The Asymmetric Effects of Oil Shocks on Output Growth: A Markov-Switching Analysis for the G-7 Countries

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Summary

In this paper we specify and estimate different Markov-switching (MS) regime autoregressive models. The empirical performance of the univariate MS models used to describe the switches between different economic regimes for the G-7 countries is in general not satisfactory. We extend these models to verify if the inclusion of asymmetric oil shocks as an exogenous variable improves the ability of each specification to identify the different phases of the business cycle for each country under scrutiny. Following the wide literature on this topic, we have considered six different definitions of oil shocks: oil price changes, asymmetric transformations of oil price changes, oil price volatility, and oil supply conditions. We measure the persistence of each economic regime, as well as the ability of each MS model to detect the business cycle dates as described by widely acknowledged statistical institutions. Our empirical findings can be summarized as follows. First, the null hypothesis of linearity against the alternative of a MS specification is always rejected by the data. This suggests that regime-dependent models should be used if a researcher is interested in obtaining statistically adequate representations of the output growth process. Second, three-regime MS models typically outperform the corresponding two-regime specifications in describing the business cycle features for each country. Third, the introduction of different oil shock specifications is never rejected. Fourth, positive oil price changes, net oil price increases and oil price volatility are the oil shock definitions which contribute to a better description of the impact of oil on output growth. Finally, models with exogenous oil variables generally outperform the corresponding univariate specifications which exclude oil from the analysis.

Keywords: Oil shocks, Output growth, Markov-switching models

JEL Classification: E31, E32, E52, Q41

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1 Introduction

Early studies in the business cycle literature share the view that economic recessions represent distinct, identifiable events in the behaviour of a few crucial economic variables. For instance, real GDP is typically characterized by episodes of significant divergence from its usual trending path during periods of serious economic downturn. This view is also common to recent theoretical and applied business cycle research, which shows revived interest in the regime switching nature of aggregate output (see, among others, Hamilton, 2005).

Different statistical methods have been developed to model and interpret the level and the dynamics of macroeconomic activity. For instance, calibrated real business cycle (RBC) models have been proposed to explain particular stylized aspects of the data (see the seminal contributions of Long and Plosser, 1983 and King and Plosser, 1984). The performance of RBC models crucially depends on their ability to match selected moments of the detrended growth cycle with the corresponding moments obtained from model-simulated data. Starting with the work of Hamilton (1989), the Markov-switching (MS) autoregressive time series models have emerged as an interesting alternative to describe specific features of the business cycle. As an example, a relevant number of empirical regime-switching models have been proved to be able to capture nonlinearities and asymmetries which are present in many macroeconomic variables (Krolzig, 1997; Clements and Krolzig, 2001, 2002).

Since oil shocks are generally acknowledged to have important effects on both economic activity and macroeconomic policy, our study concentrates on the analysis of the dynamic relationship between the business cycle and the conditions on the oil market for the G-7 countries. Our investigation of how oil price shocks affect the growth rate of output is based on the comparison of alternative MS models. Our model selection strategy comprises the following criteria: i) model fit, as summarized by the standard error of the residuals; ii) value of the log-likelihood function; iii) values of means and/or intercepts estimated in the different economic regimes; iv) relation between the probability of regime switching and the macroeconomic fundamentals. This paper starts with analyzing the business cycle features in the real GDP series for each country. In particular, asymmetries are supposed to exist where the estimated parameters of the alternative MS specifications are indicative of different regime-dependent responses of real output. Most of the empirical studies which use an MS modelling approach focus almost exclusively on univariate models for real GDP. A novelty of this paper is that we explicitly assess the dynamic impact of exogenous oil shocks on the movements of real output. In this respect, our paper can be regarded as an extension of the studies by Raymond and Rich (1997), Clements and Krolzig (2002), and Holmes and Wang (2003). An additional innovative feature of our study is that it provides a comparison of the ability of the most popular definitions of oil shocks to detect asymmetries in the oil-output relationship. Following the wide literature on this topic, we have considered six different definitions of oil shocks. In particular, oil shocks are proxied by oil price changes, asymmetric transformations of oil price changes (i.e. positive oil price changes and net oil price increases), oil price volatility (that is, scaled oil price increases and standard deviation of oil prices), and oil supply conditions. We have measured the persistence of each economic regimes, as well as the ability of each MS model to detect the business cycle dates as described by widely acknowledged statistical institutions (namely ECRI and NBER).

The paper is structured as follows. Section 2 reviews the empirical literature on the macroeconomic effects of oil shocks. Section 3 presents the data. Section 4 describes the MS framework and our model selection strategy. Section 5 introduces the MS specifications which are relevant to the empirical analysis. In Section 6 we present and discuss the empirical findings obtained by using MS models for the statistical assessment of the business cycle dynamics for the G-7 countries. Section 7 concludes.

2 Does oil matter? What the empirical literature says

Many studies are available which offer different theoretical explanations for the inverse relationship between oil price changes and the level of economic activity. Many other contributions are directed to empirically test the existence of a statistical relationship between oil and the macroeconomy (see, for details, the references in Barsky and Kilian, 2004).

The empirical literature devoted to assess the relationship between business cycle and oil price fluctuations has evolved after 1973, the year of the first oil price shock (see Huntington, 2005 for an updated survey). The first two authors who estimate the impact of oil price increases on real income in the U.S. and other developed economies are Darby (1982) and Hamilton (1983). While Darby is not satisfied with the ability of the classical macroeconomic variables to explain the major recessions which have characterized the economic history of U.S., Hamilton, using post-war data, finds a statistically significant relationship between oil price changes and real GDP growth.

Other studies confirm Hamilton's results. While Gisser and Goodwin (1986) introduce the growth rate of nominal crude oil price in St. Louis-type equations of four indicators of macroeconomic performance (namely, real GDP, general price level, rate of unemployment and real investment), Burbidge and Harrison (1984) use a vector autoregression (VAR) model and compute impulse responses to oil price changes. They find evidence of a causal relationship from oil price shocks to economic variables, although the results for some countries are ambiguous.

The failure of the 1986 oil price collapse to produce an economic boom has led several authors to hypothesize the existence of an asymmetric relationship between oil prices changes and economic activity. While oil price increases have clear negative effects, the impact of oil price declines is not always positive, indeed it may slow down output growth. Mork (1989) verifies that, if the Hamilton's analysis is extended to include the oil price collapse of 1986, the oil price-macroeconomy relationship breaks down. Hence, he decides to test the symmetry hypothesis on U.S. data by allowing real increases and decreases in oil price to have different coefficients in a regression equation with real GDP as the dependent variable. The coefficients on oil price increases turn out to be negative and highly significant; the coefficients on price declines tend to be positive, but small and not statistically significant. In an extension of this analysis to other countries, Mork, Olsen and Mysen (1994) find that all countries, except Norway, experience a negative relationship between oil price increases and GDP growth.

Other authors assert that the relationship between oil price shocks and U.S. macroeconomic fluctuations broke down because of a new regime of highly volatile oil price movements. For example, Lee, Ni and Ratti (LNR) (1995) argue that an oil price shock is likely to have a greater impact in an economic environment where oil prices have been stable than in a context where oil price movements have been frequent and erratic.

A different specification for oil price changes has been proposed by Hamilton (1996). In direct response to Hooker (1996), who finds strong evidence that oil prices no longer do Granger-cause many U.S. macroeconomic variables after 1973, Hamilton introduces the concept of "net oil price increase" (NOPI), which is defined as the positive difference between the current oil price level and the maximum oil price relative to the previous four quarters. The introduction of NOPI in a VAR model for the U.S. economy is able to restore a significant relationship between oil prices and real GDP.

The hypothesis of direct effects of oil price shocks has been rejected by other studies. Actually, several economists have blamed the U.S. monetary policy to be responsible for the asymmetric response of aggregate economic activity following an oil price shock. For example, Bohi (1989) asserts that the restrictive monetary policy carried out by the central banks of these countries accounts for much of the decline in aggregate economic activity in the years which follow an oil price increase. In particular, he does not find any statistical relationship between enegy-intensive industries and their level of energy-intensity, as well as no statistically significant effects of oil price shocks on the business cycle of four countries. This view is supported in a later study by Bernanke, Gentler and Watson (BGW) (1997). Using a VAR model, BGW conclude that, if the Federal Reserve had not increased interest rates after an oil price shock, the economic downturns that hit the U.S. might have been largely avoided. Finally, the analysis by Barsky and Kilian (2001) suggests that the Great Stagflation observed in the 1970s was primarily a monetary phenomenon: its effects could have been mitigated, should the Federal Reserve have not accommodated the massive monetary expansion of the early 1970s. The analyses of Hamilton and Herrera (2001) and Brown and Yucel (1999) reject these conclusions. Their results are consistent with the thesis that counter-inflationary monetary policy is only partially responsible for the real effects of oil price shocks that hit the U.S. during the last thirty years.

The analysis of the macroeconomic impacts of oil shocks has been extended to countries other than U.S. only recently. Cunado and Perez de Gracia (2003) concentrate on the effects of oil price shocks on the industrial production and consumer price indices for 14 European countries. Jimenez-Sanchez and Rodriguez (2005) carry out simple multivariate regressions for 8 countries (the G-7 countries plus Norway), in order to account for the inverse relationship between GDP and oil prices. Kilian (2006) estimates the effects of exogenous shocks to global oil production on the most industrialized countries. Other authors have proposed the use of more advanced econometric techniques. In particular, Raymond and Rich (1997), Clements and Krolzig (2002) and Holmes and Wang (2003) use the MS approach to assess the impact of oil shocks on U.S. and U.K. business cycles. Huang, Huang and Peng (2005) apply a multivariate threshold model to investigate the impacts of oil price changes and their volatility on economic activity.

3 The data

In this study we employ quarterly data for the period 1970q1-2004q1.[1] For each country the real price of oil (*roil*) is obtained by multiplying the nominal oil price (average crude oil price) expressed in U.S. dollars by the nominal exchange rate and deflated with the Consumer Price Index (see Figures 1-2).[2] The natural logarithm of real GDP in first differences is referred to as the output growth rate, Δgdp_t (see Figures 3-4). The macroeconomic data we use are from the International Financial Statistics databases (IFS). For Italy, the source of real GDP is ISTAT, while for France the data since 1978q1 are from INSEE. Observations referring to the period 1970q1-1977q4 are obtained by considering the growth rates based on IFS data (nominal values deflated by the GDP deflator). For U.K. the IFS data have been seasonally adjusted.

In order to account for the asymmetric effects of an oil shock, we introduce six different definitions of oil shocks. The first is simply the real price of oil in first differences, i.e. $\Delta roil_t$, $t = 1, ...T$. The second variable is defined as the positive change in the natural logarithm of the real oil price (see Mork, 1989):

$$\Delta roil_t^+ = \begin{cases} \Delta roil_t & \text{if } \Delta roil_t > 0 \\ 0 & \text{if } \Delta roil_t \leq 0 \end{cases} \tag{1}$$

The third specification of oil shocks is based on the movements of oil prices in the last year. More precisely, net oil price increases (NOPI) are defined as the difference between the current real price of oil and the previous year's maximum if positive, or zero otherwise:

$$\text{NOPI}_t = \begin{cases} roil_t - \max\{roil_{t-1}, ..., roil_{t-4}\} & \text{if } roil_t > \max\{roil_{t-1}, ..., roil_{t-4}\} \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

[1] For Japan the sample goes from 1970q1 to 2004q3, while for Canada and U.S. the period spanned is 1970q1-2004q4. [2] Since 1999q1 the exchange rate of Italy, Germany and France is computed by considering the irreversible parity rate with Euro.

Following the work by LNR (1995), the fourth oil shock variable we consider is aimed at capturing the volatility in the oil price market. In particular, LNR normalize the oil price changes with their GARCH volatility, estimated according to the following model:

$$roil_t = \alpha_0 + \alpha_1 roil_{t-1} + \alpha_2 roil_{t-2} + \alpha_3 roil_{t-3} + \alpha_4 roil_{t-4} + \epsilon_t, \qquad \epsilon_t | I_{t-1} \sim N(0, h_t) \tag{3}$$

$$h_t = \gamma_0 + \gamma_1 \epsilon_{t-1}^2 + \gamma_1 \epsilon_{t-1}^2 \tag{4}$$

$$\text{LNR}_t = \max(0, \hat{\epsilon}_t / \sqrt{\hat{h}_t}) \tag{5}$$

The fifth definition of oil price shocks draws from Ferderer (1993), who introduces the quarterly standard deviation of oil prices:

$$oil\_vol_q = \left[\frac{1}{4} \sum_{m=1}^{4} (oil_{q,m})/(cpi_{q,m}) - \mu_{q,m}^2 \right]^{1/2} \tag{6}$$

where $oil_{q,m}$ and $cpi_{q,m}$ are the nominal price of oil (in national currency) and the Consumer Price Index in the m-th month of the q-th quarter, respectively.

Finally, the sixth specification defines as oil shocks the exogenous fluctuations in the production of oil, *oil_disr* (see Kilian, 2005). This variable is based on monthly production data for OPEC and non-OPEC countries.[3]

4 The econometric framework

4.1 The Markov switching approach

In this section we describe a general econometric framework which allows for regime switching in the dynamics of GDP. In his seminal article, Hamilton (1989) introduces a model of the business cycle where deviations of output growth from its mean follow a p-th order autoregressive process:

$$\Delta gdp_t - \mu(s_t) = \alpha_1(\Delta gdp_{t-1} - \mu(s_{t-1})) + \ldots + \alpha_p(\Delta gdp_{t-p} - \mu(s_{t-p})) + \epsilon_t \tag{7}$$

The errors ϵ_t are assumed to be independently and identically distributed (IID) with zero mean and constant variance σ^2, while the mean of the process (μ) depends on a latent variable s_t. Since this dependence implies that different regimes are associated with different conditional distributions of the growth rate of real output, the

[3] The variable *oil_disr* is based on the dynamics of oil production in absence of any exogenous disruption of oil supply. For an alternative formulation see Hamilton (2003). Given the availability of data on oil supply from the Energy Information Agency, this variable can be computed only for the period 1974q1-2004q4.

latent variable s_t reflects the state of the business cycle (in case of two regimes, "expansion" and "contraction"). The autoregressive parameters of model (7) can be functions of the state s_t in the Markov chain:

$$\Delta gdp_t = c(s_t) + \alpha_1(s_t)\Delta gdp_{t-1} + \ldots + \alpha_p(s_t)\Delta gdp_{t-p} + \epsilon_t \tag{8}$$

If s_t takes one of the M different values represented by the integers $1, 2, \ldots, M$, equation (8) represents a mixture of M autoregressive models. In a two-regime case, model (8) describes "falling" states (for example, if $s_t = 1$) as well as "rising" states (when $s_t = 2$) in the output variable. In particular, an economy in recession can be represented as:

$$\Delta gdp_t = c_1 + \alpha_{11}\Delta gdp_{t-1} + \ldots + \alpha_{p1}\Delta gdp_{t-p} + \epsilon_t \tag{9}$$

while, if the economy is in expansion, the growth rate of output will be modelled by the alternative equation:

$$\Delta gdp_t = c_2 + \alpha_{12}\Delta gdp_{t-1} + \ldots + \alpha_{p2}\Delta gdp_{t-p} + \epsilon_t \tag{10}$$

It is worth noting that the parameters of the conditional process depend on a regime which is assumed to be stochastic and unobservable. Therefore, a complete description of the data generating process requires the formulation of the regime generating process. In MS models the latter process is an ergodic Markov chain with a finite number of states, which is defined by the transition probabilities:

$$p_{ij} = Pr\left(s_t = j | s_{t-1} = i\right), \qquad \sum_{j=1}^{M} p_{ij} = 1 \tag{11}$$

for $\forall i, j =$ 1,..., M. More precisely, it is assumed that s_t follows an ergodic M-state Markov process with an irreducible transition matrix:

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1M} \\ p_{21} & p_{22} & \cdots & p_{2M} \\ \cdots & \cdots & \ddots & \cdots \\ p_{M1} & p_{M2} & \cdots & p_{MM} \end{bmatrix} \tag{12}$$

where $p_{i1} + p_{i2} + \ldots + p_{iM} = 1$ for $i = 1, \ldots, M$. In a two-regime case (i.e. $M = 2$), this specification assumes that, if the economy was in expansion last period, the probability of a regime switching is constant and independent of the persistence of the expansion.

4.2 A model selection strategy

In this section we present an empirical procedure aimed at comparing alternative MS models. The starting point is to test for the presence of nonlinearities in the data. In our analysis we use the test developed by Ang and Bekaert (2001), which is approximately distributed as a $\chi^2(q)$, where q represents the number of restrictions and nuisance parameters that are not defined under the null hypothesis.

The second relevant issue is how to determine the number of states required by each model to be an adequate characterization of the observed data. Unfortunately, simple and direct statistical criteria cannot be used. Although the use of likelihood ratio (LR) test to determine the state dimension of a series has been proposed (Boldin, 1996), the implementation of such a test is nevertheless problematic. Actually, since the usual regularity conditions are not fulfilled under the null hypothesis (some parameters are unidentified and the information matrix is singular), the asymptotic null distribution of the LR test is not χ^2. In order to circumvent these problems alternative statistics have been introduced (see, among others, Hansen, 1992), which unfortunately are computationally expensive. In practice, the state dimension of the hidden Markov chain that drives regime changes is either suggested by the specific problem under analysis, or determined informally by a simple visual inspection of the data. Our empirical procedure follows Psaradakis and Spagnolo (2003), who suggest to select the number of regimes using the Akaike Information Criterion (AIC). Monte Carlo experiments show that selection procedures based on the AIC and on the so-called "three-pattern method" are generally successfull in choosing the correct state dimension, provided that the sample size and parameter changes are not too small.

The third important aspect we consider in our selection strategy is the number of autoregressive terms to include in the process. We use both AIC and LR tests in order to discriminate between a p-lag and a q-lag MS process. The results of our selection procedure are presented in Tables 2-10.

Once the optimal specification within a particular type of MS models is obtained, the final stage of our selection procedure is to compare the different types of selected models, which are generally non-nested. Our comparison is based on the following criteria: i) model fit, as summarized by the standard error of the residuals; ii) value of the log-likelihood function; iii) values of means and/or intercepts estimated in the different economic regimes; iv) relation between the probability of regime switching and the macroeconomic fundamentals. This last criterion is of particular importance. It is generally acknowledged that the probability of a low growth state should be smaller than the probability of high growth, since recessions tend to be more short-lived than expansions. From the estimated transition probabilities we measure the persistence of the different economic phases. By assigning the t-th observation of the GDP to the m-th regime with the highest smoothed probability, we produce a model-based classification of regimes and dates of the business cycle phases for each country (see Hamilton, 1994).[4] We confront our empirical findings with the business cycle dates provided by official institutions, such as the Economic Cycle Research Institute (ECRI) and the National Bureau of Economic Research (NBER), as reported in Table 1.

