Macroeconomic implications of oil price fluctuations: a regime-switching framework for the euro area

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Abstract

We use a Markov-switching VAR, estimated with Bayesian methods, to study the response of the euro area economy to oil price shocks. The model identifies two regimes that are characterized by qualitatively different patterns in economic activity and inflation after oil price shocks. In the *normal regime*, oil price shocks are followed by only limited and short-lived adjustments in these variables. In the *adverse regime*, by contrast, oil price shocks set in motion sizeable and sustained macroeconomic fluctuations, with inflation and economic activity moving in the same direction as the oil price. The response of inflation expectations points to second-round effects as a potential driver of the dynamics characterising the adverse regime. The systematic response of monetary policy works against such second-round effects in the adverse regime but is insufficient to fully offset them. The model also delivers (conditional) probabilities for being (staying) in either regime, which may help interpret oil price fluctuations – and inform deliberations on the adequate policy response – in real-time.

JEL Classification: E31,E 52, C32

Keywords: *Markov Switching models, time-varying transition probabilities, oil prices, inflation expectations, inflation*

[2]We thank Lutz Kilian, Hans-Joachim Klöckers, Wolfgang Lemke, Simone Manganelli, Roberto Motto, Massimo Rostagno, conference participants at the International Association for Applied Econometrics Conference 2016, the Oxmetrics Conference for Macroeconomics and Finance 2016, and the 10th International Conference on Computational and Financial Econometrics, as well as seminar participants at Princeton University, the European Central Bank and the US Federal Reserve Board for useful comments. The authors can be contacted at federic.holm-hadulla@ecb.europa.eu and kirstin.hubrich@frb.gov. We also thank Nikolaj Broberg, Mattia Colombo, and Nick Ligthart for excellent research assistance. The views expressed here are those of the authors and do not necessarily reflect those of the European Central Bank or the Federal Reserve System or the staff of either of these institutions.

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.

(The Wall Street Journal, November 14, 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, December 4, 2014)

1 Introduction

How has the sharp oil price decline since mid-2014 affected macroeconomic prospects in the euro area? Like in previous episodes of major oil price fluctuations, this question has generated substantial debate – and strongly divergent assessments – in the economics profession. Adopting a benign view, several observers have argued that the lower oil price will support the economic recovery by raising real disposable incomes and profits of euro area households and firms. Others, instead, have cautioned that the oil price slump may become entrenched in inflation expectations, thus leading to second-round effects that reinforce the prevailing disinflationary pressures and potentially dampen the recovery.[1]

From a monetary policy perspective, it is crucial to establish the relative merit of these different assessments. Judging by public statements of policy-makers in various jurisdictions, central banks would typically consider changing the monetary policy stance only in the latter scenario, in which oil price fluctuations feed through to inflation expectations, hence risking to exert long-lasting effects on inflation. By contrast, absent such second-round effects, central

[1] See, for instance, Mohaddes and Pesaran (2016) for a benign interpretation and Obstfeld et al. (2016) for an adverse interpretation of this recent collapse in oil prices. An analogous debate took place in the context of the steep upward trend in oil prices starting in end-2003 and accelerating from early-2007 to mid-2008, when some observers expressed concerns that second-round effects may lead to sustained inflationary pressures, whereas others contested this claim. For a summary of the debate at that time, see Hannon (2008).

banks would tend to preserve the prevailing monetary policy stance, thus 'looking through' the oil price fluctuations.[2]

To operationalise this nuanced reaction function, central banks in turn have to take a stand on which scenario they consider more likely to prevail; and, since the occurrence of second-round effects may be an episodic phenomenon, they may have to update this assessment on a regular basis. At the same time, a large body of literature has shown that policy mistakes in either direction (*i.e.* overly activist monetary policy responses to oil price fluctuations that may prove to be transient, as well as overly inertial monetary policy that allows inflation expectations to become unanchored) may severely hamper macroeconomic performance.[3]

The aim of the current paper is to examine whether the notion of episodic changes in the macroeconomic implications of oil price fluctuations finds empirical support in the euro area context. To this end, we use a Markov-switching vector autoregression (MS-VAR) model, estimated with Bayesian methods, that allows for time-variation in model coefficients, thus helping to detect regime-dependent differences in how economic activity and inflation evolve in the aftermath of oil price shocks (henceforth referred to as *coefficient switching*). The model also allows for time-variation in shock variances (*variance switching*) since regime-dependent differences in macroeconomic dynamics could also result from unusual sequences of shocks in certain episodes. Accounting for variance switching helps avoid that these differences are wrongly attributed to coefficient switching, which is the key hypothesis in the debate on second-round effects.[4]

In terms of methodology, we employ the MS-VAR model developed in Hubrich et al. (2015). In contrast to earlier MS-VAR models, such as those proposed in Sims et al. (2008)

[2]See for instance ECB President Mario Draghi before the European Parliament on June 23, 2011: *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.* A similar distinction emerges from Chair Yellen's assessment in the December 12, 2015 press conference: *For a number of years between 2004 and 2008, we had a series of increases in oil prices that (...) raised inflation (...) and we judged those increases to be transitory as well and looked through them. We do monitor inflation expectations very carefully. If we saw in a meaningful way that inflation expectations were either moving up in a way that made them seem unanchored or down, that would be of concern.*

[3]See, for instance, Bernanke et al. (1997); Barsky and Kilian (2001); Bodenstein et al. (2008); Nakov and Pescatori (2010); Kormilitsina (2011); Bodenstein et al. (2012); and Natal (2012).

[4]The importance of time-variation in the variance of key macroeconomic aggregates has most clearly emerged from the analysis of competing explanations for the steep decline in inflation and output volatility since the mid-1980s (often referred to as the Great Moderation); see, for instance, Primiceri (2005); Sims and Zha (2006); and Justiniano and Primiceri (2008).

and Hubrich and Tetloff (2015), this framework includes time-varying transition probabilities that depend on the state of the economy. Moreover, the method developed in Hubrich, Waggoner and Zha (2015) is, to our knowledge, the first to incorporate time-varying transition probabilities in a VAR framework. We discuss related autoregressive and single equation regression models suggested in the literature in section 2.

