expressed in million barrels (MMbbl) and, as discussed above, come from three different sources, namely the BP Statistical Review of World Energy (BP, 2014), the U.S. Energy Information Administration (EIA, 2014) and (OPEC, 2014). On the other hand, price data include crude oil prices in 2013 U.S. dollars per barrel ($/bbl) and come from the BP Statistical Review of World Energy (BP, 2014).

To begin our empirical analysis, we firstly examine the stationarity properties of the variables under consideration by using panel unit root tests. This is a necessary condition to avoid spurious regression, and on the other hand, the results of the unit root tests will have implications for the choice of the econometric models, which will be then estimated with different techniques. In the first place, we employ the LLC unit root test (Levin et al., 2002) which is an extension of the standard Augmented Dickey Fuller (ADF) test to the panel data framework.

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \sum_{j=1}^{k} \alpha_j \Delta y_{it-j} + \varepsilon_{it} \tag{1}$$

where Δ is the first-difference operator, y_{it} is the value of the series to be tested for country i in period t, k is the number of lags and ε_{it} is a white noise error term. The LLC test assumes β_i to be identical across countries. Then the null hypothesis of $b_1 = b_2 = \ldots = b_i = 0$ for all i can be tested against the alternative hypothesis of $b_1 = b_2 = \ldots = b_i < 0$ for all i (i.e. the null of panel being unit root series against the alternative hypothesis of panel being stationary series). Im et al. (2003) relaxed the assumption of identical β_i coefficient across countries and proposed the so-called IPS unit root test which allows thus for a heterogeneity of β coefficients. Then it tests the null hypothesis of $\beta_i = 0$ for all i against the alternative hypothesis of $\beta_i < 0$ for all i. In order to check the robustness of the results, this paper employs also Fisher-type tests proposed by Maddala and Wu (1999) and Choi (2001). The basic idea of their method is to combine the estimated significance levels (i.e. the *p*-values) from individual ADF or Phillips-Perron (PP) unit root tests. More specifically, first the *p*-values for each country *i* (π_i) should be estimated, then the test statistics can be obtained by $\lambda = -2\sum_{i=1}^{N} ln\pi_i$ that has a χ^2 distribution with $2N$ degrees of freedom, where N stands for the number of countries in the panel. The main advantages of this method are that it can be used in the presence of an unbalanced panel (which is not the case in this study) and that the lag length of any variable in the ADF regressions given in Eq. (1) can be specified separately for each country, providing hence more robustness against the choice of a common lag structure in the panel. Furthermore, through Monte Carlo simulations the authors show that this non-parametric method outperforms the IPS and LLC unit root tests. Besides these first-generation tests we also employed one of the second-generation panel unit root tests in order to account for any cross-sectional dependence. In fact, as emphasized in the related literature (for instance, see Pesaran, 2004, 2007), in panel data, a cross-sectional dependence may emerge from unobserved common shocks, which then become part of the disturbance term. This issue is particularly important in the context of oil market dynamics that can imply substantial cross-sectional interactions. Thus, Pesaran cross-section dependence (CD) test (Pesaran, 2004) is employed to deal with this issue. In the case where cross-sectional dependence is found to exist, Pesaran cross-sectional IPS (CIPS) test (Pesaran, 2007), which augments the IPS framework by including cross-sectional mean of the variable under consideration, can be used to test for unit root in the panel data.[5]

