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Article

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Crude oil: market trends and simulations point toward stable equilibrium

By Aleksandar Zaklan, Dawud Ansari, and Claudia Kemfert

In this study, we report on the current state of the international market for crude oil. The market data we analyzed indicate that competition has intensified as a result of the now firmly-established shale oil extraction industry in the U.S. Model-based simulations also show that supply-side shifts should only have moderate price effects. This applies to both an expansion in U.S. shale oil production and a disruption of production in OPEC countries.

Market data and simulations indicate that the crude oil market is currently in a new equilibrium that appears to be relatively robust in the short term. In the absence of further shocks, we can continue to expect a moderate price level for crude oil in the short term with corresponding implications for economic and climate policy.

In this study, we report on our analysis of the current state of the international market for crude oil.[1] Alongside a presentation of current price and quantity trends, we use a model-based analysis to show how robust the current oil market equilibrium would be in the face of supply-side changes. We closely examine two cases, the first one being increased shale oil production as a result of gains in efficiency in the U.S. shale oil sector. The second one focuses on production disruptions in OPEC (Organization of the Petroleum Exporting Countries)[2] countries as a result of increased geopolitical tension in the Middle East.

Moderate price level in today's oil market

The price of crude oil has fallen sharply since the middle of 2014. From a low of less than 30 U.S. dollars per barrel of Brent crude[3] at the beginning of 2016, prices have been fluctuating between 40 and 60 U.S. dollars per barrel ever since (Figure 1). Most recently in the wake of increased political tension in the Middle East, it exceeded the 60-dollar mark.

This price level is moderate in comparison to that of the period before mid-2014, currently favoring economic growth in oil-importing countries such as Germany.[4] At the same time, compared to the low in 2016, a recovering oil price is stabilizing the budgetary situation of oil-

1 The present study is an update of an earlier analysis. See Aleksandar Zaklan and Claudia Kemfert, "Rohölmarkt: US-amerikanisches Schieferöl schwächt Marktmacht der OPEC," *DIW Wochenbericht* no. 19 (2015): 429–433 (in German only; available online, accessed November 20, 2017. This applies to all other online sources in this report unless stated otherwise).

2 The current members of OPEC, the Organization of the Petroleum Exporting Countries, are: Algeria, Angola, Equatorial Guinea, Ecuador, Gabon, Iran, Iraq, Qatar, Kuwait, Libya, Nigeria, Saudi Arabia, Venezuela, and the United Arab Emirates.

3 Brent crude oil is produced in the North Sea and traded on the Intercontinental Exchange in London. The price of Brent is recognized as the global reference price. See Lutz Kilian, "How the Tight Oil Boom Has Changed Oil and Gasoline Markets," *CEPR Discussion Paper*, 11876 (2017) (available online).

4 See Projektgruppe Gemeinschaftsdiagnose, "Gemeinschaftsdiagnose Herbst 2017," *DIW Wochenbericht*, no. 40 (2017): 809–883 (available online).

Figure 1

Spot market prices for crude oil
In U.S. dollars per barrel Brent

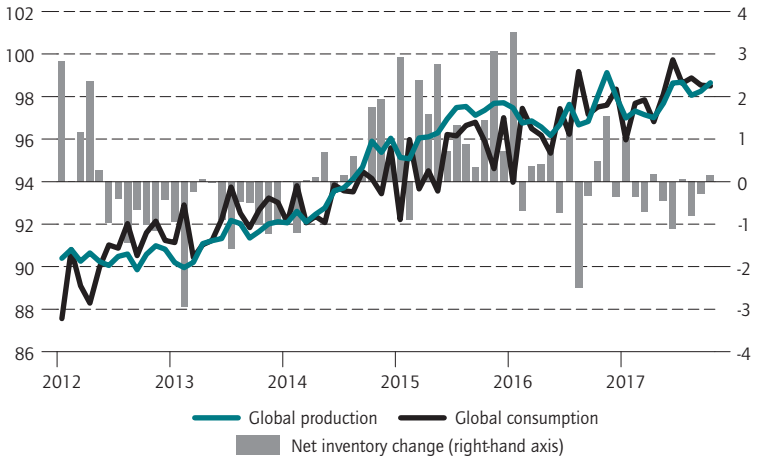
Note: In current prices.

Source: U.S. Energy Information Administration.

Since mid-2016, prices have been largely stable.