[4] For the simplest case of two regimes, our selection rule reduces to assign the t-th observation of the GDP to the first regime if $Pr(s_t = 1|gdp_t > 0.5)$, or to the second regime if $Pr(s_t = 1|gdp_t < 0.5)$

5 Model specification

In this section we investigate the ability of different MS model to capture business cycle asymmetries and we assess the role of oil price changes in affecting the mean level of output. We begin with the analysis of univariate models for real GDP. Since output volatility in recessions is generally different from the volatility which characterizes economic expansions, we have also considered extensions of the univariate models which incorporate a regime-varying variance of the disturbance terms. The state of the economy is assumed to belong to one of three regimes, namely low, moderate and high growth rates. The three-regime hypothesis is tested against the alternative of two regimes (i.e. recession/expansion) using the model selection strategy discussed in Section 4.

The second stage of our empirical analysis deals with the potential effects that different conditions in the oil market may have on the correct identification of alternative economic regimes and of the probabilities of switching from one to another. Although oil prices seem to be characterized by a nonlinear pattern, for each country the regimes characterizing real GDP do not coincide with those representing the oil market.[5] Therefore, we cannot implement the framework adopted by Hamilton and Lin (1996), where a single latent variable (i.e. the state of the economy) determines both the mean of DGP growth and the scale of the volatility of the exogenous variable. In our case, the analysis is extended to test whether oil prices affect the mean of the GDP growth process. The dynamic linkages between oil and GDP are explored by adding lagged coefficients of the oil market variable to the autoregressive MS model for Δgdp_t (see Raymond and Rich, 1997; Clements and Krolzig, 2000). The first specification we estimate is an extension of equation (7), known as the MS-mean (MSM) model according to the notation introduced by Krolzig (1997):

$$\Delta gdp_t - c(s_t) = \sum_{i}^{p} \alpha_i (\Delta gdp_{t-i} - c(s_{t-i})) + \sum_{j}^{q} \gamma_j oil_{t-j} + \epsilon_t \tag{13}$$

$$\epsilon_t \sim IID(0, \sigma^2) \tag{14}$$

where oil_t represents one of the six alternative specifications of oil price shocks described in Section 4 (namely, $\Delta roil$, Δo^+, NOPI, LNR, oil_vol and oil_disr). Moreover, s_t is a latent variable which reflects the state of the business cycle. When $s_t = m$, $m = 1, ..., M$, the DGP average growth rate is given by the parameter $c(m) \equiv c_m$. The number of lags q for the oil price variable is equal to four, following Clements and Krolzig (1998). If the MSM model (13)-(14) accounts for a once-and-for-all jump in the DGP series, the MS-intercept (MSI) model:

[5] When MS models for oil only are estimated, the selection criteria illustrated in Section 4 indicate the autoregressive specification with switching error variance on three regimes as the preferred model. Our empirical findings suggest that the oil price series switches from low to high volatility.

$$\Delta gdp_t = d(s_t) + \sum_i^p \alpha_i \Delta gdp_{t-i} + \sum_j^q \gamma_j oil_{t-j} + \epsilon_t \tag{15}$$

implies a shift in the intercept $d(s_t)$, that is a smooth adjustment of the DGP after a regime shift. It is important to notice that MSI specification assumes the same variance (14). Models (13)-(14) and (15)-(14) can be easily generalized in two directions. The first allows for regime shifts in the variance of the error terms:

$$\epsilon_t \sim IID(0, \sigma^2(s_t)) \tag{16}$$

Equations (13)-(16) define the MSM-heteroskedastic (MSMH) models, whereas the MSI-heteroskedastic (MSIH) specification combines model (15) with (16). The second direction deals with the parameters of the autoregressive part of the MSI models, which become functions of the state variable s_t. Formally, the MSI-autoregressive (MSIA) model is written as:

$$\Delta gdp_t = d(s_t) + \sum_i^p \alpha_i(s_t) \Delta gdp_{t-i} + \sum_j^q \gamma_j(s_t) oil_{t-j} + \epsilon_t, \quad \epsilon_t \sim IID(0, \sigma^2) \tag{17}$$

and it assumes the homoskedastic error structure (14), while the MSI-autoregressive-heteroskedastic (MSIAH) specification is obtained by combining equations (17) and (16).

6 Empirical results and discussion

The six MS models briefly presented in Section 5 are estimated with the Expectation-Maximization estimator described in Hamilton (1994) for each of the G-7 countries using the six alternative specifications of oil price shocks illustrated in Section 4 (a total of 252 different MS regressions).[6] The main features of each specification are reported in Tables 3-9.[7] Following our model selection strategy outlined in Section 4.2, we are able to select the best model in detecting the business cycle features of each country. Empirical details on the selected models are presented in Table 10. Figures 5-11 provide a diagnostic evaluation of the selected model for each country. In particular, we analyze the behaviour of the regime probabilities, and the dynamics of actual values, fitted values and residuals. We also compute the probability of duration of each regime, and we present the plots of the cumulative probabilities of duration for each regime against the duration of that regime (predicted h-step probabilities). This section is devoted to the presentation and discussion of our empirical findings for each country under analysis.

[6] All computations are carried using Krolzig's MS-VAR Ox package [7] The complete set of empirical results is available from the authors upon request.

6.1 Canada

The first model we have estimated is the MSM model for quarterly real GDP growth over the period 1970-2004. The LR test for linearity (which is reported in Table 2) strongly suggests that real GDP is characterized by a nonlinear behaviour.[8] In particular, the first two autoregressive coefficients point out that in regime 1 the economy experiences a negative growth. According to the estimated transition probabilities, regime 1 is able to detect the economic slowdowns of 1973, 1981-1983 and 1990-1991, whereas in regime 2 real GDP actually increases by about one percentage point. All coefficients are statistically significant at conventional significance levels. Low growth rate phases are highly persistent and tend to last, on average, three quarters, in contrast with the five-year length of high growth periods. Alternative two-regime MS models are also considered. For example, the MSMH model is obtained by relaxing the assumption of homoskedastic errors. A general-to-particular procedure suggests that one lag is sufficient to capture the dynamics of GDP. A second model is estimated which eliminates the restrictions on the autoregressive coefficients and on the error variance (MSIAH). Both models are unable to capture the switches of different economic regimes.

The next step is to estimate MS models with three regimes. A MSM(3)-AR(4) specification, that is a MSM with three regimes with a four-lag autoregressive component, presents the best econometric performance. All coefficients are statistically significant, and, compared with the peaks and troughs of the Canadian business cycle reported in Table 1, the three regimes have a neat economic interpretation. In particular, the first regime is able to detect the periods of recessions which have characterized the last thirty years of the Canadian economy (namely, 1973, 1981-1983 and 1990-1991), while regime 3 well describes the periods of high economic growth. Similar results are obtained by considering an MSI-type model. In this case, two lags on the GDP are sufficient in order to capture the dynamic structure of the dependent variable.[9]

In order to investigate whether oil price shocks are able to increase the accuracy of MS regression models, we have estimated a MSM specification with three regimes, a fourth-order autoregressive component and a four-lag augmentation on the exogenous oil prices changes ($\Delta roil$). We indicate this model with MSM(3)-ARX(4,4), or simply with MSM(3)-ARX(4), since the optimal number of lags on oil price changes is equal to four for each MS specification. As we can see from Table 3, only the second lag is negative and marginally significant. This model does not achieve any significant improvement over the MSM(3)-AR(4) specification, according to a conventional LR test. In this case, the computed value for the LR test is equal to 9.21. Since the test is distributed as a χ^2 with 4 degrees of freedom, the null hypothesis of validity of the MSM(3)-AR(4) specification against the MSM(3)-ARX(4) model is rejected at 10% only. Significant improvements are obtained with the introduction

[8] See Hamilton, 1996 for a critical discussion of this test. [9] If we allow the error variance to vary across regimes, we do not obtain a significant improvement in the likelihood function. Similar results are found by relaxing the restrictions on the autoregressive component of this model.

of NOPI and *oil_vol* in the regressions. If we consider four lags of these variable, the null hypothesis of validity of the MSM(3)-AR(4) model with $\Delta roil$ is rejected by conventional LR tests at 1% (LR= 16.46 and 17.00, respectively). For model MSM(3)-ARX(4) with NOPI, two of four coefficients are negative and statistically significant (the fourth coefficient is positive and not statistically different from zero at 10%). Conversely, in model MSM(3)-AR(4) with *oil_vol* only the fourth coefficient is not statistically different from zero.[10]

The best econometric results are obtained by using the definition of oil price increases (Δo^+) in the MSM(3)-ARX(4) model (see Table 10 and Figure 5). The null hypothesis of validity of the MS(3)-AR(4) specification is rejected at 5% (the likelihood function value increases from 493.01 to 499.63). The second and the fourth coefficients of the distributed-lag component are negative and statistically significant at 1%, while the first and third coefficients are positive, but not statistically different from zero. With regard to the autoregressive structure of the model, four lags are needed to capture the dynamics of real GDP. The transition probabilities ($Prob(s_t = 1|s_{t-1} = 1) = 0.61$) and ($Prob(s_t = 2|s_{t-1} = 2) = 0.96$) suggest the presence of important asymmetries in the business cycle. Regime 2 (i.e. moderate growth phases) is found to be the most persistent. The average duration of each regime supports this conclusion: while regime 2 is estimated to last on average 27.27 quarters, the average duration of a recession is 2.55 quarters. Conversely, high growth periods tend to be very short-lived, with an expected duration of 1.73 quarters.

6.2 France

We start with the original MSM Hamilton's model for quarterly real GDP with two regimes (see Table 2). The time period covered is 1970q1-2004q1. Both coefficients capturing the mean value of the GDP in each regime are positive. While in regime 1 GDP tends to grow at a 0.5% rate, in the second regime the average growth rate is 1.41%, although in this case the mean coefficient is not statistically significant. The GDP series shows significant serial correlation effects. The transition probabilities suggest that the model is not designed to capture asymmetries in the business cycle, since the probability of observing regime 1 is very close to one. Furthermore, while regime 1 captures all observations which are posterior to 1975, regime 2 characterizes the first part of the sample. If we relax the hypothesis of a constant error variance and reduce the number of autoregressive coefficients, the empirical performance of the resulting model does not improve. Although the null hypothesis of the linearity test is strongly rejected, most of the sample observations are captured by regime 1.

The empirical results produced by the MSI model are more satisfactory. Both constants are statistically significant. While slow growth economic phases (namely, 1974-1975, 1977-1987, 1990-1997 and 2001-2004) are attributable to regime 1, regime 2 describes a larger portion of the observed data. If high growth phases tend

[10] The two measures of oil price volatility and the measure of oil disruptions never outperform the univariate model for real GDP only.

to last on average 8.56 quarters, sluggish economic growth periods are more persistent (i.e. 19 quarters). The next step of our modelling strategy is to estimate a MSIH model. The empirical findings strongly reject the null hypothesis that recessions are more volatile than expansions. Finally, for this model regime switches have no sound economic meaning.[11]

If we extend the analysis to three regimes, model MSM-AR(2) for real GDP is not able to describe the French business cycle. Regime 2 is highly persistent, while regimes 1 and 3 capture recessions and high growth periods in the 1970s. By removing the assumption of constant error variance, and using a dummy variable to remove an outlier in correspondence of the fourth quarter of 1974, we obtain a model with good economic properties. The three mean-coefficients are statistically significant and describe low, moderate and high growth periods, respectively. According to this model, periods 1977-1987, 1990-1997 and 2001-2004 are characterized by low economic growth. In regimes 1 and 3 standard error are larger, suggesting higher volatility. If we allow the autoregressive component of real GDP to vary across regimes, switches from one economic regime to another can be described more accurately. It is worth noticing that, according to the AIC, six lags are needed to capture the dynamic structure of the series. The estimates of the three intercept terms are only slightly different, while the average durations of the three regimes are equal to 3.59, 3.71 and 7.51 quarters, respectively.

From the previous univariate analysis for real GDP, two models have emerged as statistically adequate, namely the MSMH(3) and MSIA(3) specifications. Our aim is to verify if the introduction of oil shock variables can improve the identification of the different business cycle phases. We augment both models by including four lags on the oil shock variable (Table 4). If we start our analysis with the MSMH model, we note that the null hypothesis of a simpler specification versus a more general model is rejected for each alternative oil price definition. LR test values range from 38.71 (i.e. oil shocks measured as simple oil price changes) to 51.13 (that is, oil shocks as scaled oil price increases). In particular, parameter estimates and the regime classification performance of the model significantly improve by introducing asymmetric specifications of oil prices. For instance, a MSMH(3) model which includes *oil_vol* is able to detect the main slowdowns in the last 30 years of the French economy. Its three mean-parameters are statistically significant and describe low, moderate and high growth periods, respectively. All coefficients associated with the oil shock specification are negative. The transition probabilities suggest that the third regime is the most persistent ($p_{33} = 0.89$) and is more frequently followed by regime 1 ($Prob(s_t = 1|s_{t-1} = 3) = 0.11$). When the economy is in regime 2, the probability that it switches to regime 1 is higher ($Prob(s_t = 1|s_{t-1} = 2) = 0.19$). The average durations of the three regimes are 2.85, 3.09 and 8.96, respectively. Regime 1 and 3 are characterized by higher volatility, since the associated

[11] An alternative specification is obtained by removing the restrictions on the autoregressive part of the model. Although for the MSIA specification regime switches have an plausible economic interpretation, only one observation can be attributed to regime 1. This limitation persists also if we consider a MSIAH model.

standard error are larger (see Table 10 and Figure 6).

6.3 Germany

The analysis starts by considering the MSM(2)-AR(4) model (see Table 2).[12] Only the mean for regime 2 is statistically significant, which denotes switches from low-growth to high-growth periods. The dynamics of the real GDP is captured by the fourth lag of the dependent variable. More robust statistical results are obtained if the model is extended to allow the series to switch among three different economic regimes, as well as assuming regime-dependent intercepts, autoregressive components and heteroskedastic errors (i.e. the MSIAH(3) specification). The three regimes can be attributed to different economic phases, namely null, moderate and high economic growth, with the first regime characterizing the periods 1973-1975, 1980-1983 and 1991-2004. According to this model, regime 1 tends to last 22 quarters on average, while regime 2 is less persistent. Finally, high growth periods tend to last 10 quarters on average.

The role of oil shocks is assessed with different MSIAH specifications with three states (see Table 5).[13] If we include positive oil price changes (Δo^+), we are able to describe the first regime as a zero-growth period. All four lags on Δo^+ are negative, and lags from two to four are statistically different from zero. The log-likelihood function increases from 437.52 to 444.71, and the null hypothesis that the coefficients of the distributed-lag component are jointly zero (LR value = 14.34) is easily rejected at any confidence level. Thus, the inclusion of oil in the MS specifications is appropriate. Furthermore, if we employ the variable "net oil price increases", switches from one regime to another have a clearer economic meaning. The first regime well approximates the dates of recessions as reported by ECRI (1973-1975, 1980-1982, 1991-1994 and 2001-2003; see Table 1). Regimes 2 and 3 describe moderate and high growth phases. With respect to the coefficients on the oil shock variable, our results suggest that net oil price increases seem to have significant economic effects, in particular during "low-growth" and "high-growth" periods. Parameter estimates suggest that, during expansions, oil shocks have negative, quasi-simultaneous effects that tend to last for a limited number of periods. During highly recessionary phases, oil shocks affect the economic system only gradually. According to the computed ergodic probabilities, the dominant regime is the second (the value of the corresponding probability is 55.36%). At the same time, the transition probabilities ($p_{11} = 0.88$, $p_{22} = 0.93$ and $p_{33} = 0.75$) signal the presence of important asymmetries in the business cycle. Regime 2 is found to be the most persistent, which is also confirmed by the average duration of each regime. While regime 2 is assumed to last 15.36 quarters on average, the average durations of a low-growth rate and an expansionary phase are 8.33 and 4.02 quarters, respectively (see Table 10 and Figure 7).

[12] All specifications use a dummy variable for the first quarter of 1991, which takes into account a structural break in the series due to the reunification of West and East Germany. [13] Other models present good statistical properties (see Table 5). In particular, meaningful empirical results are obtained by considering two-regime MSMH models.

6.4 Italy

Our empirical findings point out that, in general, three-regime models tend to outperform the corresponding models with two regimes (Table 2). The MSM(3)-AR(3) specification, for instance, merits some attention. The first mean coefficient suggests that in regime 1 GDP tends to grow at a 0.13% rate. Regime 2 covers moderate growth rate periods, while state 3 can be related to the post-recession periods of rapid growth. More specifically, in the high-growth regime, real GDP growth rate is equal to 1.28%. The coefficients associated with the three-lag autoregressive structure of this model are statistically significant at 5%.

We limit the study of the effects of oil shocks on economic growth to the improvements achieved by the MSIAH model with different exogenous oil shock specifications (see Table 6). In general, regime 1 is able to detect the recessions which characterized the Italian economy in the last thirty years, and regime 3 describes the high growth phases of the 1970s. The parameters of the distributed-lag component are highly statistically significant, although the MSIAH(3)-ARX specification, when compared with the univariate model, does not lead to a significant increase in the likelihood function. The introduction of four lags on the oil price variable increases the log-likelihood value from 486.66 to 494.27. Therefore, the LR statistic, which is distributed as a χ^2 with 12 degrees of freedom is equal to 15.21 and does not reject the univariate model.

From a statistical perspective, significant gains are obtained by introducing asymmetric specifications of oil price changes. In the case of positive oil price changes, the null hypothesis of a univariate model for real GDP can be rejected at 10%. However, if we concentrate on the ability of the model to offer a meaningful regime classification, the model which includes oil price volatility seems to outperform its competitors. Since the LR test is equal to 26.93, the introduction of the oil price variable is statistically relevant at any significance level. Oil shocks seem to affect primarily high growth periods and low growth phases. In regime 1, the third and fourth coefficients on oil lags are negative, with the latter being statistically significant at 1%. In regime 3, lags one and four are both negative and statistically relevant. Moreover, the second and third lags are positive and not significant. This model predicts that low growth rate phases and expansions last on average 2.21 and 3.76. Conversely, regime 2 is highly persistent and exhibits an expected duration of expansions that is remarkably longer than the duration of recessions and of high growth periods (i.e. 25.64 quarters). An inspection of the computed transition probabilities, as well as of Figure 8 (panel d) confirms the relative instability of the recessionary regime. Actually, the probability of observing a recession which lasts for more than 5 quarters is less than 5%. The persistence of a moderate growth rate phase is high, although the probability that the economy falls in a recessionary state is not negligible. As in Germany, a high growth regime tends to be followed by a recessionary phase more often than a phase of moderate growth.

6.5 Japan

Our results are similar to Sichel (1994), who suggests that univariate models extended to account for three different economic regimes outperform univariate specifications on two regimes (Table 2). In particular, we obtain the most interesting findings with a MSMH model, where the error variance is allowed to vary across regimes, together with the means of the GDP process. For this specification, regime 1 represents mild recessionary periods, while regime 2 and 3 denote moderate and high growth states. Two lags are sufficient to capture the dynamics of the DGP series. High growth periods are characterized by the largest volatility. On the contrary, moderate growth tends to be less volatile. The average durations of the three regimes are 3.83, 7.09 and 7.45 quarters, respectively. The model describes quite well the business-cycle peaks and troughs as indicated by ECRI, and it captures almost all the turning points.

