Department of Economics and Finance

Functional Oil Price Expectations Shocks and Inflation

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March 2024

Abstract

This paper investigates the

1. Introduction

Few global variables have received as much attention in the literature as oil prices. In particular, the macroeconomic impact of oil price shocks is of key interest to both economists and policymakers. It is now well established that such shocks can be important determinants of inflation (Kilian, 2008c; Choi et al., 2018) and inflation expectations (Coibion and Gorodnichenko, 2015; Nasir et al., 2020a, 2020b; Kilian and Zhou, 2022a, 2022c). The recent literature has focused in particular on their possible second-round effects on inflation through the inflation expectations channel. Because of the existence of this propagation mechanism the management of inflation expectations in the presence of oil price shocks represents a key task for central banks. Existing studies provide limited empirical support for second expectations channel. Next, nonlinear functional local projections are used to investigate to what extent these effects vary with the degree of inflation expectations anchoring. This method also allows us to ascertain which term structure factor makes the strongest contribution to the response of economic aggregates to functional oil price expectations shocks. Finally, as an extension we consider different measures of inflation expectations as well as functional shocks

A separate, relatively small literature focuses on future oil price expectations, one possible measure of which is based on survey responses. For instance, Prat and Uctum (2011) use Consensus forecast survey data on WTI oil price expectations for the 3- and 12-months horizons and reject the hypothesis that they are rational, since they appear to be characterised by significant forecast errors. However, outside of professional forecasts, no data exist on household or firm expectations of future oil prices. An important source of information about the expectations of agents regarding future oil price developments are oil futures markets (Baumeister, 2023). Baumeister and Kilian (2016), for instance, compare different measures of oil price expectations, including those of economists, policymakers, consumers and financial market participants, and report that the most accurate one can obtained by using the method of Hamilton and Wu (2014). Baumeister (2023) tests the forecasting properties of oil futures prices and finds that they do not represent a rational expectation of the future spot price of oil, since the futures-spot price differential only accounts for a very small portion of subsequent oil price changes.

3. Empirical Framework

3.1 The oil futures term structure

International organisations such as the International Monetary Fund and central banks around the world often derive oil price expectations from oil futures prices. Since future contracts allow market participants to lock in today a price at which they can purchase crude oil at a fixed date in the future, the price of the futures contract with maturity h represents the h-period ahead market expectation of the price of crude oil. Despite its simplicity and popularity, this measure of oil price expectations can only be fully accurate if one takes into account the existence of a risk premium. For this purpose, we follow the approach of Hamilton and Wu (2014), who estimate the time-varying risk premium directly from current and past oil futures prices. Compared to other methods of calculating risk instance, in their full sample estimation Hamilton and Wu (2014) notice a change in the risk premium since the beginning of 2005 and thus split their sample accordingly. The sub-sample results for the risk premium differ substantially from the full sample ones. In our estimation, we allow for two breaks, one coinciding with the 2005 one identified by Hamilton and Wu (2014), and the other in June 2011, at the end of their sample. The model is estimated using weekly data and the estimates of the risk premium are subsequently averaged over the month to obtain the market expectations measure (Baumeister, 2023).

We follow the well-known Nelson-Siegel (1987) approach to estimate the term structure parameters from the standard and risk-adjusted oil futures term structures:

where is the oil futures price for a given time to maturity , , and are the level, slope and curvature factors, respectively, and is a factor which determines the contribution of and to the term structure curve relative to . The functional oil price shocks are then defined as shifts in the entire oil futures term structure, i.e. a simultaneous shift in

Table 1. Sign restrictions in the VARX

	Supply (cost-push)	Demand	Monetary policy	Expectations	Functional oil
				0	

the inflation target of 2%. Any periods during which inflation expectations are outside this range are defined instead as unanchored times. The dummy variable takes a value of 1 during anchored times and of 0 during unanchored times. The nonlinear functional local projections allow us to decompose the IRFs to ascertain which term structure factor makes the strongest contribution to the macroeconomic responses.

