Housing and the Business Cycle

Morris Davis and Jonathan Heathcote

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Motivation

- Need to distinguish between housing and non–housing investment

$\hookrightarrow$ produced using different technologies

$\hookrightarrow$ different rates of depreciation

$\hookrightarrow$ housing yields "home production" services not in National Accounts

- "Stylized facts" for models with heterogeneous capital goods:

(1) comovement between consumption and investment in different assets

(2) residential investment is 2x as volatile as business investment

(3) residential investment leads cycle, business investment lags it

Model Overview

Households — consume goods and housing services, supply land and labour

↑

Real estate developers — combine land and structures to build houses

↑

Two final goods sector — one produces structures; the other C and K

↑

Three intermediate sectors — construction, manufacturing and services

↑

Labour, capital and productivity shocks

Main Findings

- Purely neoclassical model can account for "puzzles" (1) and (2), but not (3)
- Also matches facts on relative volatility of sub-sectors
- Implies pro-cyclical house prices, but not volatile enough
- Why positive comovement and high volatility?

$\hookrightarrow$ not due to correlated shocks

$\hookrightarrow$ final goods sectors use all intermediates

$\hookrightarrow$ housing requires land, which acts like an adjustment cost

$\hookrightarrow$ residential investment is relatively labour intensive

$\hookrightarrow$ low depreciation of housing

Population

- Gross population growth: $\eta > 1$
- All variables in per capita terms

Intermediate sectors

- Intermediate firms' output:

$$x_{it} = k_{it}^{\theta_i} \left(z_{it} n_{it} \right)^{1-\theta_i} \qquad i \in \{b, m, s\}$$

$\hookrightarrow$ rent capital at rate r_t and hire labour at w_t

$\hookrightarrow$ output prices p_{it}

$\hookrightarrow$ productivity shocks:

$$\hat{\mathbf{z}}_{t+1} = \mathbf{B}\hat{\mathbf{z}}_t + \varepsilon_{t+1} \qquad \varepsilon_{t+1} \sim \mathbf{N}(\mathbf{0}, \mathbf{V})$$

where

$$\begin{aligned} \hat{\mathbf{z}}_t &= \left[\ln \tilde{z}_{bt}, \ln \tilde{z}_{mt}, \ln \tilde{z}_{st} \right]' \\ \ln \tilde{z}_{it} &= \ln z_{it} - t \ln g_{zi} - \ln z_{i0} \end{aligned}$$

Final goods sectors

- Final goods' output:

$$y_{jt} = b_{jt}^{B_j} m_{jt}^{M_j} s_{jt}^{S_j} \qquad j \in \{c, d\}, \quad S_j = 1 - B_j - M_j$$

$\hookrightarrow$ output prices, $p_{ct} = 1$ (numeraire) and p_{dt} = relative price of residential investment

Land and real estate

- Each household sells one unit of land each period
- Developers combine new residential structures, x_d, and new land, x_l, to build houses:

$$y_{ht} = x_{lt}^{\phi} x_{dt}^{1-\phi}$$

- Structures depreciate at rate δ_s
- Total stock of "effective" housing:

$$\eta h_{t+1} = x_{dt}^{1-\phi} x_{lt}^{\phi} + (1 - \delta_s)^{1-\phi} h_t$$

- Let

$$1 - \delta_h = (1 - \delta_s)^{1-\phi}$$

Households

- Optimization problem:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \eta^t U(c_t, h_t, n_t) \quad \text{s.t.}$$

$$\begin{aligned} c_t + \eta k_{t+1} + \eta p_{ht} h_{t+1} &= (1-\tau_n) w_t n_t + [1 - (1-\tau_k)(r_t - \delta_k)] k_t \\ &\quad + (1-\delta_h) p_{ht} h_t + p_{lt} x_{lt} + \xi_t \end{aligned}$$

where

$$U(c_t, h_t, n_t) = \frac{1}{1-\sigma} \left(c_t^{\mu_c} h_t^{\mu_h} (1-n_t)^{1-\mu_c-\mu_h} \right)^{1-\sigma}$$

