ALL TIME CHEATERS VERSUS CHEATERS IN DISTRESS: AN EXAMINATION OF CHEATING AND OIL PRICES IN OPEC

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Abstract: This paper investigates the OPEC quota share system and whether there is any pattern to "cheating". Using threshold cointegration methods, we examine each OPEC member's cheating behavior in periods of rising and falling real oil prices. Most OPEC members behave differently in response to rising oil prices than falling oil prices. For shocks of typical historical size, most members overproduce their quotas regardless of the direction of the real oil prices in the medium to long run. However, in response to large real oil price shocks, most members conform to a "public finance argument" whereby they underproduce their quotas in response to rising oil prices and overproduce in response to falling real oil prices. In an extended model with cheating by Saudi Arabia and other OPEC members, we find no statistically significant relationship between Saudi Arabian cheating and other cheating. The impulse response functions reveal that for typical shocks, neither Saudi Arabia nor other OPEC members absorb cheating by the other party. However, when there is a large incidence of cheating by other OPEC members, Saudi Arabia responds in kind: this forceful response is in line with a tit-for-tat strategy when there is "too much" cheating.
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ABSTRACT

Abstract: This paper investigates the OPEC quota share system and whether there is any pattern to "cheating". Using threshold cointegration methods, we examine each OPEC member's cheating behavior in periods of rising and falling real oil prices. Most OPEC members behave differently in response to rising oil prices than falling oil prices. For shocks of typical historical size, most members overproduce their quotas regardless of the direction of the real oil prices in the medium to long run. However, in response to large real oil price shocks, most members conform to a "public finance argument" whereby they underproduce their quotas in response to rising oil prices and overproduce in response to falling real oil prices. In an extended model with cheating by Saudi Arabia and other OPEC members, we find no statistically significant relationship between Saudi Arabian cheating and other cheating. The impulse response functions reveal that for typical shocks, neither Saudi Arabia nor other OPEC members absorb cheating by the other party. However, when there is a large incidence of cheating by other OPEC members, Saudi Arabia responds in kind: this forceful response is in line with a tit-for-tat strategy when there is "too much" cheating.

1. INTRODUCTION

The recent surge in crude oil prices necessitates a close examination of the world oil market and the behavior of the players therein. Undoubtedly, OPEC is one such player and one of its principal strategies is the quota share system. Inaugurated in 1982, the quota share system stipulates that each member country produce a certain level of crude oil. Since it is not explicitly clear how quotas within OPEC are assigned, some papers have attempted to explain and evaluate the quota allocation process (e.g., Bakhtiari 1992, and Gault et. al., 1999). There is agreement that production capacity is a major factor in the assignment of the quotas and the quotas are adjusted from time to time to coincide with the changes in market fundamentals (Dahmani and Al-Osaimy, 2001).

Although all OPEC countries agreed initially to the quota share system, they all have shown a clear tendency to deviate from their quota shares. A *casual* examination of quotas and actual production reveal that (i) cheating is a permanent phenomenon (ii) some countries cheat more than others (iii) the intensity of cheating varies over time. Even though numerous papers have examined OPEC behavior (e.g., Griffin 1985; Jones 1990; Dahl and Yucel 1991; Gulen 1996; Kohl 2002), limited attention has been paid to the empirical examination of the quota share system and its effectiveness within OPEC. One recent exception is Kaufman et al. (2004) who found that OPEC capacity utilization, quotas, cheating and OECD stocks of crude oil ‘Granger cause’ real oil prices but real oil prices do not Granger cause OECD capacity utilization, OECD production quotas, or cheating.

Rotemberg and Saloner (1986) argued that growing demand is a motive for oligopoly members to behave in a competitive way. When demand is relatively high the firm that lowers its price slightly gets to capture a large market until the others are able to change their prices. Others argue that the bias in allocating the quotas is an important reason behind the cheating behavior. Griffin and Xiong (1997) argue that the allocation is biased toward small producers and emphasize discount rates as a determinant of the volume of cheating. Countries that disregard the future for present gains cheat more than other countries.

According to Adelman (1986), discount rates figure prominently in oil production decisions. Lower oil prices translate into lower revenues for OPEC members, and in order to compensate for the loss of revenue, they increase production. By increasing their production, they are implicitly discounting the future more.

There is a good reason to expect fluctuations in oil price to influence cheating. Since most oil exporting countries rely heavily on oil revenues for public finance, in wake of lower oil prices one would expect a country to exceed its quota to compensate for falling oil revenues. If cheating takes place to compensate for lower revenues under falling prices, one would expect cheating to decrease when prices are rising. Is the cheating behavior within OPEC different when oil price are rising than when the prices are falling? Does cheating significantly alter real oil prices? Do some members particularly, Saudi Arabia, adjust their production to “absorb” some overproduction of the quotas by others? Does Saudi Arabia enforce the rules, and if so, does the underlying behavior conform to a tit-for-tat strategy?

This paper provides direct evidence on these questions and the behavior of cheating within OPEC using threshold cointegration methods with asymmetric adjustment. Specifically, we use threshold and momentum models of cointegration developed by Enders and Granger (1998) and Enders and Siklos (2001). These methods are suitable for testing whether cheating behavior within OPEC exhibits different patterns in response to rising and falling oil prices, as statistical properties of these methods are well established[1]. Moreover, threshold cointegration methods allow us to discern if each OPEC member, and OPEC as a whole, respond differently to a "small oil price shock" versus a "large oil price shock". The issue is germane since oil prices are currently at record high levels and understanding OPEC behavior is a major step towards understanding the global oil market.

2. DATA AND METHODOLOGY

We use monthly data from January 1986 through March 2004. The quota shares of OPEC members are obtained form *OPEC Annual Statistical Bulletin*, OPEC, 2003; the 2004 quota figures are from *Middle East Economic Survey*. The actual production data are form *Energy and Oil statistics Review*, OPEC, various issues. Price of crude oil is deflated using the consumer price index (CPI) of industrial countries; both are obtained from the *International Financial Statistics*, published by the International Monetary Fund.

We measure cheating (ch_{it}) by the percentage deviation of actual production (AP_{it}) from the assigned quota (Q_{it}) for each OPEC member, that is, $ch_{it} = AP_{it} - Q_{it} /$

Q_{it}. Cheating for OPEC is defined as the aggregate deviation of actual total oil production from the total OPEC quota. Descriptive statistics regarding cheating within OPEC are given in Table 1. A quick glance at the table reveals that "cheating" is practiced within a broad range over the sample period. While the UAE stands as the member to overproduce her quota the most at 17.6 percent per month, Indonesia, underproduces her quota at 1.7 percent per month on average. Venezuela and Iran also stand out as countries with a relatively high level of compliance within the OPEC quota system. OPEC members as whole overproduce their quotas by 3.4 percent per month. The highest variability of "cheating" occurs in Kuwait at 34.3 percent, followed by the UAE at 30.9 percent. Again, Indonesia stands as the OPEC member with the least variability of "cheating" at 4.6 percent.

Consider the following relationship between cheating and the real oil price[2] (p_t):

$$ch_t = \beta_0 + \beta_1 p_t + \mu_t, \tag{1}$$

where μ_t is a stationary random variable that represents the deviation from the long run equilibrium, if any. Notice that equation (1) is not a structural equation in that it is impossible to determine the sign of the relationship between cheating and the real oil price, assuming a market-clearing framework. The relationship between cheating and the real oil price can be of either sign, as oil supply and oil demand shifts may generate positive or negative correlations between the two variables depending on the magnitude of these shifts and the shape of the supply curve[3]. Moreover, additional variables such as demand side variables can influence cheating but these are assumed to influence cheating through oil prices.

Before outlining the methodology, we pretest the variables for stationarity using KPSS tests. The KPSS test results in Table 2 soundly reject the null hypothesis of stationarity for all series in levels for a majority of countries at the 10 percent level except the cheating measure for Libya, Kuwait and Qatar. For these countries cheating seems stationary. We proceed with the assumption that the real oil price and cheating for Algeria, Indonesia, Iran, Nigeria, Saudi Arabia, United Arab Emirates, Venezuela, and OPEC are difference stationary. Even though the cointegration framework is warranted in the presence of unit roots, conventional cointegration tests with linear adjustment are inappropriate if the dynamic adjustment of prices and cheating exhibit non-linear behavior.

