Dynamic Impact of Housing Bubbles on the US Macroeconomy[1]

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June 2013

[1]The views expressed herein are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of Atlanta or the Federal Reserve System or the National Bureau of Economic Research.

Housing and land prices

Housing demand shocks are a driving force:

1. Burnside, Eichenbaum, and Rebelo (2012).
2. Liu, Wang, and Zha (2013).
3. Davis and Heathcote (2007).

Housing rent: A puzzle

- The data, however, indicate that the rent of house does not fluctuate significantly to justify large movements in house or land prices.
- Campbell, Davis, Gallin, and Martin (2009) examine the patterns of rent-price ratio.
- Lack of a general-equilibrium treatment.

Housing bubbles

Housing bubbles are widely blamed for the boom and bust in housing price and the great recession.

- In theory, bubbles in land prices could have dramatic aggregate effects (Kocherlakota 2009).
- Not even a thread of empirical evidence.

Questions

The following questions are essential to understanding the recent financial crisis:

- Do housing bubbles have dramatic macro effects?
- If so, how do we reconcile the movements of land/house prices with those of rental prices (the rent-price ratio puzzle)?

Challenges

- How do bubbles emerge in the first place?
  - In most rational bubble literature, bubble existence requires interest rate $\leq$ economic growth rate. This rules out bubble in productive asset as $p = \frac{d}{r-g} \to \infty$.
- How do bubbles fluctuate?
  - A common way is to allow stochastic bubbles, which implies the economy asymptotically becomes bubbless.

What do we do

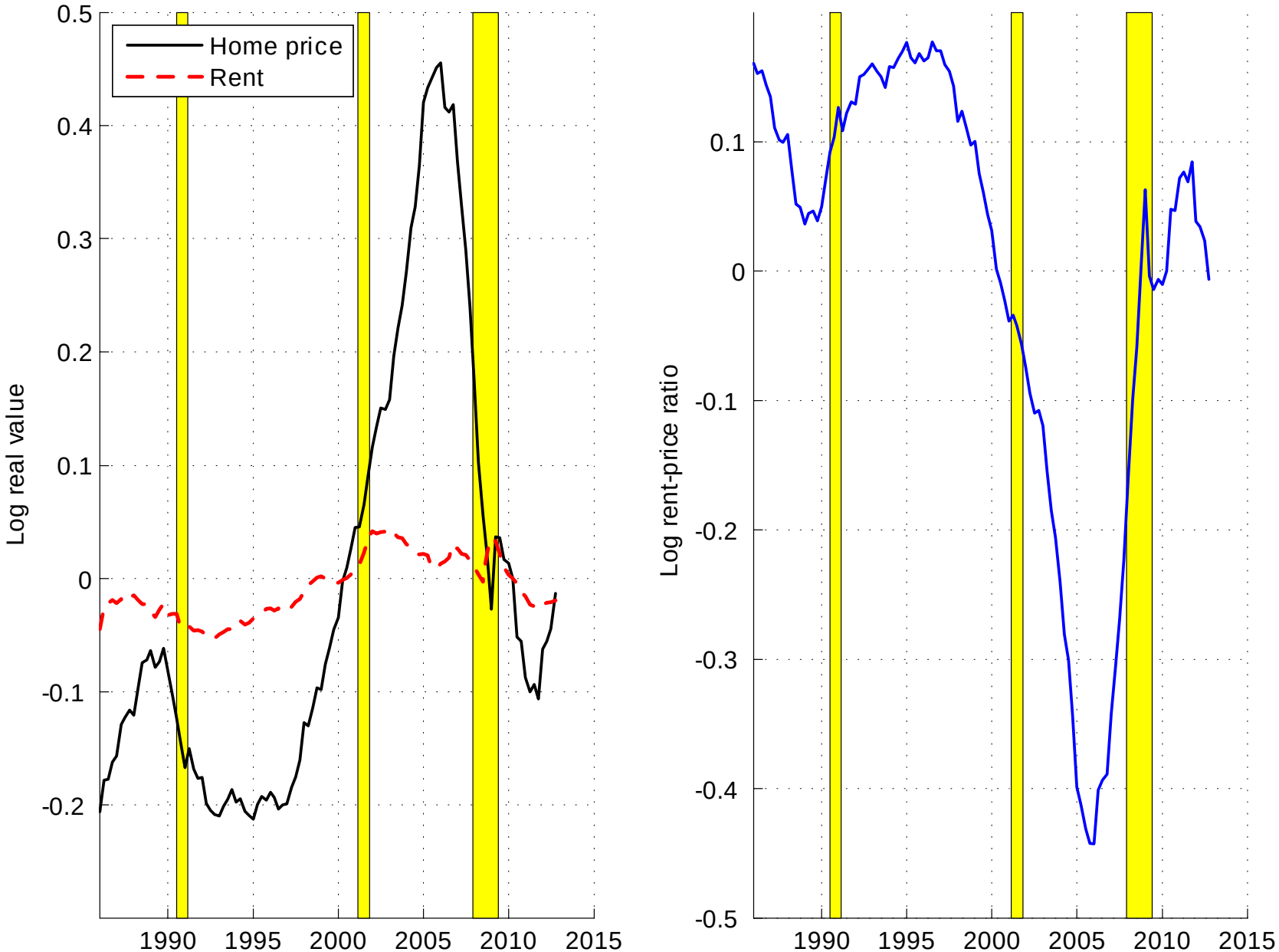
Construct a dynamic general-equilibrium model allowing recurrent housing bubbles to show that

- taking proper account of the rent-price ratio is essential to understanding the aggregate impact of housing bubbles.
- the macroeconomic impact of housing bubbles is significant by confronting our model to the data.
- sentiment shocks (speculation shock) are the main driving force for housing rent/price puzzle.
- it is feasible to bring bubbles to the core of macroeconomics.

Literature

- Rational bubbles: Kocherlakota (2009), Farhi and Tirole (2010), Hirano and Yanagawa (2010), Martin and Ventura (2011a,b), Wang and Wen (2011), Miao and Wang (2011a,b, 2012a,b), and Miao, Wang and Xu (2012)
- DSGE:
  - Risk shocks: Christiano, Motto, Rostagno (2010, 2012)
  - News shocks: Beaudry and Portier (2004), Fujiwara, Hirose, and Shintani (2011) and Schmitt-Grohe and Uribe (2012)
  - Financial shocks: Jermann and Quadrini (2012), Liu, Wang and Zha (2013)
  - Uncertainty shock: Bloom (2009)
- Self-fulfilling equilibria: Benhabib and Farmer (1994), Wen (1998), Perri and Quadrini (2012), and Bacchetta, Tille, and van Wincoop (2012),

rent-price ratio



Housing sentiment

Setup of the simple model

- A representative worker supplies labor to solve

$$\max_{n_t} w_t N_t - \frac{1}{1+\frac{1}{\gamma_n}} N_t^{1+\frac{1}{\gamma_n}} \Rightarrow N_t = w_t^{\gamma_n}. \tag{1}$$

- A continuum of entrepreneurs solve

$$V_t(a_{it}, h_{it}) = \max_{n_{it}, h_{it+1}} \left\{ \begin{array}{c} a_{it} n_{it} - w_t n_{it} - p_t(h_{it+1} - h_{it}) + \xi h_{it} \\ +\beta E_t V_{t+1}(a_{it+1}, h_{it+1}) \end{array} \right\} \tag{2}$$

  subject to an incentive-compatible constraint to be specified. Here a_{it} is i.i.d.

