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The influence of OPEC+ on oil prices:
a quantitative assessment

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Abstract

Between January 2017 and March 2020 a coalition of oil producers led by OPEC and Russia (known as OPEC+) cut oil production in an attempt to raise the price of crude oil. In March 2020 the corona virus shock led to a collapse of this coalition, as members did not agree on keeping the oil market tight in the face of a large negative demand shock. Yet, was OPEC+ actually effective in sustaining the price of oil? Between 2017 and early 2020 when the OPEC+ strategy was in place, oil inventories fell substantially and the price of oil reached a peak of around 80 USD per barrel, from a minimum of 30 USD in 2016. This suggests that the OPEC+ strategy had a significant impact on the global oil market. Yet, to what extent did crude prices actually reflect OPEC+ production cuts rather than other factors, like swings in demand for oil? How would the price of oil have evolved had OPEC+ not cut supply? This paper provides an answer to these questions through a counterfactual analysis based on two structural models of the global oil market. We find the impact of OPEC+ on the market was overall quite limited, owing to significant deviations from the assigned quotas. On average, without the OPEC+ cuts, the price of oil would have been 6 percent (4 USD) lower.

JEL Classification Codes: Q43, C53

Keywords: Oil price, OPEC, oil supply, oil demand, shale oil

Non-technical summary

The advent of US shale oil has substantially changed the structure of global oil production. The emergence of the US as a dominant market player has had profound implications for the strategic behaviour of other oil producers, and in particular for those coalesced in the Organization of Petroleum Exporting Countries (OPEC). OPEC, which includes 14 members including large producers like Saudi Arabia, Iraq, Iran and the United Arab Emirates, accounted for around 43 percent of global oil production in 2008. In 2019 its share had fallen to 39, as the US increased its oil market share from 8 to 15 percent. Not only the US are by now the largest oil producers, they have also become oil exporters, after a ban that prevented producers to sell oil abroad was lifted in December 2015. In 2016, in an attempt to regain some control over crude prices, OPEC and a number of other non-US oil producers forged an alliance, known as OPEC+. Among non-OPEC members, this coalition included large producers like Russia (the second largest oil producer), Mexico and Kazakhstan. Overall, OPEC+ accounted for around 45 percent of global crude production. The strategy adopted by OPEC+ consisted of setting explicit production targets for each member with the aim of bringing oil inventories down to their 2010-2014 average. In March 2020 the OPEC+ coalition broke down. Following a general risk-off sentiment related to the spreading of the corona virus, the price of oil collapsed. When OPEC suggested the implementation of further production cuts to lift the price of crude, Russia refused to cooperate arguing that US producers would gain the most from new efforts to prop up prices. The clash between Saudi Arabia and Russia meant the end of the OPEC+ coalition. This paper takes stock of the impact that OPEC+ had on the global oil market while it operated, between the end of 2016 and the beginning of 2020. Using Structural Vector Autoregressions we construct counterfactual scenarios that allow us to quantify how oil production and the price of oil would have evolved, had this agreement not been in place. The empirical strategy consists of computing a counterfactual path of global oil production assuming that all the fall in the production of OPEC+ after December 2016 can be attributed to an exogenous shift in their oil supply. Our counterfactual path of oil production is then constructed assuming that OPEC+ would have kept production steady at the level recorded before OPEC+ started implementing production cuts in line with the agreed upon targets. To evaluate the effects of these production cuts on the price of crude we use two complementary specifications. The former is a small model in which we pool together OPEC+

production with that of other producers. In the second specification we split the production of OPEC+ from that of the rest of the world, allowing for strategic interactions between these two large oil producing blocks. We find that the impact of OPEC+ on the price of oil varied over time, together with the cohesion of the coalition, and that it was overall quantitatively modest. Averaging over the whole period under analysis, our results indicate that the price of oil would have been around 4 USD per barrel lower, had OPEC+ not cut production. It would have taken a much deeper cut in oil production and a much stronger cohesion to achieve the ambitious target that the coalition had set for itself.

1 Introduction

The advent of US shale oil has substantially changed the structure of global oil production. The emergence of the US as a dominant market player has had profound implications for the strategic behaviour of other oil producers, and in particular for those coalesced in the Organization of Petroleum Exporting Countries (OPEC). OPEC, which is composed by 14 members including large producers like Saudi Arabia, Iraq, Iran and the United Arab Emirates, accounted for around 43 percent of global oil production in 2008 , see Figure 1 (left panel). In 2019 its share had fallen to 39, as the US had increased its oil market share from 8 to 15 percent. The US is by now not only the largest oil producer, but also an important oil exporter, after a ban that prevented producers to sell oil abroad was lifted in December 2015. As a result, the pricing power of OPEC members weakened substantially, oil prices plunged and a supply glut emerged, as testified by a persistent increase in oil inventories. In 2016, in an attempt to regain some control over crude prices, OPEC and a number of other non-US oil producers forged an alliance, known as OPEC+. Among non-OPEC members, this coalition included large producers like Russia (the second largest oil producer), Mexico and Kazakhstan. Overall, OPEC+ accounted for around 45 percent of global crude production. The strategy adopted by OPEC+ consisted of setting explicit production targets for each member with the aim of bringing oil inventories down to their 2010-2014 average.

In March 2020 the OPEC+ coalition broke down. Following a general risk-off sentiment related to the spreading of the corona virus, the price of oil collapsed. When OPEC suggested the implementation of further production cuts to lift the price of crude, Russia refused to cooperate arguing that US producers would gain the most from new efforts to prop up prices. The clash between Saudi Arabia and Russia meant the end of the OPEC+ coalition.

Yet was the OPEC+ coalition actually effective in steering the price of oil while it operated? A glance at raw data indicates that, while the coalition was in place, the price of crude rose substantially, suggesting a significant role for the supply cuts implemented by these oil produc-

ers. Yet inventories remained high compared to their historical average, somewhat confuting the idea that OPEC+ achieved their target of substantial market tightening. And oil demand played a key role in keeping oil prices high as economic activity kept growing at a robust pace over these three years, providing an important confounding factor.

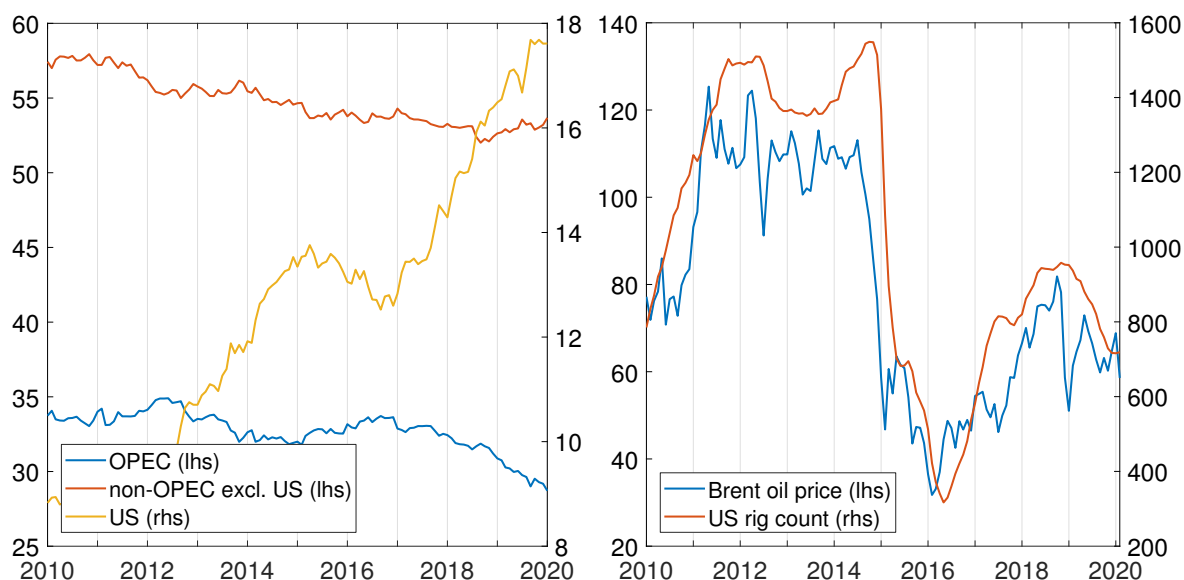
In this paper we provide a quantitative evaluation on the actual impact of the OPEC+ alliance on the global oil market between January 2017 and early 2020 by constructing counterfactual scenarios that allow us to quantify how oil production and the price of oil would have evolved, had this agreement not been in place. These scenarios are constructed and evaluated using structural econometric models of the oil market. Such models have now a long tradition, since the seminal work by [Kilian \(2009\)](#) and [Kilian and Murphy \(2012, 2014\)](#).

