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Discussion Paper

Managing the Oil Market Under Misinformation

A Reasonable Quest?

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Abstract

This paper examines the type and quality of information that OPEC needs to stabilize the oil market. We extend our previous structural model, in which OPEC makes potential mistakes in judging the size of market shocks, to now include the possibility of OPEC misestimating how the market price would react to any given adjustment to its production level. Thus, we present a model that incorporates both observational errors regarding physical market developments and potentially erroneous judgments regarding the elasticities of supply and demand. We use the model to determine the counterfactual (unstabilized) prices that would have prevailed if OPEC, acting under a broad range of misinformation, had not attempted to stabilize the price. We find that the misestimation of the elasticities of demand and supply generally increases the computed counterfactual price volatility. In comparison to historical volatility, these elevated counterfactual volatilities support our previous finding that OPEC has substantially decreased price volatility by regulating production from its buffer of spare capacity. This situation is true of the OPEC+ period and the period prior to OPEC+.

Introduction

How much information does OPEC need to succeed in its mission of stabilizing the oil market? There are many uncertainties with which to contend, including the magnitude and timing of market shocks, the size of demand and supply responses to any adjustment to OPEC's production level, and the prevailing inventory conditions. Misreading any of these factors could undermine OPEC's attempt to stabilize the oil price. In this paper, we address both theoretically and empirically the type and quality of information that is required for OPEC to effectively stabilize the price.

Pierru, Smith, and Zamrik (PSZ, 2018) and Almutairi, Pierru, and Smith (APS, 2023) previously demonstrated that OPEC (and more recently OPEC+) have managed to significantly reduce crude oil price volatility by using spare capacity to offset short-term shocks to the demand and supply of crude oil. OPEC has done this despite its presumed inability to anticipate shocks with full precision. For example, PSZ found that even if its typical error in estimating the size of the shock is assumed to be quite large (approximately +/-400,000 barrels/day), OPEC appears to have been able to reduce price volatility by approximately 25%. APS 2023 found similar results when studying the impact of OPEC+. Moreover, Almutairi, Pierru, and Smith (APS, 2021) estimated that the annual value to the world economy of these reductions in volatility would reach almost 200 billion in 2019 US dollars. Therefore, it seems that perfect information, specifically regarding the *size of shocks,* is hardly required for the beneficial management of oil prices.

However, the analysis, counterfactual calculations, and conclusions in each of the foregoing studies were built on the strong assumption that in making its decisions, OPEC held exact knowledge of the elasticity of demand for its oil. That is, OPEC could correctly anticipate the precise price impact of any particular change in its own production levels. Given the recent debate and empirical disagreements among economists regarding the magnitude of the elasticities of supply and demand for crude oil, this assumption seems to be rather heroic.

Indeed, there are several sources of ambiguity, particularly regarding the short-term reaction to variations in the level of OPEC production. As Baumeister and Peersman (2013) demonstrated, the short-term (quarterly) elasticity of global demand (supply) for crude oil appears to have decreased significantly in magnitude during the past four decades, decreasing from approximately −0.4 (+0.4) to approximately −0.1 (+0.05) by 2010. Just where does the elasticity of global demand stand today, and are we justified in assuming that OPEC was able to correctly anticipate and incorporate this declining trend into its plan to stabilize the market? Beyond the declining trend, we face the econometric question of how best to estimate the unobservable elasticities of demand and supply. Static analyses of the short-term market reaction to discrete, exogenous shocks, as in Smith (2009), Kilian and Murphy (2012) and Caldara, Cavallo, and Lacoviello (2019), seem to indicate that the short-term (monthly) elasticities of demand and supply for crude oil are small, perhaps within ±0.05. In contrast, recent time-series studies by Kilian and Murphy (2014), Baumeister and Hamilton (2019), and Balke, Jin, and Yucel (2024) produced significantly larger estimates of short-term elasticities. It should be noted, however, that the second and third abovementioned studies produced posterior estimates that greatly exceed the authors' own prior estimates of the short-term elasticity of the demand for crude oil, which is a stark indication of the uncertainty that remains despite economists' careful attempts to measure this elusive and unobservable parameter. In addition, in a more recent work employing an alternative methodology, Baumeister and Hamilton (2023) substantially reduced their previous estimate. Moreover, Herrera and Rangaraju (2020) attributed most of the variation in these recent estimates to differences in identification assumptions and in model specifications, including whether changes in inventory levels are taken into account. Thus, it is quite natural for OPEC to closely monitor inventory levels if it wishes to anticipate the reaction to a proposed change in production levels. However, the success of such effort is limited by the relatively poor quality and incomplete nature of the available data on global inventories,[1] which is yet another factor that obscures how the market would react to any change in production that OPEC may contemplate.

For these reasons, in the current paper, we relax the assumptions of our earlier papers and introduce the possibility of OPEC misestimating the elasticity of demand for its oil. Combined with OPEC's presumed inability to precisely estimate the size of shocks, the question becomes whether this more comprehensive analysis that encompasses a greater scope for error and misjudgment still supports our previous conclusion that by attempting to offset shocks to the market, OPEC has the ability, and has indeed been able, to significantly reduce price volatility.

The implications of misperceived elasticity are not clear *a priori*. On the one hand, if OPEC is able to form an unbiased estimate of the size of a shock based on careful market observation and intelligence, then it would retain the ability to directly offset that shock by an equal and offsetting adjustment to its own production—and this action would not depend on knowledge of the elasticity of demand. On the other hand, if OPEC is mistaken in terms of elasticity, even in the absence of shocks, then it would not know the amount of production required to support a desired price level. Therefore, the goal of offsetting shocks to stabilize the market around a given target price may involve perceived elasticity. In this paper, we develop an extension of previous models and conduct new counterfactual analyses that reveal whether OPEC's potential lack of knowledge regarding the true elasticity of residual demand is a problem.

Related Studies

A prerequisite for market stabilization is OPEC's ability to willfully impact the market price of oil by varying its own production levels. This ability has been researched extensively over several decades, and although there has been some dissent,[2] most studies have confirmed that OPEC production decisions do impact market prices.

One strand of this research applies the event study methodology to measure the price impacts of OPEC Conference announcements and ministerial communications. For example, see Wirl and Kujundzic (2004), Demirer and Kutan (2010), Lin and Tamvakis (2010), Schmidbauer and Rosch (2012), Mensi, Hammoudeh, and Yoon (2014), Loutia, Mellios, and Andriosopoulos (2016), Känzig (2021), and Nazer and Pescatori (2022). Although no impact may be detected by an event study if market participants have anticipated the announced decision to cut, maintain, or increase production levels,[3] all of these studies find a significant impact of OPEC announcements on the market price. Some of these studies (Wirl and Kujundzic (2004); Demirer and Kutan (2010); Loutia, Mellios, and Andriosopoulos (2016); Mensi, Hammoudeh, and Yoon (2014)) find asymmetric effects, with stronger impacts coming when OPEC's decision is to cut rather than maintain or increase production levels.

A different line of research that utilizes time-series data confirms the existence of a direct relationship between OPEC's selected production level and the market price of oil. For example, Kaufmann et al. (2004) applied cointegration analysis to quarterly data over the period 1986-2000 and found that real oil prices are Granger-caused by OPEC capacity utilization, quotas, the degree of exceeding quotas, and OECD stocks of crude oil. The above authors concluded that "OPEC plays an important role in determining world oil prices." These authors do not, however, attempt to show whether OPEC production decisions have lowered the volatility of those prices. More recently, there is a large and growing body of literature that applies structural vector autoregression analysis to identify the impact of supply shocks, including those that emanate from OPEC, on market prices. Quint and Venditti (2023) exploited this methodology using monthly data to conduct counterfactual analysis and estimated the price impact of OPEC+ production decisions made prior to the COVID-19 pandemic (2017-2020). The above authors concluded that although the impact of OPEC+'s production cuts on the market price was weak, it was nevertheless economically significant. By applying a different structural model to the same period, Almutairi, Pierru, and Smith (2023) found a similar result regarding the price impact of OPEC cuts.

Regarding the impact of scheduled announcements (whether to cut, maintain, or increase production), it is natural for price volatility to drift upward prior to the release of information and drop afterward, as noted by Horan, Peterson, and Mahar (2004). These authors confirmed this phenomenon surrounding OPEC announcements. Moreover, similar findings were reported by Wang, Wu, and Yang (2008); Schmidbauer and Rösch (2012); Mensi, Hammoudeh, and Yoon (2014); and Nazer and Pescatori (2022). However, it is important to distinguish the temporary rise in volatility observed as the market waits for imminent news from the longer-term and sustained volatility impact of timely variations in OPEC's actual production levels during the ordinary course of business. Our focus is on the latter, which aligns with Nazer and Pescatori's (2022) conclusion (based on multinomial logit analysis of the factors that trigger OPEC's actions) that OPEC's motivation in making production decisions appears to be to stabilize the oil price around a medium-term equilibrium price. The structure of our model is also consistent with Wirl and Kujundzic's (2004) conclusion that OPEC Ministers' decisions quickly and efficiently accommodate recent events. Our objective is to better understand how much information OPEC requires to achieve this goal.