- In equilibrium, wage/housing price clears the labor/housing market,

$$N_t = \int_0^1 n_{it} di; \int_0^1 h_{it+1} di = 1. \tag{3}$$

Incentive-compatible constraint

- If entrepreneur i defaults on the wage payment, the only penalty is to be excluded from the labor market in the future. Define $V_t^a(h_{it})$ as the value function for such entrepreneur

$$V_t^a(h_{it}) = \xi h_{it} + \beta E_t V_{t+1}^a(h_{it}), \tag{4}$$

$$\Rightarrow \beta E_t V_{t+1}^a(h_{it}) = p_t^a h_{it},$$

$$p_t^a = \beta E_t[\xi + p_{t+1}^a] = \frac{\beta\xi}{1-\beta}, \tag{5}$$

- Incentive-compatible constraint:

$$\begin{aligned} & V_t(a_{it}, h_{it}) \\ \geq \quad & a_{it} n_{it} + \xi h_{it} + \beta E_t V_{t+1}^a(h_{it}) \end{aligned} \tag{6}$$

Incentive-compatible constraint

- Conjecture $\beta E_t V_{t+1}(a_{it+1}, h_{it+1}) = p_t h_{it+1}$, we obtain

$$w_t n_{it} \leq (p_t - p_t^a)\, h_{it} \equiv b_t h_{it}, \tag{7}$$

- Labor/production decision:

$$n_{it} = \begin{cases} \frac{b_t h_{it}}{w_t} & \text{if } a_{it} \geq w_t \\ 0 & \text{otherwise} \end{cases}, \tag{8}$$

$$y_{it} = \begin{cases} a_{it} \frac{b_t h_{it}}{w_t} & \text{if } a_{it} \geq w_t \\ 0 & \text{otherwise} \end{cases}. \tag{9}$$

Equilibrium Conditions

Equilibrium can be characterized by

$$p_t = \beta E_t \left[\xi + p_{t+1} + b_{t+1} \int_{w_{t+1}} \frac{a - w_{t+1}}{w_{t+1}} f(a) da \right], \tag{10}$$

$$b_t = \beta \left[b_{t+1} + b_{t+1} \int_{w_{t+1}} \frac{a - w_{t+1}}{w_{t+1}} f(a) da \right]. \tag{11}$$

$$\frac{b_t}{w_t}(1 - F(w_t)) = N_t = w_t^{\gamma_n}. \tag{12}$$

Equilibria

- Bubless equilibrium (trivial): $b = N = w = Y = 0$ and $p = p^a = \frac{\beta}{1-\beta}\xi$.
- Bubbly equilibrium:

$$
\begin{aligned}
p_b &= \frac{\beta}{1-\beta}\xi + b, \\
b &= \frac{w_b^{\gamma_n+1}}{1-F(w_b)}, \\
\frac{1}{\beta} - 1 &= \int_{w_b} \frac{a - w_b}{w_b} f(a)da.
\end{aligned}
$$

Sentiments and Recurrent Bubbles

- A rational bubble in the same asset cannot re-emerge after its collapse.
- Each period a fraction δ_h of the housing stock depreciates and is replaced by new houses. New houses bring new bubbles.
- Houses are indexed by their ages. There are total $\delta_h(1-\delta_h)^\tau$ supply of house with age τ and price $p_{t,\tau}$. In general

$$p_{t,\tau} \neq p_{t,\ell}, \text{ if } \tau \neq \ell, \tag{13}$$

  - different houses are in different location.
- Similarly to the simple model, there exist an price p_t^a, such that

$$p_{t,\tau} = p_t^a + b_{t,\tau} \tag{14}$$

Entrepreneur's problem

Entrepreneur solves

$$V_t(i) = \max_{n_t(i), h_{t+1,\tau+1}(i)} E_t \sum_{k=0}^{\infty} \beta^k [c_{t+k}(i) + \xi H_{t+k}(i)], \tag{15}$$

subject to :

$$H_t(i) = \sum_{\tau=1}^{\infty} h_{t,\tau}(i), \tag{16}$$

$$\begin{aligned} & c_t(i) + \sum_{\tau=1}^{\infty} p_{t,\tau} \left[h_{t+1,\tau+1}(i) - (1-\delta_h) h_{t,\tau}(i) \right] + p_{t,0} h_{t+1,1}(i) \\ \leq \quad & a_t(i) n_t(i) - w_t n_t(i), \end{aligned} \tag{17}$$

plus an incentive constraint.

Incentive problem

- If entrepreneur i defaults, he obtains

$$a_t(i)n_t(i) + \xi H_t(i) + \xi\beta(1-\delta_h)H_t(i) + \xi\beta^2(1-\delta_h)^2 H_t(i) + ..., \tag{18}$$

- the incentive-compatibility constraint becomes

$$a_t(i)n_t(i) \leq p_{t,\tau}(1-\delta_h)\sum_{\tau=1}^{\infty} h_{t,\tau}(i) - p_t^a(1-\delta_h)\sum_{\tau=1}^{\infty} h_{t,\tau}(i), \tag{19}$$

where

$$\begin{aligned} p_t^a &\equiv \beta E_t[\xi + (1-\delta_h)p_{t+1}^a], \\ b_{t,\tau} &= p_{t,\tau} - p_t^a \end{aligned} \tag{20}$$

Housing sector

- First order condition with respect to $h_{t+1,\tau+1}(i)$

$$\begin{aligned} p_{t,\tau} &= \beta E_t[\xi + (1-\delta_h)p_{t+1,\tau+1}] \\ &\quad + \beta(1-\delta_h)E_t b_{t+1,\tau+1}\int_{w_{t+1}}\left(\frac{a}{w_{t+1}}-1\right)f(a)da. \end{aligned}$$

- Hence

$$b_{t,\tau} = \beta(1-\delta_h)E_t b_{t+1,\tau+1}\left[1+\int_{w_{t+1}}\left(\frac{a}{w_{t+1}}-1\right)f(a)da\right]$$

Housing sector

- Construct

$$b_{t,\tau} = b_t^* \theta_{t-1} \theta_{t-2} \times \ldots \times \theta_{t-\tau}, \tag{21}$$

$$\frac{b_{t+1,\tau+1}}{b_{t,\tau}} = \frac{b_{t+1}^*}{b_t^*} \theta_t \tag{22}$$

- the asset pricing equation for $b_{t,\tau}$ becomes

$$b_t^* = \beta(1-\delta_h)\theta_t E_t b_{t+1}^* \left[1 + \int_{w_{t+1}} \left(\frac{a}{w_{t+1}} - 1\right) f(a) da\right], \tag{23}$$

Aggregation

- total housing price

$$P_t = \frac{\beta(1-\delta_h)\xi}{1-\beta(1-\delta_h)} + b_t^*(M_t + \delta_h) \tag{24}$$

$$M_{t+1} = \theta_t(1-\delta_h)\left(M_t + \delta_h\right) \tag{25}$$

- total labor demand

$$w_t N_t = w_t^{1+\gamma_n} = b_t^* M_t \int_{w_t} f(a)da \tag{26}$$

- aggregate output

$$Y_t = b_t^* M_t \int_{w_t} \frac{a}{w_t} f(a)da \tag{27}$$

Key Mechanisms

- Endogenous TFP

$$Y_t = N_t \left[\frac{1}{1 - F(w_t)} \int_{w_t} af(a)da \right], \tag{28}$$

- Endogenous Markup

$$\frac{w_t N_t}{Y_t} = \frac{w_t}{\left[\frac{1}{1-F(w_t)} \int_{w_t} af(a)da \right]} \tag{29}$$

- Cutoff: entrepreneur produce if and only $a \geq w_t$,

$$w_t^{1+\gamma_n} = b_t^* M_t \int_{w_t} f(a)da, \tag{30}$$

A DSGE Model

The representative extended family consisting of three players:

1. the representative worker,
2. a continuum of entrepreneurs, indexed by $i \in [0, 1]$,
3. a continuum of intermediate goods producers, indexed by $j \in [0, 1]$.

