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OIL AND THE ASYMMETRIC ADJUSTMENT OF UK OUTPUT: A MARKOV-SWITCHING APPROACH

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Abstract

This paper examines the role played by oil in influencing the growth in UK GDP. Our particular interest is the possibility that asymmetries might exist in such a relationship. Using Hamilton's regime-switching estimation, we consider whether oil influences both the deepness and duration of the business cycle. We find that asymmetries arise insofar as positive oil price shocks are most likely to curtail the duration of the expansionary phase of the business cycle. This result is in contrast to existing studies of the oil price-macroeconomy relationship that have largely concerned the US.

JEL Codes: C3, E3, F4.

1. Introduction

There is debate as to whether two successive oil price shocks in 1973-4 and 1979-80 can be blamed for the severe recessions experienced in the world economy during the mid-1970s and early 1980s. Hamilton (1983), Burbridge and Harrison (1984), Gisser and Goodwin (1986) argue that these oil price shocks reduced world output. On the other hand, Rasche and Tatom (1981), Darby (1982) and Ahmed *et al.* (1988) argue that it was in fact the tight macroeconomic policies pursued by governments in the aftermath of the oil price shocks that worsened the recession. Bjornland (2000), however, finds that the importance of oil price shocks has varied over the UK recessions.

Economic theory provides a number of channels through which oil price increases may adversely affect economic activity. For example, Ferderer (1996) argues that a *symmetric* relationship may arise in a number of cases. For example, a *real balance effect* might occur where oil price increases serve to reduce real balances and this produces a recession through normal monetary channels [see, for instance, Hall and Taylor (1991)]. Other possibilities include an *income transfer channel* where income transfers from oil-importers to oil-exporters mean that consumers in the former countries reduce their consumption expenditure. A *potential output channel* might occur where oil and capital are complementary in the production process and there is a decline in the economy's productive capacity. This leads to negative transitional growth as the economy moves towards a new steady-state growth path. An *asymmetric* relationship between oil price increases and output might occur with the use of counter-inflationary policies by governments in response to positive oil price shocks [Rasche and Tatom (1981), Darby (1982) and Ahmed *et al.* (1988)]. There is also a line of literature which argues that increased oil price uncertainty

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means that firms postpone irreversible investment and prefer to wait before investing [Bernanke (1983), Pindyck (1991)]. Finally, it can be argued that a large increase in the relative price of oil causes aggregate unemployment to rise because it is costly for unemployed workers to shift between industrial sectors. In this context, aggregate unemployment increases as the relative price of oil becomes more volatile [see Lilien (1982), Lougani (1986)].

In this paper we focus on the asymmetric adjustment of UK GDP growth in response to positive oil price shocks. Hamilton (1989) proposes a regime-switching model in which output growth switches between two different states according to a first order Markov process. Applying this model to the U.S., he finds that shifts between positive and negative output growth accord well with the National Bureau of Economic Research (NBER) chronology of business cycle peaks and troughs. In the wake of this paper, a large number of researchers have explored various aspects of the US business cycle using the Markov regime-switching framework [see, *inter alia*, Lam (1990), Sichel (1993), Durland and McCurdy (1994), Kim (1994), Filardo (1994)]. Much less work, however, has addressed the UK business cycle [exceptions include Acemoglu and Scott (1994), Krolzig and Sensier (2000) and Simpson *et al*. (2001)].

Raymond and Rich (1997) provide an interesting application of the Markov-switching approach where they analyse the relationship between oil price shocks and post-war US business cycle fluctuations. Their novel approach is to investigate whether the oil price shocks affect the inference about the unobserved state through their influence on the estimates of the trend growth rates or through their influence on the estimates of the transition probabilities associated with switching from one regime to another. They find that the main effect is on the mean of growth phases rather than the transition probabilities.

The purpose of this paper is to utilise Markov regime-switching methodology to look at the relationship between real oil price and GDP growth in the UK. On the basis of the above discussion, there are several reasons of interest attached our study. We contribute to the debate over the role of oil prices offering the first study that employs the Markov regime-switching framework on UK data. Are asymmetries present and if so, does oil exert an influence through the transition probabilities? Much of the existing literature on asymmetries in macroeconomics has focussed on demand-side disturbances.[1] Our contribution is to examine asymmetries against the background of supply-side shocks. Oil is the most identifiable supply-side shock and we are able to address further important questions. What can we say about the role of oil during key phases of the UK business cycle? Can each of the major recessions be attributable to oil?