Figure 2

Global production, consumption and inventory change of crude oil
In million barrels per day



Source: U.S. Energy Information Administration.

At the moment, production and consumption are largely balanced.

exporting countries, in particular the members of OPEC and important non-OPEC exporters such as Russia.[5]

Overall, the growth of the global economy in recent years has led to rising demand for oil and, consequently, a recent draw-down in inventories (Figure 2). At the same time, oil production is expanding. U.S. shale oil production is currently at a very high level, as is the output of OPEC and other oil-producing countries. Further, inventories remain high in comparison to the long-run average despite the latest draw-down.[6] Currently, limited production slowdowns, such as the one caused by the hurricane in the Gulf of Mexico in fall 2017, can be absorbed with only minor price effects. The oil market appears to be relatively robust at present.

Continued high output in the oil market

Recently, crude oil production has expanded less rapidly than in previous years. While total global production increased by a solid six percent between the beginning of 2014 and the end of 2015, it seems to have plateaued since then (Figure 2). Nevertheless, the market continues to be well supplied.

Moderate curb on output in OPEC countries

OPEC's oil output levels have exhibited a stable to rising trend in recent years.[7] At the end of 2016, OPEC's total production exceeded 33 million barrels per day. Since the beginning of 2017, OPEC and key non-OPEC producers—Russia in particular—have almost fully implemented their joint plan to curb oil output.[8] As part of the strategy, Russia and Saudi Arabia's output quantities fell slightly in the first half of 2017 (Figure 3).[9] The agreement to curb output will apparently hold throughout 2018. Output cuts primarily refer to limits on the growth rate of crude oil production and not to an absolute drop in output.

In the process, OPEC countries find themselves in a trade-off: On the one hand, they have an incentive to drive oil prices upward by curbing output in order to reduce revenue losses. On the other, expanding pro-

5 See Projektgruppe Gemeinschaftsdiagnose, "Gemeinschaftsdiagnose Herbst 2017."

6 See U.S. Energy Information Administration, *Weekly Petroleum Status Report*, (2017) (available online).

7 This development has been obscured by the fact that individual countries have joined or quit OPEC in recent years. For example, Indonesia was temporarily an OPEC member in 2016.

8 Organization of the Petroleum Exporting Countries, "Declaration of Cooperation" (2016) (available online).

9 See International Energy Agency, "Oil Market Report," *Market Report Series_Oil and Annual Statistical Supplement* (2017) (available online).

Box 1

Shale oil

Shale oil is a type of crude oil found in fine-grained sedimentary rock. Conventional drilling techniques have proven to be uneconomical for this type of oil, which is why unconventional extraction processes are used. They include fracking, in which a pressurized liquid fractures the surrounding rock, and horizontal drilling.

Conventional oil extraction is characterized by decades-long project durations and high fixed costs. This is why conventional oil business reacts to new investments only with major lags. Investment decisions are typically based on longer-term market forecasts and subject to a great deal of uncertainty. These factors result in a low supply elasticity for conventional oil extraction: Assuming perfect competition, the quantity supplied reacts to price changes in the short term only to a very limited extent.

Shale oil, on the other hand, is characterized by lower fixed costs, higher operating costs, and shorter extraction cycles per well. From drilling to extraction, it can take less than six months to open a new well, and wells are depleted much faster. Most of the available oil is extracted within the first two to three years. Due to the shorter planning horizon, shale oil producers can fine-tune their investment behavior to react to price changes much more quickly, resulting in a more elastic global oil output.

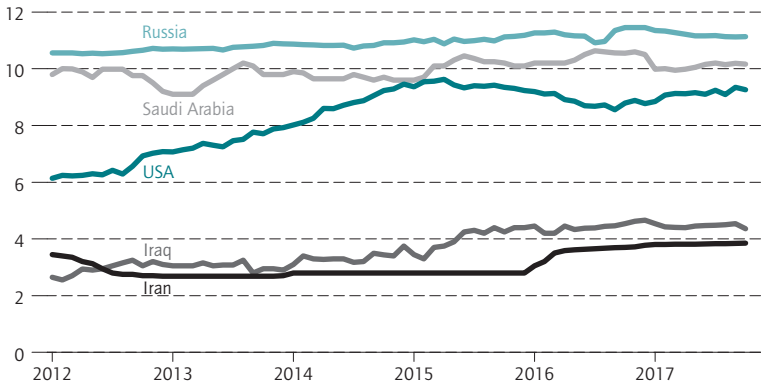
duction—a strategy that goes hand in hand with lower prices in the short term—would increase their own market share, probably reinforcing their market dominance in the long term. [10]

U.S. shale oil producers firmly established in market

U.S. crude oil production recovered from its temporary decrease in mid-2016 and currently trends toward 10 million barrels per day. Producers will probably meet this target by the end of 2018,[11] thus approaching the historical highs of the 1970s.