The analysis provides evidence of two regimes that are characterized by qualitatively different patterns in economic activity and inflation after oil price shocks. In the *normal regime*, oil price shocks (leading for instance to a drop in the price of oil) is followed by only transitory and moderate declines in inflation and a small increase in economic activity, which may attenuate the initial disinflationary effect of the oil-price declines. In the *adverse regime*, by contrast, the responses of economic activity and inflation are much more sizeable and sustained than in the normal regime and both variables move in the same direction as the oil price shock. Market-based measures of inflation expectations, which may act as a symptom for the presence of second-round effects, also show striking differences across regimes. While, in both regimes, inflation expectations initially adjust in the same direction as the oil price shock, this impact is again moderate and transitory in the normal regime whereas it is markedly stronger and persistent in the adverse regime. Overall, the dynamics characterising the adverse regime are consistent with the patterns to be expected in the presence of second-round effects that may amplify and prolong the impact of an oil price shock on inflation. The systematic response of monetary policy, in turn, works against such second round effects in the adverse regime but is insufficient to fully offset them.

The analysis also delivers time-varying probabilities that allow us to form a view on whether the euro area economy is more likely to be in one regime or the other at a given point in time, as well as the conditional probability of staying in that regime, provided it has previously prevailed. Since this information is available at regular (monthly) frequency, the model may provide information supporting the deliberations on the adequate response to observed oil price fluctuations in real-time.

These features also help us comment on past episodes and, *in particular*, the recent debate on the macroeconomic implications of the oil-price declines observed since mid-2014 until early-2015. Our model indicates that the euro area economy was in an adverse regime at that time and hence favours a pessimistic assessment of their implications for the strength of the euro area economy. Indeed, counterfactual experiments show that economic activity, inflation and inflation expectations over the second half of 2014 were much more sluggish than we would have expected, had the euro area not been mired in the adverse regime. These findings are robust to several modifications in the model set-up and sample periods considered in the analysis.

Relation to the literature. Our paper contributes to an active literature aiming to shed light on how the implications of oil price shocks may differ depending on macroeconomic circumstances. One strand of this literature focuses on the *sources* of the underlying oil price shocks as a determinant of its macroeconomic implications. To this end, several papers – including Kilian (2008, 2009), Peersmann and Van Robays (2009), Baumeister and Peersman (2013), Kilian and Murphy (2014), and Baumeister and Hamilton (2015) – have used structural VAR frameworks to model the global crude oil market and found that the macroeconomic consequences of oil price fluctuations differ depending on whether they originate from an oil supply shock, an increase in aggregate demand, or an increase in the precautionary demand for oil. A second strand of this literature focuses on differences in the *transmission* of oil price shocks, either by comparing pre-defined historical episodes (as in Blanchard and Galí (2007) and Nakov and Pescatori (2010));[5] or by developing models that explicitly allow for non-linearities (as in Hamilton (2003)) and time-variation in the impact of oil shocks (as in Van Robays (2012) and Baumeister and Peersman (2013)).[6] A third strand relevant to our analysis evaluates how central banks respond to oil price shocks, often resorting to structural (DSGE) models to assess welfare implications.[7]

Our paper is closest to the second strand of the literature in that it also explicitly models time-variation in the effect of oil price shocks. But, to our knowledge, it is the first paper to: *(i)* account for such time variation in the euro area context; *(ii)* grant an explicit role to inflation expectations in the propagation of oil price shocks; and *(iii)* use a Markov-switching

[5] Nakov and Pescatori (2010) analyse changes in oil price effects on the US economy before and after the Great Moderation in an estimated DSGE model, splitting the sample in the year 1984; Blanchard and Galí (2007) adopt a similar sample-split, but also consider VAR over rolling time windows.

[6] Van Robays (2012) uses a threshold VAR model to assess how macroeconomic uncertainty changes the impact of oil price shocks. Baumeister and Peersman (2013) use a time-varying BVAR to assess whether the prevalence of different sources of oil price shocks and their macroeconomic implications have changed over time.

[7] See papers quoted in footnote 3.

model with endogenous switching to analyse oil price shocks. Moreover, our model allows us to comment on the monetary policy response to oil price shocks in the different regimes; and, in particular, to evaluate the extent to which it counteracts the dynamics observed in the adverse regime.

The remainder of the paper is organized as follows. Section 2 presents the methodology underlying the regime-switching model. Section 3 shows how the estimated economic responses to oil price shocks differ depending on the prevailing regime; reports how the estimated (conditional) probability of being (staying) in a certain regime has evolved since the start of the sample period; and zooms in on the episode of collapsing oil prices since mid-2014, using counterfactual experiments to trace out how the euro area economy would have been expected to behave, had it not been mired in the adverse regime. Section 4 modifies and extends the baseline specification before section 5 concludes.

2 Methodology

We employ the Markov-Switching Vectorautoregressive (MS-VAR) model with time-varying transition probabilities developed in Hubrich, Waggoner and Zha (2015) (henceforth HWZ15).

Most of the methodological literature focusses on models with constant probabilities of Markov switching, including the seminal paper by Hamilton (1989), as well as the subsequent contributions by Chauvet (1998), Kim and Nelson (1999), Fruehwirth-Schnatter (2004), Sims and Zha (2006), Sims, Waggoner, Zha (2008) and Hubrich and Tetlow (2015).

A parallel strand of the literature allows for time-variation in the probability of Markov switching but resorts to univariate or multivariate regression set-ups; see: Filardo (1994), Diebold, Lee and Weinbach (1994), Kim (2004), Kim, Piger and Startz (2008), Amisano and Fagan (2010), Chang, Choi and Park (2014) as well as Bazzi, Blasques, Koopman and Lucas (2014). In these papers the probability of regime switching depends on certain variables of interest, but the regression set-ups do not permit feedback effects among the endogenous variables.

Building on and extending the framework presented in Sims, Waggoner, Zha (2008) (SWZ08), the MS-VAR model by Hubrich, Waggoner and Zha (2015) used in this paper combines these different strands of the literature. It allows for time-varying transition probabilities which depend on the state of the economy while modelling the interdependencies of the endogenous variables and imposing structural identifying assumptions.