For instance, Engel-Granger method depends on the OLS estimates of ρ in the following regression:

$$\Delta\mu_t = \rho\mu_{t-1} + \varepsilon_t \tag{2}$$

where μ_t is the residuals of the estimated regression in (1). If $-2 < \rho < 0$, then the two variables (ch_t and p_t) are cointegrated, which also implies that μ_t in (2) is stationary with mean zero. Note that (2) implies symmetric adjustment. In other words, $\Delta\mu_t$ equals ρ multiplied by μ_{t-1}, regardless of whether μ_{t-1} is positive or negative[4]. Thus, if the dynamic adjustment between cheating and oil prices is non-linear, equation (2) is misspecified.

According to Pippenger and Georing (1993) and Enders and Granger (1998) the standard tests for unit-roots and cointegration all have low power in the presence of misspecified dynamics. In our case, this is important since the linear relationship in equation (2) is misspecified if cheaters behave differently when the real oil price is falling than when it is rising. The key point is that if we presume the presence of asymmetric behavior in cheating, then the standard tests for unit roots and cointegration are not reliable and they must be modified to account for such asymmetric behavior.

As in Enders and Siklos (2001), a formal way to introduce asymmetric adjustment to our model is to let the deviation from the long-run equilibrium (i.e. μ_t) in Equation (1) behave as a Threshold Autoregressive (TAR) process. Thus, it's possible to replace (2) with

$$\Delta\mu_t = I_t\rho_1\mu_{t-1} + (1 - I_t)\rho_2\mu_{t-1} + \varepsilon_t \tag{3}$$

where I_t is the Heaviside indicator such that

$$I_t = \begin{cases} 1 & \text{if } \mu_{\text{t-1}} \geq \tau \\ 0 & \text{if } \mu_{\text{t-1}} < \tau \end{cases} \tag{4}$$

where τ is the value of a threshold.

Since the exact nature of the non-linearity may not be known, it is also possible to allow the adjustment to depend on the change in $\mu_{\text{t-1}}$ (i.e., $\Delta\mu_{\text{t-1}}$) instead of the level of $\mu_{\text{t-1}}$. In this case, the Heaviside indicator in equation (4) becomes:

$$I_t = \begin{cases} 1 & \text{if } \Delta\mu_{\text{t-1}} \geq \tau \\ 0 & \text{if } \Delta\mu_{\text{t-1}} < \tau \end{cases} \tag{5}$$

Enders and Granger (1998) and Enders and Siklos (2001) show that this specification is especially relevant when the adjustment is such that the series exhibits more "momentum" in one direction than the other; the resulting model is called momentum-threshold autoregressive (M-TAR) model.

Having different values of ρ_1 and ρ_2 implies asymmetric adjustment. Specifically, the adjustment is $\rho_1\mu_{t-1}$ when μ_{t-1} is above threshold, whereas the adjustment is $\rho_2\mu_{t-1}$ when μ_{t-1} is below the threshold. A sufficient condition for stationarity of $\{\mu_t\}$ is -2 < $(\rho_1, \rho_2) <$ 0. Moreover, if the $\{\mu_t\}$ sequence is stationary, the least squares estimates of ρ_1 and ρ_2 have an asymptotic multivariate normal distribution (Tong, 1983). Therefore, if the null hypothesis $\rho_1 = \rho_2 = 0$ is rejected, it is possible to test for symmetric adjustment (i.e. $\rho_1 = \rho_2$) using a standard *F*-test. Since adjustment is symmetric if $\rho_1 = \rho_2$, the Engle-Granger test for cointegration is a special case of Enders and Granger (1998). If the errors in equation (3) are serially correlated, it's possible to use an augmented TAR model for the residuals. Thus, equation (3) is replaced by,

$$\Delta\mu_t = I_t\rho_1\mu_{t-1} + (1 - I_t)\rho_2\mu_{t-1} + \sum_{i=1}^{p}\beta_i\Delta\mu_{t-i} + \varepsilon_t \tag{6}$$

The critical values for the statistics needed to test the null hypothesis, $\rho_1 = \rho_2 = 0$, depend on the number of variables used in the co-integrating vector. Enders and Siklos (2001) report critical values for the TAR and M-TAR models containing two variables, called the Φ (for TAR adjustment), Φ^* (for the M-TAR adjustment). Since (1) contains two variables, we use the critical values reported by Enders and Siklos (2001) to test the null hypothesis. As there is generally no presumption as to whether to use the TAR or M-TAR model, the recommendation is to select the adjustment mechanism by a model selection criterion such as the Akaike Information Criterion (AIC) or Schwarz's Bayesian Information Criterion (BIC). Similarly, the lag length can be selected by AIC or BIC.

This framework presumes the value of the threshold τ is known; however in practice one has to estimate the value of the threshold. As in Chan (1993), and Enders and Siklos (2001), we find a consistent value of the threshold by a grid search. First, we sort the $\{\mu_t\}$ sequence (or the in case of the M-TAR model, $\{\Delta\mu_t\}$ the sequence) in an ascending order. In order to have reasonable number of observations in each regime we consider each μ_t between the lowest 15 percent and the highest 85 percent values of the series as a potential threshold. We then estimate regressions in the form of (6) using each μ_t as a potential value of the threshold. The value resulting in the lowest residual sum of squares is a consistent estimate of the threshold.

Similarly, the Johansen (1995) methodology uses the specification: $\Delta x_t = \pi x_{t-1} + \nu_t$

where: x_t is the (3 x 1) vector (e_t p_t p_t^*)’, π is a (3 x 3) matrix, and ν_t is a (3 x 1) vector of stationary disturbances that may be contemporaneously correlated. The crucial point to note is that the alternative hypothesis [i.e., rank(π) $\neq 0$] implicitly assumes a symmetric adjustment process around $x_t = 0$ in that for any $x_t \neq 0$, Δx_{t+1} always equals πx_t.

3. EMPIRICAL RESULTS

We test the null hypothesis of non-cointegration between cheating and the crude oil price against the alternative of cointegration with asymmetric adjustment. We exclude from the cointegration tests countries whose cheating is stationary (Kuwait, Libya, Qatar). For each of these countries, cheating is mean-reverting in the long run regardless of the real oil price. The mean level by which Libya exceeds its quota is 2.9 percent per month, Kuwait 3.8 percent per month, and Qatar 5 percent per month in our sample. In order to investigate the dynamics of cheating for these countries, we estimate a model where *the level* of cheating is related to the changes in the real oil price. For the rest of the countries, there seems to be a relationship between cheating and the real oil price in the long run. Indeed, Table 3 reveals that the real oil price and cheating are cointegrated for all countries and for the OPEC as a whole. The critical values with one lagged change for the M-TAR model reported by Enders and Siklos (2001) are 6.63 (5 percent) and 8.84 (1 percent) respectively. As such the test statistics for $\rho_1 = \rho_2 = 0$ exceed the critical values at the 1 percent level reported by Enders and Siklos (2001) for all countries except for Algeria where the statistic is significant at the 5 percent level. The BIC selects M-TAR adjustment over TAR adjustment for all countries except for Venezuela. Moreover, the results for Venezuela also indicate cointegration as the test statistic exceeds the critical value at the 1 percent level. Note that the value of the threshold ranges from 0.0193 for Saudi Arabia to -0.0281 for Indonesia where the adjustment conforms to the M-TAR flag.

The null hypothesis of symmetric adjustment can be rejected for all countries in favor of asymmetric adjustment. The conventional F-statistics indicate asymmetric adjustment at the 1 percent level for OPEC, Algeria, Indonesia, Saudi Arabia, and the United Arab Emirates. For Nigeria and Venezuela asymmetric adjustment is significant at the 10 percent level. Note that the point estimates of ρ_1 and ρ_2 suggest substantially faster convergence for negative (below threshold) deviations from long run equilibrium than positive (above threshold) deviations, except for Indonesia and Venezuela. For example, for the OPEC as a whole, the point estimates of ρ_1 and ρ_2 suggest that negative deviations from the long run equilibrium resulting from decreases in cheating or increases in the real oil price (such that $\Delta\mu_{t-1} < 0.0164$) are eliminated at a rate of 35.2 percent per month while positive deviations are eliminated at only 7.7 percent per month. Overall, for OPEC as a whole and for Algeria, Nigeria, Saudi Arabia, and the UAE, negative deviations from long run equilibrium (such that $\Delta\mu_{t-1} <$ respective threshold) stemming from decreases in cheating or increases in the real oil price are eliminated faster. Similarly for Iran, negative deviations from long run equilibrium stemming from decreases in cheating are eliminated faster. In that sense, decreases in cheating and increases in real oil prices are reversed quickly whereas increases in cheating and decreases in the real oil price linger for a while for these countries. This behavior suggests that the OPEC quota system is not effective and the underlying behavior is more of a competitive nature. Perhaps, this reflects the underlying public finance needs of individual countries where many OPEC members overproduce their quotas in order to meet budgetary requirements.