Figure 3

Crude oil production of major producers
In million barrels per day

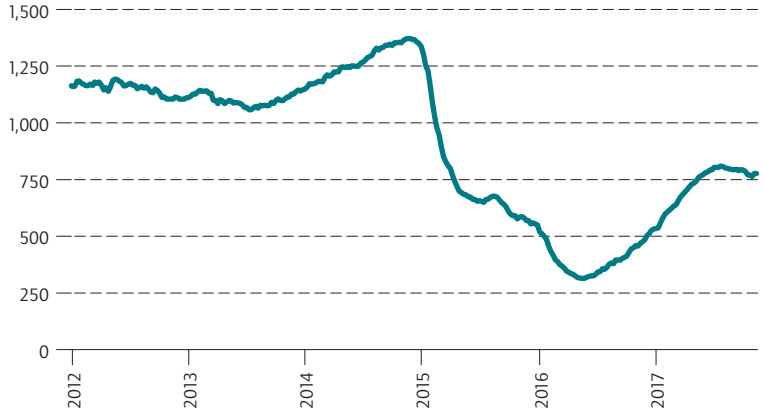


Source: U.S. Energy Information Administration.

Production in Russia and Saudi Arabia slightly decreased in the first half of 2017.

Figure 4

Number of active horizontal drilling rigs in the US



Note: Horizontal drilling rigs for shale oil and shale gas extraction.

Source: Baker Hughes.

The number of active rigs has increased significantly over the last year.

The momentum in production is primarily driven by a renewed increase in fracking activity (Box 1). Even at moderate crude oil prices, expanding shale oil production appears to be economically viable—measured by the number of active horizontal drilling rigs. This is evident in the rising number of active horizontal drilling rigs since

10 See Bassam Fattouh, Rahmat Poudineh, and Anupama Sen, "The dynamics of the revenue maximization–market share trade-off: Saudi Arabia's oil policy in the 2014–15 price fall," *Oxford Review of Economic Policy*, 32 (2) (2016): 223–240; and Dawud Ansari, "OPEC, Saudi Arabia, and the Shale Revolution: Insights from Equilibrium Modelling and Oil Politics," *Energy Policy*, 111 (2017): 166–178.

11 See U.S. Energy Information Administration, "Short-Term Energy Outlook," (2017) (available online).

Box 2

The OILMOD-E model

The price effects of the scenarios described in this study were calculated with the OILMOD-E model of the German Institute for Economic Research (DIW Berlin). OILMOD-E is a numerical partial equilibrium model used to investigate strategic interactions among profit-maximizing, oligopolistic oil producers. The model is similar to other numerical energy market models developed by DIW Berlin (e.g., GLOBAL GAS MODEL and COALMOD) to analyze trends in global natural gas or coal markets while taking imperfect competition into account.[1]

OILMOD-E determines output, consumption, and market prices based on an array of input parameters. They include: production costs, oil production capacity, a demand curve, and assumptions about the competition setup. Estimations by the International Energy Agency, *Oil & Gas Journal*, and various scientific publications serve as data sources. The actors included in the model represent over 95 percent of the global crude oil market. Due to the globalized structure of the sector, the model considers an aggregated market, but it uses sophisticated cost curves and quality parameters for different crude oils to capture technical and geophysical features of crude oil production in detail.[2]

OILMOD-E has a special feature: It can explicitly model the crude oil market's asymmetrical, imperfect competition structure. In Cournot competition, crude oil producers decide on the amount of output they will produce simultaneously and independently of each other, based on their anticipated levels of market influence and other producers' reactions. This makes it possible to account for the complex, at times sequential reality of the crude oil market. Modeled as an oligopoly of the individual member states, OPEC specifies production targets for its members strategically. Other market participants, which behave competitively, observe the OPEC targets and include them in their own production decisions. In OILMOD-E, this anticipatory process is implemented as (semi-)consistent conjectures, i.e. parameters that measure the market's anticipated reaction to the own output decision. They are selected on the basis of stylized facts, considerations of consistency, and calibration to past market results.

