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Optimal interest rate rule in a DSGE model with housing market spillovers☆

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HIGHLIGHTS

- The optimal interest rate rule in a DSGE model with housing market spillovers is examined.
- The optimal rule responds to house price inflation, even when stabilizing house price is not one of the goals of the policymaker.
- A higher response to house price inflation always results in a lower house price volatility.

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ABSTRACT

This paper studies the optimal interest rate rule in a DSGE model with housing market spillovers (Iacoviello and Neri, 2010). We find that the optimal rule responds to house price inflation even when the stabilization of house price is not among the objectives of the policymaker, and that the strength of the response depends crucially on a few structural parameters.

1. Introduction

Since Taylor (1993), there is an expanding literature on monetary policy rule from either a positive (what the central bank does) or a normative (what the central bank should do) perspective. One normative question that arises is how the central bank, if at all, should respond to movements in house prices (or asset prices in general).

House prices are related to a number of macroeconomic variables, such as consumption and investment, over the business cycle. Although house price contains information on economic activities, stabilizing house prices is not among the mandated objectives of central banks. In a large body of empirical work for models with a housing market, the monetary policy rule is usually specified to be responding only to money inflation and output gap (see Iacoviello (2005), Edge et al. (2007) and Iacoviello and Neri (2010)).

Should the central bank react to house prices? The two opposing answers to this question are "leaning against asset-price bubbles" versus "cleaning up after the bubble bursts". Some argue that central banks should lean against surges in asset prices to unsustainable levels in order to avoid macroeconomic and financial instability (see Cecchetti et al. (2000) and Borio and Lowe (2002)). Others argue that central banks should react to asset prices only to the extent that they contain information about future output growth and inflation. For example, Greenspan (2002) explains that, since it is very difficult to identify a bubble before its existence is confirmed by the bursting, the Federal Reserve does not directly react to financial imbalances. According to Bernanke and Gertler (1999), it is unnecessary for monetary policy to respond to changes in asset prices. Rules that directly target asset prices might have undesirable side effects of stifling the beneficial impact of the technology boom.

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More recently, Kannan et al. (2012) incorporate a financial sector into the model of Iacoviello and Neri (2010) and combine the macroprudential instrument with an augmented Taylor rule that also reacts to the growth rate of nominal credit. They find that strong monetary reactions to credit growth and house prices increase macroeconomic stability. However, whether a macroprudential instrument should be employed depends on the source of house price booms. In this paper, we assume that the policymaker aims at minimizing an ordinary loss function – a weighted variability of money inflation, wage inflation, output growth, and nominal interest rate – as suggested by Giannoni and Woodford (2003). Our goal is to examine whether the implementation of an interest rate rule that also responds to house price inflation reduces the policymaker's loss and how robust the optimal rule is to changes in a list of structural parameters. Unlike Kannan et al. (2012), we investigate the optimal policy rule without assuming the central bank knowing the source of housing booms; we do not intend to identify whether the observed fluctuations in house price are driven by fundamentals or not. Instead, given the housing market spillovers, we study an interest rate rule that responds not only to money inflation and output growth but also to house price inflation.

2. The model

Iacoviello and Neri (2010) construct a DSGE model that allows for housing market spillovers to the broad economy. The model includes a consumption good sector and a housing sector. There are two types of households, patient and impatient, on the demand side that work, consume, and accumulate housing. The patient households own the capital of the economy and provide funds to firms and loans to the impatient households, who face the collateral constraints in equilibrium—their maximum borrowing is given by a fraction m (the loan-to-value ratio) of the expected present value of their home. On the supply side, the consumption sector combines capital and labor to produce consumption goods and business capital for both sectors. The housing sector combines business capital, labor, and land to produce new houses.

