
**US Monetary Policy and the G7 House Business cycle :
FIML Markov Switching Approach**

Yoon, Jae-Ho

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<http://sites.google.com/site/beowulfkorea/>

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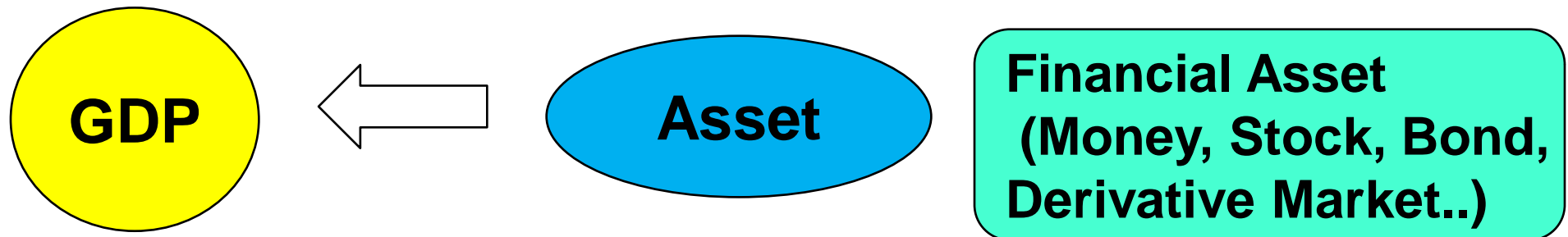
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1. Introduction

Motivation

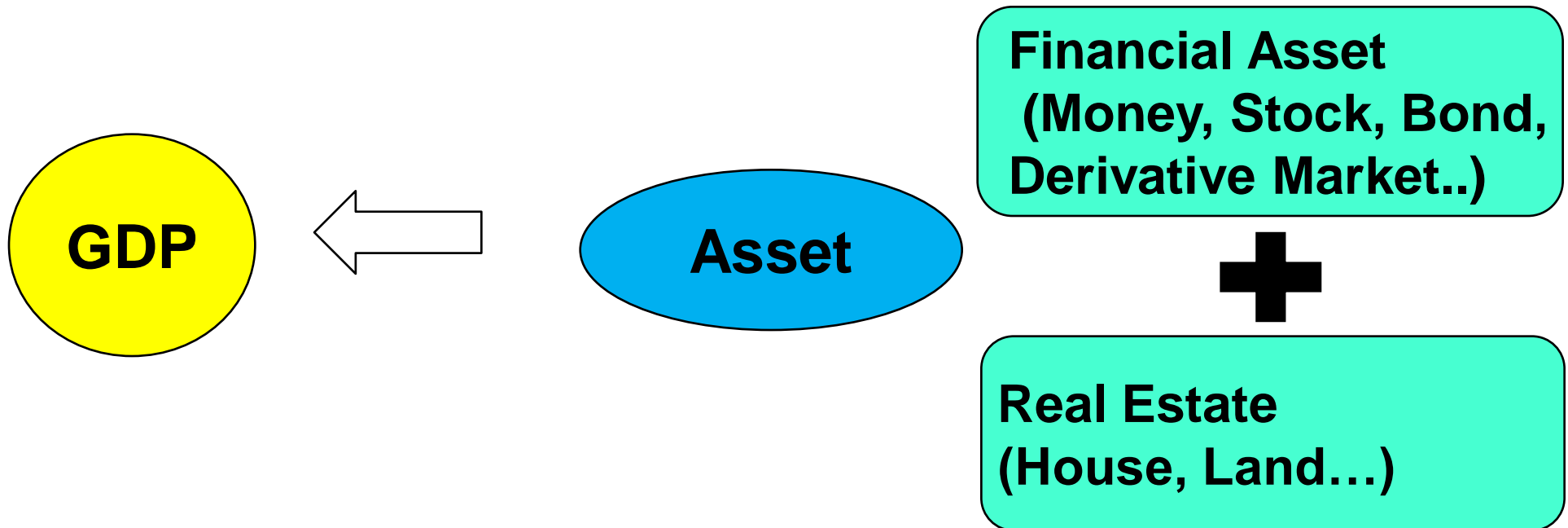
- ❑ Fisher Equation ($MV=Py$), Cambridge approach ($M=k Py$), Taylor rule ($I = \Delta P + \Delta y$)
- ❑ Greenspan Doctrine vs. Bernanke Doctrine
 - ⇒ GDP = Labor Market + Capital Market
- ❑ However, "The Wealth of Nation" by Adam Smith include the "Land Market":
 - ⇒ GDP = Labor Market + Capital Market + Land Market



1. Introduction

My Idea

- This paper try to add Real Estate variables to the Quantity Theory of Money.
($P_y = MV$) \Rightarrow ($P_y = MV + \text{Real Estate Market}$))
- ※ G7 House Business Cycle is defined as the common switching relationship between GDP and House Prices (Real Estate) in the G7 countries.



1. Introduction

My Idea

- The basic model of this paper is

$$\Delta y_t = a + b \Delta \text{House Price}_t + c I_t - d \Delta P_t + e_t$$

(P_y = Real Estate Market + MV)

- House price is important variable in the real estate market
- Interest rate is important variable in the money market

- ※ $\Delta \text{House Price} / \Delta \text{real GDP} = 1/b$ is the criteria for the house bubble.
- ※ we adopted the full information maximum likelihood (FIML) Markov-switching model of Yoon (2006).

1. Introduction

The Purpose of this paper

- ❑ Plamen Iossifov, Martin Čihák, and Amar Shanghavi¹ (2008) showed that the short-term interest rate has a sizable impact on residential housing prices. Lastrapes, W. D. (2002) showed that money supply shocks have real effects on the housing prices.
 - ❑ However, Deniz Igan and Prakash Loungani (2012) found that long-run house price dynamics are mostly driven by local fundamentals such as income and the effect of more globally connected factors such as interest rates appears to be less strong.
 - ❑ Òscar Jordà, Moritz Schularick, Alan M. Taylor (2015) disagree over interest rates increase to curb asset price booms.
- ⇒ Therefore, this paper examined whether there really is a positive relationship between US monetary policy and the G7 house business cycle

1. Introduction

Methods

- ❑ To establish a relationship between US monetary policy and the G7 house business cycle, we adopted the full information maximum likelihood (FIML) Markov-switching model of Yoon (2006).

The findings of this paper

- ❑ The paper showed a positive relationship between US interest rate and G7 GDP growth. US interest rate is a significant variable to the common business cycle between housing price and GDP in the G7 countries. However, US interest rate showed a significant effect to the G7 house business cycle for small shock periods, not extremely large shocks periods.
- ❑ This paper also found no relationship between US m2 growth and the GDP growth rate of the G7 countries.