Model of Market Stabilization with Mistaken Elasticity Values

The residual demand for OPEC oil at any given price is given by the global demand for less non-OPEC supply. Assuming, for the time being, as in APS (2023), that Allies[4] do not help by cutting their production below the competitive level, this residual demand would be as follows:

$$a_t\left(\prod_{k=0}^{K}P_{t-k}^{\omega_k}\right)e^{S_t}. \quad (1)$$

In this expression, ω_0 represents the short-term price elasticity of the demand for OPEC oil, and $\sum_{k=0}^{K}\omega_k=\omega_l$, where ω_l is the long-term price elasticity of the demand for OPEC oil. P_{t-k} is the oil price in period $t-k$. e^{S_t} is a lognormally distributed random variable representing the effects[5] of short-term shocks on the demand for OPEC crude oil. a_t is an exogenous, time-varying scaling factor that represents secular change (e.g., growth in population or income) that proceeds at a steadier and more predictable rate than do random short-term shocks that are not secular but rather idiosyncratic in nature. We assume that the shock follows the autoregressive process as follows:

$$S_t=\kappa S_{t-1}+\sigma_u u_t, \quad (2)$$

where the incremental shocks (u_t) are assumed to be *iid* $N(0,1)$.

As discussed in APS (2023), if the Allies elect to help OPEC in its effort to stabilize the market by withholding some of their own production, then the actual demand facing OPEC at any given price is greater:

$$Q_t\left(P_t,P_{t-1},\ldots,P_{t-K}\right)=a_t\left(\prod_{k=0}^{K}P_{t-k}^{\omega_k}\right)e^{S_t}+E_t, \quad (3)$$

where E_t represents the quantity of production withheld by Allies during period t.

In contrast to the true elasticities, we assume that OPEC perceives the short- and long-term elasticities to be $\alpha\omega_0$ and $\beta\omega_l$, respectively. $\alpha\neq 1$ represents the error in OPEC's estimate of the short-term elasticity, and $\beta\neq 1$ represents the error in OPEC's estimate of the long-term elasticity.

For ease of notation, we introduce γ such that $\sum_{k=1}^{K}\gamma\omega_k$ represents the delayed price effects perceived by OPEC. We therefore have that

$$\sum_{k=1}^{K}\gamma\omega_k = \beta\omega_l - \alpha\omega_0,$$

which gives the following:

$$\gamma = \frac{\beta\omega_l - \alpha\omega_0}{\omega_l - \omega_0}. \quad (4)$$

When OPEC correctly estimates both elasticities, $\alpha = \beta = 1$ and γ are equal to unity.

For each period, OPEC adopts a target price[6], denoted by P_t^*. However, OPEC's perception of the volume of production required to support this price (the "call" on OPEC) would be in error if it were to misestimate the elasticity of demand. Thus, OPEC would perceive the call in the absence of shocks to be as follows:

$$Q^*_{t|\alpha,\beta} = a_t P_t^{*\alpha\omega_0} \prod_{k=1}^{K} P_{t-k}^{\gamma\omega_k} + E_t, \quad (5)$$

In the absence of shocks to demand and given Allies' help, the true call on OPEC is given by the following:

$$Q^*_{t|1,1} = a_t P_t^{*\omega_0} \prod_{k=1}^{K} P_{t-k}^{\omega_k} + E_t. \quad (6)$$

After including the impact of the shock, the true call on OPEC's oil becomes the following:

$$\hat{Q}_t = a_t P_t^{*\omega_0} \prod_{k=1}^{K} P_{t-k}^{\omega_k} e^{S_t} + E_t. \quad (7)$$

The size of the shock is therefore given by $\hat{Q}_t - Q^*_{t|1,1}$. We assume that by carefully following market developments, OPEC forms an unbiased estimate of the size of the shock. OPEC's perception of the total call for its oil at the target price can therefore be written as follows:

$$\tilde{Q}_{t|\alpha,\beta} = \left(Q^*_{t|\alpha,\beta} + \hat{Q}_t - Q^*_{t|1,1} - E_t\right) e^{\sigma_z z_t} + E_t, \quad (8)$$

where E_t is the only nonstochastic element. z_t, which represents[7] OPEC's potential error in assessing the size of shock, is assumed to be independent of S_t and $z_t \sim iid\ N(0,1)$. Note that under our assumptions, $\tilde{Q}_{t|\alpha,\beta}$ represents OPEC's observed production in period t.

Let C_t represent OPEC's total production capacity. We assume that it includes a buffer sized as the fixed proportion $B-1$ (with $B>1$) of the stochastic portion of the call perceived by OPEC, as in APS (2023):

$$C_t = B\left(Q^*_{t|\alpha,\beta} - E_t\right) + E_t. \quad (9)$$

Spare capacity, X_t, is defined in terms of the deviation of actual output from capacity:

$$X_t = max\left\{0, C_t - \tilde{Q}_{t|\alpha,\beta}\right\}.$$

Does OPEC's Misperception of Short-Term Elasticity Impair Its Ability to Stabilize the Price?

After substituting the respective terms in Eq. (8), we have the following:

$$\tilde{Q}_{t|\alpha,\beta} = a_t\left(P_t^{*\alpha\omega_0}\prod_{k=1}^{K}P_{t-k}^{\gamma\omega_k} + P_t^{*\omega_0}\prod_{k=1}^{K}P_{t-k}^{\omega_k}e^{S_t} - P_t^{*\omega_0}\prod_{k=1}^{K}P_{t-k}^{\omega_k}\right) e^{\sigma_z z_t} + E_t. \quad (10)$$

Market price (P_t) is calculated by equating the demand and supply of OPEC oil $\left(Q_t = \tilde{Q}_{t|\alpha,\beta}\right)$ as follows:

$$a_t P_t^{\omega_0}\prod_{k=1}^{K}P_{t-k}^{\omega_k}e^{S_t} + E_t =$$
$$a_t\left(P_t^{*\alpha\omega_0}\prod_{k=1}^{K}P_{t-k}^{\gamma\omega_k} + P_t^{*\omega_0}\prod_{k=1}^{K}P_{t-k}^{\omega_k}e^{S_t} - P_t^{*\omega_0}\prod_{k=1}^{K}P_{t-k}^{\omega_k}\right)e^{\sigma_z z_t} + E_t. \quad (11)$$

As shown in Appendix B, we obtain the following:

$$P_t = P_t^{*\alpha} \prod_{k=1}^{K} P_{t-k}^{(\gamma-1)\frac{\omega_k}{\omega_0}} e^{\frac{\sigma_z z_t + b_t}{\omega_0}}, \quad (12)$$

where, for convenience, we define

$$b_t = ln\left(P_t^{*(1-\alpha)\omega_0} \prod_{k=1}^{K} P_{t-k}^{(1-\gamma)\omega_k} \left(1 - e^{-S_t}\right) + e^{-S_t}\right).$$

Eq. (12) is a generalized form of Eq. (8) in the APS (2023) since, for $\alpha = \beta = 1$, it becomes $P_t = P_t^* e^{\frac{\sigma_z z_t}{\omega_0}}$. Eq. (12) also provides a decomposition of the observed price as the product of two terms as follows:

- $P_t^{*\alpha} \prod_{k=1}^{K} P_{t-k}^{(\gamma-1)\frac{\omega_k}{\omega_0}}$, which would be the price in the absence of market shocks and OPEC's estimation error $(z_t = 0)$, and
- a stochastic term, $e^{\frac{\sigma_z z_t + b_t}{\omega_0}}$, which incorporates OPEC's error in assessing the size of the shock as well as its misperception of elasticities. Since b_t has a nonzero expected value, this stochastic term can be viewed as an estimation error of the shock that results in part from OPEC's misperception of elasticity values.

The interpretation of $\sigma_z z_t + b_t$ as a biased component of OPEC's estimate of the shock is confirmed by observing the following:

$$\frac{\tilde{Q}_{t|\alpha,\beta} - E_t}{Q^*_{t|\alpha,\beta} - E_t} = \frac{a_t\left(P_t^{*\omega_0} \prod_{k=1}^{K} P_{t-k}^{\omega_k} e^{S_t} - P_t^{*\omega_0} \prod_{k=1}^{K} P_{t-k}^{\omega_k} + P_t^{*\alpha\omega_0} \prod_{k=1}^{K} P_{t-k}^{\gamma\omega_k}\right) e^{\sigma_z z_t}}{a_t P_t^{*\alpha\omega_0} \prod_{k=1}^{K} P_{t-k}^{\gamma\omega_k}}. \quad (13)$$

which gives the following:

$$\tilde{Q}_{t|\alpha,\beta} = \left(Q^*_{t|\alpha,\beta} - E_t\right) e^{S_t + \sigma_z z_t + b_t} + E_t. \quad (14)$$

Thus, OPEC's estimate of the call on its output is misinformed (cf. Eq. 7) by the sum of two independent stochastic components, $\sigma_z z_t$ (misperception of the shock) and b_t (misperception of the elasticities). When OPEC correctly estimates the elasticity values ($\alpha = \beta = 1$), $b_t = 0$, and the formula reverts to Eq. (6) in the APS (2023):

$$\tilde{Q}_{t|1,1} = \left(Q^*_{t|1,1} - E_t\right) e^{S_t + \sigma_z z_t} + E_t. \quad (15)$$

Equation (14) implies the following:

$$ln\left(\frac{\tilde{Q}_{t|\alpha,\beta} - E_t}{Q^*_{t|\alpha,\beta} - E_t}\right) = S_t + \sigma_z z_t + b_t. \quad (16)$$

From Eq. (9), we have that

$$B\left(Q^*_{t|\alpha,\beta} - E_t\right) = \tilde{Q}_{t|\alpha,\beta} - E_t + X_t, \quad (17)$$

which implies the following:

$$B\frac{\left(Q^*_{t|\alpha,\beta} - E_t\right)}{\left(\tilde{Q}_{t|\alpha,\beta} - E_t\right)} = 1 + \frac{X_t}{\left(\tilde{Q}_{t|\alpha,\beta} - E_t\right)}. \quad (18)$$

Then, by combining Eqs. (16) and (18), we obtain the following:

$$ln(B) - ln\left(1 + \frac{X_t}{\tilde{Q}_{t|\alpha,\beta} - E_t}\right) = S_t + \sigma_z z_t + b_t, \quad (19)$$

which is the expression we use in the next section to identify the counterfactual (unstabilized) price that would result from such misperceived (α, β) elasticities.

