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OIL PRICES AND INFLATION EXPECTATIONS

by Cristina Conflitti* and Riccardo Cristadoro*

Abstract

In line with other recent studies, we find that oil price changes have had a statistically significant impact on long-term inflation expectations in the euro area since the global financial crisis. However, over the same period, (i) oil prices have shifted together with economic indicators, such as stock prices, and (ii) the correlation between short- and long-term expectations has increased. Once these factors are taken into account, the effect of oil prices on long-term inflation expectations is no longer significant. This suggests that the link between oil prices and long-term inflation expectations is not direct, but rather the result of underlying factors: the prolonged feeble economic conditions and the possible de-anchoring of long-term inflation expectations from the objective of price stability.

JEL Classification: C20, E31, E59, Q41.
Keywords: inflation expectations, oil prices, inflation swaps, de-anchoring, monetary policy.

Contents

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1. Introduction[1]

Over the past few years, inflation has been persistently below central banks' targets in several advanced economies and, more worryingly, long-term inflation expectations have shown signs of de-anchoring. As low inflation expectations feed into the behaviour of economic agents, affecting wage settlements and firms' pricing decisions, they can prolong the persistence of disinflationary pressures. For this reason, inflation expectations are a key indicator of monetary policy credibility and effectiveness.

Cecchetti et al. (2016) and Natoli and Sigalotti (2016), using a set of measures of average and tail correlation obtained from inflation swaps and options, demonstrate that long-term inflation expectations in the euro area in 2015-16 have shown signs of de-anchoring, while this is not the case in the US and the UK.

The fall in current inflation and in short and long-term inflation expectations have occurred at the same time as the drop in commodity prices and, since 2014, in oil prices. Did the fall in oil prices actually contribute to the decline in inflation expectations and, if so, to what extent? Several authors have suggested that it did and that there might be a causal link between the two phenomena.

Elliott et al. (2015) used market-based measures of inflation expectations (derived from inflation swaps) to show that since the global financial crisis, expectations have been significantly affected by changes in oil prices, also at longer horizons. This happened in several economies, including the US and the euro area. Others have found similar evidence using different methods and frequencies (Badel and McGillicuddy, 2015; Darvas and Hüttl, 2016; Sussman and Zohar, 2015). This is surprising, since oil price shocks are usually thought of as one-off, and therefore should have only a short-lived effect on inflation if monetary policy credibility is able to contain second-round effects.

Market-based inflation expectations offer the valuable advantage of being available at a higher frequency (daily or even infra-daily) compared with other direct measures of expectations, such as those obtained through surveys. However they cannot be directly observed and must be derived from market contracts, hence resulting in noisy measures of actual agent expectations as they also reflect liquidity and risk premia (Gürkaynak et al, 2010).

Inflation expectations collected through surveys do not suffer from these shortcomings. Lyziak and Palovita (2016), using survey-based measures, find that long-term inflation forecasts in the euro area have become somewhat more sensitive to shorter-term forecasts and to actual HICP inflation in the post-crisis period. Similarly, Buono and Formai (2016) find evidence of de-anchoring in survey-based measures.

One can conclude that the literature provides evidence of a de-anchoring of inflation expectations at long-term horizons, in particular for the period 2014-2016 (Natoli and Sigalotti, 2017). The literature also suggests that the decline in oil prices has affected not only short-term but also long-term inflation expectations.

[1] We thank Stefano Siviero, Stefano Neri and Giuseppe Parigi for helpful comments. We also thank M. Cecioni for sharing with us data on monetary policy surprises, and M. Pericoli, M. Casiraghi and M. Miccoli, for providing data on inflation expectations and premia components in market-based measures of inflation. All remaining errors and imprecisions are our own.

In this paper we show that the case for a causal interpretation of the correlation between oil prices and long-term inflation expectations appears weakened by a more careful analysis that takes into account other factors that influence this relationship. In particular, oil prices moved in lockstep with other indicators – like stock prices – apparently reacting more to global demand conditions than to own supply dynamics.

The oil price decline of 2014-15 was significantly driven by the weaknesses of global demand (Baumeister and Kilian, 2016; Cristadoro et al., 2014). Furthermore, over the same time period, which saw a high correlation between oil prices and inflation expectations, there was a significant increase in the co-movements between oil and stock prices. This suggests that unobserved common factors, such as (expected) weaker future global demand, were moving both oil prices and inflation expectations, while monetary policy was unable to react with the usual weaponry, being constrained by the zero lower bound (Neri and Notarpietro, 2015).

The paper is organised as follows. In section 2 we describe the data used to measure inflation expectations. In section 3 we present data on inflation, inflation expectations and their correlation with oil prices. In section 4 we illustrate and discuss the results of our empirical analysis and perform some robustness checks. Section 5 concludes.

2. The data

Since inflation expectations cannot be observed directly, one has to rely on indirect measures derived from the financial markets or surveys. Survey data on inflation expectations have a long tradition (e.g. the US Survey of Professional Forecasters has been carried out since 1960, the Michigan survey since 1991, Consensus Economics since 1989, and the Blue Chip Survey since 1979). As to market measures, the recent rapid development of new financial instruments, such as inflation options and inflation-linked swaps or bonds, has paved the way for the calculation of inflation expectations embodied in asset prices.

Generally speaking, surveys offer four main advantages: (i) inflation forecasts are reported directly, avoiding the problem of extracting an "expectation signal" from financial assets that might be affected by time-varying liquidity and risk premia; (ii) additional information is typically included in the surveys that associates forecasts of inflation to those of other variables; (iii) in some cases, individual uncertainty around point estimates may be easily assessed; (iv) expectations are available for different types of agents (households, enterprises and professional experts).

As to the advantage of market-based indicators: (i) they are available at a higher frequency; (ii) they may be more accurate since financial market agents have "skin in the game", owing to the fact that they invest real money and hence have a strong incentive in collecting and analysing all available information.

To measure market inflation expectations, we use inflation-linked swap rates in the period January 2006 to May 2017. An inflation swap is a contract in which a fixed amount of money is exchanged at a given date together with a floating amount that depends on the actual inflation rate over a predetermined horizon. For the euro area, inflation swaps have been available since 2003 for horizons from 1 to 30 years ahead. We construct the 5-year inflation swap rates, 5 years forward (5y5y) to assess long-term expectations. The latter measure is particularly relevant since it has been mentioned in speeches by ECB and Fed policymakers as a sort of benchmark for medium-to-long-term expected inflation, and its behaviour is often taken as a gauge of monetary policy credibility.

