Oil Supply Shocks Are not Alike

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Abstract

One of the crucial questions in the oil market is whether supply or demand holds more significance in explaining oil price movements. The first idea underlying our study emphasizes the need to incorporate a temporal dimension into this question. We distinguish between supply and demand shocks and considering transitory and permanent forces we analyse effects over time. This involves long-term restrictions for transitory shocks and short-term restrictions related to low supply elasticity in the oil market to identify the structural model within a system sharing a common trend. Our dataset covers the period from 1990 to 2023 and thei main conclusion is that short-term fluctuations in oil prices are primarily driven by demand around 80% in the first months, while supply-side factors exert more influence in the medium to long-term achieving 70% in 2 years while business cycle vanishes. Additionally, we have strong evidence of the distinct roles played by OPEC and non-OPEC members in both the equilibrium and market dynamics.

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1 Introduction

The oil market literature has extensively debated whether demand or supply shocks play a more crucial role in driving fluctuations in oil prices. While studies by Hamilton (2009); Blanchard and Gali (2007) have asserted that supply-side factors are the primary drivers, others, including Kilian (2009); Alquist et al. (2013), argue that demand-side factors, particularly influenced by business cycles, hold the key to understanding oil price movements. In addressing this issue, we estimate a structural model identifying business cycle and OPEC supply shocks aligned with the literature and we also incorporate two additional shocks into our model technology shocks by the non cartelized side of the supply market as evidenced in Hamilton (2012) and *TFP* shocks, building upon the work of Rebei and Sbia (2021), who provided evidence of a lasting impact on the market resulting from supply and demand factors. We specifically explore this outcome with with interpretation focus, incorporating restrictions related to transitory effects, coupled with short-term exclusion restrictions linked to low supply elasticity, to identify the model. As far as our knowledge extends, there is currently no paper providing a structural interpretation that considers a level relationship between oil prices and its fundamentals, along with the associated long-term restrictions.

Earlier studies on supply disruptions primarily focused on the period from the 1970s to the early 1990s, marked by episodes of sharp changes in oil production due to wars and cartel decisions. Additionally, evidence suggests that speculative shocks and supply shocks have diminished in relevance over time Kilian and Murphy (2014). Recent studies, exemplified by works such as Kilian (2009), Lippi and Nobili (2012), Alquist et al. (2013), and Issler et al. (2014), highlight surprises in business cycles as the predominant source explaining short-term dynamics of oil prices. These studies track economic activity using variables such as *GDP* growth and freight prices. We utilize the Global Industrial Production Index, which has been demonstrated to be the most effective economic activity tracker Hamilton (2021), enabling us to work with monthly data in a system featuring real oil prices and oil production disentangled by OPEC and non-OPEC members. These variables share a common trend, implying the presence of a single transitory shock, which we identify as the business cycle shock to oil prices, assuming no long-term effect on the endogenous variables aligning with the seminal contributions of Blanchard and Quah (1988) and Gali (1999), who employ long-term restrictions identifying business cycle surprises. We also incorporate a total factor productivity (*TFP*) shock as a source of permanent demand innovation, influenced by the results of Rebei and Sbia (2021). This shock represents a demand-induced shift in industrial production with a permanent effect, reflecting the productivity gains leading to persistent growth and additional demand for oil as a fundamental input in the global economy. On the supply side, we differentiate between OPEC and non-OPEC oil production, aligning with robust evidence of heterogeneity in oil production. We posit that the non-OPEC supply shock to oil production is linked to efficiency gains and technological advances, while OPEC production results from an oligopolistic decision, identifying both as productivity shocks to the supply side. Identification of these shocks are related to the low supply elasticity in the oil market what is found to be close to zero as in Kumar and Mallick (2023).

In summary, short-term oil price fluctuations are primarily driven by demand factors, while supply-side factors dominate long-term prices. Shocks to total factor productivity exert a pronounced influence, impacting industrial production, oil prices, and OPEC oil production significantly. Demand shocks, persistent through *TFP* or cyclical via business cycles, induce positive correlations in the systems where industrial production input prices and quantities increase. On the other hand, supply shocks in the oil market from both OPEC and non-OPEC members result in negative correlation between oil price and quantities what would be expected for exogenous variations in supply. Moreover we find that these shocks prompt competitors to decrease production, leading to a more than proportional increase in market share as evidence of competition between the groups. OPEC responds to business cycles, with the most substantial adjustments occurring approximately six months after the average business cycle shift, while non-OPEC producers show limited changes in oil production. Moreover, OPEC reacts negatively to unexpected increases in non-OPEC oil production, and vice versa, with the overall impact of a supply shock reduced by the production withdrawal of the other group of players.

On the one hand our key findings align with previous research, indicating that demand factors are a major source of volatility and price movements in the short run. However, as business cycles vanish, the supply side of the market becomes the primary driver of unpredictability, with a notable contribution from non-OPEC members. OPEC oil production is highly influenced by *TFP* shocks, attenuating persistent demand growth, while productivity and technological improvements, as explained by Hamilton (2012), dictate the long-term trajectory of the commodity. In the next section, we discuss the discuss the low oil supply elasticity and the third section presents the model, both in reduced and structural forms, along with the identification hypothesis. The fourth section is the empirical section, where we present structural estimates. In the fifth section we conclude.