Counterfactual Price

We now compute the counterfactual price that would have prevailed if OPEC had not attempted to offset shocks. We equate counterfactual supply and demand as follows:

$$\dot{Q}^*_{t|\alpha,\beta} = a_t P_t^{*\alpha\omega_0} \prod_{k=1}^{K} \dot{P}_{t-k}^{\gamma\omega_k} = a_t \dot{P}_t^{\omega_0} \prod_{k=1}^{K} \dot{P}_{t-k}^{\omega_k} e^{S_t}, \quad (20)$$

where $\dot{Q}^*_{t|\alpha,\beta}$ is the counterfactual call perceived by OPEC, who ignores the shock, and $\{\dot{P}_{t-k}\}$ represents the preceding series of counterfactual prices. Hence,

$$P_t^{*\alpha\omega_0} = \dot{P}_t^{\omega_0} \prod_{k=1}^{K} \dot{P}_{t-k}^{(1-\gamma)\omega_k} e^{S_t}. \quad (21)$$

By combining Eq. (21) with our previous results, as shown in Appendix B, we solve for the counterfactual price as follows:

$$ln\left(\dot{P}_t\right) = ln\left(P_t\right) + \frac{ln\left(1 + \frac{X_t}{\tilde{Q}_{t|\alpha,\beta} - E_t}\right) - ln(B)}{\omega_0} + (\gamma - 1)\sum_{k=1}^{K} \frac{\omega_k}{\omega_0} ln\left(\frac{\dot{P}_{t-k}}{P_t - k}\right). \quad (22)$$

If $\gamma = 1$ (for instance, OPEC correctly estimates both price elasticities), then Eq. (22) is the same as the counterfactual price (Eq. (10a)) derived by APS (2023). This equation, written in equivalent form below, explicitly shows how the counterfactual price depends on the misperception of short- (α) and long-term (β) elasticities:

$$ln\left(\dot{P}_t\right) = ln\left(P_t\right) + \frac{ln\left(1 + \frac{X_t}{\tilde{Q}_{t|\alpha,\beta} - E_t}\right) - ln\left(B\right)}{\omega_0} + \frac{\left(\beta - 1\right)\omega_l - \left(\alpha - 1\right)\omega_0}{\omega_l - \omega_0}\sum_{k=1}^{K}\frac{\omega_k}{\omega_0}ln\left(\frac{\dot{P}_{t-k}}{P_t - k}\right). \tag{23}$$

Eq. (22) allows for a recursive calculation of the counterfactual price. The estimated value of B may depend on the values assumed for α and β, but adding the fixed term $-\frac{ln\left(B\right)}{\omega_0}$ to every log of the counterfactual price does not impact the value calculated for counterfactual volatility (the standard deviation of the log of counterfactual prices).

The counterfactual price depends on $\gamma - 1$, which represents the relative size of OPEC's misestimation of delayed price effects. This misestimation directly impacts OPEC's choice of subsequent prices. Although we assume that OPEC intends to target the same price, whether stabilizing or not, in reality, OPEC inadvertently targets the following two distinct prices: $P_t^{*\alpha}\prod_{k=1}^{K}\dot{P}_{t-k}^{(\gamma-1)\frac{\omega_k}{\omega_0}}$ in the counterfactual scenario versus $P_t^{*\alpha}\prod_{k=1}^{K}P_{t-k}^{(\gamma-1)\frac{\omega_k}{\omega_0}}$ in the historical scenario, neither of which corresponds to the intended target.[8] The log difference between these two price targets is precisely the term that appears in Eq. (22): $\left(\gamma - 1\right)\sum_{k=1}^{K}\frac{\omega_k}{\omega_0}ln\left(\frac{\dot{P}_{t-k}}{P_t - k}\right)$. Compared to APS (2023), the log difference between the counterfactual (unstabilized) and historical (stabilized) prices is therefore augmented by the inadvertent difference in the target prices.

Range of Plausible Misperceptions

Our main interest in the remainder of the paper is to determine how OPEC's potential misperception of elasticities impacts its ability to stabilize prices. Although we do not pretend to know whether or to what degree such misperceptions exist (and we therefore consider a broad range), we do know that certain combinations of values for α and β are not plausible. First, presumably, OPEC holds the conventional view that the magnitude of short-term elasticity is smaller than that of long-term elasticity, i.e., that $\alpha\omega_0 \geq \beta\omega_l$.

This situation implies that we must have that $\beta \geq \alpha\frac{\omega_0}{\omega_l}$. Second, when the target price remains stable, Eqs. (B3) and (B4) constitute autoregressive processes[9] with the sum of lagged coefficients equal to $(\gamma-1)\sum_{k=1}^{K}\frac{\omega_k}{\omega_0} = 1+(\beta-1)\frac{\omega_l}{\omega_0}-\alpha$. A necessary condition[10] for such a process to be stationary is that the sum of the coefficients be smaller than unity, which implies that $(\beta-1)\frac{\omega_l}{\omega_0} < \alpha$. Otherwise[11] (i.e., if $\beta > 1+\frac{\omega_0}{\omega_l}\alpha$), the price process is not stationary but potentially explosive, resulting in either high or negative log-price values, which implies extremely high prices or prices close to zero. The necessary condition for stationarity can be rewritten as $\beta\omega_l - \alpha\omega_0 < \omega_l$, which means that the perceived delayed price impacts may not exceed the true long-term elasticity. This finding is confirmed by numerical simulation, where values α and β that violate the above conditions cause the counterfactual price to collapse. We therefore assume that β belongs to the interval $\left[\alpha\frac{\omega_0}{\omega_l};1+\alpha\frac{\omega_0}{\omega_l}\right]$, arguing that logic or experience prevents OPEC from believing in values outside of this interval.

As mentioned, if γ =1, then Eq. (22) is the same as Eq. (10a) in APS (2023), and the resulting counterfactual volatilities are the same as those presented in APS (2023). Perhaps surprisingly, this outcome does not necessarily require OPEC to correctly estimate both elasticity values. There exist compensating pairs of offsetting biases in α and β that result in γ being equal to unity (and, therefore, preserve the counterfactual volatilities of APS (2023)).

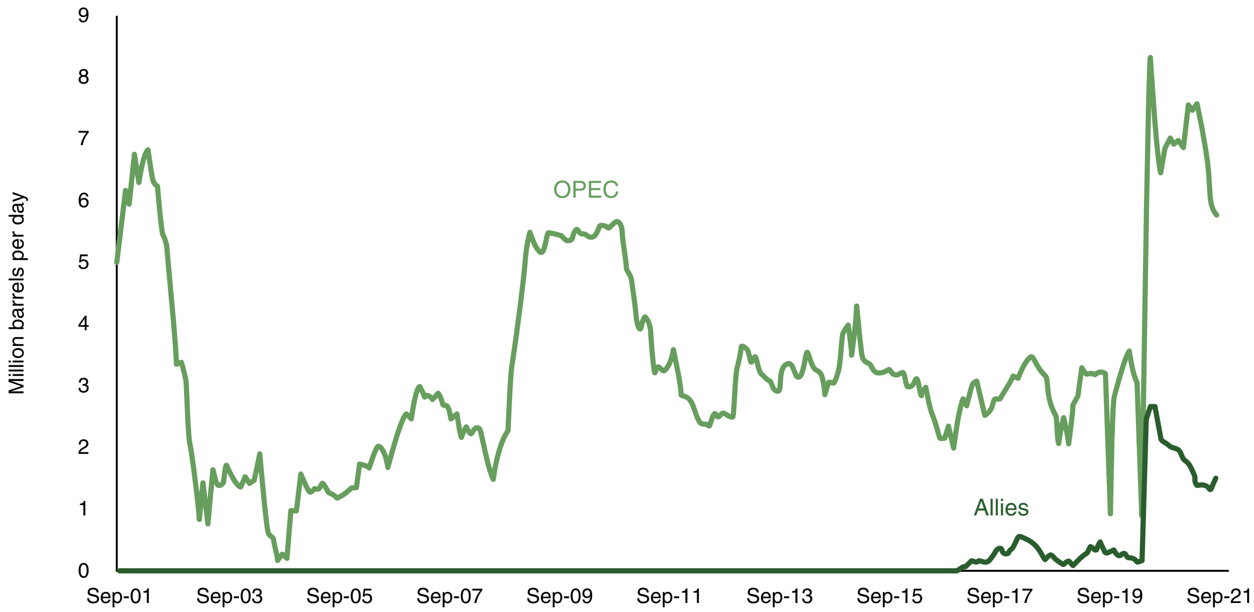
These compensating pairs satisfy the condition $\beta\omega_l-\alpha\omega_0=\omega_l-\omega_0$, which guarantees that the lagged price effects are estimated correctly, even if the immediate and long-term price effects are misestimated. This situation represents the only case in which misperceptions regarding elasticities fail to impact the counterfactual (unstabilized) price scenario. It may be unlikely for such compensating pairs to occur in reality.