2. FIML Markov-Switching Model (Yoon Model)

FIML Markov Switching Model

= **Simultaneous Equation** + **Markov Switching**

- **FIML : Full Information Maximum Likelihood**

3. Derivation of the FIML Markov Switching Model

$$YBs_t + Z\Gamma s_t = U_{S_t} \quad U_{S_t} \sim i.i.d.N(0, \Sigma_{S_t} \otimes I_T)$$

Where,

$$Y = \begin{bmatrix} Y_{11} & Y_{12} & \cdots & Y_{1M} \\ Y_{21} & Y_{22} & \cdots & Y_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ Y_{T1} & Y_{T2} & \cdots & Y_{TM} \end{bmatrix} = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_T \end{pmatrix} \quad B_{S_t} = \begin{bmatrix} \beta_{11,S1t} & \beta_{12,S2t} & \cdots & \beta_{1M,SMt} \\ \beta_{21,S1t} & \beta_{22,S2t} & \cdots & \beta_{2M,SMt} \\ \vdots & \vdots & \ddots & \vdots \\ \beta_{M1,S1t} & \beta_{M2,S2t} & \cdots & \beta_{MM,SMt} \end{bmatrix} \quad Z = \begin{bmatrix} Z_{11} & Z_{12} & \cdots & Z_{1K} \\ Z_{21} & Z_{22} & \cdots & Z_{2K} \\ \vdots & \vdots & \ddots & \vdots \\ Z_{T1} & Z_{T2} & \cdots & Z_{TK} \end{bmatrix} = \begin{pmatrix} z_1 \\ z_2 \\ \vdots \\ z_T \end{pmatrix}$$

$$\Gamma_{S_t} = \begin{bmatrix} \gamma_{11,S1t} & \gamma_{12,S2t} & \cdots & \gamma_{1M,SMt} \\ \gamma_{21,S1t} & \gamma_{22,S2t} & \cdots & \gamma_{2M,SMt} \\ \vdots & \vdots & \ddots & \vdots \\ \gamma_{K1,S1t} & \gamma_{K2,S2t} & \cdots & \gamma_{KM,SMt} \end{bmatrix} \quad U_{S_t} = \begin{bmatrix} u_{11,S1t} & u_{12,S2t} & \cdots & u_{1M,SMt} \\ u_{21,S1t} & u_{22,S2t} & \cdots & u_{2M,SMt} \\ \vdots & \vdots & \ddots & \vdots \\ u_{T1,S1t} & u_{T2,S2t} & \cdots & u_{TM,SMt} \end{bmatrix} = (u_{S1t} \quad u_{S2t} \quad \cdots \quad u_{SMt})$$

$$E(U_{S_t}' U_{S_t}) = E \left(\begin{pmatrix} u_{S1t} \\ u_{S2t} \\ \vdots \\ u_{SMt} \end{pmatrix} (u_{S1t} \quad u_{S2t} \quad \cdots \quad u_{SMt}) \right) = \begin{pmatrix} \sigma_{S1t,S1t} I_T & \sigma_{S1t,S2t} I_T & \cdots & \sigma_{S1t,SMt} I_T \\ \sigma_{S2t,S1t} I_T & \sigma_{S2t,S2t} I_T & \cdots & \sigma_{S2t,SMt} I_T \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{SMt,S1t} I_T & \sigma_{SMt,S2t} I_T & \cdots & \sigma_{SMt,SMt} I_T \end{pmatrix} = \Sigma_{S_t} \otimes I_T$$

3. Derivation of the FIML Markov Switching Model

Step 1 : At the beginning of the tth iteration $\Pr(S_{t-1} = i | \psi_{t-1}) \quad i = 0, 1, \dots, N$ is given. And, we calculate

$$\Pr(S_t = j | \psi_{t-1}) = \sum_{i=1}^N \Pr(S_{t-1} = i, S_t = j | \psi_{t-1}) = \sum_{i=1}^N \Pr(S_t = j | S_{t-1} = i) \Pr(S_{t-1} = i | \psi_{t-1})$$

where $\Pr(S_t = j | S_{t-1} = i)$ are the transition probabilities.

Step 2 : Consider the joint conditional density of

$$f(y_t, S_t = j | \psi_{t-1}) = f(y_t | S_t = j, \psi_{t-1}) \Pr(S_t = j | \psi_{t-1})$$

from which the marginal density of

$$f(y_t | \psi_{t-1}) = \sum_{j=1}^N f(y_t, S_t = j | \psi_{t-1}) = \sum_{j=1}^N f(y_t | S_t = j, \psi_{t-1}) \Pr(S_t = j | \psi_{t-1})$$

where the conditional density

$$f(y_t | S_t = j, \psi_{t-1}) = (2\pi)^{-M/2} \det(\Sigma_{S_t})^{-1/2} |\det(Bs_t)| \cdot \exp\left(-\frac{1}{2} (y_t Bs_t + z_t \Gamma s_t) \Sigma_{S_t}^{-1} (y_t Bs_t + z_t \Gamma s_t)'\right)$$

where

$$\Sigma_{S_t} = \frac{1}{T} (YBs_t + Z\Gamma s_t)' (YBs_t + Z\Gamma s_t) \quad y_j \text{ is the } t\text{th row of the } Y \text{ matrix.} \quad z_j \text{ is the } t\text{th row of the } Z \text{ matrix.}$$

3. Derivation of the FIML Markov Switching Model

Step 3 :

y_t is observed at the end of time t , we update the probability terms:

$$\begin{aligned}\Pr(S_t = j | \psi_t) &= \Pr(S_t = j | \psi_{t-1}, y_t) \\ &= \frac{f(S_t = j, y_t | \psi_{t-1})}{f(y_t | \psi_{t-1})} \\ &= \frac{f(y_t | S_t = j, \psi_{t-1}) \Pr(S_t = j | \psi_{t-1})}{f(y_t | \psi_{t-1})}\end{aligned}$$

As a byproduct of the above filter in Step 2, we obtain the log likelihood function:

$$\ln L = \sum_{t=1}^T \ln f(y_t | \psi_{t-1})$$

4. Data

Variables

- real GDP : t=1970:I to 2016:IV from OECD database
 - Housing Price Index : BIS database
 - CPI, federal fund rate, m2 : FRED
-
- Y_t , is real GDP in the G7
 - H_t is Housing Price Index in the G7
 - C_t is consumer Price index in the G7
 - M is federal fund rate or $\Delta m2$

Equation

$$\Delta Y_{G7} = \alpha_{S_t} + \beta_{S_t} \Delta H_{G7} + \pi \Delta C_{G7} + \lambda M + e_{S_t, G7}$$