Once the order of integration of the series is verified, and if all of them are found to be non-stationary in their levels but stationary in first difference (i.e. integrated of order one, that is, I(1)), cointegration analysis can be carried out in order to test whether or not a long-run equilibrium relationship exists among the variables involved in the analysis and, if so, to analyze both their short- and long-run dynamics. For this purpose, we use the panel cointegration technique proposed by Pedroni (2004) who extends the two-stage procedure suggested by Engle and Granger (1987) to panel data. Then a panel cointegration model of oil exports can be implemented as follows:

$$X_{it} = \alpha_{0i} + \alpha_{1i} R_{it} + \alpha_{2i} P_{it} + u_{it} \tag{2}$$

where *X*, *R* and *P* represent oil exports, oil reserves and oil prices for country *i* in year *t.* α_{0i} is a country-specific fixed effect and other coefficients of the model can change with individual countries. As such, the test accounts for the heterogeneity in the long-run cointegrating vectors. Based on this, to test the stationarity of the estimated residuals (u_{it}), Pedroni (2004) proposed four statistics that are obtained by pooling the autoregressive coefficients across different countries. This approach is called within-dimension or panel approach and provides (1) panel variance *v*-statistic, (2) panel ρ-statistic, (3) panel *PP*-statistic, and (4) panel *ADF*-statistic. Pedroni (2004) proposed also

[5] Note that one should pay much more attention to the cross-sectional dependence issue while using panel data having cross-sectional dimension (N) greater than time dimension (T). Although for all the panels considered in the present study, T is largely higher than N, we employ these tests to assess the robustness of other tests once cross-sectional dependence is accounted for. For a description of the CD and CIPS tests in detail the reader is referred to the above references.

a second type test called "between-dimension" or group approach, which provides averages of the individually estimated coefficients by means of three statistics, that are, (5) group ρ-statistic, (6) group *PP*-statistic, and (7) group *ADF*-statistic.

To assess the robustness of the results we also employ Westerlund's (2007) cointegration test with bootstrap approach. Of the four statistics computed within the framework of this test, two (namely P_t and P_a) test the hypothesis that the panel is not cointegrated as a whole, while the remaining two (namely G_t and G_a) test the null hypothesis of no cointegration against the alternative that at least one country in the panel is cointegrated. Contrary to Pedroni's (2004) test, Westerlund's (2007) cointegration test, which is a second-generation test, is not residual based and it can consider cross-sectional dependence. It s therefore complement to the above-mentioned CD and CIPS tests. It is also reported to have good small-sample properties (see Westerlund (2007) for more details and derivation of the four test statistics).

The cointegration test results will then indicate which panel causality test should be implemented in the next stage of the empirical work. If the variables involved in the analysis are not cointegrated, vector autoregressive (VAR) model should be specified using differenced data and the results will indicate short-run causal links between the variables. In our case a VAR system can be written as follows.

$$\Delta X_{i,t} = \lambda_{1i} + \sum_{n=1}^{m} \gamma_{11n} \Delta X_{i,t-n} + \sum_{n=1}^{m} \gamma_{12n} \Delta R_{i,t-n} + \sum_{n=1}^{m} \gamma_{13n} \Delta P_{i,t-n} + e_{1i,t} \tag{3.1}$$

$$\Delta R_{i,t} = \lambda_{2i} + \sum_{n=1}^{m} \gamma_{21n} \Delta X_{i,t-n} + \sum_{n=1}^{m} \gamma_{22n} \Delta R_{i,t-n} + \sum_{n=1}^{m} \gamma_{23n} \Delta P_{i,t-n} + e_{2i,t} \tag{3.2}$$

$$\Delta P_{i,t} = \lambda_{3i} + \sum_{n=1}^{m} \gamma_{31n} \Delta X_{i,t-n} + \sum_{n=1}^{m} \gamma_{32n} \Delta R_{i,t-n} + \sum_{n=1}^{m} \gamma_{33n} \Delta P_{i,t-n} + e_{3i,t} \tag{3.3}$$

where the λ coefficients stand for the country fixed effects, e is the error term and *m* is the order of lags on the first differenced variables that can be determined by using Akaike information criterion (AIC) or Schwartz information criterion (SIC). Then the hypothesis of non-causality can be tested by looking at the joint significance of γ parameters.

