**Fédéric Holm-Hadulla**
European Central Bank

**Kirstin Hubrich**
Federal Reserve Board

# Macroeconomic implications of oil price fluctuations

## A regime-switching framework for the euro area

**Nonlinear Models in Macroeconomics and Finance for an Unstable World**
January.26-27, 2018

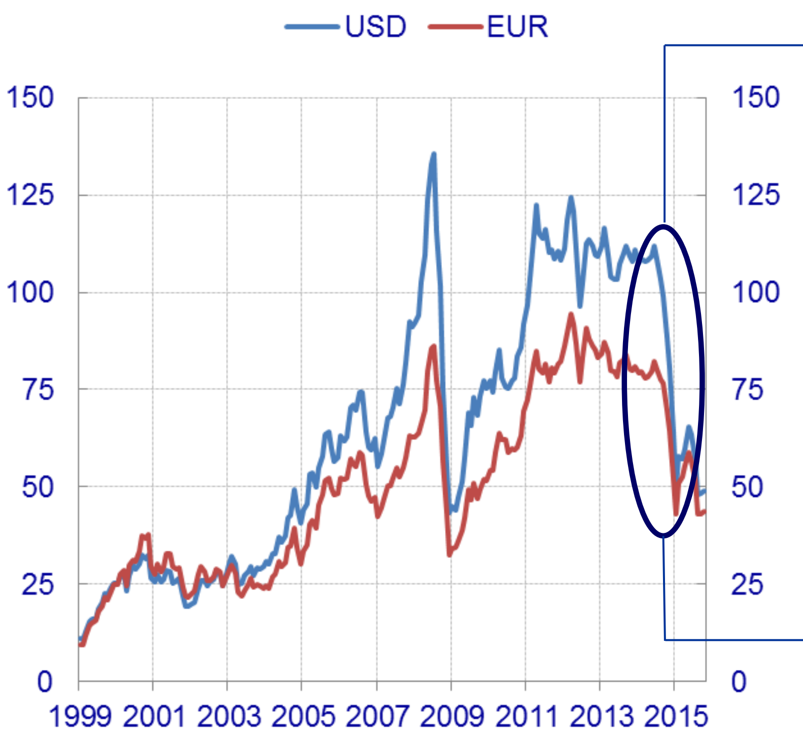
*The views expressed here are those of the authors and do not necessarily reflect those of the European Central Bank, the Federal Reserve Board or the Federal Reserve System or its staff.*

.

# Oil price fluctuations typically trigger divergent assessments

Example: oil price slump in 2014H2

**Brent crude oil prices**
*(in different currencies)*




Source: Bloomberg

*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***

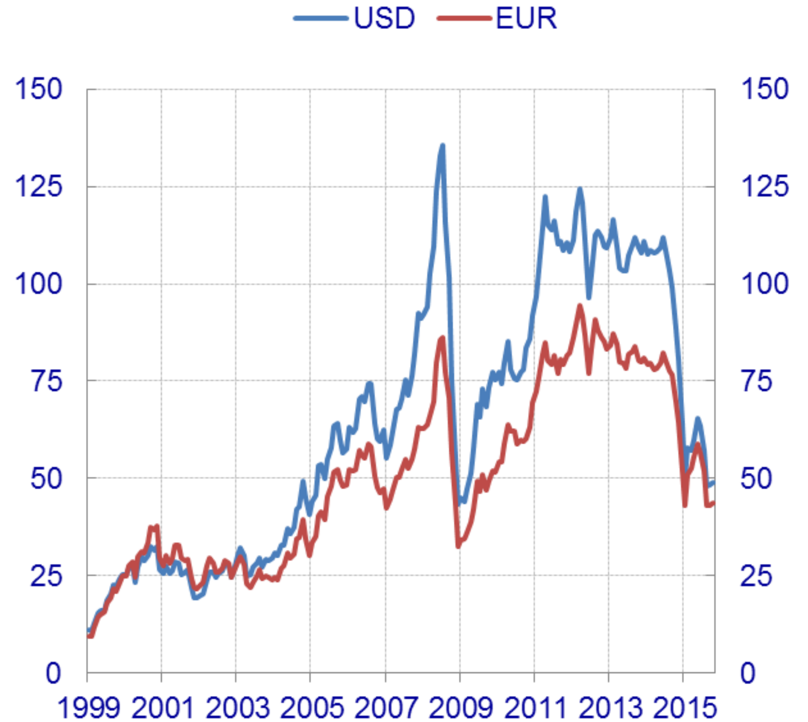
*(...) a danger [of the oil-price slump] is that an even deeper dip in inflation (…) may have an* ***unwelcome second-round effect*** *by dragging down inflation expectations.*

***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

**Brent crude oil prices**
*(in different currencies)*




Source: Bloomberg

*"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***

# 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)

# Contribution to the literature

## 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

# Regime-switching Structural VAR model with time-varying transition matrix

**Hubrich, Waggoner and Zha (2015)**

$$A_0(s_t^c)y_t = A_+(s_t^c)x_t + \Xi^{-1}(s_t^v)\varepsilon_t \qquad (1)$$

$y_t$: Endogenous variables; $x_t' = [y_{t-1}', \ldots, y_{t-p}', 1]$

$\varepsilon_t$: Vector of standard normal shocks

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

$\Xi^{-1}(s_t^v)$: 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)

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

- Hubrich, Waggoner and Zha (2015): **time-varying transition matrix**

# Specification of 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**:

$$p_{i,j,t} = \left(1 - p_{j,j,t}\right)$$

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)