As a benchmark in our descriptive analysis we also use the ECB Survey of Professional Forecasters (SPF), which has collected data on inflation, GDP growth and unemployment rates in the euro area on a quarterly basis[2] since 1999. The ECB SPF provides not only point forecasts but also information on forecast disagreement (the standard deviation of point forecasts) and forecast uncertainty.[3]

For market-based measures, the underlying reference for quoted swaps is the Harmonized Index of Consumer Prices (HICP) excluding Tobacco for the euro area, while the respondents to the ECB survey provide forecasts for the overall HICP index. Our sample includes data from 2006 to April 2017, while survey data ranges from the first quarter of 2000 to the first quarter of 2017.

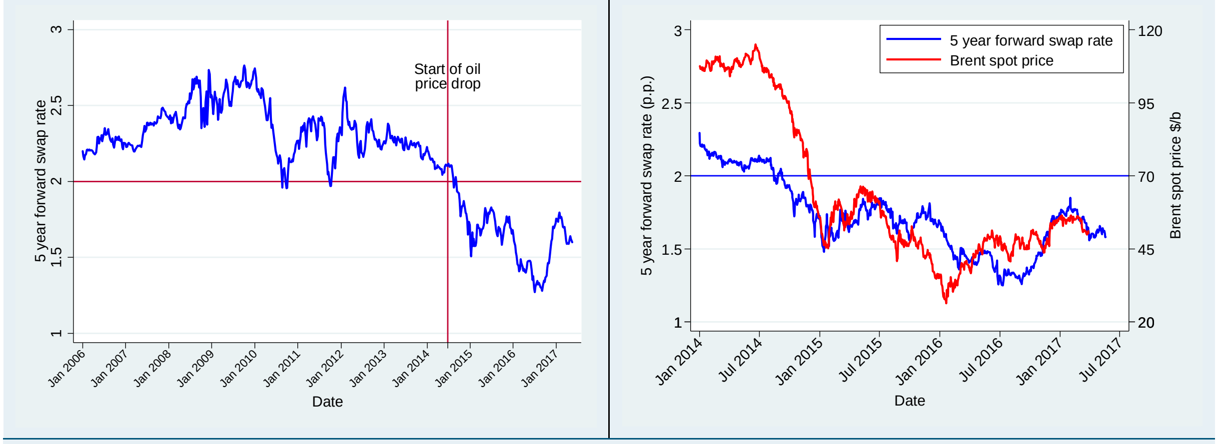
3. The price of oil and inflation expectations: evidence and existing literature

Figure 1 reveals two facts: first, inflation expectations in the euro area drifted away from the ECB target over the last few years, even at longer horizons; second, the correlation between long term market-based inflation expectations and crude oil prices appears to be very high over the same period (0.87 from January 2014 to April 2017).

Figure 1 – Market-based long-term inflation expectations and oil prices

a. Inflation swaps 5 year - 5 year forward (weekly data, 2006-17)

b. Euro area inflation expectations and oil prices (daily data, 2014-17)



Source: Based on Bloomberg data.

Concerning the first fact, a similar gradual disanchoring of inflation expectations from the ECB target is also visible in the SPF results, albeit to a lesser degree (Figure 2).

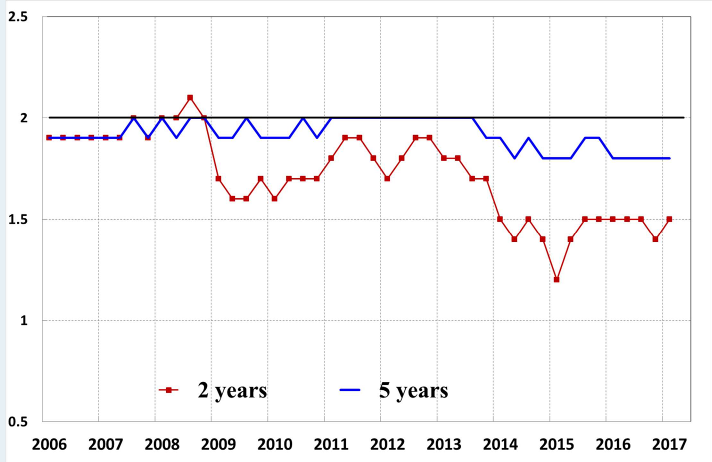
This can be due to the fact that only under the hypotheses of risk-neutral agents and constant liquidity conditions do market-based measures reflect genuine changes in agents' inflation expectations over the time of the contract. By contrast, changing liquidity conditions, uncertainty

[2] Data downloaded from: http://www.ecb.europa.eu/stats/prices/indic/forecast/html/index.en.html. A description of the ECB SPF is in Bowles et al. (2007).

[3] Survey respondents also report the probability they assign to the event that inflation will fall into pre-determined ranges around the central point forecast. See C. Conflitti (2012) for details concerning the construction of various measures of disagreement and uncertainty.

and risk aversion imply that inflation swap rates also include a risk and a liquidity premium. In fact, some authors have proposed exploiting the difference between inflation expectations derived from inflation-linked swaps and survey-based inflation expectations to obtain an estimate of the "true" inflation expectations contained in inflation derivatives.[4]

Figure 2 – Survey-based inflation expectations (2006Q1 – 2017Q1)
(quarterly data)



Source: Based on data from the ECB SPF.

Concerning the second fact, it would be premature to draw general conclusions from the behaviour observed over a short time span. A closer look at the correlation between changes in oil prices and in inflation expectations over a longer time span (starting in January 2006) reveals two features: (*i*) the correlation is lower for longer-term expectations and lowest for the 5y5y; (*ii*) the correlation increases significantly for all horizons after June 2014, when oil prices started declining (see Table 1).

Table 1 - Correlation of inflation swaps with oil price changes in the euro area
(daily data)

Inflation swaps	*all_sample*	Jan06-Jun08	Jul08-May09	Jun09-Jun14	Jul14 - Jan16	>=21jun16
1 year	*0.14*	0.04	0.11	0.18	0.36	0.25
5 years	*0.16*	0.11	0.03	0.19	0.32	0.36
10 years	*0.16*	0.11	0.06	0.19	0.26	0.31
5y5y	*0.10*	0.05	0.08	0.11	0.14	0.17

Source: Based on Bloomberg data.

