Abstract

This paper provides a historical perspective from 1990 to 2018 of the functioning of the world oil market with and without OPEC. The analysis builds on a new methodology simulating counterfactual (i.e. what-if) outcomes in the rich context of state-of-the-art structural VAR models of the world oil market to empirically assess OPEC’s contribution to oil markets and the global economy by quantifying the impact of OPEC’s balancing role via its spare capacity cushion on the historical evolution of oil production, oil prices and price volatility, the joint evolution of the supply and demand elasticities and global welfare. A counterfactual scenario is constructed of how global oil production would have evolved if OPEC had been producing at maximum capacity, held no spare capacity and did not play any balancing role since 1990. The analysis also employs a general equilibrium approach to determine the global welfare implications of a world without OPEC spare capacity across oil-exporting and oil-importing regions. The welfare effects are calculated based on regional GDP gains and losses following changes in oil production patterns globally. The methodology to determine the impact on GDP is based on a computable general equilibrium (CGE) framework which offers a high level of detail regarding the world economy in terms of economic sectors and regional interdependencies.

1. Introduction

Historically, the oil market has been subject to a large number of shocks. These shocks come in different forms (for instance, flow supply versus flow demand versus speculative demand shocks), their impact on market balances can be permanent or transient, and they can be positive or negative (Kilian and Murphy, 2014; Baumeister and Kilian, 2016; Economou et al., 2017). In face of a negative demand shock such as the COVID-19 crisis, oil exporters under the umbrella of OPEC and OPEC+ can coordinate their output policies and adjust their output to counter the shock, balance the market and draw down inventories. All OPEC+ members recognise the fact that in the face of ex ante excess supply due to overproduction and/or a negative demand shock, reliance on price or
market mechanisms to correct the market imbalance and clear the resulting large build-up in inventories is a lengthy and painful process as the sharp fall in revenues impacts adversely their economies and public finances (Fattouh and Sen, 2015; Fattouh, 2016).

There is rarely a disagreement on this general principle. However, reaching agreements to cut output with a diverse and heterogeneous group of producers has always been challenging, and this has become increasingly so with the larger number of producers under the OPEC+ umbrella. Also, agreements may take a long time to conclude due to bargaining problems (Hyndman, 2008). These could be on the timing of the cut, its size, the allocation of the cut among individual members and the timing of exiting the agreement. Even if producers do agree on the optimal size of the collective cut, how to distribute the burden of the cut across individual members remains a key challenge (Bain, 1948; Gault et al., 1999). However, as noted by Mabro (1998), ‘[OPEC members’ ability to] compromise to reach agreement should not be underestimated. It is founded on the belief that all members, including the largest producers, would be worse off without OPEC’. Hyndman (2008) shows that the larger the shock (positive or negative), the more likely it is for OPEC to reach an agreement. But reaching an agreement does not imply the end of the process. Since agreements extend over multiple months or even years, ensuring compliance over an extended period of time is not straightforward. The incentive for each individual country to comply with agreement results from comparing the short-run gain from deviating from the agreement and the cost or losses resulting from a collapse of the agreement and the resulting fall in oil prices. These trade-offs are not constant over time, especially if some producers believe that deviations from the agreement will not be detected immediately. In this regard, the ability to swing production can play an important role in enforcing discipline. Increasing output in response to low compliance increases the cost of exiting the agreement and can encourage discipline in the absence of formal enforcement mechanisms (Geroski et al., 1987; Griffin and Nielson, 1994).

While OPEC’s response to negative demand or positive supply shocks is widely analysed in the literature, the role of OPEC spare capacity in offsetting negative supply shocks due to supply disruptions or positive demand shock due to strong economic growth has received much less attention in the literature. Fattouh (2006) analyses the impact of the lack of OPEC spare capacity on price swings and volatility, but it does not quantify these effects. Fattouh and Mahadeva (2013) argue that in the absence of spare capacity and in face of a disruption, most of the market adjustment is likely to occur through price increases given the low short-term elasticity of oil supply and demand. Thus, when OPEC is producing close to its maximum capacity, it loses the ability to influence the oil price. Historically, this has been compounded by market scepticism about the actual size of OPEC spare capacity and the willingness of producers to put a cap on rising oil price.
Recently, few studies have attempted to quantify the impacts of spare capacity on price behaviour and welfare. Almutairi et al., (2021) find that during 2001–2014, OPEC’s management of spare capacity decreased price volatility by at least 25 per cent relative to what it otherwise would have been, and the impact could have been even higher depending on the assumptions made about the price elasticity of short-run oil demand and non-OPEC supply. The authors also find that a sudden and unexpected loss of 1.5 million barrels per day (mb/d) from global supply over a 6-month period would generate cumulative GDP losses of $166 billion over the next 5 years. In similar vein, Pierru et al., (2018) find that OPEC’s use of spare capacity has reduced price volatility and that OPEC’s buffer capacity has been in line with global macroeconomic needs.

In this paper, we provide a historical perspective from 1990 to 2018 of the functioning of the world oil market with and without OPEC. Our analysis builds on a new methodology simulating counterfactual (i.e. what-if) outcomes in the rich context of state-of-the-art structural VAR models of the world oil market to empirically assess OPEC’s contribution to oil markets and the global economy by quantifying the impact of OPEC’s balancing role via its spare capacity cushion on the historical evolution of global oil production, oil prices, volatility, the joint evolution of the supply and demand elasticities and global welfare. A counterfactual scenario is constructed of how global oil production would have evolved if OPEC had been producing at maximum capacity, held no spare capacity and played no balancing role since 1990. The analysis also employs a general equilibrium approach to determine the global welfare implications of a world without OPEC spare capacity across oil-exporting and oil-importing regions. The welfare effects are calculated based on regional GDP gains and losses following changes in oil production patterns globally. The methodology to determine the impact on GDP is based on a computable general equilibrium (CGE) framework which offers a high level of detail regarding the world economy in terms of economic sectors and regional interdependencies.

