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Monetary Policy and House Price Volatility

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Abstract

House prices are of special importance for monetary policy since their sudden falls are usually associated with credit crunch followed by long-lasting and painful recessions. Despite several spectacular episodes of such events, each time house prices exhibit long-lasting growth trend with little volatility around it, it is argued that this pattern is a "new normal". This paper shows that a central bank following this view would increase the volatility of inflation and output as compared to a policy that assumes high volatility of house prices. In the former case the monetary authority would conduct too accommodative monetary policy during abrupt house price expansions significantly increasing output and inflation fluctuations. In the latter situation, in turn, the policy would work well irrespective of the realized house price volatility.

Keywords: monetary policy, house prices, model uncertainty

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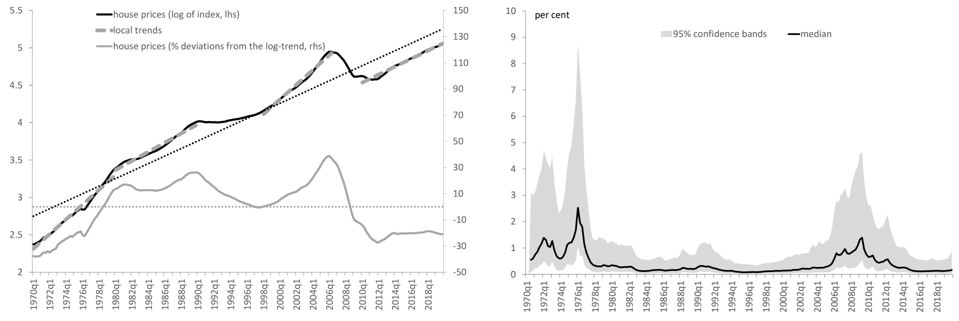
1 Introduction

House prices are of special importance for monetary policy since their reversals are usually associated with credit crunch followed by long-lasting and painful recessions. Therefore, many papers have investigated the optimal response of monetary policy to asset prices (see Cecchetti, 2008; Gilchrist and Leahy, 2002; Borio and Lowe, 2002; Bernanke and Gertler, 2001) and central bankers seem to have reached the consensus that housing market indicators are important in assessing economic imbalances (see Yellen, 2014; Zhu, 2014). At the same time house price dynamics stands out from other assets as it has more momentum and exhibits long-run reversal (Piazzesi and Schneider, 2016). Despite the progress in understanding interactions between asset markets and the real economy as well as common knowledge about several spectacular episodes of house price collapses, often when they follow closely a local trend, some agents argue that this pattern is a long-lasting one. For instance, Federal Deposit Insurance Corporation in its report in 2005 claimed that house price burst is likely to be avoided (see e.g. report "U.S. Home Prices: Does Bust Always Follow Boom?" available at: `https://www.fdic.gov/bank/analytical/fyi/021005fyi.pdf`).

To illustrate why such opinions might have emerged, the left panel of Figure 1 presents house prices (in natural logarithms) in the United States in last 50 years against several linear trends. Even though one can ex-post identify a long-run growth trend, it is clear that there were also some local tendencies that were very different from it. While assessing developments in house prices in the real time some observers might have perceived those local trends with little volatility around them to be the "new normal".

Figure 1: Trends in house prices and deviations from them



Left plot presents data on home prices obtained from Fred (S&P/Case-Shiller 20-City Composite Home Price Index), its linear trend and deviations from the trend. Right plot presents median residuals from Bayesian time-varying-parameter univariate model of house price deviations from the trend. Shaded area depicts 95% confidence interval.

In order to formalize the motivation, let me account for time-varying volatility and trends in house prices estimating a simple time-varying parameter autoregressive model.Computations are conducted in BEAR toolbox (Dieppe et al., 2016). Periods of stable growth around the time-varying trends are reflected in low volatility of residuals (housing shocks), as the right panel of Figure 1 presents. They dominated in 1980s, 1990s and the first half of 2000s. Thus, during these long periods of time agents might have believed that house prices followed trend closely and housing shock volatility was low. On the other hand, just after collapses in house prices as in 1970s or in 2008 they might have perceived the volatility of housing shock to be large.

The evidence of local trends and time-varying housing shock volatility together with the importance of house prices for business cycle dynamics and the optimal monetary policy motivate this paper. It assumes that the central bank impacts only cyclical component of the house prices defined as the house price gap, i.e. the difference between observed prices and the long-run trend (as it is the case for other variables such as output gap), it asks what the monetary policy should assume about housing shock volatility. To the best of my knowledge this is the first paper to analyze the optimal monetary policy under two assumptions about housing shock volatility.