In our models we follow broadly [Kilian and Murphy \(2014\)](#) and use sign restrictions in combination with elasticity bounds to identify structural oil price shocks in structural vector autoregressions. Our work is close in spirit to [Kilian \(2017\)](#), who quantifies the effect of shale production on the production of Saudi Arabia and the global oil price between 2008 and 2015. The empirical strategy adopted by [Kilian \(2017\)](#) consists of computing a counterfactual path of global oil production assuming (i) that US production would have remained constant rather than rising after 2008 (ii) that the increase in the output of shale producers between 2008 and 2015 was due entirely to exogenous supply shocks, rather than being a reaction to favourable demand conditions. Given these two assumptions one can easily recover the implied path of oil production and oil prices that would have cleared the market, given an estimated structural model. We adopt the same philosophy and assume that all the fall in the production of OPEC+ producers can be attributed to an exogenous shift in their oil supply. Our counterfactual path of oil production is then constructed assuming that OPEC+ would have kept production steady at the level recorded before OPEC+ started implementing production cuts in line with the agreed targets. To evaluate the effects of these production cuts on the price of crude we use two complementary specifications. The former is a stripped down version of the [Kilian and](#)

[Murphy \(2014\)](#) in which we model global oil production, global economic activity and the price of Brent and identify supply shocks alongside with demand and precautionary demand shocks. In the second specification we split the production of OPEC+ from that of the rest of the world, allowing for strategic interactions between these two large oil producing blocks. Assuming a counterfactual path for OPEC+ production, we estimate the effect of this on oil prices allowing for a strategic reaction by US producers.

We find that the impact of OPEC+ on the price of oil varied over time, together with the cohesion of the coalition, and that it was overall quantitatively modest. Averaging over the whole period under analysis, our results indicate that the price of oil would have been around 4 USD per barrel lower (6 percent of the average price over the period) had OPEC+ not cut production. It would have taken a much deeper cut in oil production and a much stronger cohesion to achieve the ambitious target that the coalition had set for itself.

Whereas to our knowledge we are the first to focus explicitly on OPEC+ and the period after 2016, our paper is close to a stream of papers that analyse the implications of the shale oil boom in the US for oil prices and the behaviour of non-US producers. [Feroni and Stracca \(2018\)](#) focus on whether the world supply function of oil has changed with the advent of US shale oil. They do not find a significant effect on the global oil market as a higher price sensitivity of US producers seems to be offset by OPEC countries becoming less responsive to oil price changes. Focusing on the effect on oil prices, [Kilian \(2016\)](#) finds that the Brent oil price declined by around 9 percent due to the US shale oil revolution. According to [Baumeister and Kilian \(2016b\)](#) the sharp decline in oil prices in the second half of 2014 by around 50 percent can be attributed to a large extent to an unexpected weakening of the world economy amid strong world (shale) oil supply and to less extent to the strategic behaviour by OPEC. Focusing on a longer time period, [Fronzel and Horvath \(2019\)](#) conclude that OPEC supply decisions still significantly affect oil prices despite the increased US production and its negative effect on oil prices.



NOTE: The left panel shows the share of production on world production (in percent), source: *International Energy Agency*. The right panel shows the Brent oil price (in US dollar per barrel) and US rig count (i.e. the number of drilling rigs actively exploring for or developing oil or natural gas), source: *Energy Information Administration* and *Bloomberg*.

Figure 1: Market shares, oil prices and US rig count

The remainder of the paper is organized as follows. The next section discusses recent developments in global oil markets and how OPEC and its allies reacted to them. Section 3 describes the empirical methodology and data. Section 4 presents the main empirical analysis. Finally, Section 5 concludes.

2 OPEC strategy since the advent of shale oil

During the past decade, US shale oil production capacity has risen greatly. Advances in extraction technology together with investments in pipeline systems and rail capacity have allowed US producers to expand production above that of the two other largest oil producers, Russia and Saudi Arabia.¹ Between 2011 and 2015, the share of US production in the global oil market increased from 9 percent to 14 percent, at the expense of OPEC countries as well as of other producers outside of the cartel (Figure 1, left panel).

In 2014 OPEC reacted to the US production boom by abandoning production quotas and

¹For a detailed overview, see e.g. [ECB \(2017\)](#).

increasing oil production. According to market analysts, this strategy aimed at crowding out US competitors by driving oil prices below the levels at which US shale oil producers could be profitable.² In the same period, a large demand shock stemming from the slowdown of the Chinese economy put further downward pressure on the price of crude. The combination of higher oil supply and lower oil demand resulted in a supply glut, testified by a steep surge of inventories. However, despite a substantial fall in the price of oil, from around USD 110 per barrel in mid-2014 to USD 30 per barrel in January 2016, (Figure 1, right panel), US production did not fall dramatically. Efficiency gains, achieved through mergers and acquisitions in the shale sector, more than offset the loss in production from a number of oil rigs that had become unprofitable and that were therefore discontinued (Figure 1, right panel). The resilience of US producers made OPEC's strategy unsustainable in the longer term, as the fiscal position for most OPEC countries deteriorated sharply between 2014 and 2016 due to lower oil prices.³

In late 2016, OPEC reconsidered its approach by returning to a policy of price stabilisation and by forging alliance with some major non-OPEC countries. With the objective of rebalancing a largely oversupplied oil market, OPEC negotiated with 10 non-OPEC nations, notable among them Russia, Mexico and Kazakhstan, explicit production targets for every member state. The OPEC+ alliance, in which Saudi Arabia and Russia played a key role, accounted for around 45 percent of the world oil production. The strategy, announced in November 2016, consisted of cutting production by 1.8 million barrels per day, effective from January 2017. The agreement was subsequently prolonged and strengthened. In December 2018 and December 2019, OPEC+ negotiated further reductions by 3.0 and 0.9 million barrels per day, respectively.⁴ The rebalancing of the oil market was concretely defined by OPEC+ as the return of the level of inventories to their “five years average” (later specified as the average reached

²For a detailed economic interpretation of OPEC's strategic actions, see e.g. [Behar and Ritz \(2016\)](#).

³See [Kose *et al.* \(2017\)](#).