Economic environment

- The worker supplies labor to producers and earns wages.
- Producers hire labor and rent capital from the family to supply intermediate goods.
- Producers provide working capital loans to entrepreneurs in the form of trade credit.
- Entrepreneurs demand (use) intermediate goods to produce final output.
- Only entrepreneurs can own and trade houses.
- Perfect consumption insurance within the family.

Family

- Utility function (choosing C_t, N_t, I_t, K_{t+1}, and u_t):

$$E \sum_{t=0}^{\infty} \beta^t \left[\ln \left(C_t - \gamma C_{t-1} \right) + \xi_t \int_0^1 \ln H_t - \psi_t N_t \right],$$

- Law of motion for capital:

$$K_{t+1} = (1 - \delta(u_t)) K_t + \left[1 - \frac{\Omega}{2} \left(\frac{I_t}{I_{t-1}} - \bar{g}_I \right)^2 \right] I_t,$$

where $\delta' > 0, \delta'' > 0$, and $\delta'(1) = R_k$ in steady state.

- H_{t+1} is decentralized by entrepreneur

Intermediate goods producers

- Producer j's problem is to choose $N_t(j)$ and $K_t(j)$ (taking $P_{Xt}(j)$, w_t, and r_t as given) such that

$$\max P_{Xt}(j)X_t(j) - w_t N_t(j) - r_t K_t(j),$$

  where $X_t(j) = A_t K_{jt}^{\alpha} N_{jt}^{1-\alpha}$ and the TFP shock A_t has both permanent and transitory components.
- Euler equations for the *supply* of $X_t(j)$:

$$\alpha P_{Xt}(j)X_t(j)/K_{jt} = r_t, \tag{31}$$

$$(1-\alpha)P_{Xt}(j)X_t(j)/N_{jt} = w_t. \tag{32}$$

- Again, the standard RBC setup.

Entrepreneur's problem

- Entrepreneur i's production function:

$$y_{it} = a_{it} \exp\left(\int \log x_{it}(j)\,dj\right),$$

- Entrepreneur i's sales revenue is:

$$\Pi_{it} = y_{it} - \int P_{Xt}(j) x_{it}(j)\,dj,$$

- Entrepreneur i' trades houses

$$\sum_{\tau=1}^{\infty} p_{t,\tau}\left[h_{t+1,\tau+1}(i) - (1-\delta_h) h_{t,\tau}(i)\right] + p_{t,0} h_{t+1,1}(i) + d_{it} \leq \Pi_{it}, \tag{33}$$

Determination of house prices and house rent

First-oder conditions of the Bellman equation, with the help of the envelope theorem, give us the following Euler equations:

- Fundamental price p_t^a:

$$\begin{aligned} p_t^a &= \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t} \left[R_{Ht+1} + (1-\delta_h) p_{t+1}^a \right] \\ &\quad + \beta (1-\delta_h) \tau_{ax} E_t \frac{\Lambda_{t+1}}{\Lambda_t} \varpi_{t+1} p_{t+1}^a . \end{aligned}$$

- Fundamental rent R_{Ht}:

$$R_{Ht} = \frac{\xi_t}{\Lambda_t},$$

Determination of house prices and house rent

- Housing price

$$
\begin{aligned}
p_{t,\tau} &= \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t}[R_{Ht+1} + (1-\delta_h)p_{t+1,\tau+1}] \\
&\quad + \beta(1-\delta_h)E_t \frac{\Lambda_{t+1}}{\Lambda_t} b_{t+1,\tau+1} \int_{a^*_{t+1}} (\frac{a}{a^*_{t+1}} - 1) f(a) da.
\end{aligned}
$$

- By definition $b_{t,\tau} = p_{t,\tau} - p^a_t$ is given by

$$
b_{t,\tau} = \beta(1-\delta_h)E_t \frac{\Lambda_{t+1}}{\Lambda_t} b_{t+1,\tau+1} \left[1 + \int_{a^*_{t+1}} (\frac{a}{a^*_{t+1}} - 1) f(a) da\right].
$$

Key idea of identification

- Use 2 distinct data series, house price and housing sentiment, to help jointly identify the bubble (credit) shock.
- Use the house rent data to help identify a housing preference shock.
- Use the debt data to help identify a leverage shock.
- Use other standard macroeconomic series to identify other standard shocks.

Data

1. Consumption (consumer non-durables and non-housing services).
2. Investment (consumer durables and S&Es).
3. Core logic home price.
4. Home rental price.
5. Relative price of investment goods.
6. Hours.
7. Housing sentiment.
8. Non-farm and non-financial business debt.

Calibration

Parameter	Description	value
α	Capital income share	0.33
I/Y	Share of investment	0.26
K/Y	Capital to output ratio	4.6
P/Y	Home value to output ratio	9.4
R_H/Y	Rental income to output ratio	0.1
R_f	Interest rate	1.01
δ_h	Housing depreciation	1.15%
τ	Tax credit	0.35%
L/Y	Loan to output ratio	4.0%

Estimated values of structural parameters

Parameter	Description	value
η	Hazard rate $(a^* f(a^*)/(1 - F(a^*)))$	7.174
δ''	Curvature of capital depreciation function	1.073
γ	Habit	0.407
Ω	Investment adjustment cost	0.179
a_s	Intercept in sentiment data equation	0.356
b_s	Slope coefficient of bubble (credit) shock	0.456
c_s	Slope coefficient of housing preference shock	0.009
d_s	Slope coefficient of leverage shock	0.000