In the case of a long-run relationship between the variables, a vector error correction (VEC) model should be used instead of a VAR model. Then Eqs. (3.1-3.3) take the following form.

$$\Delta X_{i,t} = \lambda_{1i} + \sum_{n=1}^{m} \gamma_{11n} \Delta X_{i,t-n} + \sum_{n=1}^{m} \gamma_{12n} \Delta R_{i,t-n} + \sum_{n=1}^{m} \gamma_{13n} \Delta P_{i,t-n} + \phi_1 ECT_{i,t-1} + e_{1i,t} \tag{3.4}$$

$$\Delta R_{i,t} = \lambda_{2i} + \sum_{n=1}^{m} \gamma_{21n} \Delta X_{i,t-n} + \sum_{n=1}^{m} \gamma_{22n} \Delta R_{i,t-n} + \sum_{n=1}^{m} \gamma_{23n} \Delta P_{i,t-n} + \phi_2 ECT_{i,t-1} + e_{2i,t} \tag{3.5}$$

$$\Delta P_{i,t} = \lambda_{3i} + \sum_{n=1}^{m} \gamma_{31n} \Delta X_{i,t-n} + \sum_{n=1}^{m} \gamma_{32n} \Delta R_{i,t-n} + \sum_{n=1}^{m} \gamma_{33n} \Delta P_{i,t-n} + \phi_3 ECT_{i,t-1} + e_{3i,t} \tag{3.6}$$

where $ECT_{i,t-1}$ refers to error correction terms that should be derived from the long-run cointegrating relationship given in Eq. (2). Then returning back to Eqs. (3.4-3.6) the long-run causality can be tested by examining the significance of the speed of adjustment (ϕ) with or without γ parameters.

4. Empirical results and discussions

4.1 Does the impact of proven oil reserves differ depending on the data source?

We begin with testing for stationarity by examining the presence of unit root in the series. The above-mentioned panel unit root tests are performed on all panel data series. All unit root test results for both the OECD and OPEC panels are presented in the upper panel of Table A.1 in Appendix A (the lower panel of the table (i.e. unit root results for the variable *DF*) will be discussed later). Table A.1 gives also the CD test results. The null hypothesis of independence is strongly rejected for all variables in the OPEC panel while it cannot be rejected for the reserves variable in the non-OPEC panel. This result provides a strong indication that there is no cross-country interaction between the oil reserves data in the oil-exporting OECD countries. Overall, the results indicate that all variables under study exhibit a unit root process and they are all integrated of order one.[6]

Since all variables are found to be I(1), the second stage consists of testing for the existence of a cointegration relationship between them. As implied by Eq. (2), we use Pedroni's (2004) panel cointegration test and the results are presented in Table 1.

[Table 1 here]

For the OPEC panel all statistics reject clearly the null of no cointegration. For the OECD panel, however, none of the tests indicates the existence of a cointegrating relationship between the variables *X*, *R* and *P*. Furthermore, the results of Westerlund's (2007) panel cointegration test support this outcome (see Table B.1 in Appendix B). As a result, we can reasonably conclude that, only for OPEC countries, oil exports have a long-run equilibrium relationship with respect to oil reserves and prices. Furthermore, the results are robust with respect to the choice of the database used for the reserves

[6] It is worth noting that since the oil price variable *P* has the same values for all countries in the panels, adding cross-sectional means in the CIPS framework produces the same test statistics for *P* and its first difference ΔP. Hence the stationarity property of this variable is drawn based on other unit root tests.

variable.[7] This result has also methodological implications. Since the variables are cointegrated for the OPEC panel, the long-run dynamic interactions among them should be identified employing a VEC specification (see Eqs. 3.4-3.6). On the other hand, for the case of OECD countries, a VAR model involving three non-stationary and non-cointegrated variables in first differences (see Eqs. 3.1-3.3) should be used to determine short-run dynamics.