2.1 Model

For $1 \leq t \leq T$, let y_t be an n-dimensional vector of endogenous variables, let z_t be an m-dimensional vector of exogenous variables, and let s_t be a discrete latent variable taking h distinct values. Let Θ be a vector of parameters controlling the distribution of y_t and let q be a vector of parameters controlling the process s_t. We will denote $\{y_1, \cdots, y_t\}$ by Y_t, $\{z_1, \cdots, z_t\}$ by Z_t, and $\{s_1, \cdots, s_t\}$ by S_t. We assume the distribution of the exogenous variable z_t satisfies

$$p(z_t | s_t, Y_{t-1}, Z_{t-1}, \Theta, q) = p(z_t | Z_{t-1}). \tag{1}$$

In this paper, we consider the time varying structural vector autoregression (SVAR) defined by

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

where

$$x_t' = \left[y_{t-1}', \cdots, y_{t-p}', 1 \right],$$

ε_t is a standard normal vector of shocks, and s_t^c and s_t^v take on values in $\{1, \cdots, h^c\}$ and $\{1, \cdots, h^v\}$, respectively. In the notation of equation 1, $s_t = (s_t^c; s_t^v)$, with the number of regimes for each Markov process being $h = h^c, h^v$ and the only exogenous variable being a constant, $z_t = 1$; in this paper, we allow for two coefficient regimes and for two shock-variance regimes. The vector Θ consists of the elements of $A_0(s_t^c)$, $A_+(s_t^c)$, and $\Xi(s_t^v)$.

2.2 The Transition Matrix

We denote $p(s_{t+1} = i | s_t = j, Y_t, Z_t, \Theta, q)$ by $p_{i,j,t}$ and assume that the diagonal elements are of the form,

$$p_{j,j,t} = \frac{1}{1 + e^{-u_j}}$$

where

$$u_j = c_j + \gamma_j y_{t,t-k+1}.$$

and $y'_{t,t-k+1} = [y'_t, \cdots y'_{t-k+1}]$. To achieve parsimony in the context of this complex specification, in our model we choose $k = 1$ and most of the elements of γ_j will be restricted to zero. The off-diagonal will be of the form

$$p_{i,j,t} = (1 - p_{j,j,t})\hat{p}_{i,j}$$

where $\sum_{i \neq j} \hat{p}_{i,j} = 1$. The prior on the parameters c_j and γ_j will be normal. In our model, the probability of staying in one of the two coefficient regimes ($p_{j,j,t}$) is a function of the change in oil prices.

2.3 Estimation procedure, data and identification

We present our empirical results in terms of estimates at posterior mode. The posterior mode is estimated via a blockwise BFGS optimization algorithm following SWZ08.

The MS-VAR, in the baseline specification, includes: euro area industrial production as a measure of economic activity (which, in contrast to data on real GDP, is available at monthly frequency); the euro area Harmonized Index of Consumer Prices (HICP) as a measure of inflation; the Brent crude oil price (in current US-Dollars); the bilateral US-Dollar/Euro exchange rate;[8] 5-year/5-year break-even inflation rates as a market-based measure of long-term inflation expectations; and the 3-month EURIBOR as a measure for short-term interest rates.[9]

For identification, we apply a Cholesky decomposition. In our baseline specification, the variables are ordered as in the previous paragraph, which implies that we impose a zero restriction on the contemporaneous effect of oil price shocks on economic activity and inflation, while allowing the oil price to react to these variables immediately. This assumption is consistent with the approach adopted, for instance, in Bernanke et al. (1997) and Christiano et al. (1996) and may be motivated by the role of oil as a globally-traded financial asset whose price

[8]One of the modifications of our baseline specification directly include oil prices in Euro and therefore drop the exchange rate from the system of equations.

[9]Industrial production, HICP and oil prices are included as year-on-year percentage changes and the remaining variables are defined in percent.

could, in principle, reflect any relevant information at high frequency, whereas adjustments in industrial production and overall price dynamics in the economy are likely to proceed at a more sluggish pace.[10] At the same time, substantial parts of the related literature have adopted an alternative approach, treating oil prices as predetermined with respect to innovations in economic activity and inflation – an assumption that received empirical support from Kilian and Vega (2011).[11] Against this background, and in line with the related literature, we thus assessed the robustness of our model to an alternative ordering (with oil prices ranking first) and found our key findings to remain broadly unchanged.[12]

The basic sample includes euro area data at monthly frequency over the period from February 2004 to January 2015 and, for some of the model extensions, the period from February 2004 to December 2015. The starting point of the sample is dictated by the availability of data on break-even inflation rates, which were not recorded in a consistent manner prior to February 2004 (neither were any other market-based measures of long-term inflation expectations and survey-based measures of inflation expectations are generally not available at monthly frequency).

The use of different sample end-dates is motivated by the evolution of the macroeconomic environment over recent years: to keep the baseline model tractable, it includes one short-term interest rate variable to capture the prevailing monetary policy stance; however, since mid-2014, and even more forcefully since end-January 2015, the ECB has started relying on asset purchase programmes to inject additional monetary policy accommodation, also reflecting an increasingly limited scope for further reductions in monetary policy interest rates. Since such central bank asset purchases directly intervene at the longer end of the yield curve, it appears more suitable to move to a broader specification in this environment, including also a longer-term interest rate to provide a more comprehensive characterization of the monetary policy stance.

For this reason, we first estimate the baseline model over a shorter sample period until end January 2015, before the ECB engaged in its expanded asset purchase programme (see

[10] See Fratzscher et al. (2014).

[11] See, e.g., Davis and Haltiwanger (2001), Kiseok and Ni (2002), Leduc and Sill (2004), Blanchard and Galí (2007) and Kilian and Lewis (2011).

[12] For example, Blanchard and Galí (2007) explore different orderings for the price of oil whereas Rotemberg and Woodford (1996) approach similar endogeneity concerns through sample splits.

section 3); second, we extend the model to also include data for the entire year 2015 and add a measure for the long-term interest rate as a further variable to the model (see section 4).

3 Regime-dependent effects of oil price shocks – baseline results

Impulse Responses. The results from our baseline specification, shown in Figure 1, provide evidence of two regimes that are characterized by very different patterns in economic activity and inflation in response to the oil price shock. In the *normal regime* (slashed blue line) oil price shocks are followed by only small macroeconomic fluctuations. Inflation briefly declines after the shock, but only by a few basis points and the decline is fully reversed over the 24-months horizon for which impulse response functions are shown. Inflation expectations follow a similar path as actual inflation, declining slightly after the shock but then recovering after a few months. Economic activity, in turn, increases slightly after the shock (in line with the benign interpretation of the oil price shock as supporting domestic demand) – and so does the short-term interest rate, consistent with the more dynamic economic conditions observed in the aftermath of the oil price shock.

In the *adverse regime* (solid red line), the oil price shock is slightly larger on impact (in both regimes, the shock is calculated as one standard deviation of the observed oil price moves over the time periods when the respective regime prevailed; accordingly, the difference in the magnitudes of the respective shocks indicates that oil prices tended to be somewhat more volatile in the adverse regime). But the oil price then recovers more quickly than in the normal regime and, overall, does not display strikingly different patterns across regimes.