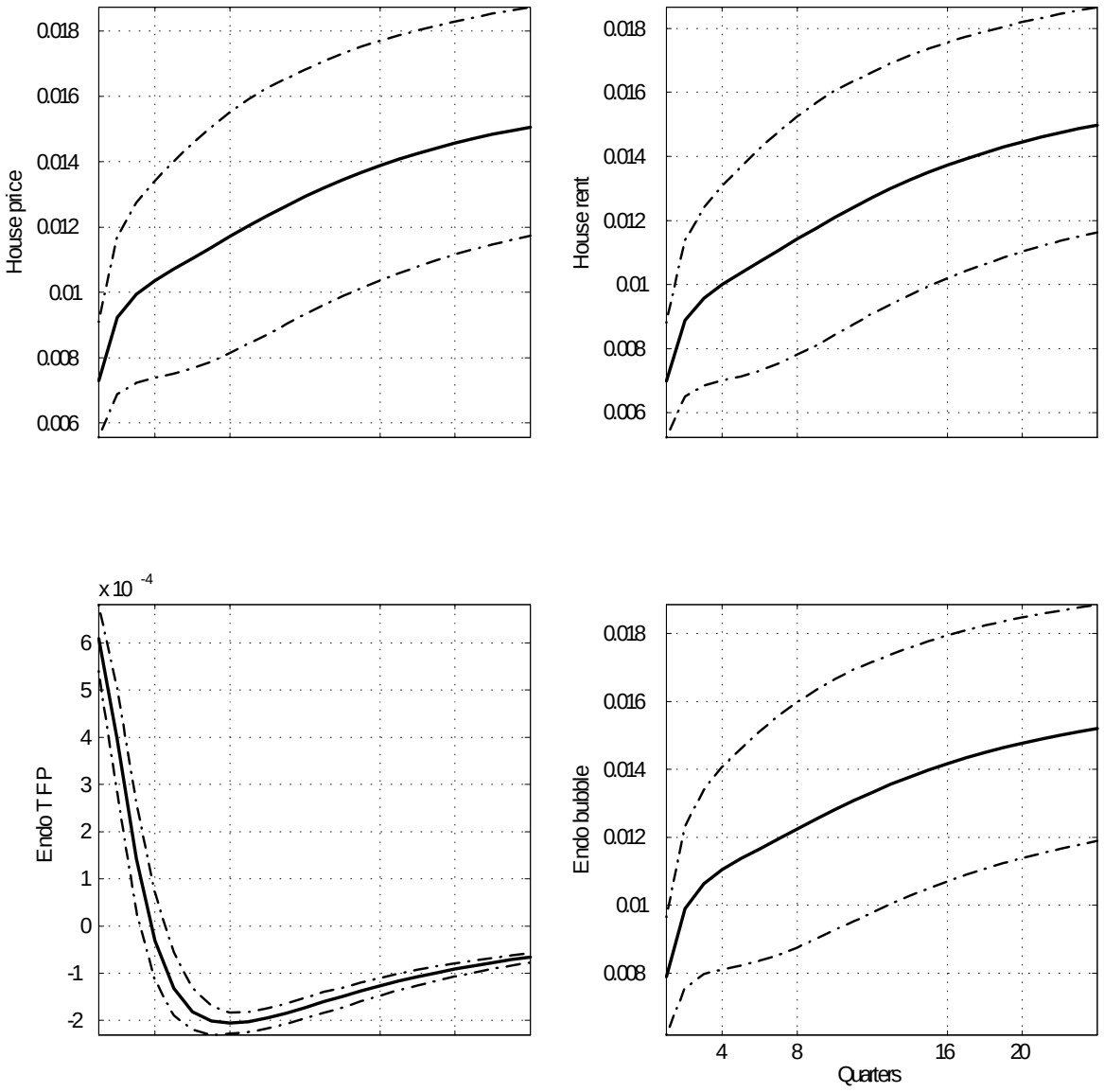
Estimated values of structural parameters

		Parameter
Parameter	Persistence	value
ρ_{zp}	permanent investment tech shock	0.167
$\rho_{\nu z}$	transitory investment tech shock	0.089
ρ_{Ap}	permanent TFP shock	0.516
$\rho_{\nu A}$	transitory TFP shock	0.897
ρ_{θ}	bubble shock	0.842
ρ_{ξ}	housing preference shock	0.996
ρ_{ψ}	abor supply shock	0.996
ρ_{ϖ}	leverage shock	0.963
ρ_{ζ}	sentiment measurement error	0.979

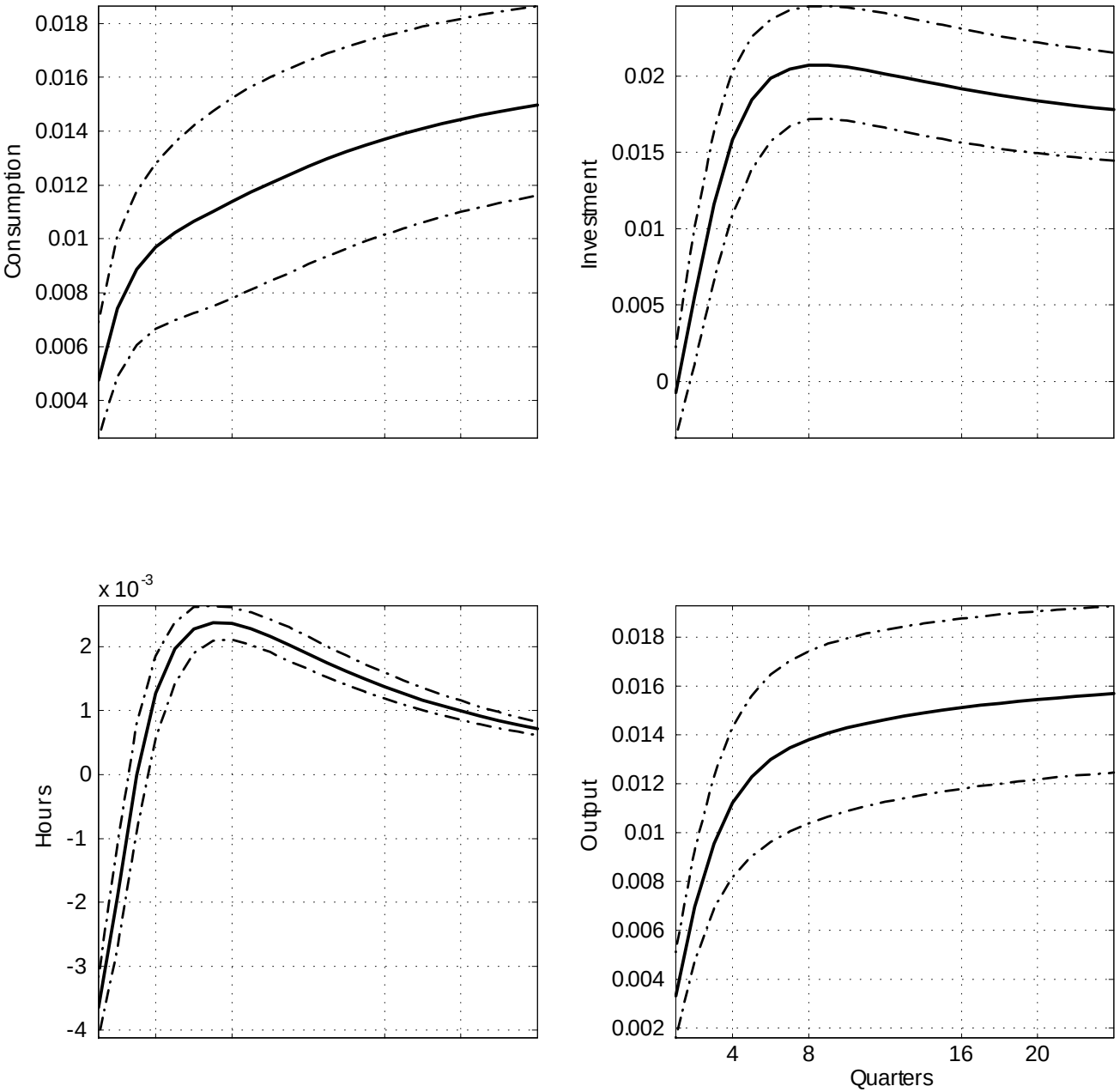
Estimated values of structural parameters