3. Data and Empirical Results

In Figure 1, Panel A displays the historic WTI crude oil price series, which fluctuates considerably over time. Oil price movements were often unexpected, and were subsequently functional oil price shock in Figure 4 indicates that oil futures prices increased across all maturities in August 1990, especially at the short end. By contrast, the risk-adjusted term structure shifted downwards more at the medium to long horizons. The shock in March 2003, which is related to the Iraq war, led to a small downward shift in the oil futures term structure at shorter maturities, but almost no movement at longer maturities. In the risk-adjusted case, instead, there was an upward shift across all maturities.

Figure 2. Functional shocks over time	
Panel A. Functional shocks	**Panel B. Level shock**

sharply at short maturities and increased at longer ones in the standard case, but decreased for all maturities in the risk-adjusted case. At the beginning of the Covid-19 pandemic in April 2020 there was a positive shift in both term structures at longer maturities, but a negative one at short maturities in the risk-adjusted case. After the Russian invasion of Ukraine, the oil futures term structures increased, with a noticeably smaller (larger) shift at short maturities in the standard (risk-adjusted) case.

Figure 3. Risk-adjusted functional shocks over time

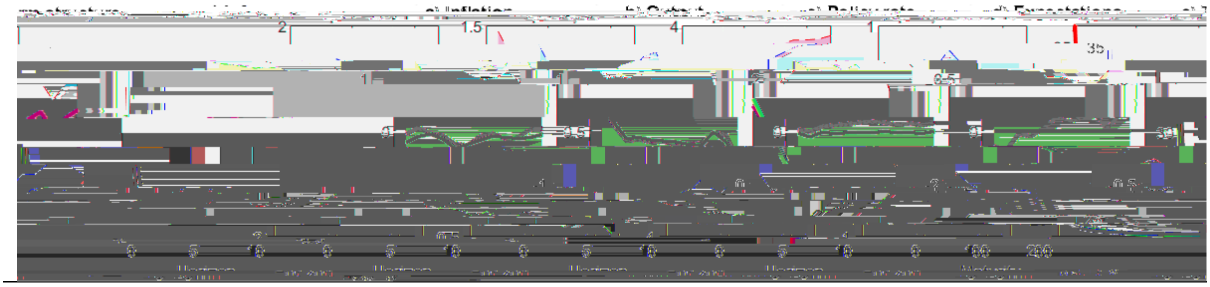
Panel A. Functional shocks	**Panel B. Level shock**
Panel C. Slope shock	

Figure 4. Shifts in the oil futures term structure during key historic events

Panel A. Standard term structure		Panel B. Risk-adjusted term structure	

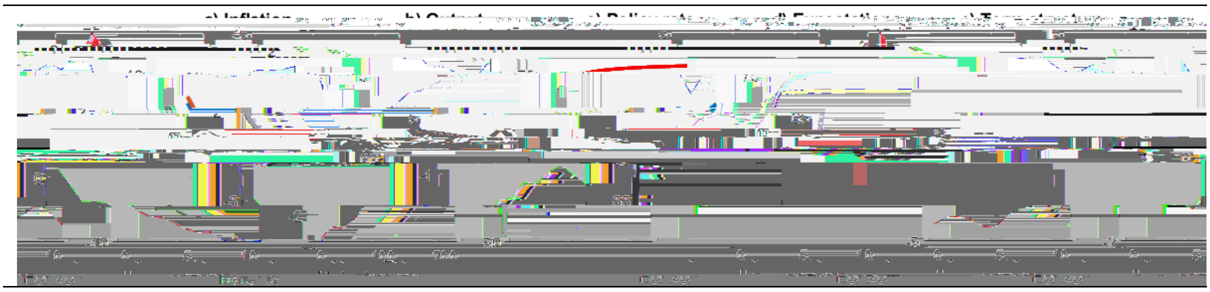
Figure 5. Responses to standard shocks in anchored times