Where:

$$\alpha_{S_t} = \alpha_1 S_t + \alpha_0 (1 - S_t) \quad \beta_{S_t} = \beta_1 S_t + \beta_0 (1 - S_t)$$

$$\Pr(S_t = 0 | S_{t-1} = 0) = q \quad \Pr(S_t = 1 | S_{t-1} = 1) = p$$

4. Data

$$\Delta Y_{us} = \alpha_{S_t} + \beta_{S_t} \Delta H_{us} + \pi \Delta C_{us} + \lambda M + e_{S_t,us} \quad (3)$$

$$\Delta Y_{uk} = \alpha_{S_t} + \beta_{S_t} \Delta H_{uk} + \pi \Delta C_{uk} + \lambda M + e_{S_t,uk} \quad (4)$$

$$\Delta Y_{fr} = \alpha_{S_t} + \beta_{S_t} \Delta H_{fr} + \pi \Delta C_{fr} + \lambda M + e_{S_t,fr} \quad (5)$$

$$\Delta Y_{de} = \alpha_{S_t} + \beta_{S_t} \Delta H_{de} + \pi \Delta C_{de} + \lambda M + e_{S_t,de} \quad (6)$$

$$\Delta Y_{it} = \alpha_{S_t} + \beta_{S_t} \Delta H_{it} + \pi \Delta C_{it} + \lambda M + e_{S_t,it} \quad (7)$$

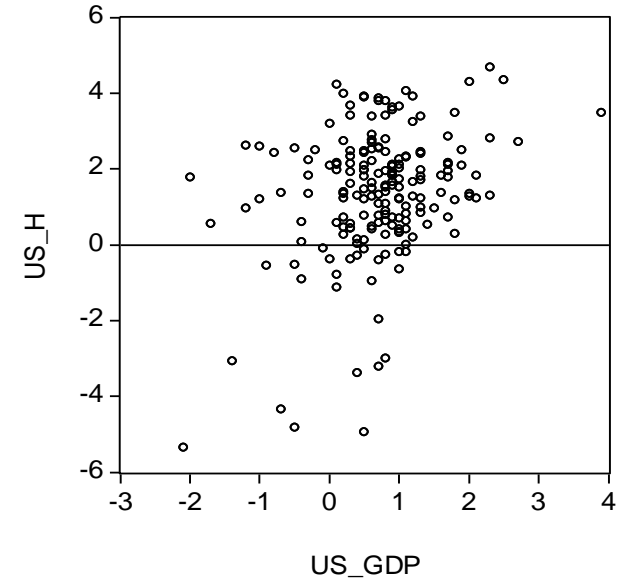
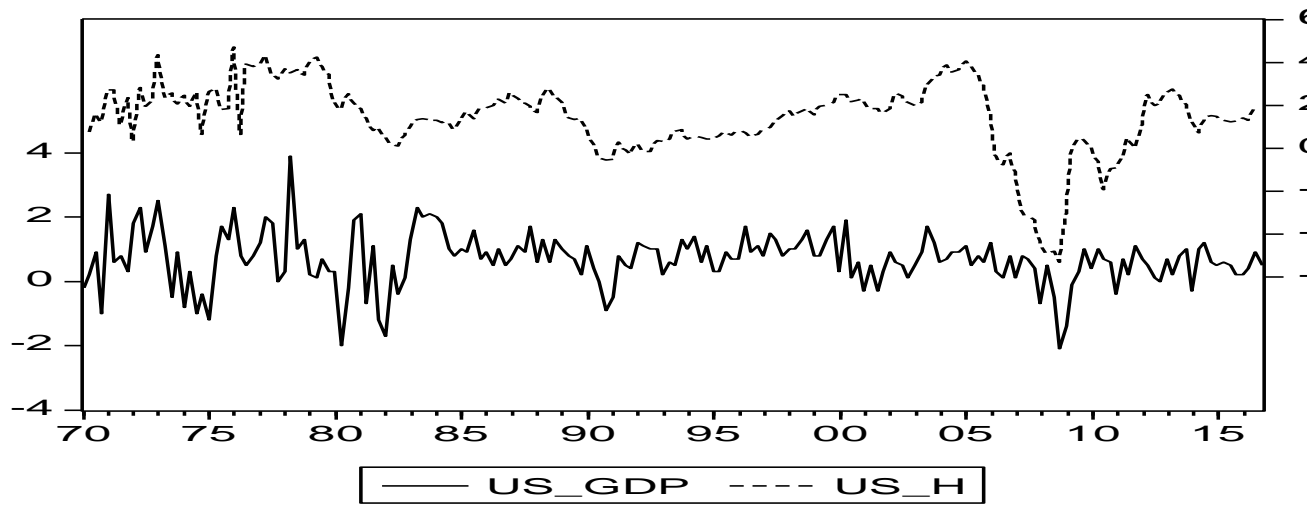
$$\Delta Y_{ca} = \alpha_{S_t} + \beta_{S_t} \Delta H_{ca} + \pi \Delta C_{ca} + \lambda M + e_{S_t,ca} \quad (8)$$

$$\Delta Y_{jp} = \alpha_{S_t} + \beta_{S_t} \Delta H_{jp} + \pi \Delta C_{jp} + \lambda M + e_{S_t,jp} \quad (9)$$