		Parameter
Parameter	Description	value
σ_{zp}	s.d of permanent investment tech shock	0.005
$\sigma_{\nu z}$	s.d of transitory investment tech shock	0.000
σ_{Ap}	s.d of permanent TFP shock	0.004
$\sigma_{\nu A}$	s.d of transitory TFP shock	0.008
σ_{θ}	s.d of bubble shock	0.026
σ_{ξ}	s.d of housing preference shock	0.007
σ_{ψ}	s.d of labor supply shock	0.005
σ_{ϖ}	s.d of leverage shock	0.022
σ_{ζ}	s.d of sentiment measurement error	0.043

Effects of TFP shock on the housing sector



Effects of housing pref shock on the housing sector



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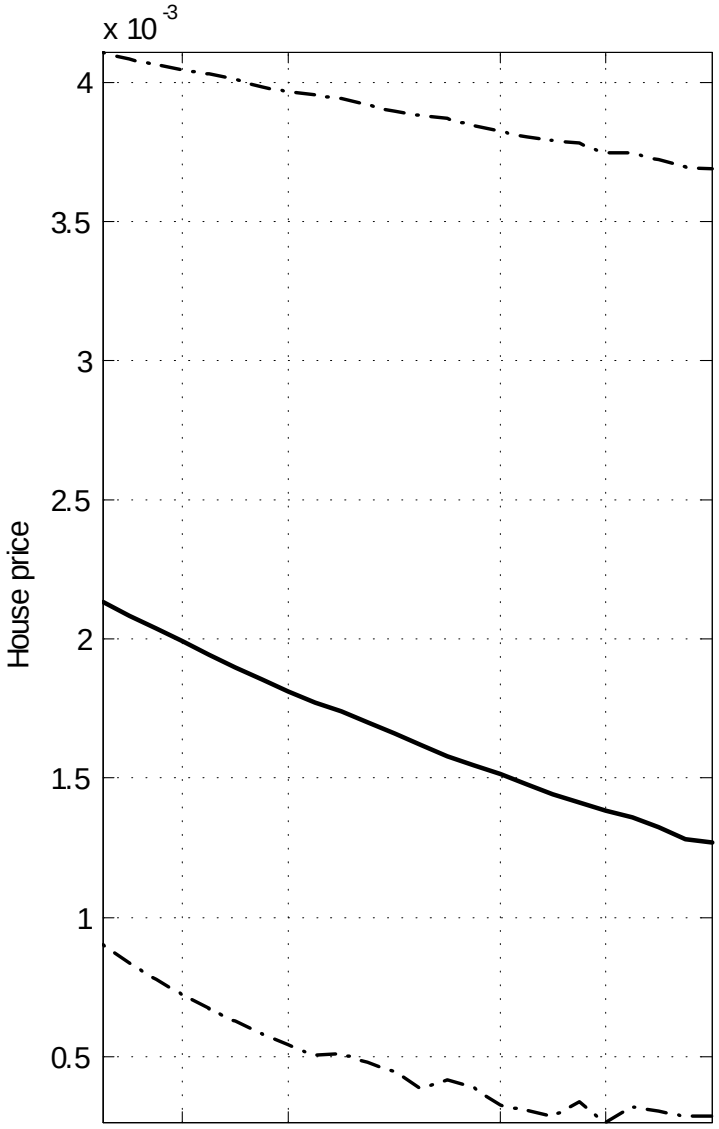
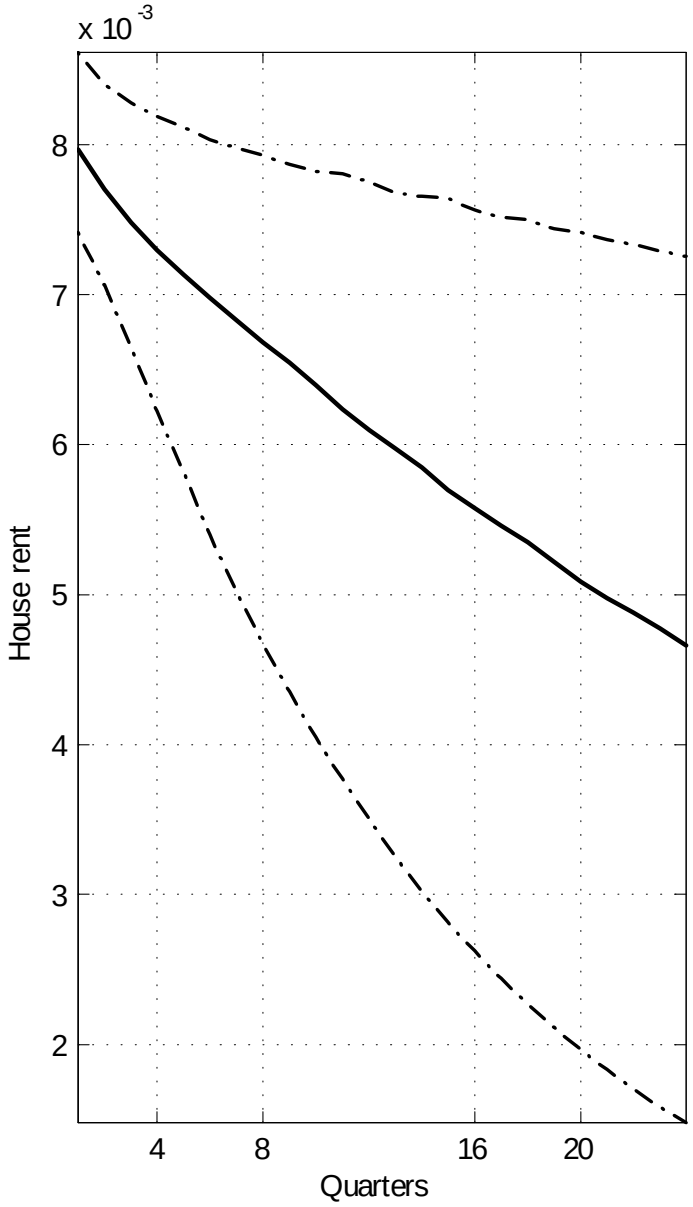
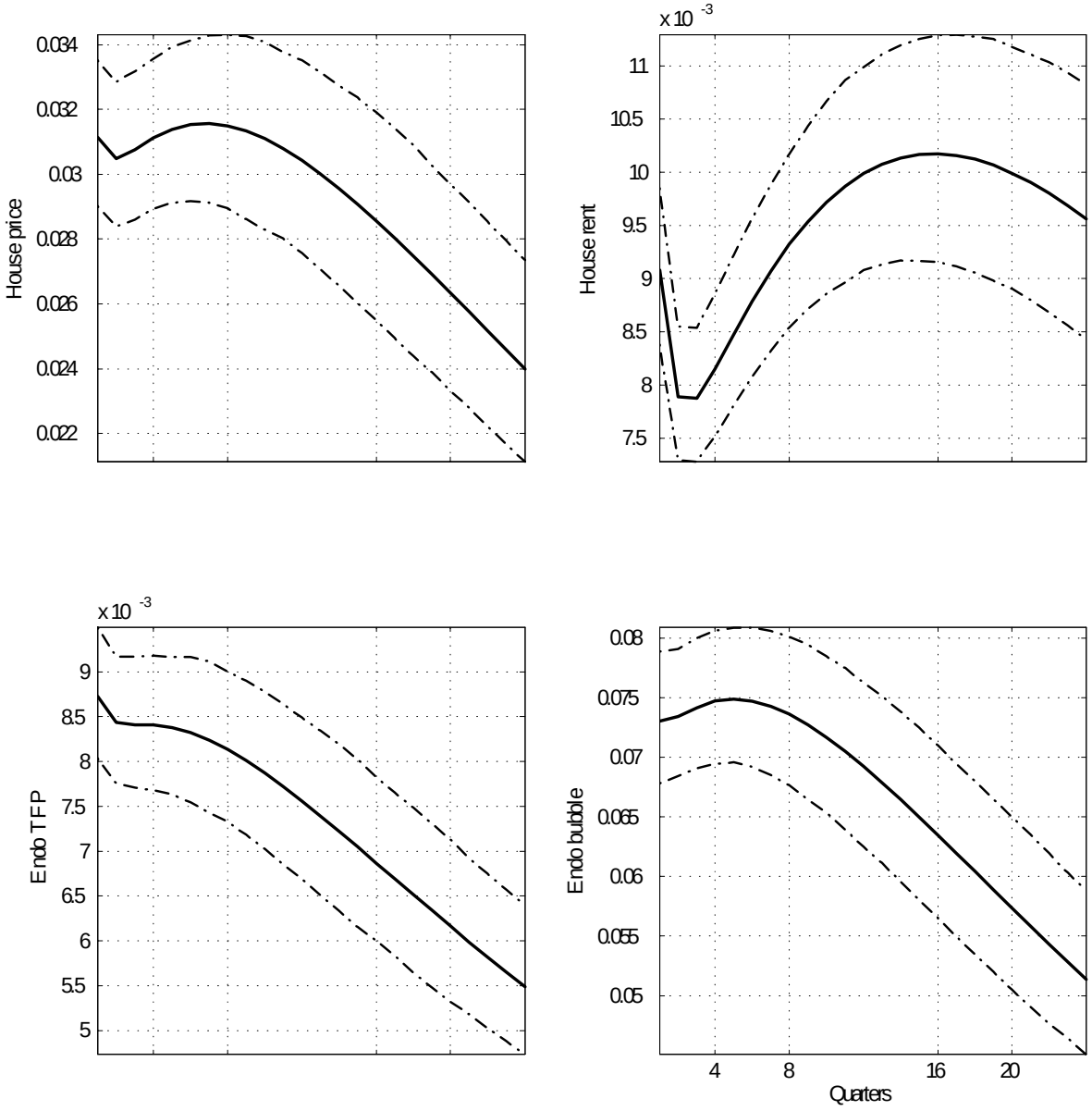
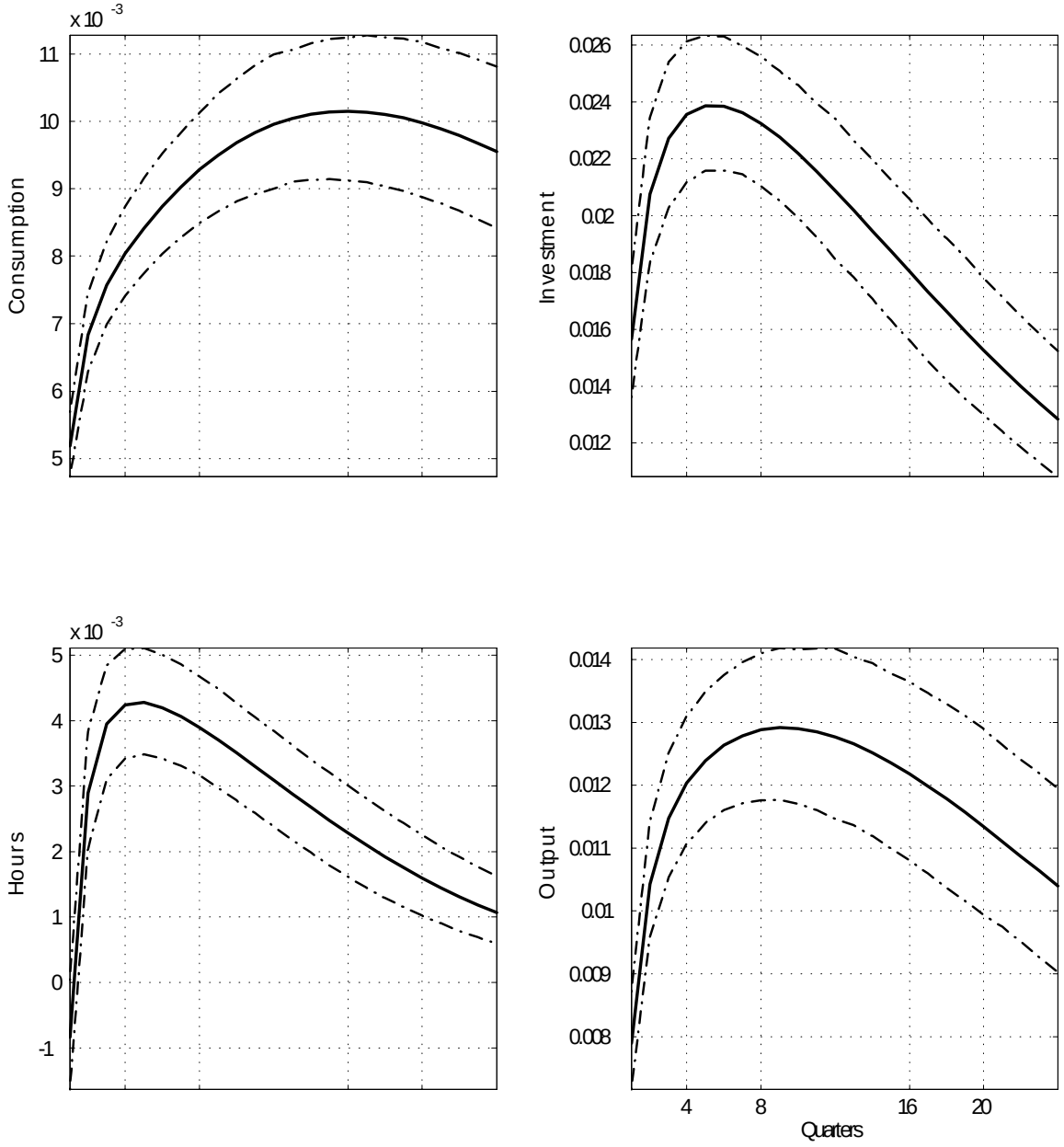