On the other hand, for Indonesia and Venezuela, the point estimates of ρ_1 and ρ_2 suggest that deviations from the long run equilibrium stemming from increases in cheating are eliminated faster. In a sense, these countries behave much in line to preserve the cartel. Venezuela had long sought coordination of oil production before the formal establishment of OPEC in 1960 and is known to maintain a hard line within OPEC.[5]

4. CHEATING AND THE OIL PRICE: THE DYNAMIC ADJUSTMENT

In this section we examine the dynamic adjustment of cheating behavior and oil prices using an asymmetric vector error correction model. To that end, we estimate equations of the form:

$$\Delta ch_t = A_{11}^{+}(L)\Delta ch_{t-1}^{+} + A_{11}^{-}(L)\Delta ch_{t-1}^{-} + A_{12}^{+}(L)\Delta p_{t-1}^{+} + A_{12}^{-}(L)\Delta p_{t-1}^{-} - \alpha_1^{+} z_{t-1}^{+} - \alpha_1^{-} z_{t-1}^{-} + \mathrm{e}_{1\mathrm{t}} \quad (7)$$
$$\Delta p_t = A_{21}^{+}(L)\Delta ch_{t-1}^{+} + A_{21}^{-}(L)\Delta ch_{t-1}^{-} + A_{22}^{+}(L)\, p_{t-1}^{+} + A_{22}^{-}(L)\Delta p_{t-1}^{-} - \alpha_2^{+} z_{t-1}^{+} - \alpha_2^{-} z_{t-1}^{-} + \mathrm{e}_{2\mathrm{t}} \quad (8)$$
$$z_t^{+} = I_t\,(ch_t\text{-}\beta_0 - \beta_1\, p_t)$$
$$z_t^{-} = (1 - I_t)\,(ch_t\text{-}\beta_0 - \beta_1 p_t)$$

where the Heaviside indicator is set in accord with M-TAR adjustment except for Venezuela where it is TAR, $A_{ij}^{+}(L)$ are p-th order lag polynomials, $\Delta ch_t^{+} = max(\Delta ch_t$, 0), $\Delta ch_t^{-} = min(\Delta ch_t^{-}$, 0); Δp_t^{+} and Δp_t^{+} are similarly defined. For Kuwait, Libya, and Qatar where cheating is stationary, we estimate a dynamic model of the form:

$$ch_t = A_{11}(L)ch_{t-1} + A_{12}^{+}(L)\Delta p_{t-1}^{+} + A_{12}^{-}(L)\Delta p_{t-1}^{-} + \mathrm{e}_{1\mathrm{t}} \quad (9)$$
$$\Delta p_t = A_{21}(L)ch_{t-1} + A_{22}^{+}(L)\Delta p_{t-1}^{+} + A_{22}^{-}(L)\Delta p_{t-1}^{-} + \mathrm{e}_{2\mathrm{t}} \quad (10)$$

The specifications in equations (7)-(8) assume both short term and long term asymmetric adjustments as in Chen, Finney and Lai (2005) whereas some other papers such as Ewing, Hammoudeh, and Thompson (2006) use asymmetry in the short term. Even though some countries may be too small to influence oil prices, we do not make any presumption regarding the influence of cheating on oil prices for any country. The exact nature of the relationship between cheating and oil price can be determined empirically.

Using the specifications in (7)-(8) or (9)–(10), we test for weak exogeneity, Granger causality, and symmetry. The results are given in Table4.

The point estimates of the error correction terms indicate that the real oil price adjusts in the “wrong” direction in OPEC as whole (above threshold deviations), Algeria, Iran, Nigeria (above threshold deviations), Saudi Arabia (above threshold deviations), and the UAE. Of these error correction terms, several are significant. However, the majority of error correction terms for the real oil price are not significant indicating that the real oil price is weakly exogenous with respect to the long run relationship between cheating and the real oil price. This is particularly true for Saudi Arabia, the largest oil producer in the world, where neither of the error correction terms is significant. This implies that for Saudi Arabia, the real oil price does not adjust to “restore” the equilibrium between the real oil price and the level of cheating.

While the oil price Granger causes itself in all cases, cheating Granger cause itself in the OPEC as a whole, Algeria, Iran, and Venezuela. The real oil price Granger causes cheating in the OPEC as a whole, Algeria, Iran, Kuwait, Nigeria, and Venezuela. These results are in contrast to Kaufman et al. (2004), who find that real oil price fail to Granger cause cheating within OPEC. For Saudi Arabia, the UAE, and Indonesia the real oil price fails to Granger cause cheating. Indonesia has a fairly diversified domestic production base while the UAE and Saudi Arabia are considered as “low absorbers” of oil wealth because the latter countries have plentiful oil reserves and smaller populations, which makes them favor extending the commercial life of oil over time, and prefer moderate oil prices (Kohl, 2002). As such these countries do not have as pressing financial needs.

There is weak evidence that aggregate OPEC cheating Granger causes the real oil price (the p-value is 12.8 %). Similarly cheating does not seem to affect the real oil price for all OPEC members considered, except cheating by Indonesia and Iran. This may be due to offsetting production decisions where some members underproduce when others exceed their quotas. It may also reflect the endogenous changes in the quotas where quotas are raised for those overproducing members.

Note that, the symmetry hypothesis is strongly rejected for cheating for the OPEC as whole and for all individual members[6]. Thus, there is evidence that cheating responds to negative shocks differently than positive shocks. This implies that there may be a strong connection between oil price developments and cheating on part of OPEC members. Given rising populations, and increased fiscal dependence on oil, it seems OPEC members' cheating behavior is heavily influenced by oil price developments. Indeed, the OPEC in 1999 abandoned its previous market share strategy and adopted a revenue strategy where it aims to maintain a price target high enough to meet the financial requirements of its members (Ait-Laousinne, 2000; Kohl 2002). Finally, in most cases, the real oil price adjusts symmetrically to positive versus negative shocks as the symmetry is rejected at the 5 % level for all members. In Iran and Indonesia, there is weak evidence that the adjustment of the real oil price is asymmetric.

4.1. The Role of Saudi Arabia within OPEC

Being the world's largest oil producer, Saudi Arabia's role within the OPEC has been discussed extensively in the literature[7]. It is argued that in the beginning of 1980s, Saudi Arabia acted as a swing producer within OPEC where Saudi Arabian oil output adjusted to stabilize the OPEC production and the target price. Persistent cheating then forced Saudi Arabia to follow a tit-for-tat production strategy that is aimed at maintaining market shares (Griffin and Neilson 1994; Griffin and Xiong, 1997). In this section, we examine the dynamic interactions of cheating between Saudi Arabia and the rest of the OPEC. In order to account for the interactions, we let ch_{SA} denote cheating by Saudi Arabia while ch_{OPEC} denotes cheating by OPEC members other than Saudi Arabia ("other cheating"). We test for threshold cointegration by estimating an equation of the form:

$$ch_{SA,t} = \beta_0 + \beta_1 p_t + \beta_2 ch_{OPEC,t} + \mu_t \qquad (11)$$

The test results from this model are given in panel (a) of Table 5.

The test statistics indicate that the null hypothesis of non-cointegration can be strongly rejected in favor of cointegration with asymmetric adjustment. Moreover, the null hypothesis of symmetric adjustment is rejected indicating asymmetric threshold adjustment toward the long run equilibrium, while the BIC favors the M-TAR flag over the TAR flag. Finally, negative deviations from the long run equilibrium stemming from increases in the real oil price or decreases in cheating are eliminated eight times faster than positive deviations.

Next we estimate an *extended* error correction model similar to that is given in equations (7)-(8) except we have three endogenous variables: Δch_{SA}, Δp, Δch_{OPEC}. The results are given in panel (b) of Table 5. The estimated error correction terms indicate that the real oil price somewhat adjusts to restore the long run equilibrium as the estimate of the negative adjustment coefficient is significant at the 10 percent level. Similarly the negative error correction term on Δch_{OPEC} is statistically significant indicating that cheating by OPEC members other than Saudi Arabia responds to restore the long run equilibrium. Note that Saudi Arabian cheating, Δch_{SA}, responds significantly to positive and negative deviations from long run equilibrium in this extended model.