The paper is organised as follows. The following section discusses the data and methodology. The third section reports and discusses the results. The final section concludes.

2. Data and Estimation

We employ quarterly data for the period 1960Q1-2000Q1. The first differences of the natural logarithm of UK quarterly real GDP are multiplied by 100 and referred to as the output growth rate, y. The real price of oil is constructed by the multiplying the nominal $ oil price by nominal £: $ exchange rate and deflating the UK consumer price index.[2] There exist a number of alternative methods of real oil price shocks. The conventional method is to use the change in the natural logarithm of the oil price [for

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[1] See, for example, Karras (1996).
[2] All data are obtained from Datastream.

example, Mork (1989), Hooker (1996)]. However, Hamilton (1996) recommends the calculation of a net oil price increase variable that compares the current price of oil with the previous year rather than the previous quarter.[3] More precisely, it is defined as the percentage change in the current real price of oil from the previous year's maximum if positive and zero otherwise. Raymond and Rich (1997) calculate net real oil price increases in their examination of the US.[4]

The specification of our estimating model is based on the Hamilton's Markov switching model that allows for time-varying transition probabilities which change according to the nature of oil price shocks. Suppose a discrete random variable S_t takes on two possible values ($S_t = 0 \ or \ 1$) and serves as an indicator for the state of the economy at time t. The expected growth rate of GDP conditional on the value of S_t is given by

$$E(y_t \mid S_t) = \mu(S_t) = \mu_0(1 - S_t) + \mu_1 S_t, \tag{1}$$

where μ_0 and μ_1 are the expected values of the growth rate during recessions and expansions respectively. S_t is an unobserved indicator variable that evolves according to a first-order Markov-switching process as in Hamilton (1989),

$$P[S_t = 1 \mid S_{t-1} = 1] = p$$
$$P[S_t = 1 \mid S_{t-1} = 0] = 1 - p$$
$$P[S_t = 0 \mid S_{t-1} = 0] = q$$
$$P[S_t = 0 \mid S_{t-1} = 1] = 1 - q$$
$$0 < p < 1, \qquad 0 < q < 1 \tag{2}$$

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[3] Hamilton (1996) argues that many oil price increases after 1986 have acted to offset earlier price declines. Therefore, measures that focus on positive first differences overstate the significance and magnitude of oil price movements.
[4] We also estimated for the UK using the change in real oil prices. Ultimately, there was no difference in the qualitative conclusions drawn. These results are available on request.

where p and q are fixed transition probabilities of being in expansions and recessions respectively.

To incorporate the effects of oil price shocks on the deepness of the cycle, we add oil to equation (1) in the following manner,

$$[y_t - \mu(S_t)] = \sum_{i=1}^{k} \beta_i o^+_{t-i} + \varepsilon_t, \qquad \varepsilon_t \sim i.i.d. N(0, \sigma_\varepsilon^2) \qquad (3)$$

where o^+_{t-i} denotes the net real oil price increase. A priori, we expect $\beta_i < 0$ where net oil price changes have an adverse impact on the growth in UK real GDP. We can extend the fixed two-state Markov switching chain to allow for the possibility of time-varying transition probabilities. Moreover, let

$$P[S_t = 1 | S_{t-1} = 1, o^+_t, o^+_{t-1}, o^+_{t-2}, \cdots] = p_t = \Phi(\delta_0 + \sum_{i=0}^{m} \delta_i o^+_{t-i})$$

$$P[S_t = 0 | S_{t-1} = 0, o^+_t, o^+_{t-1}, o^+_{t-2}, \cdots] = q_t = \Phi(\gamma_0 + \sum_{i=0}^{n} \gamma_i o^+_{t-i}) \qquad (4)$$

where $\Phi(\cdot)$ refers to the cumulative density function of the standard normal distribution and ensures that the time-varying transition probabilities p_t and q_t lie in the open interval (0,1).[5] Asymmetries will be present if oil price shocks affect the transition probabilities differently. We can consider the type of "news" contained in the oil price variable to make predictions concerning the signs of the time-varying transition probability coefficients in equation (4). If positive oil price shocks are regarded as "bad" news, then we would expect $\delta_i < 0$ and $\gamma_i > 0$. The impact of "bad" news to the economy is to reduce probability of being in expansionary regime and increase the probability of being in the recessionary regime.