The importance of oil shocks is assessed and the results presented in Table 7. Results confirm that, if we start with the MSMH model, oil price shocks affect the mean of the process. More specifically, the introduction of asymmetric specifications of oil price shocks improves the log-likelihood function. In case of NOPI, the maximum values of the likelihood function increase from 441.14 to 450.35. Therefore, according to standard LR tests, we reject the null hypothesis of no oil shock effects at 5% significance level. An examination of the coefficients of the three means, which are all statistically significant, shows the presence of switches in output growth between the three different states. In regime 1 (recession regime), output growth per quarter is equal to -0.82%, on average, while in regime 2 the average growth rate is equal to 0.69%. In regime 3 (i.e. high growth regime) Japan's average growth rate amounts to 1.53%. A single autoregressive term is sufficient to describe the autocorrelation structure of the GDP series. Coefficient estimates suggest that oil shocks (net oil price increases) have a delayed negative impact on real GDP growth. While the second coefficient is positive and not statistically significant, the other three coefficients are negative, although only the fourth is statistically different from zero. Regime transitions and business cycle features are not affected by extending the model to a MSIAH(3)-ARX(5) specification. Results from the estimated transition probabilities suggest that regime 2 and 3 are highly persistent. During a moderate growth phase, GDP is most likely to remain in regime 2 (estimated probability equal to 88.93%). On the contrary, the probabilities that the series switches from regime 2 to regimes 1 or 3 are very low (equal to 4.45% and 6.60%, respectively). Finally, the probability that GDP changes directly from a recessionary regime to a high growth regime is virtually identical to zero. Results on the expected duration of each regime confirm the information provided by the transition probabilities. The expected duration of regime 2 is considerably longer than the duration of either regime 1 or regime 3. If the economy is in state 1 (recessionary phase) at time t, it will maintain this position for 1.91 quarters, on average. On the other hand, moderate growth and high growth phases are expected to last on average 9.03 and 7.97 quarters (see Table 10 and Figure 9).

6.6 United Kingdom

Univariate specifications which incorporate three regimes are empirically superior to their two-state counterparts (Table 2). For example, the three coefficients which capture the average of GDP in the MSM(3)-AR(4) model are statistically significant. Regime 1 describes recessionary phases, regime 2 denotes periods of moderate growth, whereas regime 3 represents high growth economic performances. As far as the dynamics of the series is concerned, all four lags on GDP are statistically significant, all with a negative sign. Business cycle peaks and troughs are well captured by the model. A moderate growth phase lasts on average 37 quarters and tends to be followed by a high growth regime. On the other hand, the computed probability (i.e. $Prob(s_t = 3|s_{t-1} = 1) = 0.25$) reflects the high chance that a recession is followed by a period of high growth. Since, as suggested by the value of AIC, the null hypothesis of no heteroskedastic errors is rejected by the data, we have extended the MSM model to a MSMH(3)-AR(3) specification, which appears to adequately represent the main features of the business cycle.

We have then considered MS models with exogenous oil shocks (see Table 8). If we include four lags of net oil price increases and the two measures of oil price volatility to describe the conditional mean of the process, we obtain encouraging results. In comparison with the univariate specification, these models lead to a significant improvement in the respective likelihood functions. The LR statistics are 25.12, 14.05 and 33.72 for the oil shock definitions NOPI, LNR and *oil_vol*. Since these tests are χ^2-distributed with 4 degrees of freedom, in each case we can reject the univariate specification with no oil shocks at any significant level. The coefficients of the NOPI variable are positive but not statistically significant for the first, second and fourth lags. The third lag is negative and statistically significant. These results are in line with the analysis of Holmes and Wang (2001). When the oil price shocks are measured by *oil_vol*, all lags are negative, and the first is strongly significant. These results suggest that oil shocks have a quasi-instantaneous impact on the mean equation for GDP growth. The estimated parameters for the second and third mean coefficients are both statistically significant, and denote moderate and high growth, respectively. Moreover, the time intervals 1973-1975, 1980-1982 and 1990-1991 are described as sluggish economic growth periods. According to this model, in the subsample 1970-1992, the U.K. economy switches from low growth rates (which characterize the early 1970s, as well as the periods 1974-1977, 1980-1982 and 1989-1992) to high growth rates. A remarkable feature of this model is that the last part of the sample (from 1993 to 2004) is described as being characterized by regime 2. The standard errors of the model depict the first regime as high volatile. On the other hand, regime 2 is characterized by lower volatility. According to the calculated transition probabilities, the probability that an expansionary phase is followed by a low-growth phase is high ($Prob(s_t = 1|s_{t-1} = 3) = 0.16$) (see Table 10 and Figure 10).

6.7 United States

Our empirical evidence suggests that different models can be used to adequately describe the U.S. business cycle (Table 2). Although, given the success of the seminal article by Hamilton (1989), two-regime MS models are the most widely used in the empirical literature, our estimates confirm that more robust results come from models which incorporate three regimes. A MSM(3)-AR(4) specification describes the three regimes as recession, moderate growth and high growth. If we relax the assumption of constant error variance, we obtain a generalized improvement of the statistical properties of the resulting MS models. However, specifications MSMH or MSIH are not able to detect the recessions which characterize the last thirty years of the U.S. economic history. In particular, time periods such as 1990q3-1991q1 and 2001q1-2001q4 are not correctly identified as recessionary episodes.

When we augment a MSMH(3)-AR(4) model with different oil shock specifications, we obtain mixed empirical findings (see Table 9). If oil price changes and *oil_disr* are used as proxies for oil shocks, no significant improvements in the likelihood function are achieved. Conversely, better results are found if we consider the oil price volatility as measured by *oil_vol* and NOPI. In the latter case, for instance, the value of the log-likelihood function increases from 477.36 to 482.27. According to this specification, all coefficients on the oil variable are negative, and statistically significant as well. Although a MSMH(3)-AR(0) model which includes *oil_vol* is more appropriate from a statistical viewpoint, nonetheless this specification is not able to justify the two most recent recessions in the U.S. economy. The transition probabilities associated with each of the three regimes point out that the second regime is highly persistent, with p_{22}=0.62. These estimates imply that the average duration of the moderate growth regime is 8.58 quarters. In contrast, the average durations of the recessionary and high-growth regimes are 3.42 and 2.79 quarters. The recessionary state shows a relative high probability to be followed by a high growth period ($Prob(s_t = 3|s_{t-1} = 1) = 0.14$), while the probability of an expansion to be followed by a recession is 0.13. The ergodic probabilities imply that the economy would spend about 62.40% of the time spanned by our sample of data in the second regime (i.e. high-growth). In contrast, regime 1 and regime 3 have ergodic probabilities of 17.30% and 20.30%, respectively. Finally, another relevant feature of this model is the significant variability in the residual standard errors across different regimes. These results provide us with a more detailed interpretation of each single regime. Recessionary states show a strong increase in the variability of the standard errors, which reflects the view that recessions are less stable than expansions. On the other hand, moderate growth rate periods are characterized by relatively smaller residual standard errors.

7 Conclusions

In this paper we have specified and estimated different Markov-switching regime autoregressive models. The empirical performance of the univariate MS models which we have used to describe the switches between different economic regimes for the G-7 countries is, in general, not satisfactory. We have extended these models to verify if the inclusion of oil shocks as an exogenous variable improves the ability of each specification to identify the different phases of the business cycle for each country under scrutiny. Following the wide literature on this topic, we have considered six different definitions of oil shocks. In particular, oil shocks are proxied by oil price changes, asymmetric transformations of oil price changes (i.e. positive oil price changes and net oil price increases), oil price volatility (that is, scaled oil price increases and standard deviation of oil prices), and oil supply conditions. We have measured the persistence of each economic regimes, as well as the ability of each MS model to detect the business cycle dates as described by widely acknowledged statistical institutions (namely ECRI and NBER).

Our empirical findings can be summarized as follows. First, the null hypothesis of linearity against the alternative of a MS specification is always rejected by the data. This suggests that regime-dependent models should be used if a researcher is interested in obtaining statistically adequate representations of the output growth process. Second, three-regime MS models typically outperform the corresponding two-regime specifications in describing the business cycle features for different countries. Third, according to our model selection strategy, the introduction of different oil shock specifications is never rejected. Fourth, positive oil price changes, net oil price increases and oil price volatility are the oil shock definitions which, once included in a univariate model for real GDP, contribute to a better description of the impact of oil on the output variable. Fifth, models with exogenous oil variables generally outperform the corresponding univariate specifications which exclude oil from the analysis, since they provide a more accurate identification of the switches between different economic phases.

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Figure 1: Different definitions of oil shocks

