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# Revisiting the oil price and expected inflation in the U.S. - a wavelet approach

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## Abstract

The paper revisits the 'oil price - expected inflation' nexus in the U.S. by using as a novelty the wavelet. The study covers 08/08/2005-14/04/2022. The main findings show that in the 'smooth' economic periods, the oil price is an important 'signal' for expected inflation on long-run. Otherwise, expected inflation influences the oil price on medium-run, during financial crises and major monetary adjustments. Pandemic or war crises have no notable implications on the 'oil price - expected inflation' nexus, other factors being more prominent.

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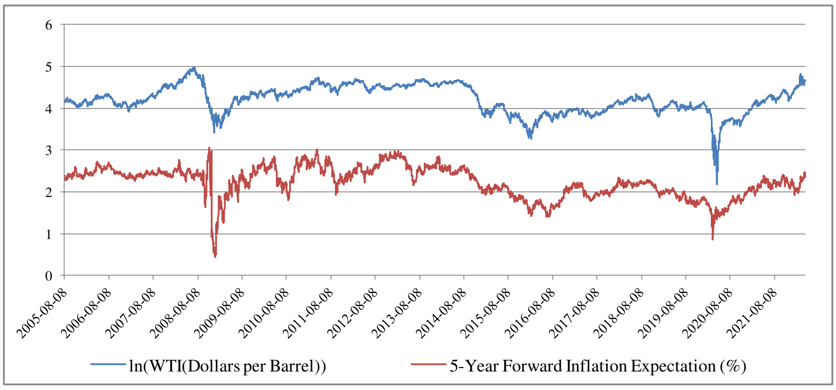
# 1. Introduction

After the oil crises in '70, many scholars explored the interaction between oil prices and expected inflation. The financial crisis in 2007-2008, Covid-19 pandemic and recent Ukrainian war also motivated the investigations in the field. In this context, the United States (U.S.) raised a particular interest, especially after the Great Recession of 2007-2008. This country plays a major role in the international oil market, being the second-largest importer after China, with 5.8 mil. barrels/day in 2020 (EIA, 2022).

Figure 1 shows daily oil prices and expected inflation rates over 2005-2021, they generally co-moving.




Note: based on West Texas Intermediate (WTI) crude oil prices and 5-Year forward inflation expectation rate, provided by FRED (2022) online database.

Figure 1: Oil prices and expected inflation in U.S. over 2005-2021

Interestingly, opposite or same dynamics are observed during the financial or pandemic shocks, but with different amplitudes (i.e. Financial crisis from 2007-2008, Covid-19 pandemic over 2020-2021).

There is generous literature trying to explain the mechanism of 'oil price - expected inflation' nexus, both directions of co-movement being considered. For example, Bruno and Suchs (1985) show that the rise in oil price can induce an expected stagflation effect pass-through production costs (i.e. higher inflation with slower growth). Conversely, the fall of oil prices reduces the expected inflation by compressing the production costs. Aastvei et al. (2021) prefer oil supply and demand to explain the change in the expected inflation, especially during a financial crisis. Bernanke (2007) and Mishkin (2007) contribute in this strand. Unlike them, Conflitti and Cristadoro (2018) show that the effect of oil prices on long-term inflation expectations is no longer significant. Wong (2015) more generally confirms those findings.

Otherwise, expected inflation can affect oil prices when oil is seen as an asset (Andolfatto and Ebsim, 2020). Herein, under a long-run prediction of low inflation, the investors will prefer the safe assets (i.e. U.S. Treasury securities), the value of oil stock declining along with expected inflation.

In this context, the paper revisits the 'oil price - expected inflation' nexus in the U.S. by using as a novelty the wavelet. Contribution of the study is twofold. First, the paper offers one of the first analysis covering financial, pandemic and war shocks in the U.S. Second, thanks of wavelet valence against classical time-domain methods, both directions of co-movements are considered, ranging across frequencies and sub-periods of time.