The impact of the shock on the other variables in the system does, however, differ in relevant ways. Instead of rising, as in the normal regime, economic activity declines, hitting a trough after two quarters that is almost a percentage point below steady state and, despite some recovery, remains below steady state levels until the end of the horizon. In contrast to the benign regime, where economic activity acts as a stabiliser, this downward effect of the oil price shock on economic activity thus tends to amplify the disinflationary forces. As a consequence, actual HICP inflation undergoes a pronounced and persistent decline, settling almost 0.2 percentage points below steady state by the end of the horizon. This decline is also reflected in inflation expectations, which show a similarly modest drop on impact as in the normal regime, but then continue to drift down over the entire horizon.[13]

Overall, the dynamics observed in the adverse regime are consistent with second round effects exerting a protracted adverse impact on the economy, translating into declines in actual as well as expected inflation. While the short-term interest rate declines in response to the shock, the resultant monetary loosening is not sufficient to offset the disinflationary forces.[14]

Failing to account for these regime-dependent dynamics may lead observers to miss important characteristics of the inflation process and economic activity in the aftermath of an oil price shock. This becomes clear when comparing the impulse response functions from a constant parameter VAR (also plotted in Figure 1 via the dotted black line) with those from the regime-switching model. In particular, restricting coefficients and variances to be constant may lead observers to underestimate the pronounced and persistent effects that oil price shocks may exert on economic activity and inflation in the adverse regime, while providing the wrong sign for output and inflation response in the normal regime. Both types of misjudgement may, in turn, contribute to policy mistakes in the response to oil price shocks.

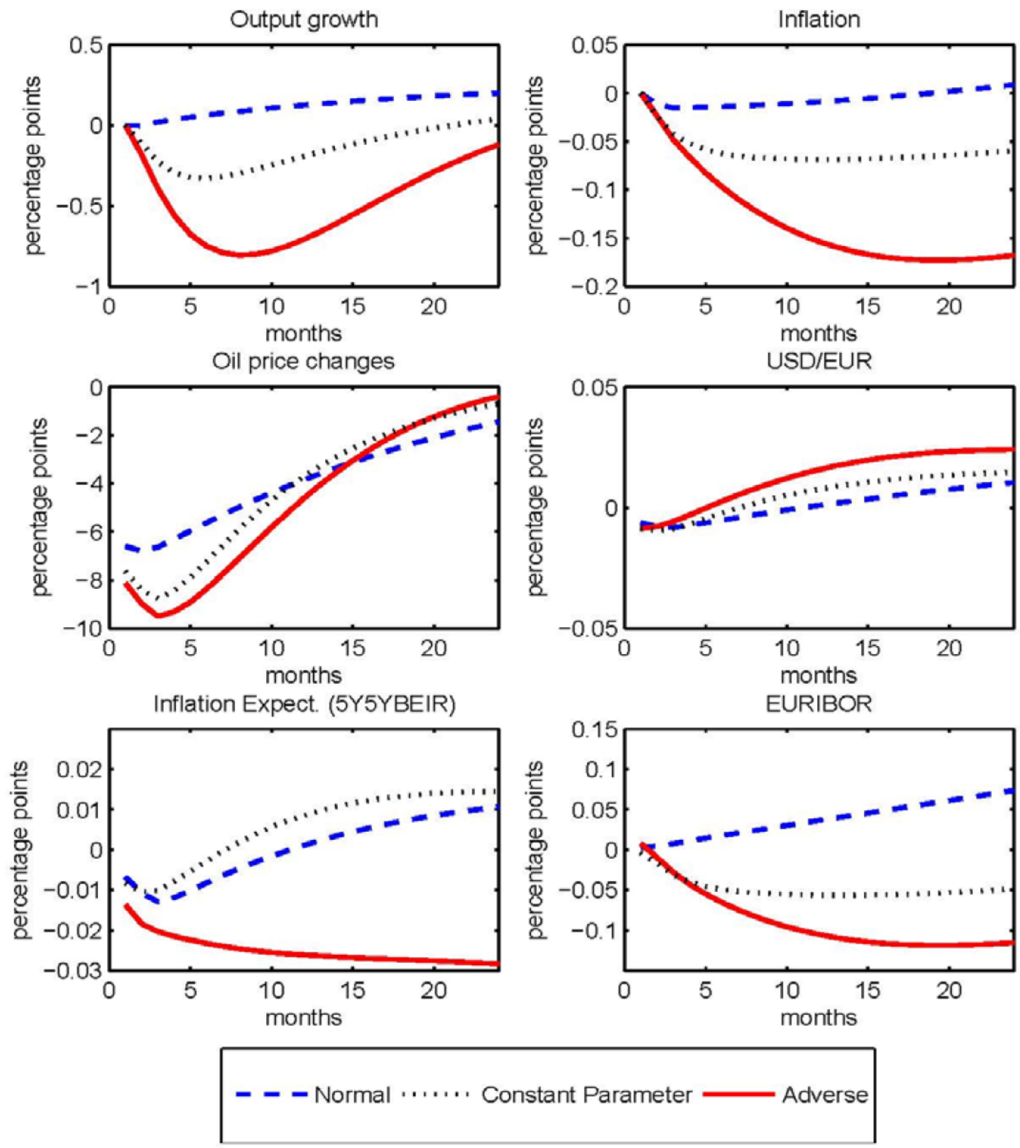
Regime probabilities. Figure 2 displays smoothed probabilities of being in a normal regime (with grey-shaded areas showing periods in which this probability exceeded 50%) and the time-varying conditional probabilities of staying in a normal regime (depicted by the solid black line).

The smoothed probabilities show that the euro area economy entered the adverse regime at various occasions since the start of the sample. Typically, regime-switches occurred after a sequence of pronounced, unidirectional oil price changes – for instance in the episodes of strong oil price declines and subsequent increases over the period 2008-2011 (for reference, see Figure 6 plotting the evolution of oil prices over the sample period). In August-2014, the euro area economy again switched to the adverse regime and, after a short period in the normal

[13]One could argue that, under certain circumstances, an adjustment in inflation expectations as observed in the adverse regime may support the central bank in counteracting deviations of inflation rates from its preferred levels. For instance, if oil prices suddenly rise in conditions of below-target inflation rates, an upward adjustment in inflation expectations may accelerate the return to target. Still, we consistently refer to this regime as "adverse" based on the well-established notion that a de-anchoring of inflation expectations generally renders a central bank's macroeconomic stabilization objectives harder to a achieve; see Woodford (2007).