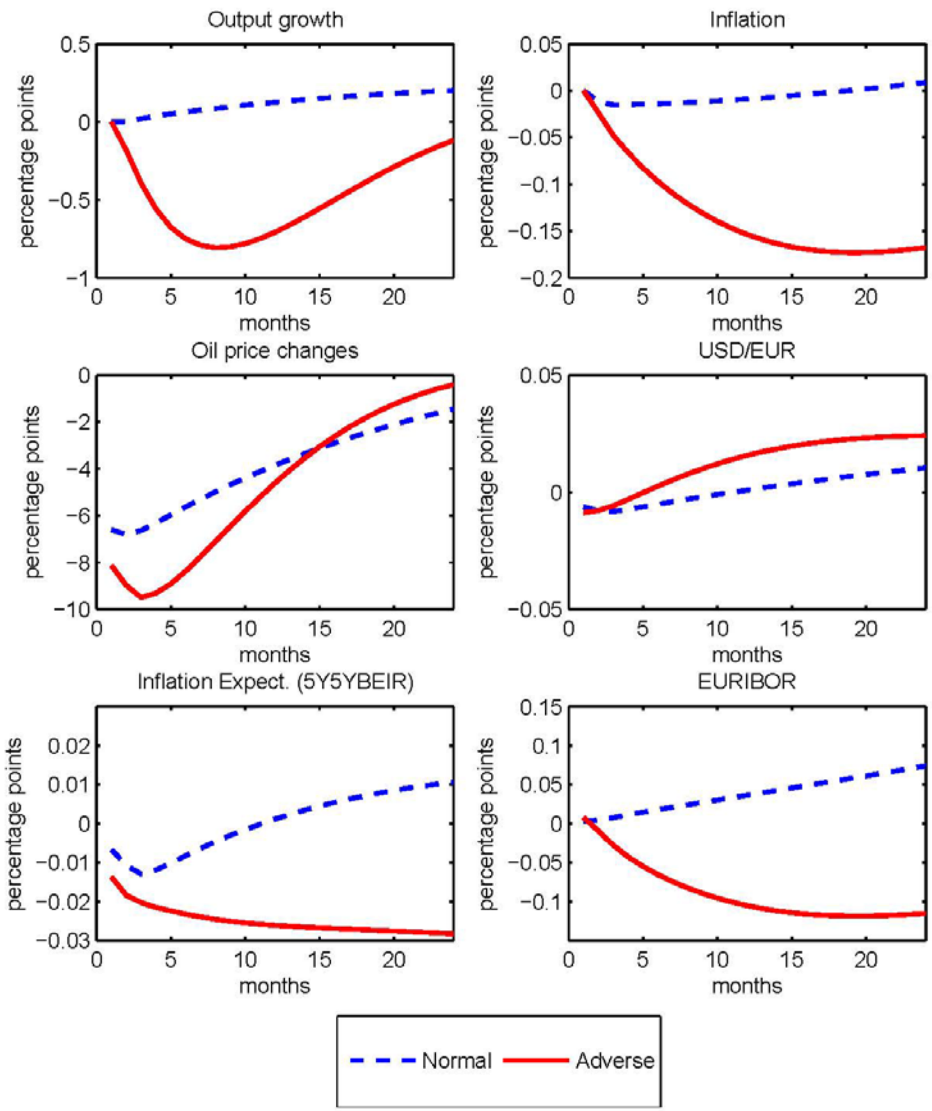
## Regime-Switching SVAR model

### *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 (Δw) 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

## Impulse response functions

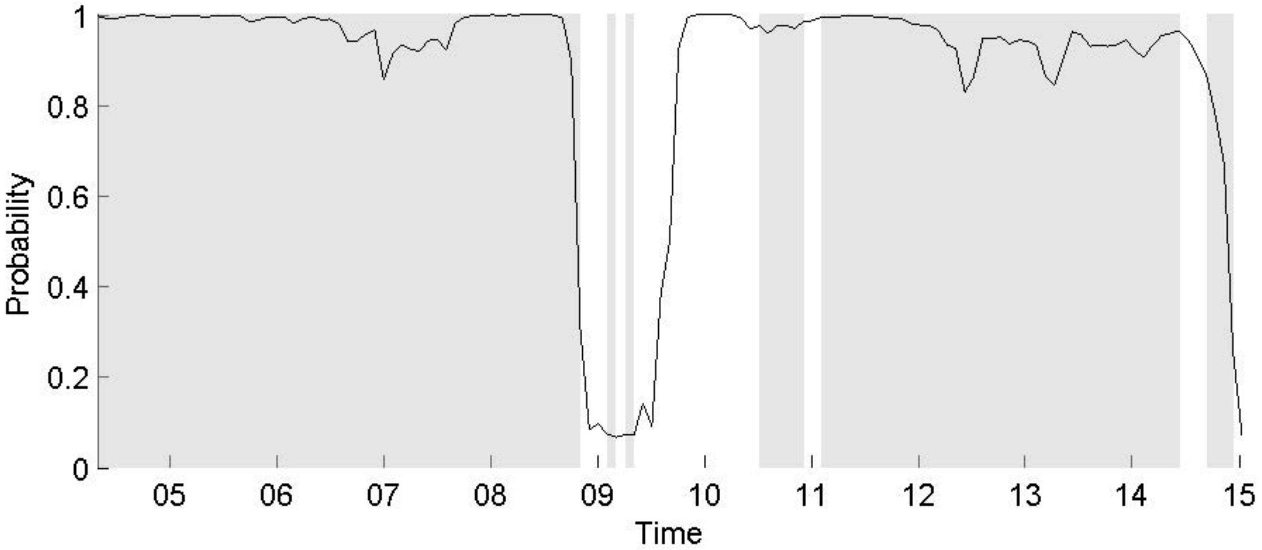



## Downward (negative) oil price shock

- 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

# Regime probabilities

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

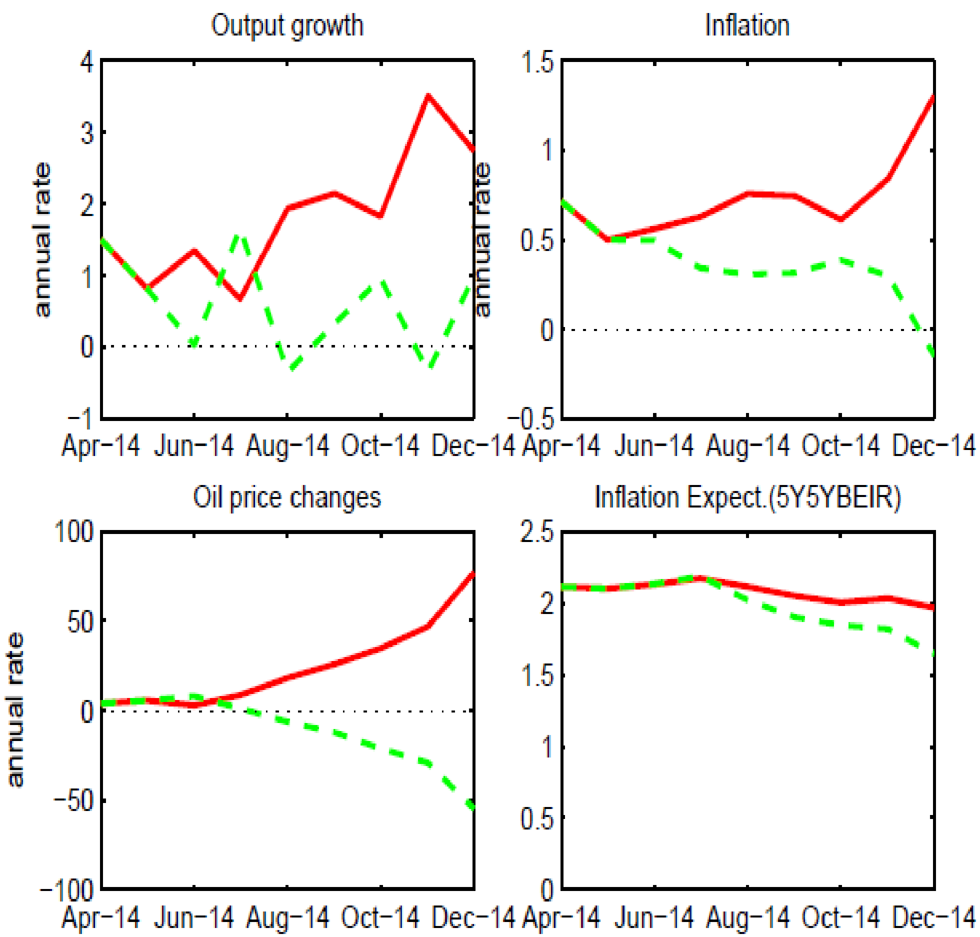



Note: on the x-axis ’05 refers to the beginning of the year 2005 etc.