- First–order conditions:

$$
\begin{aligned}
U_c(t) &= -U_n(t)(1-\tau_n)w_t \\
U_c(t) &= \beta E_t \left[U_c(t+1) \left(1 - (1-\tau_k)(r_{t+1} - \delta_k)\right)\right] \\
U_c(t) p_{ht} &= \beta E_t \left[U_c(t+1) (1-\delta_h) p_{ht+1} + U_h(t+1) \right]
\end{aligned}
$$

where

$$
\begin{aligned}
U_c(t) &= \mu_c c_t^{-1} \left(c_t^{\mu_c} h_t^{\mu_h} (1-n_t)^{1-\mu_c-\mu_h} \right)^{1-\sigma} \\
U_n(t) &= -(1-\mu_c-\mu_h)(1-n_t)^{-1} \left(c_t^{\mu_c} h_t^{\mu_h} (1-n_t)^{1-\mu_c-\mu_h} \right)^{1-\sigma} \\
U_h(t) &= \mu_h h_t^{-1} \left(c_t^{\mu_c} h_t^{\mu_h} (1-n_t)^{1-\mu_c-\mu_h} \right)^{1-\sigma}
\end{aligned}
$$

Market Clearing Conditions

- Final goods and real estate

$$
\begin{aligned}
c_t + \eta k_{t+1} + g_t &= y_{ct} + (1 - \delta_k)\, k_t \\
\eta h_{t+1} &= y_{ht} + (1 - \delta_h)\, h_t \\
x_{dt} &= y_{dt} \\
x_{lt} &= 1
\end{aligned}
$$

- Intermediate goods

$$
\begin{aligned}
b_{ct} + b_{dt} &= x_{bt} \\
m_{ct} + m_{dt} &= x_{mt} \\
s_{ct} + s_{dt} &= x_{st}
\end{aligned}
$$

- Factor markets

$$
\begin{aligned}
k_{bt} + k_{mt} + k_{st} &= k_t \\
n_{bt} + n_{mt} + n_{st} &= n_t
\end{aligned}
$$

Government budget constraint:

$$\xi_t + g_t = \tau_n w_t n_t + \tau_k \left(r_t - \delta_k\right) k_t$$

Equilibrium prices

- Factor prices

$$\begin{aligned} r_t &= p_{it}\theta_i k_{it}^{\theta_i - 1}\left(z_{it} n_{it}\right)^{1-\theta_i} \qquad\qquad i \in \{b, m, s\} \\ w_t &= z_{it} p_{it}(1-\theta_i) k_{it}^{\theta_i}\left(z_{it} n_{it}\right)^{-\theta_i} \end{aligned}$$

- Prices of intermediates

$$\begin{aligned} p_{bt} &= B_c \frac{y_{ct}}{b_{ct}} = B_d \frac{p_{dt} y_{dt}}{b_{dt}} \\ p_{mt} &= M_c \frac{y_{ct}}{m_{ct}} = M_d \frac{p_{dt} y_{dt}}{m_{dt}} \\ p_{st} &= S_c \frac{y_{ct}}{s_{ct}} = S_d \frac{p_{dt} y_{dt}}{s_{dt}} \end{aligned}$$

- Prices of structures and land

$$\begin{aligned} p_{dt} &= (1-\phi)\frac{p_{ht} y_{ht}}{x_{dt}} \\ p_{lt} &= \phi \frac{p_{ht} y_{ht}}{x_{lt}} \end{aligned}$$

Implication for House prices

- Relative price of residential investment can be written as

$$\begin{aligned}\ln p_{dt} &= (B_c - B_d)(1-\theta_b)\ln z_{bt} + (M_c - M_d)(1-\theta_m)\ln z_{mt} \\ &\quad + (S_c - S_d)(1-\theta_s)\ln z_{st} + \text{other terms}\end{aligned}$$

$\hookrightarrow$ a positive shock in sector i will reduce p_{dt} if residential investment is relatively intensive in input i