Panel A. March 2003

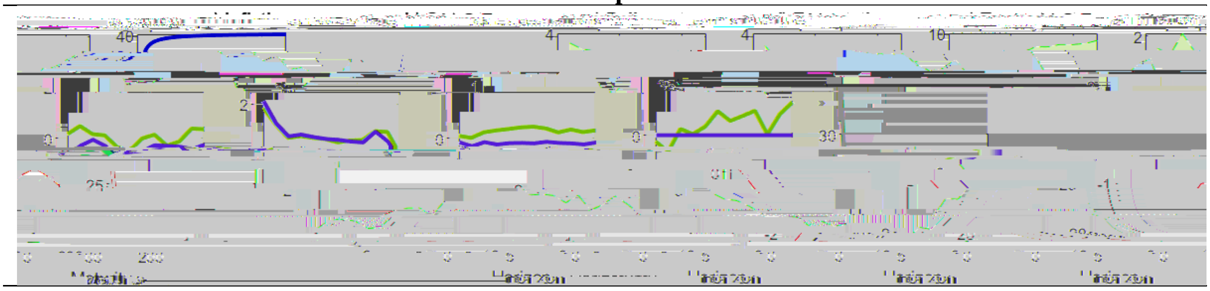


Panel B. December 2008

Panel C. December 2014



Panel D. April 2020



Notes: IRFs to functional oil price expectations shocks. The solid blue line in graphs (a) – (d) in all panels depicts the median response to a functional oil price expectations shock, while the light shaded blue shaded area shows the 68% confidence bands. The orange solid line denotes the counterfactual with the expectations channel shut off. Graph (e) in all panels depicts the size of the functional oil price expectations shock where the solid blue line depicts the oil futures term structure before the shock and the solid red line after the shock.

We are also interested in establishing whether the functional oil price shocks which capture the entire maturity structure of oil futures are more representative of demand or supply shocks. Kilian (2008c) notes that oil price increases tend to cause recessions, but equivalent oil price decreases do not lead to economic expansions. He also provides evidence for asymmetries in

2003 and January 2008. The inflation and output responses do not seem to follow a consistent pattern in response to functional shocks of similar size and sign. For instance, in December 2008 (December 2014) output responded negatively (positively) to a similar negative functional oil price expectations shock. The inflation expectations response to the risk-adjusted shocks reflects the sign of the shocks, namely negative (positive) functional oil price expectations shocks which are represented by a downward (upward) shift in the oil futures term structure have a negative (positive) effect on inflation expectations resulting in deflationary (inflationary) second-round effects on inflation. In general, inflation expectations seem to respond more strongly to term structure shifts at the short rather than the long end. Further, there is a larger difference between the standard and counterfactual monetary policy response our analysis of shocks during both anchored and unanchored times suggests that large second-round effects occur even when inflation expectations are anchored.

Figure 8. Responses to risk-adjusted shocks in unanchored times

Panel A. August 1990

Panel B. January 2008

Panel C. April 2011

Panel D. March 2022

Notes: IRFs to risk-

Figure 9 displays the IRFs obtained from nonlinear functional local projections for the two regimes of anchored and unanchored expectations. Inflation tends to respond negatively to risk-adjusted functional oil price expectations shocks in the anchored regime but positively in the unanchored one. The same holds for output and inflation expectations. While the response of the policy rate varies in the anchored regime, it is consistently positive in the unanchored regime. The size of the responses seems to reflect that of the shocks in all cases. Overall, these findings suggest that the extent to which inflation expectations are anchored matters greatly for the transmission of oil price expectations shocks. However, there are substantial differences in the contribution of the individual term structure factors as drivers of the responses.