⁴OPEC+ communicated these cuts somewhat differently. While production cuts announced in 2016 were based on production levels reached at the end of 2016, the two subsequent reductions were based on levels reached in late 2018. Thus, OPEC+ actually announced additional cuts by 1.2 million barrels per day in December 2018 as the reference level had already fallen by 1.8 million barrels per day. The announced cuts in December 2019 also include additional voluntary cuts of 0.4 million barrels per day by Saudi Arabia.

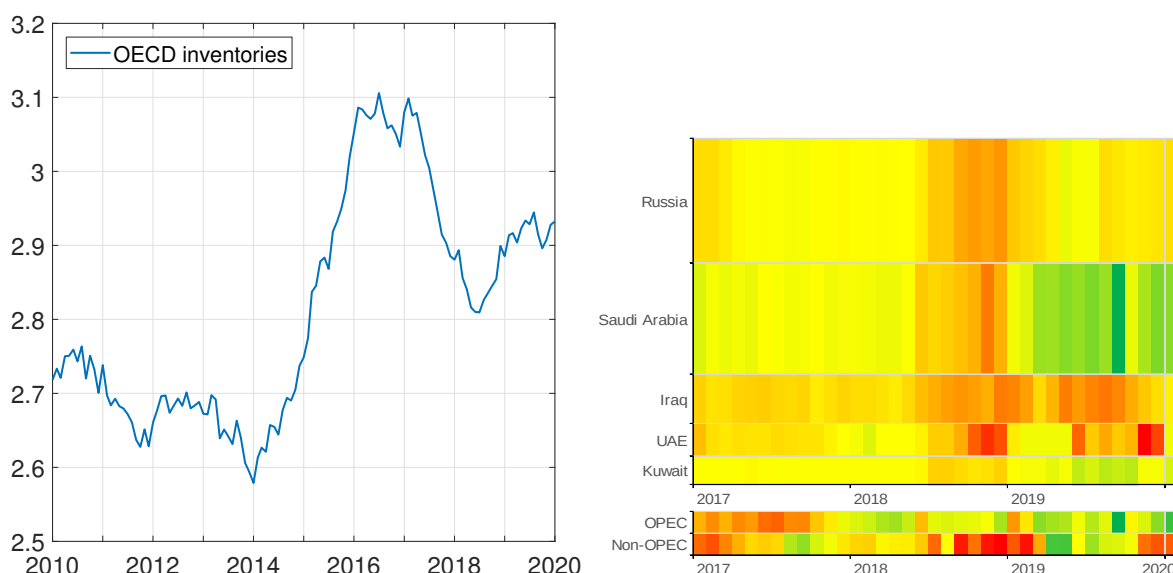
between 2010 and 2014). Since an excessive level of inventories can weaken the link between prices and supply (as excess demand can be satisfied by a draw-down of oil in storage) a fall of inventories was seen as the first step to regain control over the price of oil. Indeed, the initial reaction of oil prices to the OPEC+ production cuts was relatively muted, with prices only starting to rise after inventories decreased (Figure 2, left panel).

Besides high levels of inventories, OPEC+ faced additional challenges in the attempt to preserve its market power. First, technical advances in the production of shale oil allow producers to easily stop and reactivate production. Such degree of flexibility, allowing US producer to react more easily to market developments, makes it more challenging for other large producers to affect prices. Second, the cohesion of OPEC+ faltered from time to time as production targets were occasionally exceeded (especially by non-OPEC members) – limiting their ability to effectively steer market expectations (Figure 2, right panel). In particular, towards the end of 2018, amid downward revisions for global oil demand, compliance of key producers (including the two largest producers Saudi Arabia and Russia) worsened, casting some doubts on the stability of the coalition, and contributing to a marked decline in oil prices in the final months of 2018. In March 2020, as the corona virus shock sent the price of oil into a nose dive, Russia feared that any attempt to revive prices would benefit US producers. Its decision not to agree on any further production cuts put *de facto* an end to the coalition.

In the next section, we describe two structural econometric models that we use to quantify the effect of the OPEC+ production cuts on oil prices.

3 Empirical Methodology

We assess the effect of OPEC+ strategy on the price of oil on the basis of two variants of the econometric model developed in Kilian and Murphy (2014). In both models, production cuts are modelled as a sequence of exogenous shocks to the supply of oil. Our counterfactual path for oil production assumes that production cuts would not have taken place after December



NOTE: The left panel shows OECD inventories (in billion barrels). The right panel shows compliance with OPEC+ production targets: yellow signifies compliance with production targets, red undercompliance and green overcompliance. Height of country rows represents the share in world oil production. Source: *Energy Information Administration*.

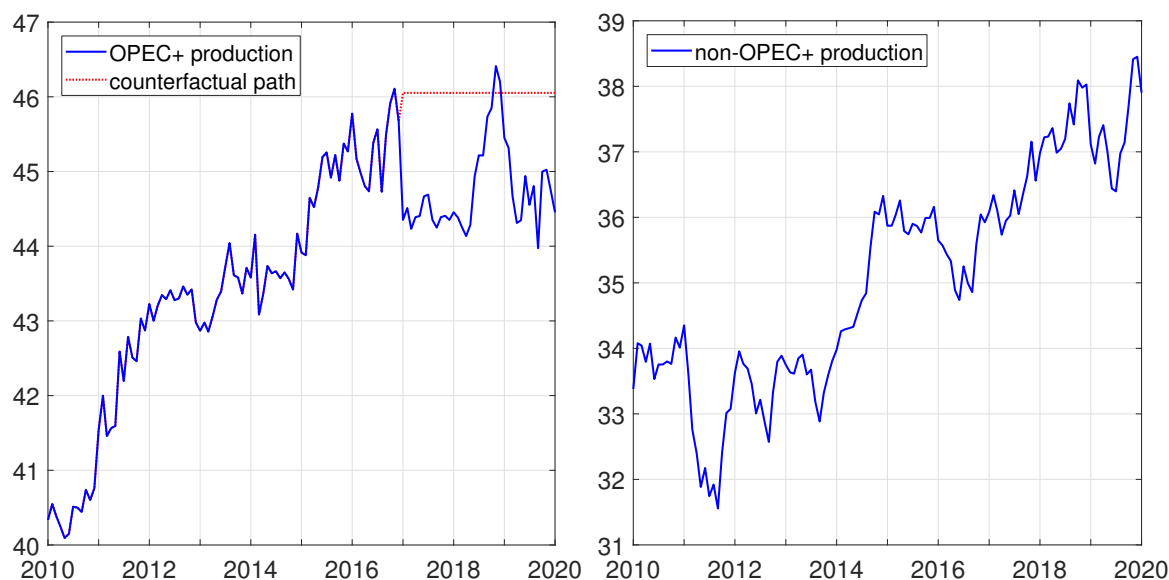
Figure 2: Inventories and compliance with OPEC+ production targets

2016. We then back out the sequence of flow supply shocks in each model that are required to produce the counterfactual path of oil production, following [Kilian \(2017\)](#). Finally, we derive the corresponding counterfactual path for the price of oil, as the price that would have cleared the market under the counterfactual sequence of the structural shocks. The difference between the actual and the counterfactual price of crude provides an estimate of the effect of OPEC+ production cuts on the oil price.