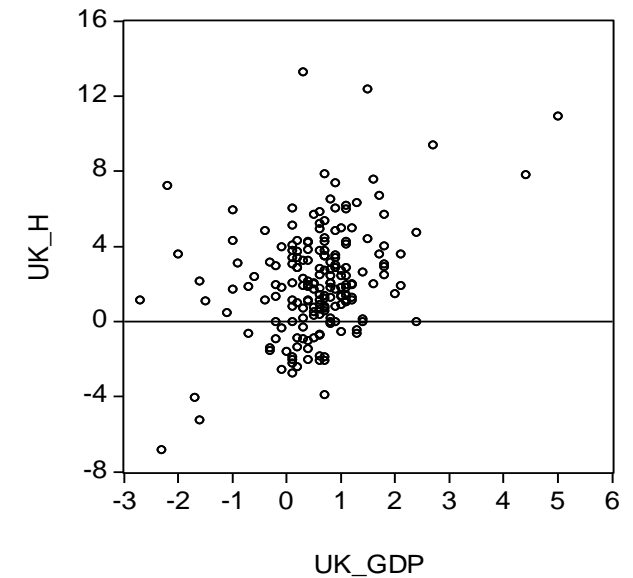
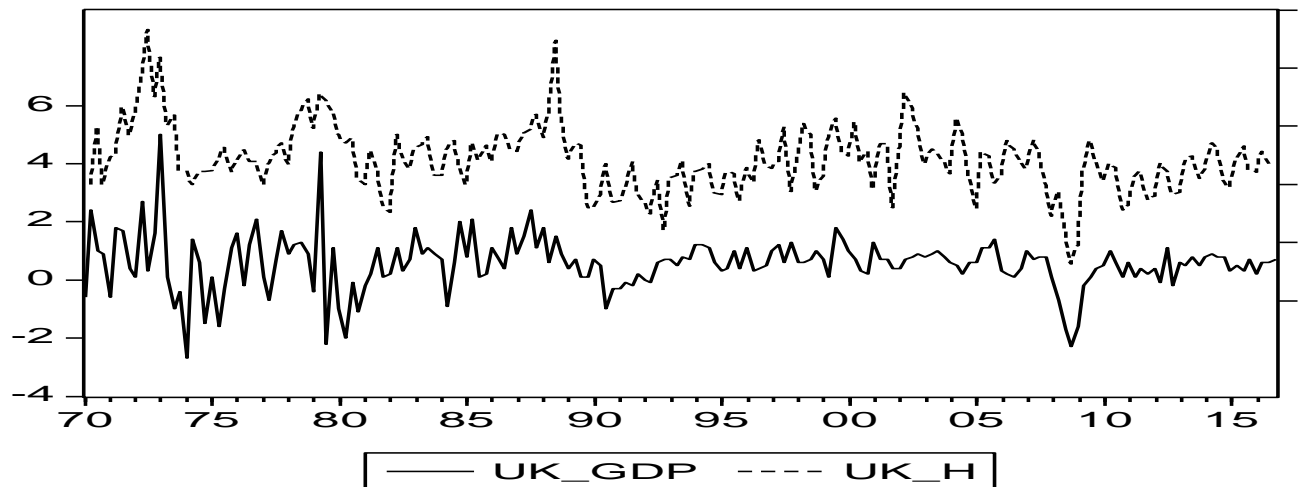
where ΔY , is the log differenced real GDP. ΔH is the log differenced housing price in the G7 countries. ΔC is the log differenced consumer price in the G7 countries. M , is federal funds rate or the log differenced $m2$

4. Data (GDP and House Price)

GDP ΔY and House Price ΔH in the US

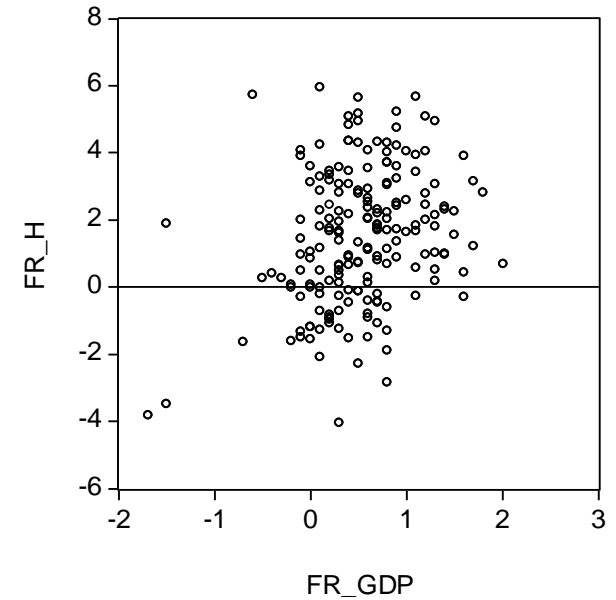
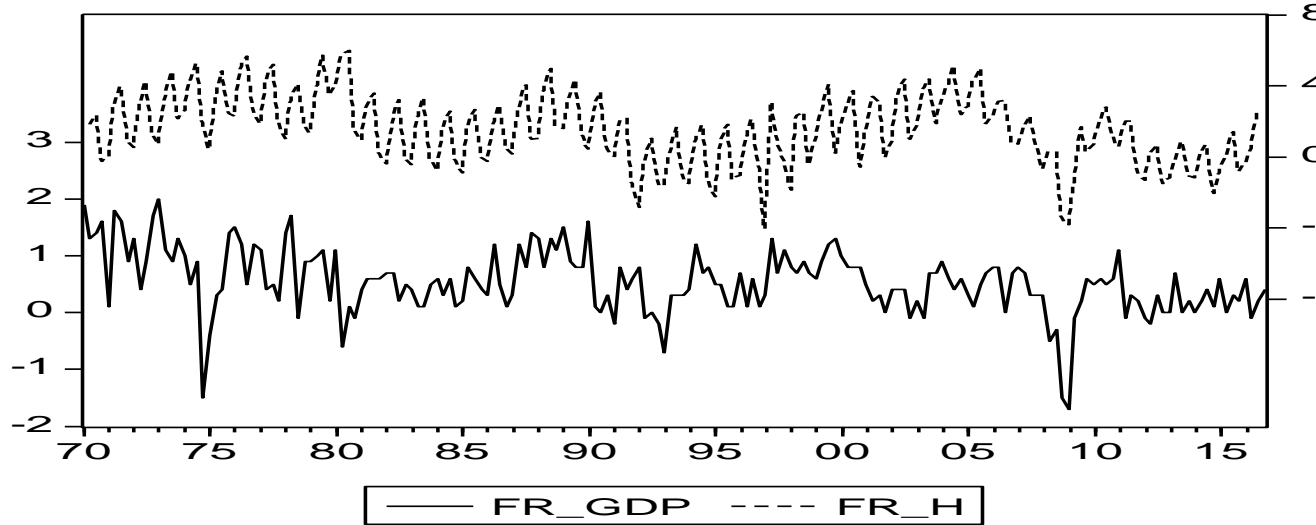