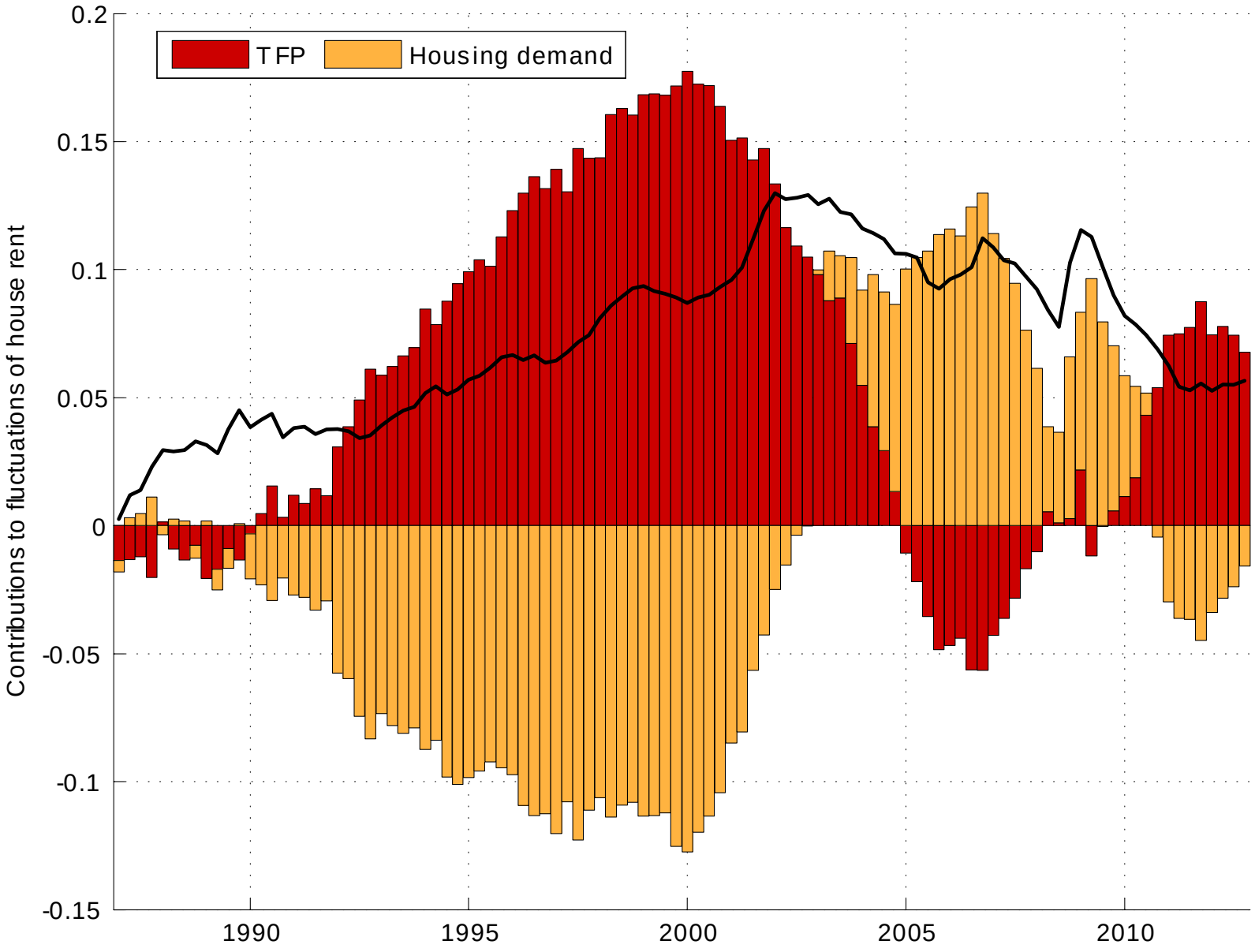
Effects of bubble shock on the housing sector