$\Rightarrow$ implications for comovement

- Price of new housing

$$\ln p_{ht} = -\ln(1-\phi) + \phi \ln y_{dt} + \ln p_{dt}$$

Mapping between model and NIPA

- In NIPA private consumption includes imputed value for rents from owner–occupied housing:

$$PCE_t = c_t + q_t h_t$$

where

$$q_t = \frac{U_h(c_t, h_t, n_t)}{U_c(c_t, h_t, n_t)}$$

- In NIPA, raw land is not part of GDP $\Rightarrow$ should only include value of residential investment, not of new houses:

$$GDP_t = y_{ct} + p_{dt} y_{dt} + q_t h_t$$

- Real private consumption and GDP defined using balanced growth prices $\Rightarrow$ does not capture short-run price movements

Balanced Growth Path

- Although each sector has different growth rates, a BGP exists due to Cobb-Douglas assumptions

- All variables are made stationary by dividing by gross growth rate

$$\hat{x}_t = \frac{x_t}{g_x^t}$$

- Model is solved using Klein (2000)

Table 1: Growth Rates on Balanced Growth Path (growth rates gross, variables per-capita)

n_b, n_m, n_s, n, r	1
k_b, k_m, k_s, k, c, i_k, g, y_c, w	$g_k = \left[g_{zb}^{B_c(1-\theta_b)} g_{zm}^{M_c(1-\theta_m)} g_{zs}^{S_c(1-\theta_s)} \right]^{\frac{1}{1-B_c\theta_b - M_c\theta_m - S_c\theta_s}}$
b_c, b_h, x_b	$g_b = g_k^{\theta_b} g_{zb}^{1-\theta_b}$
m_c, m_h, x_m	$g_m = g_k^{\theta_m} g_{zm}^{1-\theta_m}$
s_c, s_h, x_s	$g_s = g_k^{\theta_s} g_{zs}^{1-\theta_s}$
x_d	$g_d = g_b^{B_h} g_m^{M_h} g_s^{S_h}$
x_l	$g_l = \eta^{-1}$
y_h, h	$g_h = g_l^{\phi} g_d^{1-\phi}$
$p_h y_h$, $p_d x_d$, $p_l x_l$, $p_b x_b$, $p_m x_m$, $p_s x_s$	g_k

Table 2: Tax Rates, Depreciation Rates, Adjustment Costs, Preference Parameters

	Davis Heathcote	*Grenwood Hercowitz (GH)*
Tax rate on capital income: τ_k	0.3788	0.50
Tax rate on labor income: τ_n	0.2892	0.25
Govt. cons. to GDP	0.179*[4]	0.0
Transfers to GDP	0.076*	
Depreciation rate for capital: δ_k	0.0557*	0.078
Depreciation rate for res. structures: δ_s	0.0157*	0.078
Land's share in new housing: φ	0.106	
Population growth rate: η	1.0167*	0.0
Discount factor: β	0.9512	0.96
Risk aversion: σ	2.00*	1.00
Consumption's share in utility: μ_c	0.3139	0.2600
Housing's share in utility: μ_h	0.0444	0.0962
Leisure's share in utility: $1-\mu_c-\mu_h$	0.6417	0.6438

[4] Starred parameter vales are chosen independently of the model.

Calibration

- Period is one year
- μ_c and μ_h chosen so that $\hat{n} = 0.3$ and value of stock of residential structures $=$ GDP
- τ_k and τ_n chosen so that non-residential capital stock $= 1.5$ x annual output and $\xi / GDP = 0.076$
- Shock processes estimated as VAR

$\hookrightarrow$ little evidence of spillovers — weak correlation of shocks

$\hookrightarrow$ shocks to construction and manufacturing much more volatile

- input shares based on input–output tables

Table 3: Production Technologies

	Con.	*Man.*	*Ser.*	*GH*
Input shares in cons/inv production B_c, M_c, S_c	0.0307	0.2696	0.6997	
Input shares in res. structures B_d, M_d, S_d	0.4697	0.2382	0.2921	
Capital's share by sector $\theta_b, \theta_m, \theta_s$	0.132	0.309	0.237	0.30
Trend productivity growth (%) g_{zb}, g_{zm}, g_{zs}	-0.27	2.85	1.65	1.00
Autocorrelation coefficient		see table 4		$\rho = 1.0$
Std. dev. innovations to logged productivity		see table 4		0.022