Let us first present the empirical results of the VAR model for the non-OPEC panel. From the upper panel of Table 2 (i.e. estimations based on the reserves data from OPEC), it follows that all variables appear to be neutral with respect to each other with the exception of oil exports-reserves nexus, for which a short-run unidirectional causality running from oil reserves to oil exports can be identified. We conclude that, although for the case of the three OECD oil-exporting countries, the three variables do not "move together" in the long run, the level of oil reserves have a causal impact on oil exports in the short run. In other words, annual variations in oil reserves may affect the short-run behavior of oil exports, and this is the only interaction that occurs between these three variables. This result however does not hold when the reserves data are obtained from EIA (2014) instead of OPEC (2014). The results reported in the lower panel of Table 2 show no impact of reserves on oil exports when using data from EIA (2014). This implies that depending on the sources of oil reserves, scholars may lead to different conclusions when examining the same dynamic relation within the same sample.

[7] As noted above, we have also conducted all econometric tests using the reserves data from BP (2014) (not reported here). The unit root and cointegration tests give the same results as obtained by using EIA (2014) and OPEC (2014). The causality results follow those that obtained with the OPEC's database. This is not surprising since BP uses OPEC's reserves data as face value.

[Table 2 here]

We now turn our attention to the case of OPEC countries for which the variables are found to have a long-run cointegrating relationship. Table 3 reports the estimation results of the VEC model.

[Table 3 here]

First consider the upper panel of Table 3 where the estimations use the OPEC's data for the reserves variable. The panel causality test results reveal that at the 1% level, unidirectional long-run causality runs from oil reserves and oil prices to oil exports. There is only a marginally significant (at the 10% level) short-run bidirectional causal link between oil exports and oil reserves. Neither oil exports nor oil reserves appear to have a causal effect on oil prices. Consider now the estimations based on the reserves data from the EIA given in the lower panel of Table 3. The long-run unidirectional causalities from reserves and oil prices to oil exports remain unchanged. This is thus a robust relation whatever the database used for the reserves data. Oil reserves statistically significantly cause oil exports also in the short run. More interestingly, oil prices are found to have a causal impact on the level of oil reserves both in the short and long runs. In other words, OPEC's reserves follow oil price movements as long as reserves data from the EIA are considered. In the next section, implications of these findings will be discussed.

4.2 Investigating the divergences

The previous section leads to the conclusion that the impacts of oil reserves in both panels are different depending on whether the reserves are estimated by OPEC or EIA. The subsequent questions are whether these differences in reserves are anecdotal, systematic or simply random. Either, these differences indicate a pure measurement error, as one cannot know exactly what the quantity of the oil in subsoil is. However, these reserves constitute an endogenous variable in the dynamics of oil, i.e. they are a product of common variables that affect their evaluation regardless of the data sources.

To study these questions, we analyze first the stationarity properties of the variable *DF* that indicates the differences between the OPEC's and the EIA's reserves data (that is we have $DF=R_{OPEC} - R_{EIA}$). We use once again the above-mentioned unit root tests and the results are reported in the lower panel of Table A.1 in Appendix A. While for the non-OPEC panel all tests indicate that the variable *DF* is non-stationary in levels, but stationary in first differences, they all reject the null of a unit root for the OPEC panel at the 1% level.

Based on these results we can reasonably conclude that the differences in the evaluation of reserves for the non-OPEC countries show a random evolution. This suggests that the results obtained for the non-OPEC panel using different sources (BP, EIA, OPEC) could be due to non-systematic measurement errors and that the estimations of oil reserves are not driven by common factors.

In contrast, the differences in the reserves data for the OPEC panel are stationary suggesting that they are driven by common variables and that the evolution of the differences in the estimated reserves is neither anecdotal nor random. This conclusion merits a more detailed investigation and this is what the next section deals with.

4.3 Causality between the data on oil reserves

We now turn our attention to the case of OPEC countries for which the differences in the reserves data are found to follow a deterministic evolution (i.e. co-movement of the OPEC's and the EIA's reserves data). The subsequent question is how this relationship can be characterized in terms of causality. In other words, we should assess the causal links between the two reserves data in order to provide a better understanding of this co-movement and to see which institution has an influence on the reserves estimations of the other.

