Macroeconomic implications of oil price fluctuations

A regime-switching framework for the euro area

Nonlinear Models in Macroeconomics and Finance for an Unstable World

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Oil price fluctuations typically trigger divergent assessments

Example: oil price slump in 2014H2

Cheaper oil is a rare piece of good news for (...) the euro currency area, since [it] should boost the spending power of Europe’s consumers (...) amid the eurozone’s long slump.

Wall Street Journal, 14 November 2014

(...) a danger [of the oil-price slump] is that an even deeper dip in inflation (...) may have an unwelcome second-round effect by dragging down inflation expectations.

The Economist, 4 December 2014
… but central banks have to form a view on the macro implications in real-time.

Commodity price fluctuations in the ECB’s reaction function

“**In principle, if commodity price changes are of a temporary nature, one can look through the volatility in inflation triggered by their first-round effects.**

However, the risk of second round effects must be contrasted (...) to prevent that they have a lasting impact on medium-term inflation expectations (...)

In such cases, an adjustment of the monetary policy stance would be required to preserve price stability and keep inflation expectations well-anchored.”

*Mario Draghi before ECON Committee, June 2011*

Source: Bloomberg
Overview of our paper

**Aim:** model episodic changes in transmission of oil price shocks to the economy in a regime-switching VAR model with time-varying transition matrix

**Key findings:**

- Oil price fluctuations typically exert limited effects on inflation and economic activity (‘normal regime’), e.g. downward oil price shock leads to higher growth.
- Occasionally, economy enters into ‘adverse regime’ in which:
  - Oil price shocks trigger sizeable and sustained macroeconomic effects
  - Inflation and economic activity move in the same direction as the oil price shock
  - …as do inflation expectations, consistent with presence of second-round effects
  - Role of wage change as channel for a wage-price spiral / second-round effects
- Model assigns ‘pre-APP episode’ (mid-2014 to early-2015) to adverse regime
Related economic literature

Relevance of source of oil price shocks:
- Disentangle oil supply, aggregate demand & precautionary oil demand shocks using structural VARs
  e.g., Kilian (2009); Jo (2014), Caldara, Cavallo & Iacoviello (2016)

Differences in transmission of oil price shocks:
- Assess how impact of oil price shocks has differed across historical episodes
  e.g. Blanchard & Galí (2007); Nakov & Pescatori (2010)
- Explicitly model non-linearities/time-variation in impact of oil shocks (US)
  e.g. Hamilton (2003); Baumeister & Peersman (2013); Leduc, Moran & Vigfusson (2016), Bjørnland, Larsen and Maih (2018)

Monetary policy response to oil price shocks
- Assess role of monetary policy as propagator of oil price shocks, ZLB
  e.g. Bernanke, Gertler and Watson (1997); Bodenstein, Guerrieri and Kilian (2012); Bodenstein, Guerrieri and Gust (2013)
Our paper is the first to

- Model time-variation in impact of oil price shocks on euro area macroeconomy
- Explicitly account for inflation expectations
- Employ novel regime-switching VAR framework with time-varying transition matrix
Hubrich, Waggoner and Zha (2015)

\[ A_0(s_t^c)y_t = A_+(s_t^c)x_t + \Xi^{-1}(s_t^\nu)\epsilon_t \quad (1) \]

\( y_t \): Endogenous variables; \( x'_t = [y'_{t-1}, ..., y'_{t-p}, 1] \)

\( \epsilon_t \): Vector of standard normal shocks

\( A_0(s_t^c), A_+(s_t^c) \): Coefficient matrices

\( \Xi^{-1}(s_t^\nu) \): Diagonal matrix with standard deviations of shocks

- Previous literature: MS-SVAR **constant transition matrix** (Sims & Zha, AER, 2006; Sims, Waggoner & Zha, JoE, 2008; Hubrich and Tetlow, JME, 2015)

  \( s_t = (s_t^c, s_t^\nu) \): Unobserved state variables evolve according to two independent first-order Markov processes

- Hubrich, Waggoner and Zha (2015): **time-varying transition matrix**
**Regime-Switching SVAR model: Transition matrix**

$p_{i,j,t}$: time-varying probability of switching from regime $j$ to $i$,

- $p_{i,j,t}$ denotes $p(s_{t+1} = i \mid s_t = j, Y_t, \theta, q)$

- **Diagonal elements** of $p_{i,j,t}$ give the time-varying persistence of $j^{th}$ regime:

\[
p_{j,j,t} = \frac{1}{1 + e^{-u_{j,t}}}
\]

where

\[
u_{j,t} = c_j + \gamma_j y_{t,(t-k+1)}
\]

and:

\[
y'_{t,(t-k+1)} = [y'_t, \ldots, y'_{(t-k+1)}]
\]

- Intercept and slopes determine transition process
Specification of time-varying probabilities

**Regime Switching SVAR model: Transition matrix**

\( p_{i,j,t} \): time-varying probability of switching from regime \( j \) to \( i \)

