The Seeds of the 2007-2009 Crisis - the Housing Market and the Business Cycle

On-going

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Motivation

- Historical linkage between business cycle and the housing market cycle

- Understanding the relationship between the two cycles can shed light on the seeds of the housing crisis.

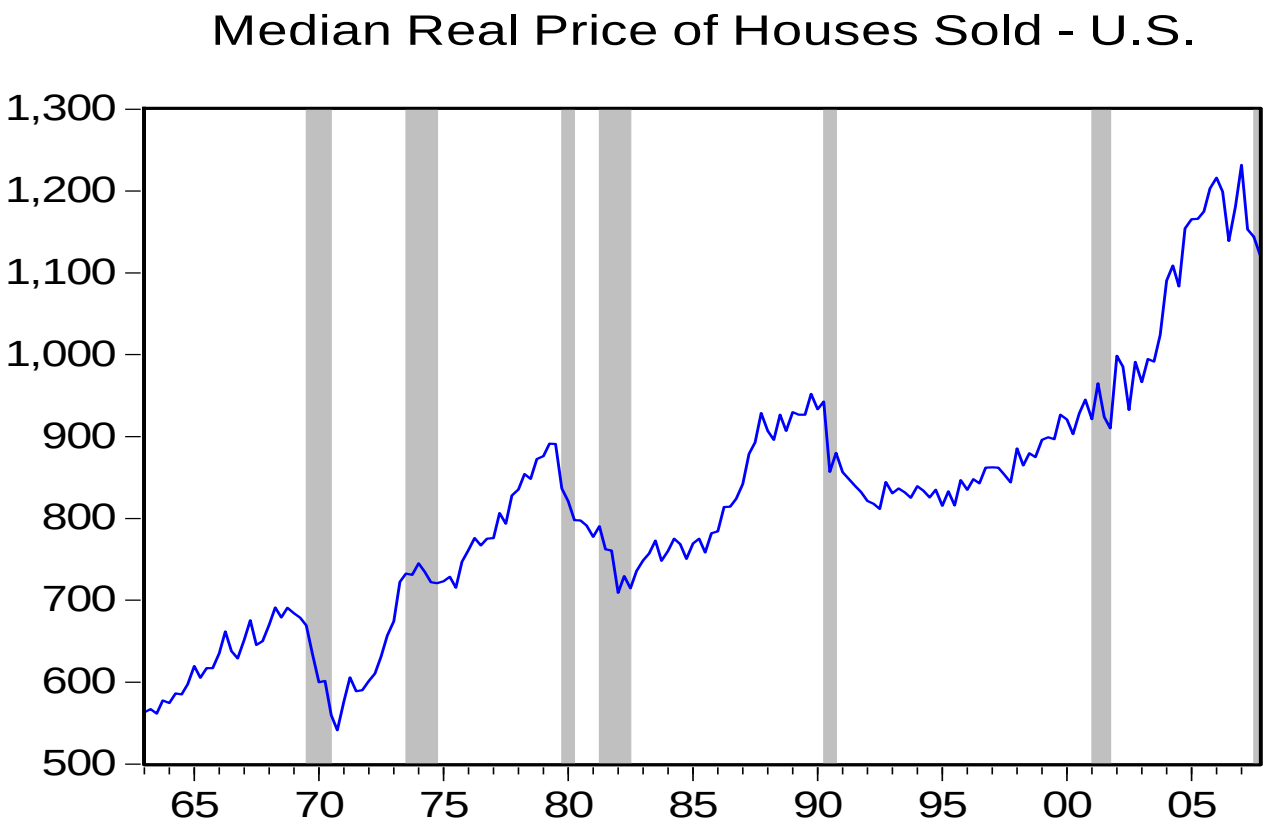
  - Crisis in housing market sector is associated with the particular features of the 2001 recession

Goal

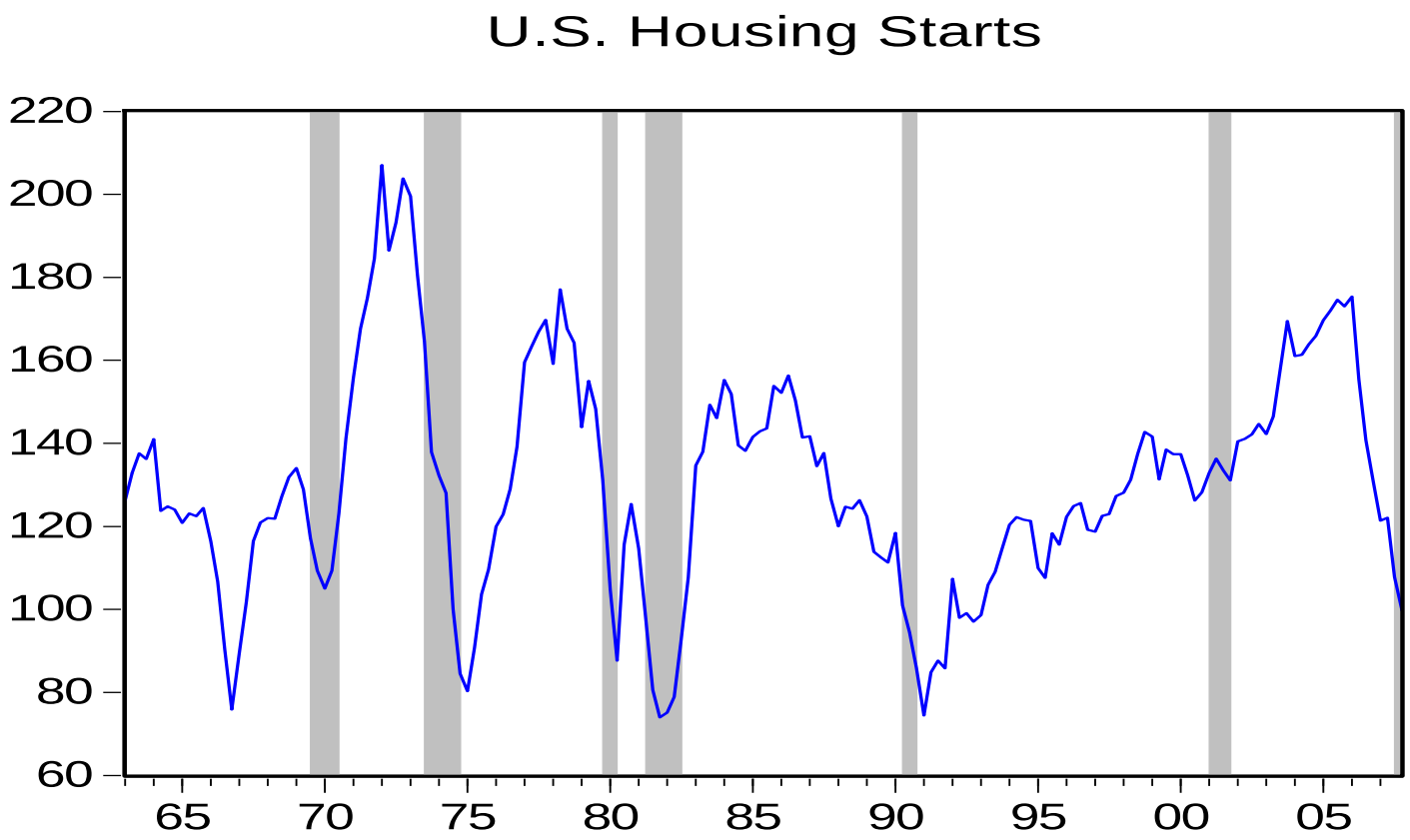
- This paper proposes a nonlinear two-factor model to represent the phases of the housing market cycle and the phases of the business cycle.

  - Model as a tool to investigate the historical relationship between the housing market and the business cycle, and the recent bubble-bust in the housing market.

Housing Market – Basic Facts

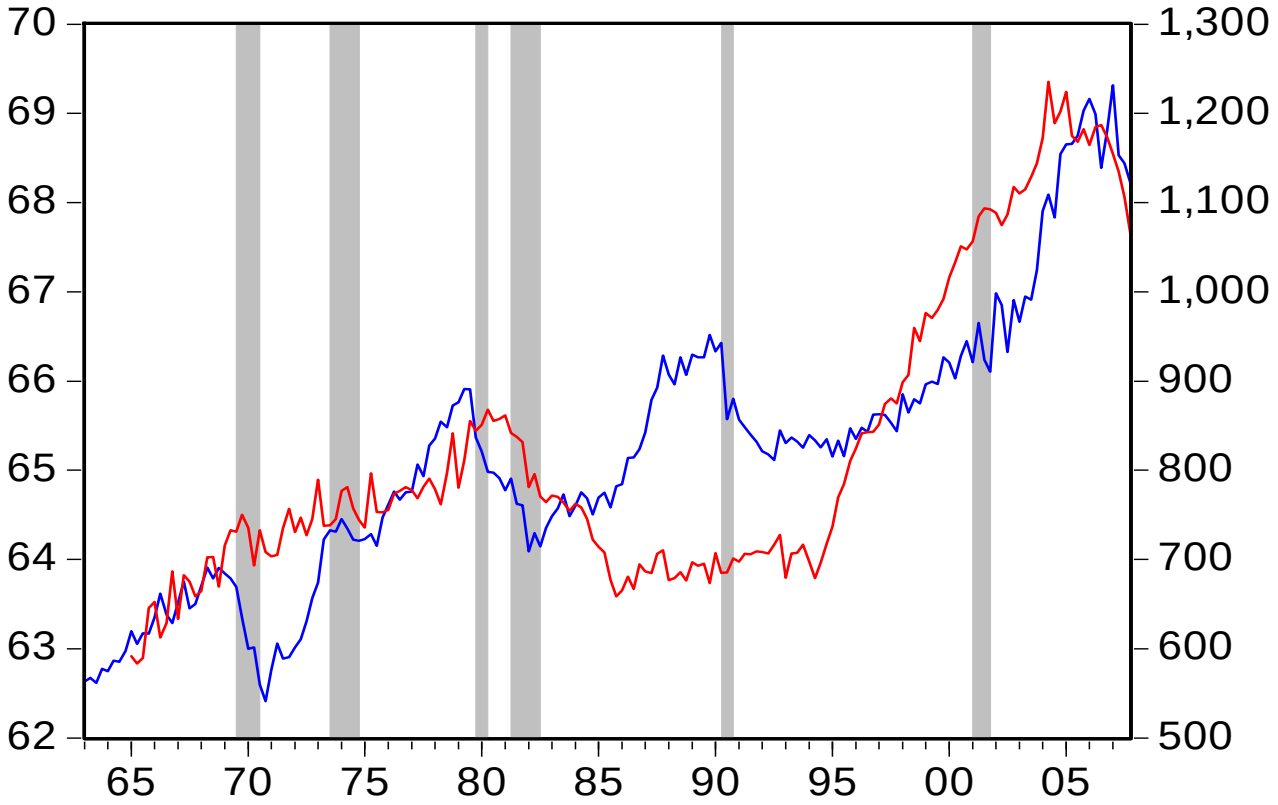


Housing Market – Basic Facts



New Privately Owned Housing Units Started (Housing Starts). Source: U.S. Census Bureau