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[5] The functional form of transition probabilities can also be modelled as a logistic form as shown in Filardo (1994). This procedure gave the same qualitative results as with the cumulative normal distribution function.

Our investigation of how oil price shocks affect the growth rate of output, is based on the comparison of four estimated models.

Model I: Fixed transition probabilities (FTP) model. This is the Hamilton Markov switching model of the business cycle.

$$\delta_1 = \cdots = \delta_m = \gamma_1 = \cdots = \lambda_n = 0 \text{ and } \beta_1 = \cdots = \beta_k = 0$$

Under these null hypotheses there is role for oil price shocks in either the mean equation or the determination of the transition probabilities.

Model II: Time-varying transition probabilities (TVTP) + mean model. This is a generalised model where oil prices enter both the mean and the transition probabilities, i.e.

$$\delta_1 \neq \cdots \neq \delta_m \neq 0, \gamma_1 \neq \cdots \neq \lambda_n \neq 0 \text{ and } \beta_1 \neq \cdots \neq \beta_k \neq 0$$

Model III: TVTP model. In this model, oil prices enter the transition probabilities only, i.e.

$$\delta_1 \neq \cdots \neq \delta_m \neq 0, \gamma_1 \neq \cdots \neq \lambda_n \neq 0 \text{ and } \beta_1 = \cdots = \beta_k = 0$$

Model IV: FTP + mean model. In this model, oil prices enter the mean equations only, i.e.

$$\delta_1 = \cdots = \delta_m = \gamma_1 = \cdots = \lambda_n = 0 \text{ and } \beta_1 \neq \cdots \neq \beta_k \neq 0$$

Estimation of these models is carried out by maximum likelihood using the non-linear filter algorithm described in Hamilton's (1989). An important by-product of the estimation procedure is the computation of the filter probabilities that allow us to draw conclusions about the unobserved state for each time period. Given that Model II nests Models I, III and IV, we can compare the contrast the appropriateness of these models in explaining UK GDP growth.

3.   Results

Table 1 reports the maximum likelihood estimates of the four models.[6] An examination of Model 1, which serves as a benchmark of Hamilton (1989), shows output growth switching between two different states with mean growth estimated at 0.77% per quarter during expansions and –0.66% per quarter during recessions. The point estimates for the state-dependent means are statistically significant at the 1% level. The transition probabilities associated with these two regimes of expansion and recession are 0.961 and 0.741 respectively. These estimates imply that the average duration of the expansionary regime is $(1-p)^{-1} = 25.6$ quarters. This can be contrasted with $(1-q)^{-1} = 3.9$ quarters which is the average duration of the recessionary regime.

Figure 1 plots the inferred probability of a low-growth-state of output conditional on information available through t, $\Pr[S_t = 1 | \Psi_t] (t = 1,2,\cdots,T)$, and the smoothed probability based on the information up to T, $\Pr[S_t = 1 | \Psi_T] (t = 1,2,\cdots,T)$. While the two graphs are very similar, they clearly show that the UK economy experienced three major recessions during the last four decades, namely those of 1973-75, 1979-81, and 1990-92.[7]

To investigate the role of oil price shocks, we can now turn our attention to the estimation of the extended Markov switching models (Models II to IV). We first consider the estimation of the *TVTP + mean model* (Model 2) which is the generalised model with oil prices affecting both the mean equation and the transition

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[6] Following Hamilton (1989), the strategy of modelling the variance across regimes are assumed to be the same and consistent with the data.

[7] These estimates for the transition probabilities and average duration are consistent with other UK-based studies. See, for example, Simpson *et al.* (2001) who identify 1973Q4-1975Q3, 1979Q3-1981Q1 and 1990Q3-1992Q2 as the three major recession periods that have occurred during our period of study.

probabilities. Having started with a maximum of six lags, the inclusion of four lagged values of net real oil price increases in the conditional mean process of output and contemporaneous net real oil price increases in the state transition probability processes were found to be appropriate.