Before we investigate the causality, we should examine the dynamic relationship between the two data. As discussed earlier, we check whether they are cointegrated and the results are shown in Table 4.

[Table 4 here]

The results clearly indicate that the oil reserves estimations of the two institutions are cointegrated. Taking into account cross-sectional dependence in these data, Westerlund's (2007) test confirms also this finding (see Table B.2 in Appendix B). The two reserves data are not only instantaneously linked (i.e. stationarity of *DF*) but also have a long-run equilibrium relationship. Now the estimation of the causal links can be done using a bivariate VEC model that involves R_{OPEC} and R_{EIA}. The results are given in Table 5.

[Table 5 here]

From the causality results, it follows that R_{OPEC} causes R_{EIA} both in the long and short runs. The interpretation of this result is straightforward. The oil reserves estimations of OPEC have an influence on those of EIA. If one pushes further this result to get a stronger argument on that relationship, one might reasonably conclude that OPEC has an authority on the estimations of its own reserves and that if the reserves data should be seen as a political variable, than OPEC seems to have a political power over other countries at least with respect to the oil market.

To sum up, these results demonstrate that the assessments of the oil reserves of OPEC countries are not random regardless of the sources (OPEC, EIA and BP). While the co-movement of reserves from OPEC and BP can be explained by the fact that BP uses the OPEC's statistics as the main data source of oil reserves for OPEC countries, the non-random or systematic gap between OPEC and EIA is cumbersome. Although the two agencies seem to assess the oil reserves of OPEC members much more independently, their evaluations seem to follow an equilibrium relationship in which EIA's data are dictated by the OPEC's estimations.

5. Conclusion

In contrast to the most of the studies in the field, this paper has explicitly investigated the exhaustible characteristic of oil resources and its interaction with key variables in the oil market. More specifically, we have examined the dynamic relationship between oil exports, oil reserves and prices for two country samples, the OPEC countries and the net oil-exporting OECD countries. Different data sources have been used for the reserves variable in order to see whether empirical results depend on the choice of the data source.

In short, our results suggest that the scarcity constraint is not expressed in the same way in two types of oil-exporting country panels. For the OPEC panel, the cointegration analysis highlights a long-term relationship between oil reserves, oil exports and prices. More interestingly, we find no cointegrating relationship between these variables in the non-OPEC panel. These cointegration results hold true whatever the database chosen for the reserves variable. However, as regards causality, the results vary depending on the data choice. The most remarkable difference is found in the oil reserves-oil prices relationship for the OPEC countries. Oil prices are found to have a causal influence on the OPEC's oil reserves provided that the reserves data from the EIA are used in the estimations.

In order to understand more thoroughly the reasons behind these findings, we investigated the origin of these differences for the same variable by analyzing time-series properties of the data and we found that the evolution of the estimates of oil reserves for OPEC countries has a long-run relationship and that the OPEC's estimations cause the ones from other institutions. In contrast, regarding the non-OPEC countries the differences in oil reserves data tend to be random.

The implications of these robust results can be seen on two levels. First, without providing empirical evidence on the market power of OPEC, the results of this paper reveal the influence of OPEC countries on the evaluation of their reserves whatever the energy agency that assesses them. This means that any discussion on the sources of reserves data by scholars seems not to be relevant since OPEC has an influence on the measure of its reserves. Moreover, since the cointegrating relationship implies that the reserves estimations from different institutions may be pulled by some other common factors, future research can determine and test those factors having potentially an influence on the reserves estimates. Second, the growing literature on the oil curse should consider oil reserves as an endogenous variable for the resource abundance. The results of this paper indicate that the changes in oil reserves of OPEC might have a relationship with the oil market variables, which are commonly involved in the econometric estimates of this strand of the literature. The bottom line is that differences in reserves estimates are not only a question of measurement error and that oil reserves should not be considered as an exogenous variable regardless of the energy data sources.