The model allows for sticky prices in the consumption sector and sticky wages in both sectors. In each period, a fraction θ_π of retailers are able to set prices optimally, while another fraction $1-\theta_\pi$ only index prices to the previous period inflation rate with an elasticity of ι_π. Hence, the consumption sector Phillips curve takes the following form:

$$\ln \pi_t - \iota_\pi \ln \pi_{t-1} = \beta G_C (E_t \ln \pi_{t+1} - \iota_\pi \ln \pi_t) - \frac{(1-\theta_\pi)(1-\beta G_C \theta_\pi)}{\theta_\pi} \ln\left(\frac{X_t}{X}\right) + u_{p,t}, \quad (1)$$

where β is the discount factor of the patient households; G_C is the growth rate of consumption in the balanced growth path; π_t is the money inflation in the consumption sector; X_t is a markup over the marginal cost charged by retailers and X is the steady-state value; $u_{p,t}$ is an independently and identically distributed cost shock that affects inflation.

Similarly, the wage Phillips curves can be written as:

$$\ln \omega_{i,t} - \iota_{wi} \ln \pi_{t-1} = \beta G_C (E_t \ln \omega_{i,t+1} - \iota_{wi} \ln \pi_t) - \frac{(1-\theta_{wi})(1-\beta G_C \theta_{wi})}{\theta_{wi}} \ln\left(\frac{X_{wi,t}}{X_{wi}}\right), \quad (2)$$

$$\ln \omega'_{i,t} - \iota_{wi} \ln \pi_{t-1} = \beta' G_C (E_t \ln \omega'_{i,t+1} - \iota_{wi} \ln \pi_t) - \frac{(1-\theta_{wi})(1-\beta' G_C \theta_{wi})}{\theta_{wi}} \ln\left(\frac{X_{wi,t}}{X_{wi}}\right), \quad (3)$$

where $i = c, h$ (c and h denote the consumption sector and the housing sector, respectively). θ_{wi} characterizes the wage stickiness in sector i; $X_{wi,t}$ is the corresponding wage markup; $\omega_{i,t}$ is the nominal wage inflation in each sector, i.e. $\omega_{i,t} = \pi_t w_{i,t}/w_{i,t-1}$, where $w_{i,t}$ is the real wage. Parameters and variables with a prime refer to impatient households.

To close the model, the central bank sets the nominal interest rate, R_t, as a contemporaneous version of the Taylor rule that responds to money inflation, π_t, and GDP growth, $GDP_t/(G_C GDP_{t-1})$:

$$\text{Rule (I):} \quad R_t = R_{t-1}^{r_R} \pi_t^{(1-r_R)r_\pi} \left(\frac{GDP_t}{G_C GDP_{t-1}}\right)^{(1-r_R)r_Y} \times \left(\frac{q_t}{G_Q q_{t-1}}\right)^{(1-r_R)r_Q} \overline{rr}^{1-r_R} \frac{u_{R,t}}{s_t}, \quad (4)$$

i.e., the parameter r_Q that corresponds to house price inflation, $q_t/(G_Q q_{t-1})$, is fixed at zero.[1] In Eq. (4), G_Q is the growth rate of house price in the balanced growth path; $\overline{rr}$ is the steady-state real interest rate; $u_{R,t}$ is an independently and identically distributed monetary shock; s_t is an AR(1) stochastic process that captures long-lasting deviations of inflation from its steady-state level, i.e. $\ln s_t = \rho_s \ln s_{t-1} + u_{s,t}$.

Besides $u_{p,t}$ in Eq. (1) and $u_{R,t}$, $u_{s,t}$ in Eq. (4), the model specifies a number of shocks, including intertemporal preference shock $u_{z,t}$, housing demand shock $u_{j,t}$, labor supply shock $u_{\tau,t}$, productivity shocks $u_{C,t}$ and $u_{H,t}$ in the two sectors, and the investment-specific technology shock $u_{K,t}$. Among them, the housing demand shock and the housing technology shock account for more than half of the volatilities of housing investment and house price (see Iacoviello and Neri (2010)).

Based on this model, we examine whether the optimal monetary policy reacts to house price inflation, under the assumption that the policymaker seeks to minimize an ordinary expected loss criterion as in Giannoni and Woodford (2003):

$$\mathfrak{L} = \lambda_\pi var(\ln \pi_t - \iota_\pi \ln \pi_{t-1}) + \lambda_w var(\ln \pi_{wc,t} - \iota_{wc} \ln \pi_{t-1}) + \lambda_y var(\ln GDP_t - \ln(G_C GDP_{t-1})) + \lambda_r var(\ln R_t - \ln \overline{rr}), \quad (5)$$

where $\pi_{wc,t} = \pi_t(w_{c,t} + w'_{c,t})/((w_{c,t-1} + w'_{c,t-1}))$ is the nominal wage inflation in the consumption sector.[2] Under the objective $\mathfrak{L}$, the policymaker minimizes the weighted variability of money inflation, wage inflation, output growth, and nominal interest rate, but does not put any weight on house price inflation.