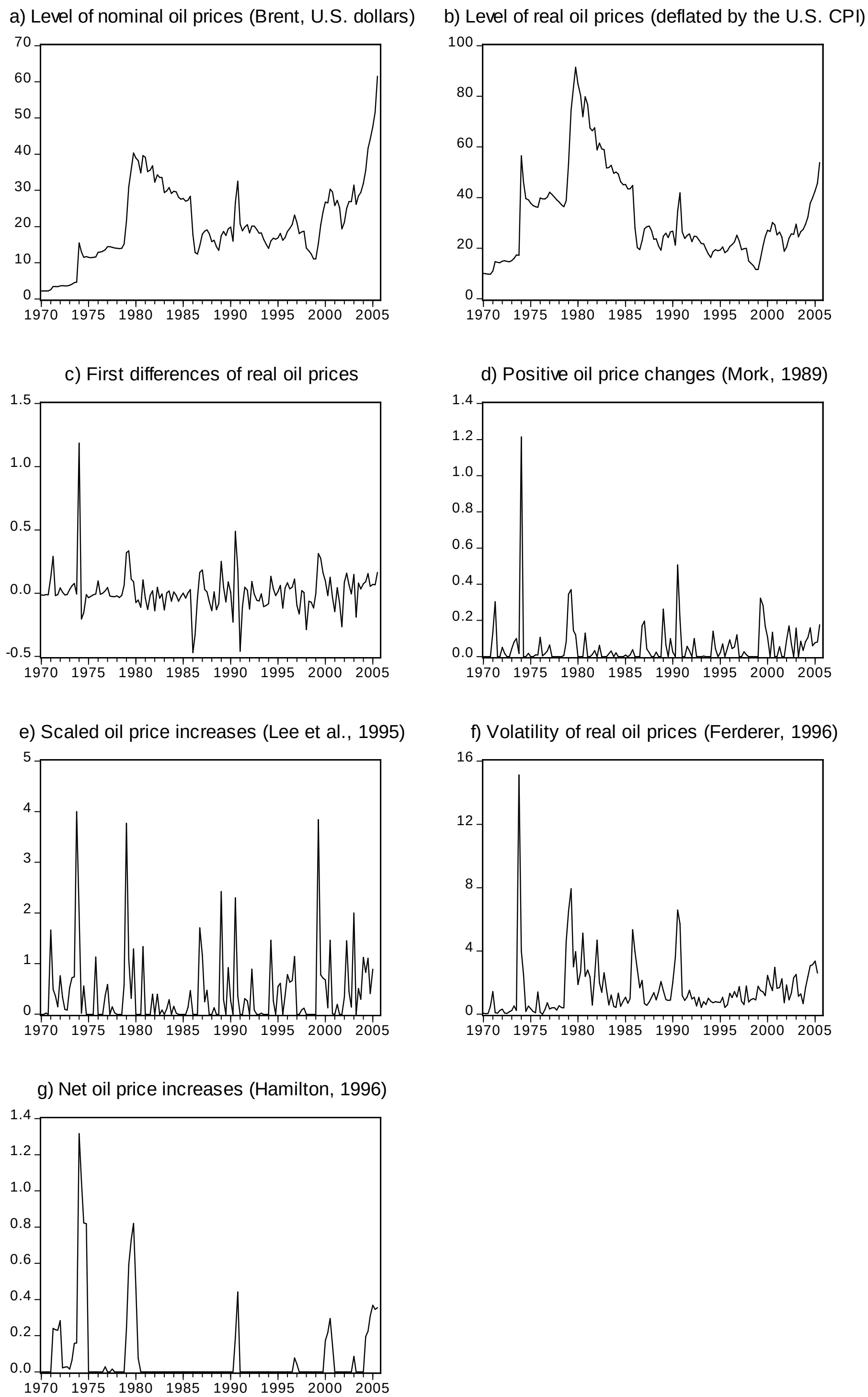


Figure 2: Oil production shortfalls

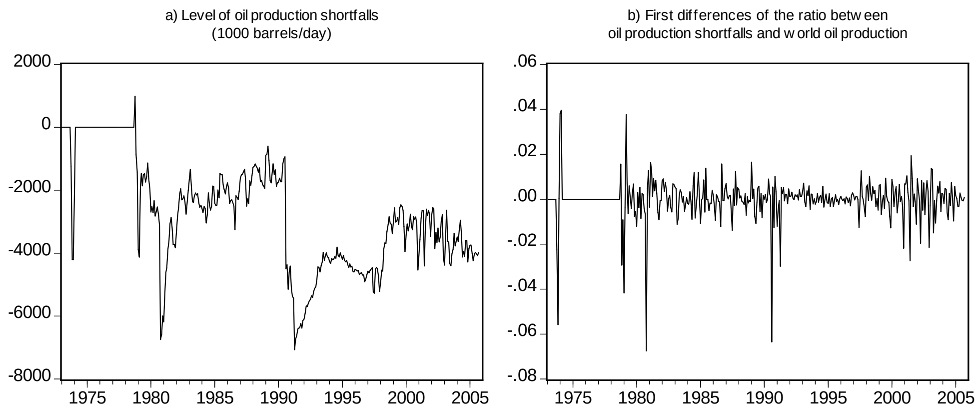


Figure 3: Real GDP

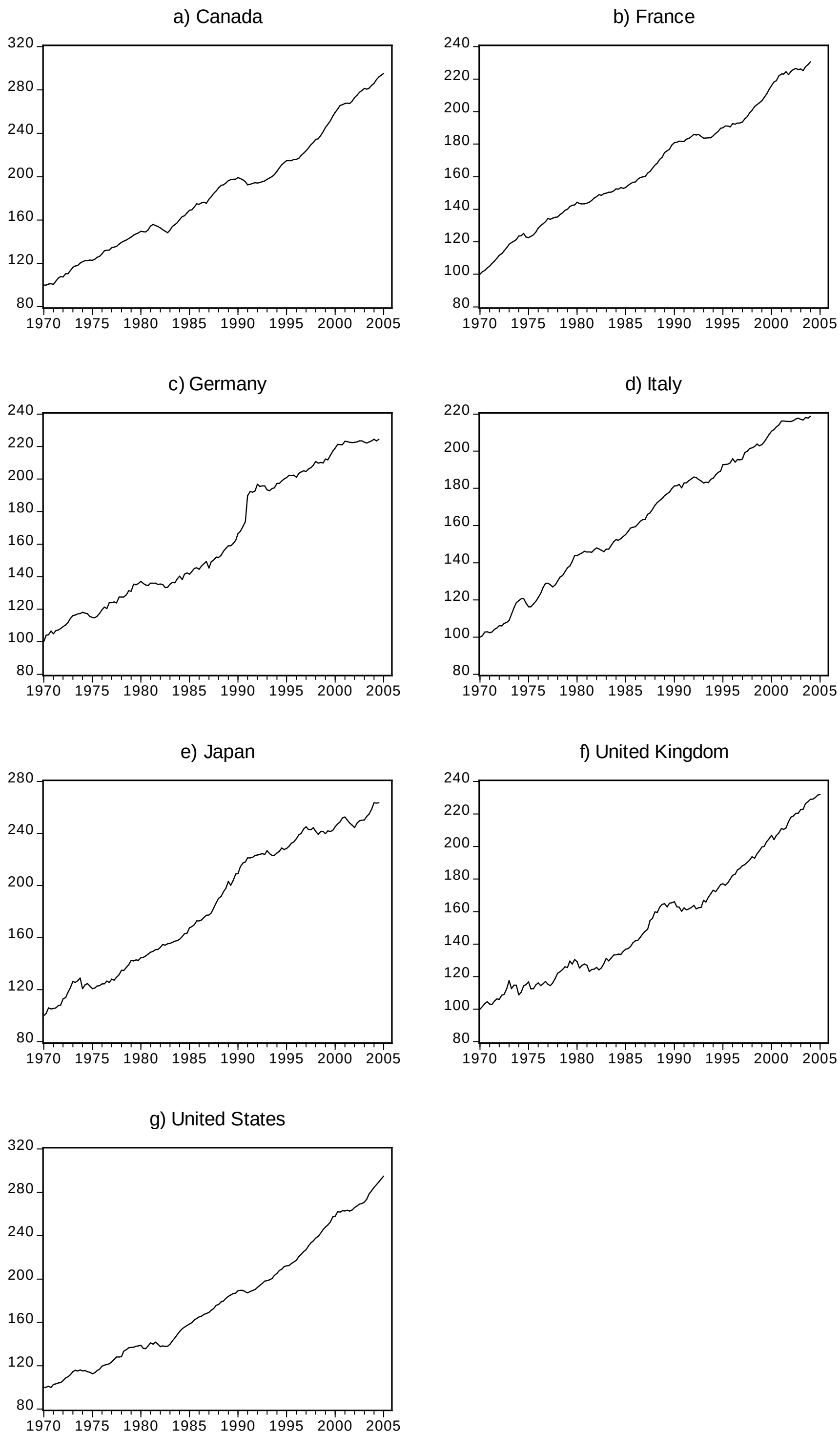


Figure 4: First differences of real GDP

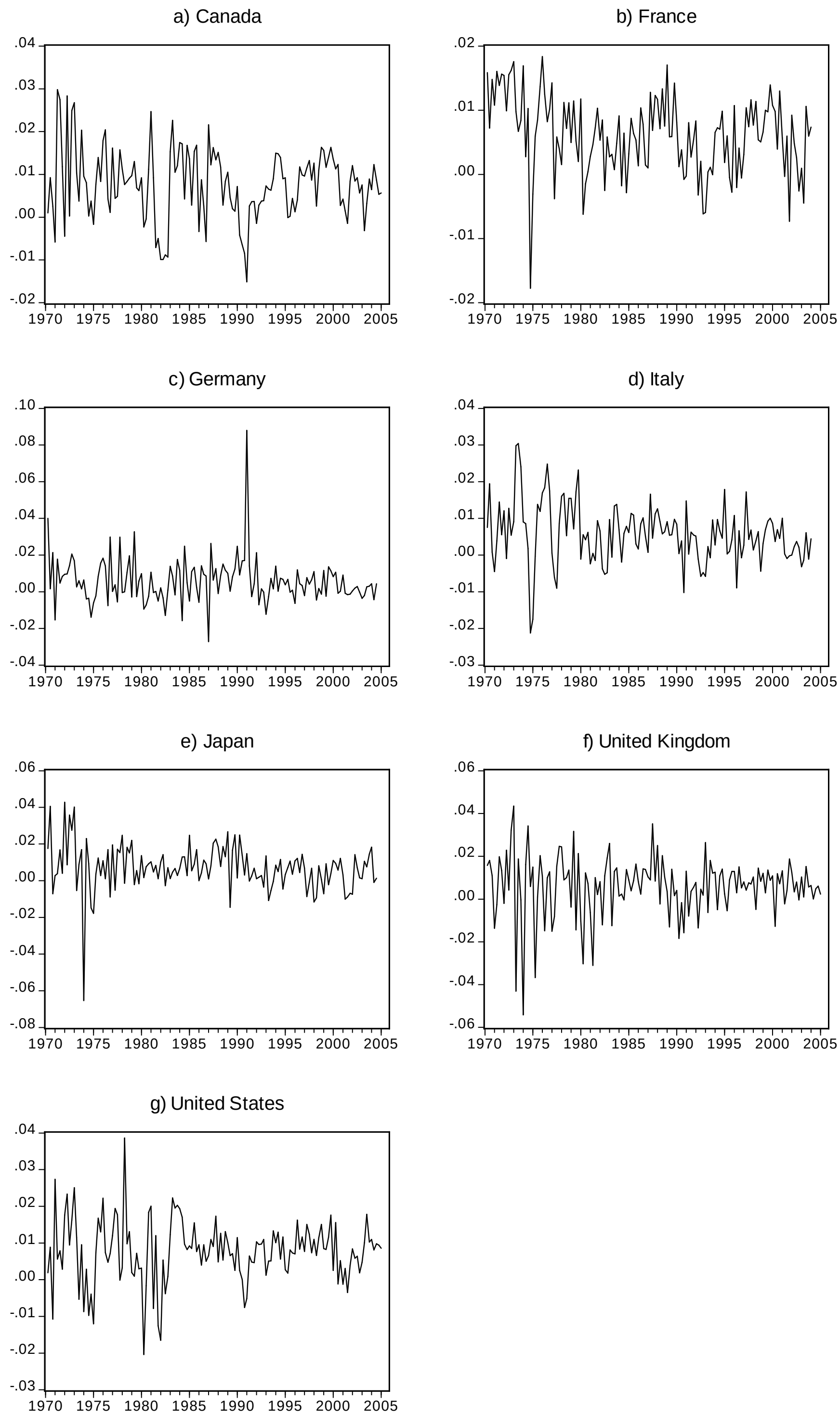


Table 1: Business cycles for the G-7 Countries

		Canada	France	Germany	Italy	Japan	United Kingdom	United States
1970-1975	Peak				10/1970			
	Trough				*8/1971*			
	Peak		7/1974	8/1973	4/1974	11/1973	9/1974	11/1973
	Trough		*6/1975*	*7/1975*	*4/1975*	*2/1975*	*8/1975*	*3/1975*
1976-1980	Peak		8/1979	1/1980	5/1980		6/1979	1/1980
	Trough		*6/1980*		*5/1983*		*5/1981*	*7/1980*
1981-1985	Peak	4/1981	4/1982					7/1981
	Trough	*11/1982*	*12/1984*	*10/1982*				*11/1982*
1986-1990	Peak	3/1990					5/1990	7/1990
	Trough							
1991-1995	Peak		2/1992	1/1991	2/1992	4/1992		
	Trough	*3/1992*	*8/1993*	*4/1994*	*10/1993*	*2/1994*	*3/1992*	*3/1991*
1996-2000	Peak					3/1997		
	Trough					*7/1999*		
	Peak					8/2000		
	Trough							
2001-2005	Peak			1/2001				3/2001
	Trough			*8/2003*		*4/2003*		*11/2001*

Notes. Entries of this table are the business cycle peak and trough dates (month/year) as indicated by the Economic Cycle Research Institute (ECRI) in September 2005, with the exception of United States, where the source of information is the National Bureau of Economic Research (NBER).

Table 2: Markov switching models for real GDP

		Canada	France	Germany	Italy	Japan	United Kingdom	United States
MSM	Regimes	3	3	3	3	3	3	3
	Log-likelihood	491.76	516.05	435.60	478.19	437.04	386.83	482.15
	AIC	-7.12	-7.56	-6.37	-7.00	-6.33	-5.65	-6.94
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	2/5 stat. sign.	2/3 stat. sign.	1/4 stat. sign.	3/3 stat. sign.	3/5 stat. sign.	4/4 stat. sign.	3/4 stat. sign.
	Regime prob. (duration)	0.11 (2.70) 0.82 (26.12) 0.07 (1.69)	0.01 (1.00) 0.36 (2.65) 0.63 (4.57)	0.03 (1.40) 0.67 (27.97) 0.29 (12.13)	0.35 (1.73) 0.31 (7.67) 0.35 (2.05)	0.09 (1.87) 0.81 (16.97) 0.10 (4.89)	0.26 (3.30) 0.56 (37.88) 0.17 (2.22)	0.00 (2.35) 1.00 (na) 0.00 (2.05)
MSI	Regimes	3	3	3	3	3	3	3
	Log-likelihood	489.72	519.14	437.84	481.33	441.13	401.12	475.46
	AIC	-7.12	-7.57	-6.41	-6.97	-6.36	-5.87	-6.87
	Means/Intercepts	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/6 stat. sign.	1/4 stat. sign.	2/2 stat. sign.	1/1 stat. sign.	3/4 stat. sign.	1/4 stat. sign.	2/5 stat. sign.
	Regime prob. (duration (2)	0.11 (2.82) 0.84 (25.14) 0.04 (1.13)	0.00 (1.00) 1.00 (na) 0.00 (12.96)	0.65 (6.27) 0.02 (1.00) 0.32 (2.69)	0.00 (1.82) 1.00 (na) 0.00 (4.76)	0.21 (2.29) 0.86 (8.22) 0.04 (3.58)	0.03 (1.00) 0.93 (40.55) 0.04 (2.96)	0.00 (1.23) 1.00 (na) 0.00 (2.07)
MSMH	Regimes	3	3	3	3	3	3	3
	Log-likelihood	492.26	519.04	442.46	478.18	448.61	407.01	487.66
	AIC	-7.09	-7.54	-6.45	-7.04	-6.38	-5.89	-6.99
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	1/3 stat. sign.
	N. of Lags on GDP	4/5 stat. sign.	1/2 stat. sign.	1/4 stat. sign.	3/5 stat. sign.	1/2 stat. sign.	3/3 stat. sign.	2/4 stat. sign.
	Regime prob. (duration)	0.14 (2.84) 0.78 (28.04) 0.08 (1.71)	0.00 (1.68) 1.00 (na) 0.00 (9.47)	1.00 (na) 0.00 (10.19) 0.00 (44.57)	0.32 (2.38) 0.36 (2.89) 0.32 (4.20)	0.16 (3.83) 0.56 (7.09) 0.28 (7.45)	0.28 (9.00) 0.53 (35.27) 0.19 (4.05)	0.00 (2.45) 1.00 (na) 0.00 (2.18)
MSIH	Regimes	3	3	3	3	3	3	3
	Log-likelihood	491.25	520.98	441.14	482.25	441.45	408.39	487.59
	AIC	-7.12	-7.57	-6.43	-6.95	-6.40	-5.95	-6.99
	Means/Intercepts	3/3 stat. sign.	2/3 stat. sign.	1/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	1/3 stat. sign.	1/3 stat. sign.
	N. of Lags on GDP	3/6 stat. sign.	1/2 stat. sign.	1/4 stat. sign.	1/1 stat. sign.	4/6 stat. sign.	1/4 stat. sign.	2/4 stat. sign.
	Regime prob. (duration)	0.10 (2.50) 0.84 (23.79) 0.06 (1.21)	0.01 (1.62) 0.92 (107.76) 0.06 (7.20)	0.40 (2.11) 0.25 (1.58) 0.35 (3.45)	0.00 (1.97) 1.00 (na) 0.00 (5.66)	0.13 (2.06) 0.60 (10.84) 0.27 (10.60)	0.16 (7.34) 0.40 (2.10) 0.44 (2.10)	0.22 (4.12) 0.58 (26.85) 0.21 (5.71)
MSIA	Regimes	3	3	3	3	3	3	3
	Log-likelihood	501.76	523.35	449.99	486.79	453.92	417.56	492.63
	AIC	-7.12	-7.57	-6.44	-7.04	-6.41	-5.99	-6.98
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	2/5 stat. sign. (1st r.) 3/5 stat. sign. (2nd r.) 3/5 stat. sign. (3rd r.)	1/2 stat. sign. (1st r.) 1/2 stat. sign. (2nd r.) 1/2 stat. sign. (3rd r.)	1/5 stat. sign. (1st r.) 4/5 stat. sign. (2nd r.) 4/5 stat. sign. (3rd r.)	4/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	3/6 stat. sign. (1st r.) 2/6 stat. sign. (2nd r.) 4/6 stat. sign. (3rd r.)	4/5 stat. sign. (1st r.) 1/5 stat. sign. (2nd r.) 1/5 stat. sign. (3rd r.)	3/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 5/5 stat. sign. (3rd r.)
	Regime prob. (duration)	0.18 (3.69) 0.60 (8.14) 0.22 (4.01)	0.00 (1.01) 1.00 (na) 0.00 (8.30)	0.27 (1.01) 0.62 (3.91) 0.11 (1.00)	0.00 (2.74) 1.00 (na) 0.00 (5.49)	0.17 (1.74) 0.49 (2.12) 0.33 (1.33)	0.07 (2.33) 0.82 (19.45) 0.11 (1.47)	0.27 (2.24) 0.55 (8.74) 0.18 (1.45)
MSIAH	Regimes	3	3	3	3	3	3	3
	Log-likelihood	502.79	529.24	451.51	487.35	452.94	427.73	494.33
	AIC	-7.11	-7.63	-6.43	-7.02	-6.36	-6.12	-6.98
	Means/Intercepts	3/3 stat. sign.	1/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	1/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	1/6 stat. sign. (1st r.) 3/6 stat. sign. (2nd r.) 4/6 stat. sign. (3rd r.)	1/2 stat. sign. (1st r.) 2/2 stat. sign. (2nd r.) 2/2 stat. sign. (3rd r.)	0/3 stat. sign. (1st r.) 1/3 stat. sign. (2nd r.) 3/3 stat. sign. (3rd r.)	4/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	3/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 2/5 stat. sign. (3rd r.)	5/6 stat. sign. (1st r.) 3/6 stat. sign. (2nd r.) 4/6 stat. sign. (3rd r.)	2/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 5/5 stat. sign. (3rd r.)
	Regime prob. (duration)	0.10 (2.92) 0.78 (18.98) 0.12 (4.12)	0.43 (1.00) 0.44 (1.00) 0.13 (1.22)	0.60 (22.32) 0.18 (4.30) 0.22 (10.34)	0.15 (1.26) 0.64 (6.07) 0.21 (7.94)	0.20 (2.56) 0.60 (7.84) 0.20 (7.71)	0.10 (1.46) 0.82 (32.71) 0.09 (1.28)	0.26 (2.27) 0.53 (10.79) 0.21 (1.91)

Notes. MSM = Markov-switching model in-mean; MSI = Markov-switching model in-intercept; MSMH = Markov-switching model in-mean with regime-varying error variance; MSIH = Markov-switching model in-intercept with regime-varying error variance; MSIA = Markov-switching model in-intercept with regime-varying autoregressive coefficients; MSIAH = Markov-switching model in-intercept with regime-varying error variance and autoregressive coefficients; Stat. sign. = statistically significant at 5% significance level; na = extremely large (i.e. implausible) duration values; (1) the null hypothesis of linearity (LR test) cannot be rejected at any significant level.

Table 3: Markov switching models for real GDP with exogenous oil - Canada

		$\Delta roil_t$	Δo^+_t	$NOPI_t$	LNR_t	oil_vol_t	oil_disr_t(2)
MSM	Regimes	3	3	3	3	3	3
	Log-likelihood	495.62	499.63	495.92	495.50	498.75	469.76
	AIC	-7.09	-7.14	-7.12	-7.07	-7.16	-7.27
	Means/Intercepts	3/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	2/3 stat. sign.	4/4 stat. sign.	2/5 stat. sign.	4/4 stat. sign.	5/5 stat. sign.	2/4 stat. sign.
	N. of Lags on OIL	2/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.	0/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.
	Regime prob. (duration)	0.08 (2.20) 0.83 (22.72) 0.09 (1.66)	0.09 (2.55) 0.83 (27.27) 0.08 (1.73)	0.10 (2.76) 0.83 (29.39) 0.07 (1.62)	0.10 (2.40) 0.82 (25.50) 0.08 (1.62)	0.12 (2.97) 0.85 (32.33) 0.06 (1.80)	0.12 (3.81) 0.82 (32.11) 0.06 (1.88)
MSI	Regimes	3	3	3	3	3	3
	Log-likelihood	497.16	498.11	498.68	494.35	496.58	463.30
	AIC	-7.18	-7.19	-7.08	-7.13	-7.17	-7.23
	Means/Intercepts	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	4/6 stat. sign.	4/6 stat. sign.	2/3 stat. sign.	4/6 stat. sign.	4/6 stat. sign.	1/1 stat. sign.
	N. of Lags on OIL	2/4 stat. sign.	2/4 stat. sign.	0/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.	0/4 stat. sign.
	Regime prob. (duration)	0.11 (2.30) 0.83 (25.45) 0.06 (1.14)	0.11 (2.55) 0.83 (23.72) 0.06 (1.12)	0.10 (2.51) 0.84 (21.64) 0.05 (1.37)	0.11 (2.63) 0.83 (25.45) 0.06 (1.11)	0.09 (2.82) 0.85 (20.24) 0.06 (1.11)	0.20 (2.16) 0.65 (20.10) 0.14 (1.56)
MSMH	Regimes	3	3	3	3	3	3
	Log-likelihood	501.50	500.87	496.77	499.21	500.79	465.53
	AIC	-7.15	-7.14	-7.10	-7.06	-7.16	-7.23
	Means/Intercepts	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/3 stat. sign.	3/3 stat. sign.	3/5 stat. sign.	3/3 stat. sign.	2/5 stat. sign.	1/1 stat. sign.
	N. of Lags on OIL	2/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.
	Regime prob. (duration)	0.08 (2.17) 0.85 (23.16) 0.08 (1.54)	0.08 (2.20) 0.83 (27.63) 0.09 (2.00)	0.08 (2.92) 0.82 (27.67) 0.09 (2.22)	0.08 (2.33) 0.84 (22.31) 0.08 (1.53)	0.06 (3.32) 0.80 (23.22) 0.13 (2.59)	0.00 (4.67) 1.00 (na) 0.00 (28.41)
MSIH	Regimes	3	3	3	3	3	3
	Log-likelihood	499.80	501.34	499.02	497.43	504.63	468.99
	AIC	-7.19	-7.21	-7.17	-7.15	-7.22	-7.29
	Means/Intercepts	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/6 stat. sign.	3/6 stat. sign.	3/6 stat. sign.	4/6 stat. sign.	2/5 stat. sign.	1/1 stat. sign.
	N. of Lags on OIL	2/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.	0/4 stat. sign.	2/4 stat. sign.
	Regime prob. (duration)	0.10 (2.48) 0.84 (26.56) 0.06 (1.23)	0.10 (2.46) 0.83 (25.21) 0.06 (1.25)	0.10 (2.49) 0.84 (27.85) 0.05 (1.19)	0.10 (2.46) 0.84 (26.07) 0.06 (1.24)	0.06 (3.15) 0.82 (26.65) 0.11 (2.57)	0.00 (4.28) 1.00 (na) 0.00 (26.80)
MSIA	Regimes	3	3	3	3	3	3
	Log-likelihood	524.28	516.92	512.78	518.29	526.48	491.98
	AIC	-7.27	-7.17	-7.21	-7.18	-7.30	-7.39
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	3/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 5/5 stat. sign. (3rd r.)	2/6 stat. sign. (1st r.) 5/6 stat. sign. (2nd r.) 2/6 stat. sign. (3rd r.)	2/5 stat. sign. (1st r.) 3/5 stat. sign. (2nd r.) 4/5 stat. sign. (3rd r.)	3/5 stat. sign. (1st r.) 4/5 stat. sign. (2nd r.) 4/5 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 4/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)
	N. of Lags on OIL	2/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.32 (2.63) 0.45 (5.28) 0.22 (1.81)	0.15 (4.95) 0.72 (11.93) 0.21 (2.18)	0.41 (4.14) 0.44 (4.36) 0.15 (3.81)	0.25 (2.14) 0.52 (6.34) 0.23 (3.02)	0.44 (444) 0.38 (2.45) 0.19 (2.60)	0.19 (9.27) 0.50 (7.84) 0.31 (3.62)
MSIAH	Regimes	3	3	3	3	3	3
	Log-likelihood	505.73	515.98	520.10	515.11	515.08	506.74
	AIC	-7.05	-7.13	-7.16	-7.10	-7.13	-7.54
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	1/2 stat. sign. (1st r.) 1/2 stat. sign. (2nd r.) 1/2 stat. sign. (3rd r.)	3/6 stat. sign. (1st r.) 4/6 stat. sign. (2nd r.) 2/6 stat. sign. (3rd r.)	2/3 stat. sign. (1st r.) 2/3 stat. sign. (2nd r.) 1/3 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	2/2 stat. sign. (1st r.) 1/2 stat. sign. (2nd r.) 2/2 stat. sign. (3rd r.)	4/5 stat. sign. (1st r.) 3/5 stat. sign. (2nd r.) 4/5 stat. sign. (3rd r.)
	N. of Lags on OIL	2/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 0/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 0/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.18 (11.19) 0.57 (28.98) 0.26 (9.37)	0.13 (4.77) 0.70 (18.12) 0.17 (4.27)	0.21 (1.85) 0.60 (9.64) 0.18 (3.35)	0.18 (2.20) 0.71 (24.77) 0.12 (1.48)	0.12 (1.88) 0.38 (27.05) 0.20 (3.10)	0.11 (6.97) 0.79 (20.02) 0.10 (2.16)

Notes. See Table 2. (2) For the variable oil_disr the sample spans from 1974q1 to 2004q4; Δroil = first differences of real oil prices; Δo^+ = positive oil price changes; NOPI = net oil price increases (Hamilton, 1996); LNR = scaled oil price increases (Lee et al., 1995); oil_vol = volatility of real oil prices; oil_disr = first differences of the ratio between oil production shortfalls and world oil production