- 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

## Counterfactual Experiment

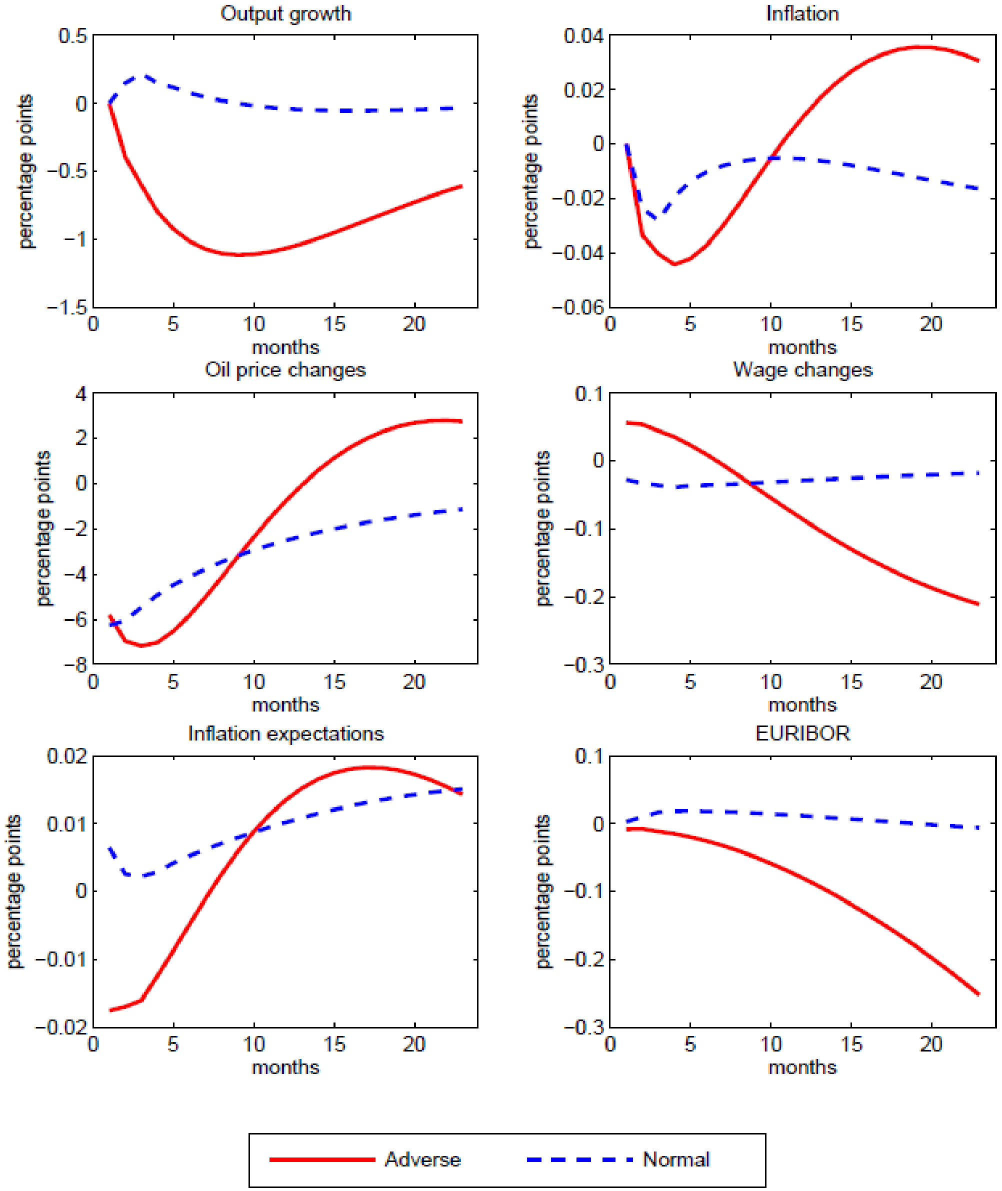



## Main findings

- 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

## Impulse response functions




## Downward oil price shock

- 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

Holm-Hadulla & Hubrich

# 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

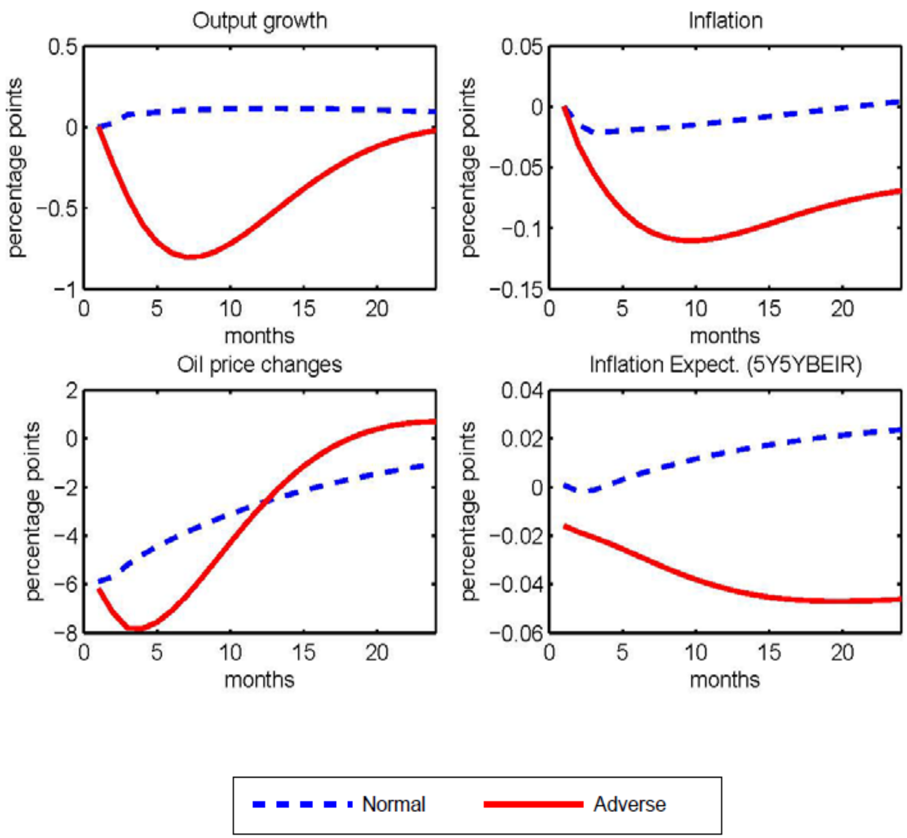
- Key findings:
  - Oil price fluctuations typically exert limited effects on inflation and economic activity (‘**normal regime**’), e.g. downward oil price shock leads to higher growth
  - Occasionally, economy enters into ‘**adverse regime**’ in which:
    - oil price shocks trigger sizeable and sustained 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)

## Impulse response functions

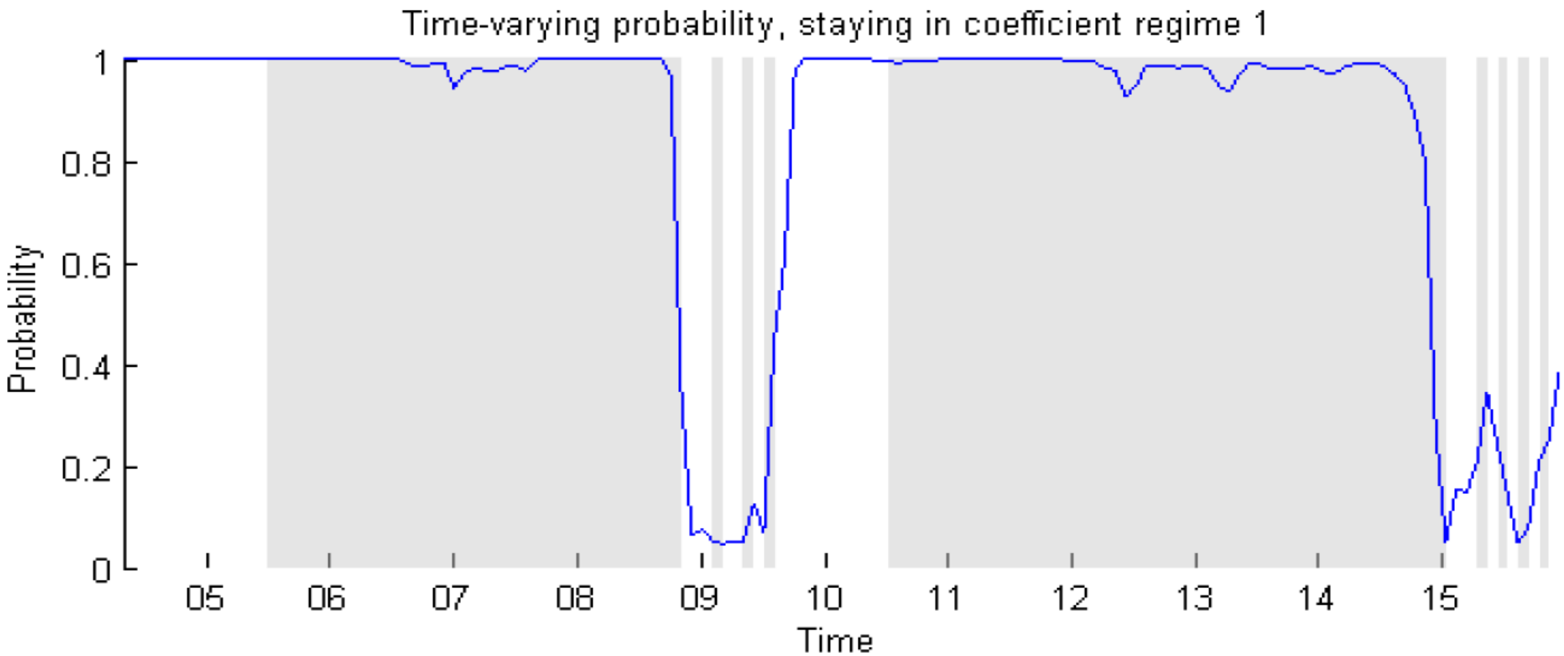



## Main findings

- 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

# Regime probabilities

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

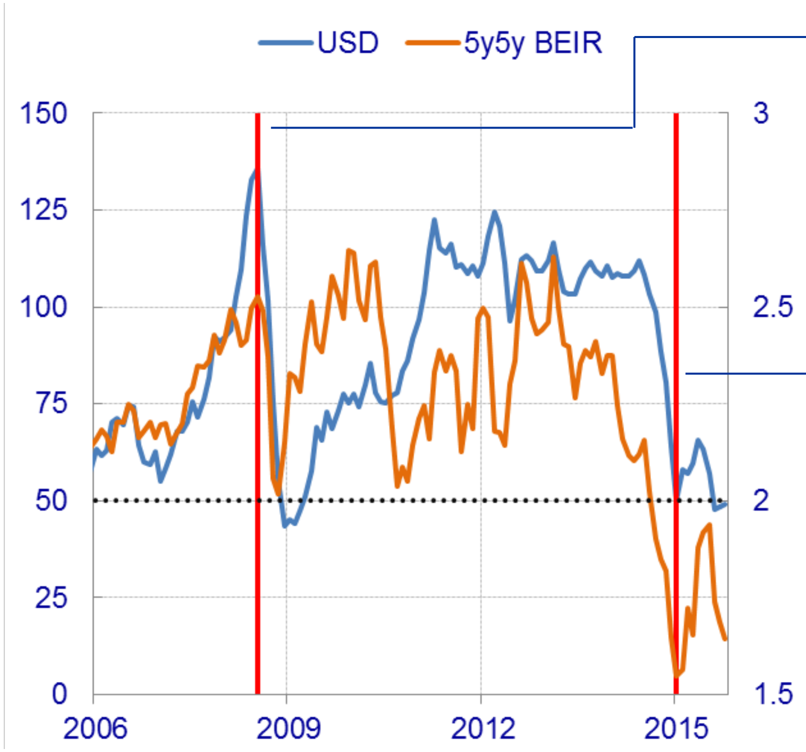



- Euro area economy entered adverse regime at various occasions
- Typically switch after sequence of pronounced, unidirectional oil price changes
- Conditional probability of staying in normal regime declined steeply in 2014H2
- Overall, supports unfavourable interpretation of that episode of oil price declines