2 Short-Term Low Supply Elasticity

The conceptual framework is built upon the approach introduced by Issler et al. (2014) related to the derived demand for inputs. The authors consider an equilibrium condition based on the cost-minimizing industrial firm operating within an input market with supply constraints in the short term, as is the case in the oil market. When the firm needs to increase its production in the short run, it naturally exerts upward pressure on input. This happens because if firms are operating efficiently to enhance production, the firm must employ more inputs, thereby pressuring its demand with a low potential supply response. In line with this, Kumar and Mallick (2023) finds zero short-run supply elasticity but zero long-term effect from business cycle shocks.

As visualized in Figure 1, in the second plot, fluctuations in industrial production returns are tightly linked to oil returns with a positive correlation. This leads us to understand that the dynamics between the variables are induced by demand shocks since, for supply shocks, a negative correlation would be expected. Linking to our interpretation model, supply and *TFP* shocks are shocks that cause changes in the equilibrium, while business cycle shocks shift demand, pressuring prices and quantities but only for a while. Our findings indicate that OPEC is significant in responding to business cycles after a couple of months, while non-OPEC producers are never significant for the transitory demand shock, but both respond to permanent innovations.

Supply-Side Heterogeneity: The oil market is characterized by heterogeneous supply with a few organized producers responsible for approximately 50% of total production with a lower cost function and with to adjust production in the short run but acting as a first mover oligopolist and market price fluctuates way above their average or marginal costs. Further insights into the heterogeneity on the supply side of the oil market can be found in Al Rousan et al. (2018), exploring network structures in supply interaction, and Baumeister and Hamilton (2023), employing a granular IV approach and highlighting the relevance of Saudi Arabia's production and inventories in smoothing oil price volatility. In this sense we would expect at least the same response from OPEC members than from non-OPEC member to demand shocks since the cartel have some room to adjust production and also is the first mover of the game in the supply side and this idea contributes to explaining our findings.

3 Model

3.1 Reduced Form

Let $y_t = (p_t, ip_t, q^O, q^R)$ denote the logarithms of oil price, global industrial production, OPEC, and non-OPEC oil production. We find that the cointegration rank is one, in line with previous studies He et al. (2010); Lardic and Mignon (2006). There exists a shared long-term trend among the variables, representing an equilibrium in the level relationship. This relationship generates a stationary residual component that is crucial for explaining oil price returns through the error correction mechanism. In this mechanism, the expected value for oil return is precisely the negative of the disequilibrium, ensuring the long-term convergence of prices to the fundamental level.

The classical concept of the natural value encompassing neutral interest rates, potential GDP, unemployment levels, and more recently applied to capital flows Burger et al. (2022), aims to identify the intrinsic value within the supply. This concept possesses the characteristic of being slow-moving, thereby possessing the ability to capture information about trends. In our case, the supply side of the global economy, tracked using global industrial production, demands oil from the supply side of the oil market. Given the levels of global industrial production and oil production, we have an oil price such that deviations are transitory. A linear combination of the variables in levels defines the equilibrium, and the dynamics of oil price are given by the error correction term, the lags of the endogenous variables, and a residual term, the reduced form error of the oil price[1]:

$$\Delta p_t = \alpha_1 e^c_{t-1} + \sum_{1 \leq i \leq 6} a'_{1,i} \Delta y_{t-i} + e_{1,t}$$

We explain oil return as a function of the error correction term and the lags of the variable returns, where $a'_{1,i}$ is a 4-dimensional vector of parameters. The same specification is applied to the other variables of the system, assuming that the system can be approximated by a VAR model expressed in levels:

[1] Details in the Appendix

$$y_t = \sum_{i=1}^{p} A_i y_{t-i} + e_t$$

Here, e_t is the reduced form innovation with $Var(e_t) = \Sigma_e$, a non-diagonal matrix. We can rewrite this process[2]: obtaining the following VECM Representation:

$$\Delta y_t = \alpha\beta^{'} y_{t-1} + \sum_{i=1}^{p-1} \tilde{A}_i \Delta y_{t-i} + e_t$$

where α is an $n \times 1$ loading vector, β defines the cointegration relation with dimension $1 \times n$, and r is the cointegration rank or the rank of the matrix $\alpha\beta'$. Precisely, β corresponds to the normalized cointegration vector, and $\beta^{'} y_{t-1} = e^c_{t-1}$ is the lagged cointegration error. If there is no cointegration in the system, $\alpha = 0$, and the level $VAR(p)$ process turns out to be a pure first difference $VAR(p-1)$ process. In a system with cointegration, we have the $VAR(p-1)$ process adding the error correction mechanism.