Table 4: Estimation of Exogenous Shock Process

System estimated: $\tilde{z}_{t+1} = B\tilde{z}_t + \varepsilon_{t+1}$

where $\tilde{z}_t = \begin{pmatrix} \log \tilde{z}_{bt} \\ \log \tilde{z}_{mt} \\ \log \tilde{z}_{st} \end{pmatrix}$, $\varepsilon_t = \begin{pmatrix} \varepsilon_{bt} \\ \varepsilon_{mt} \\ \varepsilon_{st} \end{pmatrix}$ and $\varepsilon_t \sim N(0,V)$.[5]

Autoregressive coefficients in matrix B
(Seemingly unrelated regression estimation method: standard errors in parentheses)

	$\log \tilde{z}_{b,t+1}$	$\log \tilde{z}_{m,t+1}$	$\log \tilde{z}_{s,t+1}$
$\log \tilde{z}_{bt}$	0.707 (0.089)	-0.006 (0.078)	0.003 (0.038)
$\log \tilde{z}_{mt}$	0.010 (0.083)	0.871 (0.073)	0.028 (0.036)
$\log \tilde{z}_{st}$	-0.093 (0.098)	-0.150 (0.087)	0.919 (0.042)
R^2	0.551	0.729	0.903

Correlations of innovations

	ε_b	ε_m	ε_s
ε_b	1	0.089	0.306
ε_m		1	0.578
ε_s			1

Standard deviation of innovations

ε_b	0.041
ε_m	0.036
ε_s	0.018

[5] All variables are linearly detrended prior to estimating this system.

Main Results

- Steady state implications look "reasonable"

- Second moments:

$\hookrightarrow$ accounts well for high relative volatility of residential investment
$\hookrightarrow$ yields comovement between investment sectors
$\hookrightarrow$ relative volatilities of sub-sectors is correct
$\hookrightarrow$ house price volatility is too low
$\hookrightarrow$ housing investment does not lead cycle

Table 5: Decomposition of Final Expenditure into Final Sales From Industries (%)
(based on 1992 IO-Use Table)

	PCE	BFI + RESI	RESI[6]	BFI	G[7]
Construction	0.0	43.9	100.0	22.6	33.6
Manufacturing	23.3	41.3	0.0	56.9	44.2
Services	76.7	14.8	0.0	20.5	22.2

Table 6: Decomposition of Final Expenditure into Value Added by Industry (%)

	PCE	BFI + RESI	RESI	BFI	PCE + BFI + GOVI[8]
Construction	1.4	21.3	47.0	11.6	3.1
Manufacturing	23.0	40.6	23.8	46.9	27.0
Services	75.7	38.1	29.2	41.5	70.0

Table 7: Properties of Steady State: Ratios to GDP %

	Data (1948-2001)	*Model*
Capital stock (K)	152	152
Residential structures stock (P_d x S)	100	100
Private consumption (PCE)	63.8	63.9
Government consumption (G)	17.9	17.9
Non-residential inv (non-RESI)	13.5	13.9
Residential inv (P_d x RESI)	4.7	4.4
Construction (P_b x Y_b)	5.2[9]	4.8
Manufacturing (P_m x Y_m)	32.8	24.7
Services (P_s x Y_s)	61.5	70.6
Real after tax interest rate (%)		6.0

[6] We attribute all $225.5 billion of residential investment in 1992 to sales from the construction industry, since the first I/O use table does not have a 'residential investment' column. We defend this choice in the data appendix.
[7] G is government expenditure, which includes government consumption and government investment expenditures.
[8] GOVI is government investment. We assume that the value-added composition of government investment by intermediate industry is the same as business fixed investment.
[9] The shares of construction, manufacturing and services do not add to exactly one, since the product approach to computing GDP does not give exactly the same answer as the expenditure approach. In both model and data, imputed rental income from owner-occupied housing is attributed to the service sector.