[14]Exchange rates do not play a major role in the adjustment dynamics, possibly reflecting the countervailing effects of the declining oil price, which would tend to induce an appreciation of the Euro versus the US-Dollar, and the weakening euro area economy, which would induce a depreciation.

Figure 1: Impulse responses to oil price shock (one standard deviation shock), slashed blue: normal regime, solid red: adverse regime



regime in the last quarter of 2014, returned to the adverse regime by the turn of the year.

Meanwhile, the conditional probability of staying in a normal regime (given the economy was in that regime), which is a function of the oil price evolution, declined steeply just before the economy transitioned to the adverse regime in late-2008. After a prolonged period with a high conditional probability of staying in the normal regime (which starts in end-2009 – before the smoothed probabilities actually indicate a return to the normal regime), this probability again fell steeply in the second half of 2014 and approached zero by January 2015.

Accordingly, our model clearly assigns the period from August 2014 to January 2015, which had triggered intense debate among the policy observers (see section 1), to the adverse regime. Hence, the regime-switching framework indicates that the oil price declines observed over that period are likely to have reinforced the prevailing disinflationary pressures via second-round effects, thus favoring the more pessimistic assessment of that episode.

Discussion. It is interesting to relate these findings to the strand of the literature that emphasises different sources of oil price shocks as a key determinant of their macroeconomic effects. When comparing the impulse response functions between the normal and the adverse regimes, important parallels emerge with that literature. In the normal regime, the macroeconomic adjustments to oil price fluctuations resemble the dynamics one may expect after a genuine supply-driven shock: in response to falling oil prices, for instance, euro area economic activity temporarily strengthens, consistent with increased disposable income for euro area households and reduced energy input costs for euro area producers; meanwhile, the oil price decline initially exerts some moderate direct downward pressure on inflation, probably reflecting the role of energy in the consumption basket and some pass-through of lower input costs to consumer prices, but the decline is quickly offset by the uptick in activity. Consistent with the short-lived inflation response, inflation expectations quickly return to steady state.

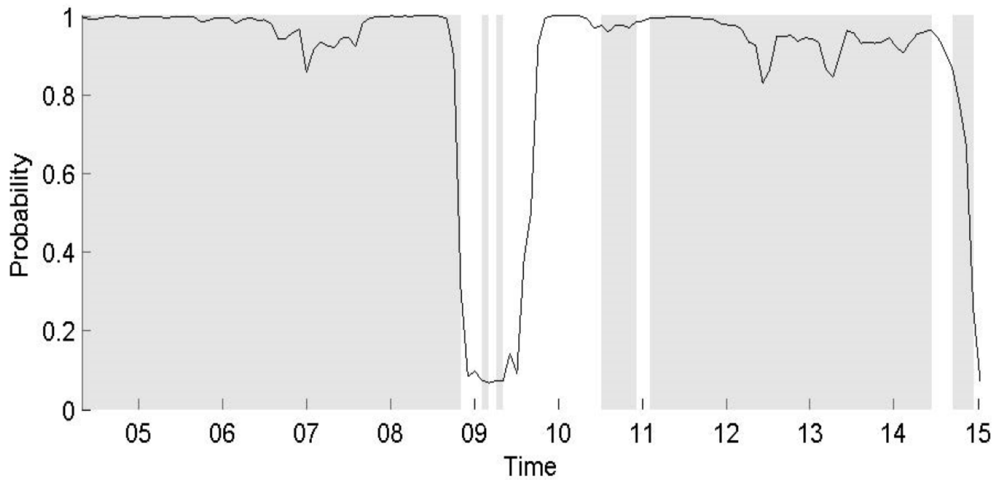
In the adverse regime, by contrast, the co-movement patterns are closer to what may be expected in response to a global demand-driven oil price shock. Again resorting to the example of falling oil prices, the concomitant protracted slump in economic activity, which materialises despite an initial beneficial effect on euro area disposable incomes and input costs, is consistent with a situation in which the oil price decline signals a downgrade in broader economic prospects, inducing firms and households to revise down their expectations for future inflation and, via this channel, providing an incentive to postpone nominal spending decisions to future. This inter-temporal substitution, in turn, further depresses domestic activity and reinforces the downward pressure on inflation, thus giving rise to second round effects.

While these parallels are intuitively plausible, the overlap between the different approaches remains partial. First, the regime-switching framework produces a sharper distinction in the estimated impulse response functions between the different regimes than what the related literature finds for different types of shocks in the euro area context. For instance, Peersmann and Van Robays (2009) find a quantitatively similar, positive, impact of oil price increases on euro area inflation, independently of whether it is driven by a supply or demand shock (in contrast to the qualitatively different patterns observed in Figure 1). Second, the periods assigned to the adverse regime in our model have received different appraisals when viewed through the lens of the nature of shocks. For instance, the shock decompositions in Baumeister and Hamilton (2015) indeed attribute an important part of the oil price collapse at the onset of the 'Great Recession' in 2008 to global economic activity and oil demand shocks.[15] While our model also assigns the euro area economy to the adverse regime in this episode, this regime persists well beyond the period over which Baumeister and Hamilton (2015) see global economic activity and demand shocks to dominate; also, according to our model, the euro area economy re-enters the adverse regime around end-2010 to early-2011 – a period over which global activity and demand shocks have been fairly mute according to Baumeister and Hamilton (2015).

Accordingly, the regime-switching perspective constitutes an interesting complement to the existing literature that disentangles supply- and demand-factors causing oil price changes. In particular, by allowing for different propagation patterns of oil price shocks at different points in time and determining the probability of being in a specific regime, the model may add to policy-makers' information sets when deciding on the appropriate response to an observed oil price fluctuation.

[15] Baumeister and Hamilton (2015) measure global economic activity by industrial production in the OECD and six large non-OECD economies.