Data and Results

Here, we compare the observed volatility of historical oil prices to the computed volatility of the counterfactual prices predicted to have occurred if OPEC had not attempted to stabilize prices. A higher counterfactual volatility is an indication that OPEC's attempt to stabilize prices has been successful. The essential point (as seen in Eq. (23)) is that the computed counterfactual prices that serve as a benchmark for judging OPEC's success depend on the actual elasticities of residual demand and on OPEC's perception of these elasticities. This point is where our analysis transcends APS (2023), who assumed that perception matches reality.

We rely on the same monthly estimates of OPEC and OPEC+ production and spare capacity, global oil production, and historical monthly oil prices, which were used in the abovementioned previous study.[12] Figure 1 shows the volumes of spare capacity held by OPEC and its Allies from September 2001 to August 2021.

Figure 1. Monthly Spare Capacity Held by OPEC+.



Source: APS (2023)

As explained in PSZ (2018), ω_0 (ω_l) is a function of the short-term (long-term) elasticity of global oil demand, the short-term (long-term) elasticity of non-OPEC oil supply, and OPEC's market share. Like Pierru, Smith and Almutairi (2020), we assume that the long-term price elasticity is –0.3 for global oil demand and 0.3 for non-OPEC supply. The results shown below are based on the assumption that the short-term elasticities of global oil demand and non-OPEC oil supply are −0.055 and 0.000, respectively, according to Caldara et al. (2019), but we explore the sensitivity of these results to these parameters in the Appendix. In all cases, we consider K = 48, $\omega_1,\dots,\omega_{48}$ to be identical and equal to the difference between ω_l and ω_0 divided by 48.

The analysis focuses on two distinct periods. The first period extends from September 2001 through February 2015; the second period extends from January 2017 through August 2021 (excluding March and April 2020, as discussed in APS 2023). These intervals correspond to the "Commodity Boom" and "OPEC+" periods treated by APS (2023) and exclude the so-called "Market Share Campaign," during which OPEC is thought to have refrained from its efforts to stabilize the market.

Evidence from the Commodity Boom Period

We look first at the Commodity Boom, the period before non-OPEC members began to collaborate with OPEC to stabilize the price. Consistent with the spare capacity data illustrated in Figure 1, we set $E_t = 0$ throughout the Commodity Boom period. Then, for any given hypothesis regarding OPEC's misperception of short- and long-term elasticities (i.e., α and β), we use Eq. (23) to calculate the predicted series of counterfactual prices that would have resulted had OPEC not used spare capacity to stabilize the price[13]. We then calculate the volatility of that counterfactual price series and compare the result with the actual volatility of the historical price series observed from September 2001 through February 2015. The result is summarized by the ratio of counterfactual volatility to historical volatility, which we call the "Volatility Index." The Volatility Index measures the extent to which the volatility of oil prices would have been higher or lower if not for OPEC's utilization of spare capacity. The higher the volatility index is, the more efficiently OPEC attempts to stabilize the price.

The results are displayed in Table 1 below. The table shows the volatility index predicated on a wide range of admissible hypotheses regarding the nature and extent of OPEC's potential misperception of the elasticities.[14] One notable feature of the table is that the Volatility Index everywhere exceeds unity. Thus, the conclusion that OPEC has managed to reduce volatility through its effort to stabilize the price is robust against what one might hypothesize regarding OPEC's misperception of elasticities. Moreover, the volatility index is never less than 1.5, which implies that volatility would have been at least 50% greater than OPEC's efforts to stabilize the price.

Another notable feature of Table 1 relates to the incremental impact of better information. As the accuracy of OPEC's presumed estimate of long-term elasticity improves (as $\beta \to 1$) the volatility of the counterfactual price decreases. This situation is true regardless of the value of α and is reflected in the fact that as β approaches

Table 1. Volatility Index during the Commodity Boom. Entries represent the ratio of counterfactual volatility to historical volatility, computed over the period September 2002-February 2015.

β \ α	0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
0.00	1.57										
0.05	1.57	1.57									
0.10	1.57	1.57	1.57								
0.15	1.56	1.57	1.57	1.57							
0.20	1.56	1.56	1.56	1.57	1.57	1.57					
0.25	1.56	1.56	1.56	1.56	1.56	1.57	1.57				
0.30	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.57	1.57		
0.35	1.55	1.55	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.57	
0.40	1.55	1.55	1.55	1.55	1.56	1.56	1.56	1.56	1.56	1.56	1.56
0.45	1.54	1.55	1.55	1.55	1.55	1.55	1.56	1.56	1.56	1.56	1.56
0.50	1.54	1.54	1.54	1.55	1.55	1.55	1.55	1.55	1.56	1.56	1.56
0.55	1.54	1.54	1.54	1.54	1.54	1.55	1.55	1.55	1.55	1.55	1.56
0.60	1.53	1.53	1.54	1.54	1.54	1.54	1.54	1.55	1.55	1.55	1.55
0.65	1.53	1.53	1.53	1.53	1.54	1.54	1.54	1.54	1.54	1.55	1.55
0.70	1.53	1.53	1.53	1.53	1.53	1.53	1.54	1.54	1.54	1.54	1.54
0.75	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.54	1.54	1.54
0.80	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.54
0.85	1.52	1.52	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53
0.90	1.52	1.52	1.52	1.52	1.52	1.53	1.53	1.53	1.53	1.53	1.53
0.95	1.51	1.51	1.52	1.52	1.52	1.52	1.52	1.53	1.53	1.53	1.53
1.00		**1.50**	**1.51**	**1.51**	**1.51**	**1.52**	**1.52**	**1.52**	**1.52**	**1.53**	**1.53**
1.05			1.50	1.50	1.51	1.51	1.51	1.52	1.52	1.52	1.52
1.10				1.50	1.50	1.50	1.51	1.51	1.51	1.52	1.52
1.15					1.51	1.50	1.50	1.50	1.51	1.51	1.51
1.20							1.52	1.50	1.50	1.50	1.50
1.25								1.81	1.54	1.50	1.50
1.30										1.93	1.56
compensating pairs:	0.82	0.85	0.89	0.93	0.96	1.00	1.04	1.07	1.11	1.15	1.18
min β for $\beta\omega_1 \leq \alpha\omega_0$:	0.00	0.04	0.07	0.11	0.15	0.18	0.22	0.26	0.29	0.33	0.37
max β for stationarity:	1.00	1.04	1.07	1.11	1.15	1.18	1.22	1.26	1.29	1.33	1.37

Positive Delayed Price Effects

Non-Stationary

Source: Authors.

unity from either direction (up or down in the table), the volatility index decreases (with only a few very minor exceptions). This finding not only suggests that learning more about long-term elasticity helps OPEC defend its target price but also points out that $\beta = 1$ (the row set off in bold) serves as a limiting case in the following sense. Without specifying any particular learning model, we observe that, however, OPEC may arrive at a more accurate estimate of the long-term elasticity; its ability to defend the target price improves and price volatility decreases even if OPEC does not attempt to offset shocks.

The exceptions to this pattern, although slight in magnitude, appear to be systematic and are interesting in and of themselves. In every case, as OPEC is assumed to overestimate the magnitude of the long-term elasticity ($\beta > 1$), we observe that the counterfactual volatility initially tends to decline slightly before again increasing as the size of the error grows relative to the unbiased case $\beta = 1$. What could be responsible for this curious phenomenon? We interpret this situation as follows: an overestimation of the demand response has two consequences. First, it inadvertently pushes the market price away from OPEC's desired target, as discussed previously. Second, it convinces OPEC that smaller quantity adjustments are sufficient to move the price by any desired amount (due to the perceived greater elasticity). This second effect dampens OPEC's output adjustments and the resulting variation in market price. However, eventually, as the market price is inadvertently pushed farther from the intended target, the first effect dominates and increases volatility.[15] Statistically, the effect is similar to the behavior of a James – Stein estimator,[16] which achieves a lower mean square error by shrinking a parameter estimate toward zero and thereby reducing its variance. However, only a limited amount of shrinkage achieves a favorable tradeoff in which the induced decrease in variance offsets the inevitable and increasing bias in the resulting estimate. We believe that a similar tradeoff produces the results shown in Tables 2 and 3. However, in our case, it is not a shrinkage in the estimated elasticity but rather its enlargement, which causes the resulting volatility to decline due to the inverse relation between price and quantity.

The red line in Table 1 represents a boundary where OPEC perceives only a short-term response to a price change, with no lagged effects. That is, combinations (α, β) along this boundary imply that OPEC perceives the long-term elasticity to be equal to the short-term elasticity. For a given α, any smaller value of β (gold area) implies positive lagged elasticities, which is inadmissible.

The pairs (α, β) highlighted in green (descending from left to right near the center of the table) produce compensating misperceptions that effectively cancel out (γ = 1) in the sense that the resulting counterfactual price series matches the unbiased case presented in APS (2023). The values displayed in the first line below the table indicate the compensating value of β for the given α. The values in the second line below the table indicate the smallest admissible value of β for the given α; any smaller β implies that OPEC perceives the effects of lagged prices as being positive. The values in the third line below the table indicate the largest admissible value of β for the given β; any larger α results in a nonstationary (explosive) price process.