3. Optimal monetary policy

The baseline model is estimated for the period 1965:Q1–2006:Q4 by fixing r_Q at zero (see Iacoviello and Neri (2010) for details) and the loss function related parameters are taken from Giannoni and Woodford (2003) (see Table 1). We conduct a 4-dimensional optimization over $(r_R, r_\pi, r_Y, r_Q) \in [0, 1] \times [0, 15] \times [0, 5]^2$ and find the combination that minimizes the loss function $\mathfrak{L}$ in Eq. (5) as well as the region that satisfies the Blanchard–Kahn condition for determinacy.

3.1. Determinacy and uniqueness

According to Blanchard and Kahn (1980), the rational expectations equilibrium has a unique solution if and only if the number of unstable eigenvectors is exactly equal to the number of

[1] Most related work specify a Taylor rule that responds to output gap, instead of output growth, beyond money inflation. Compared to output gap, output growth is first of all much easier to observe. Secondly, Sims (2013) suggests that responding to the growth rate of output is often welfare-improving.

[2] We do not consider the wage inflation in the housing sector, since both types of households contribute most of their labor to the production of consumption goods.

Table 1
Parameter values in a calibrated baseline model.

Structural equations				Shock processes		Loss function	
Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
β	0.9925	η	0.5325	ρ_{AC}	0.9576	λ_π	0.500
β'	0.9700	η'	0.4984	ρ_{AH}	0.9957	λ_w	0.500
j	0.1200	ξ	0.7186	ρ_{AK}	0.9236	λ_y	0.003
μ_c	0.3500	ξ'	0.9960	ρ_j	0.9563	λ_r	0.236
μ_h	0.1000	ϕ_{kc}	17.4921	ρ_z	0.9602		
μ_b	0.1000	ϕ_{kh}	10.7499	ρ_τ	0.8928		
μ_l	0.1000	θ_π	0.8201	ρ_s	0.9750		
X	1.1500	θ_{wc}	0.8165	σ_{AC}	0.0099		
X_{wc}	1.1500	θ_{wh}	0.9216	σ_{AH}	0.0198		
X_{wh}	1.1500	ι_π	0.7314	σ_{AK}	0.0136		
δ_h	0.0100	ι_{wc}	0.0799	σ_j	0.0431		
δ_{kc}	0.0250	ι_{wh}	0.4052	σ_R	0.0032		
δ_{kh}	0.0300	ζ_{kc}	0.8060	σ_z	0.0159		
m	0.8500	γ_{AC}	0.0032	σ_τ	0.0330		
ϵ	0.3417	γ_{AH}	0.0008	σ_p	0.0047		
ϵ'	0.5913	γ_{AK}	0.0027	σ_s	0.0339		
α	0.7936						

Note: Parameter λ_y is obtained as the value of 0.048 in Giannoni and Woodford (2003) divided by 16, since we are using quarterly data for each variable throughout this paper.

non-predetermined variables. By searching over $(r_R, r_\pi, r_Y, r_Q) \in [0, 1] \times [0, 15] \times [0, 5]^2$, we find that $r_\pi > 1$ is a sufficient condition for the equilibrium to be determinate. For $r_\pi \leq 1$, however, the equilibrium becomes indeterminate under any combination of (r_R, r_Y, r_Q). These results are consistent with the finding of Bullard and Mitra (2002) that determinacy is guaranteed by $r_\pi > 1$, except for a subtle difference. By considering a contemporaneous interest rate rule that reacts to inflation and output gap in a simple DSGE model with sticky prices, Bullard and Mitra (2002) find that a relatively low value of $r_\pi < 1$ can be "compensated" by choosing a sufficiently large value for r_Y for the equilibrium to be determinate. On the contrary, we do not find any (r_R, r_Y, r_Q) combination that supports the determinacy for $r_\pi \leq 1$ under the model considered in this paper.[3]