GDP ΔY and House Price ΔH in the UK

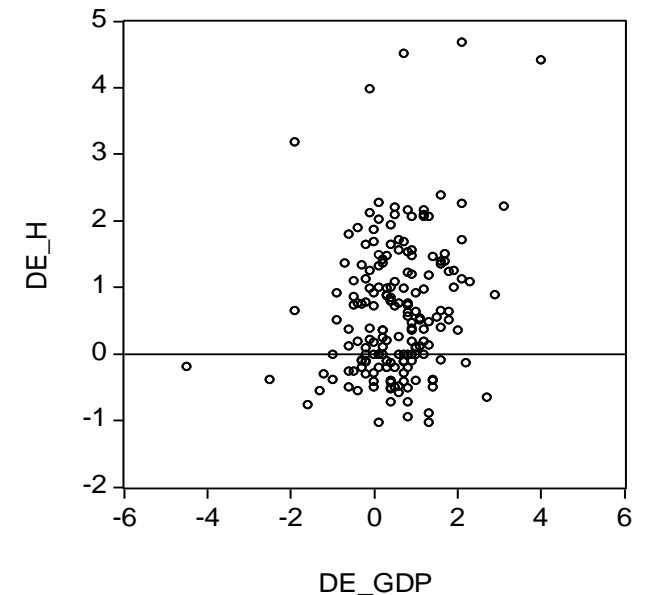
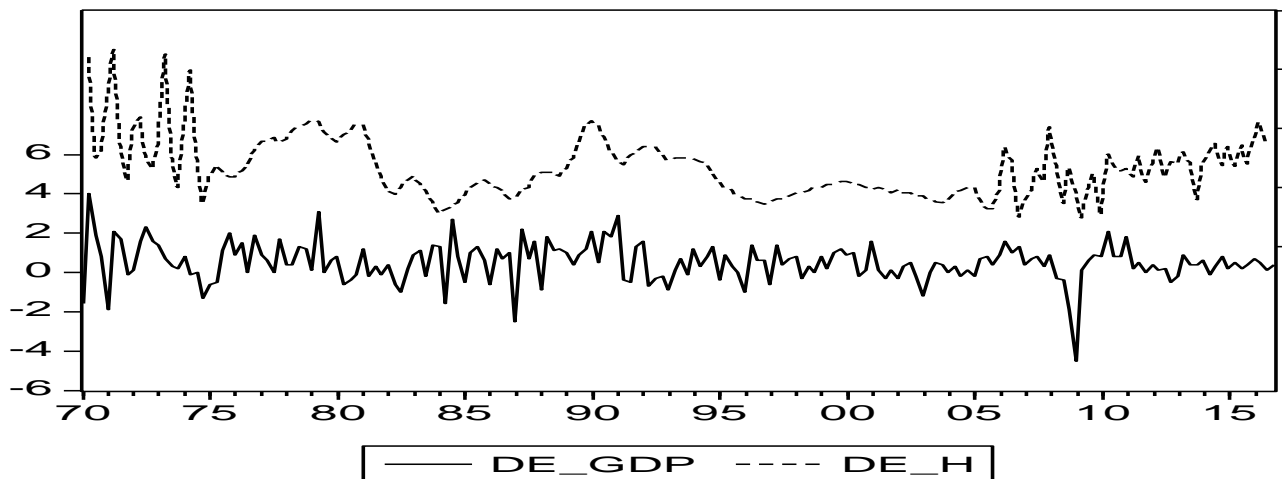


4. Data (GDP and House Price)

GDP ΔY and House Price ΔH in the FR

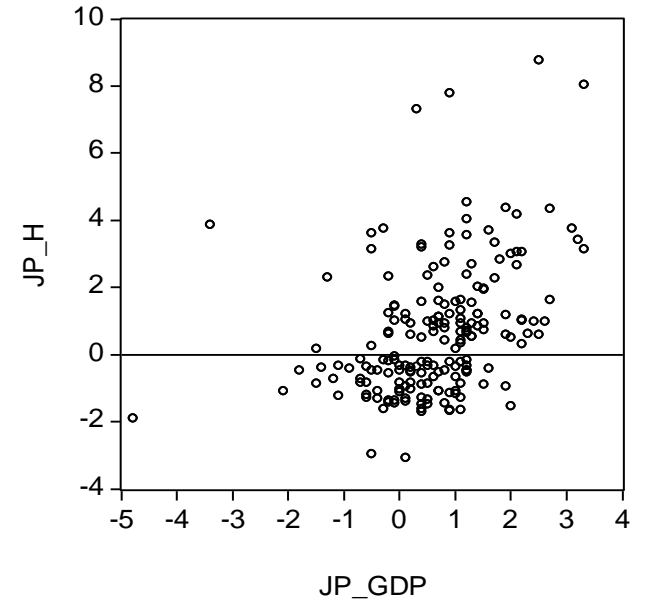
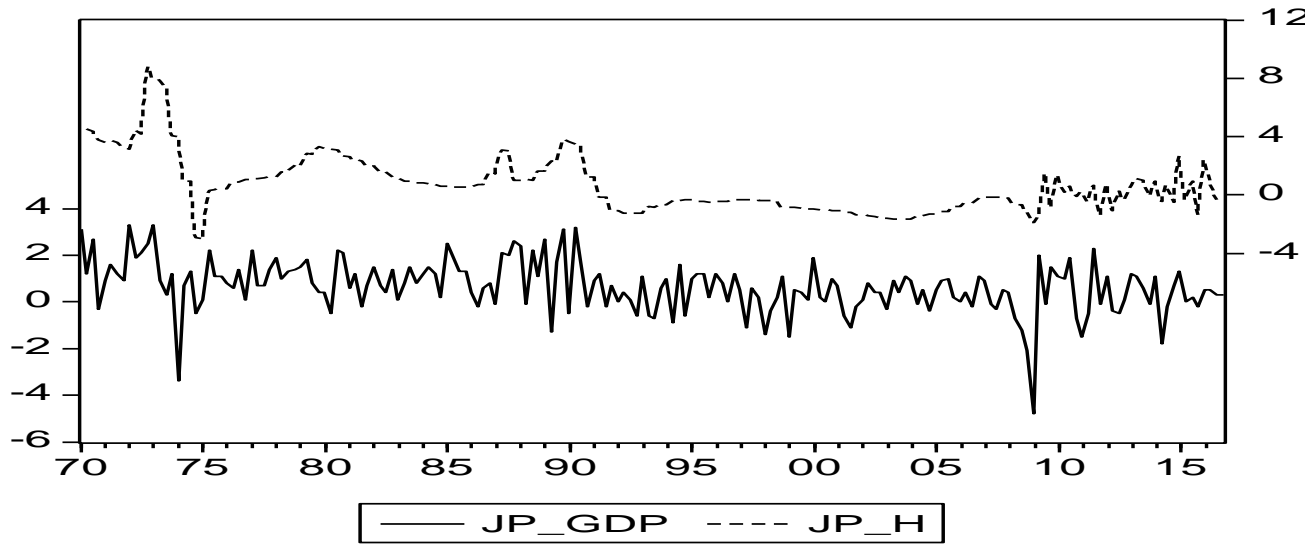