The Granger causality results in the extended model indicate that the real oil price is Granger caused by Saudi Arabian cheating and "other cheating" (with p-values 5.1 and 6.8 percent respectively). Thus there is stronger evidence in the extended model that cheating in the OPEC does have some significant influence on the real oil price, which implies that the quota share system is not effective[8]. How does Saudi Arabia respond to cheating by other OPEC members as a whole? According to the Granger causality statistics given in Table5, not by much. The extended model indicates that neither "other cheating" within OPEC nor the real oil price significantly Granger cause Saudi Arabian cheating. This extends the results of Dahl and Yucel (1991), who found that the Saudi Arabian oil production does not have any relationship with the oil production of other OPEC members. Finally, the symmetry hypothesis is soundly rejected for Saudi Arabian cheating and other cheating in the extended model; hence, cheating exhibits more momentum in one direction than the other. Note also that the real oil price adjustment seems to be symmetric in the extended model.

5. IMPULSE RESPONSE FUNCTIONS

The dynamic interaction of cheating and prices can best be understood by examining the impulse response functions. We assume that the system is in long-run equilibrium and consider the responses to 1-standard deviation shocks. Instead of a standard analysis where the results depend on the ordering of the variables in a Choleski decomposition, we use Generalized Impulse Response Functions (GIRF) as proposed by

Koop, Pesaran and Potter (1996) and Pesaran and Shin (1998). GIRFs compare the "average" dynamic responses of the variable given a "typical" historical shock and the history of the model, compared to a baseline model where no shock has taken place. Since, within the time frame of one month, cheating can affect oil prices and vice versa, GIRFs are more suitable than a Choleski decomposition.

Figure 1 presents the GIRFs based on the dynamic model given in (9)-(10) for Kuwait, Libya, and Qatar, and the Vector Error Correction Model given in (7)–(8) for the rest of OPEC members. The figure gives the response of cheating to a "typical" positive and negative real oil price shock for each OPEC member, OPEC excluding Saudi Arabia, and OPEC as a whole. Venezuela and Indonesia respond to both positive and negative real oil price shock by underproducing their quotas. Iran and Kuwait respond to positive real oil price shocks by underproducing while they respond to negative real oil price shocks by overproducing their quotas. Libya, Nigeria, Qatar, Saudi Arabia, and the United Arab Emirates overproduce their quotas regardless of whether the real oil price shock is positive or negative. However, in response to a typical positive real oil price shock, Qatar, Saudi Arabia, and the United Arab Emirates all undeproduce their quotas in the very short run. OPEC excluding Saudi Arabia, and OPEC as whole, underproduce when the real oil price is rising and overproduce when the real oil price is falling. This indicates that public finance considerations are important in OPEC behavior as many OPEC countries rely heavily on oil revenues. However, the asymmetry in the cheating response indicates a lack of commitment to abide by the assigned quotas. Hence even when the price increases, countries decrease their cheating only temporarily, and resume to exceed their assigned quotas.

Figure 2 presents the response of the real oil price to a cheating innovation in OPEC as a whole. In response to a positive cheating shock, the real oil price declines for a month and then recovers after three months. In response to a negative cheating shock, the real oil price increases on impact but declines afterwards. This indicates that the response of the real oil price to a cheating innovation in the OPEC as a whole is asymmetric. This is may be due to endemic cheating and the lack of an enforcement mechanism where the market does not expect underproducing the quotas to last.

How does Saudi Arabia respond to other cheating and vice versa within OPEC? Figure 3 presents the generalized impulse response functions of Saudi Arabian cheating and other cheating within OPEC based on the *extended* error correction model. The upper panel depicts the response of Saudi Arabian cheating to other cheating. In response to positive cheating, Saudi Arabia seems to respond in kind. However, when other members underproduce their quota shares, Saudi Arabia responds in kind only temporarily. It seems that after the initial impact effect, Saudi Arabia resumes cheating. Panel b of the figure indicates that other members of OPEC display similar behavior. Positive cheating by Saudi Arabia elucidates positive cheating by other members but negative cheating elucidates a temporary negative response after which everyone, on average, resumes cheating. This indicates that for shocks of typical size and in the long run, the underlying behavior is more of a competitive nature rather than a tit-for-tat nature.

5.1. The Size of the Shocks

In the threshold adjustment framework, large shocks may produce different responses than small shocks. From a technical standpoint, the number of crossovers between regimes (above versus below threshold) depends on the size of the shock. In this section, we consider the response of cheating to "unusually high" (say equal to 100 times the size of a "typical shock") real oil price shocks. Even though shocks of this size occur very rarely, we present simulations for comparison purposes.

Figure 4 presents the response of cheating to an unusually high real oil price shock. There is a notable difference in the response to "large" oil price shocks. First, almost all countries display a different cheating behavior in response to large oil price shocks. Second, as expected, fiscal considerations figure more prominently in response to large oil price shocks. This is particularly true for Kuwait, Qatar, Saudi Arabia, United Arab Emirates and Venezuela. Finally, for the OPEC as a whole, large positive and negative real oil price shocks elucidate almost a symmetric response. In response to negative real oil price shocks OPEC members overproduce whereas in response to positive real oil price shocks, they underproduce their assigned quotas. Since the individual member responses are mostly asymmetric, this implies that some OPEC members "absorb" overproduction of others by underproducing their quotas when oil prices change dramatically. However in the aggregate, the OPEC aggregate conforms to a "public revenue" view where members overproduce in response to negative real oil price shocks.

How does Saudi Arabia respond to an "unusually high" cheating by other OPEC members? There is some evidence that Saudi Arabia responds more forcefully to unusually high level of cheating. Figure 5 simulates the response of Saudi Arabian cheating to an unusually high cheating level by other OPEC members. As compared to Figure 3a the response is more symmetric indicating a tit-for-tat behavior. This in line with Griffin and Neilson (1994) who found that Saudi Arabia tolerates some minor cheating by other OPEC members but responds forcefully to higher levels of cheating.

6. CONCLUSIONS

This paper investigates OPEC cheating behavior and whether there is a pattern to cheating. Using threshold cointegration methods, we examine each OPEC member's cheating behavior in periods of rising and falling real oil prices. In doing so, we examine the OPEC aggregate cheating behavior, OPEC-minus-Saudi-Arabia cheating behavior, and how Saudi Arabia responds to other cheating within OPEC. In addition, we distinguish between the response of cheating to "small" and "large" real oil price shocks.

Granger causality tests show that typically prices Granger cause cheating but not the other way around. The statistical tests of asymmetry based on the error correction model show that the response of cheating to the real oil price is asymmetric whereas the response of the real oil price to cheating is symmetric.

Results based on the Generalized Impulse Response Functions show that there is no uniform response to rising and falling real oil prices. While most members conform to a "public finance argument" whereby they underproduce their quotas in response to rising oil prices and overproduce in response to falling real oil prices, this is true only for "unusually large" oil price shocks. For shocks of typical historical size, most members overproduce their quotas in the medium to long run. For shocks of typical size, the only OPEC members that underproduce their quotas in wake of both rising and falling real oil prices are Indonesia and Venezuela. This indicates that the typical behavior is of competitive nature and that the quota system is not very effective. This is confirmed by the response of the real oil price to a typical cheating innovation where the real oil price only rises temporarily in response to a decrease in cheating; in the long run the price declines no matter whether OPEC as whole is overproducing or underproducing the quotas. Our results also show that there is no difference between the cheating behavior of small oil producers and large oil producers.

Statistically speaking, we find no significant relationship between Saudi Arabian cheating and other cheating. That is neither Saudi Arabian cheating nor other cheating within OPEC Granger causes the other. Moreover, the impulse response functions reveal that for typical shocks, neither Saudi Arabia nor other OPEC members absorb cheating by the other party. Even though for typical shocks Saudi Arabia underproduces its quota when other OPEC members do, this is only temporary. In the long run both Saudi Arabia and other OPEC members overproduce their quotas no matter what the other party is doing. However, Saudi Arabia does seem to respond to a large incidence of cheating by other OPEC members by responding in kind: this forceful response is in line with a tit-for-tat strategy when there is “too much” cheating.