Housing Market – Basic Facts



U.S. Census Bureau Home Ownership Rate (---), U.S. Median House Prices (—)

Housing Market Cycle and NBER-Dated Recessions

- Peaks towards the end of business cycle expansions
  - ➢ Beginning of low housing market phases slightly leads recessions
- Troughs in the end of business cycle recessions
  - ➢ Beginning of high housing market phases coincides or slightly lags the end of recessions

Literature

State-level housing prices in U.S.

- Vansteenkiste (2007), Dees, Dimauro Pesaran, and Smith (2005) and Pesaran, Schuermann, and Weiner (2004)) – VAR; Negro and Otrok (2007) - Dynamic factor model: house price indexes (48 states in U.S)
- Kim and Bhattacharya (2007) Smooth Transition Autoregressive (STAR) model to examine nonlinear properties of housing prices (nominal median sales price of existing single-family homes) during 1969-2004 in the U.S. and its four regions.
- Fadiga and Wang (2009) multivariate state-space model

U.S. metropolitan-level housing market

- Clayton, Miller, and Peng (2008) bivariate panel VAR model (114 metropolitan areas in the U.S.).
- Wheaton and Lee (2007) panel estimation (with 101 MSA market in U.S.)
- Wheaton and Nechayev (2007) housing price in 59 MSA during 1998 to 2005 in U.S.: demand fundamentals (population, income growth, and decrease in interest rates) fail to explain this period increase in housing prices.
- Goodman and Thibodeau (2008)

Contributions of this Paper

- Proposes a new model of the joint dynamics of the housing market and the business cycle (extends Chauvet 1998/1999)
- Common variation and asymmetries in the phases of housing market and the business cycle are modeled in a flexible setting.
- Relationship between the two cycles is analyzed simultaneously in a unified framework. Combined information from the business cycle, interest rates, and the housing market to shed light on housing market bubble and bust
- Findings:
  - Strong correlation between business cycles and the housing market cycles
  - Relationship has changed over time

Modeling Strategy

- We use a dynamic two-factor model with regime switching to characterize the housing market and the business cycle. Model distinguishes between low value and high value periods using Markov switching.

- The housing market factor follows a two-state Markov process representing low and high housing price phases
  - The factor is constructed from the median price of houses sold in the four regions of the U.S. (Northeast, South, Midwest, and West)

- The business market factor follows a two-state Markov process representing recessions and expansion phases
  - The factor is built from key coincident economic indicators

- The model is used to study the interrelationship between the two factors and the two cycles that they represent

Baseline Model

$$Y_{it} = \lambda_i F_t^H + \gamma_i F_t^{BC} + z_{it}$$

$$z_{it} = \Psi_i z_{it-1} + \varepsilon_{it} \qquad \varepsilon_{it} \sim \text{i.i.d. } N(0,\sigma_i^2)$$

where:

- Y_{it} is 8 x 1 vector:
  Growth rate of housing prices in the West, Northeast, Midwest, and South
  Growth rate of industrial production, real personal income, payroll employment, and manufacturing and trade sales
- F_t^H is a scalar latent dynamic factor representing housing market: common movements across regions
- F_t^{BC} is a scalar latent dynamic factor representing common movements in the coincident economic indicators associated with the business cycle
- z_{it} is a vector of idiosyncratic terms

The Baseline Model (cont.)

Latent factors follow autoregressive process

$$F_t^{H} = \mu_{St} + \phi^{H} F_{t-1}^{H} + \beta^{BC} F_{t-1}^{BC} + \upsilon_t^{H}$$

$$F_t^{BC} = \alpha_{St} + \phi^{BC} F_{t-1}^{BC} + \beta^{H} F_{t-1}^{H} + \upsilon_t^{BC}$$

- Linkages between the two sectors modeled through vector autoregressive process in the transition equations and the covariance structure of the factors.

- Each factor follows different Markov switching processes S_t^H and S_t^{BC} representing:

  Low and high price phases in the housing market

  $\mu_{St} = \mu_1 S_t^H + \mu_0 (1-S_t^H)$ $\mu_1 > 0$, $S_t^H = 0, 1$

  μ_{st} - mean growth rate of housing price in high (S_t^H=1) and low phases (S_t^H=0)

  Recessions and expansions phases

  $\alpha_{St} = \alpha_1 S_t^{BC} + \alpha_0 (1-S_t^{BC})$ $\alpha_1 > 0$, $S_t^{BC} = 0, 1$

  α_{st} - mean growth rate of business cycle in expansions (S_t^H=1) and recessions (S_t^{BC}=0)

with transition probabilities

$P[s_t^H = 0 \mid s_{t-1}^H = 0] = q^H$ $P[s_t^H = 1 \mid s_{t-1}^H = 1] = p^H$

$P[s_t^{BC} = 0 \mid s_{t-1}^{BC} = 0] = q^{BC}$ $P[s_t^{BC} = 1 \mid s_{t-1}^{BC} = 1] = p^{BC}$

- No a priori restriction is imposed on the relationship between S_t^H and S_t^{BC}

The Data

- Quarterly frequency: 1963q3 to 2007q4

- Economic indicators: Industrial Production (FRED®), manufacturing and trade sales (BEA), nonagricultural payroll (BLS), real personal income less transfer payments (BEA)

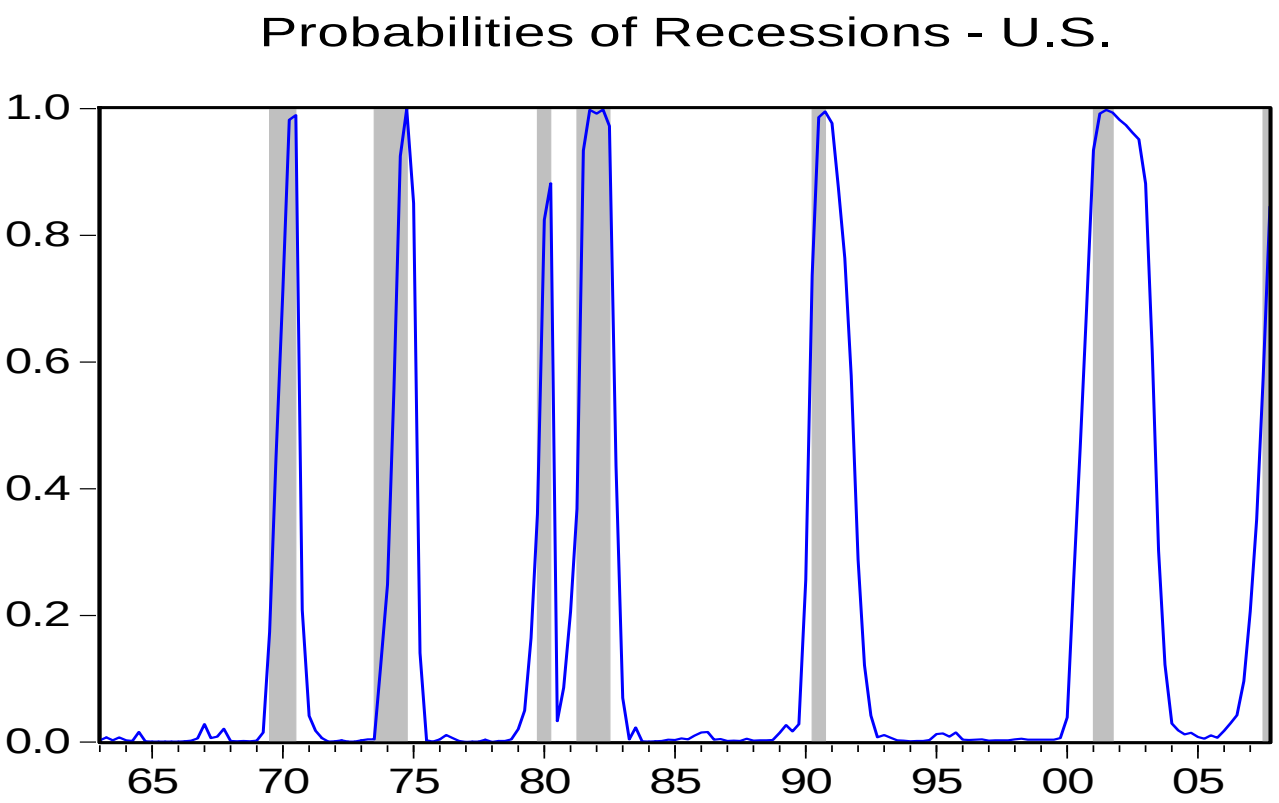
- Housing market: Median sales price of houses sold by region - West, Northeast, Midwest, and South. Source: Census Bureau
  - Deflated using CPI (Consumer Price Index for All Urban Consumers: All Items Less Food & Energy - BLS)