3.2 Structural Dynamics

Structural Form: We decompose the reduced-form oil price innovations into four distinct components. First, we explore shocks associated with surprises in the business cycle, representing the sole shock in the system with transitory effects and no permanent consequences. We also identify shocks originating from global industrial production, specifically identified as *TFP* shocks, acknowledging their significant impact on the intricate dynamics of the oil market. Different oil supply shocks are considered, one by the OPEC members, aligned with the supply shock identified in the literature driven by oligopolistic decisions, and the other originated from the non-OPEC members led by innovations in production technology. All of these shocks are allowed to affect prices in the same period. Structural innovations in the system are given by the business cycles and three productivity shocks:

[2] $A(L)y_t = e_t$ with $A(L) = I - A_1 L - \ldots - A_p L^p$, the autoregressive polynomial. Using linear transformations, we can rewrite it as:

$$\Delta y_t = -A(1) y_{t-1} + \sum_{i=1}^{p-1} \tilde{A}_i \Delta y_{t-i} + e_t$$

where $\tilde{A}_i = -(A_{i+1} + ... + A_p)$ for all $i \leq p-1$. $-A(1)$ can be expressed as a function of the loading vector and the cointegrating relationship: $\alpha\beta'$.

$$\Delta p_t = \alpha_1 \beta' y_{t-1} + \sum_{i=1}^{p-1} a'_{1,i} \Delta y_{t-i} + \tilde{b}_{1,1} \varepsilon_t^{BC} + \tilde{b}_{1,2} \varepsilon_t^{TFP} + \tilde{b}_{1,3} \varepsilon_t^{OPEC} + \tilde{b}_{1,4} \varepsilon_t^{n-OPEC}$$

In period t, we assume that the TFP shock is the variation in industrial production not explained by the business cycles and by the supply-side shocks, for which the supply response is not immediate:

$$\Delta ip_t = \alpha_2 \beta' y_{t-1} + \sum_{i=1}^{p-1} a'_{2,i} \Delta y_{t-i} + \tilde{b}_{2,1} \varepsilon_t^{BC} + \tilde{b}_{2,2} \varepsilon_t^{TFP} + \tilde{b}_{2,3} \varepsilon_t^{OPEC} + \tilde{b}_{2,4} \varepsilon_t^{n-OPEC}$$

The supply side of the oil market is characterized by a group that acts as an oligopolist with production costs lower than the non-OPEC, inducing different dynamics. OPEC choices of supply incorporate shocks of non-OPEC producers, which come from technological improvements and new discoveries, while OPEC decisions come from another data-generating process. We assume that the rest of the world does not respond contemporaneously to OPEC surprises on oil production:

$$\Delta q_t^{oil} \begin{cases} \Delta q_t^{OPEC} = \alpha_3 \beta' y_{t-1} + \sum_{i=1}^{p-1} a'_{3,i} \Delta y_{t-i} + \tilde{b}_{3,1} \varepsilon_t^{BC} + \tilde{b}_{3,3} \varepsilon_t^{OPEC} + \tilde{b}_{3,4} \varepsilon_t^{n-OPEC} \\ \Delta q_t^{n-OPEC} = \alpha_4 \beta' y_{t-1} + \sum_{i=1}^{p-1} a'_{4,i} \Delta y_{t-i} + \tilde{b}_{4,1} \varepsilon_t^{BC} + \tilde{b}_{4,4} \varepsilon_t^{n-OPEC} \end{cases}$$

Putting these equations into a system of equations, we obtain the structural model:

$$\Delta y_t = \alpha \tilde{\beta}' y_{t-1} + \sum_i A_i \Delta y_{t-i} + B_0^{-1} \varepsilon_t$$

where elements of B_0^{-1} are $\{\tilde{b}_{i,j}\}_{1 \leq i \leq 4, 1 \leq j \leq 4}$.

Identification: We present the contemporaneous and long-term impact matrices where identifying restrictions are imposed to obtain estimates of the structural model. A useful representation of a system of cointegrated variables is the Engle-Granger representation (Engle and Granger (1987)), which expresses the level of the variables in function of the errors with reduced form trend and cycles disentangled:

$$y_t = x_0 + \Xi \sum_{i=1}^{t} e_i + \Xi^*(L) e_t$$

where $\Xi = \beta_\perp \left[\alpha'_\perp \left[-\alpha\beta'\right] \beta_\perp\right]^{-1} \alpha'_\perp$, $\beta_\perp$ and $\alpha_\perp$ are orthogonal complements of β and α, $\Xi^*(L)e_t = \sum_{j=0}^{\infty} \Xi_j^* e_{t-j}$ is a stationary process. The rank of the matrix Ξ is $n - r$, reflecting the independent trends in the system.

For our purposes, we are interested in the structural VEC model:

$$B_0 \Delta y_t = -B_0 \alpha \beta' y_{t-1} + \sum_{i=1}^{p-1} B_0 \tilde{A}_i y_{t-i} + \varepsilon_t$$

where ε_t is the structural error, i.e., mutually and serially uncorrelated error, with $Var(\varepsilon_t) = \Sigma_\varepsilon = Diag(V_1, ..., V_n)$, where $V_i = \mathbb{E}[\varepsilon_{it}^2]$.

Using the relation $e_t = B_0^{-1} \varepsilon_t$ in the Engle-Granger representation:

$$y_t = x_0 + \Gamma \sum_{i=1}^{t} \varepsilon_i + \Gamma^*(L) \varepsilon_t$$

where we define $\Gamma = \Xi B_0^{-1}$ and $\Gamma^*(L) = \Xi^*(L) B_0^{-1}$.