1 More information on the Energy, Transportation, Environment Department's energy market models can be found on the DIW website (available online).

2 Most recently, the OILMOD-E model was used to analyze the drop in prices in the global oil market between 2014 and 2016. See Dawud Ansari, "OPEC, Saudi Arabia, and the Shale Revolution."

mid-2016 (Figure 4). Made more attractive by rising efficiency in the shale oil sector, investment in new production capacity increased again after a phase of consolidation from the end of 2014 to the beginning of 2016.[12] At current prices, shale oil is firmly established in the market.

Therefore, beyond OPEC, the continuation and expansion of U.S. shale oil production represents a component of global oil supply that can react to price changes quickly. Shale oil production reduces the power that strategic producers such as OPEC have over the market.[13]

Growing political risk in the Middle East

For some years, political tension has been growing between Saudi Arabia and Iran, two of the most important members of OPEC. The two countries are competing for political influence in the Middle East, as expressed by opposing roles in a series of regional conflicts—currently in Yemen, Qatar, Lebanon, and Syria, for example. At the same time, the political reality within Saudi Arabia is being restructured.[14]

These circumstances did not prevent OPEC from enacting and implementing its latest curb on production. Yet heightened political tension does increase the risk of a partial disruption in OPEC production. This also probably contributed to the most current rise in the price of oil to more than 60 U.S. dollars per barrel.

Model-based simulation of supply-side shifts

At the German Institute for Economic Research (DIW Berlin), we conducted a model-based study of oil price reactions to possible shifts on the supply side of the oil market. The study used the OILMOD-E crude oil market model (Box 2) and a database that includes the fourth quarter of 2017. The assumption was that oil demand would continue to increase at its average rate between 2015 and 2017. The study examines the consequences of further efficiency growth in U.S. shale production as well as the price effects of OPEC production disruptions on the global crude oil price up to the first quarter of 2019. The following scenarios were analyzed:

- The **base scenario** assumes that the current expansion in production capacity will continue. It serves primarily as a means of calculating baseline values for the remaining scenarios.

12 See U.S. Energy Information Administration, "Drilling Productivity Report for Key Tight Oil and Shale Gas Regions," (2017) (available online).

13 Zaklan and Kemfert, "Rohölmarkt: US-amerikanisches Schieferöl."

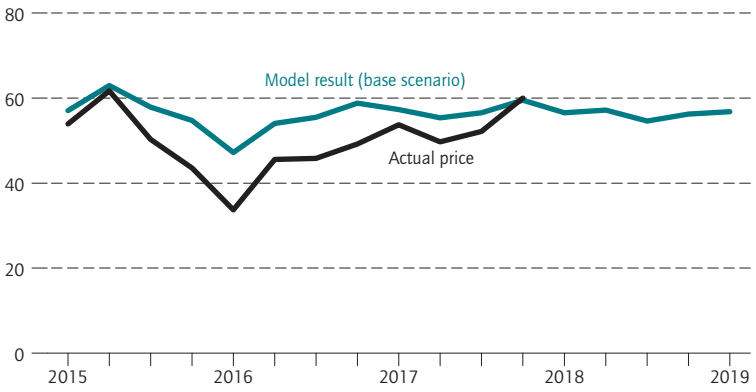
14 See David D. Kirkpatrick, "Saudi Crown Prince's Mass Purge Upends a Longstanding System," *New York Times*, November 5, 2017, (available online).

- The **U.S. shale oil expansion** scenario examines the influence of intensified shale oil production expansion in the U.S. due to reductions in production costs of up to 20 percent.[15] We assume that such reductions in production costs would go hand in hand with increases in output capacity of the same level (also up to 20 percent). Two cases are examined. The first case assumes that OPEC members would strategically react to the expansion in shale oil production by cutting their own output. The second case assumes that OPEC would not adjust its output to counteract the expansion in U.S. shale oil production. This would be similar to the situation between 2014 and 2016, when OPEC members could not agree to cut production despite a dramatic drop in the price of oil.

- The **OPEC supply disruption** scenario examines the outcome if individual OPEC members were no longer able to maintain production at previous levels as a consequence of a hypothetical conflict in the Middle East. The model presents this case as a decline in overall OPEC output capacity of up to 15 percent. As an example, this would amount approximately to Iraq's total oil output.