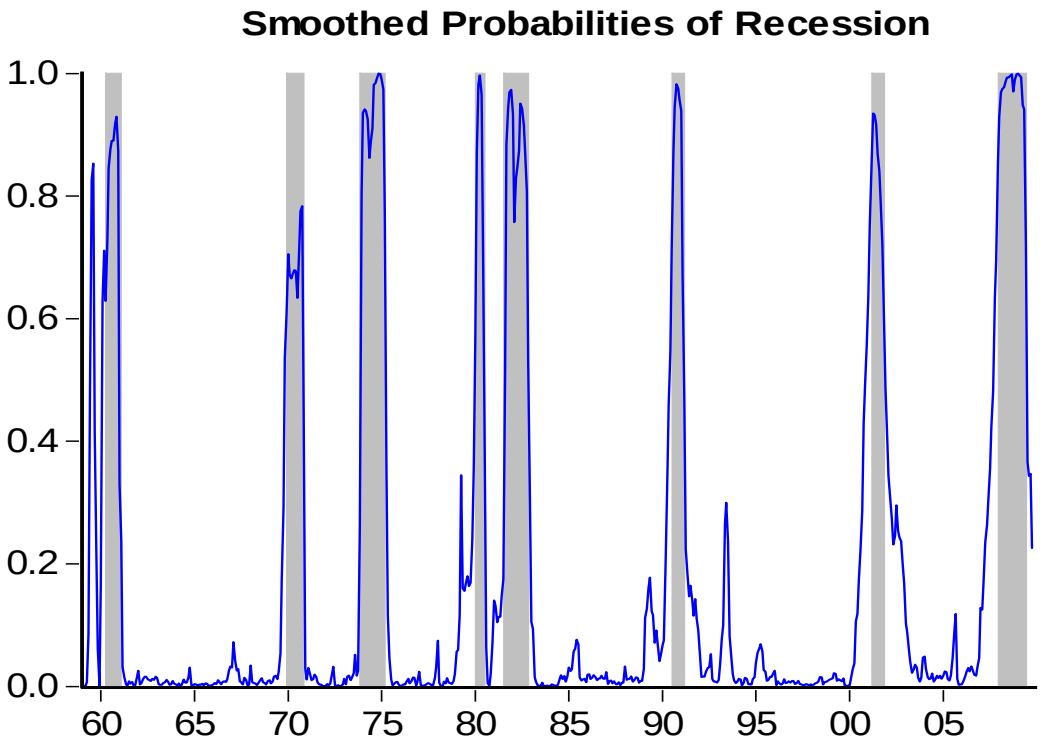
- Effective Federal Funds Rate (1963:1 on) and 30-Year Conventional Mortgage Rate (1971:2 on). Source: Board of Governors of the Federal Reserve System

Results – Business Cycles

- Smoothed probabilities of recession closely match NBER-dated recessions.
- However, the 1990-1991 and especially the 2001 recessions were followed by slow recovery – probabilities of recession remained high
- Recovery after 2001 recession sluggish due to payroll employment: "jobless recovery"
- Probability of recession did not remain high during the recovery when other measures of employment are used. However, payroll is the series used by the NBER to date recessions.
  - Uncertainty in real time regarding the true state of the economy – NBER announced that the recession ended in November 2001 only in July 2003 (around 1 ½ years after the fact).

U.S. Business Cycles




Smoothed Probabilities of Recession
1.0
0.8
0.6
0.4
0.2
0.0
60
65
70
75
80
85
90
95
00
05

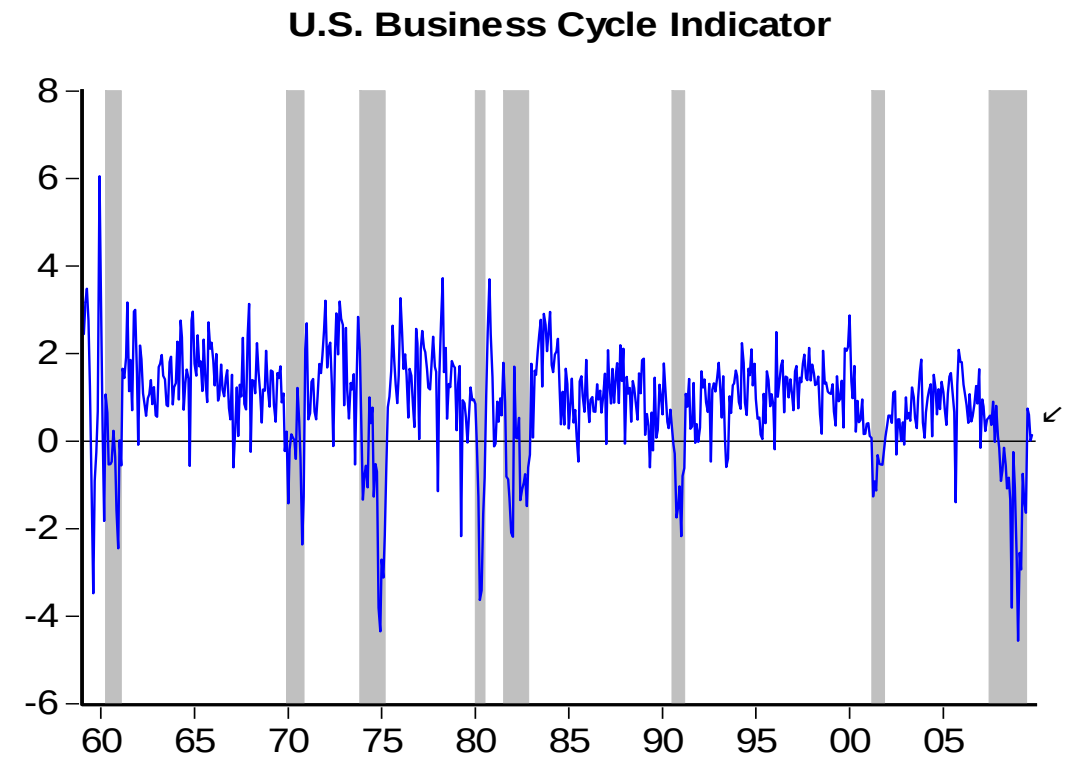
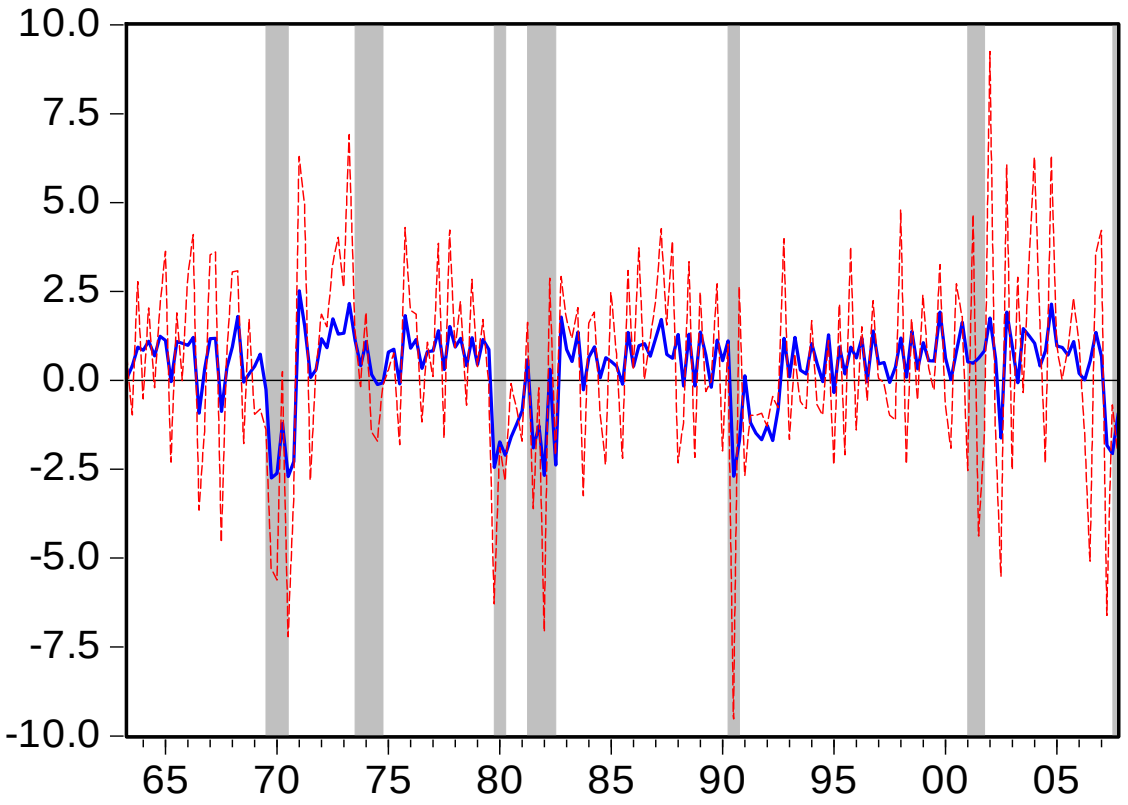