The rest of the paper is as follows: Section 2 presents data and methodology, Section 3 shows the main results, while Section 4 checks for robustness. Finally, Section 5 concludes.

# 2. Data and methodology

## 2.1. Data

Two variables are the ground of study: oil price and expected inflation. The sample covers 08/08/2005-14/04/2022, having daily frequency. Oil price is captured via West Texas Intermediate (WTI) as crude oil price in dollars per barrel. Expected inflation (EI) is measured as 5-years forward inflation expectation rate expressed as a percentage.

Variables are finally considered in their level, the stationarity not being a required property in wavelet approach (Aguiar-Conraria et al., 2008). The variables come from FRED (2022) online database, WTI being treated in its natural logarithm form.

## 2.2. Methodology

A battery of wavelet tools is used to connect oil price and expected inflation in time and frequency, comprising: wavelet transformation (CWT), and wavelet coherency (WTC) with phase-difference (Grinsted et al., 2004; Aguiar-Conraria et al., 2008).

Morlet function $\psi_0(\eta)$, with nondimensional 'time' parameter $\eta$ and nondimensional frequency $\omega_0$, supports the CWT process, as follows:

$$\psi_0(\eta) = \pi^{-\frac{1}{4}} e^{i\omega_0\eta} e^{-\frac{1}{2}\eta^2}, \tag{1}$$

where $i$ denotes $\sqrt{-1}$, while $\omega_0$ is set to 6 (Farge, 1992). For a time-series $\{x_n\}$, with $n=0...N-1$, CWT has this form:

$$w_n^x(s) = \frac{\delta t}{\sqrt{s}} \sum_{n'=0}^{N-1} x_{n'} \psi^* \left( (n' - m) \frac{\delta t}{s} \right), \tag{2}$$

where $s$ is the scale by time-step $\delta t$, while $m=0, 1, ..., N-1$.

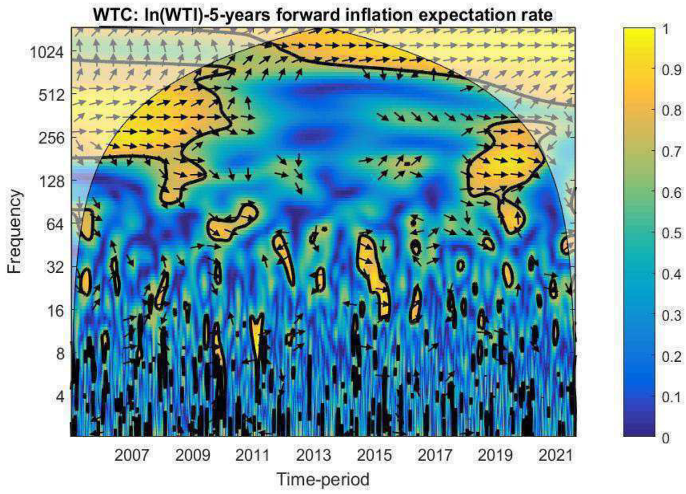
Further, WTC allows connecting two transformed time-series $x=\{x_n\}$ and $y=\{y_n\}$, both in time and frequency (Torrence and Webster, 1999), the local correlation being:

$$R_n(s) = \frac{|S(s^{-1}W_n^{xy}(s))|}{S(s^{-1}|W_n^x|)^{\frac{1}{2}} S(s^{-1}|W_n^y|)^{\frac{1}{2}}}. \tag{3}$$

where, $W_n^x$ and $W_n^y$ are the wavelet transforms of $x$ and $y$, $S$ is the smoothing operator in both time and scale, while $|W_n^{xy}|$ denotes the cross-wavelet power. Finally, the phase difference can also be considered, showing the position of transformed variables in the pseudo-cycle as sign, directions and lead-lag status.

# 3. Results

Figure 2 plots the WTC of 'WTI - EI' pair in the case of the U.S., over the 08/08/2005-14/04/2022.