The results indicate that the generalised model, compared with the benchmark model, achieves a significant improvement in the likelihood function according to conventional likelihood ratio testing. Moreover, the likelihood ratio statistic is 13.54 and distributed as $\chi^2(6)$ on the null which leads to the rejection of benchmark model at 5% significance level. The coefficients on the o^+'s are positive but insignificant for the first two lags. While β_i is negative for the third and fourth lags, only β_3 is significant (at the 1% significance level). This suggests that the oil price shocks have a delayed negative impact in mean equation for GDP growth. We also find that $\delta_1 < 0$ and $\gamma_1 = 0$ which suggests that net real oil price shocks significantly influences the transition probability associated with expansions but not in recessions. A positive oil price shock would be expected to reduce $\delta_0 + \delta_1 o_t^+$. By using the standard normal distribution, it can be confirmed that this will reduce the transition probability of staying in regime 1 thereby reducing its duration. Thus, in the UK oil price shocks affect both the duration and deepness of the UK cycle. These findings may be contrasted with Raymond and Rich (1997) who find that oil price shocks influence the deepness but not the duration of the US business cycle. Using these estimates for the generalised model, we can further quantify the relationship between the magnitude of an oil price shock. Table 2 considers a range of shocks from 5 to 30% and the corresponding duration of the expansionary state. The duration associated with a

positive oil price shock of 30% is less than 6% of the duration associated with a positive oil shock of 5%.[8]

Figure 2 plots the filtered and smoothed probability of a low-growth state of output for the generalised model. A comparison of Figure 1 and Figure 2 reveals the changes in the pattern of estimated probabilities. Unlike the benchmark model, the generalised model does not associate 1975 with a shift in trend growth rates and a movement of real GDP in recession. This might be a reflection of the tight anti-inflationary macroeconomic policies implemented by the UK government which worsened the recession that was already associated with the energy price increases [See, *inter alia*, Rasche and Tatom (1981), Darby (1982) and Ahmed *et al.* (1988)]. There is evidence that oil price shocks played a partial role in the behaviour of output during the 1990-1992 recession where the inferred probability falls from 0.8 to 0.5. This might be a reflection of the early 1990s recession being influenced partly by real oil price increases and partly by other factors such as the high UK interest rates, the overvaluation of the sterling exchange rate and the decline in national consumer confidence that occurred over this period [see also Dow (1998)]. The 1979-81 recession is similarly presented in both figures suggesting that oil price shocks were of major importance. Bjornland (2000) argues that while the UK was self-sufficient in oil resources when the second oil price shock occurred, much of the revenue from increased oil prices went towards the provision of social security and the payment of existing external debts.

Further insight into the role played by oil on growth can be gained by imposing restrictions $\beta_1 = \cdots = \beta_4 = 0$ or $\delta_1 = \gamma_1 = 0$ in Model II. The corresponding

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[8] Some perspective is placed on these simulations if one bears in mind that in 1974Q1 the real price of oil rose by 137%.

results for Models III and IV are also reported in Table 1. Model IV confirms that

$\delta_1 < 0$ at the 5% significance level. The likelihood ratio statistics for the restrictions

$\delta_1 = \gamma_1 = 0$ and $\beta_1 = \cdots = \beta_4 = 0$ are 7.42 and 6.91 respectively. As these tests are

distributed asymptotically as $\chi^2(2)$ and $\chi^2(4)$ under each null hypothesis, they

indicate that the null hypothesis for the former (Model II versus Model III) can be

rejected at the 2% level and for the latter (Model II versus Model IV) at the 14%

level. This final result might lead one to reject a role for oil price shocks in the mean

equation. To look at this more closely, we can employ a procedure advocated by

Filardo (1994) that enables one to examine the source of the changes in the inferred

probabilities. Moreover, we can discriminate between the effects of oil price shocks

on the estimated transition probabilities and the estimated states dependent mean

effects of the Markov switching model. The methodology is as follows. First, we

consider the consequences of evaluating the inferred probabilities for the generalised

Markov switching model of GDP using the estimates of p and q from the benchmark

model (Model I). This is to control for the transition probability effect on the inferred

probabilities and implies that the resulting inference about the unobserved state

should display little change if oil prices are principally influencing the means of the

growth states. Second, we consider the consequences of evaluating the inferred

probabilities for the generalised Markov switching model of GDP by estimating the

generalised model's parameters and then zeroing out the parameters on o_t^+.[9]

Similarly, this is to control for the state-dependent mean effects on the inferred

probabilities and implies that the resulting inference about the unobserved state

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[9] We also experimented with Filardo's alternative way to control for the state-dependent mean effect, that is to use the FTP estimates with the TVTP + mean model's transition probabilities, p_t and q_t. The results are consistent with our conclusion below and are available upon request.

should display little change if oil prices are principally influencing the transition probability.