We find that oil supply shocks in the counterfactual scenario associated with geopolitical events in oil-producing countries and other shocks to crude oil production would have been significantly larger and more persistent. The reason is that without spare capacity there is little room for oil producers not affected by the geopolitical episode to increase production and offset the supply shortfall within a short period of time, nor is there much flexibility to bring new productive capacity on stream due to the lead times and long gestation periods associated with new production despite higher prices. Historical evidence also shows that OPEC spare capacity has had a smoothing effect on global oil price movements, with prices under the counterfactual scenario exhibiting much sharper cycles both on the upside and the downside. We find that in a world without OPEC spare capacity, volatility would have been higher relative to the actual observed. Also, in a world where OPEC is producing at maximum capacity, oil
supply and demand would have become even less elastic with the average elasticity estimates halved compared to the actual. We also find that shifts in OPEC oil output policy and abandonment of its balancing role have global welfare implications. On the one hand, increases in OPEC’s output under normal market conditions lead to an increase in world GDP. However, in the absence of spare capacity, supply shortfalls from elsewhere lead to increasing negative impacts on world GDP across time. This observation underscores the growing welfare importance of spare capacity over time to smooth out unexpected and abrupt oil shocks.

This paper is divided into four sections. Section 2 provides a historical perspective from 1990 to 2018 of the functioning of the global oil market with and without OPEC by quantifying the role of spare capacity on the historical evolution of global oil production, oil prices and volatility, and the joint evolution of the short-run oil supply and demand elasticities in the rich context of structural vector autoregressive (VAR) models of the global oil market. Section 3 employs a general equilibrium approach to determine the global welfare implications of a world with and without OPEC’s spare capacity across different oil-importing and oil-exporting regions. The welfare effects are calculated based on regional GDP gains and losses following changes in oil production globally. Section 4 draws the conclusions.

2. The role of OPEC for global oil market stability

OPEC’s pricing power has come under extreme scrutiny in the oil literature (Smith, 2005; Almoguera et al., 2011; Fattouh and Mahadeva, 2013; Golombek et al., 2018; Berk and Çam, 2020). OPEC’s market power stems from its ability to adjust production and manage a spare capacity cushion that can be utilised at any given point in time to offset sudden and abrupt disruptions in either the supply or demand side of the global oil market (Fattouh and Mabro, 2006). Spare capacity played a key role for the functioning and the evolution of the oil market long before OPEC. Prior OPEC’s formation, the world’s available spare capacity was held by the US federal and state commissions in order to promote conservation and prevent ‘physical waste’ in oil production, but in 1972 these conservation efforts were lifted in response to the mounting demand pressures of the late 1960s and surplus US production quickly disappeared (Hamilton, 2013). This development signalled the end of the US control over spare capacity and the rise to prominence of OPEC, who holds the world’s only available spare capacity cushion.

Unlike the US regulatory system however, OPEC has historically been faced with many challenges as a spare capacity manager as it had to manage production across a wide range of heterogeneous oil producers with different economic and political structures and market objectives, and with no obvious enforcement mechanism. But
while OPEC has survived for more than 60 years, the existing literature still offers a wide range of conflicting interpretations about the role and importance of OPEC for global oil market stability, to the extent that a prevailing view is that OPEC has had little effect on oil market and price dynamics, albeit this has proved difficult to empirically pin down (Smith, 2005; Almoguera et al., 2011; Cairns and Calfucura, 2012; Fattouh and Mahadeva, 2013). Empirical results show that varying behaviour models tend to outperform constant-conduct models. Almoguera et al., (2011) identify multiple switches between collusive and non-cooperative behaviour during the 1974–2004 period. They find that although there were periods in which oil prices were higher due to collusion among OPEC members, overall OPEC has not been effective in systematically raising prices above Cournot competition levels. Using quarterly data from 1986 to 2016, Golombek et al., (2018) also find that while OPEC exerts market power, this power tends to vary over time. Berk and Çam (2020) find that oligopolistic market structures fit the market outcomes before 2014, but they fail to explain the low oil prices during 2015 and 2016, which were closer to levels generated by a competitive market, supporting the view that the market has shifted to a more competitive structure.

The reality of the oil industry is that since the collapse of the huge OPEC surplus production capacity in the mid-1980s that is estimated close to 12 mb/d to below 2 mb/d in the early 1990s, no oil-producing country within or outside OPEC has been willing to undertake the financing burden of building and maintaining new spare capacity, nor has this issue been properly addressed to date (Fig. 1). The exception has been Saudi Arabia, which is the only country that has an official policy to maintain at all times between 1.5 and 2 mb/d of spare capacity that can be effectively brought online in a relatively short period of time (Fattouh and Sen, 2015). Therefore, the starting point of our analysis is to consider a world with OPEC (actual) and without OPEC (counterfactual). In the counterfactual scenario, OPEC producers—in particular Saudi Arabia—are assumed to produce at maximum capacity and, hence, hold no spare capacity and play no balancing role since 1990. In constructing this counterfactual, we estimate how global oil production would have evolved in the absence of OPEC spare capacity, such as:

$$ Q_i^{\text{counterfactual}} = Q_i^{\text{actual}} + S_i^{\text{actual}}, $$

where $Q_i$ is global oil production and $S_i$ is total OPEC spare capacity. The counterfactual production levels allow us to quantify the role of spare capacity on the historical evolution of global oil production, oil prices and volatility, and the joint evolution of the short-run oil supply and demand elasticities with the help of a recently developed structural vector autoregressive (VAR) model of the global oil market in the tradition of Kilian and Murphy (2014) and Baumeister and Peersman (2013a). The Kilian and Murphy (2014) structural VAR framework has become the workhorse model for the
analysis of oil markets, because for the first time it incorporates storage demand and allowed for forward-looking behaviour in oil markets to be modelled alongside the flow supply and flow demand determinants of the price of oil (Economou et al., 2017; Herrera et al., 2019; Zhou, 2019).

We utilise a sign-identified structural VAR model based on monthly data for $y_t = (\Delta prod_t, rea_t, \Delta rpo_t, \Delta stocks)'$ that decomposes the historical evolution of the price of oil to its distinct flow supply and flow demand components, along its component driven by speculative demand, based on a combination of sign restrictions and bounds on the impact price elasticities of oil supply and demand based on Kilian and Murphy (2014). The sample period extends from February 1990 to September 2018. Accordingly, $\Delta prod$ is the percentage change in global oil production as reported by the International Energy Agency (IEA), $rea_t$ denotes an updated measure of global real economic activity proposed by Kilian (2009) designed to capture shifts in the global demand for all industrial commodities driven by fluctuations in the global business cycle, $\Delta rpo$ refers to the real price of oil defined as the spot Brent price deflated by the US consumer price index and is expressed in log-differences, and $\Delta stocks$ is the level changes in closing OECD total oil stocks in million barrels as reported by the IEA. Considering that there are no readily available data in the public domain of global oil stocks, we follow the literature in approximating global stocks based on OECD oil inventories (see Hamilton, 2009; Kilian and Lee, 2014). All measures are stationary by construction.

Let $y_t$ be a vector of the four observables, then the structural VAR of the global oil market may be written as:

**Figure 1** Total OPEC spare capacity, 1975–2018. Note: Data are from the U.S. Energy Information Administration (EIA). [Colour figure can be viewed at wileyonlinelibrary.com]
\[ B_0 y_t = \sum_{i=1}^{24} B_i y_{t-i} + \varepsilon_t, \]  

where \( B_i, i = 0, \ldots, 24 \) denotes the coefficient matrices and \( \varepsilon_t \) is the vector of orthogonal structural innovations. We consider 24 autoregressive lags in line with the literature (Kilian, 2009; Hamilton and Herrera, 2014), an intercept and seasonal dummies to remove seasonal variation.

The vector \( \varepsilon_t \) consists of four structural shocks. The first shock incorporates shocks to crude oil production associated with exogenous geopolitical events in oil-producing countries, as well as unexpected supply decisions by OPEC producers and other oil supply shocks, defined as *flow supply shock*. The second shock corresponds to unexpected fluctuations in the global business cycle that drive demand for crude oil and other industrial commodities defined as *flow demand shock*. The third shock captures changes in stock demand reflecting the forward-looking behaviour of market participants referred to as *speculative demand shock*.3 Finally, the fourth shock corresponds to other idiosyncratic oil demand shocks that cannot be classified as one of the preceding structural shocks, defined as *other demand shock*. The latter is essentially a residual shock that escapes economic interpretation, but it implicitly represents other exogenous shifts in the demand for oil that can be driven by a myriad of reasons (e.g. weather shocks, changes in inventory technology and releases of government stocks from the Strategic Petroleum Reserves).

The identification strategy is based on a combination of sign restrictions on the impact responses, bounds on the short-run price elasticities of oil supply and demand and dynamic sign restrictions on the responses to unexpected *flow supply shocks* motivated by economic theory and the oil literature. Considering the structural VAR model of the world oil market (2), we allow for an immediate effect of all four structural shocks \( \varepsilon_t \) to the model variables, according to \( e_t = B_0^{-1} \varepsilon_t \), where:

\[
e_t \equiv \begin{pmatrix} e^{\Delta \text{prod}}_t \\ e^{\Delta \text{rea}}_t \\ e^{\Delta \text{po}}_t \\ e^{\Delta \text{stocks}}_t \end{pmatrix} = \begin{pmatrix} - & + & + & . & . \[ \end{pmatrix} \begin{pmatrix} \varepsilon^{\text{flow supply shock}}_t \\ \varepsilon^{\text{flow demand shock}}_t \\ \varepsilon^{\text{speculative demand shock}}_t \\ \varepsilon^{\text{other demand shock}}_t \end{pmatrix}. \tag{3}
\]

The signs of the elements of the impact multiplier matrix \( B_0^{-1} \) have been normalised to imply an increase in the oil price. Missing entries (denoted by dots) mean that no sign restriction is imposed. Accordingly, on impact, a negative *flow supply shock* raises the oil price and lowers global real economic activity within the same month. The impact
effect on oil stocks is ambiguous a priori, and hence, it remains unrestricted. For example, on the one hand, a supply disruption associated with a geopolitical episode will cause oil stocks to be drawn down in an effort to offset the supply gap, smooth consumption and mitigate the price shock (Hamilton, 2009). On the other hand, the same shock may raise storage demand to the extent that it triggers a predictable increase in the real price of oil (Alquist and Kilian, 2010). A positive flow demand shock, which is associated with increased real activity by construction, raises the oil price and stimulates global oil production. As in the previous case, the inventory responses to flow demand shocks are ambiguous a priori and hence they remain unrestricted. A positive speculative demand shock reflecting expectations of a tightening oil market (i.e. the expected shortfall of future oil supply relative to future oil demand) is associated with an increase in stocks and the oil price by construction. The accumulation of oil stocks in the current period necessitates a decline in oil demand (and hence real economic activity) and an increase in oil production, as the oil price increases. Lastly, these sign restrictions identify other demand shocks that are not otherwise accounted for.