The matrix Γ is the long-run impact matrix. It captures the long-run effect of the vector of structural innovations in the y_t variables $\frac{\partial y_{t+h}}{\partial \varepsilon_t'} \to^h \Gamma$. Identifications using long-term restrictions set to zero elements or columns of this matrix. The ij entry of the matrix Γ where $\gamma_{ij} = \lim_{h \to \infty} \frac{\partial x_{it+h}}{\partial \varepsilon_{j\,t}}$ is the long-term effect of shock j in the $i - th$ endogenous. To identify the structural shock related to business cycles with this restrict we set $\gamma_{,1} = 0$ assuming no long-term effect in all variables of the system. Since the Ξ comes from data we identify the first column of B_0^{-1} combining with referred short-run restrictions we identify the model.

$$B_0^{-1} = \begin{bmatrix} \hat{\tilde{b}}_{1,1} & \tilde{b}_{1,2} & \tilde{b}_{1,3} & \tilde{b}_{1,4} \\ \hat{\tilde{b}}_{2,1} & \tilde{b}_{2,2} & \tilde{b}_{2,3} & \tilde{b}_{2,4} \\ \hat{\tilde{b}}_{3,1} & 0 & \tilde{b}_{3,3} & \tilde{b}_{3,4} \\ \hat{\tilde{b}}_{4,1} & 0 & 0 & \tilde{b}_{4,4} \end{bmatrix} \qquad \Gamma = \begin{bmatrix} 0 & \gamma_{1,2} & \gamma_{1,3} & \gamma_{1,4} \\ 0 & \gamma_{2,2} & \gamma_{2,3} & \gamma_{2,4} \\ 0 & \gamma_{3,2} & \gamma_{3,3} & \gamma_{3,4} \\ 0 & \gamma_{4,2} & \gamma_{4,3} & \gamma_{4,4} \end{bmatrix}$$

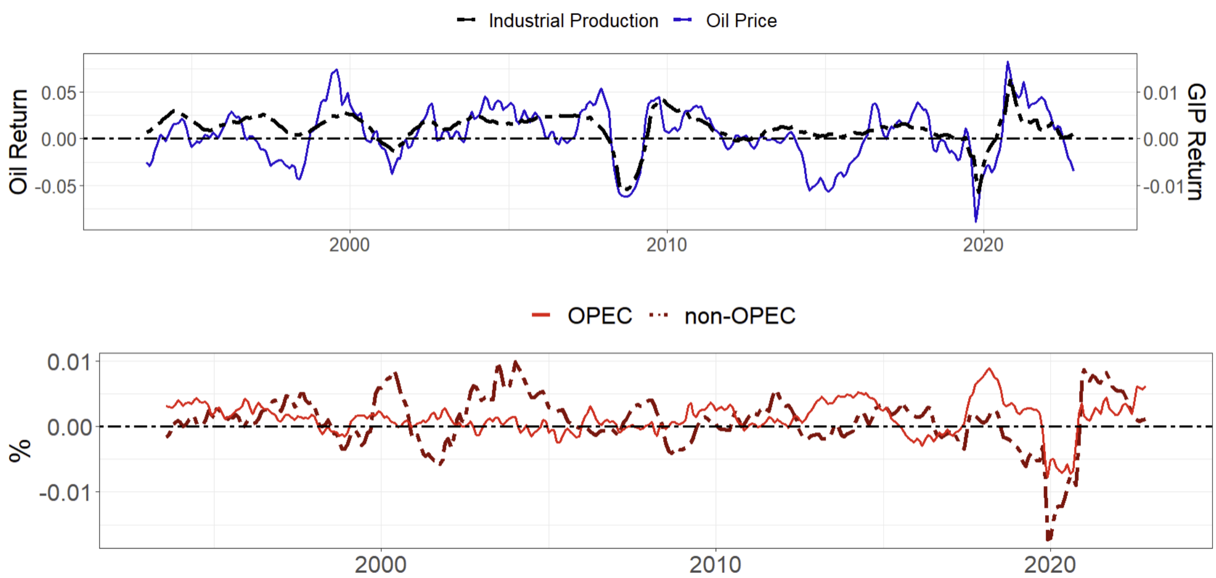
4 Empirical Analysis

4.1 Data

In our investigation we utilized monthly data spanning from January 1993 to May 2023. The oil-price data was sourced from the FRED database of the St. Louis Federal Reserve and specifically comprises the global price of West Texas Intermediate (WTI) crude oil. We obtain the real oil price after deflating the nominal price using the US Consumer Price Index (CPI), also retrieved from the FRED database.

Additionally, we incorporated the Global Industrial Production index, following the approach by Hamilton Baumeister and Hamilton (2019). These series are seasonally adjusted and serve as a robust proxy for global economic activity and combines OECD Industrial production with Brazil, China, India, Indonesia, Russia, and South Africa. The level of industrial production reflects a substantial demand for oil, making it a reliable indicator of aggregate demand. For data on oil production, we accessed information from the US Energy Information Administration open data.

Figure 1: The Industrial Production Index by Baumeister and Hamilton (2019) and the real oil price log levels in the top and 9month moving average in the bottom. In the second figure the level of OPEC and non-OPEC production in millions of barrels per day and the 12-month moving average of the return of the series.



4.2 Structural Estimates

In this section, we present estimates of the contemporaneous impact matrix B_0 and the long-term impact matrix Γ, reflecting the short-term impacts and cumulative effects of demand and supply shocks in the oil market. These estimates recover the marginal effects within the impulse response functions and emphasize the more interesting short to medium-term dynamics of real oil prices and OPEC production. Notably, there is a transition from demand to supply shocks for oil prices and the opposite for OPEC production, moving from supply shocks to demand shocks over time.