- \( p_{i,j,t} \) denotes \( p(s_{t+1} = i | s_t = j, Y_t, \theta, q) \)
- Off diagonal elements for application with 2 regimes:

\[
p_{i,j,t} = (1 - p_{j,j,t})
\]

where \( p_{i,j,t} + p_{j,j,t} = 1 \)

- Off diagonal elements for more than 2 regimes
  - Off-diagonal elements sum to \( 1 - p_{j,j,t} \), (scaled) Dirichlet prior
Model estimation

- Estimation with Bayesian methods

- Estimation of posterior mode:
  - Blockwise BFGS optimization algorithm
  - Algorithm: parameters divided into blocks; initial guesses for parameters used in hill-climbing quasi-Newton optimization routine
  - Use draws from the simulations of the posterior distribution as starting points
  - Dynamic Striated Metropolis Hastings sampler (Waggoner, Wong & Zha, 2016)
Macroeconomic Effects of Oil Price Fluctuations

Regime-Switching SVAR model

Data and Identification

\[ y_t = [\Delta ip, \pi, \Delta poil, FX, \pi^e, R] \]

- \( ip \): industrial production;
- \( \pi \): HICP inflation;
- \( poil \): Brent crude oil price (in USD);
- \( EXR \): USD/EUR exchange rate;
- \( \pi^e \): 5Y5Y BEIR
- \( R \): 3-month EURIBOR
- Additional specification: change in nominal negotiated wages (\( \Delta w \)) added

- Baseline sample: euro area aggregates, monthly frequency, Feb 2004 to Jan 2015 (availability of 5Y5Y BEIR is restraining factor for start of sample period);
- Different sample extensions
- Identification: Cholesky decomposition, variables ordered as shown above
- Persistence of regime: depends on oil price inflation
Impulse responses to downward oil price shock

Model reveals relevant differences in economic dynamics across regimes

- **Normal regime:**
  - Oil price shocks only trigger small macroeconomic effects
  - Increase in growth

- **Adverse regime:**
  - Inflation declines and inflation expectations decline
  - Output growth declines
  - Effects are long-lasting
  - MP loosens but not sufficiently to pre-empt second-round effects
Euro area economy entered adverse regime at various occasions
- Typically switch after sequence of pronounced, unidirectional oil price changes
- Conditional probability of staying in normal regime declined steeply in 2014H2
- Overall, supports unfavourable interpretation of that episode of oil price declines
Counterfactual Experiment

Main findings

- Consider regime switch in August 2014: What if no regime change and stay in normal regime?
- **Actual** compared to **Counterfactual** path
  - Higher path for oil price changes
  - Inflation higher
  - Inflation expectations 0.4pp higher, substantial since move within a narrow range
  - Growth substantially higher
Impulse responses to downward oil price shock, Model with nominal negotiated wages

Model reveals relevant differences in economic dynamics across regimes

- **Normal regime:**
  - Increases in growth
  - Inflation declines
  - Declines in Nom. wage growth, but only modestly

- **Adverse regime:**
  - Inflation declines (after a year increase due to oil price dynamics)
  - Inflation expectations
  - Nominal wage growth declines (with lag)
  - Substantial growth decline
  - MP loosens but not sufficiently to pre-empt second-round effects

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Summary and conclusion

- Depending on source and transmission of underlying shock, observed oil price fluctuations may have very different macroeconomic consequences.

- Aim of our paper is to model episodic changes in transmission of oil price shocks to the economy in a regime-switching SVAR with time-varying transition matrix.

- Key findings:
  - Oil price fluctuations typically exert limited effects on inflation and economic activity (‘normal regime’), e.g. downward oil price shock leads to higher growth.
  - Occasionally, economy enters into ‘adverse regime’ in which:
    - Oil price shocks trigger sizeable and sustained macroeconomic effects.
    - Inflation and economic activity move in the same direction as the oil price shock.
    - …as do wage changes and inflation expectations, consistent with presence of second-round effects.
  - Model assigns ‘pre-APP episode’ (mid-2014 to early-2015) to adverse regime.

- Key contribution:
  - Model helps assess effect of oil price fluctuations in real-time and inform deliberations on the adequate policy response.
Background
Robustness check (oil prices in EUR)

**Main findings**

- Ultimately, it is the oil price in EUR that matters for EA consumers and firms.
- Baseline specification includes oil price in USD and USD/EUR exchange rate.
- Robustness test (incl. oil price in EUR) confirms key results of baseline spec.
- Nearly identical responses of growth, inflation, and inflation expectations.

**Impulse response functions**

- Output growth
- Inflation
- Oil price changes
- Inflation Expect. (5Y5YBEIR)
Euro area economy entered adverse regime at various occasions
- Typically switch after sequence of pronounced, unidirectional oil price changes
- Conditional probability of staying in normal regime declined steeply in 2014H2
- Overall, supports unfavourable interpretation of that episode of oil price declines
Past policy action motivated by risk of oil-price induced 2nd-round effects

“I(…) we decided at today’s meeting to increase the key ECB interest rates by 25 basis points. This decision was taken to prevent broadly based second-round effects.”