Clearly, there are other factors that impact house prices apart from its past values and residuals. Therefore, to address the research question the paper builds on the cornerstone macroeconomic model with housing market from a seminal paper by Iacoviello (2005). In particular, in this model I analyze two extreme assumptions about the volatility of housing shock. On the one hand the modeling framework follows the original contribution of Iacoviello (2005) in which the housing shock drives house price gap substantially from the steady state. On the other hand, I investigate the same framework without the housing shock implying that house price gap fluctuates moderately around the steady state driven by remaining shocks. This reflects the argument that the low volatility of prices around the trend is a new normal. I find the optimal policy rules both in the model with the housing shock and in its counterpart when the shock is absent. Then, I compare the effectiveness of these rules in each model by looking at the loss function value of the “correct” (optimal in this model) and “incorrect” (optimal in the other model) policy rules in both cases treating a difference between them as a cost of the incorrect assumption on house price volatility.

The main result of the paper (and its value added) is to show that the central bank should follow the policy rule optimized in the model with the housing shock. It should not be tempted to conjecture no housing shock (and thus the low volatility of house price gap) since in this case it would conduct too loose monetary policy that would result in increasing output and inflation fluctuations if the housing shock hits the economy (and the volatility of house prices turns out to be large). In the opposite case, i.e. being wrong in assuming the presence of housing shock, the costs of making the incorrect assumption will be relatively small.

As the key issue in the paper could be seen as the measurement of the house price gap, it relates to articles investigating the performance of policy rules in macroeconomic models amidst uncertainty concerning measurement of other variables. This strand of literature was surveyed by Taylor and Williams (2010), thus here I present only most relevant positions. In particular, the uncertainty surrounding output gap has been investigated in a number of studies which were looking into its impact on Taylor rule coefficients and optimal monetary policy design. Billi (2020) shows that, given output gap uncertainty the monetary should focus either on stabilizing inflation (in the absence of the zero lower bound; ZLB) or nominal GDP (under ZLB). Similarly, output gap uncertainty led Rudebusch (2002) to advise nominal GDP targeting. McCallum (2001) argues that potential error resulting from using the wrong measure of output gap (more precisely, he assumes that the correct is McCallum-Nelson measure whereas the central bank assumes the measure based on linear detrending) leads to high volatility of inflation and output that supports the view that it is undesirable to respond strongly to the output gap. Orphanides et al. (2000) find that the current estimates of historical output gap and the real time estimates show significant differences in the United States in 1966Q1 – 1994Q4 with mean error equal to 3.2 p.p. (underestimation of real-time output gaps) and root mean squared error equal to 4.2 p.p.

Rudebusch (2001) attempts to match the historical policy rule with the optimal rule by incorporating uncertainty into the latter and by examining plausible variations in the policymaker's model and preferences. Smets (2002) finds that output gap uncertainty reduces the response of the Taylor rule to the current estimated output gap relative to the current inflation. It may partially explain why the estimated coefficients in the Taylor rule are usually lower than those obtained from optimal control exercises. In case of interest rates, Edge et al. (2010) found that its natural level is an important source of uncertainty, while regarding exchange rate Leitemo and Soderstrom (2005) showed that the Taylor rule may suffice to stabilize a small open economy in which there is uncertainty about deviations from uncovered interest parity. This paper adds to existing literature by analyzing the impact of uncertainty concerning house price gap on the performance of the optimal monetary policy.

The rest of the paper is structured as follows. Section 2 briefly presents the model and Section 3 describes calibration and optimization of the policy rule. Results are presented in Section 4, whereas Section 5 concludes.

2 The model

In simulations I apply a medium-scale dynamic stochastic general equilibrium model with a housing sector building on the seminal paper by Iacoviello (2005). This is a relatively simple framework that entails a financial friction relevant for research question of this paper, i.e. collateral constraint. It constitutes the cornerstone of more complex models that analyze the interactions between house prices and macroeconomic variables. Thanks to its simplicity and impact on literature, this set-up provides a good environment to analyze and better understand the interaction between the optimal monetary policy, housing shock and house price volatility, that is at the heart of this paper.

The economy is populated by patient and impatient households as well as by entrepreneurs. Housing serves as a collateral for credit constrained households and entrepreneurs. This specification ensures a link between lending and house prices in the economy as well as a role of housing in the production process. There are also retailers that give rise to nominal stickiness and the central bank that follows the standard Taylor rule. Households purchase consumption goods and housing as well as provide labor input. Entrepreneurs spend on consumption goods and produce intermediate goods using technology, labor, capital, and housing. Their output is differentiated at no cost and sold to aggregators by retailers who act in a monopolistically competitive market with time-dependent sticky prices. Aggregators combine differentiated intermediary goods into one final good.