Table 4: Markov switching models for real GDP with exogenous oil - France

		$\Delta roil_t$	Δo^*_t	$NOPI_t$	LNR_t	oil_vol_t	oil_disr_t (2)
MSM	Regimes	3	3	3	3	3	3
	Log-likelihood	516.98	511.86	514.03	513.95	520.97	468.48
	AIC	-7.59	-7.50	-7.52	-7.49	-7.62	-7.45
	Means/Intercepts	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	2/2 stat. sign.	3/3 stat. sign.	-	1/2 stat. sign.	-	2/4 stat. sign.
	N. of Lags on OIL	2/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	0/4 stat. sign.
	Regime prob. (duration)	0.00 (1.00) 1.00 (na) 0.00 (15.00)	0.38 (3.15) 0.52 (3.64) 0.10 (4.82)	0.15 (1.10) 0.43 (3.03) 0.42 (9.58)	0.18 (1.15) 0.40 (2.55) 0.41 (9.21)	0.27 (2.60) 0.44 (3.98) 0.29 (7.25)	0.01 (1.00) 0.67 (20.09) 0.32 (8.18)
MSI	Regimes	3	3	3	3	3	3
	Log-likelihood	513.94	513.10	521.21	515.18	526.67	467.78
	AIC	-7.56	-7.53	-7.58	-7.51	-7.68	-7.43
	Means/Intercepts	3/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	2/5 stat. sign.	1/2 stat. sign.	2/3 stat. sign.	1/2 stat. sign.	1/2 stat. sign.	2/4 stat. sign.
	N. of Lags on OIL	1/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.
	Regime prob. (duration)	0.00 (1.00) 1.00 (na) 0.00 (11.48)	0.45 (3.16) 0.55 (3.88) 0.00 (8.86)	0.36 (2.98) 0.57 (4.68) 0.06 (7.07)	0.31 (1.84) 0.60 (3.58) 0.09 (5.97)	0.32 (2.78) 0.61 (5.35) 0.07 (6.59)	0.34 (2.84) 0.36 (4.12) 0.30 (7.94)
MSMH	Regimes	3	3	3	3	3	3
	Log-likelihood	518.22	515.38	518.64	519.71	525.26	476.36
	AIC	-7.58	-7.52	-7.53	-7.53	-7.64	-7.56
	Means/Intercepts	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	2/2 stat. sign.	3/3 stat. sign.	1/2 stat. sign.	2/3 stat. sign.	1/1 stat. sign.	2/3 stat. sign.
	N. of Lags on OIL	2/4 stat. sign.	3/4 stat. sign.	3/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	3/4 stat. sign.
	Regime prob. (duration)	0.00 (1.00) 1.00 (na) 0.00 (9.06)	0.42 (2.98) 0.32 (4.79) 0.27 (1.91)	0.47 (5.18) 0.26 (2.81) 0.27 (7.03)	0.01 (1.83) 0.45 (2.77) 0.53 (3.23)	0.30 (2.85) 0.33 (3.09) 0.37 (8.96)	0.00 (8.00) 0.71 (6.09) 0.29 (2.53)
MSIH	Regimes	3	3	3	3	3	3
	Log-likelihood	518.89	515.68	522.92	516.48	528.39	477.52
	AIC	-7.60	-7.53	-7.58	-7.50	-7.68	-7.58
	Means/Intercepts	1/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	1/3 stat. sign.
	N. of Lags on GDP	3/5 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	1/2 stat. sign.	2/2 stat. sign.	3/3 stat. sign.
	N. of Lags on OIL	2/4 stat. sign.	2/4 stat. sign.	3/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.	3/4 stat. sign.
	Regime prob. (duration)	0.02 (1.00) 0.74 (10.28) 0.24 (2.94)	0.27 (2.10) 0.53 (4.13) 0.21 (3.11)	0.44 (3.94) 0.36 (5.21) 0.20 (1.60)	0.43 (3.24) 0.49 (3.69) 0.07 (5.97)	0.30 (3.01) 0.29 (2.82) 0.41 (8.53)	0.00 (10.27) 0.66 (3.59) 0.34 (1.81)
MSIA	Regimes	3	3	3	3	3	3
	Log-likelihood	553.83	548.54	543.40	545.27	549.60	492.85
	AIC	-7.91	-7.81	-7.80	-7.76	-7.84	-7.58
	Means/Intercepts	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/6 stat. sign. (1st r.) 5/6 stat. sign. (2nd r.) 5/6 stat. sign. (3rd r.)	3/5 stat. sign. (1st r.) 4/5 stat. sign. (2nd r.) 3/5 stat. sign. (3rd r.)	4/6 stat. sign. (1st r.) 4/6 stat. sign. (2nd r.) 6/6 stat. sign. (3rd r.)	4/5 stat. sign. (1st r.) 3/5 stat. sign. (2nd r.) 2/5 stat. sign. (3rd r.)	4/6 stat. sign. (1st r.) 3/6 stat. sign. (2nd r.) 2/6 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)
	N. of Lags on OIL	3/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 0/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.30 (1.72) 0.42 (1.44) 0.29 (1.61)	0.33 (1.99) 0.31 (2.89) 0.36 (2.43)	0.29 (1.49) 0.45 (1.51) 0.27 (1.44)	0.32 (1.31) 0.41 (1.37) 0.28 (1.61)	0.28 (1.86) 0.34 (1.94) 0.38 (2.04)	0.33 (1.96) 0.25 (1.14) 0.42 (5.32)
MSIAH	Regimes	3	3	3	3	3	3
	Log-likelihood	557.51	551.30	547.18	548.09	552.82	499.02
	AIC	-7.93	-7.82	-7.88	-7.75	-7.84	-7.75
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	1/3 stat. sign.	3/3 stat. sign.	1/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/6 stat. sign. (1st r.) 4/6 stat. sign. (2nd r.) 5/6 stat. sign. (3rd r.)	4/5 stat. sign. (1st r.) 1/5 stat. sign. (2nd r.) 3/5 stat. sign. (3rd r.)	4/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 4/5 stat. sign. (3rd r.)	3/3 stat. sign. (1st r.) 1/3 stat. sign. (2nd r.) 1/3 stat. sign. (3rd r.)	3/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 2/5 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 0/4 stat. sign. (3rd r.)
	N. of Lags on OIL	3/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 0/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.30 (1.56) 0.46 (1.46) 0.25 (1.41)	0.32 (1.60) 0.30 (1.69) 0.37 (1.81)	0.34 (1.99) 0.29 (1.89) 0.37 (2.07)	0.09 (1.43) 0.37 (2.56) 0.54 (3.40)	0.36 (1.93) 0.25 (1.84) 0.38 (2.03)	0.20 (1.14) 0.50 (3.07) 0.30 (10.16)

Notes. See Table 3.

Table 5: Markov switching models for real GDP with exogenous oil - Germany

		$\Delta roil_t$	Δo^*_t	$NOPI_t$	LNR_t	oil_vol_t	oil_disr_t (2)
MSM	Regimes	2	3 (1)	3 (1)	3	3 (1)	3
	Log-likelihood	430.02	434.84	437.49	437.85	435.03	400.19
	AIC	-6.36	-6.30	-6.34	-6.34	-6.34	-6.35
	Means/Intercepts	1/2 stat. sign.	1/3 stat. sign.	1/3 stat. sign.	3/3 stat. sign.	1/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	-	1/4 stat. sign.	1/4 stat. sign.	1/1 stat. sign.	2/5 stat. sign.	1/1 stat. sign.
	N. of Lags on OIL	1/4 stat. sign.	0/4 stat. sign.	0/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.
	Regime prob. (duration)	0.79 (22.21) 0.23 (6.69)	0.34 (3.83) 0.42 (4.42) 0.24 (5.62)	0.36 (4.21) 0.39 (4.06) 0.25 (6.02)	0.01 (1.42) 0.86 (83.70) 0.12 (11.89)	0.30 (2.79) 0.44 (3.75) 0.25 (2.58)	0.00 (2.23) 1.00 (na) 0.00 (2.23)
MSI	Regimes	2	3	3	3	3 (1)	3
	Log-likelihood	430.02	442.35	445.52	439.25	435.02	405.46
	AIC	-6.36	-6.41	-6.46	-6.36	-6.34	-6.39
	Means/Intercepts	1/2 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	0/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	-	1/4 stat. sign.	2/4 stat. sign.	1/1 stat. sign.	2/5 stat. sign.	2/4 stat. sign.
	N. of Lags on OIL	1/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.
	Regime prob. (duration)	0.79 (22.21) 0.23 (6.69)	0.02 (1.00) 0.68 (5.88) 0.30 (2.30)	0.67 (5.82) 0.02 (1.00) 0.31 (2.32)	0.07 (1.00) 0.60 (21.64) 0.33 (3.42)	0.31 (2.20) 0.45 (2.95) 0.24 (1.87)	0.00 (2.20) 1.00 (na) 0.00 (2.32)
MSMH	Regimes	2	3	3	3	3	3
	Log-likelihood	440.32	448.54	452.15	455.46	447.47	416.15
	AIC	-6.50	-6.51	-6.53	-6.62	-6.50	-6.51
	Means/Intercepts	1/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	-	2/5 stat. sign.	1/4 stat. sign.	3/5 stat. sign.	3/5 stat. sign.	4/5 stat. sign.
	N. of Lags on OIL	1/4 stat. sign.	3/4 stat. sign.	1/4 stat. sign.	4/4 stat. sign.	2/4 stat. sign.	3/4 stat. sign.
	Regime prob. (duration)	1.00 (na) 0.00 (90.96)	0.30 (2.80) 0.44 (3.24) 0.26 (1.27)	0.28 (1.90) 0.28 (1.24) 0.43 (3.51)	0.31 (2.86) 0.41 (3.14) 0.28 (1.33)	0.21 (2.70) 0.34 (4.35) 0.46 (13.18)	0.49 (15.82) 0.19 (1.66) 0.32 (3.39)
MSIH	Regimes	2	3	3	3	3	3
	Log-likelihood	450.30	446.26	453.36	451.82	450.67	406.09
	AIC	-6.63	-6.50	-6.55	-6.56	-6.54	-6.43
	Means/Intercepts	2/2 stat. sign.	3/3 stat. sign.	1/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	5/5 stat. sign.	-	1/4 stat. sign.	3/5 stat. sign.	2/5 stat. sign.	-
	N. of Lags on OIL	3/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.	3/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.
	Regime prob. (duration)	0.23 (2.13) 0.77 (6.94)	0.45 (17.37) 0.11 (2.74) 0.43 (21.64)	0.32 (2.11) 0.29 (1.31) 0.39 (3.63)	0.29 (2.83) 0.40 (2.73) 0.31 (1.39)	0.54 (2.53) 0.27 (1.70) 0.19 (1.49)	0.00 (5.33) 0.99 (na) 0.00 (20.36)
MSIA	Regimes	3	3	3	3	3	3
	Log-likelihood	462.39	451.30	462.95	463.67	473.02	430.90
	AIC	-6.49	-6.41	-6.46	-6.47	-6.61	-6.46
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	1/3 stat. sign.	1/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	2/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 3/5 stat. sign. (3rd r.)	1/1 stat. sign. (1st r.) 0/1 stat. sign. (2nd r.) 1/1 stat. sign. (3rd r.)	2/6 stat. sign. (1st r.) 5/6 stat. sign. (2nd r.) 2/6 stat. sign. (3rd r.)	3/5 stat. sign. (1st r.) 4/5 stat. sign. (2nd r.) 3/5 stat. sign. (3rd r.)	4/5 stat. sign. (1st r.) 3/5 stat. sign. (2nd r.) 4/5 stat. sign. (3rd r.)	2/5 stat. sign. (1st r.) 1/5 stat. sign. (2nd r.) 4/5 stat. sign. (3rd r.)
	N. of Lags on OIL	1/4 stat. sign. (1st r.) 4/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	0/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.32 (1.01) 0.43 (1.54) 0.25 (1.87)	0.56 (8.63) 0.10 (1.00) 0.33 (2.61)	0.58 (11.16) 0.16 (10.26) 0.25 (3.71)	0.20 (1.00) 0.52 (5.94) 0.28 (1.77)	0.41 (3.06) 0.26 (1.00) 0.33 (2.36)	0.43 (13.37) 0.33 (9.85) 0.24 (10.83)
MSIAH	Regimes	3	3	3	3	3	3
	Log-likelihood	502.10	473.93	469.80	477.74	466.62	433.44
	AIC	-7.08	-6.64	-6.53	-6.66	-6.53	-6.52
	Means/Intercepts	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	5/6 stat. sign. (1st r.) 2/6 stat. sign. (2nd r.) 6/6 stat. sign. (3rd r.)	1/3 stat. sign. (1st r.) 3/3 stat. sign. (2nd r.) 3/3 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	2/6 stat. sign. (1st r.) 3/6 stat. sign. (2nd r.) 4/6 stat. sign. (3rd r.)	3/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 4/5 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)
	N. of Lags on OIL	3/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.25 (2.15) 0.60 (3.64) 0.16 (1.11)	0.60 (21.64) 0.31 (8.11) 0.09 (2.50)	0.26 (8.33) 0.56 (15.36) 0.18 (4.02)	0.36 (3.19) 0.37 (2.01) 0.27 (1.75)	0.51 (5.94) 0.35 (3.25) 0.14 (2.59)	0.47 (9.27) 0.15 (5.03) 0.39 (7.78)

Notes. See Table 3.

Table 6: Markov switching models for real GDP with exogenous oil - Italy

		$\Delta roil_t$	Δo^*_t	$NOPI_t$	LNR_t	oil_vol_t	oil_disr_t (2)
MSM	Regimes	2	3	3	3	3	2
	Log-likelihood	475.65	475.21	470.74	487.37	484.50	450.86
	AIC	-7.03	-6.97	-7.02	-7.07	-7.05	-7.24
	Means/Intercepts	1/2 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	1/2 stat. sign.
	N. of Lags on GDP	2/3 stat. sign.	1/1 stat. sign.	3/4 stat. sign.	2/3 stat. sign.	3/5 stat. sign.	4/4 stat. sign.
	N. of Lags on OIL	1/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	3/4 stat. sign.	2/4 stat. sign.	3/4 stat. sign.
	Regime prob. (duration)	0.5883 (2.76) 0.4117 (1.93)	0.11 (5.53) 0.85 (43.72) 0.04 (2.19)	0.30 (8.28) 0.39 (2.07) 0.30 (1.91)	0.37 (1.83) 0.26 (12.46) 0.37 (2.09)	0.36 (1.68) 0.36 (4.16) 0.28 (1.61)	0.61 (3.10) 0.39 (1.97)
MSI	Regimes	3	2	3	3 (1)	3	2
	Log-likelihood	477.47	475.39	479.28	479.44	481.77	439.62
	AIC	-6.98	-7.02	-6.98	-6.95	-7.02	-7.02
	Means/Intercepts	2/3 stat. sign.	2/2 stat. sign.	2/3 stat. sign.	1/3 stat. sign.	2/3 stat. sign.	2/2 stat. sign.
	N. of Lags on GDP	2/3 stat. sign.	2/3 stat. sign.	1/4 stat. sign.	2/3 stat. sign.	1/1 stat. sign.	1/6 stat. sign.
	N. of Lags on OIL	3/4 stat. sign.	2/4 stat. sign.	0/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.
	Regime prob. (duration)	0.44 (1.59) 0.54 (2.00) 0.01 (1.52)	0.9481 (30.04) 0.0519 (1.65)	0.00 (2.08) 1.00 (na) 0.00 (3.18)	0.35 (2.33) 0.63 (4.20) 0.02 (1.54)	0.25 (1.71) 0.49 (11.46) 0.26 (1.74)	0.64 (21.77) 0.36 (12.15)
MSMH	Regimes	2	3	3	2	3	2
	Log-likelihood	478.13	479.73	485.53	486.06	486.11	451.62
	AIC	-7.07	-7.00	-7.09	-7.11	-7.02	-7.23
	Means/Intercepts	1/2 stat. sign.	1/3 stat. sign.	3/3 stat. sign.	1/2 stat. sign.	2/3 stat. sign.	1/2 stat. sign.
	N. of Lags on GDP	5/5 stat. sign.	1/2 stat. sign.	4/5 stat. sign.	3/3 stat. sign.	2/4 stat. sign.	4/4 stat. sign.
	N. of Lags on OIL	1/4 stat. sign.	3/4 stat. sign.	2/4 stat. sign.	3/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.
	Regime prob. (duration)	0.5439 (2.60) 0.4561 (2.18)	0.07 (4.07) 0.93 (51.26) 0.00 (39.46)	0.31 (2.26) 0.35 (2.51) 0.34 (4.23)	0.53 (2.40) 0.47 (2.16)	0.43 (2.20) 0.44 (2.90) 0.12 (1.53)	0.60 (2.99) 0.40 (2.01)
MSIH	Regimes	2	3 (4)	3	3 (4)	3	3
	Log-likelihood	473.73	492.90	502.10	501.61	495.22	456.25
	AIC	-7.01	-7.21	-7.44	-7.29	-7.18	-7.18
	Means/Intercepts	2/2 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	1/1 stat. sign.	1/1 stat. sign.	4/6 stat. sign.	1/1 stat. sign.	2/2 stat. sign.	6/6 stat. sign.
	N. of Lags on OIL	0/4 stat. sign.	4/4 stat. sign.	4/4 stat. sign.	4/4 stat. sign.	3/4 stat. sign.	3/4 stat. sign.
	Regime prob. (duration)	1.00 (na) 0.00 (37.63)	0.00 (2.27) 1.00 (na) 0.00 (8.85)	0.07 (1.72) 0.80 (74.81) 0.13 (4.12)	0.06 (2.16) 0.86 (29.48) 0.07 (4.28)	0.08 (2.19) 0.46 (11.77) 0.45 (5.98)	0.29 (1.24) 0.21 (2.58) 0.50 (1.78)
MSIA	Regimes	3	3	3	3	3	3
	Log-likelihood	494.27	499.25	486.64	498.15	502.81	472.22
	AIC	-7.02	-7.06	-7.06	-7.07	-7.10	-7.14
	Means/Intercepts	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	1/3 stat. sign. (1st r.) 0/3 stat. sign. (2nd r.) 3/3 stat. sign. (3rd r.)	3/5 stat. sign. (1st r.) 3/5 stat. sign. (2nd r.) 3/5 stat. sign. (3rd r.)	2/3 stat. sign. (1st r.) 1/3 stat. sign. (2nd r.) 3/3 stat. sign. (3rd r.)	2/2 stat. sign. (1st r.) 1/2 stat. sign. (2nd r.) 1/2 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	2/6 stat. sign. (1st r.) 1/6 stat. sign. (2nd r.) 1/6 stat. sign. (3rd r.)
	N. of Lags on OIL	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.36 (7.39) 0.50 (10.39) 0.14 (3.53)	0.48 (3.73) 0.33 (2.50) 0.19 (2.06)	0.34 (4.23) 0.59 (8.28) 0.07 (3.91)	0.38 (4.12) 0.46 (7.71) 0.16 (4.34)	0.37 (2.58) 0.41 (4.83) 0.22 (2.45)	0.32 (2.35) 0.48 (3.76) 0.20 (2.20)
MSIAH	Regimes	3	3	3	3	3	3
	Log-likelihood	519.77	502.53	510.97	509.57	507.37	465.04
	AIC	-7.33	-7.07	-7.36	-7.17	-7.13	-7.19
	Means/Intercepts	2/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	3/3 stat. sign. (1st r.) 0/3 stat. sign. (2nd r.) 1/3 stat. sign. (3rd r.)	1/3 stat. sign. (1st r.) 0/3 stat. sign. (2nd r.) 3/3 stat. sign. (3rd r.)	2/2 stat. sign. (1st r.) 0/2 stat. sign. (2nd r.) 1/2 stat. sign. (3rd r.)
	N. of Lags on OIL	3/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	4/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.31 (2.58) 0.29 (2.39) 0.40 (2.57)	0.27 (2.88) 0.59 (7.78) 0.14 (3.37)	0.23 (2.99) 0.69 (11.02) 0.09 (3.65)	0.18 (1.62) 0.61 (11.32) 0.21 (3.05)	0.11 (2.21) 0.76 (25.64) 0.13 (3.76)	0.15 (2.07) 0.75 (18.02) 0.10 (3.08)

Notes. See Table 3.