Note:
(1) The thick black contour indicates the 5% level of significance, while the cone of influence (COI) where the edge effects might distort the picture is suggested by the lighted shadow;
(2) The power intensity range goes from blue colour (low power) to yellow one (high power). Variables are positively linked when arrows are oriented to the right (i.e. in phase, cyclical effect), and negatively connected when arrows are oriented to the left (i.e. anti-phase, anti-cyclical effect);
(3) WTI is leading when the arrows are pointed to the right and up, while EI is leading when the arrows are oriented to the right and down. Otherwise, EI is leading when the arrows are pointed to the left and up, while WTI is leading when the arrows are oriented to the left and down;
(4) The X-axis is the time-period, while Y-axis shows the frequency as 2π/period.

Figure 2: WTC 'WTI - EI' in the U.S., over 08/08/2005-14/04/2022

At very high frequency (i.e. at 16-80 days band of scale, very short-run), the plot evidences only two 'small' but notable episodes, covering 2010-2011, and 2014-2016. EI positively leads WTI, the arrows being pointed to the right and down. In the first episode, the post-crisis measures enhance inflation and oil price, while the second episode is overcome with Quantitative Easing end, reducing the inflation expectation and oil price.

At medium frequency (i.e. at 90-600 days band of scale, medium-run), WTI and EI are in phase over 2006-2010, with the arrows pointing to the right. Herein, the orientation of arrows moves from down to up, indicating that the lead-lag status of variables changes across frequencies. More precisely, EI leads WTI, and then WTI leads EI, as the frequency slightly increases. Financial Crisis seems to begin with the rise in the inflation expectation, followed by the reaction of WTI in the same way, and then back again by inflation. This is in line with Kyrtsou (2008), partially confirming Aastvei et al. (2021). Similar co-movement is observed over 2018-2020, at the same band of scale. Inflation expectation changes under pandemic context, the demand disruption reducing the inflation expectation and, consequently, the oil price.

Noteworthy is that WTI positively leads EI over 2011-2018, at low frequency (i.e. at more than 900 days band of scale, long-run), the arrows being pointed to the right and up. Without notable shocks, the oil price drives the expected inflation with the same sign in this period.

# 4. Robustness check

The robustness check follows two additional wavelet tools: (1) wavelet cohesion (WC) as an alternative method to WTC, and (2) partial wavelet coherency (PWC) to control for additional determinants.

(1) WC is proposed by Rua (2010), offering more details about phase-difference status of two time series. As a real number on [-1, 1], the test $\rho_{x_n y_n}$ has this form:

$$\rho_{x_n y_n} = \frac{\Re(W_n^x W_n^y)}{\sqrt{|W_n^x|^2 |W_n^y|^2}}. \quad (4)$$

where, an intense positive co-movement is suggested when $\rho_{x_n y_n}$tends to +1. Otherwise, a strong negative connection is indicated when $\rho_{x_n y_n}$tends to -1.

(2) PWC is promoted by Mihanović et al. (2009), being extended by Hu and Si (2021). The method allows isolating the interaction between two variables *x* and *y* by removing the influence of a considered set of controls. PWC is given by the squared of partial wavelet coherence, z denoting the control:

$$\left(RP_n^{yxz}\right)^2 = \frac{\left|RP_n^{yx} - RP_n^{yz} RP_n^{yx*}\right|^2}{\left[1-\left(RP_n^{yz}\right)\right]^2 [1-(RP_n^{zx})]^2}. \quad (5)$$

The control variable is represented by Office of Financial Research index (OFR). OFR captures the stress in global financial markets, concatenating the credit, equity valuation, funding, safe assets, volatility and elements which reflect regional market characteristics (Kyrtsou, 2008). The variable is taken from OFR (2022) online database, being expressed as an index over the same 08/08/2005-14/04/2022.

Figure A1 (Appendix) illustrates the WC of co-movement between oil price and expected inflation, while Figure A2 (Appendix) plots their related PWC by removing the influence of OFR. The yellow zones in WC reinforce the WTC outputs, while PWC adds interesting new findings.