3.1 Model without strategic interaction

To construct a counterfactual path for OPEC+ production, we assume that the agreed production cuts would not have taken place after December 2016. Thus, we keep OPEC+ production constant at 46 mbd, equivalent to the reference level that the alliance used in 2016 to calculate the production cuts (Figure 3, left chart). Non-OPEC+ production simply follows the actual

⁵See appendix A for further details on the data set and calculations. Keeping OPEC+ production equivalent to the reference level is a rather conservative approach to determine a counterfactual path for production. As a robustness check we also use an ARIMA model to predict how production would have continued to grow after December 2016 in absent of any production cuts. See Appendix B for further details.



NOTE: The left panel shows OPEC+ production together with the counterfactual path based on reference levels of the agreed supply cuts. The right panel shows non-OPEC+ production (everything in million barrels). For simplicity, data only plotted from 2010 onwards, source: *Energy Information Administration*.

Figure 3: OPEC+ and non-OPEC+ production

path observed after January 2017 (Figure 3, right chart).⁵ As visible from Figure 3, OPEC+ member states did not always meet their obligations and compliance with production cuts was low in several months. Accordingly, the average cuts of 1.3 mbd between January 2017 and January 2020 remains below the agreed cuts. With actual global crude oil production over this period standing at around 82mbd, the cut implemented by OPEC+ thus subtracted, on average, 1.6 percent of total crude oil production over the period.

The first model that we employ is a modified version of the structural vector autoregressive (VAR) model of the global market for crude oil proposed by Kilian and Murphy (2014).⁶ The model includes the log level of crude oil production, the log level of a monthly measure of global real economic activity taken from Kilian (2009) and the log of the nominal price of crude oil (Brent quality). Differently from Kilian and Murphy (2014), we do not include a measure of inventories in this baseline specification. The reason is twofold. First, the measurement of inventories is problematic, see Baumeister and Hamilton (2019). Second, these three variables

⁶See also Kilian and Lee (2014) and Baumeister and Kilian (2014, 2016a).

Table 1: Sign restrictions in model with global oil supply

	oil supply	global oil demand	precautionary oil demand
global oil production	-	+	+
real economic activity	-	+	-
oil price	+	+	+
Additional Restrictions			
- Upper bound on elasticity of demand in production -0.1			
- Upper bound on elasticity of supply 0.05			

(oil production, price of oil and economic activity) provide sufficient information to identify via sign restrictions three shocks, namely oil supply, oil demand and precautionary demand for oil.⁷

The VAR model is estimated with four lags of the endogenous variables. We apply some shrinkage on the model parameters through a standard Minnesota prior. Priors are implemented via dummy observations, see [Geweke *et al.* \(2012\)](#) section 2.2. Data are in levels, so the priors on the autoregressive coefficients are centered around 1 for first lag and 0 for the remaining lags.⁸

There are two potential caveats to keep in mind in this analysis. First, it is assumed that reduced OPEC+ production was due to exogenous oil supply shocks rather than being the endogenous response to other shocks (for instance demand or precautionary demand shocks). Second, the analysis postulates that other producers would have behaved the way they actually have, regardless of OPEC+ production decisions. In other words it postulates that they did not increase production (compared to what they would have done in the absence of OPEC+

⁷Inventories would be needed to calibrate correctly reasonable bounds for the elasticity of demand in use, that is a measure of the elasticity of demand that takes into account the depletion of inventories following a supply shock. Without inventories, a model can only provide information on the elasticity of oil in production. We calibrate an upper bound on the latter, by setting it to values roughly 70 percent higher (in absolute value) than the desired bound on the elasticity of demand in use, based on the results in Table 2 presented by [Kilian and Murphy \(2014\)](#).

⁸Let us collect the hyper-parameters in the vector $\lambda = [\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5]$. The parameters λ_1 and λ_2 set the tightness of the prior on the coefficients for first and for the remaining lags, respectively. The prior for the covariance matrix is centered at a matrix that is diagonal with elements equal to the pre-sample variance of the data, with tightness λ_3 . Finally, λ_4 and λ_5 regulate the tightness of the sum of coefficients prior and of the co-persistence priors. Values for these hyperparameters are set at conventional levels, $\lambda = [0.5, 1, 0.5, 0.5, 1]$.

production cuts) to lock in higher market shares. If this assumption is false, in the correct counterfactual world, oil supply would have been even ampler than assumed and the counterfactual price of oil lower. While we cannot address the first caveat we will allow for strategic interactions between OPEC+ and non-OPEC+ producers in the next subsection to address the second concern.

3.2 Model with strategic interaction

In our second model, strategic behaviour of non-OPEC+ producers is taken into account by identifying two supply shocks via magnitude restrictions. The model framework is slightly richer compared to previous model as the log production levels of OPEC+ and non-OPEC+ producers are modelled as separate endogenous variables and we identify two distinct OPEC+ and non-OPEC+ supply shocks (Table 2). The identifying assumptions are that a production cut implemented by either OPEC+ or non-OPEC+ lead to a fall in global oil supply and are thus associated with a rise in the price of crude and a fall in economic activity. We leave the sign of the response by the competitor unconstrained allowing the competitor country either to cut or increase production in response to rising prices. However, our identifying assumptions require that production cuts are never fully offset by the competitor and thus the reaction is assumed to be smaller in absolute magnitude. The identification of global demand and precautionary demand shocks remain unchanged. Additionally, we use the same restrictions on the short-run price elasticity of oil supply and oil demand as in the previous model specification.

The counterfactual path for the price of oil is obtained by subtracting the contribution of OPEC+ supply shocks from the historical decomposition of the oil price. Different from the approach in the previous subsection, where we first had to derive a hypothetical path for OPEC+ production, we directly observe the impact of OPEC+ on oil prices using the historical decomposition. Subtracting the contribution of OPEC+ supply shocks from the historical

Table 2: Sign restrictions in model with OPEC+ and non-OPEC+ oil supply

	OPEC+ oil supply	non-OPEC+ oil supply	global oil demand	precautionary oil demand
OPEC+ production	-	<<	+	+
non-OPEC+ production	<<	-	+	+
real economic activity	-	-	+	-
oil price	+	+	+	+
Additional Restrictions				
- Upper bound on elasticity of demand in production -0.1				
- Upper bound on elasticity of supply 0.05				

decomposition allows us to obtain a counterfactual path of oil prices that can be interpreted as the prices that would have cleared the market in absence of any OPEC+ exogenous supply shocks.

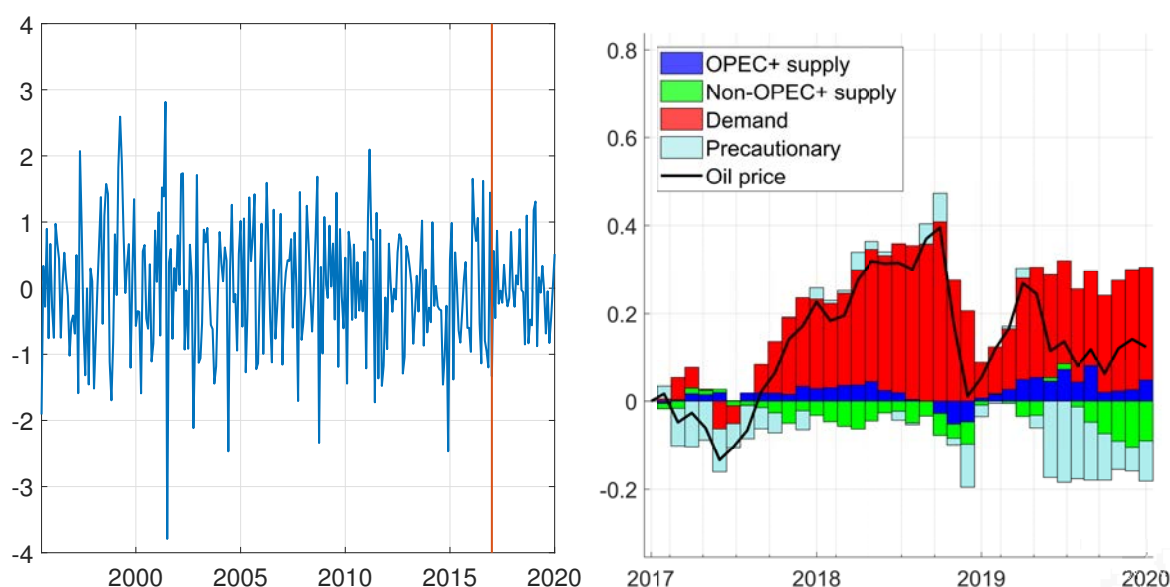
4 Results

Using the two model specifications described above, we turn to the main research question of the paper, that is how effective has been the OPEC+ alliance in steering oil prices.