U.S. Business Cycle Indicator
8
6
4
2
0
-2
-4
-6
60
65
70
75
80
85
90
95
00
05

Table 1: Maximum Likelihood Estimates – Basic Model

Parameters	Business Cycle	Parameters	Housing Cycle
μ_1^{BC}	1.50 (0.20)	μ_1^{H}	3.52 (1.06)
μ_0^{BC}	-0.54 (0.16)	μ_0^{H}	-2.47 (0.79)
p_{11}^{BC}	0.93 (0.01)	p_{11}^{H}	0.97 (0.02)
p_{00}^{BC}	0.78 (0.03)	p_{00}^{H}	0.88 (0.06)
$\sigma^2_{\eta_{BC}}$	1.43 (0.21)	$\sigma^2_{\eta_H}$	1.19 (0.18)
ϕ^{BC}	0.46 (0.05)	ϕ^{H}	-0.28 (0.16)
$\lambda_{Production}$	1	$\lambda_{Northeast}$	1
λ_{Income}	0.56 (0.02)	λ_{West}	1.60 (0.50)
λ_{Sales}	0.78 (0.03)	$\lambda_{Midwest}$	1.41 (0.43)
$\lambda_{Employment}$	0.41 (0.02)	λ_{South}	1.26 (0.36)
$\sigma^2_{v,Production}$	0.32 (0.02)	$\sigma^2_{v,Northeast}$	36.92 (3.93)
$\sigma^2_{v,Income}$	0.11 (0.01)	$\sigma^2_{v,West}$	8.85 (1.30)
$\sigma^2_{v,Sales}$	0.78 (0.05)	$\sigma^2_{v,Midwest}$	23.09 (2.60)
$\sigma^2_{v,Employment}$	0.13 (0.01)	$\sigma^2_{v,South}$	8.21 (1.05)
β^{H}	0.16 (0.07)	β^{BC}	0.17 (0.05)
$\psi_{Production}$	0.17 (0.05)	$\psi_{Northeast}$	-0.37 (0.07)
ψ_{Income}	0.16 (0.04)	ψ_{West}	-0.40 (0.08)
ψ_{Sales}	-0.24 (0.04)	$\psi_{Midwest}$	0.43 (0.07)
$\psi_{Employment}$	-0.49 (0.08)	ψ_{South}	-0.32 (0.08)
$\sigma_{BC,SM}$	0.40 (0.16)		
Log L	-3470.22		

Asymptotic standard errors in parentheses

Results - Housing Market Cycle



Housing Factor (—), U.S. Median Price of Houses Sold (---), and NBER Recessions (Shaded Area)

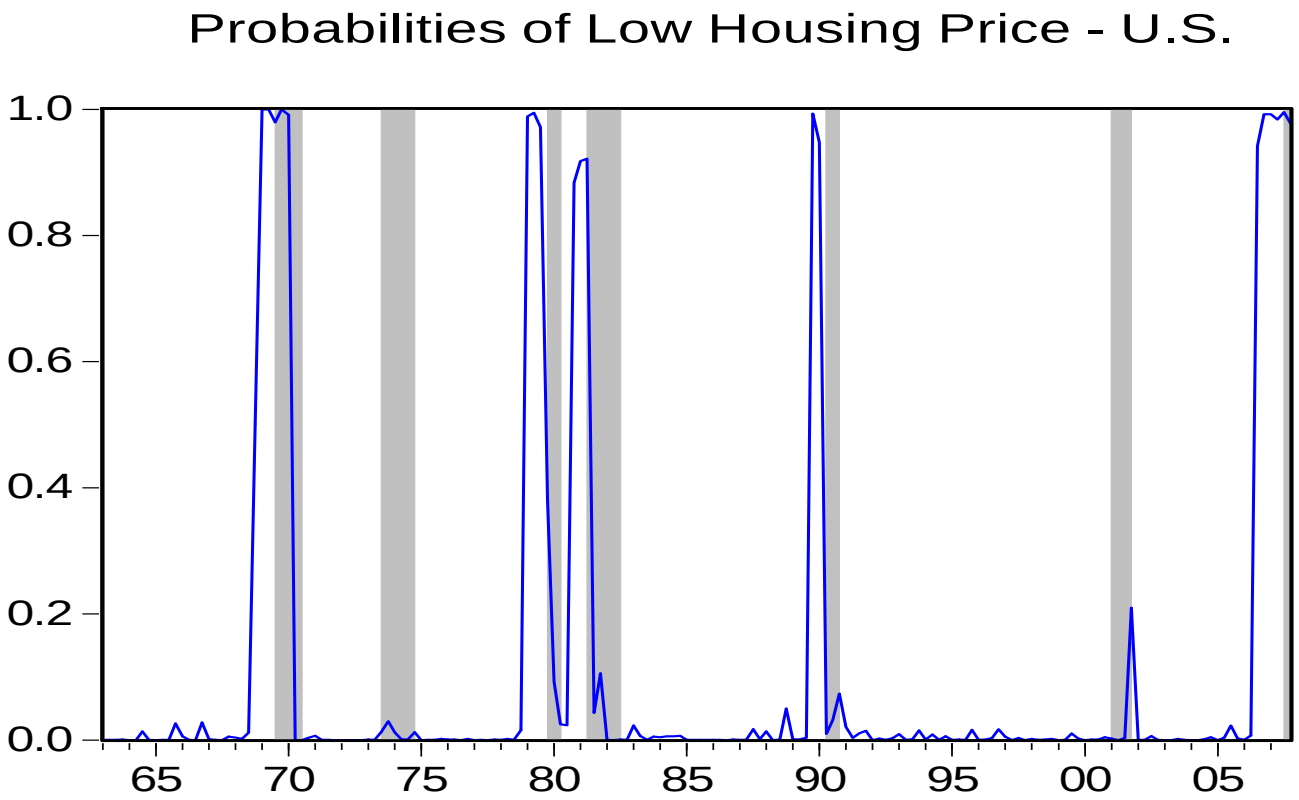
Housing Market Cycles

- Probabilities of low housing market phase did not increase during the 1974-1975 and 2001 recessions

- Housing market did not exhibit regular cycle around these recessions

  - Variables measuring housing supply, housing demand, and prices did not fall very much during the 2001 recession (prices, housing starts, house completion, ownership rate, etc.)

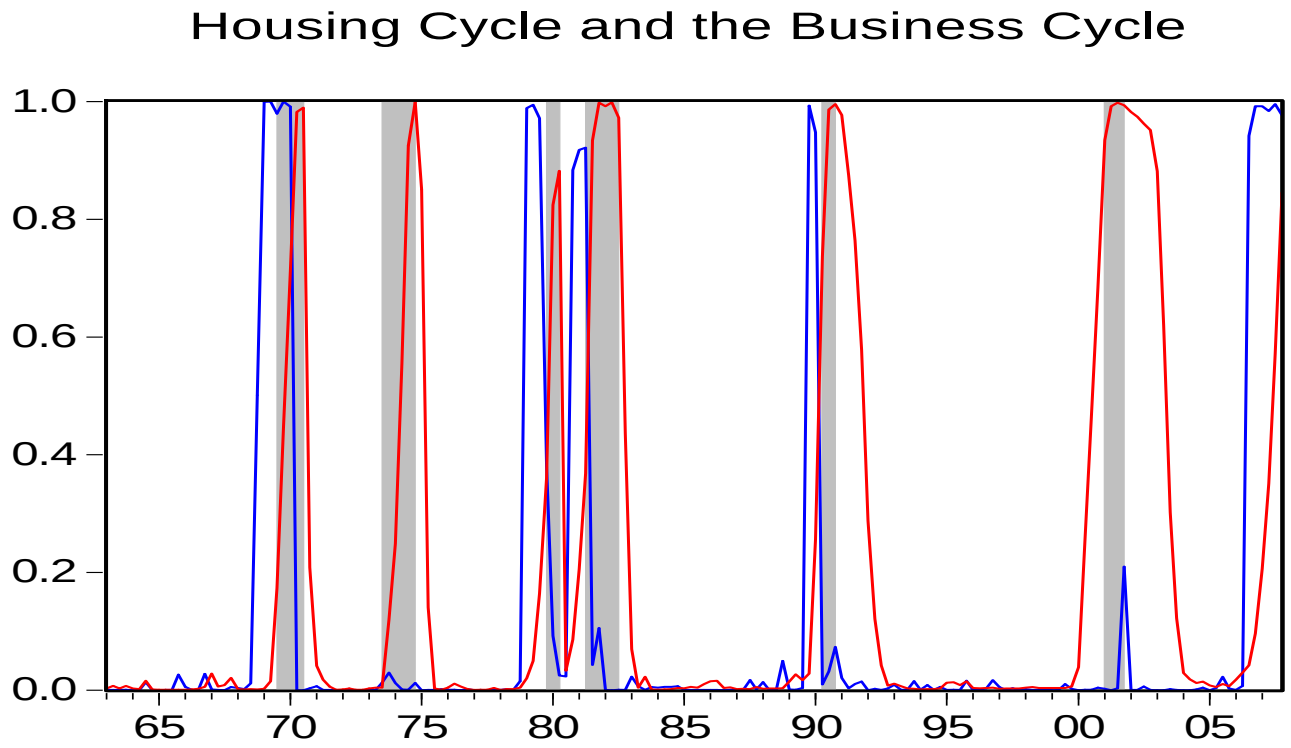
U.S. Housing Market Cycles



Results – Housing Market Cycles

- Smoothed probabilities of low housing price closely associated with NBER-dated recessions with a lead
  - average of 2 quarters for peaks
- Estimated correlation parameter between house market factor and business cycle factor around 40% for full sample
- $\beta^{BC} > 0$ $F_{t-1}^{BC} \rightarrow F_t^{H}$
- $\beta^{H} > 0$ $F_{t-1}^{H} \rightarrow F_t^{BC}$
- Coefficients only capture linear average behavior. Around beginning and end of recessions $\beta^{BC} < 0$