The contemporaneous matrix relation represents the short-term relationship between the variables of the system. Short-term restrictions are imposed to explain real oil price fluctuations. We find that an increase of 1% in global industrial production causes a 2.66% increase in oil return within the same month. Similarly, a 1% increase in OPEC production decreases prices by 2.67%, while a 1% increase in non-OPEC production decreases oil prices by 1.3%. The estimated matrix is provided in Table 1.

Table 1: Estimated Contemporaneous matrix B_0

	Oil Price	Industrial Production	OPEC oil production	non-OPEC oil production
Oil Price	1.0000	-2.6616	2.6656	1.3033
Industrial Production	0.0093	1.0000	0.0578	-0.0885
OPEC oil production	-0.0461	0.1228	1.0000	-0.2392
non-OPEC oil production	-0.0026	0.0070	-0.0070	1.0000

Additionally, Table 5 shows the estimated Contemporaneous Impact Matrix B_0^{-1}:

Table 2: Estimated Contemporaneous Impact Matrix B_0^{-1}

	Business Cycles	*TFP*	*TFP OPEC*	*TFP non-OPEC*
Oil price	0.8238	3.3684	-2.6494	-0.7190
Industrial production	-0.0157	0.9489	-0.0111	0.0756
OPEC oil production	0.0412	0.0000	0.8696	0.2223
Non-OPEC oil production	-0.0101	0.0000	0.0000	1.0032

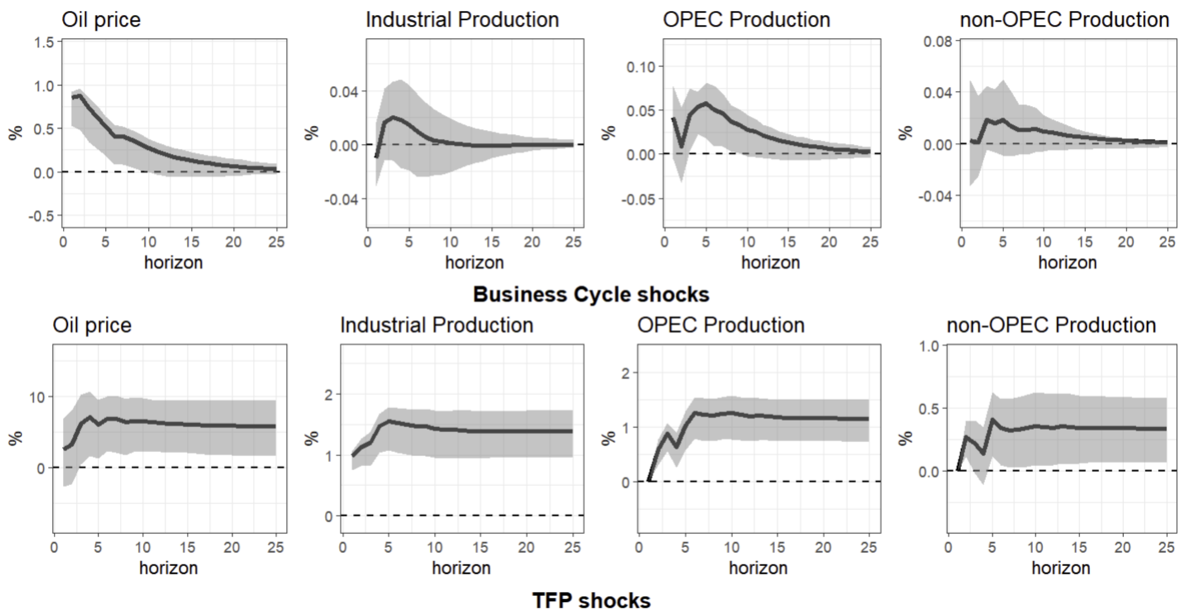
Table 3 presents the estimated long-term impact of the structural shocks through the matrix Γ. The first column of the matrix represents the long-term impact of shocks to business cycles and is assumed to be a vector of zeros. We observe positive long-term effects of shocks to total factor productivity in all variables. Notably, responses of OPEC are higher than non-OPEC producers, indicating a substantial impact of shocks on OPEC production, which in turn affects non-OPEC members and oil prices. The price impact of one standard deviation of the structural shock is approximately three times higher for non-OPEC members.

Table 3: Estimated Long-Term Impact Matrix $\Gamma = \Xi B_0^{-1}$

	Business Cycles	*TFP*	*TFP OPEC*	*TFP non-OPEC*
Oil price	0	5.73	-2.89	-7.48
Industrial production	0	1.40	-0.27	-0.25
OPEC production	0	1.14	0.51	-0.28
Non-OPEC production	0	0.33	-0.11	0.67

Demand Shocks: Transitory demand shocks primarily impact prices, while permanent demand shocks primarily affect quantities in the long term. Additionally, both lead to a positive correlation within the system, aligning with the expected behavior for demand shocks. Positive surprises in demand, as indicated by point estimates, result in a simultaneous increase in global production, prices, and oil production. This holds true for both business cycles and total factor productivity shocks. Supply-side shocks induce different patterns of comovement among the system's variables.

Figure 2: Estimated effect of one standard deviation of the business cycle shock on system variables over a 30-month horizon with 95% bounds.