GDP ΔY and House Price ΔH in the DE

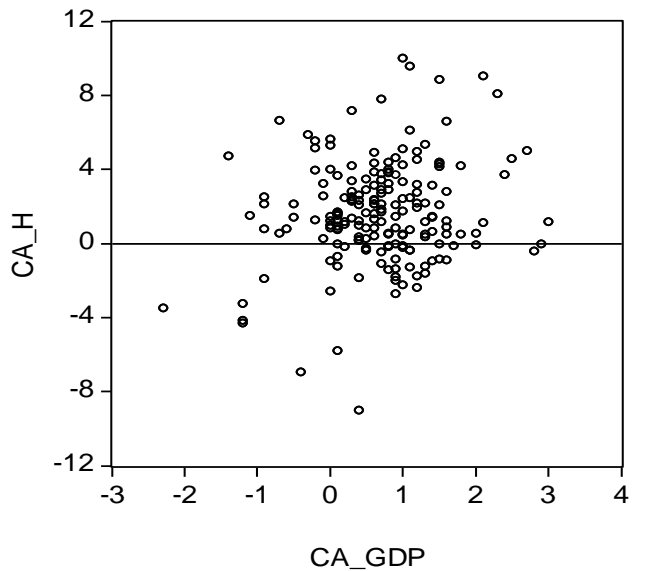
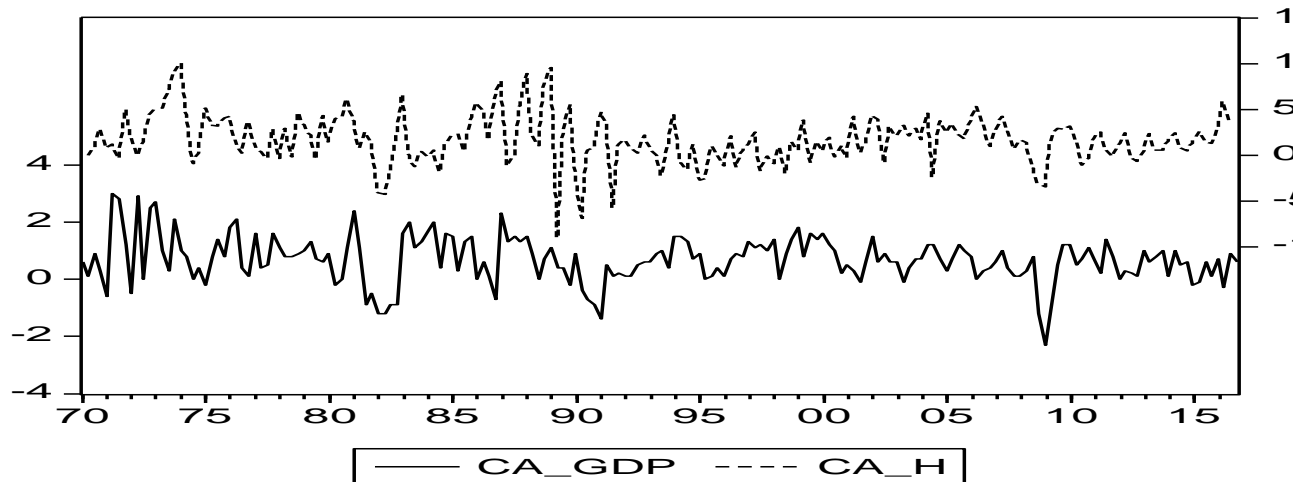


4. Data (GDP and House Price)

GDP ΔY and House Price ΔH in the JP

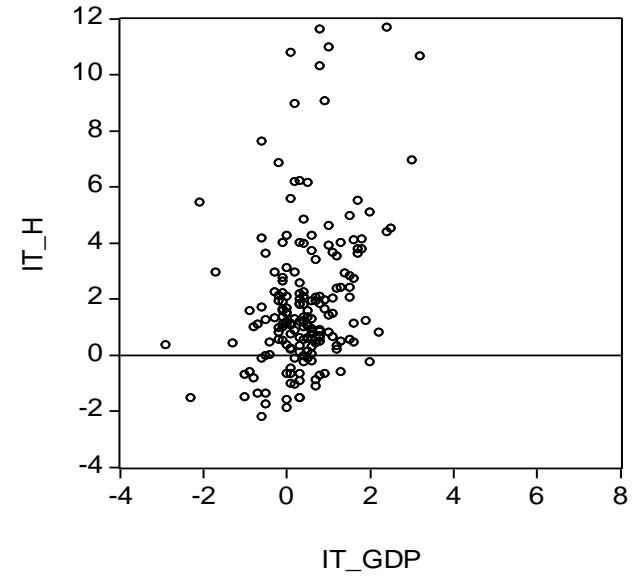
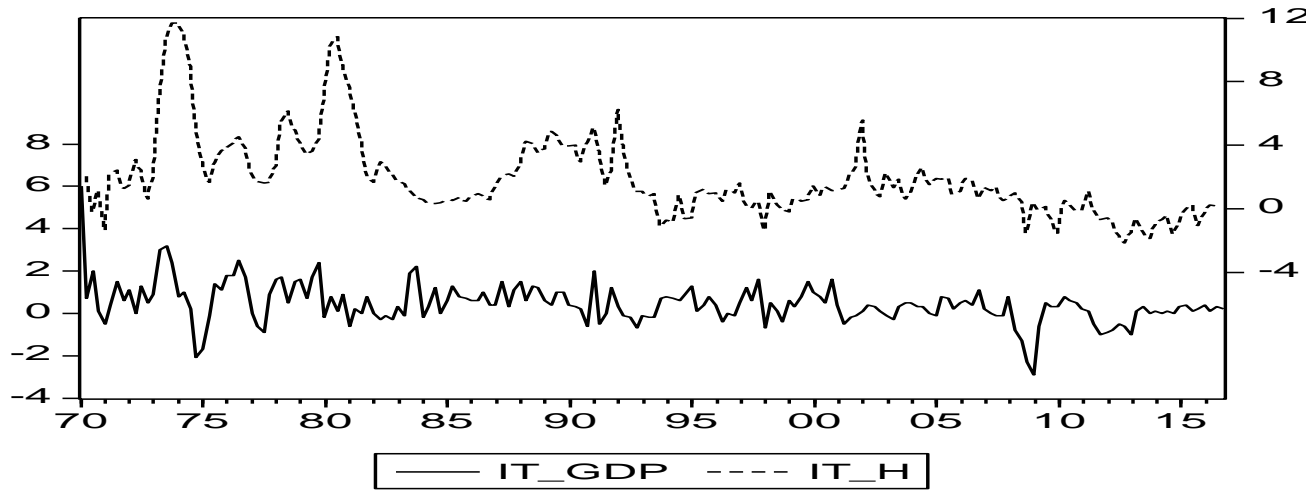