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Appendix A. Unit root and cross-sectional dependence tests

[Table A.1 here]

Appendix B. Westerlund panel cointegration tests

[Table B.1 here]

[Table B.2 here]

Tables

Table 1. Pedroni (2004) panel cointegration tests for the full model

	OPEC panel		Non-OPEC panel	
	OPEC data	EIA data	OPEC data	EIA data
Within-dimension approach				
Panel *v*-Statistic	2.997***	3.792***	0.094	-1.001
Panel *ρ*-Statistic	-1.642**	-2.387***	-0.685	1.472
Panel *PP*-Statistic	-2.973***	-4.116***	-0.984	1.555
Panel *ADF*-Statistic	-3.838***	-3.984***	-1.135	-0.907
Between-dimension approach				
Group *ρ*-Statistic	-1.957*	-1.662**	0.442	1.699
Group *PP*-Statistic	-3.075***	-3.567***	-0.129	1.650
Group *ADF*-Statistic	-2.639***	-3.294***	-1.040	-0.392

Notes: *, ** and *** reject the null of no cointegration at the 10%, 5% and 1% levels, respectively. The optimal lag lengths are selected based on AIC and SIC.

Table 2. Panel causality tests for the non-OPEC panel

	Dependent variables	Short-run sources of causation (independent variables)		
		ΔX	ΔR	ΔP
OPEC data	ΔX	-	5.531**	0.899
	ΔR	0.0007	-	0.001
	ΔP	1.253	0.232	-
EIA data	ΔX	-	0.446	1.003
	ΔR	0.004	-	0.003
	ΔP	1.533	0.558	-

Notes: F-values are reported for all of the independent variables. The optimal lag length of 1 is based on AIC. ** indicates statistical significance at the 5% level.

Table 3. Panel causality tests for the OPEC panel

	Dependent variables	Sources of causation (independent variables) Short-run causality				Strong (joint) causality		
		ΔX	ΔR	ΔP	ECT	$ECT/\Delta X$	$ECT/\Delta R$	$ECT/\Delta P$
OPEC data	ΔX	-	7.08*	3.28	-2.31**	-	17.7***	10.5***
	ΔR	6.65*	-	5.86	0.85	7.27	-	5.92
	ΔP	1.99	0.32	-	1.27	3.58	2.53	-
EIA data	ΔX	-	15.9***	5.07	-3.13***	-	29.0***	15.2***
	ΔR	3.32	-	11.5***	-0.86	4.31	-	12.2**
	ΔP	2.02	4.85	-	-0.58	2.11	2.30	-

Notes: t-values are reported for the error-correction term (ECT), F-values are given for other variables. The optimal lag length of 3 is based on AIC. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 4. Pedroni (2004) cointegration tests for the reserves data

Within-dimension approach	
Panel v-Statistic	10.44***
Panel ρ-Statistic	-4.976***
Panel PP-Statistic	-3.470***
Panel ADF-Statistic	-7.752***
Between-dimension approach	
Group ρ-Statistic	-3.733***
Group PP-Statistic	-4.240***
Group ADF-Statistic	-5.863***

Notes: *** rejects the null of no cointegration at the 1% level. The optimal lag lengths are selected based on AIC and SIC.

Table 5. Panel causality tests for the reserves data

Dependent variables	Sources of causation (independent variables)				
	Short-run causality			Strong (joint) causality	
	ΔR_{OPEC}	ΔR_{EIA}	ECT	$ECT/\Delta R_{OPEC}$	$ECT/\Delta R_{EIA}$
ΔR_{OPEC}	-	0.257	1.92*	-	3.724
ΔR_{EIA}	134.4***	-	-24.4***	735.3***	-

Notes: t-values are reported for the error-correction term (ECT), F-values are given for other variables. The optimal lag length of 1 is based on AIC. * and *** indicate statistical significance at the 10% and 1% levels, respectively.