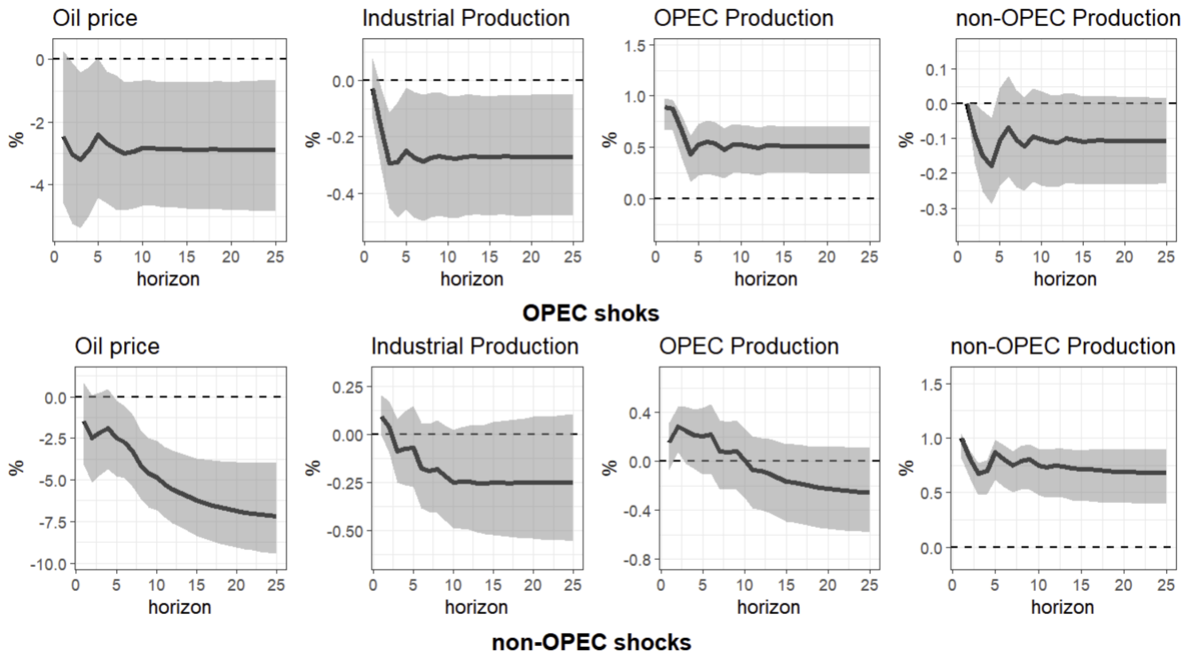
For a 1-standard deviation shock in business cycles, we estimate an 0.85% increase in prices, with a significant, albeit low, supply response from OPEC production (0.05% in 5 months), which is higher than observed by non-OPEC members and not statistically significant at the 10% level. As a temporary shock, its influence diminishes over time, with cumulative effects converging to zero for all variables. The cointegration condition suggests evidence of a transitory or strictly cyclical shock in the system, identified as surprises in business cycles, consistent with existing literature.

Shocks to the TFP represent supply-side shocks in the global economy. These shocks result in persistent increases in income, consumption, and industrial production, leading to higher demand for oil and subsequently higher prices and quantities in the long term. Positive comovement patterns persist, with effects more pronounced on quantities than on prices. A 1-standard deviation TFP shock leads to an immediate 1% increase in industrial production and a 3.5% increase in oil prices within the same month, converging to a cumulative effect of 5.7% in the long term. OPEC production responds to *TFP* shocks, converging to a 1.14% increase, while non-OPEC production increases by 0.33%.

Supply Shocks: OPEC and non-OPEC supply shocks are productivity shocks that generate higher-than-expected oil supply. These shocks have different effects on prices within each group. OPEC supply shocks immediately affect prices, with the effect remaining constant over time. In contrast, shocks to non-OPEC producers decrease prices over time, becoming significant only after six months. A monthly standard deviation of OPEC supply shock is associated with a long-term production increase of around 0.5%, while non-OPEC supply shocks increase production by 0.67%.