# Past policy action motivated by risk of oil-price induced 2nd-round effects

Commodity price fluctuations in the ECB's reaction function

**Brent crude oil prices and inflation expectations** *(LHS: USD; RHS: % per annum)*




Source: Bloomberg

*"(…) 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***

# Markov Switching Model Literature

## Markov switching with constant transition matrix

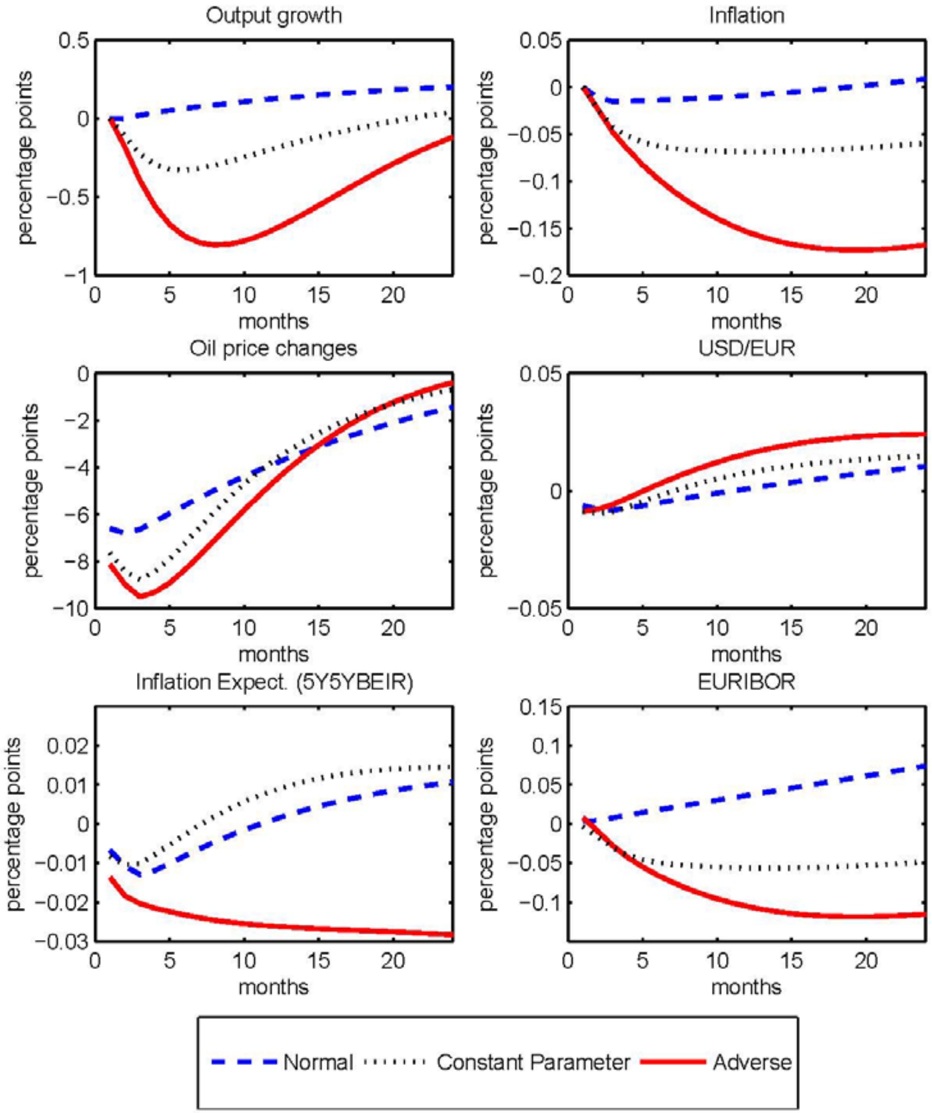
Hamilton (1989); Chauvet (1998); Kim and Nelson (1999);
Fruehwirth-Schnatter (2004); Sims and Zha (2006), Sims, Waggoner, Zha (2008);
Luetkepohl, Lanne & Maciejowska (2010); Herwartz & Luetkepohl (2014);
Brunnermeier, Palia & Sims (2014)