4.1 Quantifying OPEC+’s impact on oil prices

Before quantifying the effects of the production cuts on the price of oil, we analyze the adequacy of the two models described in Section 3 for counterfactual analysis.

We start with the model described in section 3.1, which does not account for strategic interactions. Before using this model for a counterfactual analysis, we need to assess whether the alternative sequence of supply shocks, which generates our counterfactual path of oil production, is not too different from the historical behaviour of the supply shocks in the model. If the hypothetical shocks were unusually large by historical standards, the adequacy of a linear model approximation would be poor since the policy change would not be “modest” (Leeper and Zha, 2003) and the Lucas critique (Lucas, 1976) would make our results invalid. Figure 4 (left panel) displays the sequence of supply shocks required to generate the counterfactual



NOTE: The left panel shows the sequence of supply shocks required to implement the counterfactual simulation in the model without strategic interaction. Until December 2016 (marked with the vertical line), the series corresponds to the estimated shocks. The right panel shows the historical decomposition for the oil price in the model with strategic interaction.

Figure 4: Adequacy of the two models for simulating OPEC+ production cuts

path of oil production. The red vertical line marks December 2016, the month after which our counterfactual simulation starts. It is clear that the backed-out shocks after December 2016 are centered around zero and are not unusually large by historical standards. We formally confirmed this by an F-test assessing whether the variance of the counterfactual shocks after December 2016 is significantly different from that of the actual shocks until December 2016. The null hypothesis of this test that the two series come from normal distributions with the same variance cannot be rejected, with a p-value of 0.54.

In the case of the model with strategic interactions described in Section 3.2, our estimate of the effect of the OPEC+ intervention is based on the historical decomposition of the oil price. The adequacy of this model approach can therefore be broadly assessed by inspecting the historical decomposition. Figure (4, right panel) depicts how the different shocks contributed to the development of the price of Brent since January 2017. Both, OPEC+ and non-OPEC+ production had a significant effect on the oil price, but with a different sign. With only a few exceptions, non-OPEC+ production provided a negative contribution to crude prices,

reflecting unexpectedly strong production growth, in particular in the US. OPEC+ supply shocks, in contrast, supported the oil prices, with the important exception of December 2018, when compliance levels among OPEC+ members collapsed. Global demand also supported the oil price, except around the turn of the year 2018/19 amid the sharp slow down of the world economy that led the Federal Reserve to abandon its policy tightening and its autopilot approach to balance sheet reduction. In sum, the historical decomposition looks reasonable and appears to be suitable for our counterfactual simulation exercise.

Figure 5 shows the price of Brent together with the counterfactual paths obtained with our two models. Two preliminary observations are in order. First, the counterfactual oil paths are (almost) always below the actual price of oil, indicating that OPEC+ managed, to some extent, to have an impact on the price of oil. Second, the counterfactual paths obtained with the two model specifications are rather similar to each other, although after mid-2017 the model that does not allow for strategic interactions generates a counterfactual oil path that is always higher than the one obtained with the model with strategic interactions. This suggests that the latter model attributes a relatively stronger role to OPEC+ in affecting the oil market.

According to both models, the run up in the price of crude observed between January 2017 and October 2018 would have been more muted, had OPEC+ not intervened in the global oil market. The faltering of the OPEC+ strategy in late 2018 is starkly evident in our simulations. Actual and counterfactual oil prices overlap in December 2018, and the model without strategic interactions even indicates an *over-supply* of the oil market due to OPEC+ production slippage. The renewed commitment of OPEC+ to supply reductions in January 2019 contributed to a tightening of market conditions in 2019, as the actual oil price diverged again from its counterfactual. Averaging over the whole period of OPEC+ production cuts, the two models deliver very similar estimates of the impact of OPEC+ supply cuts on the price of oil, ranging from 3.77 USD (in the model without strategic interactions) to 3.85 USD (in the model with strategic interactions). Hence, if OPEC+ had not cut production, the price of

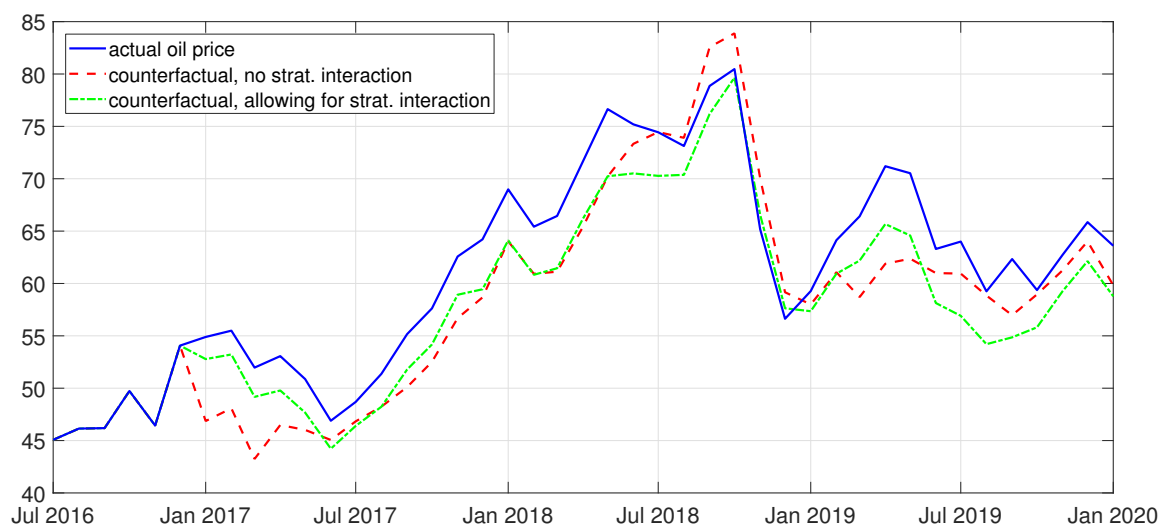


Figure 5: Actual and counterfactual oil price (US dollar per barrel)

oil would have been around 6 percent lower than actually observed. Overall, the effect seems to be quantitatively modest.

4.2 Evaluating the feasibility OPEC+’s inventory target

A question that remains unanswered is whether the inventory target set by OPEC+ was just too ambitious. Or, in other words, whether the oil market tightness needed to reach the desired level of inventories would have resulted in prohibitively high oil prices.