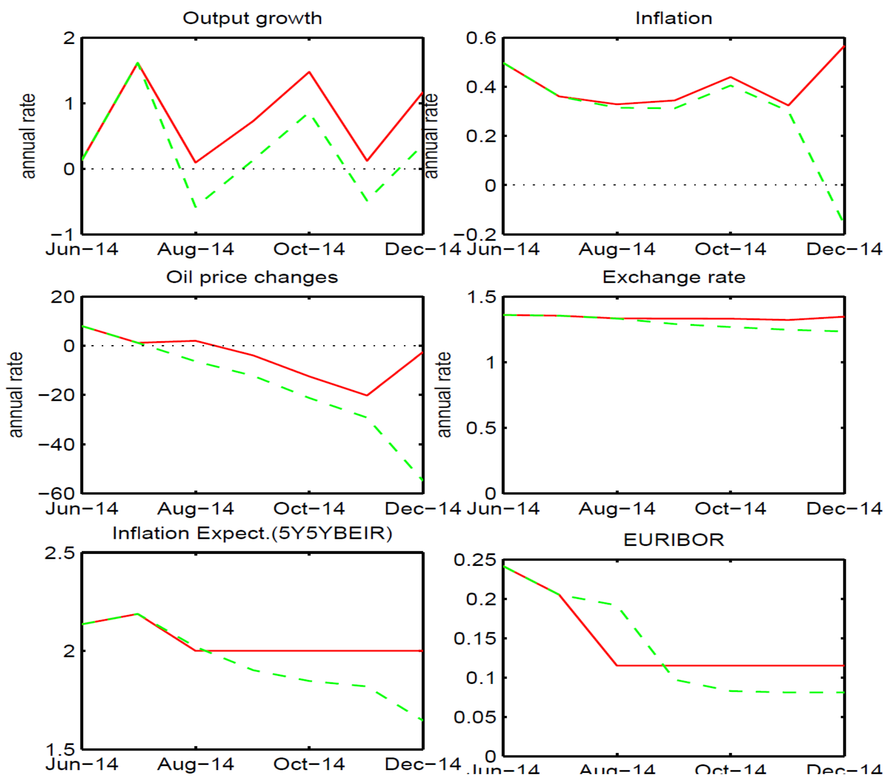
Figure 2: Time-varying probability being in a normal regime (grey-shaded area) and conditional probability of staying in that regime (black line)



Counterfactual experiments. As a final exercise with our baseline model, Figure 3 presents a counterfactual experiment that allows us to gain further insight into the contentious episode starting in the second half of 2014 and to illustrate how the dynamics of the system differ across regimes. The basic set-up of this counterfactual experiment is to trace out how the different variables would have evolved if the euro area economy had not been mired in an adverse regime. Moreover, the experiment assumes that inflation expectations had not drifted down and instead stabilised at the levels recorded in July-2014, *i.e.* before the switch to the adverse regime took place. This assumption is motivated by the prominent role of inflation expectations in the policy narrative on second-round effects adopted by several major central banks. Finally, the experiment imposes that short-term interest rates (on average) are the same across regime. The latter assumption serves to isolate the differences in key macroeconomic aggregates that derive from the change in regimes and from alternative paths for inflation expectations, while avoiding that the comparison is "contaminated" by differences in monetary policy.

The counterfactual points to striking differences in economic outcomes across regimes. In fact, according to our estimates, economic activity and inflation would have been almost 1 percentage point higher than observed by the end of 2014, had the normal rather than the adverse regime prevailed at that time and had inflation expectations not drifted down as they did. Interestingly, also the oil price decline would have been considerably less pronounced and essentially reverted to zero by the end of the simulation horizon. This would indicate that the weakness in euro area economic activity and inflation from mid-2014 to early-2015 has been one of the drivers of the global oil price collapse observed over that period.

Figure 3: Counterfactual Experiment: Normal regime instead of volatile oil price regime (green dashed line: actual data, red solid line: counterfactual path)



4 Extensions

Building on these findings, we modified and extended our baseline specification in the following ways. First, we estimated an alternative specification which – instead of including oil prices in US dollars and the USD/EUR bilateral exchange rate – directly expresses oil prices in euro and thus omits the exchange rate from the model. Second, we added a real long-term interest rate to the VAR and extended the sample period throughout 2015.

The first specification, expressing oil prices in euro, helps us reduce the relatively large size of the VAR and may be motivated by the fact that, ultimately, it is the oil price in euro that matters for euro area consumers and firms. As apparent from Figures 4 and 5 in the annex, this alternative specification confirms the key results from the baseline. In particular, the impulse response functions show nearly identical patterns for economic activity, inflation, and inflation expectations. Notably, the difference in the reaction of those variables between the different regimes is similarly pronounced. Also, the assignment of periods to different regimes is broadly unchanged, although there are some more switches to the adverse regime over the period 2010-2012 than in the baseline specification. The period around the turn of the year 2014 to 2015 is again assigned to the adverse regime and the drop in the conditional probability of staying in normal regime in the second half of 2014 is also confirmed by this alternative specification.

As explained in section 2.3, the inclusion of a long-term interest rate variable renders the model better suited to account for the effects of the ECB's expanded asset purchase programme adopted in January 2015 than if we just rely on the 3-months EURIBOR to capture the monetary policy stance.

Against this background, we computed impulse response functions for the extended model, which include, as a measure of the real long-term interest rate, the 10-year sovereign bond yields of euro area countries, weighted by their respective shares in euro-area GDP and deflated with market based inflation expectations over the same maturity. The impulse response functions confirm the findings from our baseline specification and the assignment of time periods to the two regimes largely corresponds to that deriving from our baseline specification.[16]

5 Conclusions

In this paper, we have analysed whether the dynamics of euro area economic activity and inflation following oil price shocks undergoes episodic changes. To this end, we used a Markov-switching BVAR with endogenous switching following a novel approach developed by Hubrich et al. (2015). We find that oil price fluctuations are typically followed by limited adjustments in inflation and economic activity, a situation we refer to as a normal regime. Occasionally, however, the economy enters into an adverse regime where oil price shocks herald

[16] Results available upon request.

sizeable and sustained macroeconomic fluctuations, with inflation (actual and expected), as well as economic activity, moving in the same direction as the oil price shock. Overall, the dynamics observed in the adverse regime are consistent with the presence of second-round effects of oil price shocks on growth and inflation.

Zooming in on the episode of collapsing oil prices from mid-2014 to early-2015 – which generated a lively debate among central bank observers on whether or not it warranted a monetary policy response – our model indicates that the adverse regime is likely to have prevailed at that time. Accordingly, concerns of negative second-effects reinforcing the then-prevailing disinflationary pressures appeared warranted. In fact, according to our baseline estimates, economic activity and inflation would have been almost 1 percentage point higher than observed, had the euro area economy not been mired in an adverse regime and had inflation expectations not drifted down as they did.

References

Barsky, R. B. and Kilian, L. (2001). Do we really know that oil caused the great stagflation? a monetary alternative, *NBER Macroeconomics Annual 2001* **16**: 137–183.