Beyond these static sign restrictions, the model imposes a joint set of dynamic sign restrictions such that the response of the real price of oil to a negative flow supply shock is positive for at least one year beyond the impact period and by extension the responses of oil production and real economic activity are negative. According to Kilian and Murphy (2014, p. 462), the rationale for this restriction is that an unexpected flow supply disruption would not be expected to lower the real price of oil within the same year below its starting level and that imposing a joint set of dynamic sign restrictions on the responses of oil production and real activity to a flow supply shock, is the only way for the oil market to experience higher prices and lower quantities in practice, because the decline in oil stocks as a response to a supply disruption is much smaller than the shortfall of oil production. Finally, the model imposes the restrictions that the short-run price elasticity of oil supply is close to zero and that the short-run price elasticity of oil demand is negative and smaller in magnitude than the long-run price elasticity of oil demand which is bounded between 0 and −0.8, consistent with conventional views in the literature (see, for example, Sweeney, 1984; Fattouh, 2007; Baumeister and Hamilton, 2019). Both elasticities can be expressed as functions of the impact responses in the structural VAR model. For details about the implementation procedure, the reader is referred to Kilian and Murphy (2014) and Kilian and Lütkepohl (2017).

Having constructed the counterfactual level of global oil production in the absence of OPEC spare capacity and estimated the structural VAR model of the global oil market (2) on the full sample, we are now able to determine how oil prices would have evolved if OPEC held no spare capacity cushion and played no balancing role since February 1992. We follow Kilian (2017) that postulates that this question may be answered by replacing the original sequence of flow supply shocks by the resulting counterfactual
sequence of flow supply shocks in the structural VAR oil market model and simulate the oil price evolution under this new sequence, while leaving unchanged all other structural shocks in the model. The difference between the actual and the counterfactual path of the Brent price measures the cumulative effect of OPEC spare capacity on oil price at each point in time.

2.1. Oil supply shocks in the absence of OPEC spare capacity

Figure 2a plots both the actual global oil production and the counterfactual (i.e. without OPEC spare capacity) over the period January 1990 to September 2018. As can be seen from this figure, global oil output is always higher in the counterfactual scenario, but the difference is not uniform across the entire period. For instance, in the mid-2000s (i.e. 2006, 2007 and 2008) when OPEC was producing close to maximum capacity to meet the rapid increase in global oil demand driven in large part by China’s strong economic growth, the difference between the actual and the counterfactual global oil production series is small. Similarly, in 2015 and 2016 when OPEC switched to market share strategy and increased output sharply, the difference between the two series is also small. This is in contrast for instance to 2009 and 2010, when OPEC had to cut output in the face of the 2008 Financial Crisis and the resulting sharp fall in global oil demand, which boosted OPEC’s spare capacity. Over the entire period, crude oil production would have been higher by 2.5 mb/d compared to the actual realisation, with most of the difference attributed to Saudi Arabia, as most of the spare capacity resides in the Kingdom and is the only country with an official policy to hold spare capacity. That said, the growth of

![Figure 2 Actual and counterfactual global oil production, Jan 90–Sep 18. [Colour figure can be viewed at wileyonlinelibrary.com]](image-url)
global oil production between 1990 and 2018 would have been slower by 1.5 mb/d compared to the actual observed.

Figure 2b that compares the volatility of global oil production between the actual and the counterfactual scenario shows that volatility declines on average from 1 per cent to less than 0.8 per cent. This is expected, as without OPEC adjusting its output to respond to unexpected oil supply and demand shocks hitting the market, abrupt changes in global oil output arise largely due to geopolitical episodes disrupting supplies which are less frequent and smaller in recent periods. Another important contributor to these volatility changes under the counterfactual scenario is the inability of OPEC and Saudi Arabia to respond to surges in the price of oil driven by increased demand for oil (e.g. in 2003/08) and to price slumps driven by the deterioration of global oil demand or the emergence of new suppliers (e.g. in 2014/16) (Fattouh et al., 2016).

Despite the obvious decline in global oil production volatility however, Fig. 3 shows that oil supply shocks in the counterfactual scenario associated with geopolitical events in oil-producing countries and other shocks to crude oil production are significantly larger and more persistent. The reason is that without spare capacity, there is little room for the rest of oil producers not affected by the geopolitical episode to increase production and offset the supply shortfall within a short period of time, nor there is much flexibility to bring new productive capacity on stream due to the lead times and long gestation periods associated with new production despite higher prices. This is illustrated in Fig. 4 that plots the actual and counterfactual OPEC supply disruptions associated explicitly with geopolitical episodes since 1990. Over the entire period, geopolitical supply disruptions in OPEC countries in the absence of spare capacity from Saudi Arabia would have been higher by 0.8 mb/d, while following significant episodes during which the production shortfalls have been large, the supply disruptions are twice as large as the actual observed (e.g. following the 1990 Gulf War, the 2002/03 Venezuelan crisis and Iraq War and in the aftermath of the 2011 Arab Uprising). Likewise, the OPEC supply disruptions in the absence of OPEC spare capacity are more persistent than the actual observed, for instance after 2002/03 where the counterfactual production shortfalls persist for three years and recede only in 2006, compared to just one year as it is observed based on the actual series.