Recently, using this evidence as their starting point, several researchers have investigated whether and to what extent oil prices affect inflation expectations. Considering a variety of

[4] See Ciccarelli and Osbat (2017) and the box "*Inflation risk premia in market-based measures of inflation expectations*" in the ECB Monthly Bulletin, July 2014.

expectation measures, these studies generally find that, since the global financial crisis, the relationship between oil prices and inflation expectations has changed in the main advanced economies (US, UK and euro area).

Elliott et al. (2015) regress daily changes in 3-year spot and 5y5y inflation swap rates on contemporaneous and lagged daily percentage changes in oil prices on a sample period spanning from January 2009 to July 2015. They find a significant impact of oil prices on 3-year inflation swaps for all countries considered in their analysis (UK, US, and euro area), and a smaller but still significant effect on the 5y5y only for the US and the euro area (respectively 4 bps and 2bps for a 10% change in oil prices). Darvas and Huttl (2016) confirm these results using the same approach on weekly data.

Sussman and Zohar (2015), using monthly data, regress 5-year breakeven inflation rates (BEIR)[5] on annual changes in oil prices; they distinguish between pre- and post-crisis periods and confirm the increase in size and significance of the impact of changes in oil prices. To identify the demand and supply components, they regress oil price changes on a common factor extracted from other commodity prices and establish that both supply and demand shocks affected the 5-year breakeven inflation rates after the global crisis, with the demand component accounting for a larger share of the impact. Similarly Badel and McGillicuddy (2015), following Kilian (2010), split oil price shocks into three components: a supply, a global demand and an oil-specific demand shock. They find that 5-year BEIR are highly and positively correlated in the 2008-15 period with oil price changes, while the relationship is significantly weaker in 2003-07, although the signs of the correlations are unstable over the sample period.[6]

Results suggesting that the correlation between oil and market measures of inflation expectations has increased are thus common to a number of studies.

Another stream of literature has tried to isolate the "pure" inflation expectation component in inflation swap rates from the variations due to changes in liquidity conditions and risk premia. The inflation swap rate traded at time t with maturity h, $r_t^{(h)}$, can be decomposed into the expected inflation rate over the maturity of the contract $\pi_{t,h}^e$ and an inflation risk and liquidity premium $rp_t^{(h)}$:

$$r_t^{(h)} = \pi_{t,h}^e + rp_t^{(h)}$$

However, the two terms on the right-hand side cannot be individually observed.

Under rational expectations, according to the law of iterated expectations, the expected difference between long-term inflation expectations today and tomorrow should be a martingale difference sequence. Gürkaynak et al. (2010), exploiting the TIPS yield curve, reject this hypothesis and conclude that "inflation compensation is too volatile at high frequency to represent inflation expectations alone".[7] They then proceed to estimate separately a liquidity premium and an inflation risk premium, the latter through a state-space model in which market expectations are treated as noisy measures of inflation expectations.

[5] A measure of inflation expectations computed as the difference between nominal government debt yield and inflation-indexed debt yield with the same time to maturity.

[6] In 2014-15 the correlation is strong and positive with all three components, while in the pre-crisis period the supply shock is negatively correlated with the 5-year BEIR. Considering the entire post-crisis period, the global demand shock is negatively correlated with the 5-year BEIR.

[7] Gürkaynak et al (2010), p. 85.

Campbell et al. (2017) fit a four-factor model to the nominal term structure of US interest rates and show that the risk premia must have turned negative in the last decade.

Pericoli (2017), using end-of-month euro break-even inflation rates, fits a three-latent-factor model to nominal yields and explains part of the reduction in yield differentials over longer horizons by the decline in risk premia. According to his estimates, the inflation risk premium was close to nil until 2011 and have decreased since then. Thus the fall in breakeven inflation rates is in part explained by the drop in its premium component. In particular, negative inflation risk premia over long horizons partly explain the extremely low level of breakeven inflation rates since the middle of 2014.

Casiraghi and Miccoli (2016) use monthly data[8] and assume that the ex-post "excess return" – i.e. the difference between the inflation swap rate and the realized inflation rate,- is a measure of the inflation premium plus a forecast error. The latter – under the hypothesis of rational expectations (REH) – is uncorrelated with the available information. Hence, by regressing ex-post "excess return" on relevant economic variables available at time *t*, they derive an estimate of the inflation risk premium. Their main conclusion is that over the last few years the dynamics of inflation swap rates have indeed been affected by swings in the inflation premium, but have nonetheless been dominated by changes in inflation expectations. However, the focus of their analysis is on short- to medium-term expectations only because data at longer horizons is lacking and because of the relative unreliability of the assumption that the forecast error is uncorrelated with the available information as the horizon widens and learning processes become more relevant.

Estimates of the relative importance of the risk premia in market-based inflation expectations vary with the sample and the identification procedure adopted. However, the available literature suggests that a sizable share of the recent fall in these measures reflects a genuine decline in inflation expectations.

Therefore, the correlation between inflation expectations and oil price variations at longer horizons remains a puzzle. At short horizons, this correlation is not surprising. At longer ones, instead, it is, since monetary policy is expected to react and bring inflation back on target. Some authors ascribed the effect of oil prices on long-term inflation to the fact that the policy interest rate has reached a (zero) lower bound. For example, as shown in Neri and Notarpietro (2015), under normal conditions an oil drop could be seen as a shock that moves inflation and output in opposite directions; a central bank can normally offset this shock by adjusting the policy rate but when the ZLB is reached the central bank cannot increase the real rate.