Baumeister, C. and Hamilton, J. D. (2015). Structural interpretation of vector autoregressions with incomplete identification: Revisiting the role of oil supply and demand shocks, *Working Paper* .

Baumeister, C. and Peersman, G. (2013). Time-varying effects of oil supply shocks on the us economy, *American Economic Journal: Macroeconomics* **5**(4): 1–28.

Bernanke, B. S., Gertler, M. and Watson, M. (1997). Systematic monetary policy and the effects of oil price shocks, *Brookings Papers on Economic Activity* **1**.

Blanchard, O. J. and Galí, J. (2007). The macroeconomic effects of oil shocks. why are the 2000s so different from the 1970s?, *NBER Working Paper* (13368).

Bodenstein, M., Erceg, C. J. and Guerrieri, L. (2008). Optimal monetary policy with distinct core and headline inflation rates, *Journal of Monetary Economics* **55**: S18–33.

Bodenstein, M., Guerrieri, L. and Kilian, L. (2012). Monetary policy responses to oil price fluctuations, *IMF Economic Review* **60**(4): 470–504.

Christiano, L. J., Eichenbaum, M. and Evans, C. (1996). The effects of monetary policy shocks: Evidence from the flow of funds, *The Review of Economics and Statistics* **78**(1): 16–34.

Davis, S. J. and Haltiwanger, J. (2001). Sectoral job creation and destruction responses to oil price changes, *Journal of Monetary Economics* **48**: 465–512.

Fratzscher, M., Schneider, D. and Van Robays, I. (2014). Oil prices, exchange rates and asset prices, *ECB Working Paper* (1689).

Hamilton, J. D. (2003). What is an oil shock?, *Journal of Econometrics* **113**: 363–398.

Hannon, P. (n.d.). Bis: No evidence of second-round effects from high oil prices.

Hubrich, K. and Tetloff, R. T. (2015). Financial stress and economic dynamics: The transmission of crises, *Journal of Monetary Economics* **70**(1): 100–115.

Hubrich, K., Waggoner, D. and Zha, T. (2015). Monetary and financial stability policy: Unconventional monetary policy, leverage and financial stress. Manuscript, Federal Reserve Board.

Kilian, L. (2008). The economic effects of energy price shocks, *Journal of Economic Literature* **46**(4): 871–909.

Kilian, L. (2009). Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market, *American Economic Review* **99**(3): 1053–69.

Kilian, L. and Lewis, L. T. (2011). Does the fed respond to oil price shocks, *The Economic Journal* **121**: 1047–1072.

Kilian, L. and Murphy, D. P. (2014). The role of inventories and speculative trading in the global market for crude oil, *Journal of Applied Econometrics* **29**(3): 454–478.
URL: *http://dx.doi.org/10.1002/jae.2322*

Kilian, L. and Vega, C. (2011). Do energy prices respond to u.s. macroeconomic news? a test of the hypothesis of predetermined energy prices, *The Review of Economic and Statistics* **93**(2): 660–671.

Kiseok, L. and Ni, S. (2002). On the dynamic effects of oil price shocks: A study using industry level data, *Journal of Monetary Economics* **49**: 823–852.

Kormilitsina, A. (2011). Oil price shocks and the optimality of monetary policy, *Review of Economic Dynamics* **14**(1): 199–223.

Leduc, S. and Sill, K. (2004). A quantitative analysis of oil-price shocks, systematic monetary policy, and economic downturns, *Journal of Monetary Economics* **51**: 781–808.

Mohaddes, K. and Pesaran, M. H. (2016). Oil prices and the global economy: is it different this time around?, *Cambridge Working Paper Economics* (1640).

Nakov, A. and Pescatori, A. (2010). Oil and the great moderation, *The Economic Journal* **120**(543): 137–183.

Natal, J.-M. (2012). Monetary policy response to oil price shocks, *Journal of Money, Credit, and Banking* **44**(1): 53–101.

Obstfeld, M., Milesi-Ferretti, G. M. and Arezki, R. (2016). Oil prices and the global economy: It's complicated, *iMFdirect blog posted on March 24* .

Peersmann, G. and Van Robays, I. (2009). Oil and the euro area economy, *Economic Policy* pp. 603–640.

Rotemberg, J. J. and Woodford, M. (1996). Imperfect competition and the effects of energy price increases on economic activity, *Journal of Money, Credit and Banking* **28**(4): 549–577.

Sims, C. A., Waggoner, D. F. and Zha, T. (2008). Methods for inference in large multiple-equation markov-switching models, *Journal of Econometrics* **146**(2): 255–274.

Sims, C. A. and Zha, T. (2006). Were there regime switches in u.s. monetary policy?, *American Economic Review* **96**(1): 54–81.

Van Robays, I. (2012). Macroeconomic uncertainty and the impact of oil shocks, *ECB Working Paper* (1479).

Woodford, M. (2007). The case for forecast targeting as a monetary policy strategy, *Journal of Economic Perspectives* **21**(4): 3–24.

Figure 4: Impulse responses to oil price shock (one standard deviation shock), slashed blue: normal regime, solid red: adverse regime