## 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

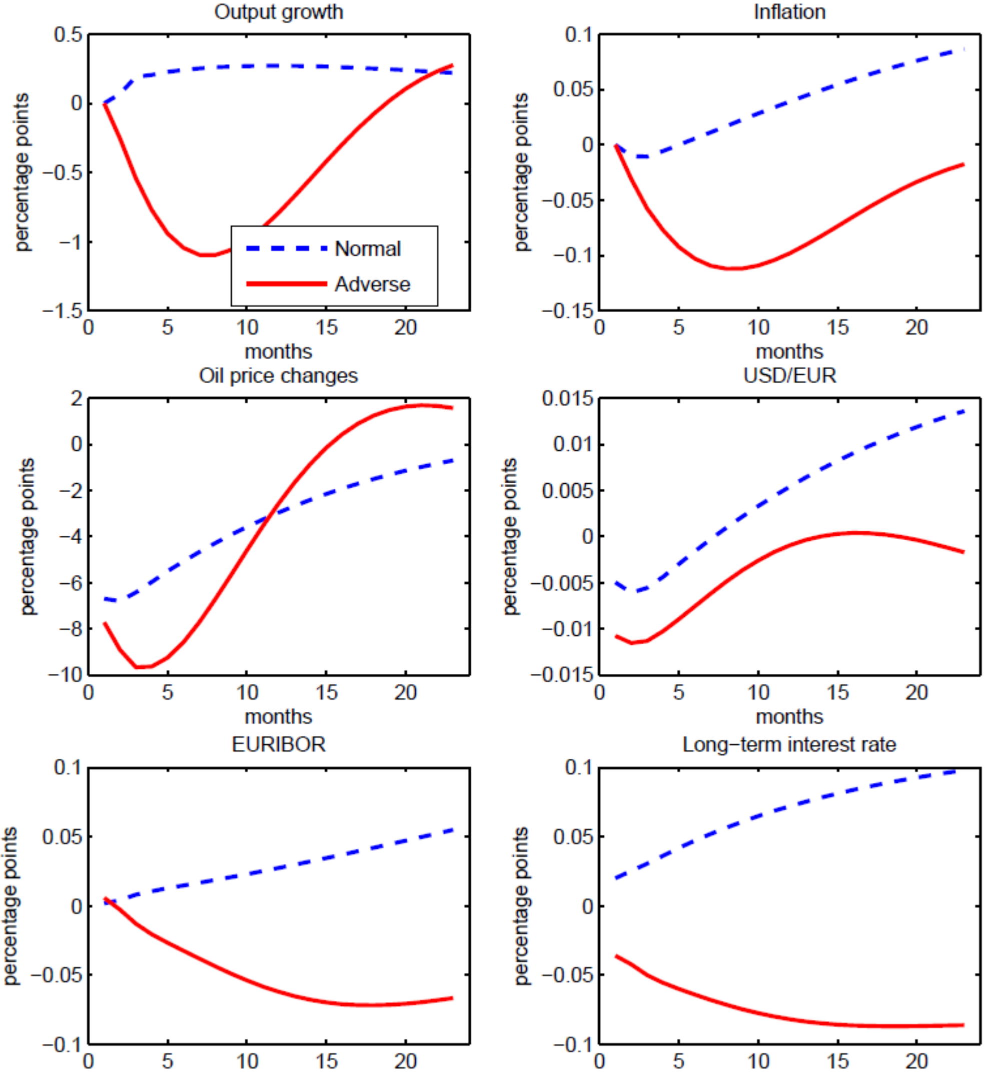



## Main findings

- 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

# Extension of Sample until December 2015, with long-term interest rate

## Impulse response functions

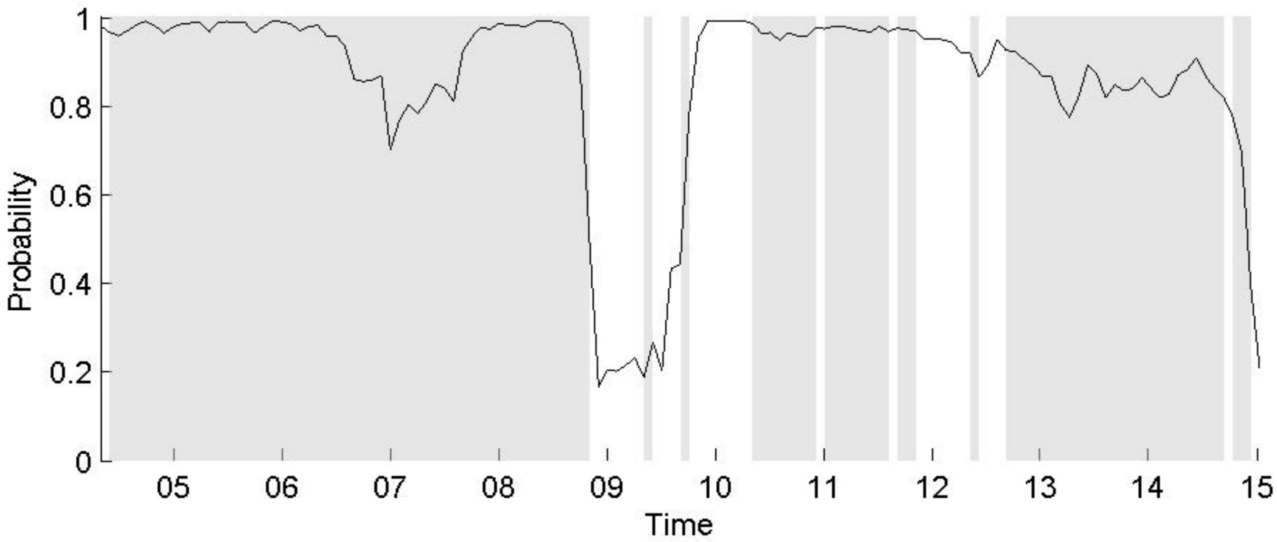



## Main findings

- 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)**

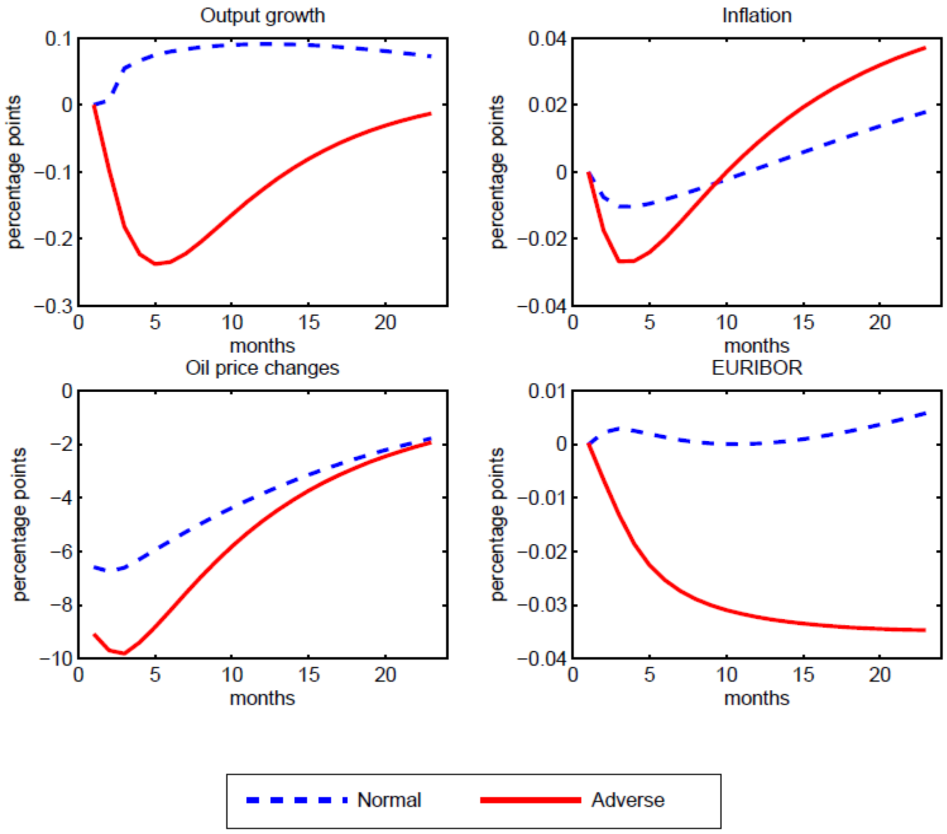



Note: on the x-axis ’05 refers to the beginning of the year 2005 etc.

- 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)