In what follows we will first revisit the analyses, documenting the rising correlation between oil prices and long-term inflation expectations showing that different conclusions can be drawn from the data once due account is taken of the co-movements among oil prices and other macroeconomic and financial variables. Then we will show that the high correlation between short- and long-term inflation expectations that arose over the same period suggests a different interpretation of the role of oil shocks: while they had a direct impact on short term expectations, the effect on longer term ones is likely the result of the constraint given by ZLB to monetary policy

[8] Inflation swaps and other daily variables are averaged to match their frequency with that of available economic indicators, such as PMI or unemployment.

credibility. A partial corroboration of this argument comes from the mitigating effects on the latter correlation by positive monetary policy surprises (both conventional and unconventional).[9]

4. An empirical analysis of the effect of oil prices on inflation expectations in the euro area

We follow two approaches in order to assess whether oil prices influenced inflation expectations over the last few years to a greater extent than in the past. First – using daily observations – we run regressions on a rolling window, over the years 2006-2017. Second, we split the overall sample into several sub-periods, capturing phases of rising, stable or falling oil prices. [10]

4.1 - Rolling and fixed subsample baseline regressions

We borrow the baseline specification from Elliott et al. (2015) and Sussman and Zohar (2015), fitting the following model to daily data on a window spanning roughly one and a half years:

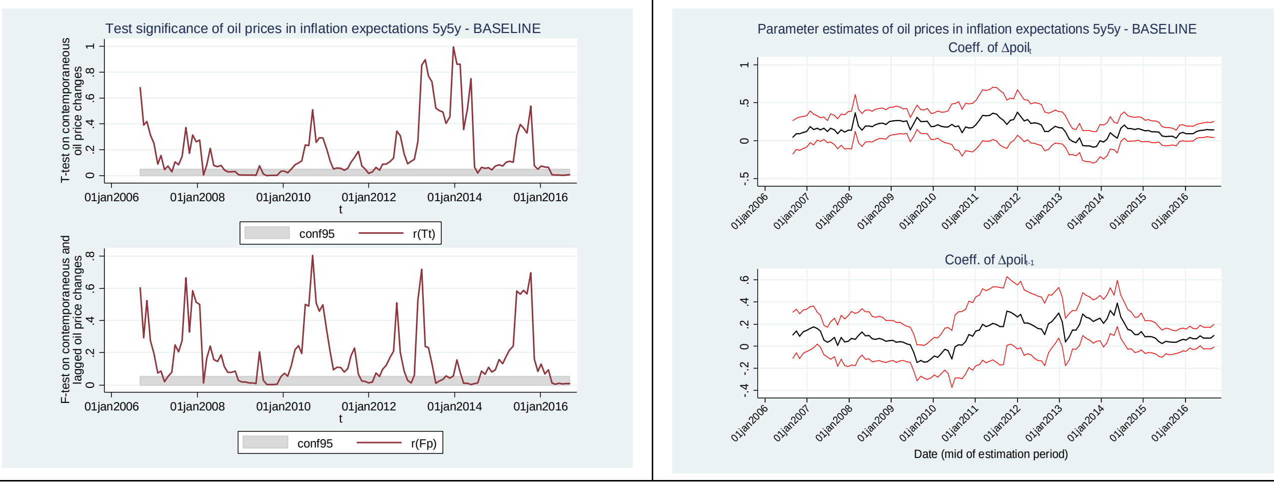
$$\Delta\pi^{e}_{t,h} = c + \beta_1 \Delta\log(poil_t) + \beta_2 \Delta\log(poil_{t-1}) + \gamma\pi^{e}_{t-1,h} + e_t \qquad (1)$$

where $\pi^{e}_{t,h}$ is a market-based measure of inflation expectations computed at time *t* for the horizon *h* (annualised rate in percent), and $\Delta\log(poil_t)$ is the daily percent change in the price of oil measured in USD.[11]

Figure 3 – Significance of the response of market-based inflation expectations to oil price changes (2006–17) (1)

(daily data)

a. Parameter significance (t and F tests) | ***b. Parameter rolling estimates***



(1) Results from regression $\Delta\pi^{e}_{t,h} = c + \beta_1\Delta\log(poil_t) + \beta_2\Delta\log(poil_{t-1}) + \gamma\pi^{e}_{t-1,h} + e_t$ where $\pi^{e}_{t,h}$ is the 5 year 5 years forward swap rate. Regression is estimated on a rolling window of 480 observations with step = 30 (at each iteration roughly one month was skipped). Dates on the graph refer to the central period in the interval. The shaded area is the 5% rejection zone for the null hypothesis.

[9] The "credibility effect" might have been amplified by the slack present in most economies during the period; the decline in actual and expected inflation provoked by lower oil prices "raises the real rate of interest, compressing demand and very possibly stifling any increase in output and employment" (Obstfeld et al., 2016).

[10] Figure A2 in the Appendix illustrates the graphical inspection that lead to the sample splits.

[11] Here the inflation swap rate is implicitly assumed as an unbiased measure of the effective change in inflation expectations ($\Delta\pi^{e}_{t,h}$). As a robustness check, using monthly data, we separated the unobserved components in the swap rate, as discussed later in this section.

Figure 3 shows, for 5y5y inflation, the results of the t-test on β_1 and the *F-test* on the joint hypothesis that both current and lagged oil prices are not significant ($\beta_1 = \beta_2 = 0$), together with rolling point estimates of the two parameters with 95% confidence bands.

Panel (a) reports the tail probability of the *t-test*. It shows that inflation swap rates were significantly and persistently affected by oil price changes over two periods (with a few additional, but short-lived, episodes): in the aftermath of the financial crisis and since the second half of 2014, with an interruption between mid-2015 and end-2015.[12] A broadly similar picture emerges for the *F-test* on the joint significance for the contemporaneous and lagged term of oil price changes.

Panel (b) reports rolling parameter estimates with theoretical confidence bands, suggesting that the correlation between oil prices and inflation expectations has increased in correspondence with the two episodes of sharp changes in oil prices.

Formally testing for a break at an unknown date in the relationship between inflation expectations and oil price changes by means of the *Quandt likelihood ratio* (QLR) statistic (Quandt, 1960) reveals that in the case of long-term expectations, the hypothesis of constant parameters is rejected with a maximum (sup-Wald) reached at the beginning of 2009.

This evidence suggests that the relationship between inflation expectations and oil prices may have changed precisely at the time when oil prices started falling. It may therefore be worthwhile splitting the sample according to different phases in the evolution of oil prices.

Equation (1) is estimated using daily data grouped into several subsamples. The period from January 2006 to March 2017 is split into 5 intervals spanning, respectively: *(i)* the period of relative oil price stability prior to the financial crisis (from January 2006 to June 2008); *(ii)* the sharp fall at the peak of the crisis (July 2008 – May 2009); *(iii)* the after-crisis rebound, with prices hovering at more than \$100 per barrel (June 2009 up to June 2014); *(iv)* the sharp drop following the surge in shale oil production (June 2014 to January 2016); and *(v)* the most recent period of slow and uncertain recovery in oil prices (from January 2016 up to March 2017).