The foregoing analysis does not take into account how the quotas are determined. Moreover, in answering the various questions this paper relies on a simple statistical relationship between cheating and the real oil price ignoring other possibly significant variables. These are avenues for future research.

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Table 1. Cheating within OPEC: Some Descriptive Statistics

	Min	Max	Mean	Standard Deviation
Algeria	-0.092	0.688	0.030	0.110
Indonesia	-0.163	0.131	-0.017	0.046
Iran	-0.304	0.212	0.010	0.059
Kuwait	-0.989	0.933	0.038	0.343
Libya	-0.091	0.263	0.029	0.052
Nigeria	-0.213	0.269	0.035	0.079
Qatar	-0.517	0.750	0.050	0.143
Saudi Arabia	-0.265	0.572	0.041	0.121
UAE	-0.094	1.148	0.176	0.309
Venezuela	-0.722	0.457	0.019	0.123
OPEC	-0.173	0.338	0.034	0.068

Source: See text.

Table 2: KPSS Test Statistics for Stationarity

Cheating	Level	First Difference
OPEC	1.188	0.028
Algeria	0.757	0.268
Indonesia	0.520	0.052
Iran	0.561	0.151
Kuwait	0.228	0.029
Libya	0.313	0.034
Nigeria	0.747	0.032
Qatar	0.057	0.014
Saudi Arabia	0.600	0.027
UAE	2.315	0.034
Venezuela	0.493	0.015
OPEC excluding SA	1.141	0.031
Real oil price	0.374	0.095

Notes: The critical values of the KPSS test at the 10 and 5 percent levels are 0.347 and 0.463 respectively. Lag truncation is set at 4.

Table 3. Threshold Cointegration Test Statistics

	$\rho_1\mu^+$	$\rho_2\mu^-$	Φ* or Φ	$\rho_1 = \rho_2$	threshold	Flag	Estimated long run relation
OPEC	-0.077 (-1.26)	-0.352 (-6.13)	19.27***	11.35***	0.0164	M-TAR	ch = 0.043 +0.006 p
Algeria	0.120 (1.34)	-0.291 (-2.42)	6.14*	12.27***	0.0000	M-TAR	ch = 0.205 + 0.115 p
Indonesia	-0.189 (-4.67)	0.137 (1.40)	12.32***	9.89***	-0.0281	M-TAR	ch = -0.082 – 0.043 p
Iran	-0.119 (-1.94)	-0.480 (-6.16)	20.24***	13.93***	-0.0214	M-TAR	ch = -0.007 – 0.011 p
Nigeria	-0.261 (-3.82)	-0.432 (-5.22)	19.25***	2.81*	-0.0024	M-TAR	ch = 0.149 + 0.075 p
Saudi Arabia	-0.042 (-0.76)	-0.550 (-8.51)	36.27***	37.94***	0.0193	M-TAR	ch = 0.145 + 0.069 p
UAE	0.003 (0.12)	-0.318 (-6.42)	20.64***	31.42***	-0.0275	M-TAR	ch = 0.541 + 0.241 p
Venezuela	-0.323 (-4.55)	-0.159 (-3.10)	14.44***	3.68*	-0.0385	TAR	ch = -0.175 - 0.128 op

Notes: 1. (*) significant at 10 percent, (**) at 5 percent, (***) at 1 percent. *t*-statistics are given in parentheses. BIC selected 1 lag for all cases.

Table 4. Tests of Exogeneity, Granger Causality, and Symmetry based on the Error Correction Model

	Equation	α^{+a}	α^{-a}	F_{11} ^{b}	F_{12} ^{c}	Sym. ^{d}	lags. ^{e}
OPEC	Δp	0.249 (1.74)	-0.041 (-0.33)	7.88 (0.000)	2.08 (0.128)	1.91 (0.128)	1
	Δch	-0.158 (-2.36)	-0.370 (-6.40)	4.24 (0.016)	3.24 (0.041)	6.54 (0.000)	1
Algeria	Δp	0.224 (1.75)	0.076 (0.39)	2.97 (0.001)	0.71 (0.739)	0.88 (0.575)	6
	Δch	0.135 (1.95)	-0.114 (-1.09)	16.61 (0.000)	2.11 (0.018)	14.69 (0.000)	6
Indonesia	Δp	-0.347 (-2.41)	-0.618 (-1.67)	8.66 (0.000)	2.95 (0.054)	2.21 (0.087)	1
	Δch	-0.203 (-5.06)	0.143 (1.39)	0.50 (0.604)	0.88 (0.414)	3.76 (0.011)	1
Iran	Δp	0.184 (1.50)	0.086 (0.44)	8.19 (0.000)	3.47 (0.032)	2.53 (0.058)	1
	Δch	-0.268 (-4.65)	-0.636 (-6.95)	3.94 (0.021)	3.96 (0.020)	5.60 (0.001)	1
Kuwait	Δp	--	--	8.97 (0.000)	1.83 (0.176)	1.46 (0.227)	1
	ch	--	--	99.11 (0.000)	7.09 (0.001)	5.68 (0.018)	1
Libya	Δp	--	--	8.86 (0.000)	0.99 (0.319)	1.87 (0.172)	1
	ch	--	--	34.60 (0.000)	0.427 (0.652)	0.58 (0.446)	1
Nigeria	Δp	0.127 (1.16)	-0.222 (-1.71)	8.41 (0.000)	0.14 (0.863)	1.86 (0.137)	1
	Δch	-0.319 (-4.51)	-0.438 (-5.22)	1.03 (0.359)	6.21 (0.002)	3.46 (0.017)	1
Qatar	Δp	--	--	5.47 (0.000)	0.18 (0.831)	0.29 (0.743)	2
	ch	--	--	89.73 (0.000)	1.19 (0.318)	1.58 (0.207)	2
Saudi Arabia	Δp	0.050 (0.67)	-0.004 (-0.05)	8.61 (0.000)	0.29 (0.745)	0.53 (0.658)	1
	Δch	-0.083 (-1.37)	-0.594 (-8.95)	0.45 (0.639)	1.86 (0.157)	14.12 (0.000)	1
UAE	Δp	0.006 (0.24)	0.079 (2.01)	8.75 (0.000)	0.55 (0.577)	1.60 (0.189)	1
	Δch	-0.019 (-0.65)	-0.306 (-6.45)	1.85 (0.159)	1.43 (0.241)	11.21 (0.000)	1
Venezuela	Δp	-0.172 (-1.83)	-0.043 (-0.67)	9.50 (0.000)	0.24 (0.783)	1.41 (0.239)	1
	Δch	-0.373 (-4.75)	-0.124 (-2.27)	2.42 (0.091)	2.35 (0.097)	2.33 (0.075)	1

Notes:

[a] The entries are estimated error correction terms given M-TAR adjustment for all countries (except for Venezuela where adjustment is TAR) with t-statistics in parentheses.

[b] The entries are estimated F-statistics that the variable does not Granger cause itself with p-values in parentheses.

[c] The entries are estimated F-statistics that the variable does not Granger cause the other variable with p-values in parentheses.

[d] The entries are the F-statistics that parameters of positive and negative polynomials are of equal value including error correction terms (where applicable) with p-values in parentheses.

[e] Lag length is selected by the multivariate version of the BIC.

Table 5. An Extended Model of Cheating by Saudi Arabia *vs.* all Other OPEC Members

				Cointegration			
	$\rho_1\mu^+$	$\rho_2\mu^-$	Φ * or Φ	$\rho_1 = \rho_2$	threshold	Flag	Estimated long run relation
Saudi Arabia	-0.101	-0.854	38.98***	51.35***	-0.0369	M-TAR	$ch_{SA} = 0.144+0.087\ p + 0.926\ ch_{OPEC}$
	(-2.12)	(-8.72)					

				Error Correction			
	$\alpha^{+(a)}$	$\alpha^{-(a)}$	Δp $^{(b)}$	$\Delta ch_{SA}{}^{(b)}$	$\Delta ch_{OPEC}{}^{(b)}$	Sym. $^{(c)}$	Lags $^{(d)}$
Δp	-0.127	0.128	5.42	2.40	2.22	1.58	2
	(-1.75)	(0.92)	(0.000)	(0.051)	(0.068)	(0.143)	
Δch_{SA}	-0.129	-0.952	1.73	0.391	0.089	7.39	2
	(-2.12)	(-8.07)	(0.145)	(0.814)	(0.985)	(0.000)	
Δch_{OPEC}	0.020	-0.151	5.44	6.43	11.73	4.30	2
	(0.63)	(-2.45)	(0.000)	(0.000)	(0.000)	(0.000)	

Notes: (*) significant at 10 percent, (**) at 5 percent, (***) at 1 percent. *t*-statistics are given in parentheses. BIC selected 1 lag for both TAR and M-TAR models.