Figure 3 plots the both filtered and smoothed probabilities for state 0 (recession) after controlling for the effect of oil price shocks on the estimated transition probabilities. Figure 4 plots state 0 probabilities after controlling for the effect of oil price shocks on the estimated dependent means. Comparisons between Figures 2 and 3 and then Figures 2 and 4 show that the patterns of the inferred probabilities are not the same. Transition probability effects are most relevant to the 1973-5 and 1990-2 recessions while mean-dependant effects have more relevance to the start of the 1979-81 recession. These findings can be contrasted with Raymond and Rich (1997) who find that oil price shocks predominately impact the mean of the growth state rather than the transition probabilities.

4. Summary and Conclusion

In this paper we have presented the first UK study that examines the influence of oil price shocks on the business cycle. Using a Markov-switching approach, we find that oil price shocks have exerted mean-dependant effects associated with expansionary and recessionary states. However, we also find that asymmetries are present because oil price shocks adversely affect the duration of the expansionary phase of the business cycle. This latter can be contrasted with the US study by Raymond and Rich (1997) who attach less significance to transition probability effects. Our work augments the growing literature on asymmetries in macroeconomics in the sense that we consider the role of played by a key supply-side variable. Avenues for future research in this area might include a more formal investigation of the relative

importance played by government policy, irreversible investment and sectoral shocks in underpinning oil-related asymmetries.

Table 1. ML estimates of the four Markov switching models of real GDP

Parameter	Model I	Model II	Model III	Model IV
μ_1	0.7657 (0.084)	0.7270 (0.090)	0.7417 (0.090)	0.7504 (0.097)
μ_0	-0.6645 (0.279)	-0.8307 (0.466)	-0.6628 (0.520)	-0.7719 (0.324)
β_1		1.0024 (0.602)	1.1013 (0.826)	
β_2		0.0429 (0.622)	-0.0023 (0.719)	
β_3		-1.3740 (0.609)	-1.4031 (0.763)	
β_4		-0.4385 (0.628)	-0.4477 (0.717)	
δ_0	1.7608 (0.267)	2.2675 (0.458)	1.8211 (0.308)	2.0786 (0.394)
δ_1		-7.8287 (3.257)		-6.6429 (3.143)
γ_0	0.6460 (0.386)	0.7614 (0.754)	0.5507 (0.813)	0.8119 (0.450)
γ_1		-2.1252 (2.611)		-2.045 (2.193)
σ_ε^2	0.7751 (0.059)	0.7650 (0.100)	0.7682 (0.110)	0.7758 (0.107)
p	0.961			
q	0.741			
LL	-202.782	-196.014	-199.724	-199.470

Notes: The estimated model is

$$[\Delta y - \mu(S_t)] = \sum_{i=1}^{4} \beta_t o_{t-i}^{+} + \varepsilon_t$$

$$p_t = \Phi(\delta_0 + \delta_1 o_t^{+}), \ q_t = \Phi(\gamma_0 + \gamma_1 o_t^{+})$$
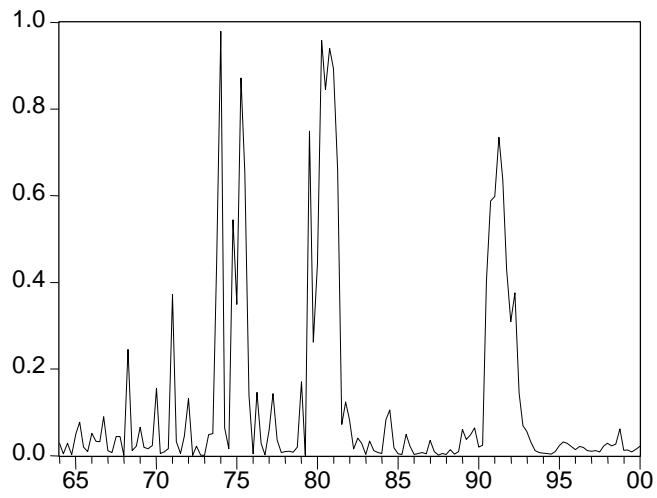
Standard errors are reported in parentheses