GDP ΔY and House Price ΔH in the CA



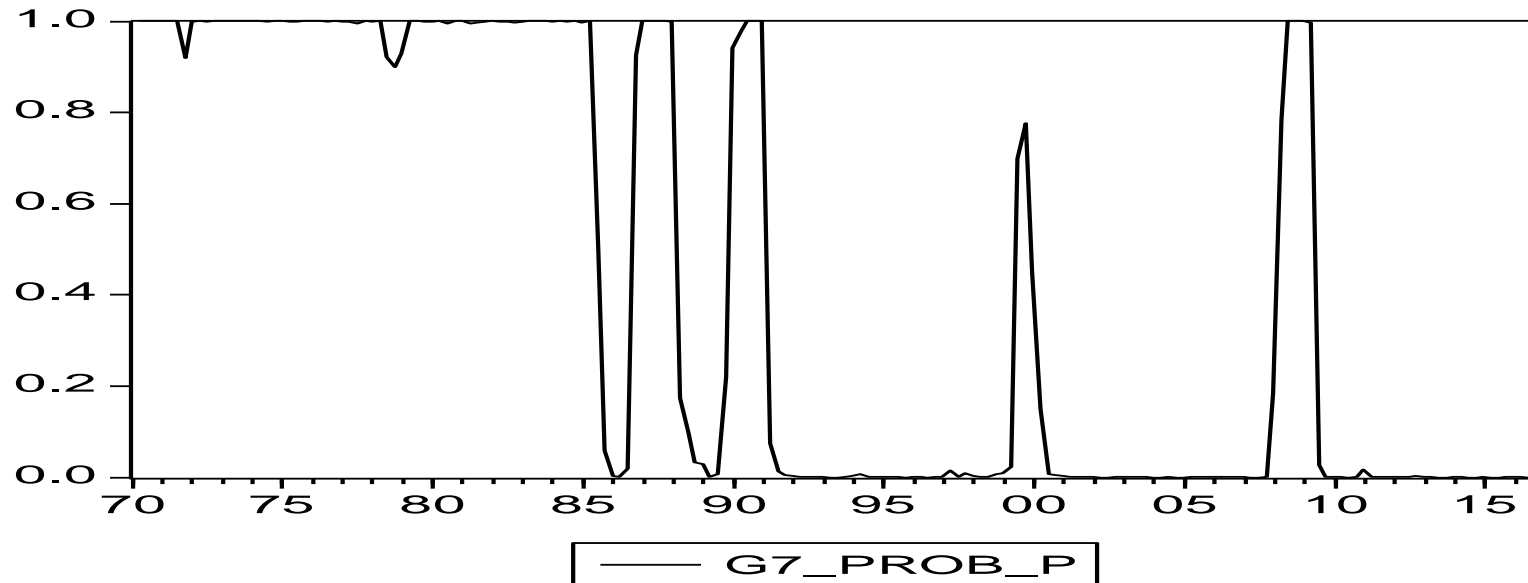
4. Data (GDP and House Price)