The main conclusion from Table 1 is that APS's (2023) finding – that OPEC's efforts to stabilize the price during the Commodity Boom period managed to substantially reduce price volatility – appears robust against any plausible hypothesis regarding OPEC's misperception of both short- and long-term elasticities of residual demand for its crude oil production. The sensitivity analysis presented in the Appendix shows that similar results are obtained under different assumptions about the true elasticities of global demand and non-OPEC supply. The main difference between the sensitivity analysis and Table 1 is that in the former, if the true magnitude of either elasticity increases (decreases) compared to our base case, then the counterfactual volatility decreases (increases). The reason for this is that more responsive demand and supply have a greater tendency to stabilize the price regardless of OPEC's actions.

Evidence from the OPEC+ Period

Table 2 presents the Volatility Index, as it varies over the range of hypothesized misperceptions computed over the OPEC+ period (January 2017 through August 2021 but excluding March and April 2020, as discussed in APS 2023). The pattern of results is the same as that observed during the Commodity Boom period. Regardless of the size or pattern of presumed misperceptions, the volatility of the counterfactual price always exceeds that of the historical price. In this case, the efforts by OPEC+ to stabilize the market had an even greater impact than during the Commodity Boom. In all cases, the computed volatility of the counterfactual price exceeds the historical volatility by nearly 100% and, in most cases, by somewhat more than that figure. This finding suggests that the volatility of crude oil prices would have been twice as high as that of OPEC+ if it were not for the efforts made by OPEC+ to stabilize the price.

We suggest two possible factors that may have contributed to the increased impact of stabilization efforts during the OPEC+ period. First, there were much larger shocks to offset during the OPEC+ period due to the impact of the COVID-19 pandemic on demand. Second, the new participation of non-OPEC members (Allies) spread the work (and pain) of stabilization across a broader swath of global production, which may have increased OPEC's capacity and willingness to offset shocks to the market.

Table 2. Volatility Index during the OPEC+ period. Entries show the ratio of counterfactual volatility to historical volatility, computed over the period Jan 2017-Aug 2021 excluding March/April 2020.

		α										
		0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
β	0.00	2.26										
	0.05	2.25	2.25									
	0.10	2.23	2.24	2.25								
	0.15	2.22	2.23	2.23	2.24	2.25						
	0.20	2.20	2.21	2.22	2.22	2.23	2.24					
	0.25	2.18	2.19	2.20	2.21	2.21	2.22	2.23				
	0.30	2.16	2.17	2.18	2.19	2.20	2.21	2.21	2.22	2.23		
	0.35	2.14	2.15	2.16	2.17	2.18	2.19	2.20	2.20	2.21	2.22	
	0.40	2.12	2.13	2.14	2.15	2.16	2.17	2.18	2.19	2.19	2.20	2.21
	0.45	2.09	2.10	2.11	2.12	2.14	2.15	2.16	2.17	2.17	2.18	2.19
	0.50	2.07	2.08	2.09	2.10	2.11	2.12	2.13	2.14	2.15	2.16	2.17
	0.55	2.04	2.05	2.07	2.08	2.09	2.10	2.11	2.12	2.13	2.14	2.15
	0.60	2.02	2.03	2.04	2.05	2.06	2.07	2.09	2.10	2.11	2.12	2.13
	0.65	1.99	2.00	2.02	2.03	2.04	2.05	2.06	2.07	2.08	2.09	2.10
	0.70	1.97	1.98	1.99	2.00	2.01	2.02	2.04	2.05	2.06	2.07	2.08
	0.75	1.94	1.95	1.96	1.97	1.99	2.00	2.01	2.02	2.03	2.04	2.06
	0.80	1.91	1.92	1.93	1.95	1.96	1.97	1.98	2.00	2.01	2.02	2.03
	0.85	1.88	1.89	1.91	1.92	1.93	1.94	1.96	1.97	1.98	1.99	2.01
	0.90	1.86	1.87	1.88	1.89	1.90	1.92	1.93	1.94	1.95	1.97	1.98
	0.95	1.83	1.84	1.86	1.87	1.88	1.89	1.90	1.91	1.93	1.94	1.95
	1.00		**1.82**	**1.83**	**1.84**	**1.85**	1.86	**1.88**	**1.89**	**1.90**	**1.91**	**1.92**
	1.05			1.81	1.82	1.83	1.84	1.85	1.86	1.87	1.88	1.90
	1.10				1.80	1.81	1.82	1.83	1.84	1.85	1.86	1.87
	1.15					1.85	1.80	1.81	1.81	1.82	1.83	1.85
	1.20							1.92	1.80	1.80	1.81	1.82
	1.25								6.97	2.08	1.81	1.80
	1.30										9.62	2.37
compensating pairs:		0.82	0.85	0.89	0.93	0.96	1.00	1.04	1.07	1.11	1.15	1.18
min β for $\beta\omega_l \leq \alpha\omega_0$:		0.00	0.04	0.07	0.11	0.15	0.18	0.22	0.26	0.29	0.33	0.37
max β for stationarity:		1.00	1.04	1.07	1.11	1.15	1.18	1.22	1.26	1.29	1.33	1.37

Positive Delayed Price Effects

Non-Stationary

Source: Authors.

Effects of the Misestimation of Elasticity on the Stabilized Price

The volatility that remains despite OPEC's market stabilization efforts results from the accumulation of the following four factors: a lack of sufficient spare capacity in the face of large positive shocks, the effect of observation and execution errors, the volatility of the target price, and the misestimation of elasticity. The first factor has not materialized since September 2001 because spare capacity never fell to zero. The magnitude of the composite of the observation and execution errors was estimated in PSZ (2018) and APS (2023). The volatility of the target price was discussed in PSZ (2018) and is likely small. We now attempt to isolate the effect of the misestimation of elasticity.

After taking the logs and differencing Eq. (12), we obtain the following:

$$ln\left(\frac{P_t}{P_{t-1}}\right)=\frac{\sigma_z\left(z_t-z_{t-1}\right)}{\omega_0}+\alpha\, ln\left(\frac{P_t^*}{P_{t-1}^*}\right)+\frac{ln\left(\frac{\prod_{k=1}^{K}P_{t-k}^{(\gamma-1)\omega_k}}{\prod_{k=1}^{K}P_{t-k-1}^{(\gamma-1)\omega_k}}\right)}{\omega_0}+\frac{\left(b_t-b_{t-1}\right)}{\omega_0} \tag{24}$$

Replacing b_t with its expression, we combine the last three terms on the right-hand side (RHS) of Eq. (24) into a single term as follows:

$$ln\left(\frac{P_t}{P_{t-1}}\right)=\frac{\sigma_z\left(z_t-z_{t-1}\right)}{\omega_0}+\frac{ln\left(\frac{P_t^{*\omega_0}\left(1-e^{-S_t}\right)+e^{-S_t}P_t^{*\alpha\omega_0}\prod_{k=1}^{K}P_{t-k}^{(\gamma-1)\omega_k}}{P_{t-1}^{*\omega_0}\left(1-e^{-S_{t-1}}\right)+e^{-S_{t-1}}P_{t-1}^{*\alpha\omega_0}\prod_{k=1}^{K}P_{t-k-1}^{(\gamma-1)\omega_k}}\right)}{\omega_0}. \tag{25}$$

The price volatility *vol* is therefore given by the following:

$$vol^2=\frac{Var\left(\sigma_z\left(z_t-z_{t-1}\right)+ln\left(\frac{P_t^{*\omega_0}\left(1-e^{-S_t}\right)+e^{-S_t}P_t^{*\alpha\omega_0}\prod_{k=1}^{K}P_{t-k}^{(\gamma-1)\omega_k}}{P_{t-1}^{*\omega_0}\left(1-e^{-S_{t-1}}\right)+e^{-S_{t-1}}P_{t-1}^{*\alpha\omega_0}\prod_{k=1}^{K}P_{t-k-1}^{(\gamma-1)\omega_k}}\right)\right)}{{\omega_0}^2} \tag{26}$$

Eq. (26) gives the general formula for price volatility that remains after OPEC attempts to stabilize the price and is equivalent to the following:

$$vol^2 = \frac{Var\left(\sigma_z\left(z_t - z_{t-1}\right) + ln\left(\frac{P_t^{*\omega_0} + e^{-S_t}\left(P_t^{i\omega_0} - P_t^{*\omega_0}\right)}{P_{t-1}^{*\omega_0} + e^{-S_{t-1}}\left(P_{t-1}^{i\omega_0} - P_{t-1}^{*\omega_0}\right)}\right)\right)}{{\omega_0}^2}$$

where P_t^i denotes the price inadvertently targeted by OPEC in period *t*, as previously defined in Footnote 11. Due to OPEC's misperception of elasticities, the target price, the price inadvertently targeted and the demand shock are intertwined in the above formula. We successively consider different specific cases.

First, when both α and β are equal to unity, Eq. (26) gives the same formula as PSZ's (2018) Eq. (9):

$$vol^2 = 2\left(\frac{\sigma_z}{\omega_0}\right)^2 + Var\left(ln\left(\frac{P_t^*}{P_{t-1}^*}\right)\right).$$

Thus, when OPEC correctly estimates the elasticities, the volatility of the stabilized price depends only on the estimation error and the volatility of the target price.