3.2. Optimal policy rule

We examine the optimal interest rate rule under different scenarios and compare the optimal rule with its estimated counterpart. Let $V_\pi = var(\ln \pi_t - \iota_\pi \ln \pi_{t-1})$, $V_w = var(\ln \pi_{wc,t} - \iota_{wc} \ln \pi_{t-1})$, $V_y = var(\ln GDP_t - \ln(G_C GDP_{t-1}))$, and $V_R = var(\ln R_t - \ln \overline{rr})$ denote the variance components in the loss function $\mathfrak{L}$. Similarly, we define the variability of house price inflation as $V_q = var(\ln q_t - \ln(G_Q q_{t-1}))$. We also define $r_\pi^* = (1 - r_R)r_\pi$, $r_Y^* = (1 - r_R)r_Y$, and $r_Q^* = (1 - r_R)r_Q$. The statistics and parameter values associated with both the estimated and the optimal rules are reported in Table 2.

Since the interest rate rule (I) is assumed to react to money inflation and output growth only in the baseline model, the parameter r_Q is restricted at zero. The persistence in the nominal interest rate, r_R, is estimated to be 0.61 and the estimates of r_π^* and r_Y^* are 0.55 and 0.19. When we relax the zero restriction, the estimated rule also does not respond much to house price inflation.

The optimal rule suggests that, in order to achieve macroeconomic stability, the rule should be more persistent and more responsive to both money inflation and output growth. More importantly, house price inflation is another variable that should be targeted. Comparing to the estimated rule, implementing the optimal rule reduces the loss by more than 70%. Moreover, the volatility of house price inflation under the optimal rule is about one-third less than what is implied by the data.[4]

We also consider the backward-looking and forward-looking versions of the policy rule:

$$\text{Rule (II):} \quad R_t = R_{t-1}^{r_R} \pi_{t-1}^{(1-r_R)r_\pi} \left(\frac{GDP_{t-1}}{G_C GDP_{t-2}}\right)^{(1-r_R)r_Y} \times \left(\frac{q_{t-1}}{G_Q q_{t-2}}\right)^{(1-r_R)r_Q} \overline{rr}^{1-r_R} \frac{u_{R,t}}{s_t}, \tag{6}$$

$$\text{Rule (III):} \quad R_t = R_{t-1}^{r_R} (E_t \pi_{t+1})^{(1-r_R)r_\pi} \left(\frac{E_t GDP_{t+1}}{G_C GDP_t}\right)^{(1-r_R)r_Y} \times \left(\frac{E_t q_{t+1}}{G_Q q_t}\right)^{(1-r_R)r_Q} \overline{rr}^{1-r_R} \frac{u_{R,t}}{s_t}. \tag{7}$$

As is shown in Table 2, neither of the two estimated rules responds much to house price inflation. However, in order to achieve macroeconomic stability, the policymaker should significantly target house price inflation under both rules.[5]

Next, we examine the robustness of the optimal rule in our baseline model to a list of important parameters in Iacoviello and Neri (2010). When varying one of these parameters, we keep all other parameters at their baseline values. Table 3 reports the results.

The parameter α measures the labor income share of patient households. The optimal rule parameters r_π^* and r_Y^* are relatively robust. As α drops to 0.2 or when most of the households in the economy are impatient, the optimal rule becomes more responsive to house price inflation. The parameter j is the steady-state value of the housing preference shock. The baseline value $j = 0.12$ is calibrated to match the ratio of business capital to annual GDP of about 2.1 and the ratio of housing wealth to GDP of about 1.35.

[3] A 4-dimensional graph of the determinacy region is not informative, since the determinacy region is simply $r_\pi > 1$.

[4] Our objective loss function does not take into consideration the variability of house price inflation. Intuition and preliminary quantitative attempts suggest that the optimal rule responds more to house price inflation when stabilizing house price is among the goals of the policymaker. Our main argument is that the optimal interest rate rule responds to house price inflation even when the stabilization of house price is not a goal itself.