GDP ΔY and House Price ΔH in the IT



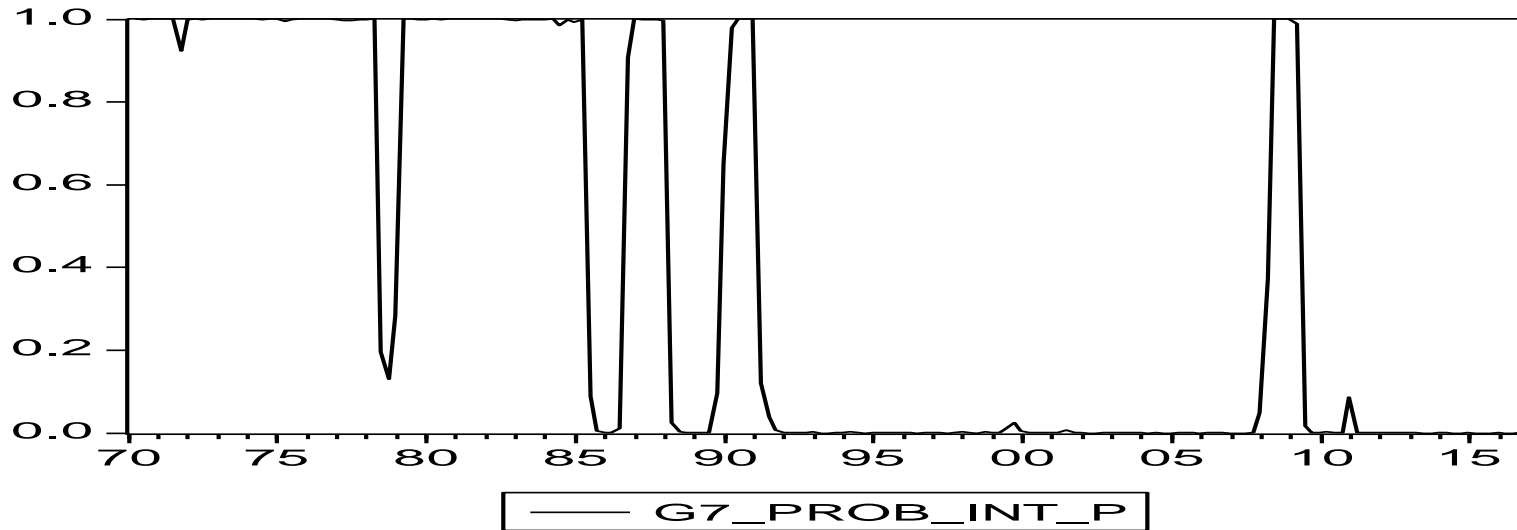
5. Empirical Results

Probabilities of regime 1 $\Pr(S_t = 1 | Y_T)$ for 1970:II~2016:IV



5. Empirical Results

Probabilities with Interest



Probabilities with m2

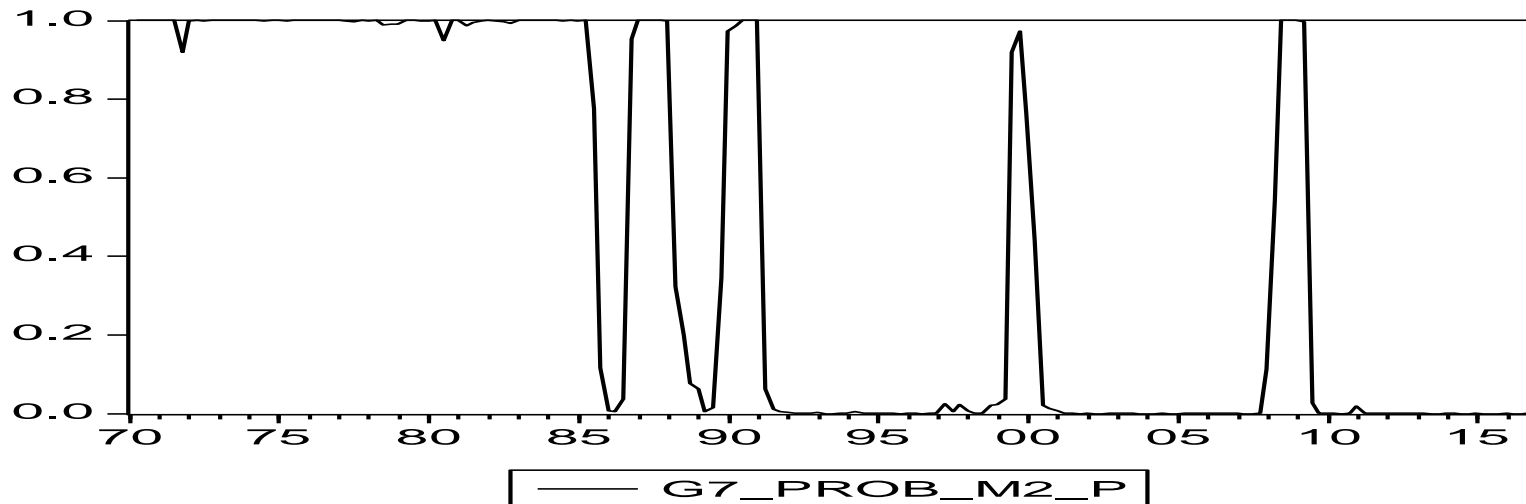


Table 1: MLE of the FIML Markov-switching model (1970.II to 2016.IV)**Parameters**

β_0 us	0.053 (0.031)	0.059(0.027)	0.055(0.029)
β_1 us	0.284 (0.071)	0.311(0.085)	0.312(0.075)
β_0 uk	0.036 (0.016)	0.042(0.015)	0.036(0.016)
β_1 uk	0.184 (0.040)	0.191(0.042)	0.181(0.039)
β_0 fr	0.057 (0.020)	0.046(0.017)	0.057(0.020)
β_1 fr	0.101 (0.043)	0.113(0.044)	0.103(0.042)
β_0 de	0.120 (0.087)	0.163(0.080)	0.112(0.089)
β_1 de	0.334 (0.116)	0.351(0.124)	0.336(0.114)
β_0 it	0.076 (0.035)	0.023(0.038)	0.070(0.035)
β_1 it	0.102 (0.074)	0.076(0.059)	0.097(0.045)
β_0 ca	-0.002 (0.022)	-0.005(0.022)	-0.000(0.021)
β_1 ca	0.112 (0.039)	0.119(0.039)	0.109(0.038)
β_0 jp	0.271 (0.081)	0.255(0.078)	0.271(0.088)
β_1 jp	0.257 (0.064)	0.248(0.067)	0.257(0.063)
α_0 us	0.727 (0.082)	0.647(0.082)	0.896(0.115)
α_1 us	0.403 (0.187)	0.129(0.257)	0.667(0.235)
α_0 uk	0.634 (0.050)	0.607(0.060)	0.672(0.077)
α_1 uk	0.427 (0.206)	0.399(0.224)	0.503(0.221)
α_0 fr	0.421 (0.051)	0.286(0.051)	0.441(0.081)
α_1 fr	0.470 (0.192)	0.210(0.154)	0.541(0.192)
α_0 de	0.526 (0.083)	0.370(0.099)	0.621(0.139)
α_1 de	0.530 (0.223)	0.136(0.258)	0.721(0.265)
α_0 it	0.208 (0.144)	0.028(0.102)	0.399(0.112)
α_1 it	0.248 (0.414)	-0.176(0.248)	0.640(0.271)
α_0 ca	0.717 (0.065)	0.665(0.078)	0.700(0.088)
α_1 ca	0.749 (0.206)	0.531(0.201)	0.772(0.217)
α_0 jp	0.499 (0.083)	0.381(0.112)	0.604(0.147)
α_1 jp	0.880 (0.196)	0.646(0.267)	1.076(0.269)
σ_0 us	0.202 (0.029)	0.197(0.026)	0.188(0.027)

σ_1 us	1.023 (0.171)	1.087(0.184)	1.010(0.164)
σ_0 uk	0.125 (0.020)	0.138(0.019)	0.123(0.018)
σ_1 uk	1.355 (0.224)	1.428(0.236)	1.334(0.212)
σ_0 fr	0.135 (0.020)	0.110(0.015)	0.134(0.019)
σ_1 fr	0.479 (0.077)	0.526(0.088)	0.470(0.075)
σ_0 de	0.375 (0.052)	0.350(0.048)	0.374(0.052)
σ_1 de	1.533 (0.249)	1.629(0.270)	1.489(0.237)
σ_0 it	0.273 (0.040)	0.236(0.032)	0.260(0.036)
σ_1 it	1.175 (0.193)	1.281(0.215)	1.149(0.183)
σ_0 ca	0.219 (0.032)	0.225(0.030)	0.212(0.030)
σ_1 ca	1.095 (0.177)	1.145(0.191)	1.081(0.172)
σ_0 jp	0.622 (0.088)	0.603(0.085)	0.611(0.089)
σ_1 jp	1.377 (0.223)	1.453(0.246)	1.358(0.215)
π us	-0.138 (0.096)	-0.206(0.092)	-0.191(0.093)
π uk	-0.171 (0.047)	-0.203(0.048)	-0.175(0.045)
π fr	-0.033 (0.098)	-0.183(0.066)	-0.048(0.071)
π de	-0.285 (0.120)	-0.356(0.111)	-0.311(0.115)
π it	0.008 (0.204)	-0.086(0.086)	-0.018(0.069)
π ca	-0.148 (0.096)	-0.152(0.076)	-0.162(0.072)
π jp	-0.308 (0.080)	-0.329(0.079)	-0.312(0.075)
q	0.956 (0.021)	0.957(0.019)	0.954(0.021)
p	0.942 (0.028)	0.938(0.029)	0.942(0.026)
		i_{us} us	$\Delta m2_{us}$ us
		i_{us} uk	$\Delta m2_{us}$ uk
		i_{us} fr	$\Delta m2_{us}$ fr
		i_{us} de	$\Delta m2_{us}$ de
		i_{us} it	$\Delta m2_{us}$ it
		i_{us} ca	$\Delta m2_{us}$ ca
		i_{us} jp	$\Delta m2_{us}$ jp

Log Likelihood -1378.60

-1346.78

-1373.51

Standard errors of the parameters estimated are reported in the parentheses

Table 2: The results of likelihood ratio test (LR test)

Monetary policy variables

Federal funds rate	63.64**
$\Delta m2$	10.18

* 5% significance level, ** 1% significance level

6. Conclusion

- **Applying FIML Markov-switching model to the G7 countries, we found that the housing price movement was procyclical with GDP during the oil shock periods of the 1970s, 80s, and 90s, and the bursting of housing bubble in 2008**
- **US interest rate is a significant variable to the common business cycle between housing price and GDP in the G7 countries.**
- **However, US interest rate showed a significant effect to the G7 house business cycle for small shock periods, not extremely large shocks periods.**
- **No relationship between US m2 growth and the GDP growth rate of the G7 countries.**

7. Reference

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