Non-linearities in oil prices: which conditions matter?

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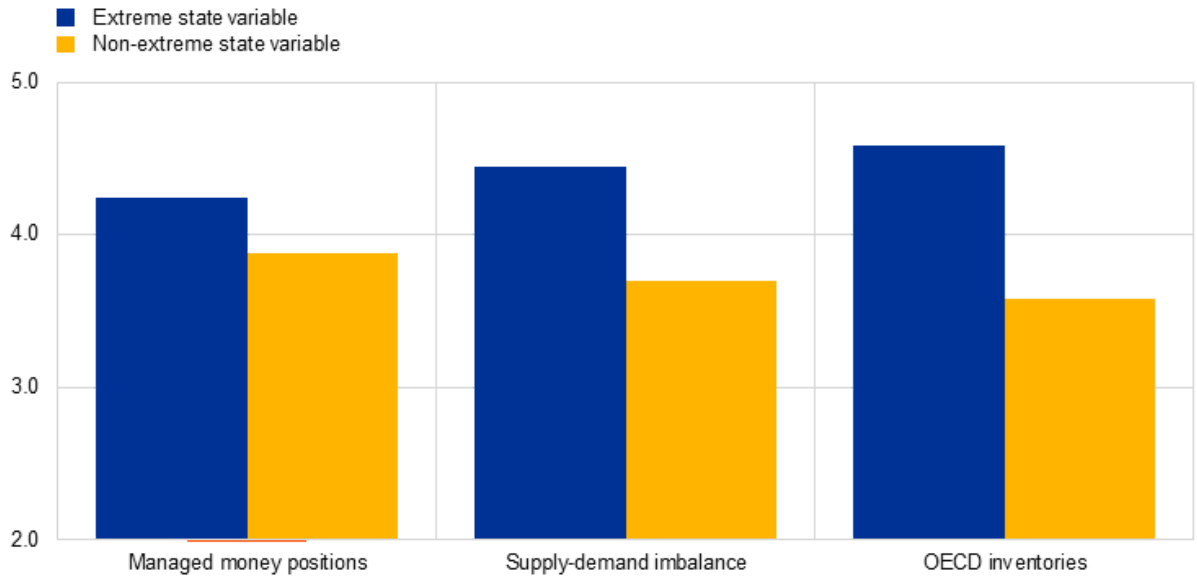
Different oil market states can significantly affect how oil prices respond to shocks. Over recent years oil prices have reacted strongly when key variables, referred to here as “state variables”, reach extreme levels. During the COVID-19 pandemic, for example, the collapse in oil prices linked to the Russia-Saudi Arabia price war was likely amplified by elevated inventories, which limited the capacity to absorb excess supply. A similar amplification mechanism was observed in October 2024, when Iran’s strike on Israel surprised the markets. Investment funds, which were short by historical standards, rapidly unwound positions, thus intensifying the price increase.[1] Oil price volatility appears to be higher when three state variables – managed money positions (derivative positions held by investment funds), supply-demand imbalances (the difference between global oil supply and demand) and OECD inventories – reach extreme levels (Chart 1).[2]

Chart A

Oil price volatility conditional on state variable levels

(standard deviation)



Sources: International Energy Agency (IEA), Bloomberg, Commodity Futures Trading Commission (CFTC) and ECB staff calculations.
Notes: “Standard deviation” refers to the average standard deviation of oil prices. Differences in the standard deviations between states are significant at the 10% level for each variable. “Extreme state” denotes periods in which a variable lies above the 75th percentile or below the 25th percentile of its recent historical distribution (i.e. the last 52 weeks).

Despite their relevance for investors and policymakers, the sources of these non-linearities have not yet been sufficiently analysed. Several studies have explored this issue, but they have generally analysed non-linearities in isolation, focusing on individual mechanisms and without interacting the state variable with the sign of the shock (see Chiţu et al., 2023, on speculative positioning and geopolitical risk; Van Robays, 2016, on macro uncertainty). In order to address this gap, we estimate non-linear local projections based on the three state variables outlined above and evaluate the reaction of prices to the oil supply shocks identified in Gazzani et al. (2024).[3] To this end, we first assess whether oil price responses intensify when these variables reach extreme levels. We then examine the responses conditional on both the state variable level and the direction of the shock.