2.2. Implications for the historical oil price evolution

Figure 5 compares the actual historical evolution of the Brent price with the counterfactual with no spare capacity from February 1992 to September 2018. The asymmetry is quite clear. In a tight market driven either by a negative supply or by positive demand shock, the Brent price would have been higher in the counterfactual scenario. This is seen most evidently in 2011 and 2012, following the large supply disruptions from a number of countries including IR Iran and Libya. In a world without
OPEC spare capacity, the price would have risen by $110/b (from $51.6/b in 2010 to $161.7/b in 2012) compared to $30.7/b in the actual world. In 2012, the Brent price would have been $39/b higher than the actual observed. On the other hand, in weak markets where OPEC had to cut output to balance the market, the oil price would have been lower in the counterfactual scenario. For instance, in 2009 and 2010, the price would have remained in the low-$50/b without the OPEC cuts, compared to the $80/b observed. Thus, overall, OPEC’s spare capacity has had a smoothing effect on global oil

**Figure 3** Sequence of flow supply shocks, Feb 92–Sep 18. [Colour figure can be viewed at wileyonlinelibrary.com]

**Figure 4** OPEC geopolitical supply disruptions, Jan 90–Sep 18. Note: Authors’ estimations based on the measure of exogenous supply shocks due to Economou (2016). [Colour figure can be viewed at wileyonlinelibrary.com]
price movements, with prices in a world without OPEC exhibiting sharper price cycles both on the upside and the downside.

The impact of spare capacity on historical oil price shocks is also illustrated in Fig. 6 that compares the actual and counterfactual net oil price increases and decreases relative to the maximum and minimum level of the oil price over the preceding three years (similar techniques are discussed in Hamilton, 2003). Evidently, the counterfactual price series exhibits sharper and more frequent shocks relative to the actual, indicatively for most of the 1990s, the early 2000s and during 2010/12.

The much sharper price cycles under the counterfactual scenario are reflected in Fig. 7a that plots the evolution of the Brent price volatility in the actual world with OPEC and the counterfactual without OPEC. It is immediately obvious that prices in a world without OPEC would have been more volatile, relative to the actual observed, as the oil price adjustments and readjustments to the prevailing oil supply and demand conditions would have been larger and more frequent. This is also depicted in Fig. 7b that compares the actual monthly, quarterly and yearly Brent price volatility with that in the counterfactual scenario. As can be seen from this figure, on a yearly basis, the volatility under the counterfactual scenario would have been higher by 15.5 per cent; on a quarterly basis, it would have been higher by 3.4 per cent, and on a monthly basis, it would have been higher by 1.2 per cent. This result is expected as in the absence of a buffer, any shock, no matter how small, will induce higher price volatility. Many studies have shown that significant price volatility affects adversely the economic interests of both producers and consumers. That is because the role of prices is to signal relative

Figure 5 Historical evolution of the Brent price, Feb 92–Sep 18. [Colour figure can be viewed at wileyonlinelibrary.com]
scarcity or abundance, which in turn causes adjustments to the allocation of resources and hence high volatility confuses the signals and leads to inefficiencies (Mabro, 2006). From the producers’ perspective, a number of uncertainties have an impact on the investment decisions of both national and international oil companies leading to situations of either under- or over-investment in upstream oil. These inefficiencies in upstream oil due to the higher price volatility help explain the slower growth of global oil production in the counterfactual scenario. Higher price volatility is also harmful for global economic growth hurting both the importing and exporting economies. Specifically higher oil price volatility increases perceived price uncertainty, reducing planning horizons, causing firms to postpone investments and results in expensive reallocation of resources.

To fully appreciate these results, it is important to examine the price responsiveness to hypothetical oil supply and demand shocks in a world with and without OPEC spare capacity. Figure 8 shows the price responsiveness in the event of a hypothetical geopolitical supply disruption in oil supplies of 1 mb/d under the actual and counterfactual scenarios. It is shown that the price response in the absence of spare capacity would have been twice as large as at its peak the oil price increases by $10.4/b compared to $6/b in the actual case. But not only is the price increase expected to be larger, but also the price episode is expected to be longer in duration. That is because in the absence of spare capacity, the production shortfalls associated with some geopolitical episode cannot be replaced by other producers, nor can stocks mitigate the impact of the supply shock on price until the latter has fully adjusted to the episode in question.

Figure 6 Historical evolution of oil price shocks, Feb 92–Sep 18. [Colour figure can be viewed at wileyonlinelibrary.com]
Essentially, in the absence of OPEC spare capacity, the market has no mechanism to act as a buffer against abrupt oil disruptions, leaving it to prices to clear the market via large, unexpected adjustments. Similarly, Fig. 9 exhibits the price responsiveness to a positive and negative demand shock. In the absence of OPEC spare capacity in a rising market where global oil production fails to meet rising demand the price response is expected to be sharper and more persistent. The situation is even worse in a falling market characterised by a slowdown in oil demand amid increasing oil supplies, as the price response is expected to be sharper, more persistent and much steeper than in the case where OPEC holds its balancing role. That is because, in a falling market, oil producers are unlikely to reverse an investment decision once costs have been sunk into a project, while shutting-in operating capacity is costly and rarely done outside OPEC (Hamilton, 1985, 2009; Smith, 2009; Fattouh, 2016). Even OPEC will find it difficult to maintain its role as a market stabiliser in an oversupplied market because of the uncertainty pertaining to the responsiveness of oil demand and non-OPEC supply to a higher price, and hence, the cost of losing market share in favour of restoring its members’ revenues (Smith, 2005; Gately, 2011; Fattouh and Mahadeva, 2013; Fattouh and Sen, 2015).