Table 7: Markov switching models for real GDP with exogenous oil - Japan

		$\Delta roil_t$	Δo^*_t	$NOPI_t$	LNR_t	oil_vol_t	oil_disr_t (2)
MSM	Regimes	3	3	3	3	3	3
	Log-likelihood	441.24	443.96	442.13	446.40	444.99	420.91
	AIC	-6.30	-6.34	-6.31	-6.38	-6.36	-6.54
	Means/Intercepts	1/3 stat. sign.	1/3 stat. sign.	3/3 stat. sign.	1/3 stat. sign.	1/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	4/4 stat. sign.	4/4 stat. sign.	1/1 stat. sign.	4/4 stat. sign.	4/4 stat. sign.	2/4 stat. sign.
	N. of Lags on OIL	0/4 stat. sign.	2/4 stat. sign.	0/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.
	Regime prob. (duration)	0.10 (1.68) 0.54 (2.67) 0.36 (1.77)	0.10 (1.60) 0.51 (2.63) 0.39 (2.03)	0.99 (na) 0.01 (35.04) 0.00 (3.90)	0.10 (1.57) 0.43 (1.85) 0.48 (2.06)	0.09 (1.67) 0.51 (2.29) 0.39 (1.75)	0.19 (1.47) 0.61 (7.85) 0.20 (2.51)
MSI	Regimes	3	3	3	3	3	3
	Log-likelihood	441.45	442.51	443.16	443.61	444.00	420.35
	AIC	-6.31	-6.32	-6.33	-6.34	-6.34	-6.53
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	1/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/4 stat. sign.	3/4 stat. sign.	2/4 stat. sign.	3/4 stat. sign.	1/4 stat. sign.	4/4 stat. sign.
	N. of Lags on OIL	0/4 stat. sign.	0/4 stat. sign.	0/4 stat. sign.	1/4 stat. sign.	0/4 stat. sign.	1/4 stat. sign.
	Regime prob. (duration)	0.21 (2.26) 0.76 (8.20) 0.04 (3.70)	0.22 (2.36) 0.74 (7.97) 0.04 (3.68)	0.25 (3.26) 0.72 (9.40) 0.04 (4.06)	0.20 (2.27) 0.76 (8.46) 0.04 (4.11)	0.20 (2.74) 0.76 (10.51) 0.04 (3.53)	0.27 (2.13) 0.49 (4.25) 0.24 (1.65)
MSMH	Regimes	3	3	3	3	2	3
	Log-likelihood	444.50	445.67	450.35	446.77	432.41	418.42
	AIC	-6.37	-6.40	-6.41	-6.35	-6.24	-6.51
	Means/Intercepts	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	2/2 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	1/1 stat. sign.	-	1/1 stat. sign.	1/1 stat. sign.	3/4 stat. sign.	1/1 stat. sign.
	N. of Lags on OIL	1/4 stat. sign.	4/4 stat. sign.	1/4 stat. sign.	0/4 stat. sign.	0/4 stat. sign.	0/4 stat. sign.
	Regime prob. (duration)	0.08 (1.94) 0.67 (9.00) 0.25 (8.27)	0.13 (2.02) 0.57 (6.47) 0.30 (8.18)	0.09 (1.91) 0.67 (9.03) 0.24 (7.97)	0.08 (1.93) 0.67 (8.82) 0.25 (7.69)	1.00 (na) 0.00 (14.52)	0.09 (1.93) 0.56 (7.21) 0.35 (11.03)
MSIH	Regimes	3	3	3	3	2	3
	Log-likelihood	445.11	450.53	450.60	446.75	429.77	419.75
	AIC	-6.40	-6.46	-6.41	-6.39	-6.24	-6.52
	Means/Intercepts	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	2/2 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	3/6 stat. sign.	1/1 stat. sign.	1/1 stat. sign.	5/5 stat. sign.	3/5 stat. sign.	2/2 stat. sign.
	N. of Lags on OIL	1/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	0/4 stat. sign.	0/4 stat. sign.
	Regime prob. (duration)	0.13 (2.15) 0.59 (11.29) 0.28 (10.97)	0.08 (2.04) 0.66 (9.03) 0.26 (7.78)	0.08 (1.97) 0.67 (9.17) 0.24 (7.54)	0.17 (1.87) 0.60 (6.79) 0.23 (7.45)	1.00 (na) 0.00 (14.52)	0.17 (4.12) 0.51 (6.33) 0.32 (8.30)
MSIA	Regimes	3	3	3	3	3	3
	Log-likelihood	467.26	475.29	476.81	464.26	470.39	455.83
	AIC	-6.47	-6.54	-6.56	-6.42	-6.48	-6.71
	Means/Intercepts	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/3 stat. sign. (1st r.) 1/3 stat. sign. (2nd r.) 1/3 stat. sign. (3rd r.)	4/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	3/3 stat. sign. (1st r.) 2/3 stat. sign. (2nd r.) 1/3 stat. sign. (3rd r.)	1/2 stat. sign. (1st r.) 1/2 stat. sign. (2nd r.) 1/2 stat. sign. (3rd r.)	4/6 stat. sign. (1st r.) 2/6 stat. sign. (2nd r.) 5/6 stat. sign. (3rd r.)	4/6 stat. sign. (1st r.) 2/6 stat. sign. (2nd r.) 4/6 stat. sign. (3rd r.)
	N. of Lags on OIL	3/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	4/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	0/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 0/4 stat. sign. (3rd r.)	4/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.39 (10.77) 0.39 (2.58) 0.22 (1.87)	0.43 (3.58) 0.23 (1.12) 0.34 (2.12)	0.48 (2.53) 0.30 (3.49) 0.22 (1.15)	0.18 (4.69) 0.60 (4.70) 0.22 (2.45)	0.29 (1.83) 0.48 (2.33) 0.23 (2.07)	0.26 (2.31) 0.37 (2.71) 0.37 (1.48)
MSIAH	Regimes	3	3	3	3	3	3
	Log-likelihood	474.84	470.19	460.29	468.49	462.53	455.29
	AIC	-6.55	-6.53	-6.48	-6.41	-6.32	-6.72
	Means/Intercepts	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/3 stat. sign. (1st r.) 1/3 stat. sign. (2nd r.) 1/3 stat. sign. (3rd r.)	1/2 stat. sign. (1st r.) 2/2 stat. sign. (2nd r.) 1/2 stat. sign. (3rd r.)	2/3 stat. sign. (1st r.) 2/3 stat. sign. (2nd r.) 2/3 stat. sign. (3rd r.)	4/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	0/3 stat. sign. (1st r.) 3/3 stat. sign. (2nd r.) 3/3 stat. sign. (3rd r.)	3/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 2/5 stat. sign. (3rd r.)
	N. of Lags on OIL	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	0/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.59 (44.06) 0.23 (2.05) 0.17 (1.75)	0.47 (10.24) 0.24 (1.58) 0.29 (2.10)	0.53 (4.48) 0.23 (1.51) 0.25 (1.65)	0.19 (4.22) 0.43 (4.34) 0.38 (4.25)	0.50 (9.23) 0.35 (6.39) 0.15 (3.49)	0.18 (3.27) 0.45 (3.33) 0.37 (2.98)

Notes. See Table 3.

Table 8: Markov switching models for real GDP with oil exogenous - United Kingdom

		$\Delta roil_t$	Δo^*_t	$NOPI_t$	LNR_t	oil_vol_t	oil_disr_t (2)
MSM	Regimes	3	3	3	3	3	3
	Log-likelihood	385.49	386.81	399.39	395.26	403.69	381.48
	AIC	-5.58	-5.60	-5.77	-5.69	-5.84	-6.02
	Means/Intercepts	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/3 stat. sign.	3/3 stat. sign.	1/4 stat. sign.	3/3 stat. sign.	4/4 stat. sign.	3/3 stat. sign.
	N. of Lags on OIL	0/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.	4/4 stat. sign.
	Regime prob. (duration)	0.23 (4.68) 0.58 (40.82) 0.19 (3.97)	0.28 (8.43) 0.55 (32.44) 0.17 (5.28)	0.00 (1.00) 1.00 (na) 0.00 (6.03)	0.26 (5.55) 0.56 (36.91) 0.18 (3.94)	0.00 (6.21) 1.00 (na) 0.00 (6.24)	0.08 (1.11) 0.72 (15.31) 0.21 (6.27)
MSI	Regimes	3	3	3	3	3	3
	Log-likelihood	404.46	404.12	406.98	408.22	410.29	386.09
	AIC	-5.86	-5.85	-5.89	-5.91	-5.91	-6.07
	Means/Intercepts	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	1/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.	3/3 stat. sign.	2/5 stat. sign.
	N. of Lags on OIL	1/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	3/4 stat. sign.	2/4 stat. sign.
	Regime prob. (duration)	0.03 (1.00) 0.93 (40.51) 0.04 (2.94)	0.03 (1.00) 0.93 (40.48) 0.04 (2.92)	0.03 (1.00) 0.93 (40.67) 0.04 (2.95)	0.03 (1.00) 0.92 (30.27) 0.04 (2.92)	0.26 (8.44) 0.53 (27.38) 0.21 (6.88)	0.02 (1.00) 0.92 (18.65) 0.06 (1.24)
MSMH	Regimes	3	3	3	3	3	3
	Log-likelihood	407.49	410.75	413.62	407.53	414.10	386.40
	AIC	-5.89	-5.92	-5.96	-5.90	-5.94	-6.06
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	1/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/3 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	3/5 stat. sign.	3/3 stat. sign.	4/4 stat. sign.
	N. of Lags on OIL	1/4 stat. sign.	1/4 stat. sign.	3/4 stat. sign.	1/4 stat. sign.	1/4 stat. sign.	3/4 stat. sign.
	Regime prob. (duration)	0.29 (7.06) 0.52 (32.80) 0.19 (3.37)	0.15 (8.64) 0.48 (29.08) 0.37 (21.92)	0.11 (1.61) 0.49 (2.29) 0.40 (1.90)	0.17 (2.90) 0.68 (5.77) 0.14 (2.25)	0.00 (6.60) 1.00 (na) 0.00 (6.34)	0.12 (2.27) 0.66 (54.94) 0.22 (4.21)
MSIH	Regimes	3	3	3	3	3	3
	Log-likelihood	410.68	410.46	398.60	413.79	427.62	387.22
	AIC	-5.92	-5.92	-5.87	-5.97	-6.18	-6.07
	Means/Intercepts	1/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	1/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	3/4 stat. sign.	3/4 stat. sign.
	N. of Lags on OIL	1/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.	4/4 stat. sign.	3/4 stat. sign.
	Regime prob. (duration)	0.15 (7.09) 0.41 (2.38) 0.44 (2.34)	0.08 (7.26) 0.52 (37.70) 0.39 (15.61)	0.02 (1.00) 0.63 (4.33) 0.35 (2.35)	0.14 (7.35) 0.37 (1.63) 0.49 (1.99)	0.31 (3.23) 0.22 (2.35) 0.47 (11.92)	0.02 (1.00) 0.34 (1.35) 0.65 (2.45)
MSIA	Regimes	3	3	3	3	3	3
	Log-likelihood	429.48	430.25	434.04	435.00	431.13	413.68
	AIC	-5.99	-6.00	-6.06	-6.08	-6.02	-6.18
	Means/Intercepts	3/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	1/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	2/6 stat. sign. (1st r.) 1/6 stat. sign. (2nd r.) 5/6 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 3/4stat. sign. (3rd r.)	3/6 stat. sign. (1st r.) 1/6 stat. sign. (2nd r.) 2/6 stat. sign. (3rd r.)	3/6 stat. sign. (1st r.) 1/6 stat. sign. (2nd r.) 2/6 stat. sign. (3rd r.)	3/6 stat. sign. (1st r.) 1/6 stat. sign. (2nd r.) 3/6 stat. sign. (3rd r.)
	N. of Lags on OIL	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	0/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	4/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.10 (2.24) 0.75 (7.49) 0.15 (1.24)	0.07 (3.24) 0.85 (78.89) 0.09 (3.40)	0.14 (1.00) 0.72 (4.71) 0.14 (1.43)	0.12 (1.56) 0.74 (19.91) 0.14 (1.45)	0.07 (2.55) 0.83 (73.31) 0.10 (4.02)	0.10 (3.85) 0.80 (41.03) 0.10 (4.44)
MSIAH	Regimes	3	3	3	3	3	3
	Log-likelihood	437.59	429.17	443.43	433.63	432.16	397.79
	AIC	-6.09	-5.96	-6.17	-6.02	-6.00	-6.08
	Means/Intercepts	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/5 stat. sign. (1st r.) 1/5 stat. sign. (2nd r.) 2/5 stat. sign. (3rd r.)	0/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	3/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 0/5 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 4/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	2/2 stat. sign. (1st r.) 2/2 stat. sign. (2nd r.) 0/2 stat. sign. (3rd r.)
	N. of Lags on OIL	2/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	0/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 1/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	4/4 stat. sign. (1st r.) 3/4 stat. sign. (2nd r.) 0/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.15 (1.24) 0.67 (10.23) 0.18 (1.89)	0.24 (2.02) 0.61 (9.41) 0.15 (2.46)	0.33 (1.98) 0.47 (1.76) 0.21 (1.22)	0.16 (1.39) 0.53 (6.39) 0.31 (1.87)	0.22 (6.41) 0.57 (33.93) 0.21 (6.39)	0.12 (2.06) 0.30 (3.85) 0.57 (13.93)

Notes. See Table 3.

Table 9: Markov switching models for real GDP with exogenous oil - United States

		$\Delta roil_t$	Δo^*_t	$NOPI_t$	LNR_t	oil_vol_t	oil_disr_t (2)
MSM	Regimes	3	3	3	3	3	3
	Log-likelihood	483.16	486.19	478.21	485.43	495.62	454.19
	AIC	-6.91	-6.95	-6.99	-6.94	-7.04	-7.05
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.
	N. of Lags on OIL	0/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.	0/4 stat. sign.
	Regime prob. (duration)	0.00 (2.41) 1.00 (na) 0.00 (2.00)	0.09 (1.98) 0.82 (77.78) 0.08 (1.76)	0.07 (1.74) 0.83 (66.87) 0.10 (1.79)	0.00 (1.85) 1.00 (na) 0.00 (1.95)	0.00 (2.77) 1.00 (na) 0.00 (1.75)	0.08 (2.78) 0.89 (50.13) 0.02 (1.34)
MSI	Regimes	3	3	3	3	3	3
	Log-likelihood	479.13	481.96	472.04	477.70	486.28	444.57
	AIC	-6.86	-6.92	-6.89	-6.84	-6.95	-6.94
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	1/2 stat. sign.	1/1 stat. sign.	1/3 stat. sign.	1/2 stat. sign.	-	1/2 stat. sign.
	N. of Lags on OIL	0/4 stat. sign.	1/4 stat. sign.	2/4 stat. sign.	2/4 stat. sign.	3/4 stat. sign.	2/4 stat. sign.
	Regime prob. (duration)	0.00 (4.66) 1.00 (na) 0.00 (2.89)	0.00 (1.19) 1.00 (na) 0.00 (2.71)	0.05 (1.25) 0.80 (39.23) 0.15 (2.36)	0.03 (1.24) 0.93 (0.03) 0.04 (1.26)	0.05 (1.89) 0.85 (41.33) 0.09 (1.93)	0.10 (4.49) 0.82 (43.25) 0.08 (2.73)
MSMH	Regimes	3	3	3	3	3	3
	Log-likelihood	487.87	494.32	482.27	489.80	497.53	455.97
	AIC	-6.96	-7.03	-7.00	-6.97	-7.08	-7.05
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	2/2 stat. sign.	4/4 stat. sign.	2/4 stat. sign.	3/3 stat. sign.	-	3/3 stat. sign.
	N. of Lags on OIL	0/4 stat. sign.	3/4 stat. sign.	3/4 stat. sign.	1/4 stat. sign.	3/4 stat. sign.	0/4 stat. sign.
	Regime prob. (duration)	0.00 (3.77) 1.00 (na) 0.00 (2.95)	0.20 (6.03) 0.53 (4.74) 0.27 (2.96)	0.17 (3.42) 0.62 (8.58) 0.20 (2.79)	0.16 (3) 0.69 (36.92) 0.15 (2.93)	0.00 (1.92) 1.00 (na) 0.00 (3.29)	0.08 (3.15) 0.82 (80.46) 0.10 (3.88)
MSIH	Regimes	3	3	3	3	3	3
	Log-likelihood	487.90	491.45	483.03	484.83	497.53	453.09
	AIC	-6.96	-7.01	-7.03	-6.95	-7.08	-7.02
	Means/Intercepts	1/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	2/2 stat. sign.	1/3 stat. sign.	3/3 stat. sign.	-	-	1/2 stat. sign.
	N. of Lags on OIL	0/4 stat. sign.	2/4 stat. sign.	0/4 stat. sign.	1/4 stat. sign.	3/4 stat. sign.	1/4 stat. sign.
	Regime prob. (duration)	0.23 (4.69) 0.56 (20.29) 0.21 (4.56)	0.31 (12.13) 0.62 (8.07) 0.07 (1.00)	0.00 (15.72) 1.00 (na) 0.00 (2.50)	0.22 (4.82) 0.58 (24.34) 0.19 (5.66)	na (1.80) 1.00 (24.34) na (2.56)	0.08 (3.53) 0.82 (84.30) 0.09 (3.98)
MSIA	Regimes	3	3	3	3	3	3
	Log-likelihood	503.82	513.35	512.19	510.35	523.39	482.13
	AIC	-7.00	-7.12	-7.10	-7.07	-6.85	-7.18
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.
	N. of Lags on GDP	1/3 stat. sign. (1st r.) 2/3 stat. sign. (2nd r.) 3/3 stat. sign. (3rd r.)	3/6 stat. sign. (1st r.) 3/6 stat. sign. (2nd r.) 6/6 stat. sign. (3rd r.)	5/6 stat. sign. (1st r.) 3/6 stat. sign. (2nd r.) 2/6 stat. sign. (3rd r.)	5/6 stat. sign. (1st r.) 1/6 stat. sign. (2nd r.) 4/6 stat. sign. (3rd r.)	5/6 stat. sign. (1st r.) 2/6 stat. sign. (2nd r.) 4/6 stat. sign. (3rd r.)	5/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 5/5 stat. sign. (3rd r.)
	N. of Lags on OIL	1/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	1/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	2/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.14 (2.61) 0.70 (57.12) 0.16 (3.32)	0.17 (1.36) 0.64 (8.75) 0.18 (2.05)	0.06 (1.33) 0.80 (8.81) 0.13 (2.71)	0.23 (2.09) 0.59 (13.47) 0.18 (2.19)	0.26 (2.51) 0.56 (8.76) 0.18 (2.61)	0.16 (1.57) 0.65 (9.69) 0.19 (1.86)
MSIAH	Regimes	3	3	3	3	3	3
	Log-likelihood	515.72	536.08	510.45	515.67	519.05	482.99
	AIC	-7.11	-7.42	-7.03	-7.12	-7.16	-7.16
	Means/Intercepts	2/3 stat. sign.	2/3 stat. sign.	2/3 stat. sign.	3/3 stat. sign.	3/3 stat. sign.	2/3 stat. sign.
	N. of Lags on GDP	4/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	4/4 stat. sign. (1st r.) 4/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	5/6 stat. sign. (1st r.) 2/6 stat. sign. (2nd r.) 4/6 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	3/5 stat. sign. (1st r.) 2/5 stat. sign. (2nd r.) 5/5 stat. sign. (3rd r.)
	N. of Lags on OIL	3/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 0/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)	3/4 stat. sign. (1st r.) 2/4 stat. sign. (2nd r.) 2/4 stat. sign. (3rd r.)	4/4 stat. sign. (1st r.) 1/4 stat. sign. (2nd r.) 4/4 stat. sign. (3rd r.)	0/4 stat. sign. (1st r.) 0/4 stat. sign. (2nd r.) 3/4 stat. sign. (3rd r.)
	Regime prob. (duration)	0.14 (1.92) 0.65 (25.81) 0.21 (4.23)	0.13 (1.29) 0.61 (8.69) 0.26 (2.59)	0.14 (2.03) 0.73 (26.86) 0.13 (1.84)	0.12 (2.17) 0.60 (15.46) 0.28 (5.03)	0.27 (1.99) 0.40 (5.63) 0.33 (2.40)	0.29 (2.64) 0.54 (9.61) 0.16 (1.91)

Notes. See Table 3.