For positions held by investment funds, pronounced non-linearities emerge when the sign of the shock aligns with the prior exposures of investors. For the first variable, investment fund positions, price reactions are indeed stronger when positions are unusually high or low (Chart B, panel a).[4] However, it is unclear whether this amplification occurs because investors are caught off guard or because the shocks confirm their prior expectations. When investment funds are already heavily long or short, price responses to price-decreasing or price-increasing shocks, respectively, are in fact muted (Chart B, panel b). This suggests that the sharp reaction in prices observed during the 2024 Iranian missile episode does not generalise across periods. By contrast, strong price responses occur when investors hold very long positions and a surge in oil prices occurs, or symmetrically, when they hold very short positions and oil prices start to decline (Chart B, panel c). This implies that the dominant mechanism is not the rapid unwinding of positions, but rather the amplification that occurs when positions and shocks are aligned, suggesting a self-reinforcing dynamic in the oil markets.

Chart B

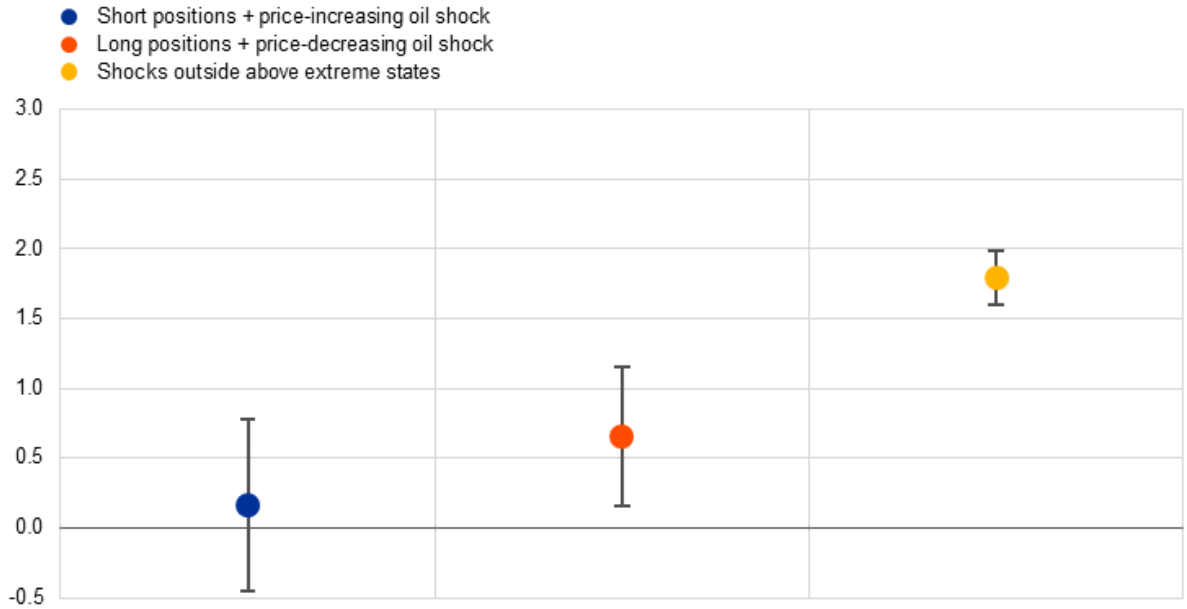
Oil price reaction to oil supply shocks conditional on investment fund positions and shock sign

a) Oil price reaction irrespective of shock sign

(percentages)

b) Oil price reaction when a shock increases (decreases) oil prices and positions are short (long)