### 2.3. Implications for the joint evolution of oil supply and demand elasticities

A key factor that can conceivably account for the inverse evolution of oil price and oil production volatilities in the counterfactual scenario is the joint steepening of the short-run oil supply and demand elasticities over time in a world with no spare capacity. To
empirically assess this hypothesis, we utilise a Bayesian structural VAR oil market model with time-varying parameters (TVP-VAR) and stochastic volatility in the innovation process estimated in the spirit of Baumeister and Peersman (2013a). The identification procedure follows Kilian and Murphy (2014), as described above. The model excludes the global oil inventories proxy and the speculative demand shocks (i.e. $3 \times 3$ structural impact matrix) and utilises quarterly rather than monthly data. That is

Figure 8 Average response of the Brent price to a one-time negative oil supply shock. [Colour figure can be viewed at wileyonlinelibrary.com]

Figure 9 Average response of the Brent price to a one-time oil demand shock by case. [Colour figure can be viewed at wileyonlinelibrary.com]
because the development of TVP-VAR models tends to be challenging and it is only feasible for small-dimensional models and a small number of variables and lags. In fact, the task of estimating monthly TVP-VAR models with a large number of variables remains computationally infeasible to date. Nonetheless, while structural VAR models go a long way towards explaining seeming time variation in the responses of the model variables to the structural shocks, the TVP-VAR structure is more compelling because it can account for additional time variation even after controlling for the shock. The overall sample extends from 1Q1947 to 3Q2018, albeit the first 25 years of data are used as a training sample to calibrate the priors for estimation over the actual sample period, which starts in 1Q1975. The number of lags is set to a year to allow for sufficient dynamics in the system, while as opposed to our principal structural VAR, we remain relatively agnostic to the bounds of the oil supply and demand elasticities, as the objective is to assess the extent the slope of the supply and demand curves have varied over time. The model is estimated once with the original variables (actual) and re-estimated by replacing global oil production with the constructed counterfactual series and the Brent price with the counterfactual path obtained by the principal analysis of the structural VAR described above.

**Figure 10** compares the actual joint evolution of the short-run price elasticities of oil supply and demand at each point in time from 1Q75 to 3Q18. As can be seen from the figure, since the mid-1980s, the oil market experienced a substantial decrease in the actual short-run price elasticity of oil supply and demand (though the oil supply elasticity has slightly increased towards the end of the sample due to US shale). According to Baumeister and Peersman (2013a,b), the joint evolution of the price elasticities since the mid-1980s is the result of an interplay between several historical developments. On the demand side, energy efficiency and sectoral shifts in advanced economies following the oil price surges of the 1970s, the change in the composition of oil demand over time, the repositioning of oil consumption to sectors characterised by a low own-price elasticity of demand (mainly transportation) and the rising share of emerging economies in global demand over time—where oil demand tends to be less sensitive to oil price changes than the advanced economies—were all important contributors. On the supply side, the lack of investment and the gradual erosion of spare capacity after the mid-1980s is another factor, as a low oil price elasticity of oil demand feeds also in the behaviour of oil producers in that it reduces their incentives to bring new capacity on stream, which leads to less capital investment in upstream oil and the gradual erosion of spare capacity as a response.

Having said that, Fig. 10 shows that in the counterfactual scenario where OPEC is producing at maximum capacity, the oil supply and demand elasticities would have been markedly lower and about half the actual observed. On average, over the entire period the counterfactual short-run price elasticity of oil supply closes to 0.06, from the actual
0.1. This is expected as with no spare capacity the oil market loses its ability to buffer abrupt supply disruptions. Interestingly, oil demand elasticity also declines in the counterfactual scenario to −0.8 on average, compared to the actual −1.3. Oil demand essentially becomes less price-sensitive because oil consumers anticipate that in the case of a major supply shock, a shortfall in production cannot be replaced by other producers, leading to an even higher share of precautionary demand in total oil demand. In fact, global stocks would stand at a much higher level in a world in which OPEC holds no spare capacity. In fact, back of the envelope estimates suggest that the difference is rather large, and averages close to 4 mb/d. This is expected as in the current context, OPEC holds stocks ‘belowground’ on behalf of the rest of the world, which are released to the market in very tight market conditions and rebuilt in weak market conditions. When OPEC is producing at maximum capacity, the stock-out avoidance (or precautionary demand) motive tends to become more prominent. In the absence of spare capacity and in times of heightened uncertainty and political instability, fears of actual disruptions deeply affect stockholding behaviour and the desired inventory levels have to increase both for precautionary reasons, but also because of expectation of future price increases. There is also the issue of the cost of holding more inventories aboveground (which is more expensive than holding it belowground) and who bears the cost of storage (big part of the cost needs to shift to final consumers and importing countries).