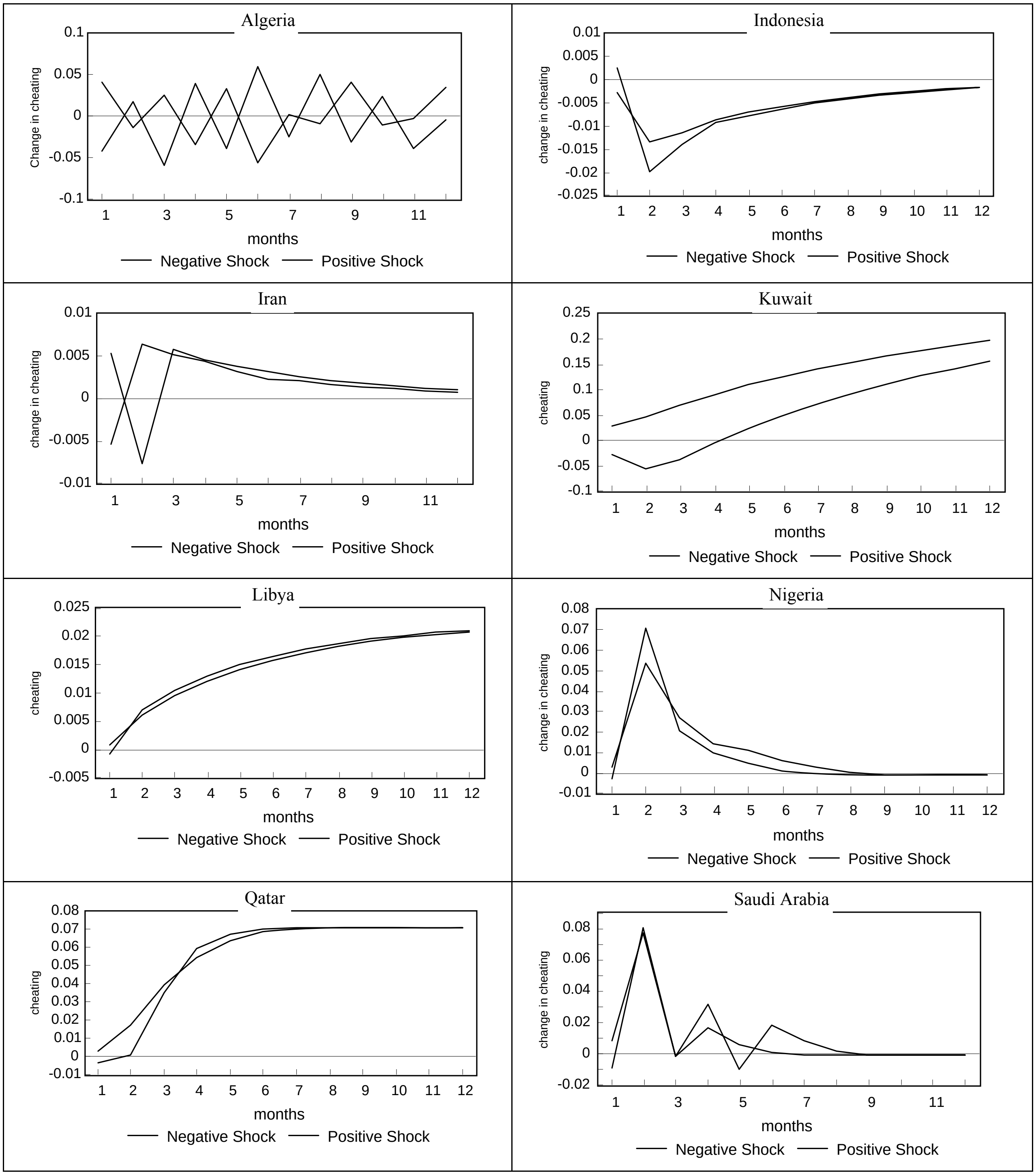
(a) The entries are estimated error correction terms given M-TAR adjustment with t-statistics in parentheses.

(b) The entries are estimated F-statistics that row variable *i*, is not Granger caused by the column variable *j*, ($j = \Delta p$, Δch_{SA}, Δch_{OPEC}) with p-values in parentheses.

(c) The entries are the F-statistics that parameters of positive and negative polynomials are of equal value including error correction terms, with p-values in parentheses.

(d) Lag length is selected by the multivariate version of the BIC.

Figure 1. Generalized Responses of Cheating to a “Typical” Price Innovation



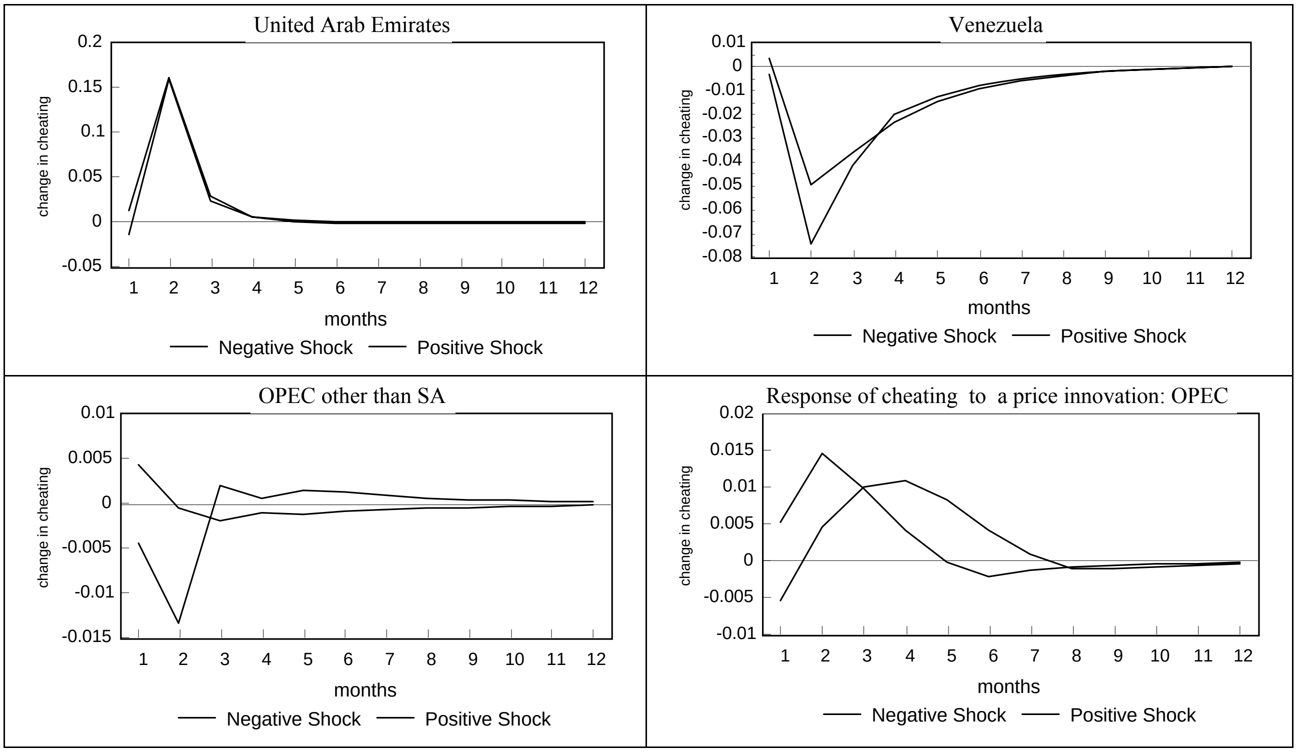

United Arab Emirates
change in cheating
0.2
0.15
0.1
0.05
0
-0.05
1 2 3 4 5 6 7 8 9 10 11 12
months
Negative Shock
Positive Shock
Venezuela
change in cheating
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
1 2 3 4 5 6 7 8 9 10 11 12
months
Negative Shock
Positive Shock
OPEC other than SA
change in cheating
0.01
0.005
0
-0.005
-0.01
-0.015
1 2 3 4 5 6 7 8 9 10 11 12
months
Negative Shock
Positive Shock
Response of cheating to a price innovation: OPEC
change in cheating
0.02
0.015
0.01
0.005
0
-0.005
-0.01
1 2 3 4 5 6 7 8 9 10 11 12
months
Negative Shock
Positive Shock