Effects of bubble shock on the macroeconomy



Counterfactual path



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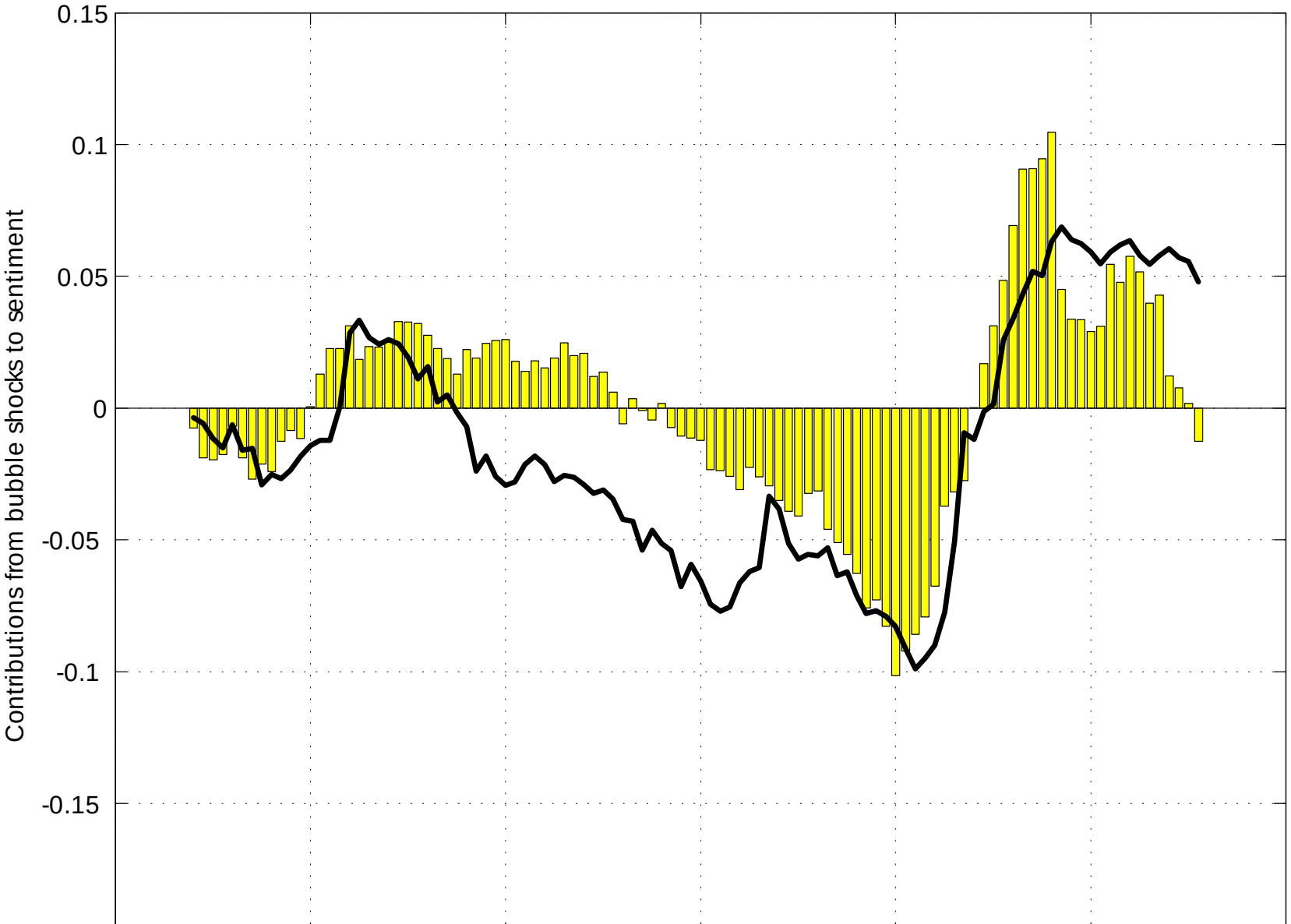