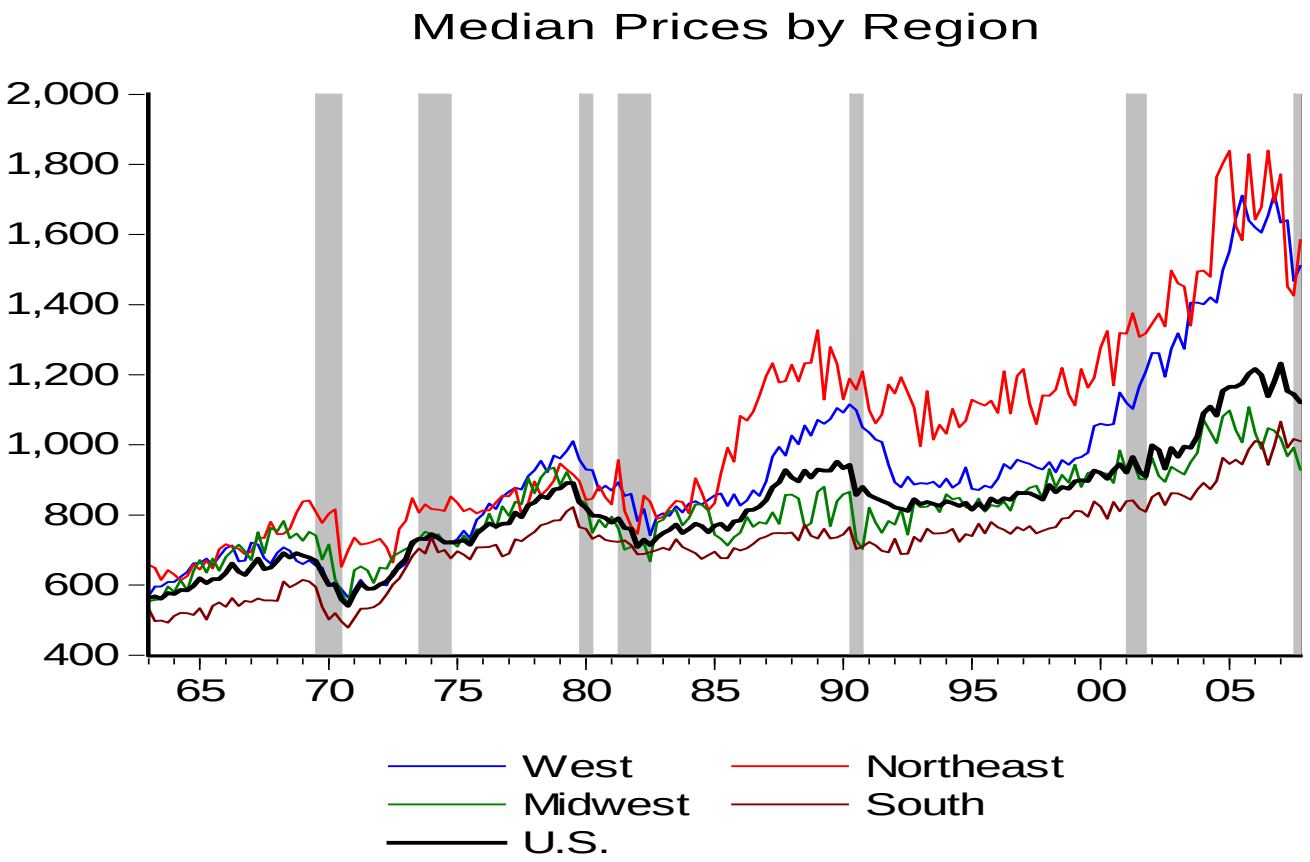
Housing Market and the Business Cycle



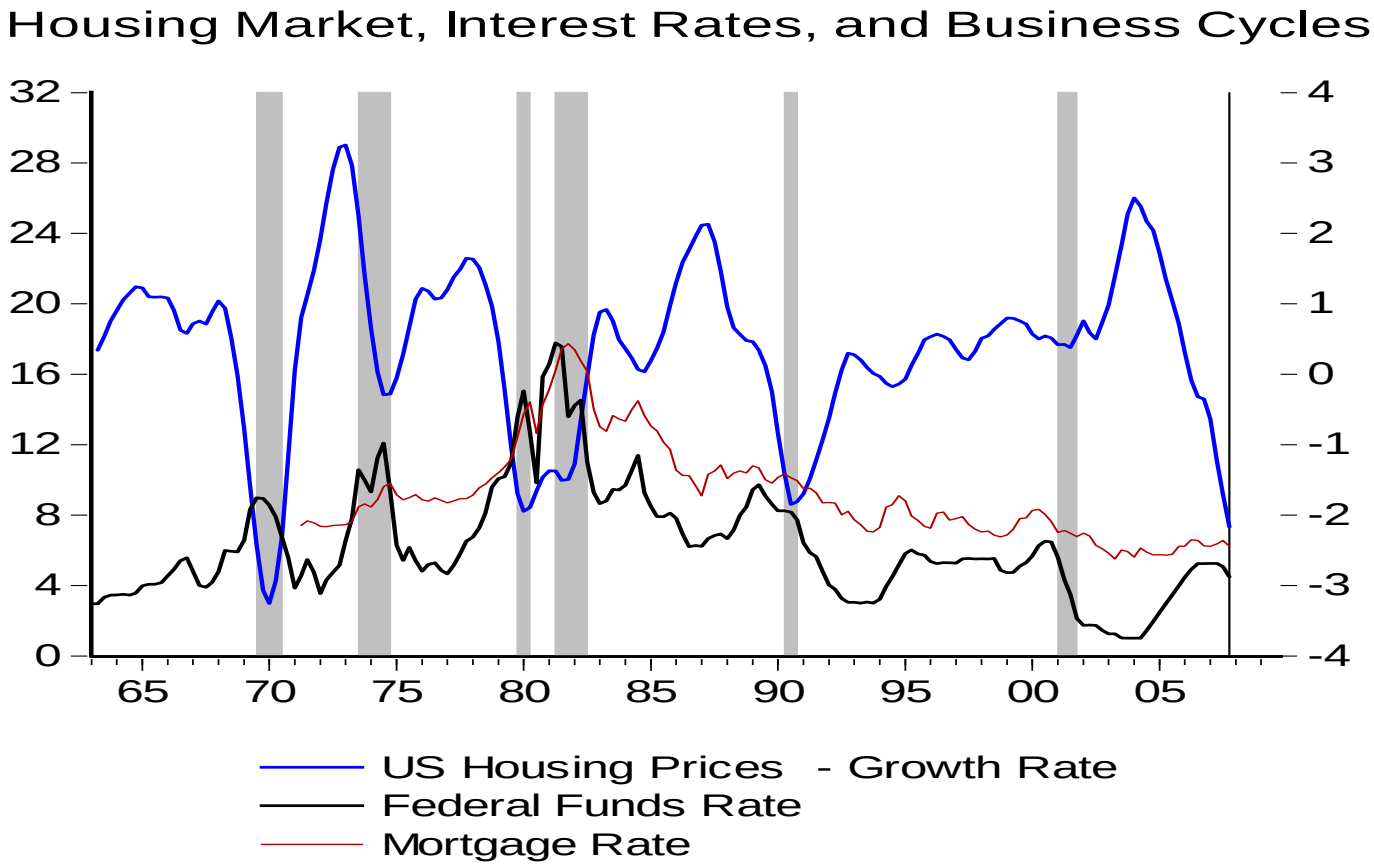
Housing Market During the 2001 Recession

- Relationship between housing market and business cycle:
  - Missed link between housing cycle and the business cycle in the early 2000s
  - Continuous increase from mid-1990 to 2006, especially between 2002-2004.
  - In the West and Northeast there was a steeper increase in housing prices even during the 2001 recession. U.S. prices, ownership, house completion, and housing starts had steep increase from 2002 on.

Housing Market During the 2001 Recession



Link between Housing Market and the Business Cycle



Housing Market and Interest Rates

- Inverse relation with the level and changes in interest rates
- Interest rates movements lead housing market cycle
  - Increases in interest rates are related to subsequent decreases in house prices and housing starts
  - Increases in interest rates are related to subsequent decreases in economic activity
- Common element in 1974-75 and 2001 recessions: relatively low level of mortgage rates compared to historical record.

Augmented Model

$$Y_{it} = \lambda_i F_t^H + \gamma_i F_t^{BC} + z_{it}$$

$$Z_{it} = \Psi_i z_{it-1} + \varepsilon_{it} \qquad \varepsilon_{it} \sim \text{i.i.d. } N(0,\sigma_i^2)$$

$$F_t^H = \mu_{St} + \phi^H F_{t-1}^H + \beta^{BC} F_{t-1}^{BC} + \varphi_{St}^{H*} r_{t-1} + \upsilon_t^H$$

$$F_t^{BC} = \alpha_{St} + \phi^{BC} F_{t-1}^{BC} + \beta^H F_{t-1}^H + \varphi_{St}^{BC*} r_{t-1} + \upsilon_t^{BC}$$

- where r_t is the Federal Funds Rate. **Now, linkages also through their relationship with interest rates**.