Figure 10. Decomposition of IRFs to risk-adjusted shocks in the anchored regime

Panel A. Inflation	**Panel B. Output**
Panel C. Policy rate	**Panel D. Expectations**

regime; instead, in the unanchored one the level and slope factors are more relevant. The curvature factor indicates the speed at which expectations in the oil futures market change, while the level and slope factors indicate changes in oil futures prices overall and at the short end. Given our interpretation of the term structure factors, it appears that when inflation expectations are anchored, inflation and inflation expectations only respond to shifts in the speed suggests that the shape and shift of the entire risk-adjusted oil futures term structure matters for inflation, output, the policy rate and inflation expectations, which is an important feature that cannot be captured by scalar shocks.

5. Extensions

We extend the analysis in two ways. First, we consider different measures of inflation expectations, in particular long-term survey expectations as well as market expectations. One would expect that both are influenced by the oil futures term structure shifts, the former especially at long maturities, and the latter at all maturities. Second, we repeat the analysis using functional shocks based on Brent crude oil futures prices. In this case, we construct functional shocks from the risk-adjusted futures prices only.

5.1 Different measures of inflation expectations

Figures 12 and 13 display the direct and second-round effects of risk-adjusted functional oil

Figure 12. Results using long-term expectations in anchored times

Panel A. March 2003

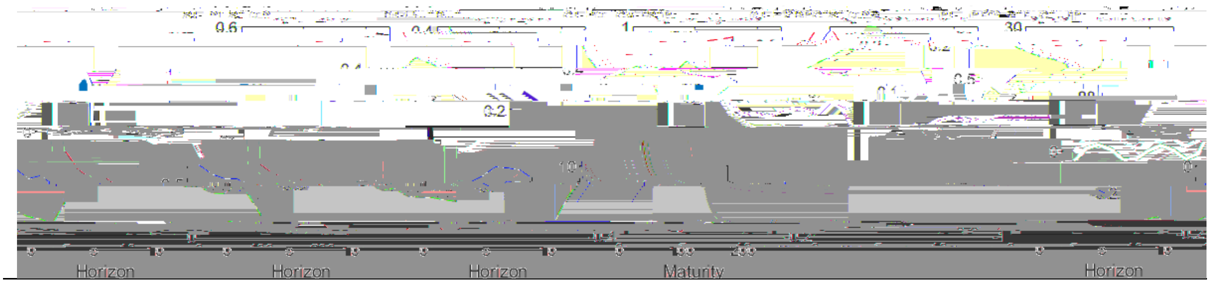
Panel B. December 2008

Panel C. December 2014

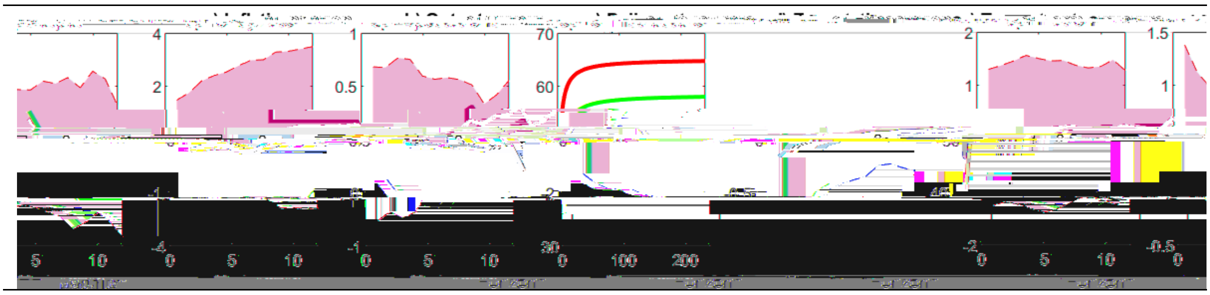
Figure

Figure 16. Results using risk-adjusted Brent futures in anchored times

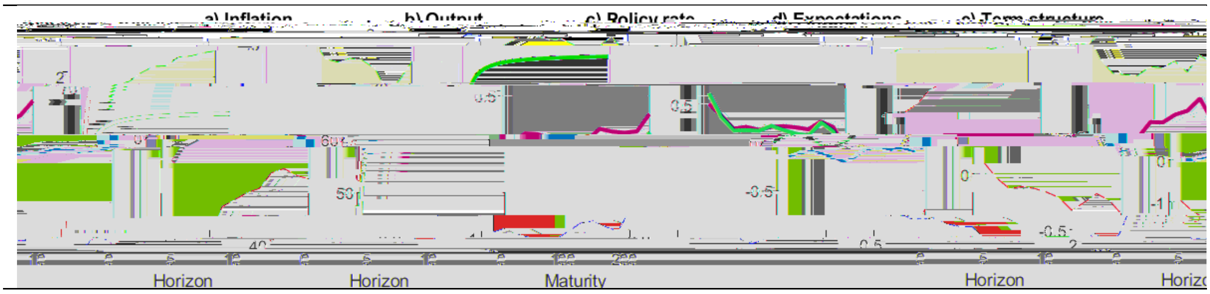
Panel A. March 2003