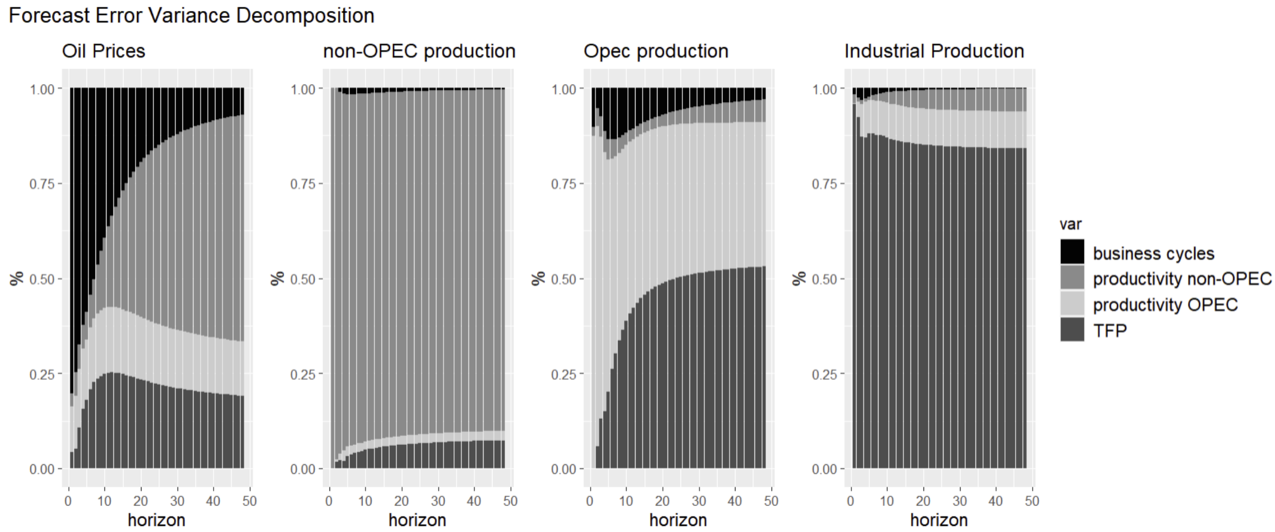
The effects on prices are heterogeneous, with OPEC shocks leading to a price reduction of 2.5% to 3% at every horizon, and non-OPEC shocks initially causing a -1.5% reduction, increasing to an estimated -7.5% in the long term. The competition in the supply side is evident as unexpected increases in production by cartel members are attenuated by reductions from the rest of the world, and vice versa, showcasing a dynamic interaction in the global oil market.

Figure 3: Estimated effect of one standard deviation of the OPEC supply shock on system variables over a 30-month horizon with 95% bounds.



Short and Long-Term Structural Dynamics: In short-term until the end of the cycle estimated to last for 24 months oil price is mostly affected by demand surprises. The business cycle shock represents a demand-side factor that gradually diminishes in significance over time and long-term prices are mostly influenced by the supply-side . In the initial months, only a quarter of oil price movements can be attributed to factors unrelated to the economic cycle, and OPEC fills almost all of this gap. As time progresses and the influence of the business cycle disappears, total factor productivity shocks within the global economy gain greater prominence, necessitating increased oil demand for growth. Simultaneously, technological advancements by fringe players on the supply side become more prominent. OPEC's influence remains significant throughout this period.

Figure 4: Forecast error variance decomposition of the return of the variables of the system. Demand shocks in dark grey and supply shocks in light grey.



Approximately two years into the forecast, roughly 70% of the variance in the forecast error can be attributed to supply shocks, as shown in Figure 4. Non-OPEC supply shocks account for approximately two-thirds of this variance, while OPEC shocks make up the remaining third. The remaining variance is distributed among *TFP* shocks and the lingering impact of the business cycle shock. It is evident that in the short run, unexpected business cycle movements are primarily reflected in oil prices. Over time, there is also an increase in oil production as OPEC responds to the business cycle.

OPEC and prices react more promptly, but most of the effect in the short run goes to prices, in line with our expectation due to the low oil supply elasticity. Moreover, the shocks attributed to total factor productivity of the economy, recovered by focusing on information on industrial production, induce positive responses in the oil production of the Cartel and lower but still positive and significant responses from the fringe. This mechanism is tied to the concept of a more vertical supply in the short term and a more horizontal supply over the long run. OPEC production are mainly unpredictable in the short-term but after the economic cycle *TFP* shocks appear to explain half of the variance of the forecast error. OPEC supply is mostly explained by demand forces in the long-term opposite to what occur to oil prices and to non-OPEC production.

5 Conclusion

Initially dominated by business cycle shocks, the dynamics of the oil price gradually shift as permanent shocks, particularly total factor productivity and supply-side factors, begin to play a more significant role. OPEC's role remained pivotal, presenting resilience in responding to medium-term market conditions. Understanding these structural dynamics carries significant implications for forecasting. While short-term fluctuations may be attributed to business cycle movements, long-term projections need to be focused on supply conditions changes and supply-side responses from both OPEC and non-OPEC entities.

While demand shocks through induce positive correlation in the system where industrial production, oil prices and quantities increase. Supply shocks in the oil market are such that prices and quantities present negative correlation, what is theoretically expected for a exogenous variations in supply. We find that for both supply innovations the other group decrease production generating a more than proportional increase in market share. Heterogeneity appears in the effect on prices and the path to long-term effect, being instantaneous for the Cartel at around 2.75%, and generated over time by non-cartel members, with a final value five times higher than the 1.5% instantaneous effect.

OPEC responds to business cycles, with the most significant adjustments occurring approximately six months after the average business cycle shift, while non-OPEC producers do not significantly change oil production. Opposite to what we observe in price dynamics OPEC movements are explained by their own unexpected movements while after the economic cycle half of their unpredictability is explained by *TFP* shocks *TFP*