Figure 10 Historical joint evolution of oil supply and demand elasticities, 1Q75–3Q18. [Colour figure can be viewed at wileyonlinelibrary.com]
3. Global welfare implications

The welfare (GDP) losses and gains are calculated using a global multi-regional CGE model and are driven by oil output and price changes as informed by the structural VAR results for the counterfactual scenario. The use of a CGE framework allows for a comprehensive accounting of the direct and indirect effects of these production changes across the entire economy. For the analysis, a static specification of the CGE model was considered which was ran using economic datasets of three different years, namely 2004, 2007 and 2011. The model is structured around 20 world regions and 22 sectors. This structuring of the world regions allows for the distinct representation of the important regions in terms of production (Saudi Arabia, other OPEC, Russia, Brazil, Mexico, Canada), consumption (EU countries, India) or both (United States, China). The results for these regions are further aggregated into KSA (Saudi Arabia), other oil exporters (combining both other OPEC and non-OPEC exporters), importers and United States. From the 22 sectors included in the model, oil and other fossil fuel-related sectors are included as stand-alone sectors. Production functions in CGE models are introduced through nested CES (Constant Elasticity of Supply) functions which allow for an advanced specification of direct substitutability between the different factors of production. The value-added (VA) composite combines the use of all factors of production (capital, labour, natural resources) by allowing, in some economic sectors, a substitutability between them. The intermediate good composite combines other cost components which enter the production function in fixed proportions, and which can be sourced through the domestic or imported varieties—through the Armington assumption for international trade, these two varieties are considered imperfect substitutes $\sigma_M > 0$. The imported goods are also sourced from different regions and are substitutable according to an inter-regional elasticity $\sigma_R$.

We consider a condensed cost structure for crude oil production in major oil regions in 2011 according to the underlying global database. Capital rents, wages and natural resources represent the largest share of costs. For crude oil production, the substitutability between labour, capital and natural resources in the value-added (VA) composite is zero ($\sigma_{VA} = 0$). In other words, when producing at full capacity (all capital assets are in use), no additional production can be obtained using more labour while keeping the capital inputs constant. An increase in crude oil production from Saudi Arabia by assuming the full use of its productive capacity is obtained through an increase in productivity of capital and natural resources in this region. Under this positive supply shock, the other oil-producing regions have a limited response capability given the rigid production function for crude oil—capital and all other inputs cannot be diverted away from the sector during a 12-month time period. The increase in oil production in Saudi Arabia determines more exports to oil-importing regions and consequently a positive
impact on GDP—the lower oil prices determine a higher demand in the oil-importing regions. For the other oil-exporting countries, the fall in prices has a negative effect on oil revenues—the reduction in income generates a general reduction in economic activity in these regions. For the United States, which is both an important oil producer and consumer, the price decline has an overall positive GDP impact in spite of a decline in oil revenues.

The negative supply shock in other OPEC production is introduced as a decline in productivity of capital and natural resources for the oil production in this region. This decline in production determines an increase in world oil prices with varying effects on oil revenues across oil-producing regions—an increase in revenues with a positive GDP impact in Saudi Arabia and the non-OPEC producers and a decrease in revenues and GDP in the other OPEC region. The reduction in oil output has a negative effect on the GDP of all major oil consuming regions, including the United States.

Considering the historical events determining oil price changes in the 1995–2017 period, the GDP impacts are determined for two types of supply shocks. First, an expansion of Saudi Arabia’s production up to maximum capacity in the absence of exogenous supply shocks—Saudi Arabia oil production increases through a positive shock of capital productivity. The increase in Saudi Arabia oil output leads to a decrease in global oil prices. A sensitivity analysis of Saudi Arabia positive productivity shocks is conducted in order to determine regional GDP response curves to changes in prices and Saudi Arabia oil output—the positive supply response curves. The response curves are aggregated to determine the global GDP impacts of an expansion of Saudi Arabia oil production. Second, exogenous production shocks in other OPEC regions under full capacity utilisation in Saudi Arabia—other OPEC oil production decreases through a negative shock on capital productivity leading to an increase in global oil prices. Again, a sensitivity analysis of this negative supply shock is conducted in order to determine the regional GDP response curves to changes in prices and oil output drop—the capacity shortfall response curve. The response curves are aggregated to determine a global value for the net costs/benefits of a negative supply shock from outside Saudi Arabia.

To calculate the 1995–2017 welfare impacts of the counterfactual production and oil prices, the positive supply and the capacity shortfall response curves are determined for each individual year within the period. This is done so as to take into account changes in the size and the structure of global GDP and the evolution of oil demand elasticities across the different world regions. Given the high economic growth in emerging economies, the weight of global GDP has increased in these regions and has also determined the global oil demand to become more inelastic over the past two decades. Finally, the welfare impacts for the 1995–2017 period are obtained by combining the SVAR price and production changes under the counterfactual scenario with the annual GDP response curves obtained using the results of the CGE sensitivity analyses.
3.1. Impact on World GDP

As discussed above, the increase of OPEC’s production to maximum capacity leads to a price decrease which can have different GDP impacts across the different regions, namely Saudi Arabia, the United States, other oil exporters and importers. Figure 11 shows that the size of the aggregate world impact from OPEC pursuing to maximise its market share varies across time. Increases in Saudi Arabia’s output led to an increase in world GDP, albeit the impacts increase over time. For instance, an increase in production leading to a 25 per cent oil price decrease has a 0.15 per cent impact on GDP in 2004/07 and 0.20 per cent in 2011. By factoring in the expansion of world GDP between 2004 and 2011, the increase of Saudi Arabia’s production leads to even higher differences across time in absolute terms. The gains in world GDP associated with a 25 per cent oil price decrease are $50 billion, $75 billion and USD $150 billion in 2004, 2007 and 2011, respectively.