Introductory Statement, 3 July 2008

“While the sharp fall in oil prices over recent months remains the dominant factor driving current headline inflation, the potential for second-round effects (…) has increased. This assessment is underpinned by a further fall in market-based measures of inflation expectations.”

Introductory Statement, 22 January 2015

Source: Bloomberg
Related methodological literature

**Markov Switching Model Literature**

**Markov switching with constant transition matrix**

Hamilton (1989); Chauvet (1998); Kim and Nelson (1999); Fruehwirth-Schnatter (2004); Sims and Zha (2006), Sims, Waggoner, Zha (2008); Luetkepohl, Lanne & Maciejowska (2010); Herwartz & Luetkepohl (2014); Brunnermeier, Palia & Sims (2014)

**Regime-switching regression models with time-varying transition matrix**

Filardo (1994); Diebold, Lee and Weinbach (1994); Kim (2004); Kim, Piger and Startz (2008); Bazzi, Blasques, Koopman, Lucas (2014); Chang, Choi and Park (2014)
Impulse responses to negative oil price shock

**Impulse response functions**

- **Output growth**
- **Inflation**
- **Oil price changes**
- **Inflation Expect. (5Y5YBEIR)**

**Main findings**

- Model reveals relevant differences in economic dynamics across regimes

- **Constant parameter VAR:**
  - may underestimate effect of oil price shock in adverse regime
  - may give wrong sign for output and inflation response in normal regime
We extend the sample to December 2015.

Long-term real interest rate included to capture potential effects of non-standard measures.

No inflation expectations to keep specification parsimonious.

Very similar responses of growth and inflation in respective regimes.
Robustness check (oil prices in EUR)

Probability of being in a normal regime (grey-shaded area) and conditional probability of staying in that regime (black line)

Note: on the x-axis ’05 refers to the beginning of the year 2005 etc.

- Assignment of time periods to different regimes broadly unaffected
- Some additional adverse-regime episodes
- Period around the turn of 2015 again assigned to adverse regime
- …. and drop in cond. probability of staying in normal regime in 2014H2 confirmed
Impulse responses to negative oil price shock, Extended sample until 2015(12)

**Main findings**

- Model reveals relevant differences in economic dynamics across regimes

- **Normal regime:**
  - Oil price shocks only trigger small macroeconomic effects

- **Adverse regime:**
  - Growth and inflation decline
  - Effects on growth long-lasting
  - MP loosens but not sufficiently to pre-empt second-round effects
Counterfactual Experiment

Output growth

Inflation

Oil price changes

Exchange rate

Inflation Expect. (5Y5YBEIR)

EURIBOR

Main findings

- Consider regime switch in August 2014: What if no regime change?
- Assume inflation expectations do not drift down
- Impose actual average interest rate path
- **Actual** compared to **Counterfactual** path
  - Higher path for oil price and inflation expectations
  - Growth and inflation higher

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Counterfactual Experiment

Main findings

- Consider regime switch in August 2014: What if no regime change?
- Assume inflation expectations do not drift down
- Impose actual average interest rate path
- Actual compared to Counterfactual path
  - Higher path for oil price and inflation expectations
  - Growth and inflation higher
Evolution of oil-price changes (variable included in VAR)

Y-o-Y changes in price of oil (in %)

Source: Bloomberg
Evolution of inflation expectations (variable included in VAR)

Breakeven inflation rate, 5y5y (in %)

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Nominal wage changes (variable included in VAR)

Nominal wage changes (yoy change in %)

dWneg

Macroeconomic implications of oil price fluctuations
Inflation (variable included in VAR)

HICP (yoy change in %)

dHICP

Macroeconomic implications of oil price fluctuations
Industrial production growth (variable included in VAR)

Industrial production growth (yoy change in %)

dIP
Macroeconomic implications of oil price fluctuations
Dynamic Striated Metropolis Hastings sampler

Basic idea:

- Tractable initial distribution one can sample from
- Transform initial distribution gradually to desired posterior distribution through sequence of stages
- Grounded in Metropolis-Hastings, but combines with the strength of equi-energy and sequential Monte Carlo samplers
- Differs from other methods in how information from previous stage is transmitted to current stage
- Allows to compute MDDs as by-product
Simulation of Posterior Distribution

Posterior distribution and model evaluation (statistical):

- Marginal Data Densities often via Modified Harmonic Mean (Gelfand & Dey, 1994)
- MHM might be unreliable when posterior distributions far from Gaussian and extremely irregular with multiple peaks
- Recently growing literature on new methods to compute posterior distributions
- Different methods within class of Sequential Monte Carlo methods developed, e.g. Durham & Geweke (2014), Herbst & Schorfheide (2014), Bognanni & Herbst (2014), Waggoner, Wong & Zha (2016)
- Here: Dynamic Striated Metropolis Hastings sampler,
  Waggoner, Wong & Zha (2016)