Oil price changes are found to affect inflation expectations at both short and long horizons, confirming the results obtained by Elliott *et al.* (2015), in almost all the sub-periods (see Table 2). These findings are roughly in line with those obtained through the rolling regressions. In particular, they show that a clear change took place after the global financial crisis: from 2009 onwards, oil price changes affect inflation expectations even at long horizons. They also demonstrate that the contemporaneous effect, measured by the oil price coefficient β_1, gets smaller as the expectation horizon increases and remains statistically significant for all horizons after the financial crisis. Finally, the findings illustrate that the impact of current changes in oil prices on inflation expectations at horizons between 1 and 5 years peaks from June 2014 to the beginning of 2016, during the long phase of plunging oil prices.

[12] We stress that the 2009-11 period is different from the period from 2014 onwards: in the first period, the policy rate was around 1% and monetary policy reacted to the increase in oil prices by raising the policy rates while in the second period, the zero lower bound constrained policy action as prices were falling.

Table 2 – Eq.1: Coefficients β_1 and β_2, *t-test* on β_1 and *F-test* on β_1 and β_2 (1)

a. β_1 estimates and *t-test* p-values

	Inflation expectation horizon			
	1 year	*5 years*	*10 years*	*5y5y forward*
SUB-PERIOD:				
(i) pre-crisis "stability"	0.18	0.12	0.09	0.06
p-value	*0.37*	*0.01*	*0.02*	*0.32*
(ii) sharp fall at peak of crisis	0.11	0.08	0.10	0.12
p-value	*0.71*	*0.45*	*0.20*	*0.15*
(iii) after crisis rebound	0.65	0.29	0.25	0.21
p-value	*0.00*	*0.00*	*0.00*	*0.00*
(iv) oil plunge (shale surge)	0.73	0.37	0.25	0.13
p-value	*0.00*	*0.00*	*0.00*	*0.01*
(v) Slow recent recovery	0.44	0.30	0.21	0.13
p-value	*0.00*	*0.00*	*0.00*	*0.00*

b. Joint significance (*F tests*) of β_1 and β_2

	Inflation expectation horizon			
	1 year	*5 years*	*10 years*	*5y5y forward*
SUB-PERIOD:				
(i) pre-crisis "stability"	0.46	13.39	11.30	2.13
p-value	*0.63*	*0.00*	*0.00*	*0.12*
(ii) sharp fall at peak of crisis	0.61	1.21	1.10	1.03
p-value	*0.54*	*0.30*	*0.34*	*0.36*
(iii) after crisis rebound	32.40	37.29	29.89	8.18
p-value	*0.00*	*0.00*	*0.00*	*0.00*
(iv) oil plunge (shale surge)	46.25	41.33	26.24	7.61
p-value	*0.00*	*0.00*	*0.00*	*0.00*
(v) Slow recent recovery	11.95	27.27	20.06	6.74
p-value	*0.00*	*0.00*	*0.00*	*0.00*

(1) Results from equation 1: $\boldsymbol{\Delta\pi^e_{t,h} = c + \beta_1 \Delta\log(poil_t) + \beta_2 \Delta\log(poil_{t-1}) + \gamma\pi^e_{t-1,h} + e_t}$ estimated on daily data. Subsamples are as follows: (i) pre-crisis stability (June 2006-June 2008), (ii) sharp fall at peak of crisis (July 2008-May 2009), (iii) after crisis rebound (June 2009 -June 2014), (iv) oil plunge (June 2014-January 2016) and (v) slow recent recovery (January 2016-March 2017).

4.2 - Augmented regressions and regressions on separate components of inflation swaps

Given the evidence above, it could be tempting to conclude that changes in oil prices have been affecting longer-term inflation expectations in the euro area, thus contributing to the de-anchoring of inflation expectations.

Table 3 – Correlation between oil and stock prices and across short- and medium-to-long term inflation expectations
(daily data)

A. Brent in US$

Dates	Dow Jones	FT500	Stoxx50
Jan05-Jun08	-0.05	-0.005	0.103
Jul08-May09	0.442	0.458	0.365
Jun09-Jun14	0.490	0.511	0.401
Jul14-0Jan16	0.327	0.341	0.137
>=21Jan16	0.381	0.393	0.318

B. Correlation of 1 year ahead inflation swap rates with longer term rates (first differences)

Inflation swaps	All sample	Jan06-Jun08	Jul08-May09	Jun09-Jun14	Jul14-Jan16	>=21jan16
5 years	0.33	0.15	0.26	0.32	0.74	0.68
10 years	0.30	0.17	0.25	0.27	0.64	0.54
5y5y	0.16	0.10	0.14	0.13	0.40	0.25

Source: Bloomberg and Datastream data.

However, it is worth noting that the relationships between oil prices and real and financial indicators also changed, turning positive and significant. Since 2008, stock markets and oil prices have been moving in lockstep, even though a negative correlation would in principle seem more plausible, as rising oil prices are a cost and hence a drag on growth for companies of oil-importing economies. Indeed, historically the correlation has been on average either negative or basically nil. Its recent tendency to turn positive may be explained, as Bernanke (2016) suggested, by the fact that both oil and stocks are reacting to a softening of global aggregate demand amid rising fears of a weaker global recovery (see Table 3, panel A).

Moreover, the relationship between short- and long-term market-based inflation expectations has changed: their correlation, as noted by a number of authors (Natoli and Sigalotti, 2016; Łyziak and Paloviita, 2016), has increased over the last decade. In particular the correlation between 1 year ahead inflation swap rates and 5y5y forward rates rose from basically zero prior to the financial crisis to 0.4 in the period from June 2014 to January 2016, as oil prices fell from $110 per barrel to less than $30 (see Table 3, panel B).

These facts point to a potentially more complex relationship between oil prices, short-term and long-term inflation expectations: oil prices could simply proxy the impact on inflation expectations of other variables that are omitted from the specification of the benchmark model. Ideally, one would like to experiment with a wide set of "control" variables that capture global economic and monetary conditions, however the analysis is conducted on daily data and hence the choice of indicators is constrained to financial data and a few other variables that are available at a daily frequency and can be thought of as proxies for the economic and monetary outlook.