- Interest rates coefficients follow independent Markov switching processes:

$$\varphi_{St}^{H*} = \varphi_1^{H*} S_t^{H*} + \varphi_0^{H*} (1-S_t^{H*}) \qquad \varphi_1^{H*} > 0,\ S_t^{H*} = 0,1$$

$$\varphi_{St}^{BC*} = \varphi_1^{BC} S_t^{BC*} + \varphi_0^{BC*} (1-S_t^{BC*}) \qquad \varphi_1^{BC*} > 0,\ S_t^{BC*} = 0,1$$

with transition probabilities:

$$P[S_t^{H*} = 0 \mid S_{t-1}^{H*} = 0] = q^{H*} \qquad P[S_t^{H*} = 1 \mid S_{t-1}^{H*} = 1] = p^{H*}$$

$$P[S_t^{BC*} = 0 \mid S_{t-1}^{BC*} = 0] = q^{BC*} \qquad P[S_t^{BC*} = 1 \mid S_{t-1}^{BC*} = 1] = p^{BC*}$$

Table 2: Maximum Likelihood Estimates – Augmented Model with Interest Rates

Parameters	Business Cycle	Parameters	Housing Cycle
μ_1^{BC}	1.48 (0.20)	μ_1^{H}	3.64 (1.04)
μ_0^{BC}	-0.53 (0.16)	μ_0^{H}	-2.45 (0.76)
p_{11}^{BC}	0.92 (0.01)	p_{11}^{H}	0.96 (0.02)
p_{00}^{BC}	0.78 (0.03)	p_{00}^{H}	0.89 (0.05)
$\sigma^2_{\eta_{BC}}$	1.41 (0.21)	$\sigma^2_{\eta_H}$	1.16 (0.16)
ϕ^{BC}	0.45 (0.05)	ϕ^{H}	-0.27 (0.15)
$\lambda_{Production}$	1	$\lambda_{Northeast}$	1
λ_{Income}	0.54 (0.02)	λ_{West}	1.61 (0.51)
λ_{Sales}	0.79 (0.03)	$\lambda_{Midwest}$	1.39 (0.41)
$\lambda_{Employment}$	0.42 (0.02)	λ_{South}	1.31 (0.34)
$\sigma^2_{v,Production}$	0.35 (0.02)	$\sigma^2_{v,Northeast}$	37.26 (3.91)
$\sigma^2_{v,Income}$	0.11 (0.01)	$\sigma^2_{v,West}$	8.17 (1.31)
$\sigma^2_{v,Sales}$	0.77 (0.05)	$\sigma^2_{v,Midwest}$	23.42 (2.58)
$\sigma^2_{v,Employment}$	0.12 (0.01)	$\sigma^2_{v,South}$	8.23 (1.10)
β^{H}	0.15 (0.06)	β^{BC}	0.14 (0.02)
$\psi_{Production}$	0.16 (0.05)	$\psi_{Northeast}$	-0.38 (0.06)
φ^{BC}	-0.08 (0.02)	φ^{H}	-0.09 (0.03)
ψ_{Income}	0.16 (0.04)	ψ_{West}	-0.41 (0.08)
ψ_{Sales}	-0.21 (0.04)	$\psi_{Midwest}$	0.43 (0.06)
$\psi_{Employment}$	-0.53 (0.08)	ψ_{South}	-0.31 (0.08)
$\sigma_{BC,SM}$	0.41 (0.16)		
Log L	-3412.98		

Table 3: Maximum Likelihood Estimates – Augmented Model with Markov Switching in the Interest Rates Coefficients

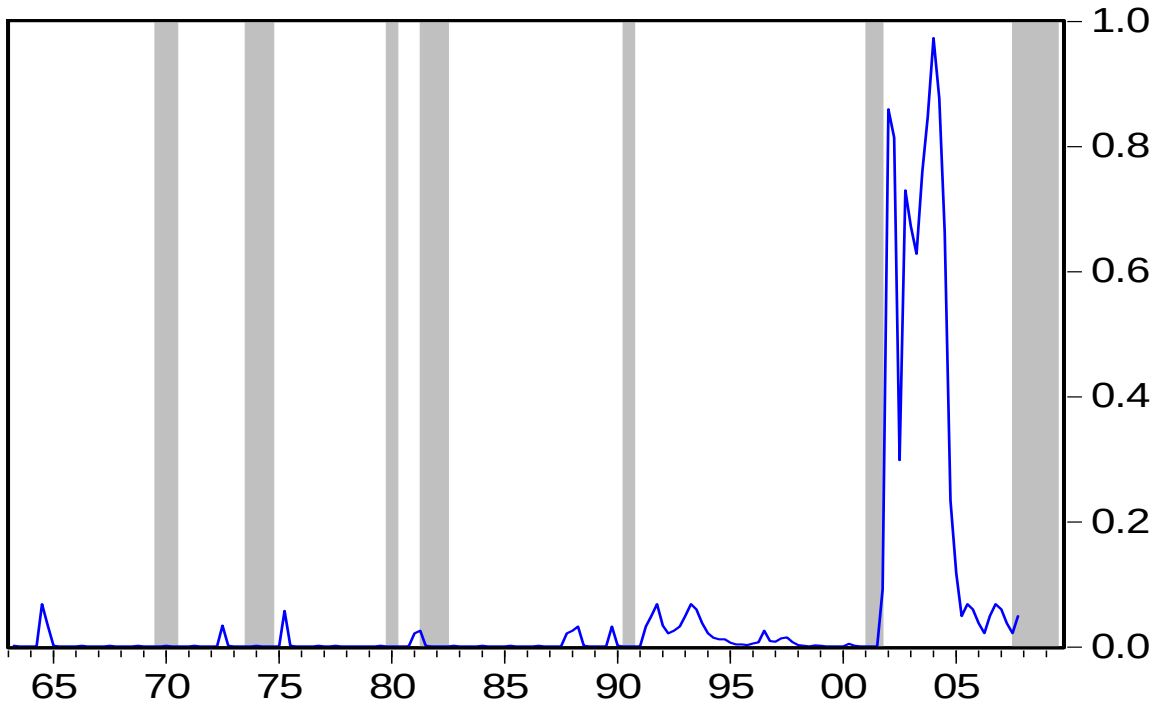
Parameters	Business Cycle	Parameters	Housing Cycle
μ_1^{BC}	1.46 (0.19)	μ_1^{H}	3.56 (1.01)
μ_0^{BC}	-0.52 (0.15)	μ_0^{H}	-2.42 (0.72)
p_{11}^{BC}	0.92 (0.01)	p_{11}^{H}	0.95 (0.02)
p_{00}^{BC}	0.79 (0.03)	p_{00}^{H}	0.88 (0.05)
$\sigma^2_{\eta_{BC}}$	1.42 (0.20)	$\sigma^2_{\eta_H}$	1.16 (0.14)
ϕ^{BC}	0.43 (0.04)	ϕ^{H}	-0.28 (0.14)
$\lambda_{Production}$	1	$\lambda_{Northeast}$	1
λ_{Income}	0.53 (0.02)	λ_{West}	1.63 (0.49)
λ_{Sales}	0.81 (0.03)	$\lambda_{Midwest}$	1.36 (0.41)
$\lambda_{Employment}$	0.45 (0.02)	λ_{South}	1.33 (0.33)
$\sigma^2_{v,Production}$	0.32 (0.02)	$\sigma^2_{v,Northeast}$	38.14 (3.92)
$\sigma^2_{v,Income}$	0.13 (0.01)	$\sigma^2_{v,West}$	8.12 (1.31)
$\sigma^2_{v,Sales}$	0.78 (0.04)	$\sigma^2_{v,Midwest}$	22.37 (2.56)
$\sigma^2_{v,Employment}$	0.11 (0.01)	$\sigma^2_{v,South}$	8.01 (1.12)
β^{H}	0.14 (0.05)	β^{BC}	0.12 (0.02)
$\psi_{Production}$	0.18 (0.05)	$\psi_{Northeast}$	-0.36 (0.05)
φ_1^{BC} *(pre-2002)*	-0.08 (0.02)	φ_1^{H} *(2001 on)*	-0.18 (0.08)
φ_0^{BC} *(2002 on)*	-0.02 (0.01)	φ_0^{H} *(pre-2001)*	-0.09 (0.03)
ψ_{Income}	0.15 (0.03)	ψ_{West}	-0.42 (0.08)
ψ_{Sales}	-0.24 (0.04)	$\psi_{Midwest}$	0.41 (0.05)
$\psi_{Employment}$	-0.51 (0.08)	ψ_{South}	-0.35 (0.08)
$\sigma_{BC,SM}$	0.43 (0.15)		
Log L	-3368.62		

Asymptotic standard errors in parentheses

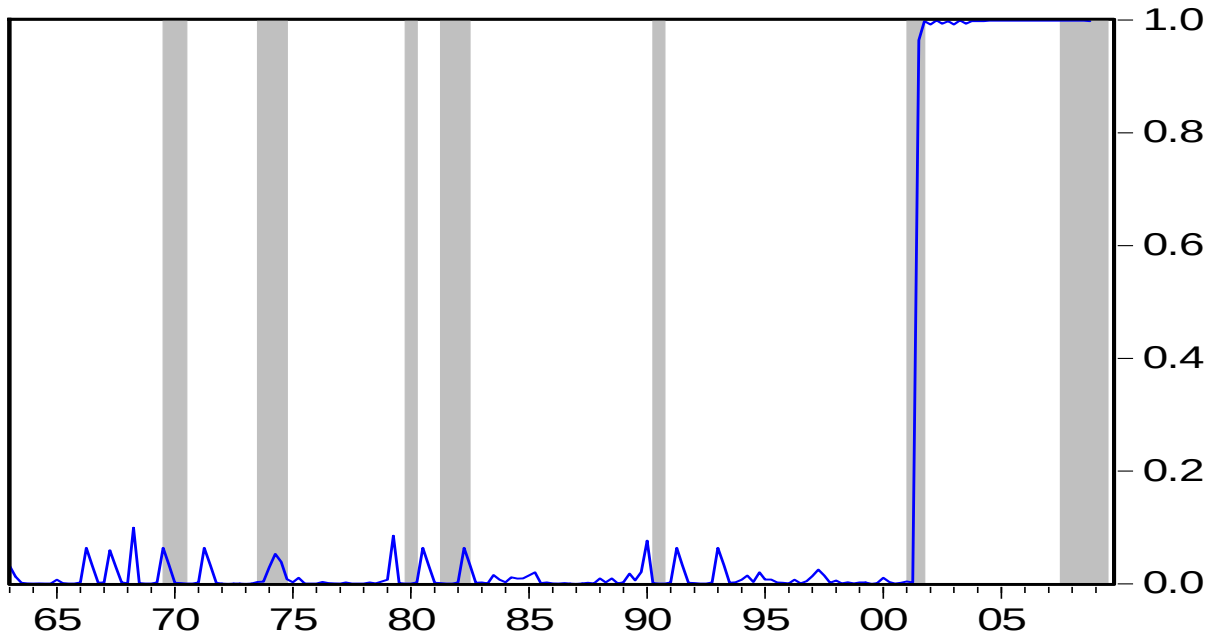
Link between Housing Cycle Factor and Business Cycle Factor