PWC shows that the oil price remains a robust determinant for expected inflation only on long-run. Financial shock and notable monetary adjustments underline the role of expected inflation in the oil price level. Other determinants seem to counteract the oil price in pandemic episode. No co-movements are curiously observed in the prelude of the Ukrainian war, confirming the WTC findings.

# 5. Conclusion

The paper uses the wavelet to explore the ‘oil price - expected inflation' nexus in the U.S. over 08/08/2005-14/04/2022. The empirical investigation evidences a significant but varying relationship across frequencies and different sub-periods of time.

In the 'smooth' economic periods, the oil price is an important 'signal' for expected inflation on long-run. Otherwise, expected inflation influences the oil price on medium-run, during financial crises and major monetary adjustments. Pandemic or war crises have no notable implications on the 'oil price - expected inflation' nexus, other factors being more prominent.

In terms of policy implications, the U.S. policymakers should carefully monitor oil prices on long-run to anticipate the inflation rate, while special attention deserves financial crisis when the expected inflation is crucial for oil price evolution.

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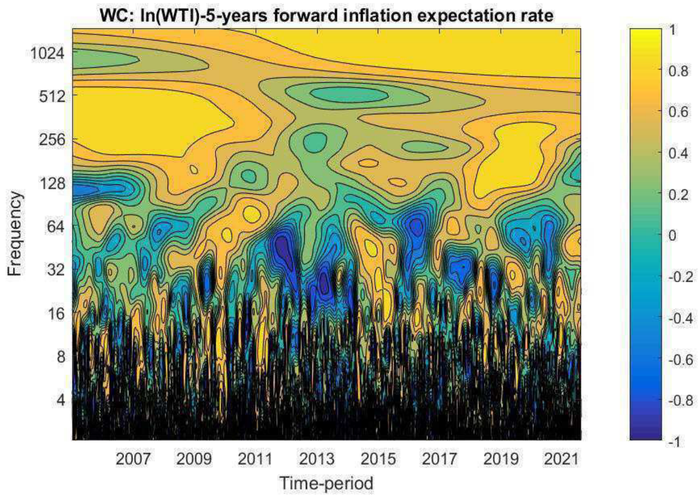
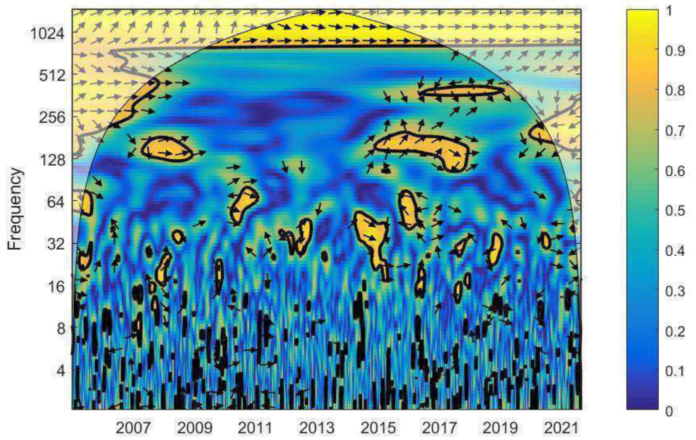
# Appendix




Note:
(1) The colour code suggests the intensity of co-movement, going from yellow (positive co-movement) to blue one (negative co-movement).
(2) The X-axis is the time-period, while Y-axis denotes the frequency as 2π/period.

Figure A1: WC of 'ln(WTI) - 5-years forward inflation expectation rate' in the U.S., over 08/08/2005-14/04/2022




Note:
(1) For PWC interpretation please refers to the Figure 1;
(2) The X-axis is the time-period, while Y-axis denotes the frequency as 2π/period.

Figure A2: PWC of 'ln(WTI) - 5-years forward inflation expectation rate' in the U.S. by removing OFR, over 08/08/2005-14/04/2022