In this section we present some tentative evidence that the price of oil needed to re-balance the oil market was indeed much higher than the one achieved by OPEC+. We start by adding to our simpler model (the one that does not take strategic interaction into account) a measure of inventories, namely “days-in-storage”. This is a measure of inventories adequacy corresponding to the number of days for which OECD countries could meet their oil demand with available inventories.⁹ As the daily consumption of oil has increased by more than 5 percent since 2010, the days-in-storage is more precise measure of the tightness of oil markets than the raw level of inventories. We then design a counterfactual path for inventories and back out the supply shocks that would have been necessary to achieve this target. We assume only gradual convergence to this target, i.e. we assume that OPEC+ would have lowered their production

⁹See Appendix C on further details of this model specification.

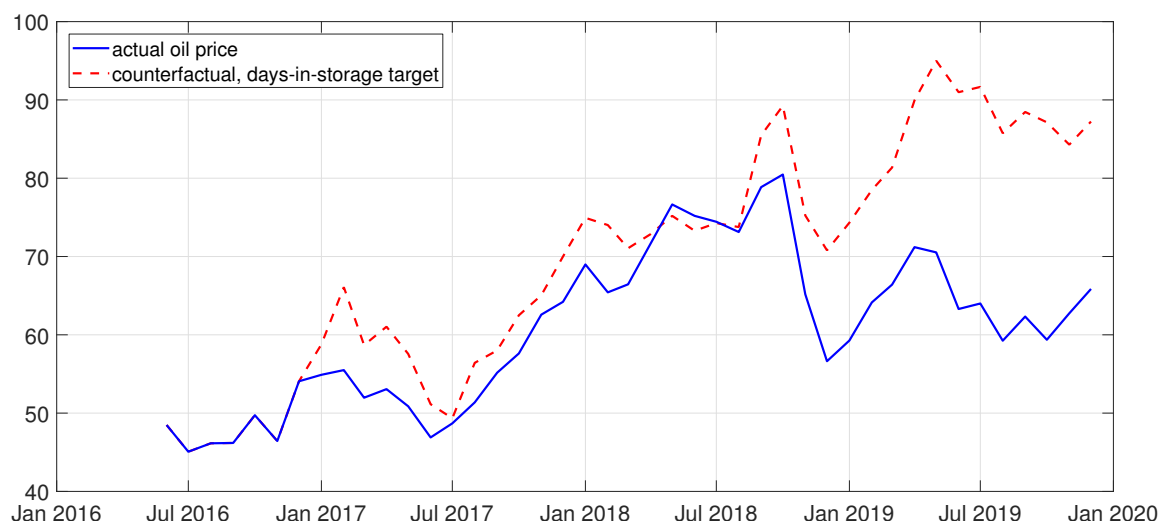


Figure 6: Actual and counterfactual oil price with OPEC+ following its inventory target (US dollar per barrel)

to bring days-in-storage within 12 months to average level reached between 2010 and 2014. Figure 6 shows the counterfactual path of oil, had OPEC+ followed such a production policy. Oil prices would have been significantly higher reaching almost 100 USD per barrel in 2019. With inventories starting to increase again after 2017, fierce production cut would have been necessary to meet the target in 2018 and 2019.

We see this evidence, however, as being only indicative. The supply shocks needed to bring days-in-storage down to the envisaged target are in fact very large and strongly autocorrelated. In other words, the deviation of the counterfactual from the actual supply behaviour is by no means modest in the sense of [Leeper and Zha \(2003\)](#). The simulation shown in Figure 6 should thus be taken with a pinch of salt. Nevertheless, this exercise suggests that it would have taken OPEC+ a gigantic effort and exceptional cohesion to reach such an ambitious inventory target.

5 Concluding Remarks

The global oil market has undergone significant changes since the emergence of the US as a large oil producer and a fierce competitor in oil export markets. Between 2017 and 2020 a coalition of OPEC and a number of other non-US oil producers, known as OPEC+, aimed at

a production strategy intended to tightening the oil market, absorbing inventories, and raising the price of oil. In March 2020 the OPEC+ coalition broke down, as Saudi Arabia and Russia failed to agree on a common strategy to respond to the collapse in demand due to the Covid-19 crisis.

This paper takes stock of the actual impact that this coalition had on the price of oil while it operated. In our empirical analysis we use two structural models to construct counterfactual paths for oil production that allow us to quantify how the price of oil would have evolved, had this agreement not been in place.

We find that the impact of OPEC+ on the price of oil varied over time, together with the cohesion of the coalition, and that it was overall quantitatively modest. Averaging over the whole period under analysis, our results indicate that the price of oil would have been around 4 USD per barrel lower, had OPEC+ not cut production. It would have, indeed, taken a much deeper cut in oil production and a much stronger cohesion to achieve the ambitious target that the coalition had set for itself.

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Appendix A Data description and manipulation

Our dataset is monthly and ranges from 1995m1-2020m1. Below we comment on the construction of the included variables.

Oil production is provided by the *International Energy Agency*. OPEC+ was founded in December 2016 by OPEC (at that time including 14 member states: Algeria, Angola, Congo, Ecuador, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates and Venezuela) and 11 non-OPEC countries (Azerbaijan, Equatorial Guinea, Kazakhstan, Mexico, Oman, Russia, Bahrain, Brunei, Malaysia, Sudan and South Sudan). OPEC+ production is the sum of its members' oil production with the following adjustments:

- To obtain a consistent sample over time, we do not include all countries listed above as not all uninterruptedly participated in the cut and some countries even left the alliance. We therefore exclude Iran, Libya, Nigeria and Venezuela as these countries did not participate in the agreed production cuts for an extended period of time.¹⁰
- We include Congo and keep Qatar and Ecuador in our sample. Congo joined OPEC in July 2018 and stated participating in the deal four months later. Qatar and Ecuador quit its OPEC membership in January 2019 and January 2020, respectively. We also include Equatorial Guinea in our sample which first participated in the deal as a non-OPEC member and continued as an OPEC member from June 2017.
- We only use crude oil supply in our data sample and do not include natural gas liquids (NGLs). Initially, the OPEC+ declaration of cooperation specified that production targets defined for OPEC countries only apply to crude oil production, whereas targets defined for non-OPEC members also include NGLs. However, the alliance later excluded NGLs also for non-OPEC members. For consistency, we thus only use crude oil data for

¹⁰Iran was exempted from the cuts in November 2018 following the US sanctions imposed on the Iranian energy sector and Libya never participated in the cuts due to ongoing civil conflicts. Due to the dire economic situation in Nigeria and Venezuela, the former has started participating in the deal in November 2018 whereas the latter was exempted in November 2018 from the cuts.

the whole data sample.

To construct a counterfactual path of oil supply for the model without strategic interaction, described in section 3.1, we keep OPEC+ production constant at the reference level that the alliance used in 2016 to calculate the production cuts. When signing the deal in December 2016, the agreed production cuts were relative to the participating countries' production levels reached in October 2016, except for Angola, for which cuts were based on levels reached in September 2016. We finally construct a data series of aggregate production of for non-OPEC+ producers by subtracting aggregate OPEC+ production from global crude oil production.

Real economic activity are taken from Kilian (2009). As the data ranges only until June 2019, we extrapolate it for the remaining months using the growth rate of the Baltic Dry index. The index, which is available on a daily frequency, is a proxy for global dry bulk shipping stocks. The Baltic Dry index is downloaded as monthly averages from Refinitiv Datastream.