- Estimated interest rate coefficient in the transition equations for the housing factor and business cycle factor highly significant
- Subsample analysis for 1995-2007 shows substantially higher interest rate parameter in the housing factor transition equation and substantially lower interest rate parameter in the business cycle factor transition equation
- Smoothed probabilities for the coefficients show:
  - Weaken link between interest rates and the business cycle during this period
  - Stronger link between interest rate and housing cycle during this period

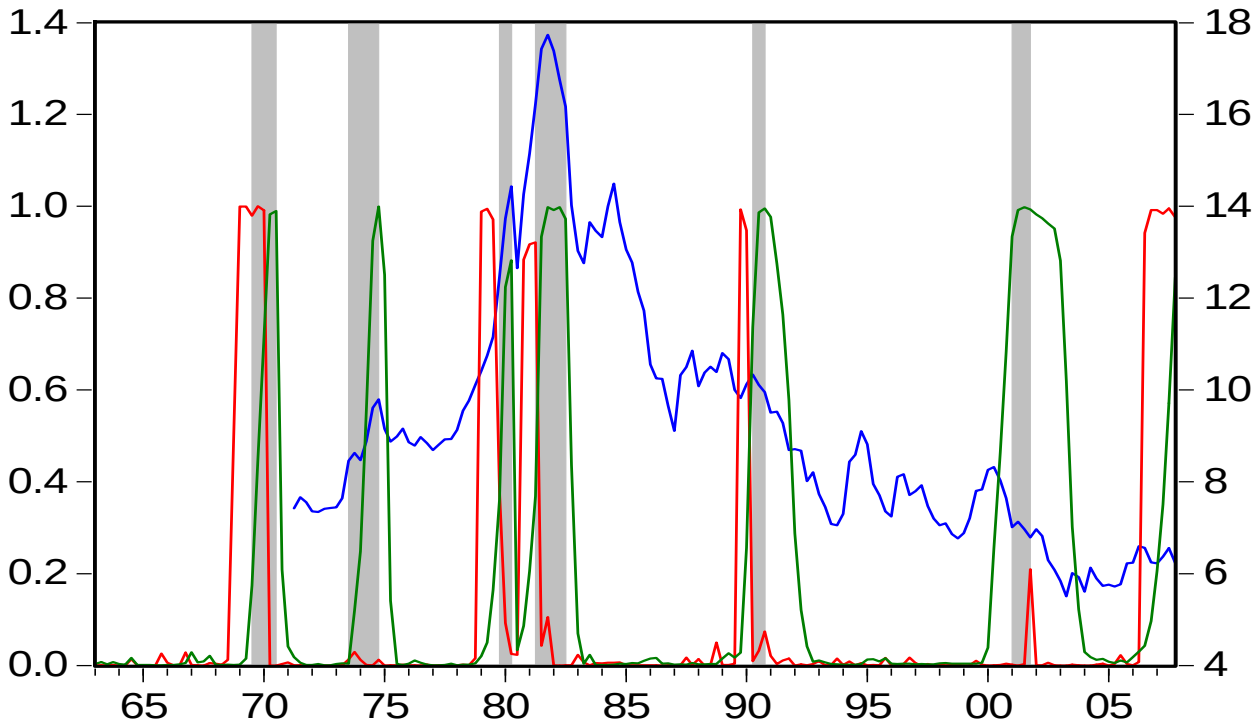
Probabilities of Low Interest Rate Coefficient
on Business Cycle Factor Equation



Probabilities of High Interest Rate Coefficient on Housing Market Factor Equation



Housing Cycle, Business Cycle, and Mortgage Rates



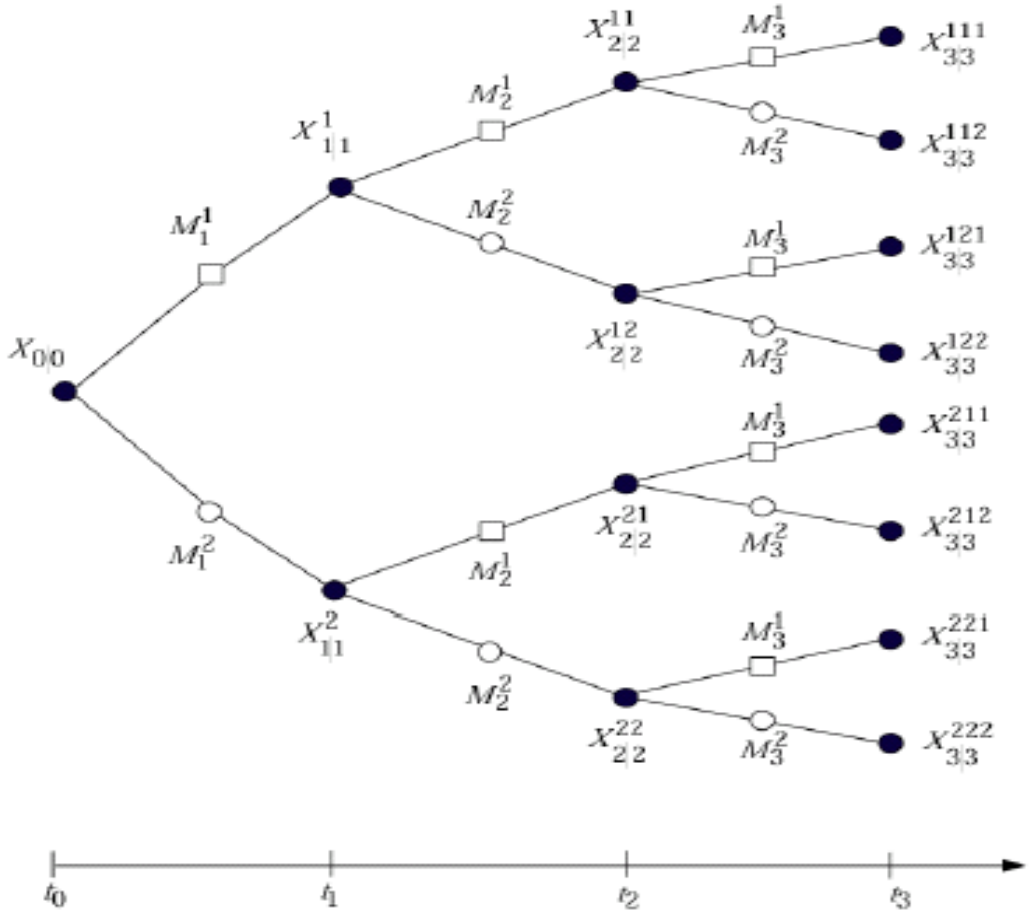
Housing Market, Interest Rates, and the 2001 Recession

- Linkage between business cycle factor and interest rate weakened during the 2001-2004 recovery.
- Low level of interest rates during this expansion period due to uncertainty regarding the end of 2001 recession
  - Slow recovery in 2002-2003 led the Fed to keep interest rates at lowest level
  - Mortgage rates at lowest levels
- Bubble: full recovery in the economy starting in 2003 with still low level of interest rates catalyzed abrupt increase in housing prices, housing starts, and ownership
- Bust: higher interest rates from mid 2004 on associated with subsequent drastic decreases in housing market in 2006-2007

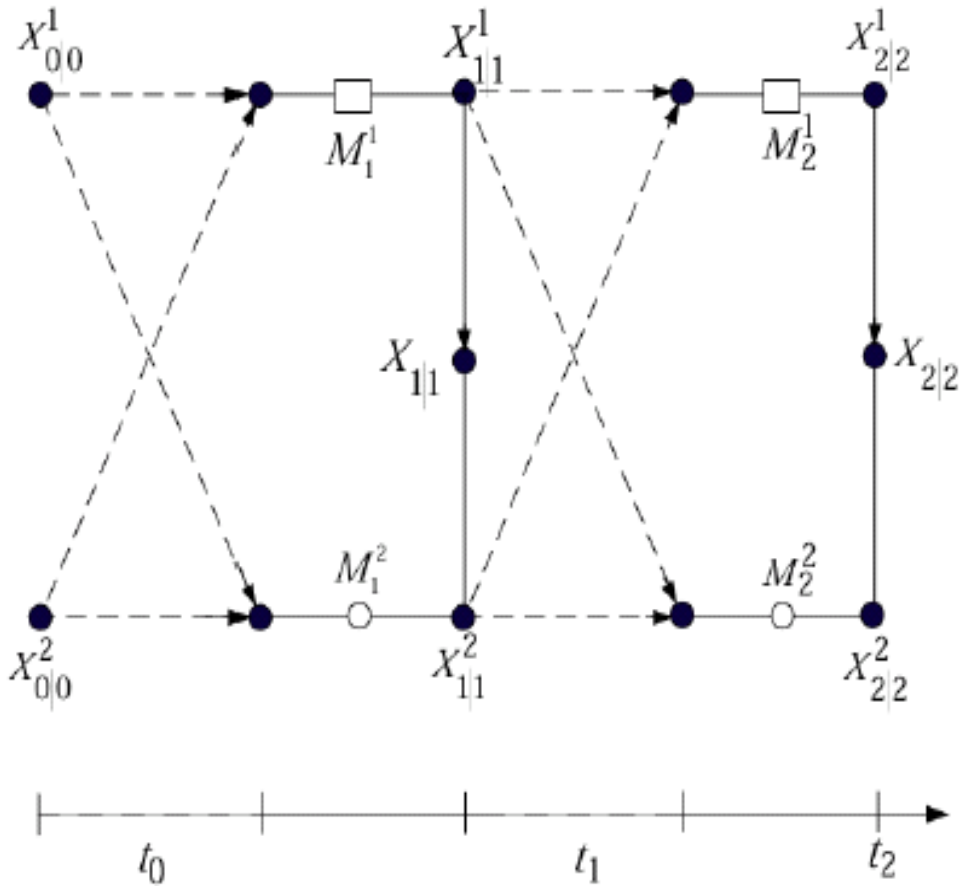
Conclusions

- Strong historical linkage between business cycles and housing market cycles
- Strong linkage between business cycle and interest rates, and housing market cycle and interest rates
- Relationship changed during the 2001 recession and subsequent recovery
- Missed link between 2001 recession and housing market cycle a seed to the subsequent housing market bubble and bust