Table 8: Business Cycle Properties[10]

		Data (1948-2001)			Model		
% Standard Deviations	GDP	2.26			1.73		
(rel. to GDP)	PCE	0.78			0.48		
	Labor (N)	1.01			0.41		
	Non-RESI	2.30			3.21		
	RESI	5.04			6.12		
	House prices (P_h)	1.37 (1970-2001)			0.40		
	Construction output (Y_b)	2.74			4.02		
	Manufacturing output (Y_m)	1.85			1.58		
	Services output (Y_s)	0.85			0.99		
	Construction hours (N_b)	2.32			2.15		
	Manufacturing hours (N_m)	1.53			0.39		
	Services hours (N_s)	0.66			0.37		
Correlations	PCE, GDP	0.80			0.95		
	P_h, GDP	0.65 (1970-2001)			0.65		
	PCE, non-RESI	0.61			0.91		
	PCE, RESI	0.66			0.26		
	non-RESI, RESI	0.25			0.15		
	P_h, RESI	0.34 (1970-2001)			-0.20		
	N_b, N_m	0.75			0.48		
	N_b, N_s	0.86			0.23		
	N_m, N_s	0.79			0.96		
Lead-lag correlations		i = 1	i = 0	i = -1	i = 1	i = 0	i = -1
	non-RESI $_{t-i}$, GDP$_t$	0.25	0.75	0.48	0.45	0.94	0.33
	RESI $_{t-i}$, GDP$_t$	0.52	0.47	-0.22	0.19	0.44	0.14
	non-RESI $_{t-i}$, RESI $_t$	-0.37	0.25	0.53	0.07	0.15	0.08

[10] Statistics are averages over 500 simulations, each of length 54 periods, the length of our data sample. Prior to computing statistics all variables are (i) transformed from the stationary representation used in the solution procedure back into non-stationary representation incorporating trend growth, (ii) logged, and (iii) Hodrick-Prescott filtered with the smoothing parameter, λ, set to 100.

Understanding the results

- Model GH — one sector RBC model with some capital entering (log) utility function
- Model A — $\sigma = 2$ and non-permanent shocks
- Model B — adding land
- Model C — sector specific shocks
- Model D — a distinct technology for residential structures
- Model E — sector specific capital shares
- Model F — asset–specific depreciation rates (benchmark)

Table 9: Alternative Parameterizations

Model	*Description*	*Selected parameter values*
GH	Greenwood and Hercowitz	see tables 2 and 3
A	One sector model, housing in utility (re-parameterized *GH*)	$\sigma = 2$, $\rho = 0.85$, $\sigma(\varepsilon) = 0.022$ $\delta_k = \delta_s = 0.0557$ $\theta_b = \theta_m = \theta_s = 0.25$ $B_{d,} = B_{c,}$ $M_{d,} = M_{c,}$ $S_{d,} = S_c$
B	*A* + land	$\varphi = 0.106$
C	*B* + sector-specific shocks	see table 4
D	*C* + two final goods technologies	see table 3
E	*D* + sector-specific capital shares	$\theta_b = 0.132$, $\theta_m = 0.309$, $\theta_s = 0.237$
F (Benchmark)	*E* + different depreciation rates	$\delta_s = 0.0157$

Table 10: Alternative Parameterizations: Business Cycle Properties

	Data	*GH*	*A*	*B*	*C*	*D*	*E*	*F*
GDP *(% std dev)*	2.26	1.37	1.93	1.88	1.69	1.69	1.67	1.73
Std. dev. relative to GDP								
PCE	0.78	0.60	0.39	0.39	0.42	0.44	0.45	0.48
N	1.01	0.36	0.47	0.48	0.45	0.44	0.45	0.41
Non-RESI	2.30	2.74	3.92	3.55	3.41	3.46	3.30	3.21
RESI	5.04	2.08	2.86	1.22	1.22	4.25	5.10	6.12
Y_b	2.74	1.25	1.15	1.16	1.82	3.66	4.36	4.02
Y_m	1.85	1.25	1.15	1.16	1.80	1.79	1.65	1.58
Y_s	0.85	1.25	1.15	1.16	1.06	1.05	1.05	0.99
P_h	1.37	0.00	0.00	0.13	0.13	0.41	0.45	0.40
Correlations								
Non-RESI, RESI	0.25	0.88	-0.10	0.73	0.75	-0.07	-0.07	0.15
P_h, RESI	0.34	-	-	1.00	1.00	-0.44	-0.48	-0.20
Lead-lag pattern: $corr(x_{t-1}, GDP_t) - corr(x_{t+1}, GDP_t)$								
x = RESI.	0.74	-0.11	-0.93	-0.48	-0.46	0.04	0.11	0.12
x = Non-RESI	-0.23	0.37	0.46	0.21	0.20	0.11	0.07	0.05