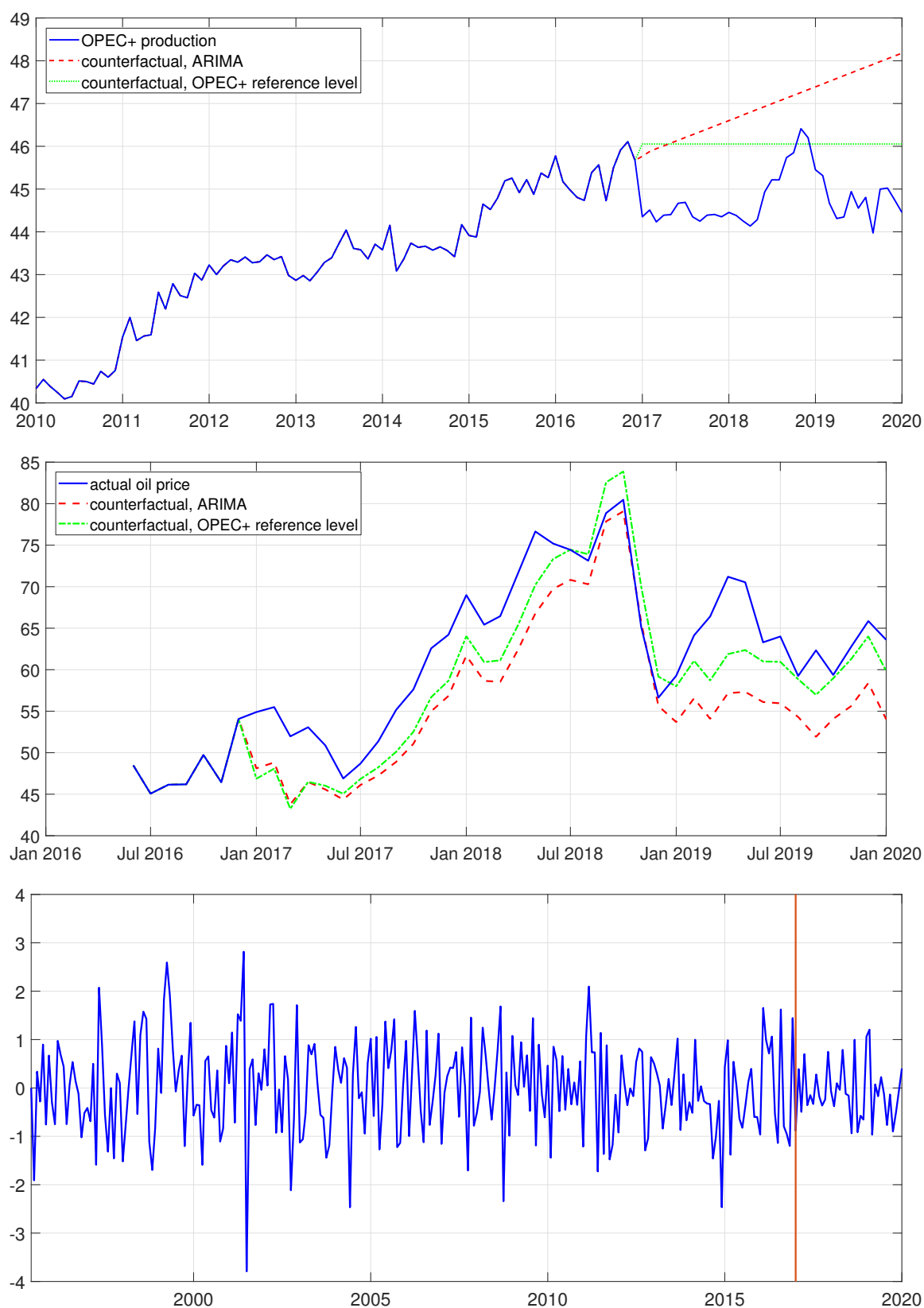
Nominal oil prices are monthly averages of the Brent oil price taken from Bloomberg.

Appendix B Alternative counterfactual path for OPEC+ oil production

For the model without strategic interaction described in section 3.1, we assume for the counterfactual path of oil production that OPEC+ would have kept production constant at the reference level it used for calculating the production cuts. Another plausible assumption would be that OPEC+ production would have continued to grow after December 2016 if the agreed production cuts had not taken place.

We derive such a plausible path by fitting an ARIMA model to the observed OPEC+ production and forecasting a hypothetical path after December 2016. Based on the AIC criteria, we find that an ARIMA(0,1,2) with drift is suited best to describe OPEC+ production between January 1995 and December 2016. Based on the estimated ARIMA model, Figure 7 (upper panel) plots the forecast for OPEC+ oil supply along with actual production and the baseline counterfactual path used before. Not surprisingly, the forecast differs greatly from the path based on the OPEC+ reference levels, especially at the end of the sample.

Despite the different hypothetical path in production, the implied path for the oil price is comparable to the benchmark results shown in section 4.1. Figure 7 (middle panel) compares the counterfactual path of the oil price based on the different assumption for production. The results are similar and are thus not too sensitive to the assumption we need to make regarding the counterfactual path of the oil supply. In addition, the sequence of supply shocks required to implement the counterfactual simulation based on the ARIMA forecast are also not unusually large by historical standards. This can be seen in Figure 7 (lower panel) plotting the simulated supply shocks and is confirmed by an F-test, which null hypothesis cannot be rejected with a p-value of 0.56.



NOTE: The upper panel shows OPEC+ production together with the counterfactual path based on an ARIMA forecast and based on OPEC+ reference levels (in million barrels, data only plotted from 2010 onwards). The middle panel compares the counterfactual path of the oil price with the baseline result and the actual price of oil (in US dollar per barrel). The lower panel shows the sequence of supply shocks required to implement the counterfactual simulation. Until December 2016 (marked with the vertical line), the series corresponds to the estimated shocks.

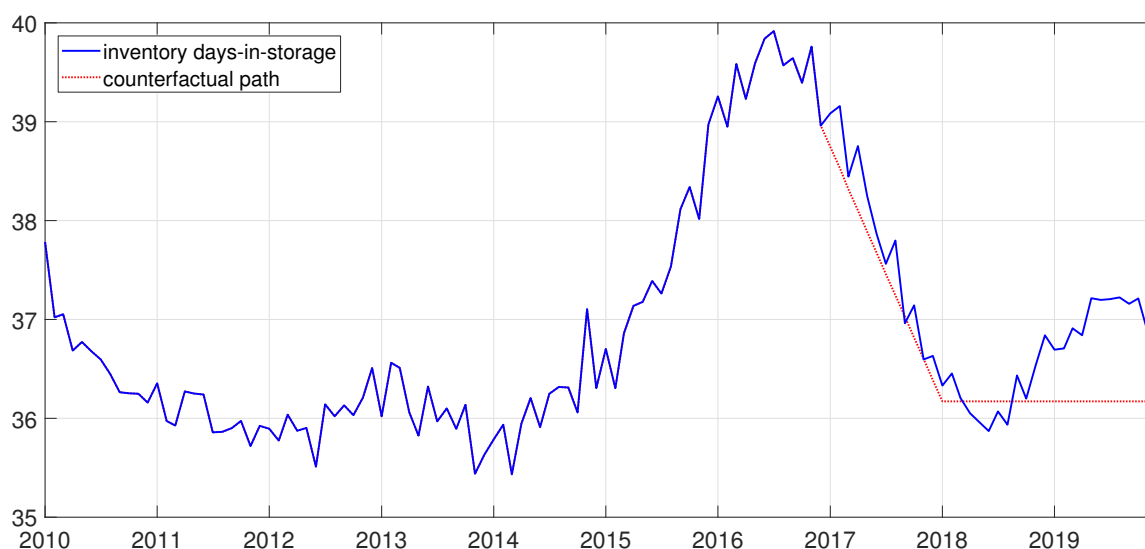
Figure 7: Results based on ARIMA forecast