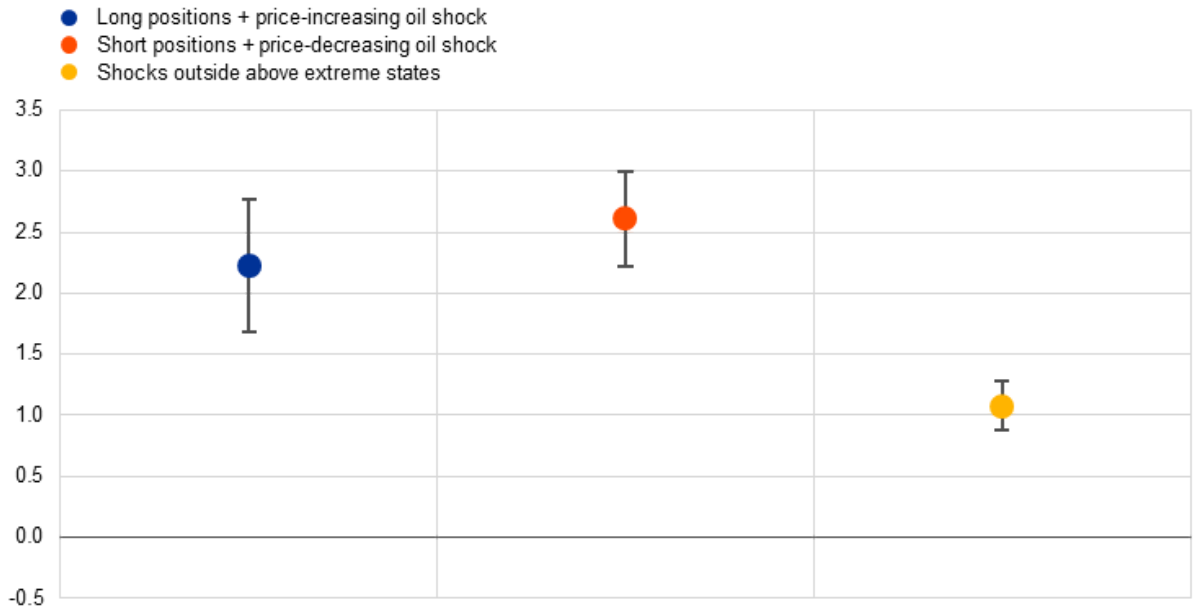
(percentages)



c) Oil price reaction when a shock increases (decreases) oil prices

and positions are long (short)

(percentages)



Sources: Bloomberg, CFTC and ECB staff calculations.
Notes: The chart shows the absolute oil price response to an oil supply shock (four weeks after the shock) based on non-linear local projections. In a linear framework, the same shock leads to a price increase of 1.5%. The extreme states in all three panels correspond to periods in which the state variable lies above the 75th percentile or below the 25th percentile of its recent historical distribution (last 52 weeks). The yellow dots denote oil price responses observed outside the extreme states shown in each panel. For example, in panel b), they capture price reactions when positions are at normal levels *or* when positions are extremely short (long) and the shock causes oil prices to fall (rise). The error bars indicate 68% confidence intervals.

Supply-demand imbalances and inventories show similar effects: when supply is abundant or inventories are high, markets react more strongly to oil price declines; when these indicators are low, they respond more strongly to oil price increases. At first glance, supply-demand imbalances and inventories appear to display different patterns, as disproportionate price responses at extreme levels, irrespective of the sign of the shock, emerge only for inventories (Charts C and D, panel a). However, once again, abstracting from the sign of the shock obscures the underlying transmission channels. Closer examination reveals a consistent mechanism across both variables. When there are abundant excess barrels – be this reflected in large supply surpluses or elevated inventories – markets tend to react strongly to oil price-decreasing shocks (i.e. positive oil supply shocks), as they further increase the surplus. Conversely, when supply is tight or inventories are low, markets react strongly to surges in oil prices (Charts C and D, panel b). The results are also intuitive under the third configuration: for instance, when a positive supply shock occurs in a period of high inventory levels, price responses are muted as excess barrels are expected to contain the upward pressure (Charts C and D, panel c).[5]