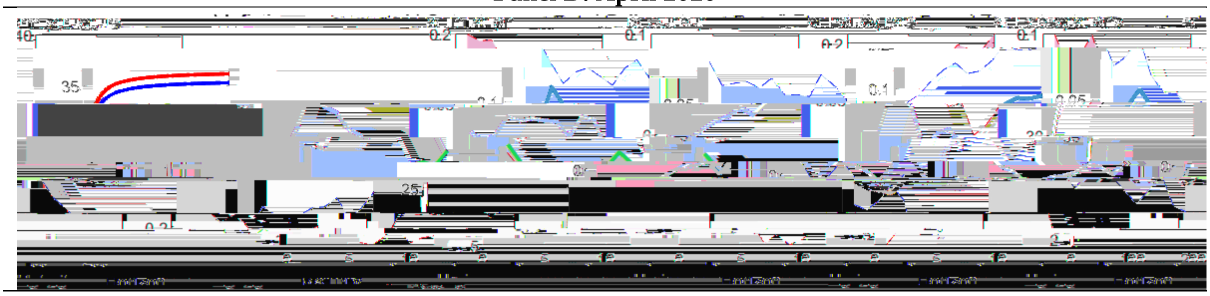
Panel B. December 2008



Panel C. December 2014



Panel D. April 2020



Notes: IRFs to risk-adjusted functional oil price expectations shocks derived from Brent futures. The solid blue line in graphs (a) – (d) in all panels depicts the median response to a functional oil price expectations shock, while the light shaded blue shaded area shows the 68% confidence bands. The orange solid line denotes the counterfactual with the expectations channel shut off. Graph (e) in all panels depicts the size of the functional oil price expectations shock where the solid blue line depicts the oil futures term structure before the shock and the solid red line after the shock.

Figure 17. Results using risk-adjusted Brent futures in unanchored times

Panel A. August 1990

Panel B. January 2008

Panel C. April 2011

Panel D. March 2022

Notes: IRFs to risk-adjusted functional oil price expectations shocks derived from Brent futures. The solid blue line in graphs (a) – (d) in all panels depicts the median response to a functional oil price expectations shock, while the light shaded blue shaded area shows the 68% confidence bands. The orange solid line denotes the interpreted as the oil price expectations of policymakers and the latter as those of financial

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Appendix A – Data appendix

Table A1. Detailed futures data sources and description

Variable	**Ticker**	**Source**
WTI Crude Oil Generic Future – 1 month expiry	CL1	Bloomberg
WTI Crude Oil Generic Future – 2 months expiry	CL2	Bloomberg
WTI Crude Oil Generic Future – 3 months expiry	CL3	Bloomberg
WTI Crude Oil Generic Future – 4 months expiry	CL4	Bloomberg

Appendix B – Additional baseline results using core inflation

Figure B1.

Figure B3. Responses to risk-adjusted shocks for key events in anchored times

Panel A. March 2003

Panel B. December 2008