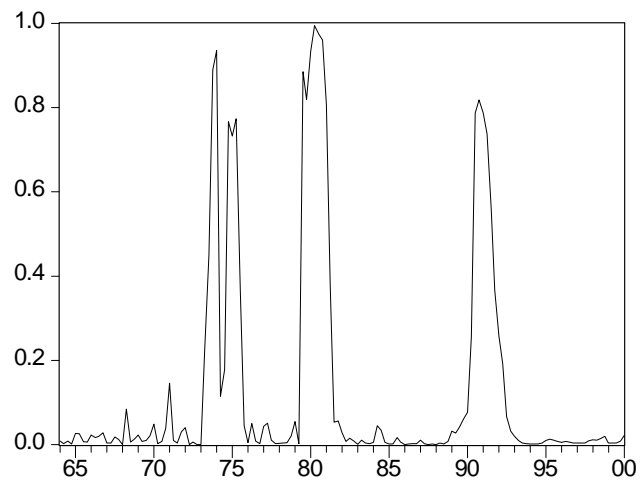**Table 2 Impact of Oil Price Shocks on Transition Probabilities**

Oil shocks (%)	5	10	15	20	25	30
p_t	0.9697	0.9312	0.8629	0.7586	0.6219	0.4677

These figures are based on the results for Model II reported in Table 1.

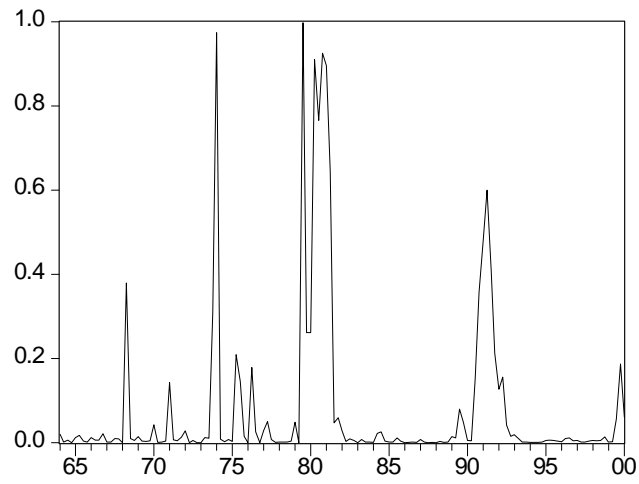**Figure 1. A benchmark Markov switching model of GDP output**
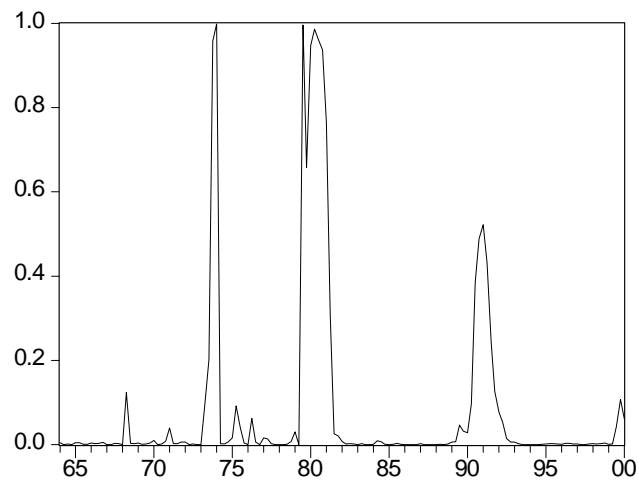