Chart C

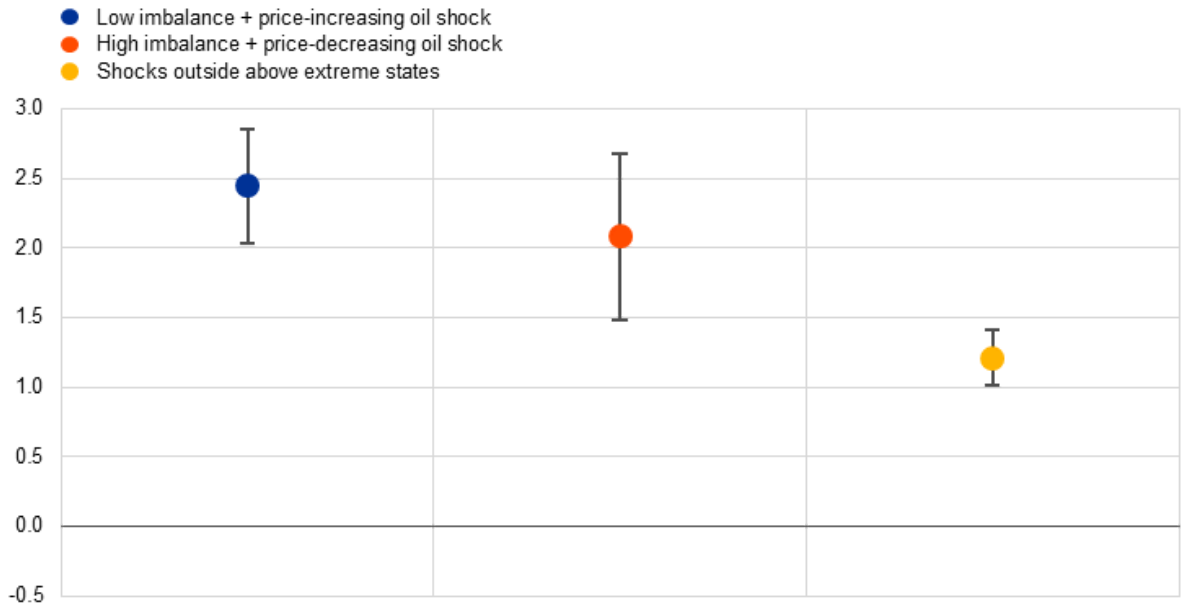
Oil price reaction to oil supply shock conditional on supply-demand imbalances and shock sign

a) Oil price reaction irrespective of shock sign

(percentages)

b) Oil price reaction when a shock increases (decreases) oil prices and oil supply is low (high)

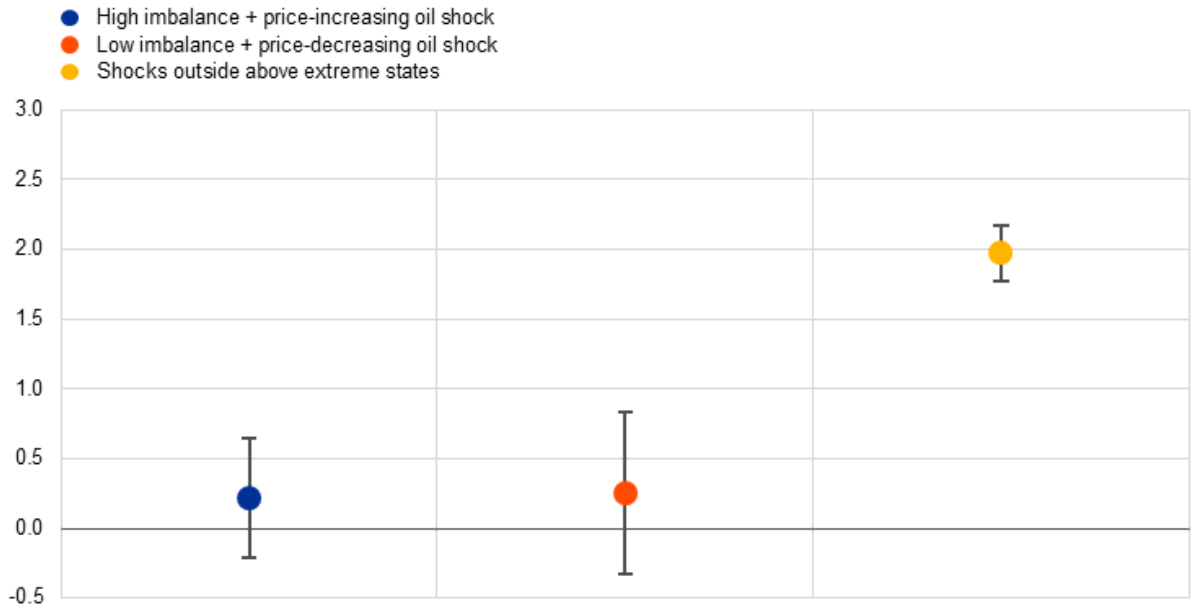
(percentages)



c) Oil price reaction when a shock increases (decreases) oil prices

and oil supply is high (low)