Table 10: Selected Markov switching models with exogenous oil prices

	Canada MSM(3)-ARX(4)			France MSMH(3)-ARX(1)			Germany MSIAH(3)-ARX(4)					
log-likelihood	499.63			525.26			469.80					
AIC	-7.14			-7.64			-6.53					
LR linearity test	Chi²(2)=54.65 [0.0000]			Chi²(4)=25.27 [0.0000]			Chi²(22)=65.90 [0.0000]					
	coefficient	standard error		coefficient	standard error	coefficient	coefficient	standard error	coefficient	standard error	coefficient	standard error
mean (regime 1)	-0.003	0.002		0.002	0.001							
mean (regime 2)	0.011	0.002		0.010	0.001							
mean (regime 3)	0.020	0.002		0.013	0.001							
constant (regime 1)							0.001	0.001				
constant (regime 2)									0.004	0.002		
constant (regime 3)											0.017	0.002
Δgdp(t-1)	0.448	0.065		-0.153	0.070		0.148	0.028	-0.305	0.127	-0.266	0.074
Δgdp(t-2)	-0.217	0.074					-0.055	0.028	-0.009	0.133	0.159	0.065
Δgdp(t-3)	0.497	0.076					-0.030	0.029	0.166	0.143	0.225	0.061
Δgdp(t-4)	-0.212	0.061					0.232	0.029	0.325	0.126	-0.126	0.055
Δgdp(t-5)												
Δgdp(t-6)												
oil(t-1)	0.005	0.005		-0.0004	0.0013		-0.004	0.002	0.001	0.035	-0.026	0.006
oil(t-2)	-0.014	0.005		-0.001	0.0005		0.0003	0.002	-0.005	0.061	0.001	0.006
oil(t-3)	0.001	0.005		-0.0003	0.0004		-0.011	0.002	-0.010	0.048	-0.008	0.005
oil(t-4)	-0.012	0.005		-0.002	0.0004		0.006	0.002	0.017	0.042	0.001	0.004
dummy							0.082	0.003	0.080	19.204	0.083	0.005
Standard error		0.005										
Standard error (reg.1)							0.002					
Standard error (reg.2)									0.009			
Standard error (reg.3)											0.003	
	regime 1	regime 2	regime 3	regime 1	regime 2	regime 3		regime 1	regime 2	regime 3		
regime 1	0.61	0.01	0.39	0.65	0.35	0.00		0.88	0.08	0.04		
regime 2	0.02	0.96	0.01	0.20	0.68	0.13		0.00	0.93	0.07		
regime 3	0.21	0.36	0.42	0.11	0.00	0.89		0.17	0.08	0.75		
regime properties	Prob.	Duration		Prob.	Duration			Prob.	Duration			
regime 1	0.09	2.55		0.30	2.85			0.26	8.33			
regime 2	0.83	27.27		0.33	3.09			0.56	15.36			
regime 3	0.08	1.73		0.37	8.96			0.18	4.02			

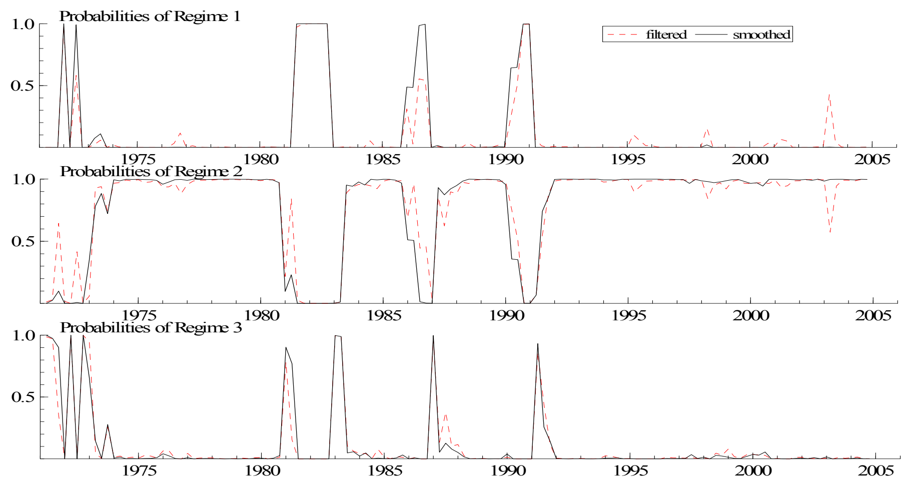
Notes . For Germany, Japan and U.S. the exogenous oil prices (oil) refer to net oil price increases (NOPI); for Italy, France and United Kingdom the model includes oil price volatility (oil_vol); for Canada the specification of oil prices is represented by oil price increases; for Germany a dummy is considered for the 1991q1; for Japan a dummy is considered for 1974q1; AIC = Akaike Information Criterion; the LR linearity test is distributed as a chi-square with d degrees of freedom, i.e. Chi²(d); p-values are reported in square brackets.

Table 10: Selected Markov switching models with exogenous oil prices (continued)

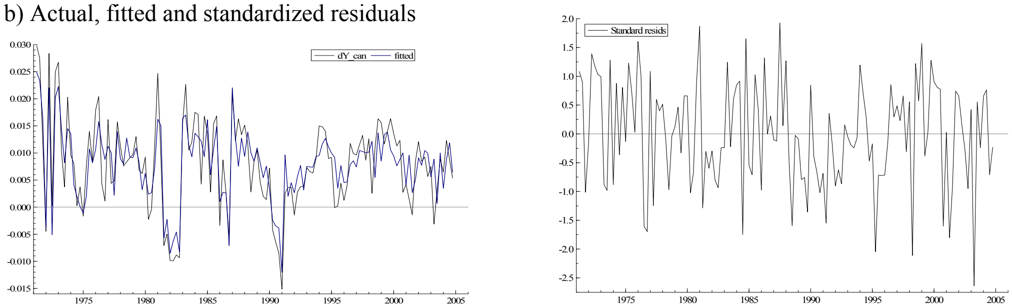
	model Italy MSIAH(3)-ARX(3)						model Japan MSMH(3)-ARX(1)			model United Kingdom MSMH(3)-ARX(4)			model United States MSMH(3)-ARX(4)		
log-likelihood	507.37						450.35			414.10			482.27		
AIC	-7.13						-6.41			-5.94			-7.00		
LR linearity test	Chi²(18)=65.17 [0.0000]						Chi²(4)=43.71 [0.0000]			Chi²(4)=49.48 [0.0000]			Chi²(4)=45.06 [0.0000]		
	coefficient	standard error	coefficient	standard error	coefficient	standard error	coefficient	standard error		coefficient	standard error		coefficient	standard error	
mean (regime 1)							-0.008	0.001		0.002	0.002		-0.001	0.002	
mean (regime 2)							0.007	0.001		0.010	0.001		0.009	0.001	
mean (regime 3)							0.015	0.003		0.017	0.002		0.018	0.002	
constant (regime 1)	-0.003	0.001													
constant (regime 2)			0.006	0.002											
constant (regime 3)					0.017	0.002									
Δgdp(t-1)	0.460	0.065	-0.055	0.113	0.500	0.090	-0.245	0.059		-0.540	0.094		-0.123	0.093	
Δgdp(t-2)	-0.047	0.091	0.148	0.098	-0.353	0.106				-0.426	0.103		0.118	0.062	
Δgdp(t-3)	-0.054	0.105	-0.022	0.091	0.355	0.087				-0.399	0.086		-0.159	0.069	
Δgdp(t-4)													-0.365	0.086	
Δgdp(t-5)															
Δgdp(t-6)															
oil(t-1)	0.0003	0.0002	-0.0005	0.0006	-0.0029	0.0007	-0.005	0.004		-0.005	0.001		-0.017	0.005	
oil(t-2)	0.0007	0.0001	0.0003	0.0006	0.0011	0.0011	0.000	0.005		0.000	0.001		-0.002	0.004	
oil(t-3)	-0.0001	0.0001	-0.0002	0.0006	0.0036	0.0013	-0.002	0.003		0.000	0.001		-0.022	0.004	
oil(t-4)	-0.0013	0.0001	-0.0004	0.0005	-0.0073	0.0012	-0.004	0.002		-0.001	0.001		-0.009	0.004	
dummy							-0.070	0.006							
Standard error															
Standard error (reg.1)	0.001						0.002			0.012			0.008		
Standard error (reg.2)			0.005				0.006			0.006			0.003		
Standard error (reg.3)					0.003		0.012			0.010			0.007		
		regime 1	regime 2	regime 3			regime 1	regime 2	regime 3	regime 1	regime 2	regime 3	regime 1	regime 2	regime 3
regime 1		0.55	0.26	0.19			0.48	0.52	0.00	0.85	0.02	0.13	0.71	0.16	0.14
regime 2		0.02	0.96	0.02			0.07	0.89	0.04	0.00	1.00	0.00	0.04	0.88	0.08
regime 3		0.26	0.00	0.73			0.00	0.13	0.87	0.16	0.00	0.84	0.13	0.23	0.64
regime properties		Prob.	Duration				Prob.	Duration		Prob.	Duration		Prob.	Duration	
regime 1		0.11	2.21				0.09	1.91		0.00	6.60		0.17	3.42	
regime 2		0.76	25.64				0.67	9.03		1.00	na		0.62	8.58	
regime 3		0.13	3.76				0.24	7.97		0.00	6.34		0.20	2.79	

Figure 5: Selected Markov switching model for Canada - MSM(3)-ARX(4)

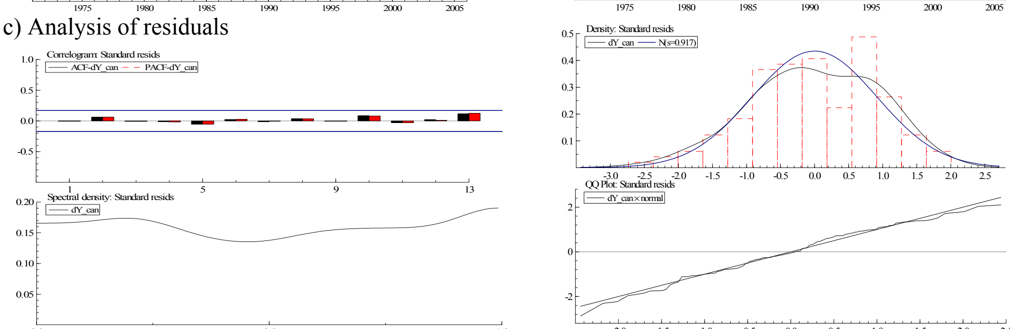
a) Smoothed and filtered probabilities



b) Actual, fitted and standardized residuals



c) Analysis of residuals



d) Predicted h-step probabilities and probability of duration

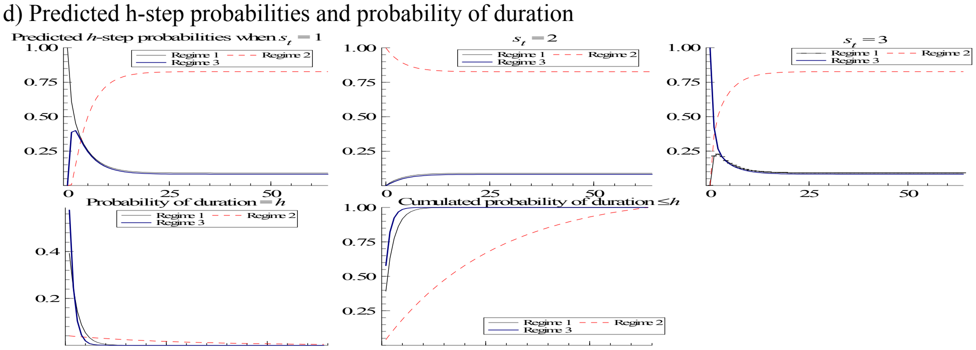
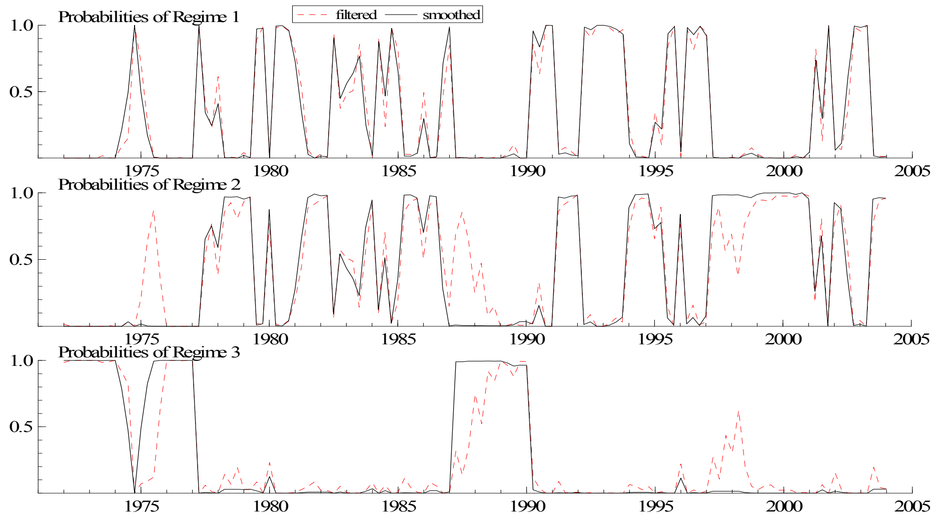
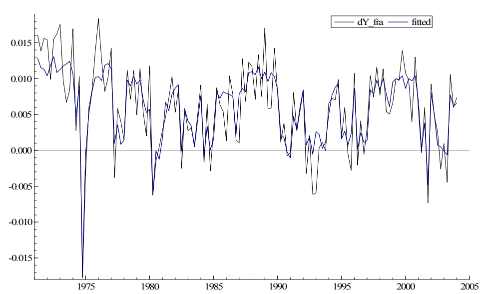


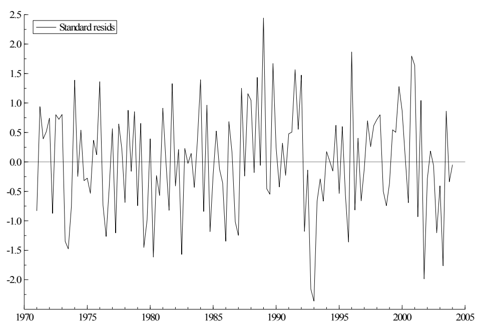
Figure 6: Selected Markov switching model for France - MSMH(3)-ARX(1)

a) Smoothed and filtered probabilities

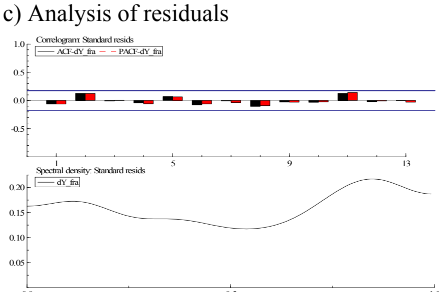


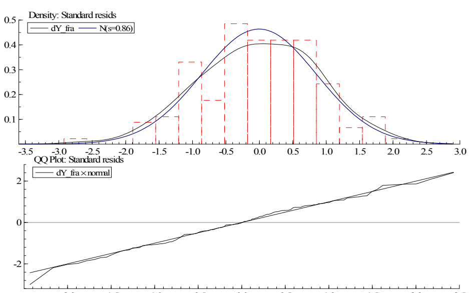
b) Actual, fitted and standardized residuals





c) Analysis of residuals





d) Predicted h-step probabilities and probability of duration

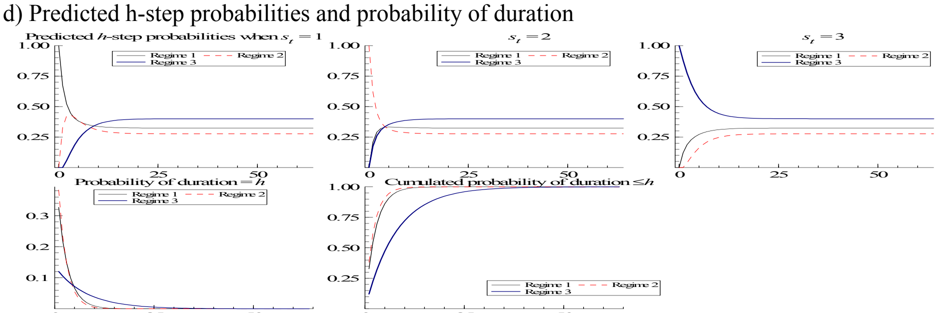


Figure 7: Selected Markov switching model for Germany - MSIAH(3)-ARX(4)