Comparison to US Historical Time Series

- Model matches trend growth in hours, consumption and output
- Residential investment exhibits relatively slow growth (due to low prod. growth in construction)
- Does not match growth of non-residential investment or manufacturing

- Model does reasonably well at business cycle frequencies
- Does not account well for house price dynamics

Figure 1: GDP, Hours Worked, Private Consumption and Non-residential Investment (mean model and data = 1)

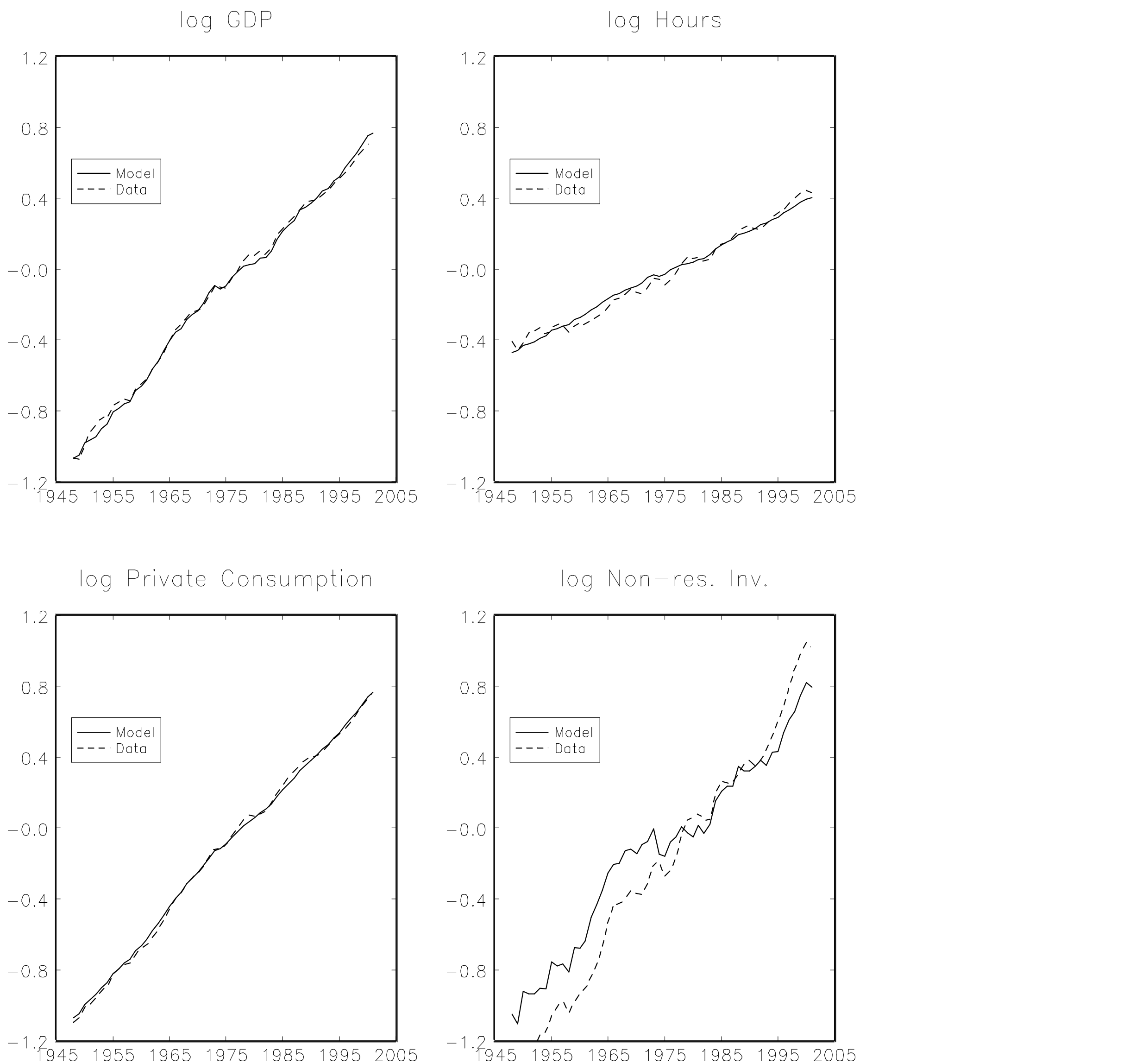


Figure 2: Residential Investment, House Prices, Construction and Manufacturing Output (mean model and data = 1)