To explore the possible implications of the increased correlation between oil prices and macroeconomic indicators, we also include in the regression the daily percentage changes of the stock market index ($\Delta pstock_t$)[13] and an indicator of economic surprises ($cesi_t$).[14]

$$\Delta\pi^{e}_{t,h} = c + \beta_1 \Delta poil_t + \beta_2 \Delta poil_{t-1} + \beta_3 \Delta pstock_t + \beta_4 cesi_t + \gamma \pi^{e}_{t-1,h} + e_t \qquad (2)$$

Table 4 – Eq.2: Coefficients β1 and β2, *t-test* on β1 and *F-test* on β1 and β2 (1)

a. β_1 estimates and *t-test* p-values

	Inflation expectation horizon			
	1 year	*5 years*	*10 years*	*5y5y forward*
SUB-PERIOD:				
(i) pre-crisis "stability"	0.36	0.11	0.08	0.06
p-value	*0.11*	*0.05*	*0.07*	*0.33*
(ii) sharp fall at peak of crisis	0.23	0.06	0.06	0.08
p-value	*0.59*	*0.66*	*0.54*	*0.50*
(iii) after crisis rebound	0.43	0.10	0.09	0.08
p-value	*0.00*	*0.06*	*0.05*	*0.21*
(iv) oil plunge (shale surge)	0.71	0.30	0.18	0.06
p-value	*0.00*	*0.00*	*0.00*	*0.25*
(v) Slow recent recovery	0.33	0.18	0.12	0.06
p-value	*0.01*	*0.00*	*0.00*	*0.21*

b. Joint significance (*F tests*) of β_1 and β_2

	Inflation expectation horizon			
	1 year	*5 years*	*10 years*	*5y5y forward*
SUB-PERIOD:				
(i) pre-crisis "stability"	1.53	11.75	9.17	2.01
p-value	*0.22*	*0.00*	*0.00*	*0.14*
(ii) sharp fall at peak of crisis	0.26	0.15	0.21	0.41
p-value	*0.77*	*0.86*	*0.81*	*0.67*
(iii) after crisis rebound	12.01	10.49	4.60	0.82
p-value	*0.00*	*0.00*	*0.01*	*0.44*
(iv) oil plunge (shale surge)	38.22	25.10	16.98	7.00
p-value	*0.00*	*0.00*	*0.00*	*0.00*
(v) Slow recent recovery	5.35	9.54	7.33	2.86
p-value	*0.01*	*0.00*	*0.00*	*0.06*

(1) Results from eq. 2: $\boldsymbol{\Delta\pi^{e}_{t,h} = c + \beta_1 \Delta\log(poil_t) + \beta_2 \Delta\log(poil_{t-1}) + \beta_3 \Delta pstock_t + \beta_4 cesi_t + \gamma\pi^{e}_{t-1,h} + e_t}$ estimated on daily data. Subsamples are as follows: (i) pre-crisis stability (June 2006-June 2008), (ii) sharp fall at peak of crisis (July 2008-May 2009), (iii) after crisis rebound (June 2009 -June 2014), (iv) oil plunge (June 2014-January 2016) and (v) slow recent recovery (January 2016-March 2017).

As shown in Table 4, once we control for developments in the real economy, contemporaneous oil price changes no longer have a significant impact on inflation expectations 5y5y, while the lagged term is significant only during the "oil plunge period". The joint test of significance of the contemporaneous and the lagged term of oil prices confirms that the overall

[13] We experimented with different stock market indexes. Results are reported for the Dow Jones Industrial Average.

[14] We considered a variety of daily indicators of economic surprises – both from Bloomberg and from Citi – and transformations (lags, moving averages) without obtaining significant differences across specifications in terms of goodness of fit: overall their influence on expectations is not always significant across samples and time horizons.

effect was nil until July 2014, became significant afterwards, up to January 2016, and then remained only weakly significant in the following months ("slow recent recovery").

As to the rising correlation between short- and long-term expectations, we take it into account by estimating the following equation:

$$\Delta\pi^{e}_{t,5y5y} = c + \beta_1 \Delta p^{oil}_{t} + \beta_2 \Delta p^{oil}_{t-1} + \beta_3 \Delta pstock_t + \beta_4 cesi_t + \gamma_1 \pi^{e}_{t-1,5y5y} + \gamma_2 \pi^{e}_{t,1} + \gamma_3 \pi^{e}_{t-1,1} + u_t \quad (3)$$

for the July 2014 – January 2016 period, when the oil effect on 5y5y rates remains significant even controlling for developments in the real economy.[15]

The significance of β_1 and β_2 is strongly rejected, and the F-test for the joint hypothesis $\beta_1 = \beta_2 = 0$ has a p-value of 0.18. Furthermore, the effect of stock market prices remains significant and positive, while that of market surprises – although statistically significant – is quantitatively negligible (see Table 5).[16]

Table 5 – Eq. 3: Regression results and *F-test* on coefficients β_1 and β_2 (1)

Coefficients	Estimate	Std. Err.	t-test	p-value
c	0.073	0.03	2.90	0.00
β_1	-0.069	0.05	-1.32	0.19
β_2	0.055	0.05	1.04	0.30
β_3	0.311	0.09	3.53	0.00
β_4	0.000	0.00	-2.36	0.02
γ_1	-0.043	0.01	-2.96	0.00
γ_2	0.183	0.02	7.51	0.00
γ_3	-0.175	0.02	-7.10	0.00
F-test on β_1 *and* β_2	**1.73**			**0.18**

(1) Results from eq. 3: $\Delta\pi^{e}_{t,5y5y} = c + \beta_1 \Delta poil_t + \beta_2 \Delta poil_{t-1} + \beta_3 \Delta pstock_t + \beta_4 cesi_t + \gamma_1 \pi^{e}_{t-1,5y5y} + \gamma_2 \pi^{e}_{t,1} + \gamma_3 \pi^{e}_{t-1,1} + e_t$ estimated on daily data on the "oil plunge" sample (June 2014-January 2016). The number of observations is 314; the R-squared is 0.25.