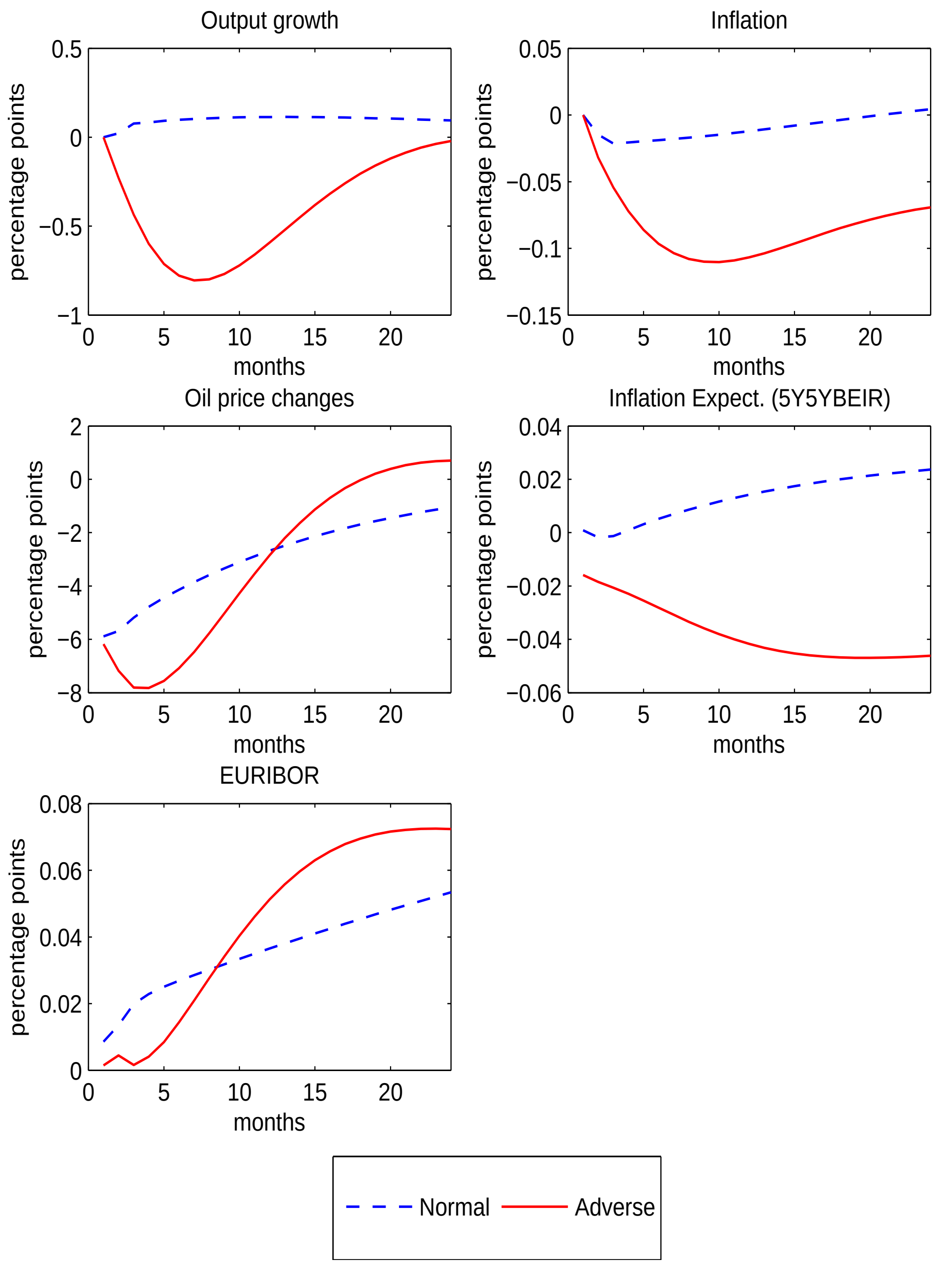


Figure 5: Time-varying probability being in a normal regime (grey-shaded area) and conditional probability of staying in that regime (black line)

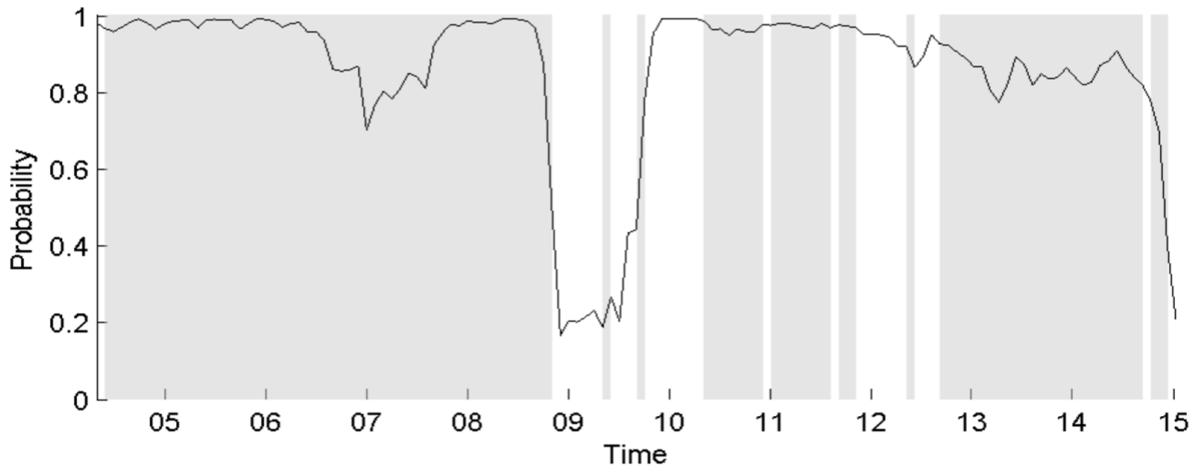
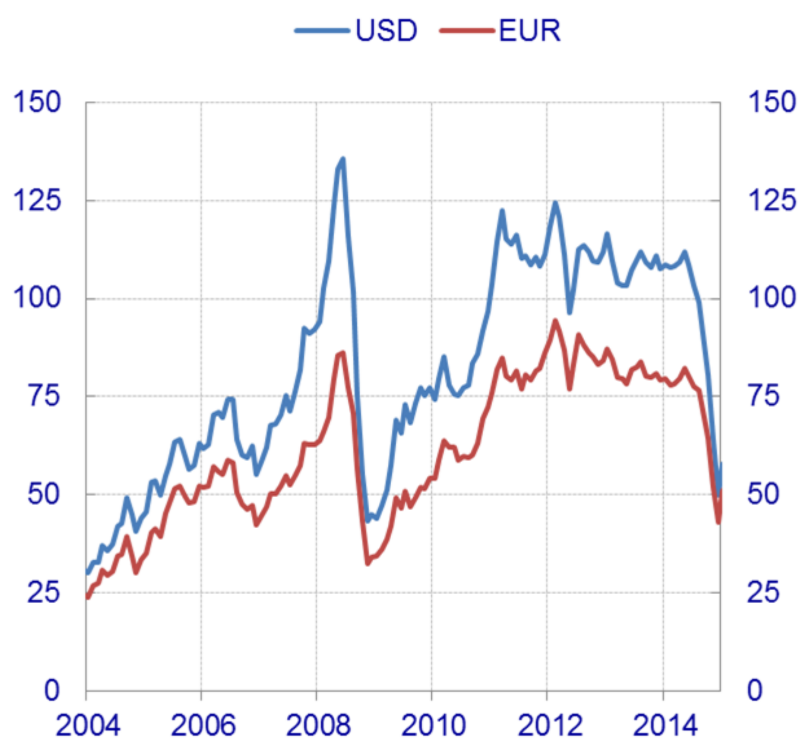


Figure 6: Evolution of Brent crude oil prices *(in different currencies)*



Source: *Bloomberg*