Figure 2. Generalized Response of the Real Oil Price to an OPEC Cheating Innovation

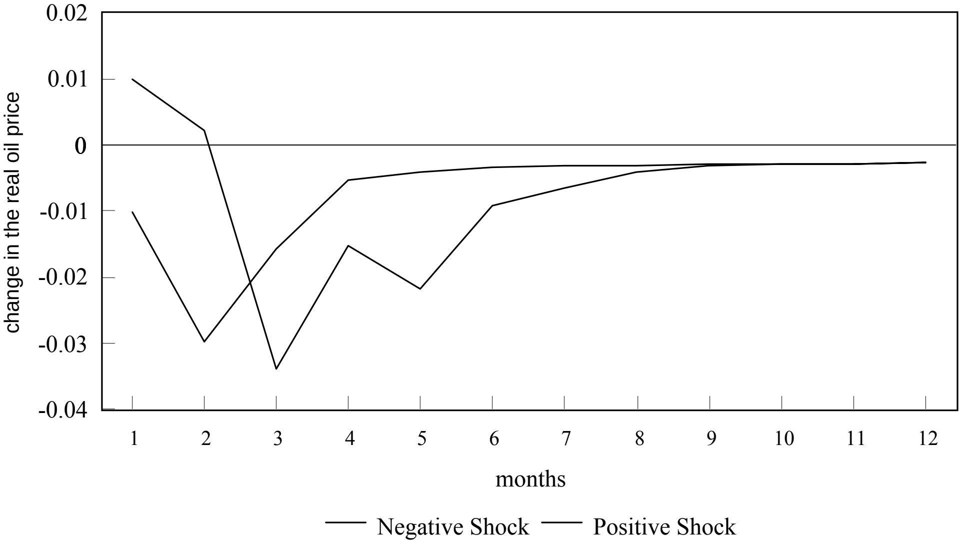
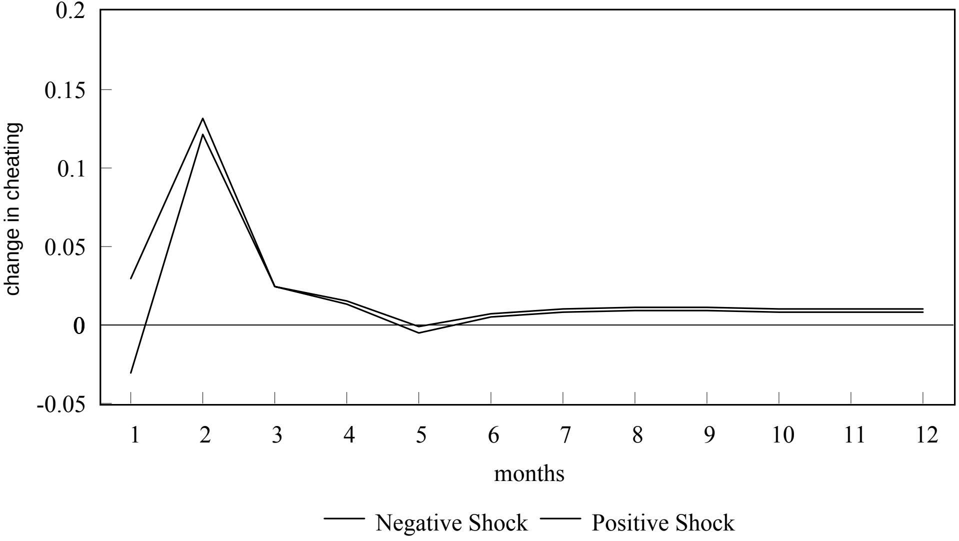