(percentages)



Sources: IEA and ECB staff calculations.
Notes: The chart shows the absolute oil price response to an oil supply shock (four weeks after the shock) based on non-linear local projections. In a linear framework, the same shock leads to a price increase of 1.5%. The extreme states in all three panels correspond to periods in which the state variable lies above the 75th percentile or below the 25th percentile of its recent historical distribution (last 52 weeks). The yellow dots denote oil price responses observed outside the extreme states shown in each panel. For example, in panel b), they capture price reactions when supply is at normal levels *or* when supply is extremely low (high) and the shock causes oil prices to fall (rise). The error bars indicate 68% confidence intervals.

Chart D

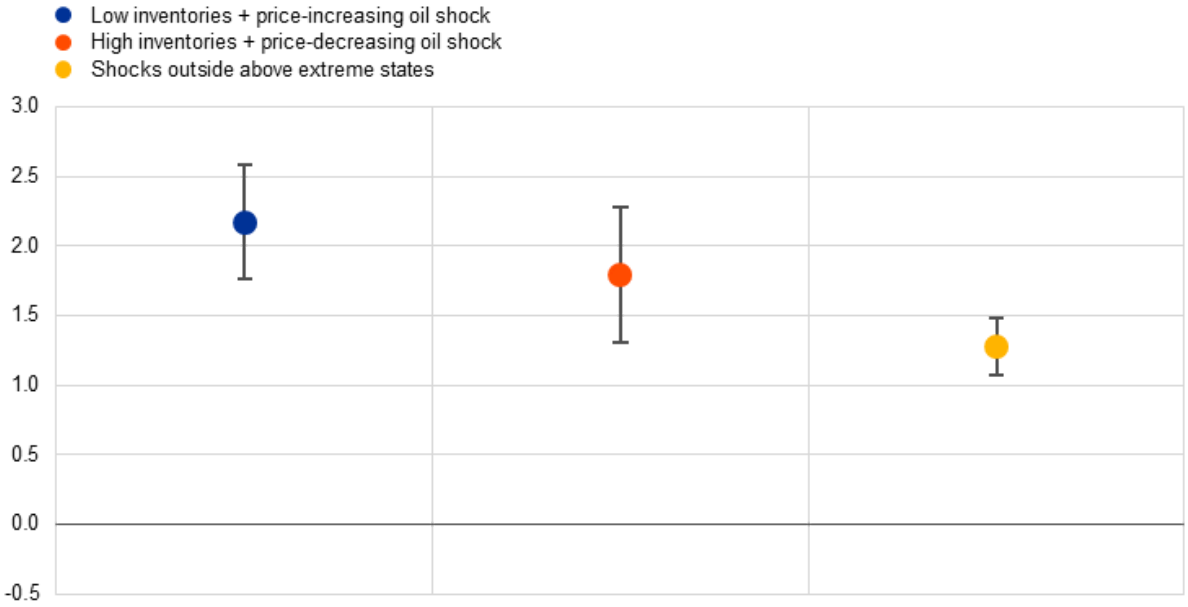
Oil price reaction to oil supply shocks conditional on inventories and shock sign

a) Oil price reaction irrespective of shock sign

(percentages)