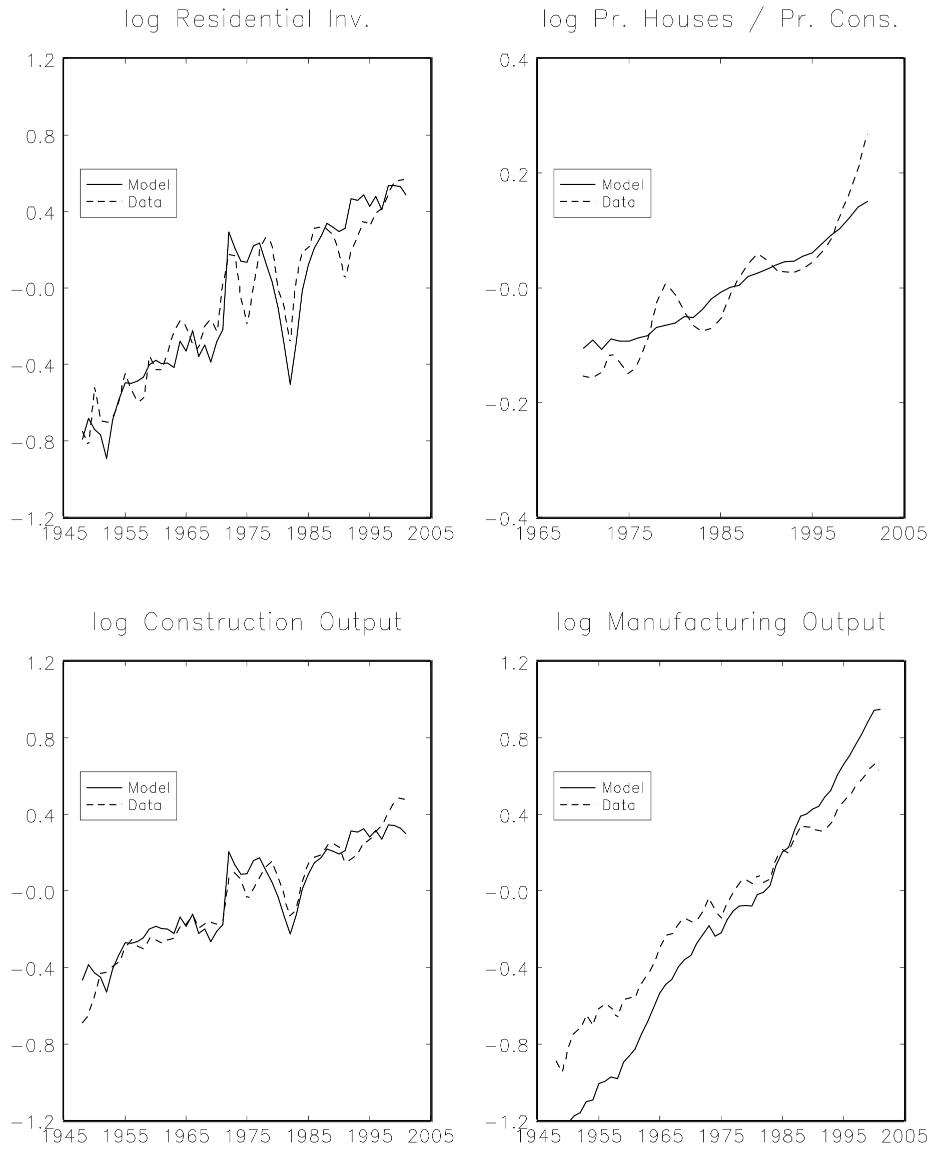
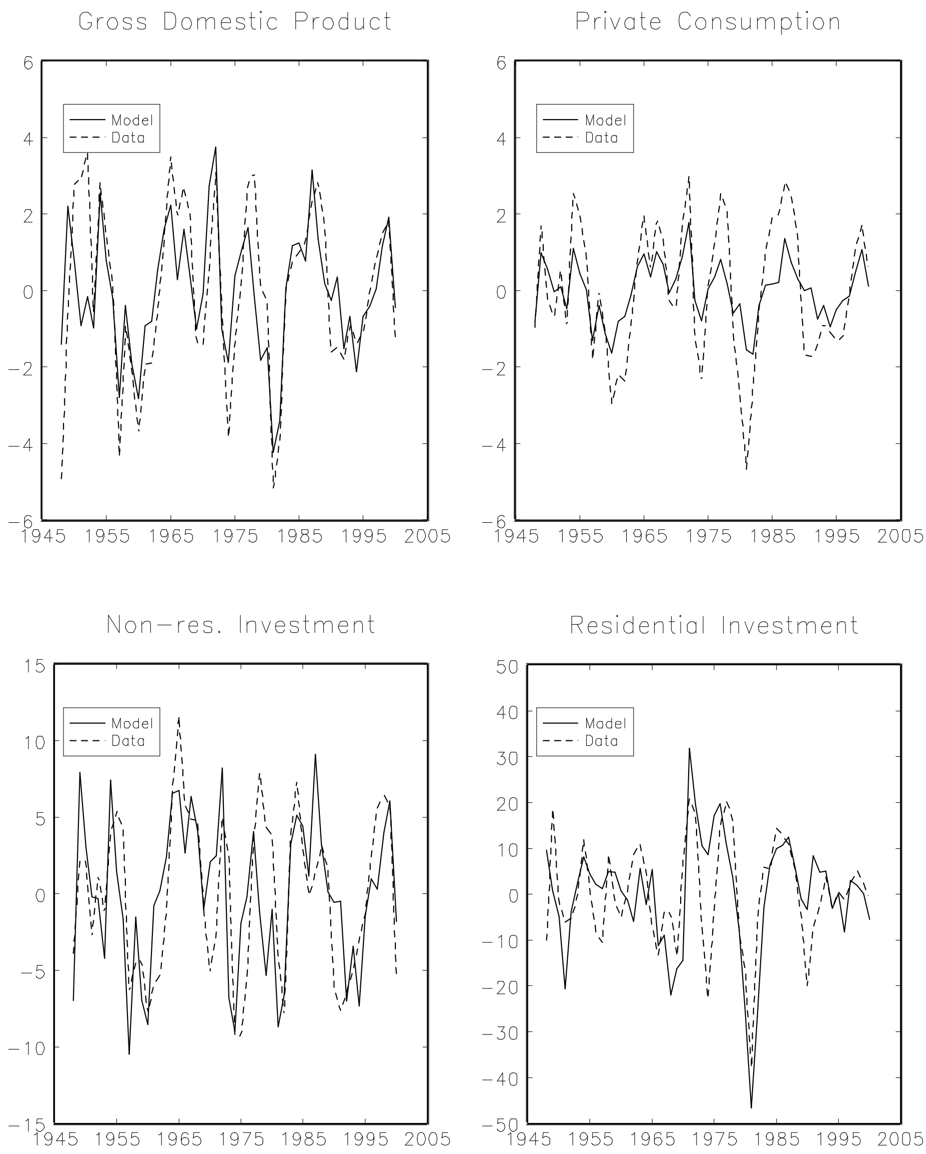


Figure 3: Percentage deviations from Hodrick Prescott trend



Supply vs. Demand Shocks

- Traditional view based on regressions of residential investment on house prices (controlling for other factors)

$\hookrightarrow$ positive coefficient $\Rightarrow$ demand shocks more important than supply shocks

- Regression using simulated data from model yields positive coefficient, despite no demand shocks

$\hookrightarrow$ due to omitted variable bias