Second, we consider the case where OPEC correctly estimates the delayed effects of prices but mistakes the true values ω_0 and ω_l; i.e., we consider compensating pairs of α and β such that $\gamma = 1$. Then, since z_t and S_t are independent, Eq. (26) becomes the following:

$$vol^2 = 2\left(\frac{\sigma_z}{\omega_0}\right)^2 + \frac{Var\left(ln\left(\frac{P_t^{*\omega_0}\left(1 - e^{-S_t}\right) + e^{-S_t}P_t^{*\alpha\omega_0}}{P_{t-1}^{*\omega_0}\left(1 - e^{-S_{t-1}}\right) + e^{-S_{t-1}}P_{t-1}^{*\alpha\omega_0}}\right)\right)}{{\omega_0}^2} \quad (27)$$

The last term on the RHS is the volatility of a composite of the target price and the demand shock. Even if the target price remains constant (and its volatility is zero), there is no reason why this composite would also remain constant since it also depends on the shock. This component therefore contributes to the volatility of the stabilized price. Thus, if we consider cases where the target price remains constant, then even if OPEC is able to correctly estimate the delayed price effects ($\gamma = 1$), the volatility of the stabilized price is greater than it would be if OPEC's perception matched the true elasticity values.

Third, we consider the case where OPEC correctly estimates the long-term elasticity ($\beta = 1$) but mistakenly estimates the short-term elasticity ($\alpha \neq 1$). For now, we assume that there is no demand shock but still an observation error, $\sigma_z z_t$; that is, OPEC perceives a shock, $\sigma_z z_t$, whereas $S_t = 0$. This implies that $b_t = 0$. Furthermore, assuming that OPEC's target price remains constant and equal to P^*, Eq. (12) becomes the following:

$$ln\left(P_t\right) = \alpha\, ln\left(P^*\right) + \left(\gamma - 1\right)\sum_{k=1}^{K}\frac{\omega_k}{\omega_0}ln\left(P_{t-k}\right) + \frac{\sigma_z z_t}{\omega_0} \quad (28)$$

The mean of the covariance-stationary process given by Eq. (28) is as follows:

$$\frac{\alpha ln\left(P^*\right)}{1 - \left(\gamma - 1\right)\sum_{k=1}^{K}\frac{\omega_k}{\omega_0}} = \frac{\alpha ln\left(P^*\right)}{1 - \left(\frac{\omega_l - \alpha\omega_0}{\omega_l - \omega_0} - 1\right)\frac{\omega_l - \omega_0}{\omega_0}} ln\left(P^*\right) = ln\left(P^*\right) \quad (29)$$

The long-term average of the log price is therefore equal to the log of the target price, which implies that despite misestimating α, OPEC can achieve a price that on average remains close to its target price. However, in the general case where $S_t \neq 0$ (i.e., $E(b_t) \neq 0$), the long-term average of the log price deviates from the log of the target price.

Conclusions

In terms of market management, OPEC attempts to stabilize the price at a certain level. However, one may question the ability of OPEC to accurately measure the shock to the demand for its oil (as in APS 2023) or to correctly anticipate the size of the demand response to an adjustment in its output. In this paper, we explore the implications of the second factor for market stability: potentially misinformed actions taken by OPEC due to uncertainty regarding the true short- and long-term elasticities of residual demand for OPEC crude oil. For example, if the magnitudes of these elasticities are overestimated, then any increase in production levels that OPEC might consider would be met by an unexpectedly large reduction in price. To what extent would such misinformed estimates confound OPEC's ability to stabilize the price around a chosen target level?

If OPEC's modus operandi is simply to monitor market developments and then use its spare production capacity to offset or absorb perceived shocks, then the knowledge of these elasticities hardly seems critical for its success. If OPEC is able to form an unbiased estimate of the magnitude of the shock and then employs spare capacity to directly offset that shock, then it would seem, as demonstrated by APS (2023), that OPEC would maintain its ability to dampen price movements. As we have shown in this paper, however, this method of argument is incomplete because it ignores the impact of misinformation on OPEC countries' pursuit of the target price itself. The goal of stabilizing the price is complicated by the fact that even in the absence of shocks, OPEC would miss its target price level if it were to misestimate the elasticities. Because the production level required to achieve any given target price depends directly on the elasticities, any error in assessing the elasticity may be reflected in additional noise in the market price that emanates from OPEC's inexact pursuit of the target level. Although this additional noise is unintended by OPEC, it is unavoidable if the elasticity of residual demand is not known with certainty.

In the current paper, we fully account for this possibility and reassess OPEC's historical success in stabilizing the market price. In summary, our results reinforce the previous conclusions and indeed somewhat increase the degree to which OPEC actions appear to have stabilized the price. We find that even if misinformed, OPEC substantially decreases price volatility by regulating production through its buffer of spare capacity. Whereas APS (2023) found that price volatility would have been approximately 50% greater than that actually observed if OPEC had not attempted to offset shocks during the Commodity Boom period, we estimate that volatility would have been approximately 55% greater than that actually observed – depending on the assumed degree and direction of OPEC's potential misestimation of the elasticities. In addition, for the OPEC+ period, for which APS (2023) found the counterfactual volatility to be 86% greater than that actually observed, our estimate again tends to be somewhat greater – between 100% and 120% greater than historical volatility – depending on the assumed degree and direction of OPEC's potential misestimation. In each case, the extra measure of stabilization is calculated by comparing historical prices to our reconstruction of the counterfactual price series, in which equilibrium prices are now subject to additional variation caused by mistaken elasticity. The conclusion that OPEC has managed to reduce volatility through its attempts to stabilize the price is robust against what one might hypothesize regarding OPEC's misperception of elasticities.

We also show that generally speaking, the greater OPEC's assumed misperception of the long-term elasticity is, the greater the extra noise imparted to equilibrium prices under the counterfactual scenario. Although we do not explore any specific models of learning, based on our results, we can say that if OPEC were able by any means to reduce its uncertainty regarding long-term elasticity, learning by doing as it were, then equilibrium prices under the counterfactual scenario would converge to the result presented in APS (2023), where the elasticities were assumed to be correctly perceived and which serves as a limiting case. Thus, those previous estimates of OPEC's success in stabilizing the market are robust to alternative hypotheses regarding both misinformation and information acquisition.

There are some minor exceptions to the rule that greater misperception causes greater counterfactual volatility, however, as noted in this paper. One example of such an exception is the existence of compensating pairs of errors in short- versus long-term elasticities that essentially cancel each other out, producing the same counterfactual production decisions and the same counterfactual prices as those produced when the true elasticities were known and acted on. Of course, only a very limited set of misperceptions leads to this conclusion.

The key to our results is the important and unexpected realization that an error in perceived elasticity is functionally equivalent to an observational error in OPEC's perception of the magnitude of each shock. We have shown (Eq. (14)) that OPEC's estimate of the call on its output at any point in time is misinformed by the sum of two independent stochastic elements: one that results from misperception of the actual shock and another that results from the potential misperception of the elasticities. Indeed, these two types of errors are isomorphic and act in a uniform manner to impact OPEC production – a point that was not obvious at the outset of our research.[17] The overall effect is as if OPEC were inadvertently targeting a price other than the intended price.

We also briefly explore the effect of the misestimation of elasticities on the stabilized price. Based on the analysis of simple cases, it appears that misestimation contributes to the volatility of the stabilized price, just as it contributes to the volatility of the counterfactual price. Although the general case is more difficult to solve, we believe that the same conclusion is warranted: greater misperception produces greater volatility despite OPEC's attempts at stabilization. Of course, the effect of OPEC's errors, if any, in estimating the elasticities is embedded in the observed historical price series, and thus, our analysis and conclusions regarding OPEC's success in stabilizing the price are robust to whatever one might assume those errors to have been. Moreover, based on our analysis, one would expect that any increase in OPEC's knowledge of the relevant elasticities going forward would enable its even greater success in stabilizing the future price of oil. Our results, therefore, show that even if misinformed, OPEC's quest to manage the market is reasonable.

Endnotes

[1] Cahill (2020) summarized some of the limitations of global inventory data as follows: "Oil storage is an opaque matter, with time lags and questions over the transparency and accuracy of self-reported data from various countries. It is especially challenging to estimate commercial inventories in emerging markets as opposed to Organization for Economic Co-operation and Development (OECD) states. Strategic petroleum reserves (SPRs) add another layer of complexity. The US and Japan publish data on their SPRs, but China does not reveal the full details of its data, forcing energy agencies and analysts to make their own estimates."

[2] Colgan (2014) questioned OPEC's ability to control the output of its members. Bremond, Hache, and Mignon (2012) and Fattouh and Mahadeva (2013) emphasized that OPEC's pricing power varies over time, depending on market conditions, and indeed that OPEC's conduct has varied over time.

[3] The market would anticipate the decision if the information was leaked in advance or, as Nazer and Pescatori (2022) suggested, if OPEC's decision was predictable. When the market correctly anticipates an OPEC decision, the impact on price may precede the announcement and not be recognized by the event study.

[4] We use the term "Allies" to refer to the non-OPEC producers who are parties to the Declaration of Cooperation and have collaborated with OPEC since 2017.

[5] The shock to the residual demand for OPEC oil is net of inventory adjustments and other measures taken by other market participants.

[6] Like PSZ (2018) and APS (2023), we do not take any particular stance on the level of the target price and how it is determined. In the model, the target price serves as an (unobserved) reference level for OPEC's market stabilization efforts each month. Our calculations of counterfactual volatilities do not require specifying the level of the target price.

[7] As in APS (2023), z_t. can be interpreted as the composite of the estimation error made by OPEC when measuring the size of the shock to offset and an execution error that may affect OPEC's production in any given month. Also note that here, we consider only the representation of market-stabilization behavior, whereas APS's (2023) formulation also includes the representation of market-share campaigns.