## Impulse response functions

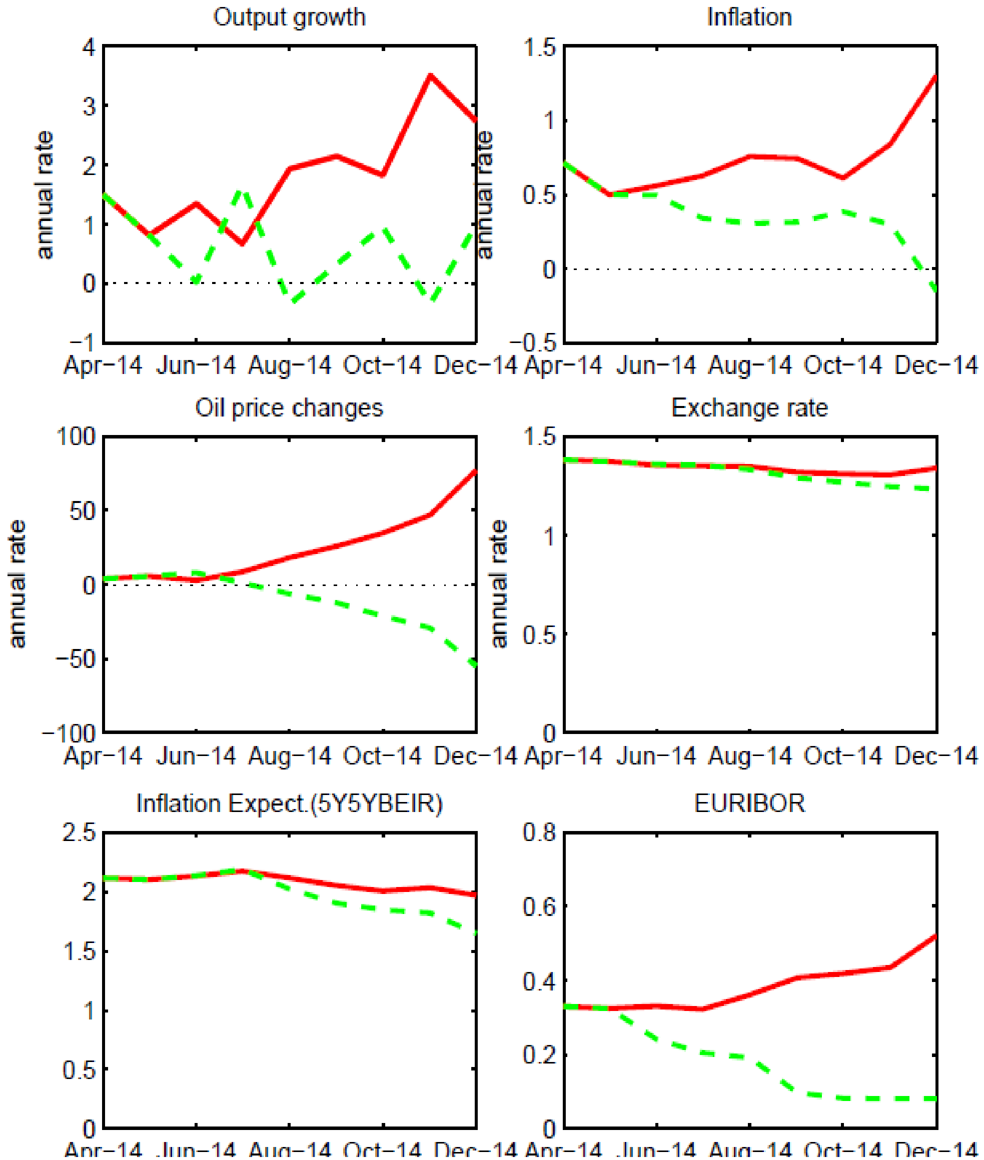



## Main findings

- 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

## Counterfactual Experiment

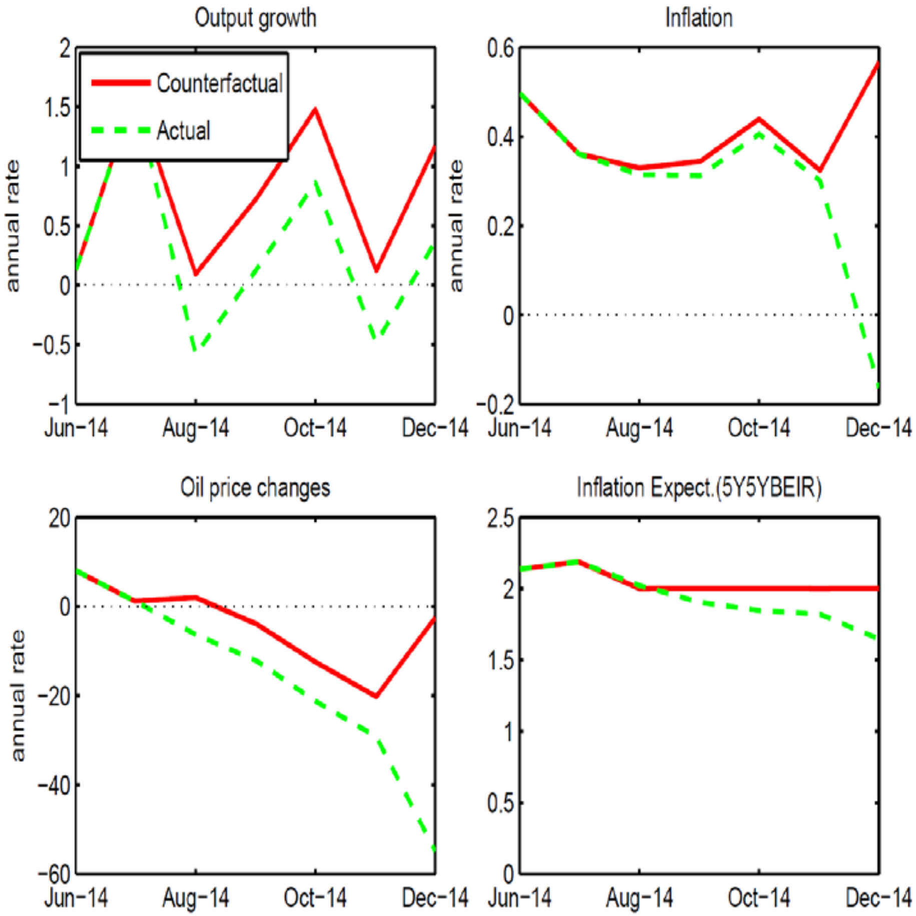



## Main findings

- 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

# Counterfactual

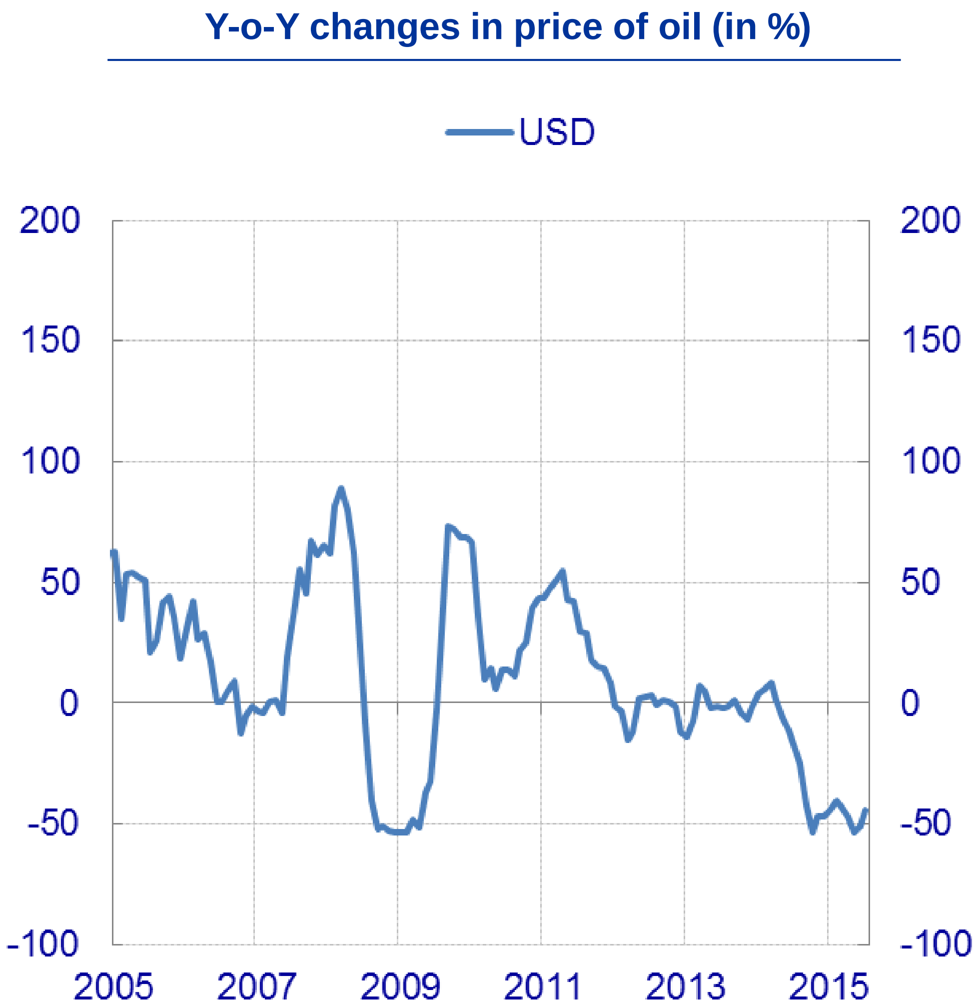
## Counterfactual Experiment




## Main findings

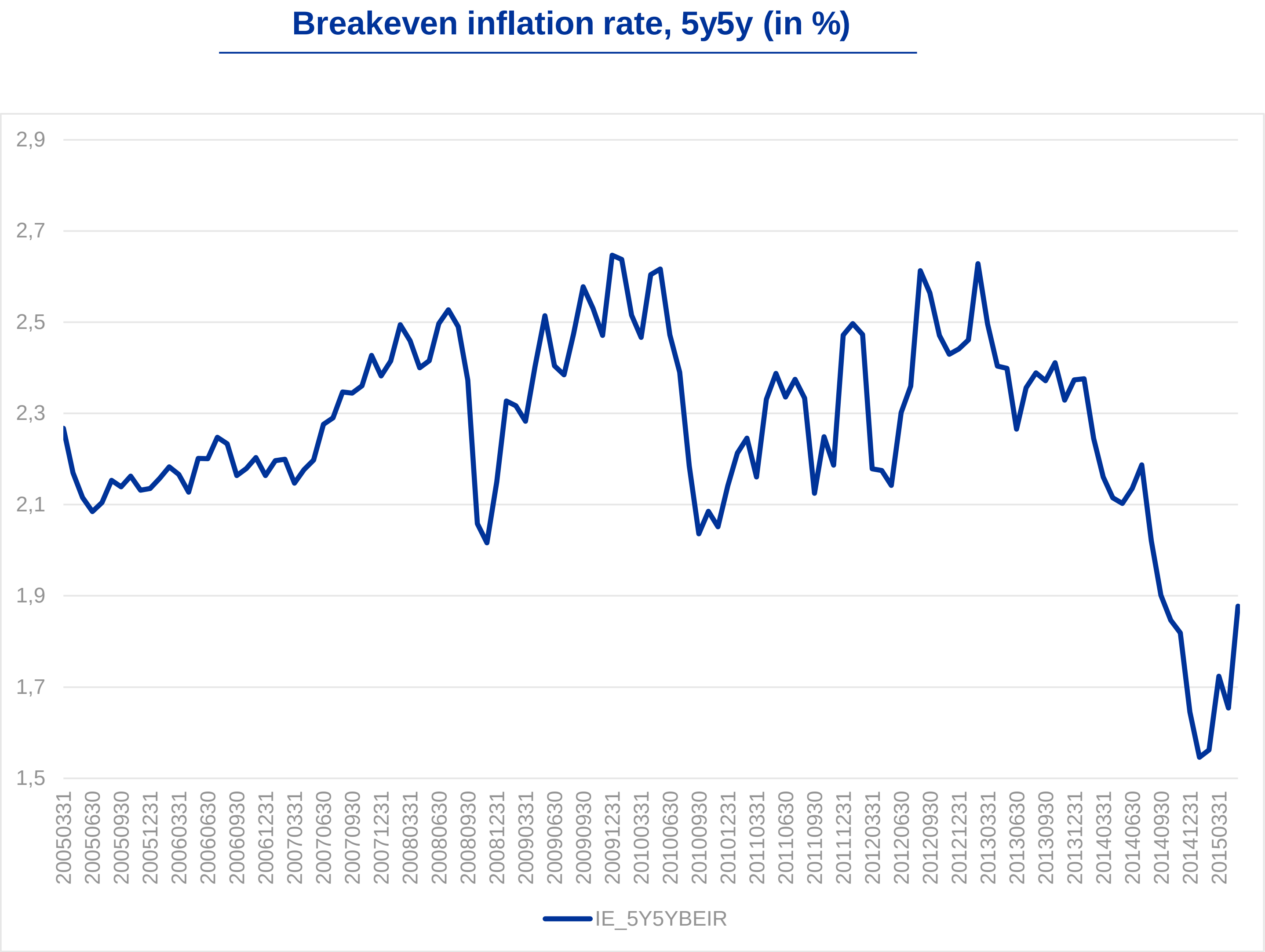
- Consider regime switch in August 2014: What if no regime change?
- Assume inflation expectations do not drift down
- Impose actual average interest rate path
- Actual compared to Counterfactual path
  - Higher path for oil price and inflation expectations
  - Growth and inflation higher