Figure 3. Generalized Impulse Response Functions of Cheating within OPEC

a. Response of Saudi Arabian cheating to other cheating



b. Response of other cheating to Saudi Arabian cheating

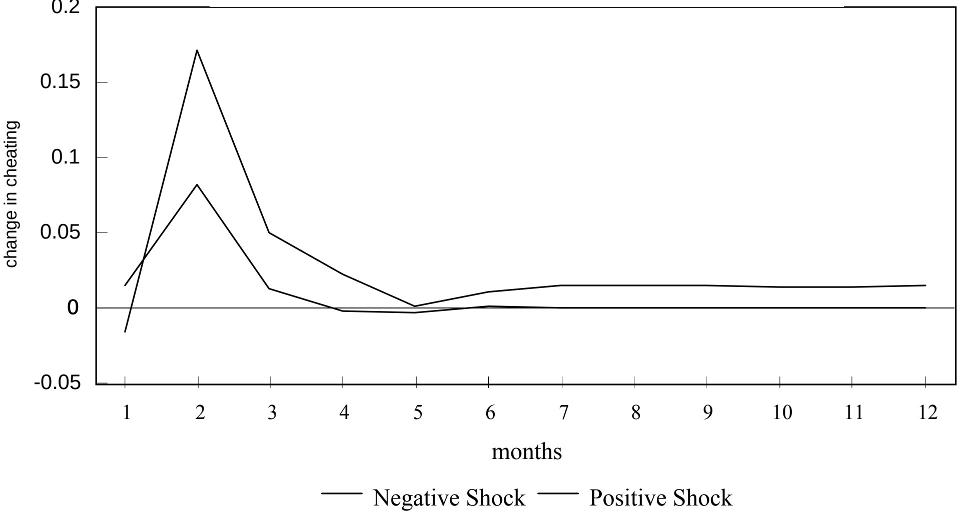


Figure 4. Response of Cheating to an “Unusually Large” Price Innovation

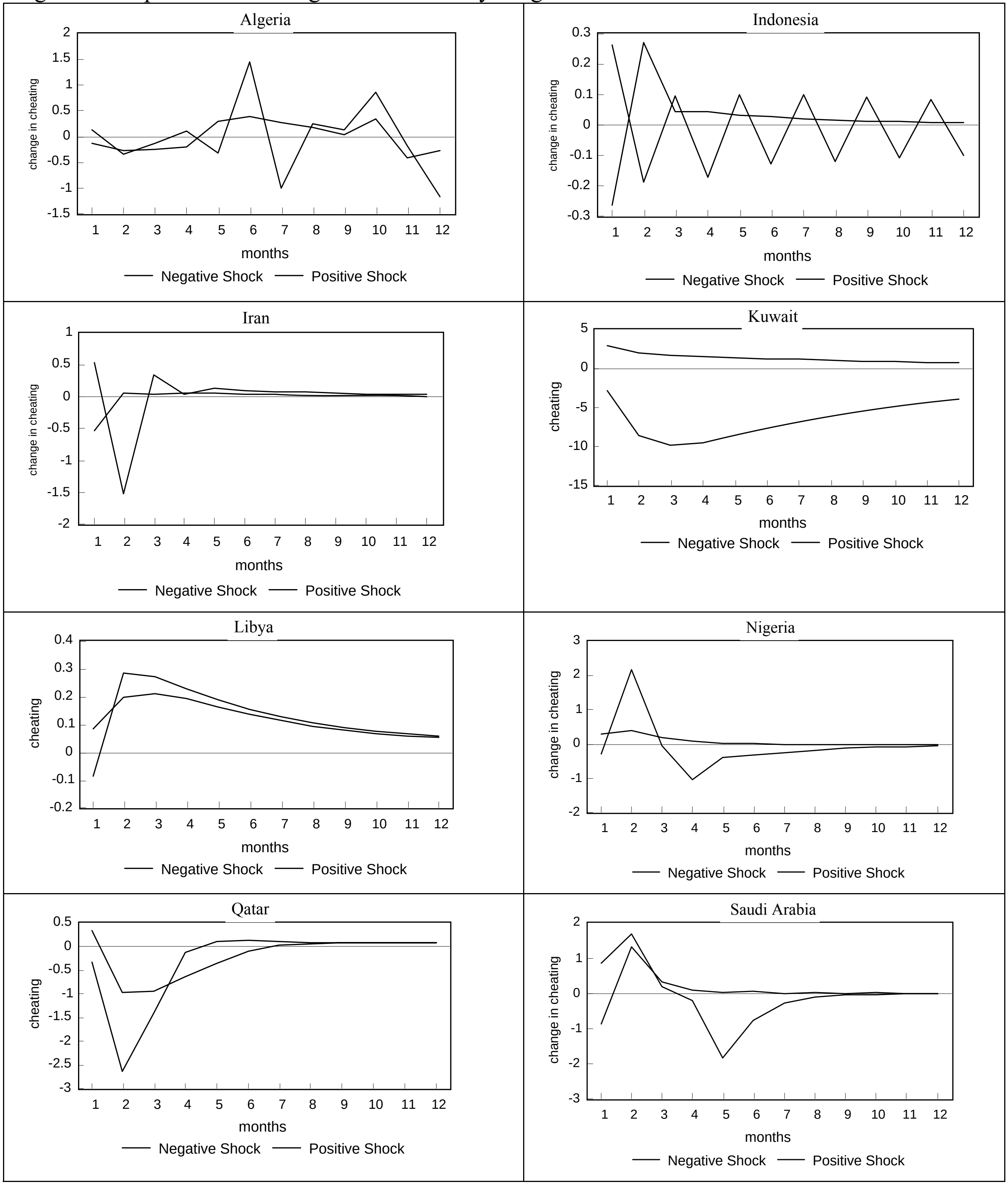


Figure 4. Cont'd.

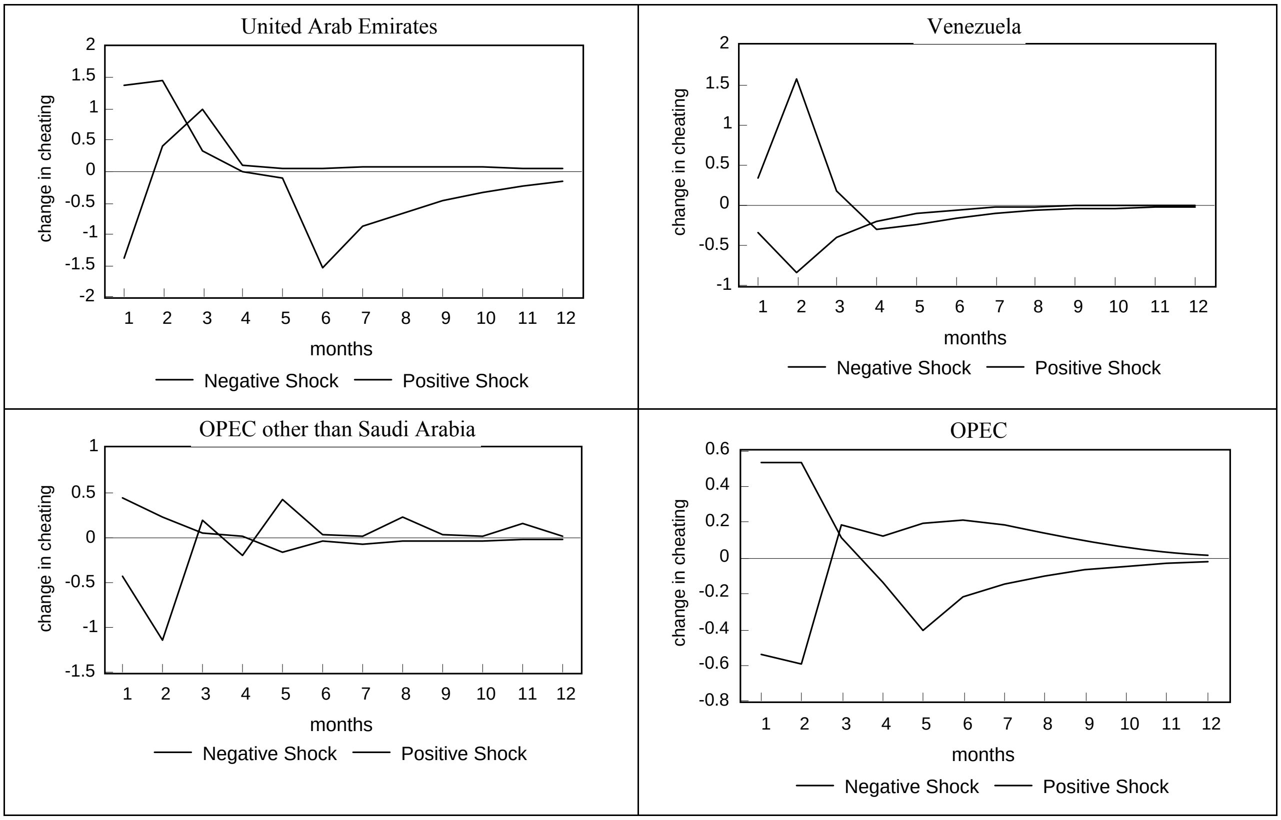
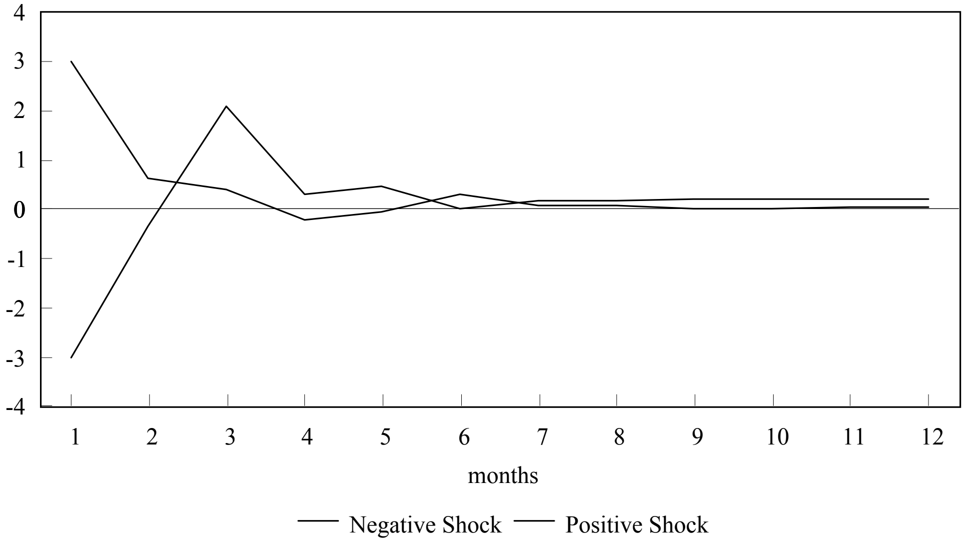


Figure 5. Response of Saudi Arabian Cheating to Unusually Large Cheating by other OPEC Members



ENDNOTES

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[1] In this paper, we use "cheating" to describe overproduction of the assigned quota without any negative value judgment.

[2] Since most oil exporting countries import from industrial countries, deflating the nominal crude price with the price level of industrial countries would serve as a proxy for their terms of trade.

[3] We do not wish to get into debates regarding the shape of the oil supply curve. For our purposes, the precise relationship can be ascertained using impulse response functions.

[4] **Error! Main Document Only.**Similarly, the Johansen (1995) methodology uses the specification: $\Delta x_t = \pi x_{t-1} + \nu_t$ where x_t is the (n x 1) vector of endogenous variables, π is an (n x n) matrix, and ν_t is an (n x 1) vector of stationary disturbances that may be contemporaneously correlated. The crucial point to note is that the alternative hypothesis [i.e., rank (π) $\neq 0$] implicitly assumes a symmetric adjustment process around $x_t = 0$ in that for any $x_t \neq 0$, Δx_{t+1} always equals πx_t. Recent applications of cointegration methods with symmetric adjustment include Maneschiöld (2006), Irandoust et al. (2006), Bahmanee-Oskoee and Goswami (2004), and Filiztekin (2004).

[5] In fact, the first step towards establishing OPEC took place in 1949 when Venezuela approached Iran, Iraq, Kuwait and Saudi Arabia and sought regular communication and coordination regarding oil production.

[6] That is, except for Libya and Qatar where cheating is stationary. Notice that Kuwait responds differently to positive and negative real oil price changes.

[7] Saudi Arabia's share of world crude oil production has been stable in the last two decades providing about one-eighth of the world's crude oil.

[8] Since results in Table 3 show little evidence that aggregate cheating in OPEC influences the real oil price, the difference in results can be attributed to offsetting changes in cheating between Saudi Arabia and other OPEC members.