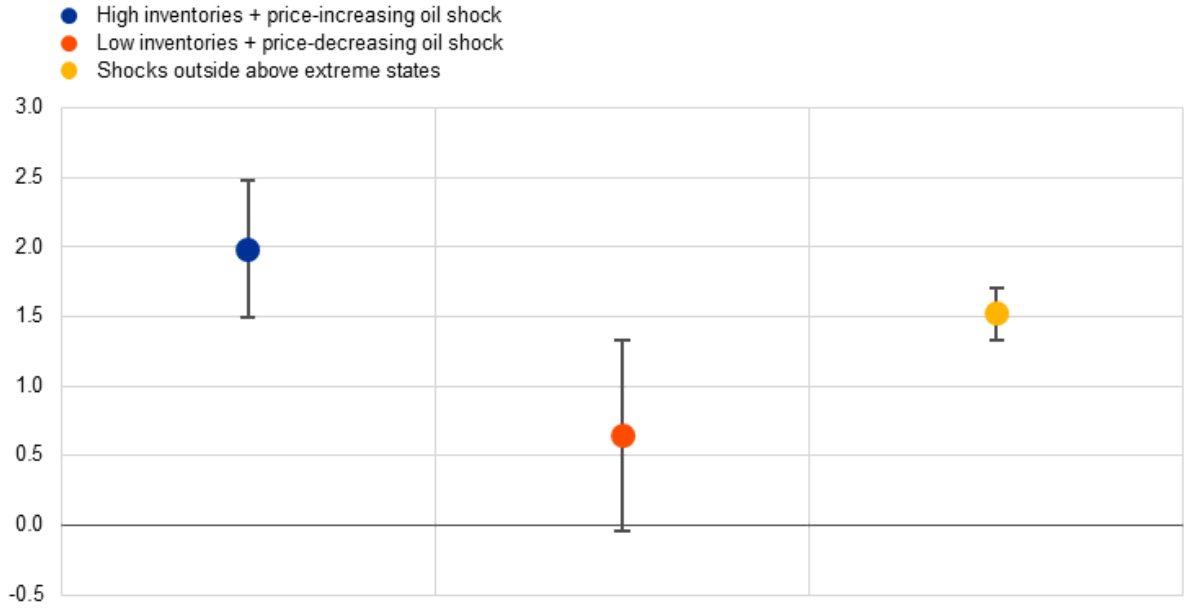
b) Oil price reaction when a shock increases (decreases) oil prices and inventories are low (high)

(percentages)



c) Oil price reaction when a shock increases (decreases) oil prices and inventories are high (low)

(percentages)



Sources: IEA, OECD and ECB staff calculations.
Notes: The chart shows the absolute oil price response to an oil supply shock (four weeks after the shock) based on non-linear local projections. In a linear framework, the same shock leads to a price increase of 1.5%. The extreme states in all three panels correspond to periods in which the state variable lies above the 75th percentile or below the 25th percentile of its recent historical distribution (last 52 weeks). The yellow dots denote oil price responses observed outside the extreme states shown in each panel. For example, in panel b), they capture price reactions when inventories are at normal levels *or* when inventories are extremely low (high) and the shock causes oil prices to fall (rise). The error bars indicate 68% confidence intervals.

Overall, non-linearities materially shape oil price dynamics, with the potential to nearly double price responses, implying significant consequences for policy assessments. On the whole, upside risks to oil prices are most critical when oil price surges occur at times of low supply-demand imbalances and very long speculative positions. Conversely, downside risks are most pronounced when oil prices fall in an environment of high supply-demand imbalances and short positions. These results underscore the importance of monitoring the different states of the oil market – particularly for forecasting purposes – as such assessments can help gauge the potential range of future price movements.

References

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1.

Short positions refer to bearish derivative exposures that profit from declines in the underlying asset price, whereas long positions profit from increases in that price.

2.

Managed money refers to investment funds that are generally viewed as the category in the CFTC classification which is most closely linked to perceived price dynamics in the commodity.

3.

We estimate local projections in which oil price returns are the dependent variable and oil supply shocks are the key regressors. These shocks are interacted with dummy variables capturing extreme states of the conditioning variables and, where relevant, the sign of the shock. All specifications are estimated separately for each state variable. The sample covers the period from June 2007 to August 2025.

4.

Although differences are not statistically significant.

5.

The only surprising result is the relatively normal price reaction when inventories are full and an oil price-increasing shock occurs. A possible explanation for this outcome is that OECD inventories do not fully reflect global storage conditions, so some regions may still be undersupplied, leaving oil prices sensitive to upward pressure.

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