Furthermore, in the absence of OPECs and in particular Saudi Arabia’s spare capacity buffer, supply shortfalls from other OPEC producers lead to increasing negative impacts on world GDP across time. This is emphatically depicted in Fig. 12 that shows that the magnitude of impacts relative to the size of the GDP, again, becomes larger over time as a marker of a decreasing oil demand elasticity. As can been seen from the figure, in absolute terms, for a 27 per cent price increase induced by a negative supply shock, the cost of the supply shortfalls in the absence of spare capacity on world GDP increases from $60 billion in 2004, to $80 billion in 2007 and $185 billion in 2011.

![Figure 11 World GDP gains without OPEC spare capacity.](colour figure can be viewed at wileyonlinelibrary.com)
3.2. Cost of spare capacity
The welfare impacts calculated as GDP deviations from the actual levels are shown in Fig. 13. In the counterfactual scenario, a price decrease driven by Saudi Arabia ramping its production leads to a net GDP increase for the US and the oil-importing regions. At the same time, lower prices determine a loss in oil revenues for the other oil exporters with a negative impact over their respective GDP. For the price increase driven by supply shortfalls in the other OPEC regions, the impact in the absence of spare capacity is much higher. Saudi Arabia and the other non-OPEC exporters both benefit from higher oil prices; nevertheless, the welfare impacts on oil-importing regions are much larger. The net cost of spare capacity in Saudi Arabia in the presence of unanticipated supply shortfalls grows significantly after 2012 with net welfare loss values in the order of $250–450 billion, and by 2017, it is estimated to rise to $360 billion. Interestingly, a similar price increases due to the supply shortfalls associated with the 2002 Venezuelan Crisis and the subsequent 2003 Iraq War, coupled with a stronger-than-expected performance of the emerging economies, led to annual welfare impacts of less than $100 billion. These results underscore the growing welfare importance of spare capacity over time to smooth out unexpected and abrupt oil shocks.

4. Conclusion
This paper provides a historical perspective from 1990 to 2018 of the functioning of the world oil market with (actual) and without OPEC (counterfactual scenario) in the rich
Results show that oil supply shocks in the counterfactual scenario associated with geopolitical events in oil-producing countries and other shocks to crude oil production would have been significantly larger and more persistent. The reason is that without spare capacity there is little room for oil producers not affected by the geopolitical episode to increase production and offset the supply shortfall within a short period of time, nor is there much flexibility to bring new productive capacity on stream due to the lead times and long gestation periods associated with new production despite higher prices. Historical evidence also shows that OPEC spare capacity has had a smoothing effect on global oil price movements, with prices under the counterfactual scenario exhibiting much sharper cycles both on the upside and the downside. We find that in a world without OPEC spare capacity, volatility would have been higher relative to the actual observed. Also, in a world where OPEC is producing at maximum capacity, oil supply and demand would have become even less elastic with the average elasticity estimates halved compared to the actual. We also find that shifts in OPEC oil output policy and abandonment of its balancing role have global welfare implications. On the one hand, increases in OPEC’s output under normal market conditions leads to an increase in world GDP. However, in the absence of spare capacity, supply shortfalls from elsewhere lead to increasing negative impacts on world GDP.
across time. This observation underscores the growing welfare importance of spare capacity over time to smooth out unexpected and abrupt oil shocks.

Historically, the world has taken the spare capacity for granted. However, the issue of maintaining spare capacity has become more complex in the context of the energy transition and the wide demand uncertainties. If the energy transition has the effect of increasing the probability of supply shocks and their size and/or causes a slowdown in supply growth outside OPEC, the call on OPEC could still rise and, in the absence of new investments, spare capacity would erode over time. The question then becomes: Should OPEC and the main capacity holder Saudi Arabia aim to invest in new productive capacity and maintain the buffer even in a world in which oil demand growth is expected to slow? If, by contrast, the call on OPEC does fall over time, then OPEC may end up with larger spare capacity over time. In this case, should OPEC adopt a strategy to reduce its productive capacity, pursue a faster monetisation strategy and utilise all its spare capacity or should it maintain spare capacity to deter entry of other sources of supply? The trade-offs of maintaining spare capacity have become more difficult and the evolution of spare capacity will depend on market factors and strategic choices. But as in the past, the decision of holding spare capacity and the size of spare capacity will be key factors in shaping oil market outcomes.

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**Notes**

1. For instance, Griffin and Nielson (1994) find evidence that rather than acting as a dominant or a swing producer, Saudi Arabia opted for a tit-for-tat strategy that punishes members for producing above their quotas and rewards those that comply. They identify three strategies used by Saudi Arabia: the Cournot strategy, the swing producer strategy and the tit-for-tat strategy. As long as Saudi Arabia earns more than Cournot profits, it would be willing to tolerate deviations from the quota, and at times, it may act as a swing producer to earn profits in excess of the Cournot equilibrium level. However, if cheating becomes flagrant, Saudi Arabia will punish the ‘cheaters’ by increasing its output until every producer is reduced to Cournot profits.

2. The US spare capacity between 1957 and 1963 totalled about 4 mb/d, equivalent to more than 10% of world output on annual basis, but by the late 1960s that surplus amount diminished to less than 1 mb/d and gradually disappeared (Yergin, 1992, p. 549).
3. For more details on the motivation, rationale and economic interpretation of speculative demand shocks, the reader is referred to Alquist and Kilian (2010) and Kilian and Murphy (2014).

4. A more detailed discussion of this procedure can be found in Kilian (2017).

5. The first 2 years of the data are used as a training sample to calibrate the priors for estimation over the actual sample period, which starts in February 1992, and hence are omitted.

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