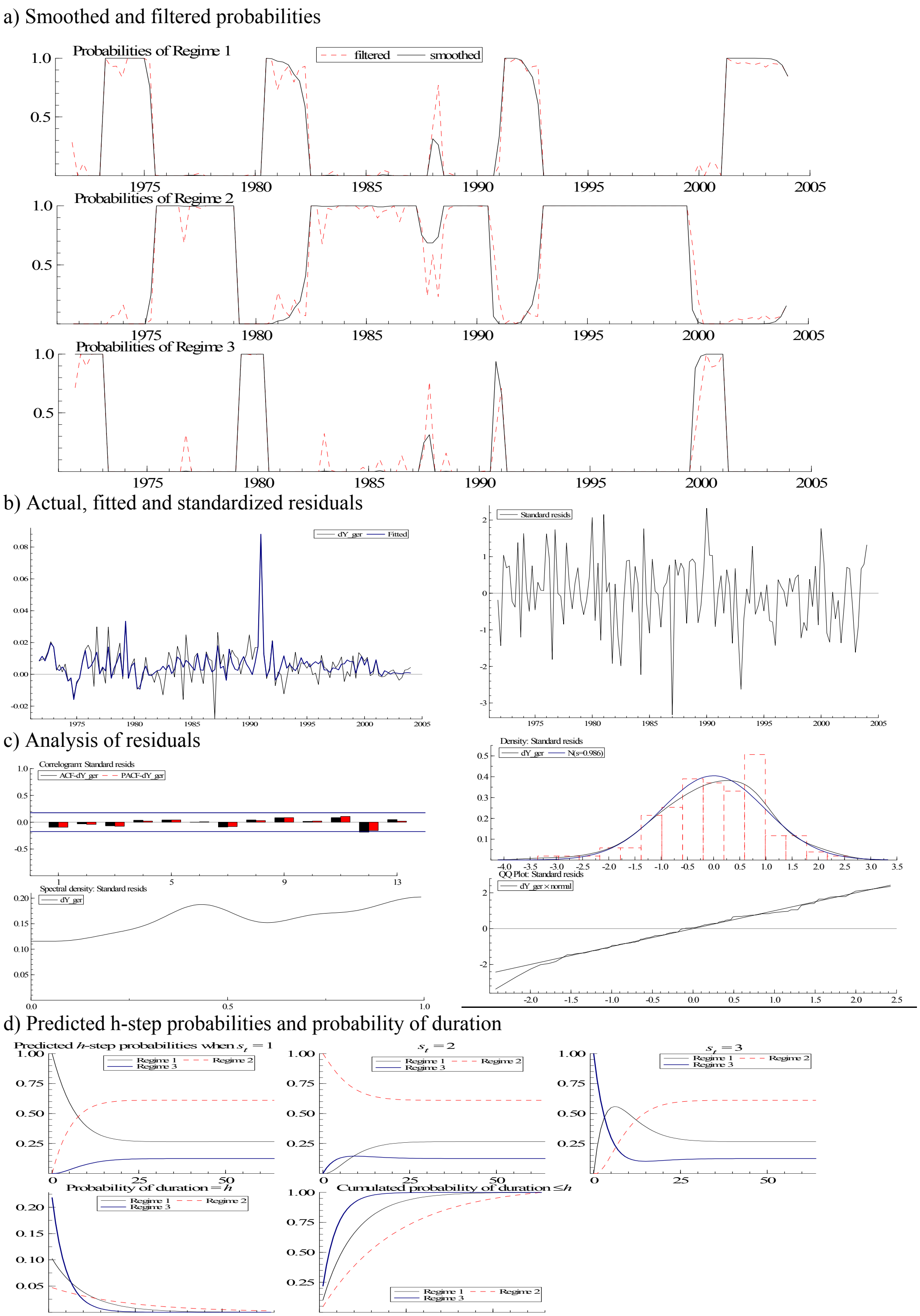


Figure 8: Selected Markov switching model for Italy - MSIAH(3)-ARX(3)

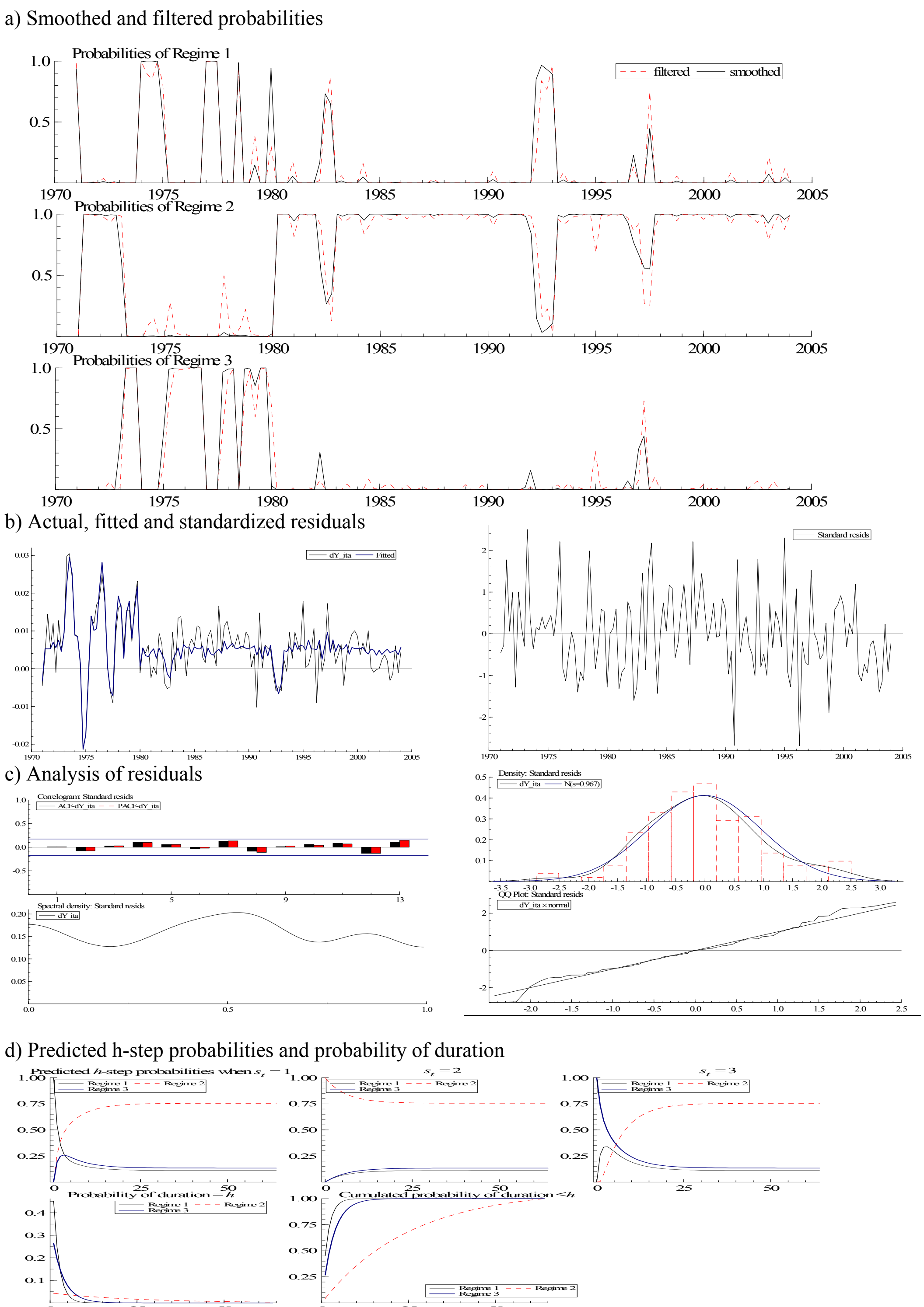


Figure 9: Selected Markov switching model for Japan - MSMH(3)-ARX(1)

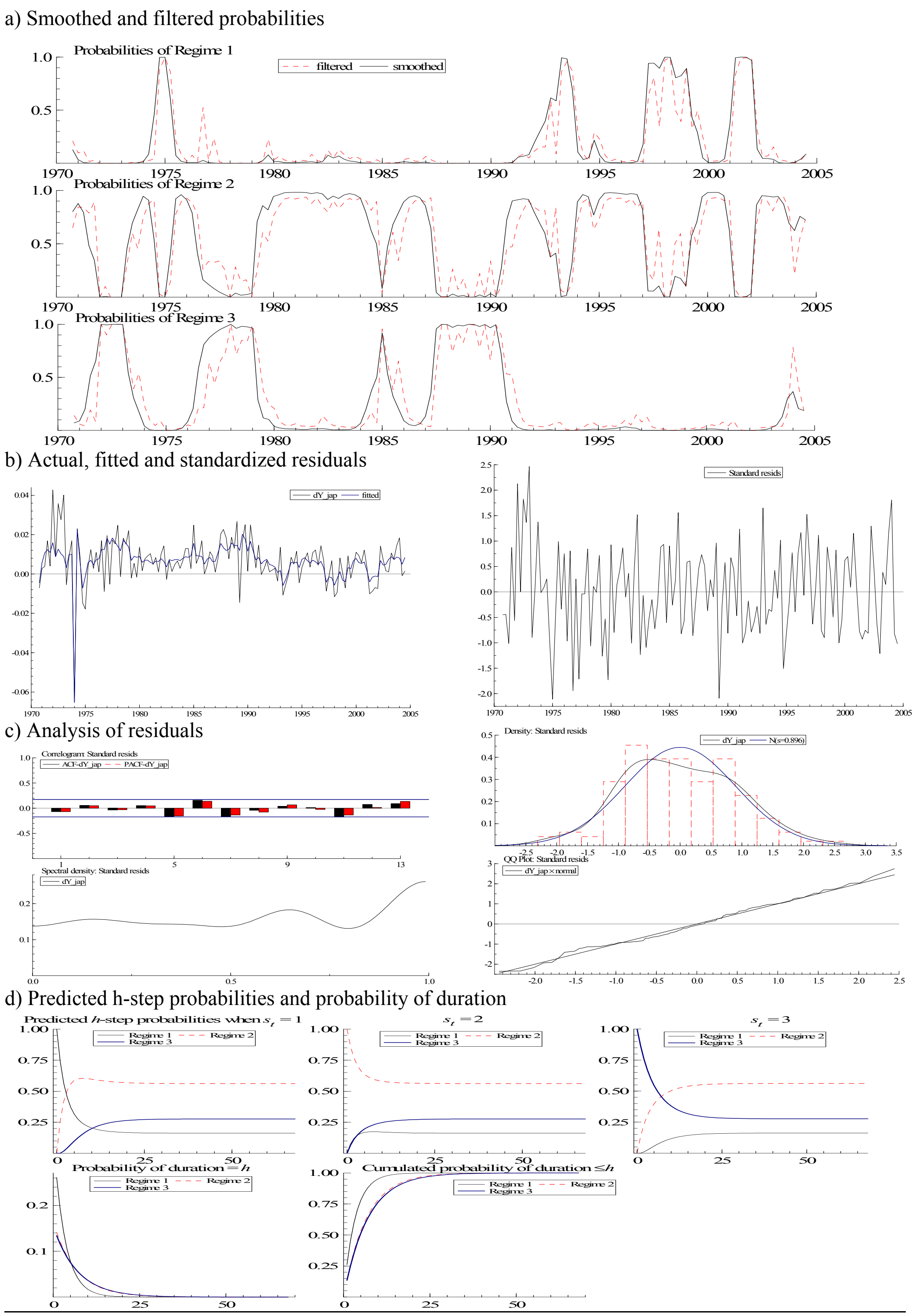
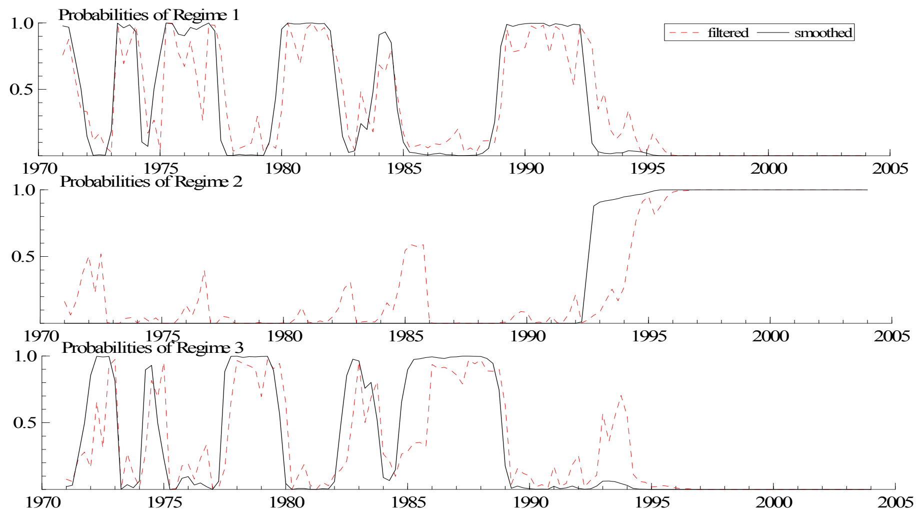
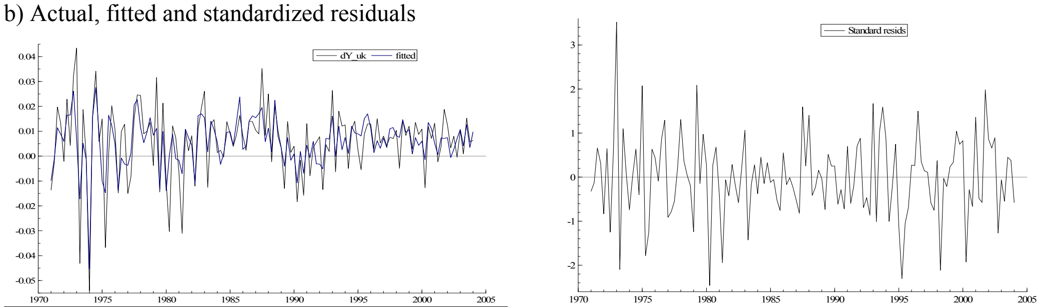


Figure 10: Selected Markov switching model for United Kingdom - MSMH(3)-ARX(4)

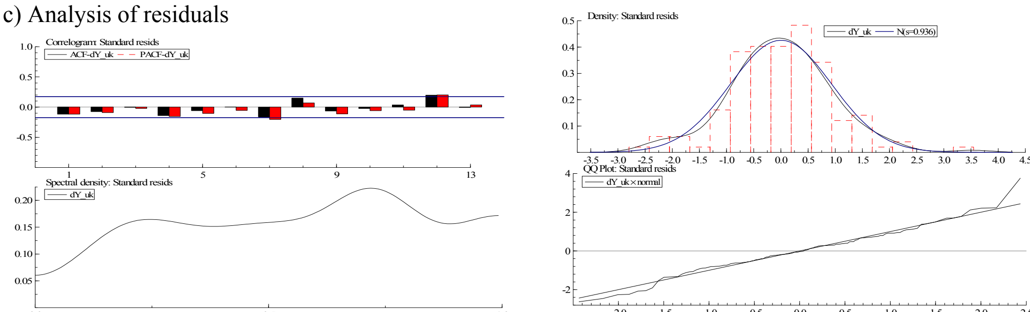
a) Smoothed and filtered probabilities



b) Actual, fitted and standardized residuals



c) Analysis of residuals



d) Predicted h-step probabilities and probability of duration

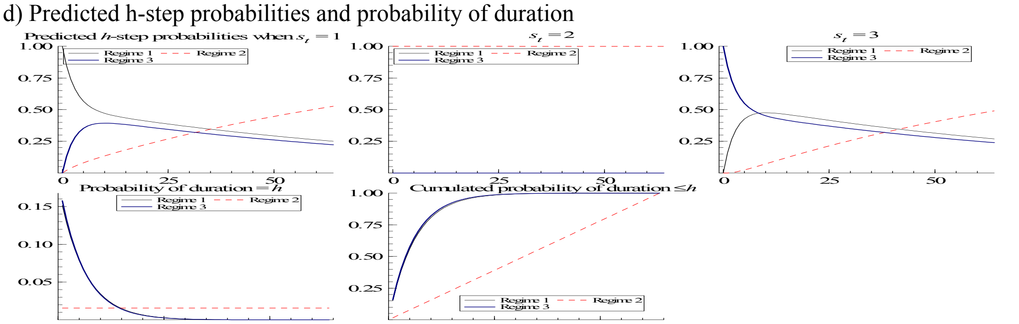
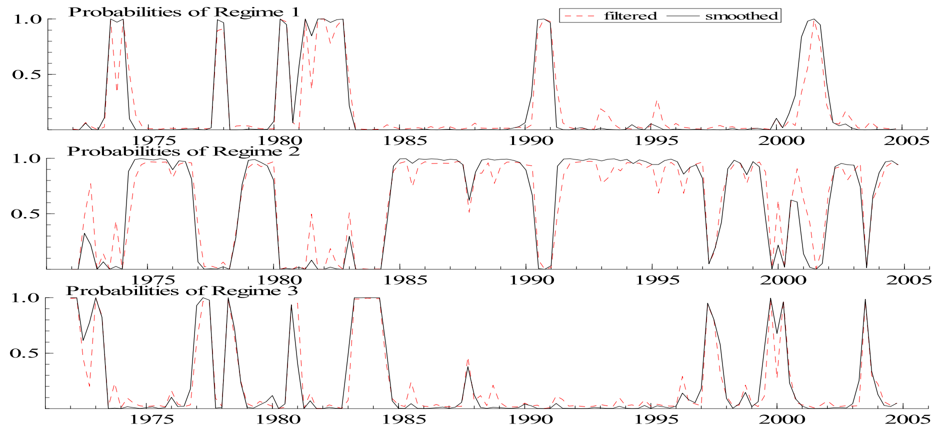
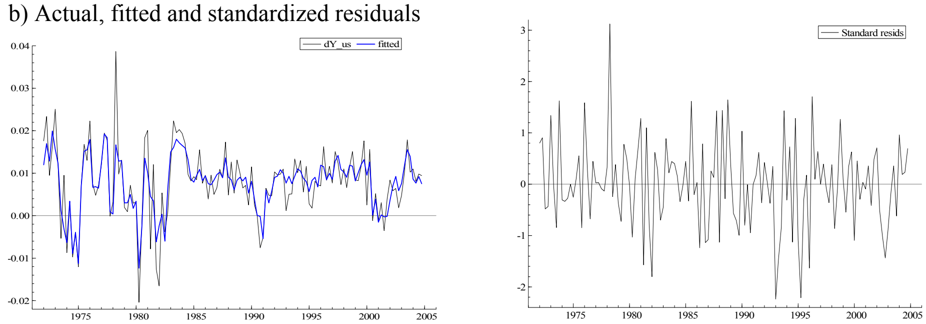


Figure 11: Selected Markov switching model for United States - MSMH(3)-ARX(4)

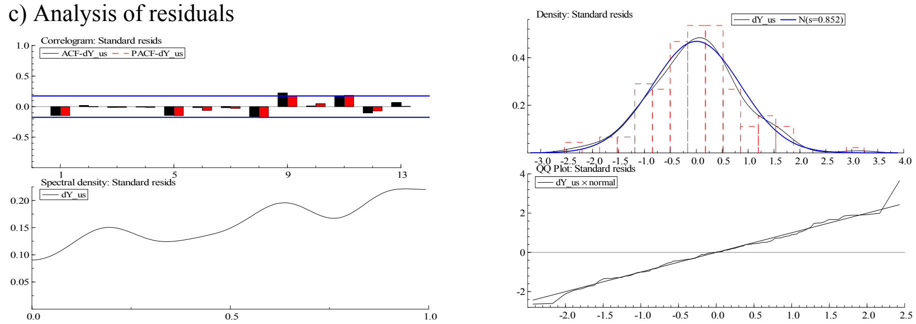
a) Smoothed and filtered probabilities



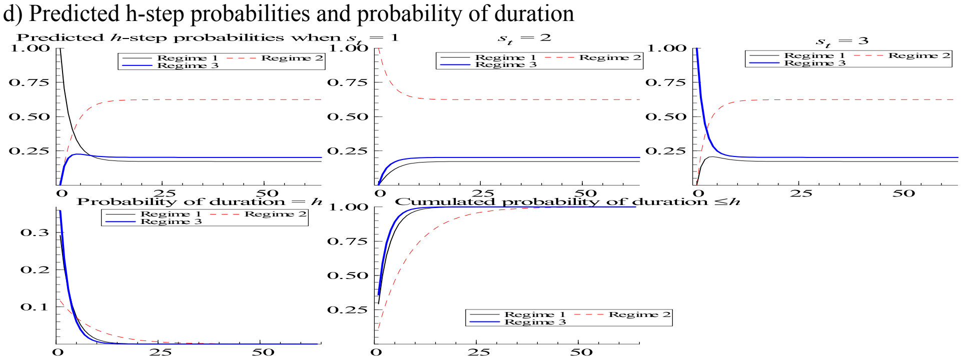
b) Actual, fitted and standardized residuals



c) Analysis of residuals



d) Predicted h-step probabilities and probability of duration



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