# Evolution of oil-price changes (variable included in VAR)



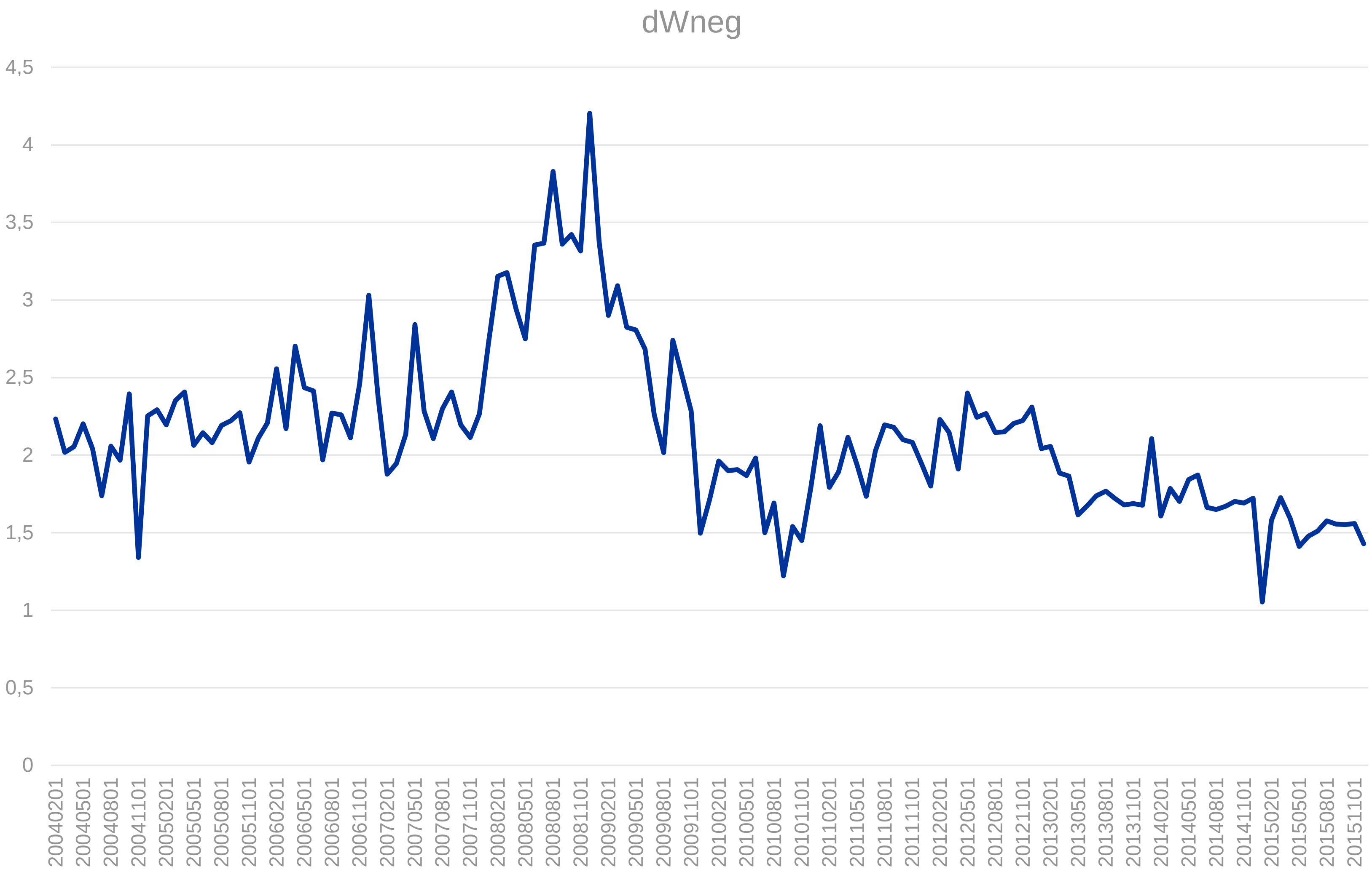

Source: Bloomberg

# Evolution of inflation expectations (variable included in VAR)



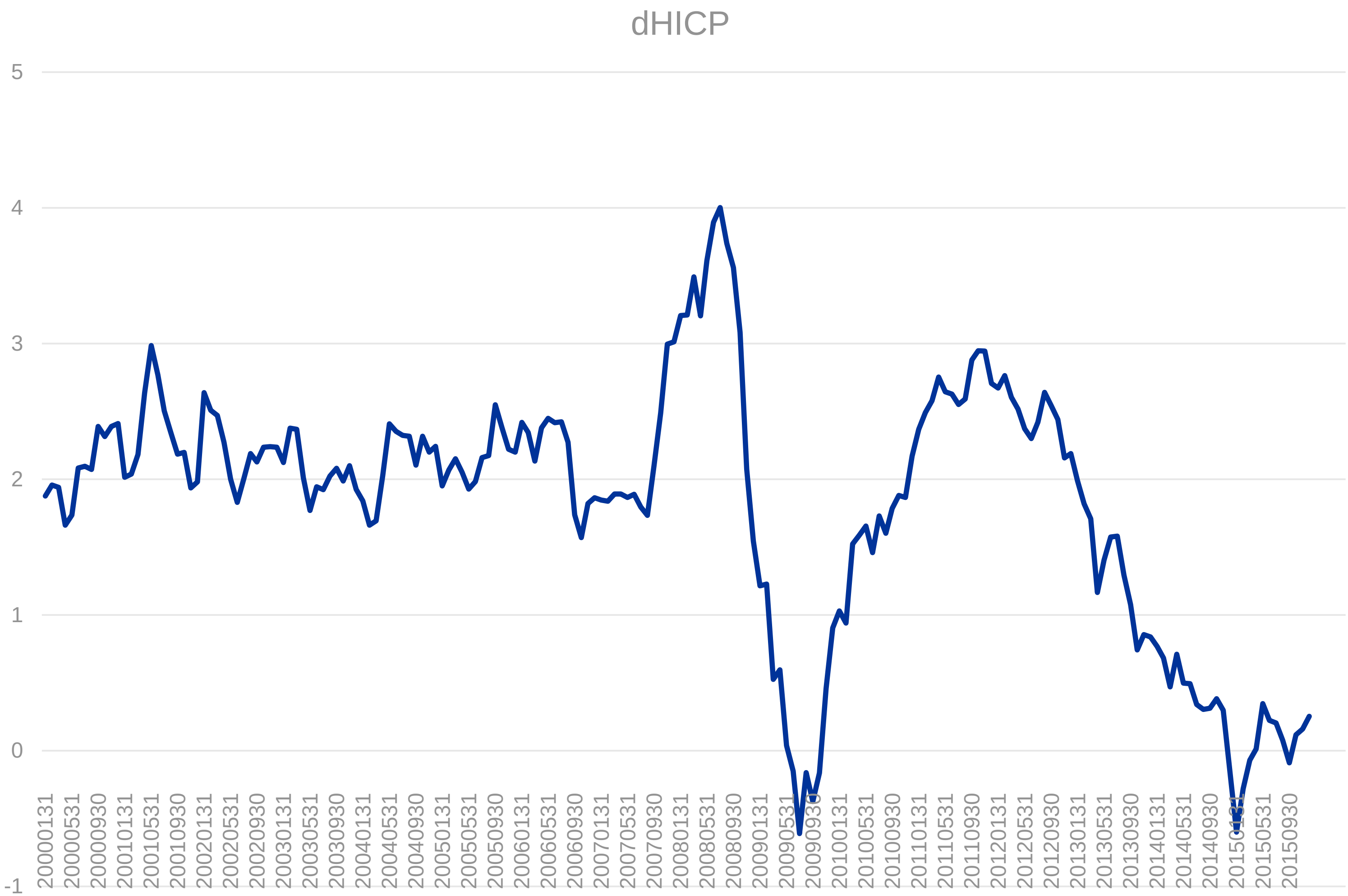
# Nominal wage changes (variable included in VAR)