Figure 5

Actual and simulated crude oil prices
In U.S. dollars per barrel



Sources: U.S. Energy Administration; authors' own calculations with OILMOD-E.

The model has been calibrated to fit simulation results to the oil price in the 4th quarter of 2017.

Simulation results indicate stable market equilibrium

Initially, spot market prices for Brent crude were simulated as part of the base scenario for the period between the first quarter of 2015 and the first quarter of 2019 (Figure 5). Forecasted prices indicate only relatively minor fluctuations around the current level. A comparison of the model results with observed prices shows that the model is able to track the actual price trend quite accurately. However, results seem to underestimate the extent of price fluctuations. One reason for this is that the simulated prices only reflect the fundamental equilibrium of supply and demand, i.e. the market outcome based on regular supply behavior and a specific demand curve. The model does not take into account fluctuations in price that result from the expectation-driven behavior of market participants, such as speculation or panic buying. Yet, this type of behavior may lead to significant price volatility compared to the fundamental equilibrium modeled here.

Moderate price reduction due to ongoing U.S. shale oil expansion

The results of the scenario of U.S. shale oil expansion show that further increases in the efficiency of the shale oil sector would only have moderate price effects. In the case of a strategic adjustment in output by OPEC members, even if efficiency increased and capacity expanded in the U.S. by 20 percent, only a comparatively insignificant price effect would be discernible (Figure 6). This demonstrates that the current equilibrium is stable. If OPEC members did not agree to curb production, the price effects would be greater since OPEC could not compensate for the increase in U.S. production, and the supply of oil would increase overall.

While an expansion up to a level of around ten percent would have a significant effect on the market, further expansion would only lead to insignificant price effects as further shale oil expansion would shift the producers' position on the global output curve. However, even in the rather unlikely case of shale oil expansion by up to 20 percent, the simulated price remained above the 40-dollar level.

Moderate price increase due to OPEC supply disruption

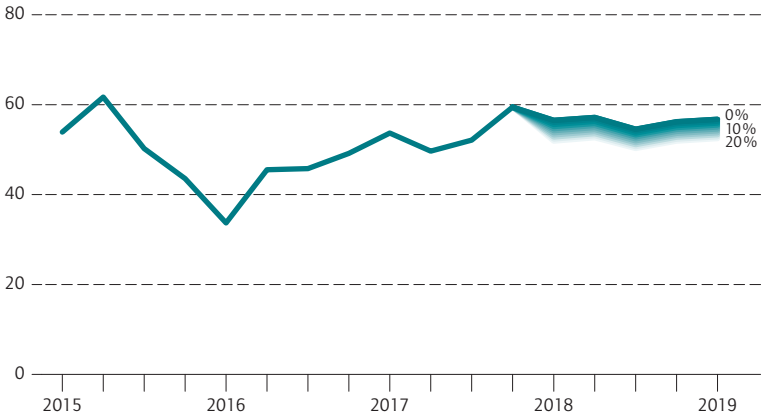
The price effect resulting from the OPEC supply disruption simulation is also comparatively moderate. Notably, the marginal price effect of supply disruptions below ten percent would still be low, since other market par-

15 All scenarios assume a change in the respective value for the total simulation period from the first quarter of 2018 until the first quarter of 2019.

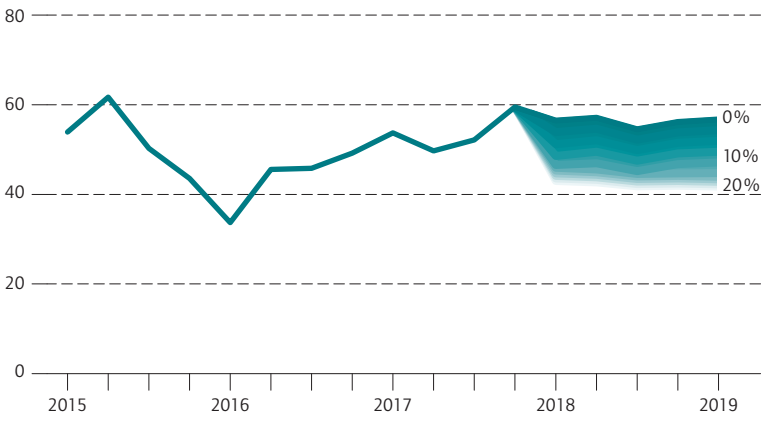
Figure 6

Oil price trajectory in the case of a U.S. shale oil expansion

With OPEC quantity adjustment, in U.S. dollars per barrel



Without OPEC quantity adjustment, in U.S. dollars per barrel



Note: Actual market prices are shown until 4th quarter 2017, followed by simulated prices starting from 1st quarter 2018. Percentage numbers show the degree of shale oil expansion. Ten percent, for instance, imply a ten percent decrease in shale oil extraction costs alongside a ten percent increase in U.S. capacity.