One interpretation of these results is that the oil price effect on long-term inflation expectations is due solely to the rising correlation between short-term and long-term expectations. This rising correlation is related to monetary policy credibility. A partial corroboration of this argument comes from the fact that monetary policy surprises have a positive impact on long-term

[15] An interesting question is whether oil prices had a similar effect on the pure inflation and the risk premia components of market-based expectations. Unfortunately, estimates of these components (see Pericoli, 2017, Casiraghi and Miccoli 2015) are available only at monthly frequency and the correlations we are analyzing at that frequency lose significance.

[16] To disentangle the "pure" oil effect on long-term inflation from the indirect one, which depends on the transmission from short- to long-term expectations, and hence on factors related to monetary policy space and credibility, we take a two-step approach. First, we regress changes in oil prices on those in one-year ahead inflation swaps and store the residuals, i.e. that part of the movements in oil prices that is not captured by contemporaneous changes in short-run inflation expectations. Next, we estimate the following regression: $\Delta\pi^{e}_{t,h} = c + \beta_1 e^{oil}_{t} + \beta_2 e^{oil}_{t-1} + \beta_3 \Delta pstock_t + \beta_4 cesi_t + \gamma_1 \pi^{e}_{t-1,h} + \gamma_2 \pi^{e}_{t,1} + \gamma_3 \pi^{e}_{t-1,1} + u_t$. Results so obtained are reported in Table A1 and confirm those from regression (3).

inflation expectations in the 2014-16 period, partly offsetting the oil price effect.[17] These results are in line with the finding that the pass-through coefficient of short to long-term inflation expectations decreased during periods of ECB balance sheet expansion while they increased during contractions (over the sample 2009-2016).[18]

4.3 – A summary and a proposed interpretation of the results

To sum up the results of the empirical analysis:

(1) pairwise correlations and simple regressions over the 2006-17 period show a significant influence of oil prices changes on market-based measures of inflation expectations, even at longer horizons, i.e. those at which inflation expectations should be relatively insensitive to short-run developments, instead being normally associated with monetary policy credibility;

(2) when controls for macroeconomic developments (stock prices and economic surprises) are included in the regressions, the relationship between oil prices and expectations weakens and remains significant only in the period 2014-16, when oil prices suffered a marked decline;

(3) the contemporaneous surge in the correlation between short-term and long-term expectations suggests that the effect of oil prices on long-term inflation expectations may be a by-product of the progressive de-anchoring of the latter as high highlighted in the literature Once short-term inflation expectations are included in the regression, oil prices become insignificant.

A possible rationalization of these results is as follows.

In recent years, inflation has been very low in advanced economies by historical standards. The persistence of low inflation raised fears that the global economy (at least in the advanced world) was on the brink of a "secular stagnation" (Summers, 2014; Obstfeld et al. 2016)[19] and that monetary policy was unwilling, or unable, because of the ZLB, to restore price stability. These facts may have contributed to a de-anchoring of inflation expectations (Neri and Notarpietro, 2015). In this situation, negative shocks to demand and prices are likely to affect expectations beyond the short term. Indeed, as pointed out by the literature, short- and long-term inflation expectations have become more synchronous, and this has induced a (spurious) rise in the correlation between long-term inflation expectations and oil price changes.

5. Conclusion

Oil prices and market-based measures of inflation expectations – even at longer horizons – have fallen in tandem over the last few years. This correlation, albeit being confirmed by many empirical analyses, is puzzling from a theoretical point of view.

We find that simple regressions of market-based measures of inflation expectations on oil price changes at a daily frequency do indeed support previous findings as they show that the correlation increased at the time of the financial crisis and then again after 2014 during the strong

[17] Monetary policy surprises in the euro area expressed as basis points deviation in interest rates from pre-announcement levels (distinguishing between "conventional" and "unconventional" monetary policy surprises) details on the construction of data on monetary policy surprises are in M. Cecioni, (2017).
[18] See Ciccarelli and Osbat (2017) p. 49-50 and the literature cited therein.
[19] In fact, peaks in Internet searches for the term "deflation" coincide with periods of higher correlation between oil prices and inflation expectations and between short- and long-term expectations (see Figure A3).

and prolonged fall in oil prices. However, we observe that in those periods both the correlation between oil and stock market prices and that between short- and long-term inflation expectations also arose. This suggests that different explanations may be behind that correlation.

Changes in oil prices no longer correlate with long-term inflation expectations once movements in stock prices and economic surprises are taken into account, with the exception of the 2014-16 period. The effect of oil price changes on long-term inflation expectations vanishes completely when short-term inflation expectations are included, revealing that it is only through their effect on long-term expectations that oil prices appear to have influenced the latter. Hence, the claim that oil prices directly affect price expectations at horizons relevant for monetary policy credibility is much weakened by these results.

A possible interpretation of these findings is that the link between oil prices and long-term inflation expectations is not a direct one, but stems from the prolonged weakness of the euro area and global economy, the subdued inflation dynamics and a gradual de-anchoring of inflation expectations. The observed, unusual correlation patterns among short-term and long-term expectations as well as between oil prices, inflation expectations and stock prices could be rooted in the growing concerns over the ability of monetary policy to effectively control inflation, as policy rates were hovering close to the ZLB.

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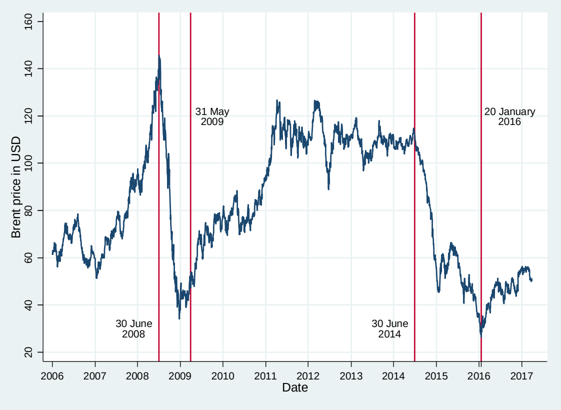
Appendix: tables and figures