[5] Under the forward-looking policy rule (III), a 4-dimensional optimization over (r_R, r_π, r_Y, r_Q) yields unreasonable results that the optimal rule is highly persistent (with the inertia parameter close to 1) and responding to price inflation only. For this case, we fix the inertia parameter at its estimated value 0.59 and conduct an optimization over (r_π, r_Y, r_Q).

Table 2
Estimated and optimal interest rate rules.

Policy rule	$r_Q = 0$	Statistics						Parameter values			
		V_π	V_w	V_y	V_R	V_q	$\mathfrak{L}$	r_R	r_π^*	r_Y^*	r_Q^*
Estimated (I)	YES	0.0221	0.0892	0.1933	0.0871	0.2675	0.0768	0.61	0.55	0.19	
Estimated (I)	NO	0.0229	0.0885	0.1827	0.0839	0.2510	0.0760	0.61	0.55	0.18	0.02
Optimal (I)		0.0143	0.0238	0.1038	0.0087	0.1857	0.0214	0.71	2.84	1.08	0.26
Estimated (II)	YES	0.0365	0.1091	0.2733	0.1040	0.3259	0.0982	0.68	0.43	0.10	
Estimated (II)	NO	0.0375	0.0906	0.2413	0.0714	0.3001	0.0816	0.68	0.42	0.11	0.01
Optimal (II)		0.0125	0.0202	0.1493	0.0192	0.2342	0.0213	0.78	1.54	0.40	0.09
Estimated (III)	YES	0.0396	0.1429	0.1948	0.1577	0.2916	0.1291	0.59	0.61	0.04	
Estimated (III)	NO	0.0435	0.1362	0.1884	0.1469	0.2902	0.1251	0.57	0.65	0.05	0.02
Optimal (III)		0.0163	0.0458	0.2998	0.0127	0.3890	0.0346	0.59	3.31	1.47	0.27

Note: Policy rules (I), (II), (III) refer to the contemporaneous rule in Eq. (4), the backward-looking rule in Eq. (6), and the forward-looking rule in Eq. (7), respectively. All statistics are multiplied by 1000. The loss function $\mathfrak{L}$ is a weighted sum of V_π, V_w, V_y, and V_R.

Table 3
Sensitivity of the optimal interest rate rule.