**Nominal wage changes (yoy change in %)**



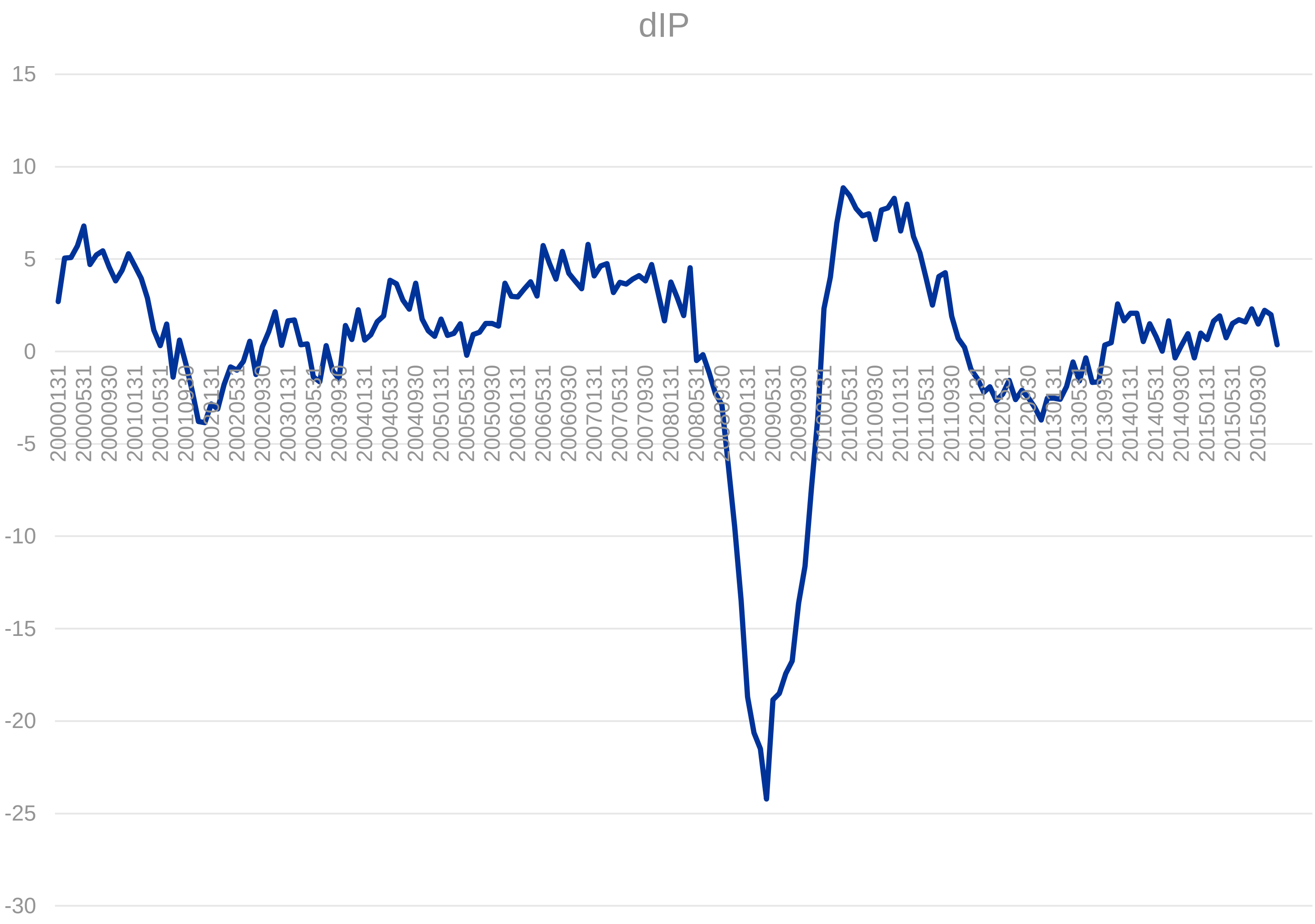
# Inflation (variable included in VAR)

**HICP (yoy change in %)**

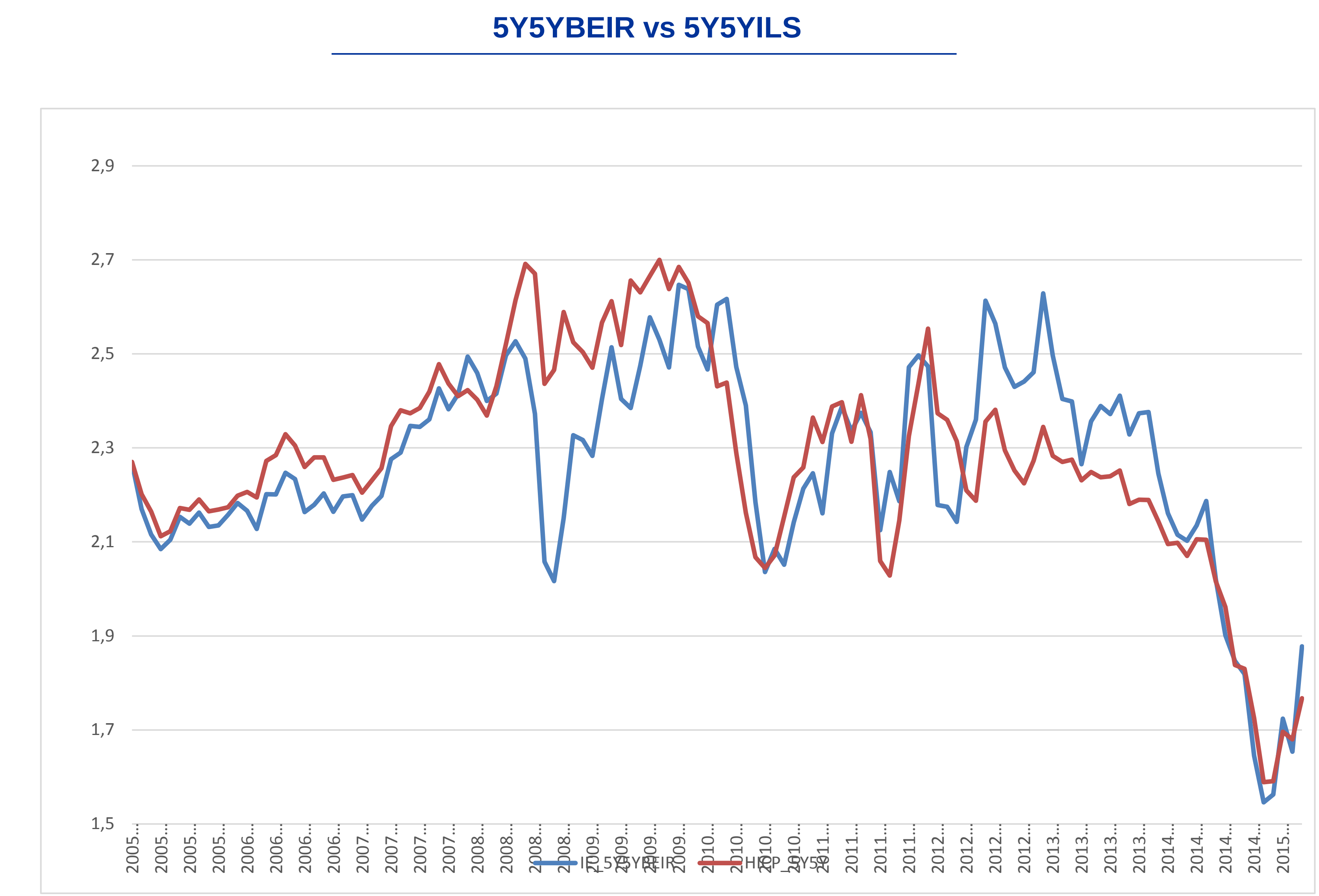


# Industrial production growth (variable included in VAR)

**Industrial production growth (yoy change in %)**



# 5Y5YBEIR vs 5Y5YILS



## 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)