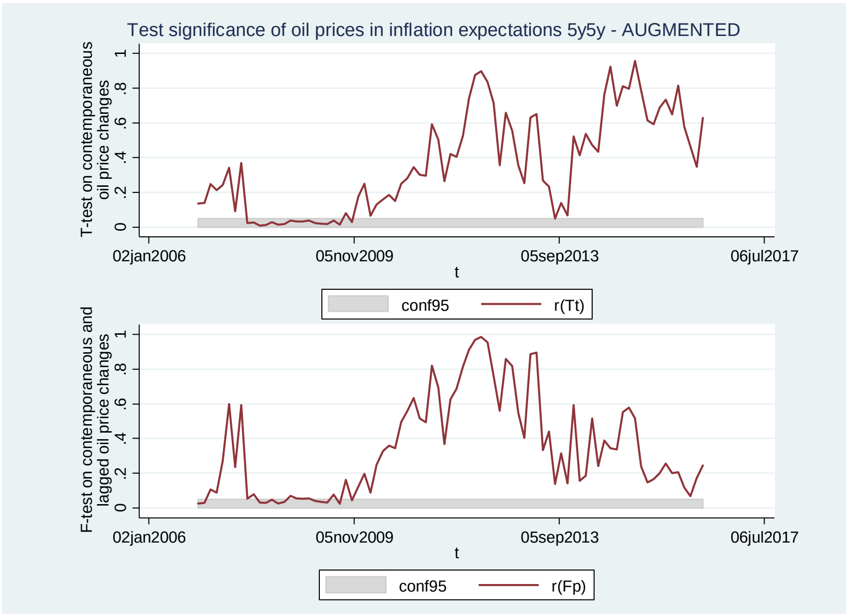
Figure A1 – Oil price phases & correlation of inflation expectations with oil price changes in the eurozone
(daily data)



Inflation swaps	all_sample	Jan06-Jun08	Jul08-May09	Jun09-Jun14	Jul14-20Jan16	>=21Jan16
1 year	0.14	0.04	0.11	0.18	0.36	0.25
2 years	0.17	0.05	0.12	0.19	0.33	0.34
3 years	0.15	0.1	0.1	0.13	0.26	0.36
4 years	0.16	0.1	0.08	0.18	0.28	0.4
5 years	0.16	0.11	0.03	0.19	0.32	0.36
6 years	0.13	0.07	0.03	0.19	0.23	0.34
7 years	0.19	0.15	0.1	0.23	0.28	0.34
8 years	0.16	0.08	0.09	0.21	0.22	0.31
9 years	0.14	0.1	0.03	0.22	0.19	0.29
10 years	0.16	0.11	0.06	0.19	0.26	0.31
5-years forward	0.10	0.05	0.08	0.11	0.14	0.17

Source: Based on Bloomberg data.

Figure A2 – Significance of the response of market-based inflation expectation to oil price changes in the euro area (2006 – 17) (1)
*(*daily data*)*



(1) Results from regression $\boldsymbol{\Delta\pi^{e}_{t,h} = c + \beta_1 \Delta\log(poil_t) + \beta_2 \Delta\log(poil_{t-1}) + \beta_3 \Delta\log(stock_t) + \beta_4 cesi_t + \gamma\pi^{e}_{t-1,h} + e_t}$ obtained with a rolling window of 480 observations with step = 30 (at each iteration roughly one month was skipped). Dates on the graph refer to the end period in the estimation interval. The shaded area is the 5% rejection zone for the null hypothesis.

Table A1 – Regression on oil price changes *cleaned* from their effect of short-term inflation expectations

(daily data – July 2014-January 2016)

a. OLS standard errors

Variables	Coef.	Std. Err.	t	p-value
constant	0.072	0.03	2.86	0.00
e_oil	-0.074	0.05	-1.42	0.16
lagged e_oil	0.030	0.06	0.53	0.60
dlstox	0.313	0.09	3.55	0.00
cesieur	0.000	0.00	-2.31	0.02
L1.ea5y5yf	-0.043	0.01	-2.92	0.00
euswi1	0.177	0.02	7.71	0.00
L1.euswi1	-0.169	0.02	-7.26	0.00

b. Bootstrapped standard errors

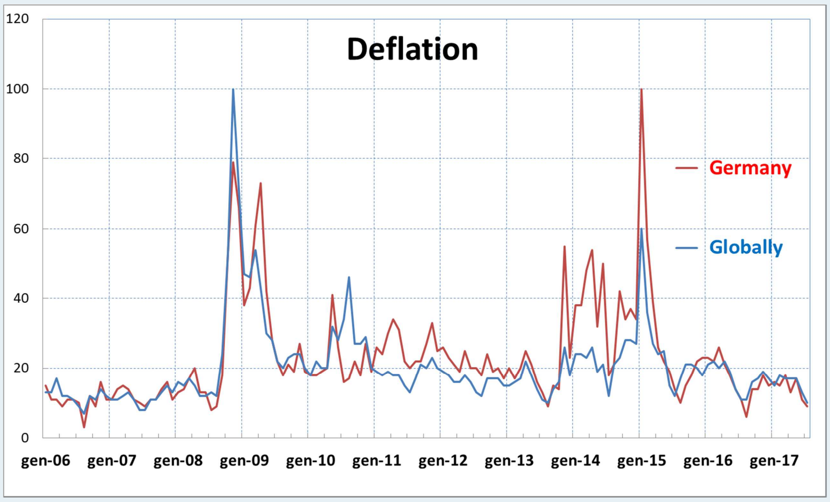
Variables	Coef.	Std. Err. (Bootstrap)	z	P>|z|
constant	0.072	0.03	2.83	0.01
e_oil	-0.074	0.06	-1.3	0.19
lagged e_oil	0.030	0.07	0.42	0.67
dlstox	0.313	0.10	3.03	0.00
cesieur	0.000	0.00	-2.17	0.03
L1.ea5y5yf	-0.043	0.01	-2.98	0.00
euswi1	0.177	0.06	3.03	0.00
L1.euswi1	-0.169	0.06	-2.84	0.00

Results from regression $\boldsymbol{\Delta\pi^e_{t,5y5y} = c + \beta_1 e^{oil}_t + \beta_2 e^{oil}_{t-1} + \beta_3 \Delta pstock_t + \beta_4 cesi_t + \gamma_1 \pi^e_{t-1,5y5y} + \gamma_2 \pi^e_{t,1} + \gamma_3 \pi^e_{t-1,1} + e_t}$ where e^{oil}_t is estimated from $\boldsymbol{\Delta poil_t = c + \beta_1 \Delta\pi^e_{t,1} + e^{oil}_{t,1}}$. Number of observations is 314; the R-squared is 0.25.

Figure A3 – Gauging the diffusion of deflation fears

(monthly data)

Internet searches for the term "deflation"



Source: Googletrends.