	Posited value	Statistics						Optimal values			
		V_π	V_w	V_y	V_R	V_q	$\mathfrak{L}$	r_R	r_π^*	r_Y^*	r_Q^*
α	0.20	0.0140	0.0303	0.1001	0.0103	0.1397	0.0249	0.48	3.27	1.13	0.50
	0.40	0.0141	0.0272	0.1024	0.0090	0.1560	0.0231	0.59	2.89	1.02	0.37
	0.60	0.0142	0.0253	0.1037	0.0083	0.1706	0.0220	0.71	2.82	1.03	0.31
	0.79[a]	0.0143	0.0238	0.1038	0.0087	0.1857	0.0214	0.71	2.84	1.08	0.26
	1.00	0.0145	0.0227	0.1030	0.0091	0.1964	0.0210	0.70	3.06	1.20	0.25
j	0.06	0.0144	0.0235	0.0952	0.0087	0.1922	0.0213	0.70	2.90	1.16	0.25
	0.12[a]	0.0143	0.0238	0.1038	0.0087	0.1857	0.0214	0.71	2.84	1.08	0.26
	0.18	0.0143	0.0243	0.1156	0.0084	0.1719	0.0217	0.74	3.01	1.04	0.37
	0.24	0.0143	0.0246	0.1302	0.0090	0.1696	0.0219	0.72	2.83	0.90	0.38
	0.30	0.0142	0.0249	0.1467	0.0093	0.1667	0.0222	0.72	2.72	0.80	0.40
m	0.65	0.0144	0.0234	0.1033	0.0091	0.1865	0.0214	0.70	2.82	1.06	0.30
	0.75	0.0144	0.0235	0.1028	0.0090	0.1923	0.0214	0.72	2.80	1.07	0.24
	0.85[a]	0.0143	0.0238	0.1038	0.0087	0.1857	0.0214	0.71	2.84	1.08	0.26
	0.95	0.0142	0.0248	0.1048	0.0082	0.1640	0.0218	0.69	3.04	1.12	0.31
	1.05	0.0142	0.0272	0.1078	0.0069	0.0966	0.0227	0.72	3.62	1.22	0.68
θ_π	0.00	0.0073	0.0144	0.3146	0.0261	0.3556	0.0180	0.76	3.48	0.07	0.09
	0.20	0.0064	0.0144	0.2449	0.0162	0.2933	0.0150	0.78	3.06	0.21	0.08
	0.40	0.0067	0.0148	0.1946	0.0136	0.2513	0.0145	0.83	2.37	0.26	0.08
	0.60	0.0092	0.0161	0.1483	0.0135	0.2203	0.0163	0.85	1.96	0.37	0.09
	0.82[a]	0.0143	0.0238	0.1038	0.0087	0.1857	0.0214	0.71	2.84	1.08	0.26
θ_{wc}	0.00	0.0140	0.4983	0.2886	0.0863	0.3323	0.2774	0.00	1.54	0.00	0.00
	0.20	0.0139	0.2672	0.2999	0.0830	0.3423	0.1610	0.00	1.62	0.00	0.00
	0.40	0.0139	0.1313	0.3158	0.0828	0.3576	0.0931	0.00	1.74	0.00	0.00
	0.60	0.0136	0.0634	0.2742	0.0601	0.2936	0.0535	0.14	1.66	0.08	0.11
	0.82[a]	0.0143	0.0238	0.1038	0.0087	0.1857	0.0214	0.71	2.84	1.08	0.26
θ_{wh}	0.00	0.0143	0.0250	0.1069	0.0103	0.1805	0.0224	0.78	2.22	0.73	0.35
	0.20	0.0143	0.0250	0.1065	0.0101	0.1806	0.0224	0.80	2.25	0.74	0.35
	0.40	0.0143	0.0249	0.1063	0.0103	0.1796	0.0223	0.75	2.27	0.75	0.34
	0.60	0.0143	0.0248	0.1069	0.0100	0.1823	0.0222	0.75	2.30	0.78	0.32
	0.92[a]	0.0143	0.0238	0.1038	0.0087	0.1857	0.0214	0.71	2.84	1.08	0.26

[a] Denotes the baseline model. All statistics are multiplied by 1000. The loss function $\mathfrak{L}$ is a weighted sum of V_π, V_w, V_y, and V_R.

As we increase the value of j or when institutional changes shift preference toward housing, the optimal rule responds more and more to house price inflation. The parameter m denotes the loan-to-value ratio. The optimal rule parameters are insensitive to the value of m when $m < 1$. However, if impatient households are allowed to borrow more than the expected value of their housing ($m > 1$), house price becomes more volatile. The optimal rule is hence more sensitive to house price inflation.

The parameter θ_π denotes price stickiness. As prices become flexible ($\theta_\pi = 0$), the optimal rule becomes more responsive to money inflation but less responsive to output growth and house price inflation. The parameters θ_{wc} and θ_{wh} stand for the wage stickiness in the consumption and housing sectors. When wages are not highly sticky in the consumption sector, the optimal rule is not responsive to either output growth or house price inflation. Moreover, the response to money inflation is much smaller in magnitude compared to that in the baseline model. The loss is considerably higher than that in any other cases, suggesting that it is hard to achieve macroeconomic stability under flexible wages ($\theta_{wc} = 0$) and sticky prices ($\theta_\pi = 0.82$).

To conclude, the interest rate rule should respond to house price inflation under a variety of scenarios, except for the case of low wage stickiness in the consumption sector. Also, even though the loss function does not include house price volatility, a stronger response to house price inflation r_Q always results in a lower value of V_q. This feature indicates an even stronger response to house price inflation in the optimal rule when V_q is in the loss function.

4. Conclusion

Historical data imply that monetary policy rule reacts only to money inflation and GDP growth but not to house price inflation. In a DSGE framework with housing market spillovers, we examine whether the interest rate rule should respond to house price inflation in order to minimize the policymaker's loss. We find that, even when stabilizing house price is *not* one of the goals of the policymaker, it is optimal to implement an interest rate rule that responds to house price inflation.

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