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6 Appendix

6.1 Other Tables and Figures

Table 4: VECM Model Coefficients with Standard Errors

	Δp_t		Δq_t^{OPEC}		Δq_t^{n-OPEC}		Δip_t	
	Coef	(SE)	Coef	(SE)	Coef	(SE)	Coef	(SE)
e_{t-1}^c	-0.0697^{***}	(0.0220)	0.0019	(0.0029)	0.0059^{**}	(0.0027)	0.0013	(0.0017)
Intercept	-0.0045	(0.0060)	-0.0015^{***}	(0.0008)	0.0017^{**}	(0.0007)	0.0018^{***}	(0.0005)
Δp_{t-1}	0.1550^{**}	(0.0563)	-0.0249^{***}	(0.0074)	0.0016	(0.0069)	0.0326^{***}	(0.0044)
Δp_{t-2}	-0.0305	(0.0617)	0.0257^{***}	(0.0081)	0.0102	(0.0076)	0.0043	(0.0048)
Δp_{t-3}	-0.0991	(0.0619)	0.0021	(0.0081)	0.0027	(0.0076)	0.0002	(0.0048)
Δp_{t-4}	-0.0838	(0.0618)	0.0117	(0.0081)	0.0053	(0.0076)	-0.0045	(0.0048)
Δp_{t-5}	0.0244	(0.0614)	0.0018	(0.0081)	-0.0085	(0.0075)	0.0006	(0.0048)
Δp_{t-6}	0.0241	(0.0611)	0.0057	(0.0080)	0.0070	(0.0075)	-0.0007	(0.0048)
Δq_{t-1}^{OPEC}	-0.4299	(0.4198)	-0.0522	(0.0553)	-0.0744	(0.0515)	-0.0659^{**}	(0.0328)
Δq_{t-2}^{OPEC}	-0.3581	(0.4233)	-0.0867	(0.0557)	0.0129	(0.0520)	-0.0837^{**}	(0.0330)
Δq_{t-3}^{OPEC}	0.3776	(0.4212)	-0.1326^{*}	(0.0555)	-0.0206	(0.0517)	0.0230	(0.0329)
Δq_{t-4}^{OPEC}	0.3240	(0.4205)	0.1225^{**}	(0.0554)	0.0635	(0.0516)	0.0285	(0.0328)
Δq_{t-5}^{OPEC}	-0.7263^{*}	(0.4131)	-0.0680	(0.0544)	0.0838^{*}	(0.0507)	-0.0431	(0.0322)
Δq_{t-6}^{OPEC}	0.0107	(0.3563)	0.0759	(0.0469)	-0.1072^{**}	(0.0437)	-0.0313	(0.0278)
Δq_{t-1}^{n-OPEC}	-0.4817	(0.4654)	0.0364	(0.0613)	-0.2059^{***}	(0.0571)	0.0002	(0.0363)
Δq_{t-2}^{n-OPEC}	0.2144	(0.4748)	-0.0036	(0.0625)	-0.1224	(0.0583)	-0.0676	(0.0371)
Δq_{t-3}^{n-OPEC}	0.2769	(0.4788)	0.1536^{**}	(0.0631)	0.0089	(0.0588)	-0.0128	(0.0374)
Δq_{t-4}^{n-OPEC}	-0.1871	(0.4805)	0.0147	(0.0633)	0.1058^{*}	(0.0590)	-0.0166	(0.0375)
Δq_{t-5}^{n-OPEC}	-0.0281	(0.4867)	-0.0190	(0.0641)	-0.0740	(0.0597)	-0.0814^{***}	(0.0380)
Δq_{t-6}^{n-OPEC}	-0.2575	(0.4662)	0.0125	(0.0614)	-0.0705	(0.0572)	-0.0242	(0.0364)
Δip_{t-1}	0.3652	(0.7156)	0.7020^{***}	(0.0942)	0.2380^{***}	(0.0878)	0.0631	(0.0559)
Δip_{t-2}	3.2303^{***}	(0.7680)	0.1838^{***}	(0.1011)	-0.0071	(0.0943)	0.0739	(0.0599)
Δip_{t-3}	0.4687	(0.7927)	-0.2647^{**}	(0.1044)	-0.0584	(0.0973)	0.2457^{***}	(0.0619)
Δip_{t-4}	-1.3993^{*}	(0.8113)	0.2029^{*}	(0.1068)	0.1170	(0.0996)	-0.0341	(0.0633)
Δip_{t-5}	0.5807	(0.8117)	-0.0232	(0.1069)	-0.1302	(0.0996)	-0.0707	(0.0633)
Δip_{t-6}	1.1755	(0.7659)	0.1882^{*}	(0.1009)	-0.0595	(0.0940)	0.0378	(0.0598)

Table 5: Estimated Contemporaneous Impact Matrix B_0^{-1}

	Business Cycles	TFP	product Opec	product non-OPEC
Oil price	0.8238	3.3684	-2.6494	-0.7190
Industrial production	-0.0157	0.9489	-0.0111	0.0756
OPEC production	0.0412	0.0000	0.8696	0.2223
Non-OPEC production	-0.0101	0.0000	0.0000	1.0032

6.2 Cost-Minimizing Industrial Firm

The industrial firm faces the problem of minimizing costs subject to a specific production level $\bar{ip}$: $\min C(q,p) = pq$ subject to $f(q) \geq \bar{ip}$ where p and q are input prices and quantities. The first-order condition yields the derived demand for inputs: $\frac{\partial C(q_t,p_t)}{\partial p_t} = q_t\left(p_t, \bar{ip_t}\right)$. In modeling short-run dynamics, it is reasonable and common[3] to assume that oil supply is fixed ($q_t^s = \bar{q}^s$). Thus, the short-term equilibrium condition ensures that $q_t\left(p_t, \bar{ip}\right) = \bar{q}^s$

[3] Highlight the literature on low supply elasticity.