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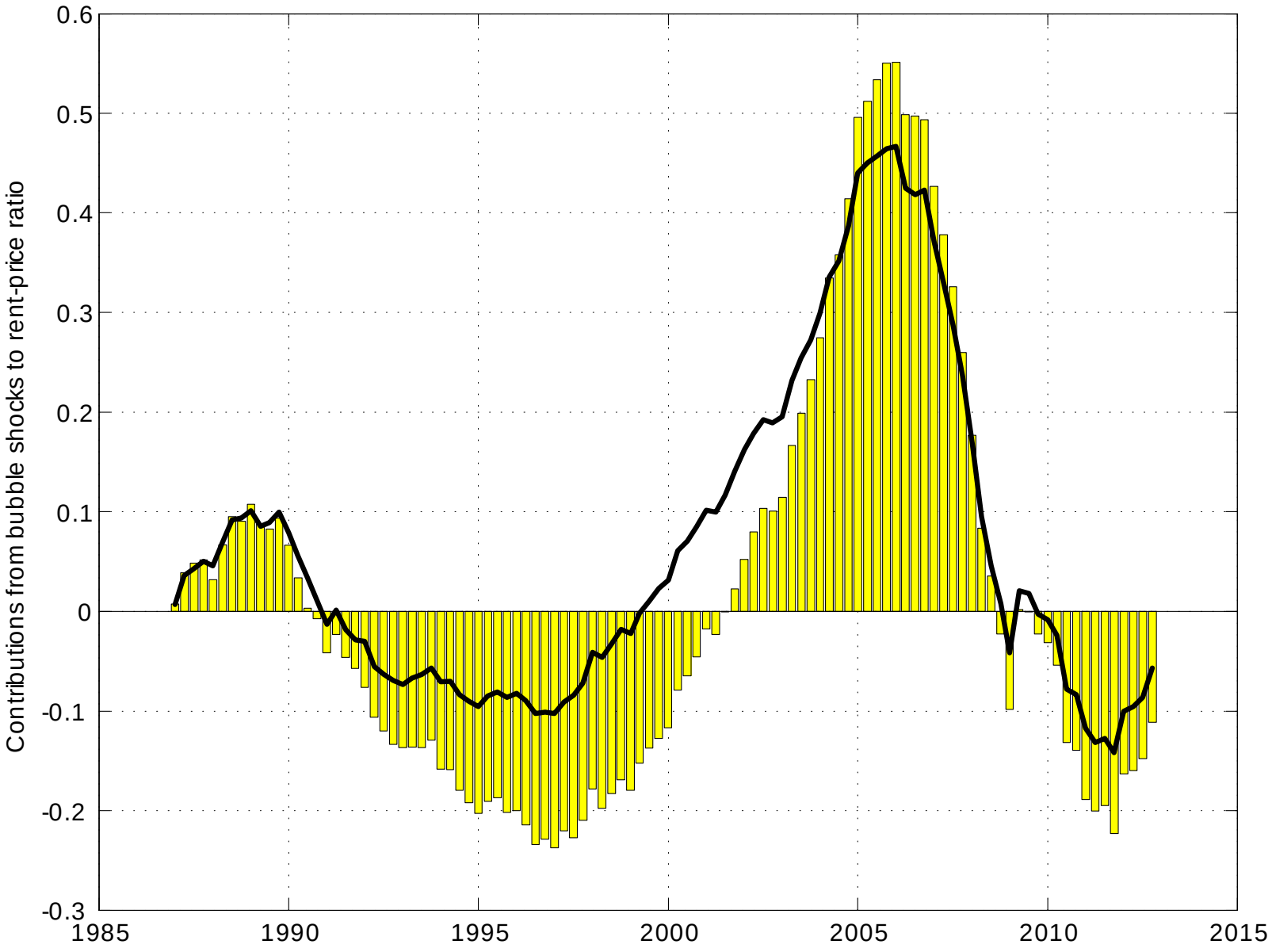
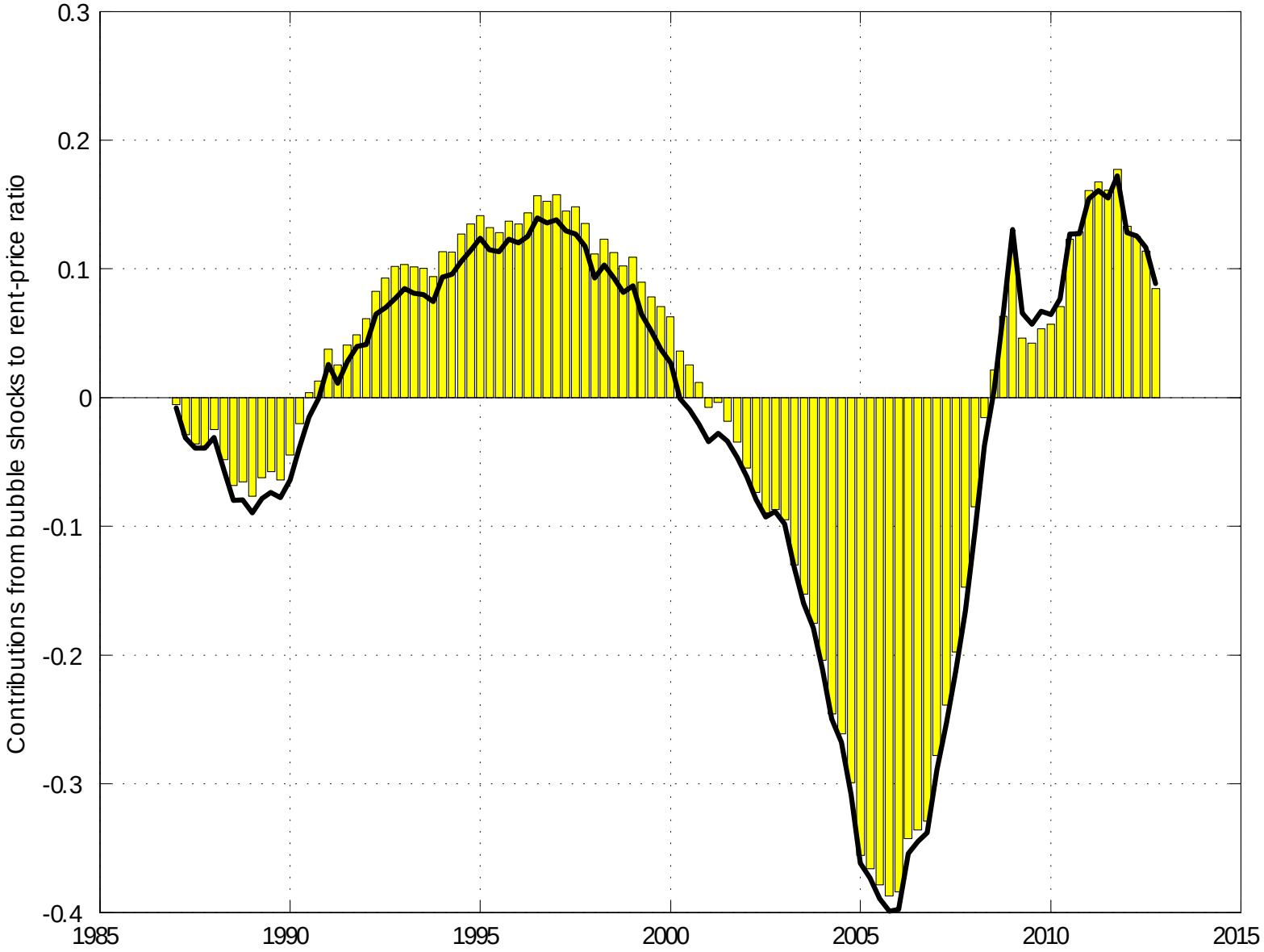
Counterfactual path