[8] Let $\dot{P}_t^i$ denote the price inadvertently targeted by OPEC in period t in the counterfactual scenario, with $\dot{Q}^*_{t|\alpha,\beta} = a_t \dot{P}_t^{i\omega_0} \prod_{k=1}^{K} \dot{P}_{t-k}^{\omega_k} + E_t,$ which gives us $\dot{P}_t^i = P_t^{*\alpha} \prod_{k=1}^{K} \dot{P}_{t-k}^{(\gamma-1)\frac{\omega_k}{\omega_0}}$. Similarly, if P_t^i denotes the price inadvertently targeted by OPEC in the historical scenario, then we have that $Q^*_{t|\alpha,\beta} = a_t P_t^{i\omega_0} \prod_{k=1}^{K} P_{t-k}^{\omega_k} + E_t,$ which gives us $P_t^i = P_t^{*\alpha} \prod_{k=1}^{K} P_{t-k}^{(\gamma-1)\frac{\omega_k}{\omega_0}}$.

[9] They are not standard autoregressive processes since their innovation terms are autocorrelated (due to the persistence of the shock).

[10] See inequality (4.3.28) p.76 in Cryer and Chan (2008).

[11] Note that if OPEC underestimates the long-term elasticity ($\beta \leq 1$), then a violation of the condition for stationarity would require α to be negative, which is implausible because it implies that OPEC believes the short-term price elasticity to be positive.

[12] OPEC's historical crude oil production is based on the IEA's "OPEC Historical Composition" series. We have deducted condensates from the IEA's global crude oil supply for consistency. The spare capacities of OPEC and OPEC+ members are based on the IEA's "Oil Market Reports" and data collected from Energy Intelligence. Our observed oil price is the average monthly spot price of Brent crude oil as reported by the US Energy Information Administration.

[13] When performing the recursion, counterfactual and observed prices are considered identical before September 2001.

[14] Inadmissible combinations of α and β are omitted, either because they imply a positive price elasticity (yellow sector) or because they imply a nonstationary price path (gray sector). We argue that neither logic nor experience would have allowed OPEC to hold such beliefs.

[15] In addition, as β ultimately approaches the upper limit for stationarity, the Volatility Index increases rapidly (which becomes even more apparent in Table 2).

[16] James and Stein (1961).

[17] For arbitrary time (t), any given error in OPEC's perception of the shock (z_t) has the same effect on its production decision as do corresponding misjudgments in either the SR or LR elasticity of demand. This correspondence exists over the entire domain of potential errors in judging the shock and is invertible, meaning that the effect of any particular misjudgment of the SR or LR elasticity has the same effect on OPEC's production decision as does a corresponding misperception of the shock. The algebraic form of this correspondence is found by setting $\sigma_z z_t = b_z$ and solving for either α *or* γ as a function of z_t.

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Appendix A: Sensitivity Analysis

Here, we show the behavior of the volatility index derived under alternative assumptions to test the robustness of our results against different magnitudes of the true elasticities of global crude oil demand and non-OPEC crude oil supply. We do not adopt or present the alternative elasticities as "best estimates;" we explore them only to gauge sensitivity.

Tables A1 and A2 are comparable to Tables 1 and 2, respectively, of the main text but are based on the assumption that the short-term (monthly) elasticity of global demand is −0.03 and that the short-term elasticity of non-OPEC supply is +0.03.

Table A1. Sensitivity analysis based on SR demand elasticity = -0.03 And SR supply elasticity =+0.03. Table entries show Volatility Index during the Commodity Boom.

		α										
	1.65	0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
β	0.00	1.70										
	0.05	1.70	1.70	1.70								
	0.10	1.70	1.70	1.70	1.70	1.70						
	0.15	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70			
	0.20	1.69	1.69	1.69	1.70	1.70	1.70	1.70	1.70	1.70	1.70	
	0.25	1.69	1.69	1.69	1.69	1.69	1.70	1.70	1.70	1.70	1.70	1.70
	0.30	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.70	1.70	1.70
	0.35	1.68	1.68	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.70
	0.40	1.68	1.68	1.68	1.68	1.68	1.69	1.69	1.69	1.69	1.69	1.69
	0.45	1.67	1.67	1.68	1.68	1.68	1.68	1.68	1.69	1.69	1.69	1.69
	0.50	1.67	1.67	1.67	1.67	1.68	1.68	1.68	1.68	1.68	1.68	1.69
	0.55	1.66	1.66	1.67	1.67	1.67	1.67	1.67	1.68	1.68	1.68	1.68
	0.60	1.66	1.66	1.66	1.66	1.66	1.67	1.67	1.67	1.67	1.68	1.68
	0.65	1.65	1.65	1.65	1.66	1.66	1.66	1.66	1.67	1.67	1.67	1.67
	0.70	1.65	1.65	1.65	1.65	1.65	1.66	1.66	1.66	1.66	1.66	1.67
	0.75	1.64	1.64	1.65	1.65	1.65	1.65	1.65	1.65	1.66	1.66	1.66
	0.80	1.64	1.64	1.64	1.64	1.65	1.65	1.65	1.65	1.65	1.65	1.66
	0.85	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.65	1.65	1.65	1.65
	0.90	1.63	1.63	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.65	1.65
	0.95	1.62	1.63	1.63	1.63	1.64	1.64	1.64	1.64	1.64	1.64	1.64
	1.00	**1.61**	**1.62**	**1.62**	**1.62**	**1.63**	**1.63**	**1.63**	**1.64**	**1.64**	**1.64**	**1.64**
	1.05				1.61	1.62	1.62	1.63	1.63	1.63	1.64	1.64
	1.10						1.61	1.62	1.62	1.62	1.63	1.63
	1.15									1.61	1.62	1.62
	1.20											1.61
	1.25											
	1.30											
compensating pairs:		0.90	0.92	0.94	0.96	0.98	1.00	1.02	1.04	1.06	1.08	1.10
min β for $\beta\omega_1 \leq \alpha\omega_0$:		0.00	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20
max β for stationarity:		1.00	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20

Positive Delayed Price Effects

Non-Stationary

Source: Authors

Table A2. Sensitivity analysis based on SR demand elasticity = -0.03 and SR supply elasticity =+0.03. Table entries show Volatility Index during the OPEC+ period.

		α										
		0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
β	0.00	2.51										
	0.05	2.49	2.50	2.50					*Positive Delayed Price Effects*			
	0.10	2.47	2.48	2.49	2.49	2.50	2.51					
	0.15	2.46	2.46	2.47	2.48	2.49	2.49	2.50	2.50			
	0.20	2.44	2.45	2.45	2.46	2.47	2.47	2.48	2.49	2.49	2.50	
	0.25	2.42	2.43	2.43	2.44	2.45	2.46	2.46	2.47	2.48	2.49	2.49
	0.30	2.39	2.40	2.41	2.42	2.43	2.44	2.45	2.45	2.46	2.47	2.47
	0.35	2.37	2.38	2.39	2.40	2.41	2.42	2.43	2.43	2.44	2.45	2.46
	0.40	2.34	2.35	2.36	2.37	2.38	2.39	2.40	2.41	2.42	2.43	2.44
	0.45	2.31	2.33	2.34	2.35	2.36	2.37	2.38	2.39	2.40	2.41	2.42
	0.50	2.28	2.30	2.31	2.32	2.33	2.34	2.35	2.36	2.37	2.38	2.39
	0.55	2.25	2.27	2.28	2.29	2.30	2.31	2.33	2.34	2.35	2.36	2.37
	0.60	2.22	2.24	2.25	2.26	2.27	2.28	2.30	2.31	2.32	2.33	2.34
	0.65	2.19	2.21	2.22	2.23	2.24	2.25	2.27	2.28	2.29	2.30	2.31
	0.70	2.16	2.17	2.19	2.20	2.21	2.22	2.24	2.25	2.26	2.27	2.28
	0.75	2.13	2.14	2.16	2.17	2.18	2.19	2.21	2.22	2.23	2.24	2.25
	0.80	2.09	2.11	2.12	2.14	2.15	2.16	2.17	2.19	2.20	2.21	2.22
	0.85	2.06	2.07	2.09	2.10	2.11	2.13	2.14	2.16	2.17	2.18	2.19
	0.90	2.03	2.04	2.05	2.07	2.08	2.09	2.11	2.12	2.14	2.15	2.16
	0.95	1.99	2.01	2.02	2.03	2.05	2.06	2.07	2.09	2.10	2.11	2.13
	1.00	**1.96**	**1.97**	**1.99**	**2.00**	**2.01**	**2.03**	**2.04**	**2.05**	**2.07**	**2.08**	**2.09**
	1.05				1.97	1.98	1.99	2.01	2.02	2.03	2.05	2.06
	1.10						1.96	1.97	1.99	2.00	2.01	2.03
	1.15			*Non-Stationary*						1.97	1.98	1.99
	1.20											1.96
	1.25											
	1.30											
compensating pairs:		0.90	0.92	0.94	0.96	0.98	1.00	1.02	1.04	1.06	1.08	1.10
min β for $\beta\omega_1 \leq \alpha\omega_0$:		0.00	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20
max β for stationarity:		1.00	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20

Source: Authors

Table A3. Sensitivity analysis based on SR demand elasticity = -0.139 and SR supply elasticity =+0.00. Table Entries show Volatility Index during the Commodity Boom.