Filtered probability of being in recessions

Smoothed probability of being in recessions

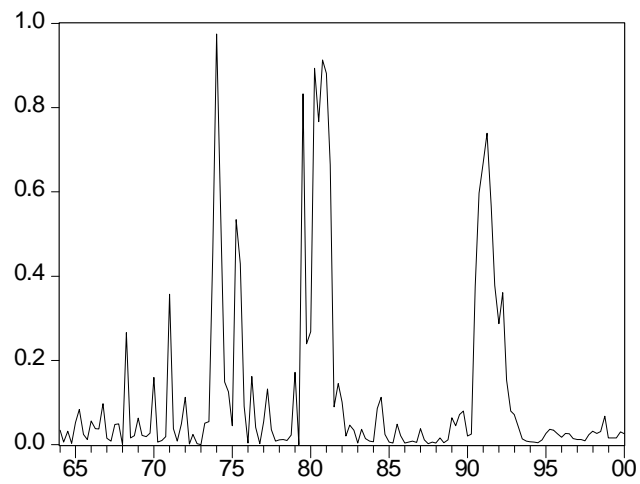**Figure 2. A generalised Markov switching model of GDP output**

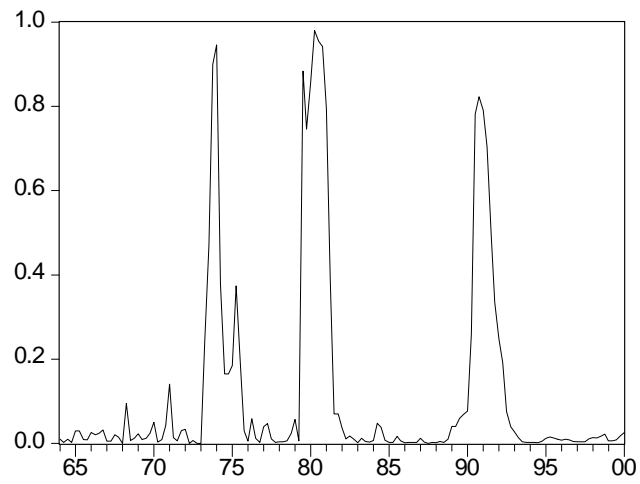Filtered probability of being in recessions

Smoothed probability of being in recessions

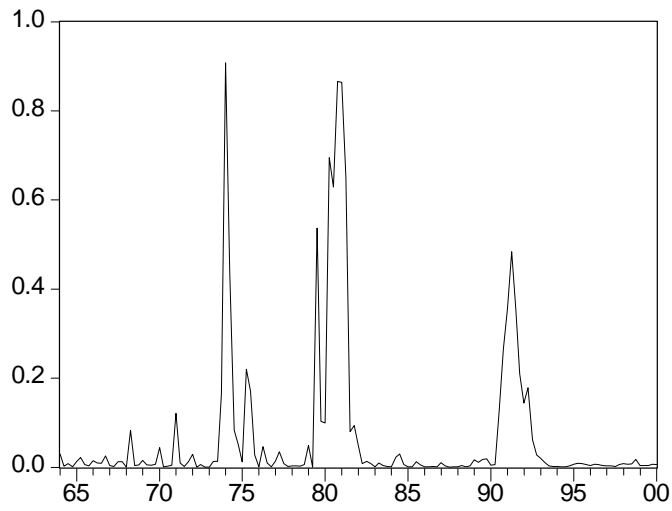**Figure 3. Transition probability effects on GDP output**

Filtered probability of being in recessions
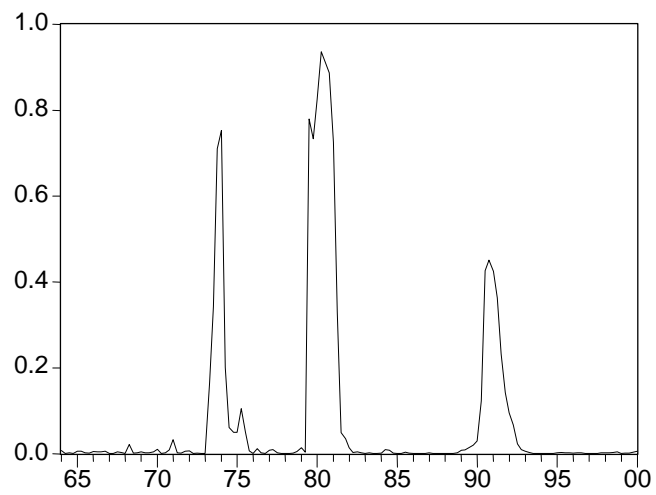

Smoothed probability of being in recessions

Figure 4. Mean-dependent effects on GDP output

Filtered probability of being in recessions

Smoothed probability of being in recessions

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