Sources: U.S. Energy Administration; authors' own calculations with OILMOD-E.

An expansion of the U.S. shale industry might only lead to moderate price reductions.

ticipants would be able to compensate for the decline in OPEC capacity (Figure 7). In the case of major disruptions in production, however, the price effect would intensify because the output potential of other producers is not sufficient to compensate for the missing production. Even in the case of a decline of 15 percent—the highest case that we assume—, simulated prices remain below 70 U.S. dollars. Production disruptions of this magnitude can be regarded as unlikely, even in the case of a limited military conflict in the Middle East. A decline of ten percent would approximately equal the total output capacity of Iran, while 15 percent is slightly above the current production of Iraq.

However, the simulated price trend does not take into consideration the possible behavioral effects of market participants, such as speculation or panic buying (see above). Such effects could significantly influence the spot price of crude oil, as was the case with the price increase at the beginning of November 2017 when political uncertainty in Saudi Arabia increased significantly.

Conclusion: moderate oil price to be expected in the short term

In comparison to the beginning of the decade, competition in the global crude oil market has intensified. The establishment of U.S. shale oil in the market has countered any OPEC bid to increase market power in the short term. The market for crude is in a new equilibrium, with prices significantly below levels at the beginning of the decade.

Fundamental data on both the supply and demand sides are fairly stable at the moment. Total, oil output is high although OPEC has largely implemented its agreement with other key oil exporting countries to curb output. Due to increased efficiency in the U.S. shale oil sector, fracking can at least partially offset the production limits of conventional extraction.

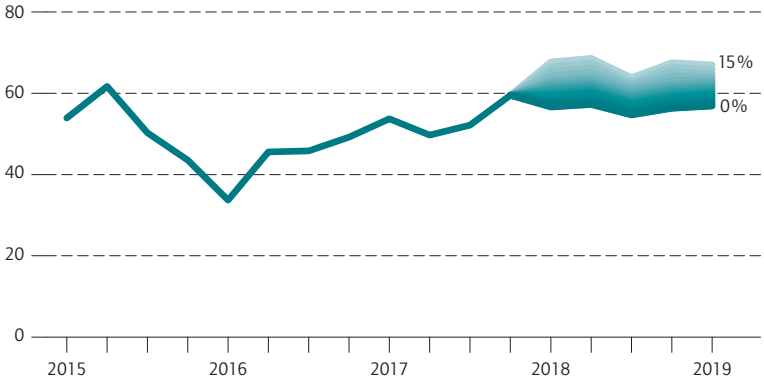
Model-based simulations show that the price effects of additional shale oil production heavily depend upon whether or not OPEC producers counter with strategic reductions in output. If OPEC cuts production accordingly, additional shale oil production would only lead to a slight drop in oil prices; while the decline in prices if OPEC production does not react would be more significant (although still moderate).

The current political tension in the Middle East increases the risk of a partial disruption of OPEC oil production. The relevant simulation shows that a moderate decline could be compensated for without dramatic price effects. Nevertheless, expectation-driven price effects are possible which cannot be captured by the model.

Based on the present study, we conclude that economic forecasters can assume a moderate oil price in the absence of any new, major shocks. However, from the perspective of climate policy, the anticipated trend in oil prices increases the need for action: At least in the short term, oil consumption is not expected to fall due to rising oil prices.

Figure 7

Oil price trajectory for an OPEC supply disruption
In U.S. dollars per barrel



Note: Actual market prices are shown until 4th quarter 2017, followed by simulated prices starting from 1st quarter 2018. Percentage numbers show the degree of the assumed supply disruption in OPEC countries.

Sources: U.S. Energy Administration; authors' own calculations with OILMOD-E.

Even for larger supply disruptions, price effects are still moderate.

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