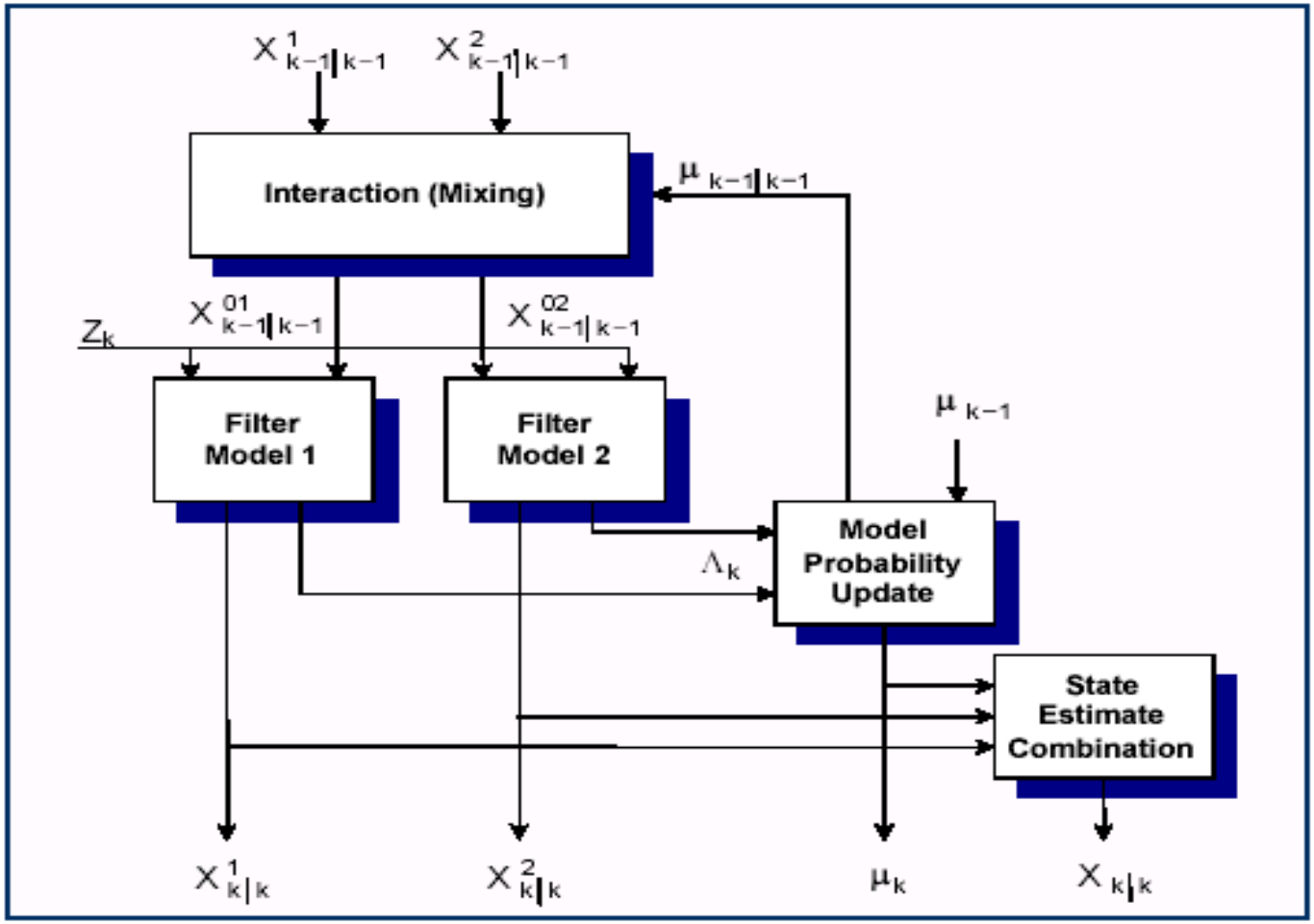
Hypothesis Management



Hypothesis Management of the Algorithm



Algorithm with Two Models



FILTER – STEP 1

- Step 1. Mixing of State Estimates
- Starting with $X^{j}_{k-1|k-1}$ Mixed estimate for the filter matched to M^{i}_{t}

$$X^{0i}_{k-1|k-1} = \sum_{j=1}^{r} X^{j}_{k-1|k-1} \mu^{j|i}_{k-1|k-1}$$

where $\mu^{j|i}_{k-1|k-1}$ is computed as

$$\mu^{j|i}_{k-1|k-1} = \frac{\mu^{j}_{k-1} p_{ji}}{\mu^{i}_{k-1|k-1}} \qquad \mu^{i}_{k-1|k-1} = \sum_{j=1}^{r} \mu^{j}_{t-1} p_{ji}$$

- The covariance is given by

$$P^{0i}_{k-1|k-1} = \sum_{j=1}^{r} \mu^{j|i}_{k-1|k-1} [P^{j}_{k-1|k-1} + (X^{j}_{k-1|k-1} - X^{0i}_{k-1|k-1})(X^{j}_{k-1|k-1} - X^{0i}_{k-1|k-1})^{T}]$$

FILTER – STEP 2

Step 2: Model Conditioned Updates

The r filters implementing the Kalman filtering equations are used to perform the model updates associated with the r models. Let $F_k^j = F_k(\theta_{k+1} = j), G_k^j = G_k(\theta_{k+1} = j)$ and $H_k^j = H_k(\theta_k = j)$

Then, for M_k^i with input $X_{k-1|k-1}^{0i}$ and $P_{k-1|k-1}^{0i}$,

$$X_{k|k-1}^i = F_{k-1}^i \, X_{k-1|k-1}^{0i}$$

$$P_{k|k-1}^i = F_{k-1}^i \, P_{k-1|k-1}^{0i} \left(F_{k-1}^i\right)^T + G_{k-1}^i \, Q_{k-1}^i \left(G_{k-1}^i\right)^T$$

$$S_k^i = H_k^i \, P_{k|k-1}^i \left(H_k^i\right)^T + R_k$$

$$K_k^i = P_{k|k-1}^i \left(H_k^i\right)^T \left(S_k^i\right)^{-1}$$

$$\tilde{Z}_k^i = Z_k - H_k^i X_{k|k-1}^i$$

$$X_{k|k}^i = X_{k|k-1}^i + K_k^i \left[\tilde{Z}_k^i\right]$$

$$P_{k|k}^i = \left[I - K_k^i H_k^i\right] P_{k|k-1}^i$$

FILTER – STEP 3

Step 3. Model Likelihood Computations

Likelihood corresponding to the r filters are computed as

$$\Lambda_t^i = f[Z_t | M_t^i, Z^{t-1}] = f[Z_t | M_t^i, X_{t-1|t-1}^{0i}, P_{t-1|t-1}^{0i}]$$

$$= f[Z_t | X_{t|t-1}^i, P_{t|t-1}^i]$$

The likelihood of M_t^i is computed with filters residuals $\tilde{Z}_t^i$, the covariance of the residuals S_t^i, and the assumption of Gaussian statistics. The likelihood of M_t^i is given by

$$\Lambda_t^i = \frac{1}{\sqrt{|2\pi\, S_t^i|}} \exp[\, -0.5 (\tilde{Z}_t^i)^T (S_t^i)^{-1} \tilde{Z}_t^i]$$

FILTER – STEP 4

Step 4: Model Probabilities Update

The Model Probabilities for output are computed as follows

$$\mu_t^i = P[M_t^i \mid Z_t, Z^{t-1}] = \frac{P\{M_t^i \mid Z_t, Z^{t-1}\}}{f[Z_t \mid Z^{t-1}]} = \frac{f[Z_t \mid M_t^i, Z^{t-1}]}{f[Z_t \mid Z^{t-1}]} P\{M_t^i \mid Z^{t-1}\}$$

$$= \frac{\Lambda_t^i}{c} \mu_{t-1|t-1}^i$$

where

$$c = \sum_{j=1}^{r} \Lambda_t^j \mu_{t-1|t-1}^j$$

FILTER – STEP 5

Step 5: Combination of State Estimates

For output only, the state estimate is computed according to

$$X_{t|t} = \sum_{i=1}^{r} X_{t|t}^{i} \mu_{t}^{i}$$

$$\sum_{j=1}^{r} \Lambda_{t}^{j} \mu_{t-1|t-1}^{j}$$

The output covariance is given by

$$P_{t|t} = \sum_{i=1}^{r} \mu_{t}^{i} [P_{t|t}^{j} + (X_{t|t}^{i} - X_{t|t})(X_{t|t}^{i} - X_{t|t})^{T}]$$