Appendix C Simulating OPEC+’s inventory target

Adding inventory days-in-storage to the model without strategic interaction described in section 3.1 allows us to simulate how oil prices would have evolved if OPEC+ had focused on achieving its inventory target. Instead of assuming a counterfactual path for OPEC+ production, we construct a counterfactual path for our measure of inventories, back out the sequence of supply shocks that would have been needed for achieving the inventory target and derive the corresponding path of the oil prices—again holding constant the remaining structural shocks. As explained in the main text, we include days-in-storage as a more precise measure of market tightness. The data is obtained by dividing total inventory levels available for OECD countries by the daily total oil consumption of these countries.¹¹

With inventory levels and with its days-in-storage levels reaching historical highs in early 2017, we need to make an assumption on how quickly OPEC+ could have reached its target. We assume that production cuts would have been gradually, aiming at bringing days-in-storage within 12 months to the average level reached between 2010 and 2014. Figure 8 compares the actual path of days-in-storage with the assumed counterfactual path. After days-in-storage had fallen in 2017, reaching the desired level in early 2018, it started to deviate again from the target soon afterwards.

¹¹The data is only available for total oil, including crude oil and NGLs and is provided by the *International Energy Agency*.



NOTE: The figure shows OECD inventory days-in-storage together with the counterfactual path based on the OPEC+ inventory target.

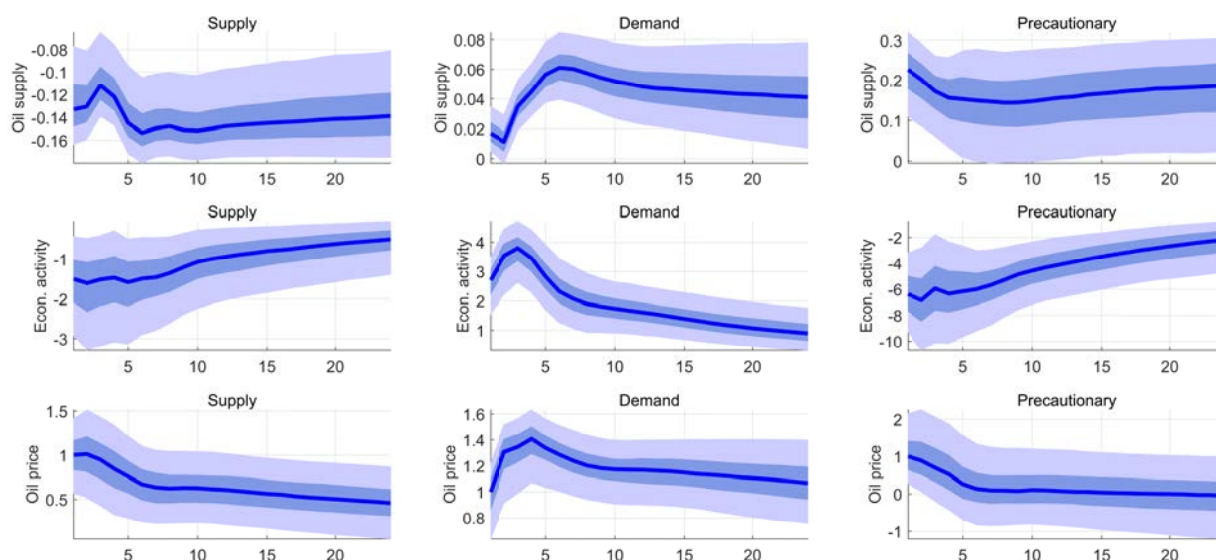
Figure 8: OECD inventory days-in-storage and counterfactual path

Structural identification is very similar to the model described in subsection 3.1 based on sign restrictions and bounds on the demand and supply elasticities. As before, we identify a supply shock and two demand shocks assuming that days-in-storage fall on impact following a negative supply shock and that they rise following a precautionary demand shock (Table 3). We leave the reaction of days-in-storage to a global demand shock unrestrained. The restrictions on the short-run price elasticity of oil supply and oil demand are similar to the previous model specifications.

Table 3: Sign restrictions in model with OECD inventories

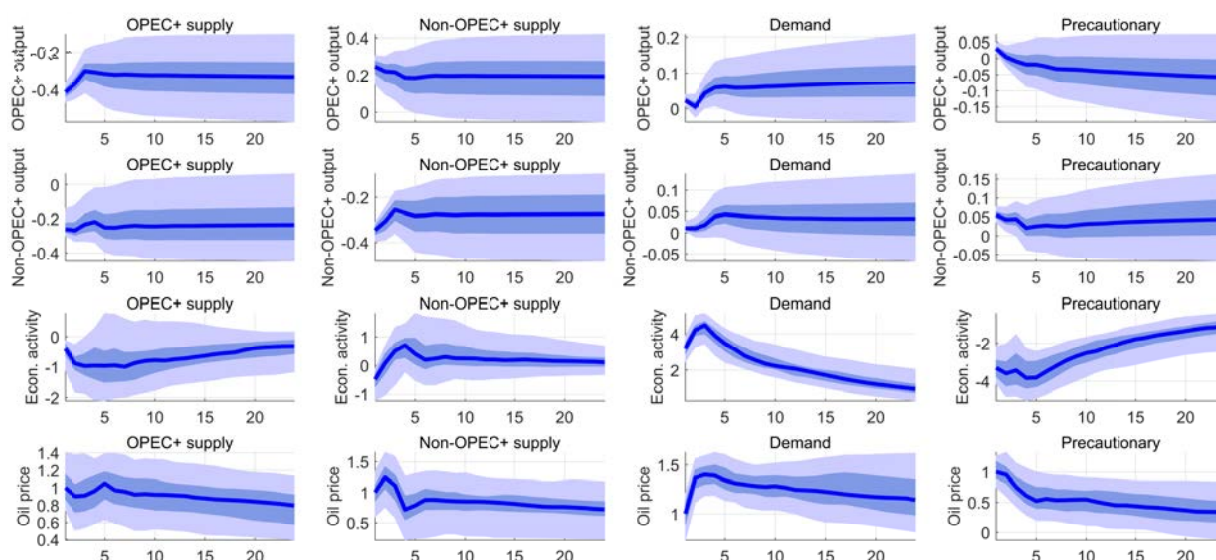
	oil supply	global oil demand	precautionary oil demand
global oil production	-	+	+
real economic activity	-	+	-
oil price	+	+	+
OECD inventories	-		+
Additional Restrictions			
- Upper bound on elasticity of demand in production -0.1			
- Upper bound on elasticity of supply 0.05			

Appendix D Impulse Response Functions



NOTE: Impulse response functions are standardized so as to lead to a 1 percent increase in the price of oil with variables in logs (oil supply and oil price) being expressed as percentage. The shaded areas are 65 and 84 percent confidence bands.

Figure 9: Impulse responses model without strategic interaction



NOTE: Impulse response functions are standardized so as to lead to a 1 percent increase in the price of oil with variables in logs (OPEC+ and Non-OPEC+ output and oil price) being expressed as percentage. The shaded areas are 65 and 84 percent confidence bands.

Figure 10: Impulse responses model with strategic interaction

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