Table A.1: Panel unit root and cross-sectional dependence tests

	Variable	LLC	IPS	ADF	PP	CD	CIPS
OPEC	X	0.92	-0.26	17.8	27.8	18.2***	-2.81*
panel	P	0.62	1.10	8.43	9.86	39.1***	2.61
	$R_{(OPEC\ data)}$	2.03	2.56	11.0	28.6*	28.1***	-1.49
	$R_{(EIA\ data)}$	1.61	2.76	13.0	8.77	27.9***	-0.76
	ΔX	-7.03***	-11.0***	150***	266***	7.03***	-5.06***
	ΔP	-5.38***	-9.70***	124***	209***	38.5***	-
	$\Delta R_{(OPEC\ data)}$	-12.9***	-12.5***	174***	195***	0.02	-5.31***
	$\Delta R_{(EIA\ data)}$	-14.9***	-13.0***	179***	198***	2.30***	-5.49***
Non-OPEC	X	-0.70	-0.23	9.63	5.76	4.95***	0.67
panel	P	0.34	0.60	2.53	2.96	10.1***	2.61
	$R_{(OPEC\ data)}$	0.19	0.89	2.73	5.36	1.25	-
	$R_{(EIA\ data)}$	0.44	-0.01	4.72	7.22	0.63	-
	ΔX	-2.68***	-3.95***	31.6***	35.7***	0.06	-
	ΔP	-2.95***	-5.31***	37.4***	62.9***	9.95***	-
	$\Delta R_{(OPEC\ data)}$	-7.07***	-7.14***	52.6***	70.6***	0.09	-
	$\Delta R_{(EIA\ data)}$	-12.8***	-11.5***	85.0***	85.0***	3.92***	-6.19***
OPEC	DF	-4.45***	-5.18***	73.4***	67.9***	2.77***	-3.19***
panel	DDF	-	-	-	-	-	-
Non-OPEC	DF	0.06	0.49	5.62	5.61	1.71*	-0.92
panel	DDF	-11.0***	-10.1***	75.4***	77.3***	1.66*	-6.19***

Notes: Probabilities were computed on the assumption of asymptotic normality for the LLC and IPS tests and on the assumption of asymptotic χ^2 distribution for the ADF-Fisher and PP-Fisher tests. The choice of lag levels is based on AIC and SIC. For all tests except CD, *, ** and *** indicate rejection of the null of non-stationarity respectively at the 10%, 5% and 1% levels, while they denote rejection of the null of cross-sectional independence for the CD test which follows a normal distribution.

Table B.1. Westerlund (2007) panel cointegration test for the full model

	OPEC panel		Non-OPEC panel	
	OPEC data	EIA data	OPEC data	EIA data
G_t-Statistic	-2.501	-2.601	-2.074	-1.214
	(0.055)	(0.026)	(0.471)	(0.939)
	[0.040]	[0.000]	[0.400]	[0.820]
G_a-Statistic	-10.90	-12.80	-10.163	-3.275
	(0.185)	(0.032)	(0.387)	(0.947)
	[0.020]	[0.000]	[0.220]	[0.860]
P_t-Statistic	-12.78	-12.57	-3.754	-3.260
	(0.000)	(0.000)	(0.223)	(0.388)
	[0.000]	[0.000]	[0.280]	[0.380]
P_a-Statistic	-17.41	-18.82	-9.256	-4.748
	(0.000)	(0.000)	(0.147)	(0.635)
	[0.000]	[0.000]	[0.220]	[0.540]

Notes: The P-values (in parentheses) are given by a test based on the normal distribution and the robust P-values (in brackets) are obtained from a test based on the bootstrapped distribution.

Table B.2. Westerlund (2007) panel cointegration test for the reserves data

	Value	P-value	Robust P-value
G_t-Statistic	-5.553	0.000	0.000
G_a-Statistic	-14.848	0.000	0.110
P_t-Statistic	-10.760	0.000	0.030
P_a-Statistic	-17.282	0.000	0.010

Notes: The P-values are given by a test based on the normal distribution and the robust P-values are obtained from a test based on the bootstrapped distribution.