		α										
	1.14	0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
β	0.00	1.14										
	0.05	1.14										
	0.10	1.14	1.14									
	0.15	1.14	1.14									
	0.20	1.14	1.14	1.14								
	0.25	1.14	1.14	1.14								
	0.30	1.14	1.14	1.14	1.14							
	0.35	1.14	1.14	1.14	1.14							
	0.40	1.14	1.14	1.14	1.14	1.14						
	0.45	1.14	1.14	1.14	1.14	1.14						
	0.50	1.14	1.14	1.14	1.14	1.14	1.14					
	0.55	1.14	1.14	1.14	1.14	1.14	1.14					
	0.60	1.14	1.14	1.14	1.14	1.14	1.14	1.14				
	0.65	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14			
	0.70	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14			
	0.75	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14		
	0.80	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14		
	0.85	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	
	0.90	1.13	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	
	0.95	1.13	1.13	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
	1.00	**1.13**	**1.13**	**1.13**	**1.14**	**1.14**	**1.14**	**1.14**	**1.14**	**1.14**	**1.14**	**1.14**
	1.05		1.13	1.13	1.13	1.14	1.14	1.14	1.14	1.14	1.14	1.14
	1.10			1.13	1.13	1.14	1.14	1.14	1.14	1.14	1.14	1.14
	1.15			1.13	1.13	1.13	1.14	1.14	1.14	1.14	1.14	1.14
	1.20				1.13	1.13	1.13	1.14	1.14	1.14	1.14	1.14
	1.25				1.13	1.13	1.13	1.13	1.14	1.14	1.14	1.14
	1.30					1.13	1.13	1.13	1.13	1.14	1.14	1.14
compensating pairs:		0.54	0.63	0.72	0.81	0.91	1.00	1.09	1.19	1.28	1.37	1.46
min β for $\beta\omega_l \le \alpha\omega_0$:		0.00	0.09	0.19	0.28	0.37	0.46	0.56	0.65	0.74	0.83	0.93
max β for stationarity:		1.00	1.09	1.19	1.28	1.37	1.46	1.56	1.65	1.74	1.83	1.93

Positive Delayed Price Effects

Non-Stationary

Source: Authors

Tables A3 and A4 are also comparable to Tables 1 and 2, respectively, of the main text but based on the elasticity estimates of Baumeister and Hamilton (2023), who find the short-term elasticity of global demand to be −0.139 and the short-term elasticity of supply from both the US and the rest of the world (which in their design includes all producing countries except the US, Russia, and Saudi Arabia) to be nonsignificantly different from zero.

Table A4. Sensitivity analysis based on SR demand elasticity = -0.139 and SR supply elasticity =+0.00. Table entries show Volatility Index during the OPEC+ period.

		α										
	1.14	0.00	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00
β	0.00	1.20										
	0.05	1.20										
	0.10	1.20	1.20									
	0.15	1.19	1.20									
	0.20	1.19	1.19	1.20								
	0.25	1.18	1.19	1.19								
	0.30	1.18	1.18	1.19	1.19							
	0.35	1.17	1.18	1.18	1.19							
	0.40	1.17	1.17	1.18	1.19	1.19						
	0.45	1.17	1.17	1.18	1.18	1.19						
	0.50	1.16	1.17	1.17	1.18	1.18	1.19					
	0.55	1.16	1.16	1.17	1.17	1.18	1.18					
	0.60	1.15	1.16	1.16	1.17	1.17	1.18	1.18				
	0.65	1.15	1.15	1.16	1.16	1.17	1.17	1.18	1.18			
	0.70	1.14	1.15	1.15	1.16	1.16	1.17	1.17	1.18			
	0.75	1.14	1.14	1.15	1.15	1.16	1.16	1.17	1.17	1.18		
	0.80	1.13	1.14	1.14	1.15	1.15	1.16	1.16	1.17	1.17		
	0.85	1.13	1.13	1.14	1.14	1.15	1.15	1.16	1.16	1.17	1.18	
	0.90	1.12	1.13	1.13	1.14	1.14	1.15	1.16	1.16	1.17	1.17	
	0.95	1.12	1.12	1.13	1.13	1.14	1.15	1.15	1.16	1.16	1.17	1.17
	1.00	**1.11**	**1.12**	**1.12**	**1.13**	**1.14**	**1.14**	**1.15**	**1.15**	**1.16**	**1.16**	**1.17**
	1.05		1.12	1.12	1.13	1.13	1.14	1.14	1.15	1.15	1.16	1.16
	1.10			1.12	1.12	1.13	1.13	1.14	1.14	1.15	1.15	1.16
	1.15			1.11	1.12	1.12	1.13	1.13	1.14	1.14	1.15	1.15
	1.20				1.11	1.12	1.12	1.13	1.13	1.14	1.14	1.15
	1.25				1.11	1.11	1.12	1.12	1.13	1.13	1.14	1.14
	1.30					1.11	1.11	1.12	1.12	1.13	1.13	1.14
compensating pairs:		0.54	0.63	0.72	0.81	0.91	1.00	1.09	1.19	1.28	1.37	1.46
min β for $\beta\omega_l \leq \alpha\omega_0$:		0.00	0.09	0.19	0.28	0.37	0.46	0.56	0.65	0.74	0.83	0.93
max β for stationarity:		1.00	1.09	1.19	1.28	1.37	1.46	1.56	1.65	1.74	1.83	1.93

Positive Delayed Price Effects

Non-Stationary

Source: Authors.

Appendix B: Derivations

Derivation of Eq. (12)

After simplification, Eq. (11) of the text becomes the following:

$$P_t^{\omega_0} e^{S_t} = \left(P_t^{*\omega_0} e^{S_t} - P_t^{*\omega_0} + P_t^{*\alpha\omega_0} \prod_{k=1}^{K} P_{t-k}^{(\gamma-1)\omega_k} \right) e^{\sigma_z z_t}. \quad \text{(B1)}$$

Solving for P_t gives the following:

$$P_t = P_t^{*\alpha} \prod_{k=1}^{K} P_{t-k}^{(\gamma-1)\frac{\omega_k}{\omega_0}}$$

$$\left(P_t^{*(1-\alpha)\omega_0} \prod_{k=1}^{K} P_{t-k}^{(1-\gamma)\omega_k} \left(1 - e^{-S_t}\right) + e^{-S_t} \right)^{\frac{1}{\omega_0}} e^{\frac{\sigma_z z_t}{\omega_0}}. \quad \text{(B2)}$$

which is equivalent to Eq. (12).

Derivation of Eq. (22)

From Eq. (21),

$$ln\left(\dot{P}_t\right) = \alpha\, ln\left(P_t^*\right) + (\gamma - 1)\sum_{k=1}^{K} \frac{\omega_k}{\omega_0} ln\left(\dot{P}_{t-k}\right) - \frac{S_t}{\omega_0}. \quad \text{(B3)}$$

We also have from Eq. (12) of the text that

$$ln\left(P_t\right) = \alpha\, ln\left(P_t^*\right) + (\gamma - 1)\sum_{k=1}^{K} \frac{\omega_k}{\omega_0} ln\left(P_{t-k}\right) + \frac{\sigma_z z_t + b_t}{\omega_0}. \quad \text{(B4)}$$

By combining Eq. (B3) with Eq. (B4), we obtain that

$$ln\left(\dot{P}_t\right) = ln\left(P_t\right) + (\gamma - 1)\sum_{k=1}^{K} \frac{\omega_k}{\omega_0} ln\left(\frac{\dot{P}_{t-k}}{P_t - k}\right) - \frac{S_t + \sigma_z z_t + b_t}{\omega_0}. \quad \text{(B5)}$$

Then, by combining Eq. (B5) with Eq. (19) of the text, we have the following:

$$ln\left(\dot{P}_t\right) = ln\left(P_t\right) + \frac{ln\left(1 + \frac{X_t}{\tilde{Q}_{t|\alpha,\beta} - E_t}\right) - ln(B)}{\omega_0}$$

$$+ (\gamma - 1)\sum_{k=1}^{K} \frac{\omega_k}{\omega_0} ln\left(\frac{\dot{P}_{t-k}}{P_t - k}\right), \quad \text{(B6)}$$

which corresponds to Eq. (22) of the text.

Notes

About the Authors

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Hossa Almutairi is currently a Principal Fellow at KAPSARC, focusing her research on energy economics, oil markets, and climate policies. During the Saudi G20 Presidency, she served as the Sherpa of Think20 (T20), which is the research and policy advice network for the G20. Additionally, she was the lead co-chair of the T20 task force "Sustainable Energy, Water and Food Systems." Prior to joining KAPSARC, Dr. Almutairi was a faculty member at the University of Wilfrid Laurier, Canada. Her research contributions have been featured in several reputable journals, and she was honored as the co-recipient of the 2023 OPEC Award for the Best Energy Research Paper.

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Dr. James L. Smith

James L. Smith is Professor Emeritus at Southern Methodist University in Dallas, Texas, where he held the Cary M. Maguire Chair in Oil and Gas Management for 23 years before retiring in 2018. Having specialized in energy studies since receiving his Ph.D. in Economics from Harvard University in 1977, Dr. Smith has been a prolific researcher and author. His publications on OPEC, energy markets, real options, auction theory, and the oil and gas business have appeared in numerous academic and trade journals, including the *American Economic Review*, the *Journal of Economic Perspectives*, the *Quarterly Journal of Economics*, *the Economic Journal*, the Journal of Economic Theory, The Energy Journal, Mathematical Geology, the *Oil and Gas Journal*, and *World Oil*. Dr. Smith is a Past-President of the International Association for Energy Economics, and recipient of the Association's 2024 award for Outstanding Contributions to the Profession. In addition, Dr. Smith served for sixteen years as Co-Editor of *The Energy Journal*.

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