The model was originally estimated with four time series for the US: GDP, inflation, house prices and interest rates. There are also four shocks in the model: technology, mark-up, housing preferences and interest rate. They represent the minimum set of disturbances necessary to estimate this framework as they may be described as respectively real, nominal, policy and asset price disturbances. The model is log-linearized around the steady state. The following subsections briefly introduce main agents and their economic problems.

2.1 Patient households

Patient households discount future with the factor β', calibrated so that they save in the equilibrium. The representative patient household maximizes lifetime utility:

$$E_0 \sum_{t=0}^{\infty} (\beta')^t \left[\ln c_t^{'} + j_t \ln h_t^{'} + \chi \ln \frac{M_t^{'}}{P_t} - \frac{l_t^{'\eta}}{\eta} \right], \tag{1}$$

where χ describes the weight on real money balance in the utility function and η labor supply aversion. Households decide on consumption $c_t^{'}$, housing $h_t^{'}$ (that has a real price equal to q_t), real money balance $M_t^{'}/P_t$ (with $M_t^{'}$ denoting nominal money holdings and P_t final goods price), and labor supply $l_t^{'}$ (receiving real wage $w_t^{'}$). Furthermore, they can borrow $b_t^{'}$ at a nominal interest rate R_t. Patient households face the housing preference disturbance j_t, that follows an AR(1) process and is subject to a housing shock. They own retail firms and receive a stream of (nominal) dividends $\Pi_t^{'}$ (it is assumed that only patient households own firms). They may also get (nominal) lump-sum transfers $T_t^{'}$ from the government. As a result, they are restricted by the following budget constraint (in real terms):

$$c_t^{'} + q_t(h_t^{'} - h_{t-1}^{'}) + \frac{R_{t-1}}{\pi_t} b_{t-1}^{'} + \frac{M_t^{'} - M_{t-1}^{'}}{P_t} = b_t^{'} + l_t^{'} w_t^{'} + \frac{\Pi_t^{'}}{P_t} + \frac{T_t^{'}}{P_t}, \tag{2}$$

where $\pi_t = P_t/P_{t-1}$ denotes gross inflation rate in period t. Note that variables with prime ($'$) refer to patient households, the variables with double-prime ($''$) – to impatient households, while variables without any of these notations – to entrepreneurs. Capital letters are used for nominal variables.

2.2 Impatient households

Impatient households borrow using housing as collateral. Their discount factor is lower than that of their patient peers, $\beta^{''} < \beta^{'}$, so that the collateral constraint is binding (without this assumption they could accumulate enough wealth to become self-financed and make collateral constraint non-binding). The representative impatient household maximizes:

$$E_0 \sum_{t=0}^{\infty} \beta^{''t} \left[\ln c_t^{''} + j_t \ln h_t^{''} + \chi \ln \frac{M_t^{''}}{P_t} - \frac{l_t^{''\eta}}{\eta} \right] \tag{3}$$

subject to the flow of funds:

$$c_t^{''} + q_t(h_t^{''} - h_{t-1}^{''}) + \frac{R_{t-1}}{\pi_t} b_{t-1}^{''} + \frac{M_t^{''} - M_{t-1}^{''}}{P_t} = b_t^{''} + l_t^{''} w_t^{''} + \frac{T_t^{''}}{P_t} \tag{4}$$

and the borrowing constraint:

$$b_t^{''} \leq m^{''} E_t(q_{t+1} h_t^{''} \pi_{t+1}/R_t), \tag{5}$$

where $m^{''}$ is a parameter denoting loan-to-value ratio for impatient households. Since the model is calibrated so that impatient households always hit the constraint, inequality 5 becomes equality.

2.3 Entrepreneurs

Entrepreneurs run production firms. They maximize utility from consumption choosing its level as well as capital, housing, and labor that are used in a production process:

$$E_0 \sum_{t=0}^{\infty} \beta^t \ln c_t. \tag{6}$$

The production function is given by:

$$y_t^w = a_t k_{t-1}^{\mu} h_{t-1}^{\nu} l_t^{'\alpha(1-\mu-\nu)} l_t^{''(1-\alpha)(1-\mu-\nu)}, \tag{7}$$

where y_t^w denotes output, a_t measures productivity and follows an $AR(1)$ process subject to a productivity shock, k_t denotes capital that depreciates at rate δ and is created at the end of period t, while α measures the wage share of patient households. Parameters μ and ν are the shares of respectively capital and housing in the production. Capital is subject to quadratic adjustment costs. Furthermore, entrepreneurs are constrained by the flow of funds:

$$\frac{y_t}{X_t} + b_t = c_t + q_t(h_t - h_{t-1}) + \frac{R_{t-1}b_{t-1}}{\pi_t} + w_t^{'}l_t^{'} + w_t^{''}l_t^{''} + i_t + \zeta_{K,t}, \tag{8}$$

where $X_t = P_t/P_t^w$ is a markup of final over intermediate goods with P_t^w being a price charged by entrepreneurs and i_t stands for investments. Adjustment costs for installing capital are given by $\zeta_{K,t} = \psi\left(\frac{i_t}{k_{t-1}} - \delta\right)\frac{k_{t-1}}{2\delta}$, while capital evolves according to $k_t = (1-\delta)\,k_{t-1} + i_t$. Parameters ψ and δ drive the pace of capital adjustment and depreciation. Mark-up is subject to an AR(1) process driven by a mark-up shock. Similarly to impatient households, entrepreneurs also face the collateral constraint and their discount factor is lower than that of patient households ($\beta < \beta'$):

$$b_t \leq mE_t(q_{t+1}h_t\pi_{t+1}/R_t). \tag{9}$$

2.4 Retailers and aggregators

Final goods, y_t^f, that are consumed and invested, are assembled by perfectly competitive aggregators who buy goods $y_t(z)$ at price $P_t(z)$ from retailers. Aggregators maximize profits

$$P_t y_t^f - \int P_t(z) y_t(z) dz$$

subject to the Dixit-Stiglitz aggregating function characterized by the parameter ϵ:

$$y_t^f = \left(\int y_t(z)^{(\epsilon-1)/\epsilon} dz\right)^{\epsilon/(\epsilon-1)}.$$

The solution provides the demand function for retailers:

$$y_t(z) = \left(\frac{P_t\,(z)}{P_t}\right)^{-\epsilon} y_t^f.$$

There is a continuum of retailers $z \in [0;1]$ who purchase from entrepreneurs homogeneous intermediate goods y_t^w at the price P_t^w in a competitive market. Retailers, in turn, mark these goods at no cost and sell them as $y_t(z)$ at the price $P_t(z)$ to aggregators. Each retailer chooses his price subject to the demand curve considering the Calvo probability of being able to change the price that equals $1-\theta$. Thus, retailers solve:

$$\max_{P_t^{new}(z), \{y_{t+j}(z)\}_{j=0}^{\infty}} E_t \sum_{j=0}^{\infty} (\theta)^j \Lambda_{t+j} \left(\frac{P_t^{new}\,(z)}{P_{t+j}} - \frac{P_{t+j}^w}{P_{t+j}}\right) y_{t+j}(z),$$

where $P_t^{new}(z)$ is the price set by the optimizing firm and $\Lambda_{t+j} = \beta^j \frac{c_t^{'}}{c_{t+j}^{'}}$ is the patient household stochastic discount factor. Profits of retailers are given by $\Pi_t^{'} = (P_t - P_t^w)\, y_t^f$ and are rebated back to patient households. Given the way price stickiness is introduced, aggregated price index evolves according to:

$$P_t = \left(\theta P_{t-1}^{1-\epsilon} + (1-\theta)\left(P_t^{new}\right)^{1-\epsilon}\right)^{1/(1-\epsilon)}.$$

2.5 The central bank

The central bank is assumed to conduct monetary policy according to the standard backward-looking Taylor rule that includes also house prices.

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\gamma_R} \left(\left(\frac{\pi_{t-1}}{\pi}\right)^{(1+\gamma_\pi)} \left(\frac{y_{t-1}}{y}\right)^{\gamma_y}\right)^{(1-\gamma_R)} \left(\frac{q_{t-1}}{q}\right)^{\gamma_Q} e_{R,t}, \tag{10}$$

where $e_{R,t}$ are i.i.d. normal innovations (interest rate shocks) and γ_R, γ_π, γ_y and γ_Q are parameters in Taylor rule that depict respectively its persistence and responses to inflation, output and house prices. The inclusion of additional potential response of monetary policy to house prices differentiates this paper from the Iacoviello (2005) baseline specification and is motivated by the special role of house prices in the economy and – particularly in the context of the research question – for the monetary policy. If the central bank cares about potential mistake it can make with respect to the assessment of house price gap volatility, it should also at least be able to react to these prices.

3 Calibration and optimization

The model described in the previous section is calibrated in two extreme versions that reflect uncertainty concerning the presence of the housing shock (Table 1). The first is the model with the housing shock which is identical to the Iacoviello (2005) framework. It includes 4 types of exogenous disturbances: productivity, mark-up, housing and interest rate. As the variance decomposition (Table 2) shows, the housing shock is to a large extent responsible for volatility in house prices. In the second model, the housing shock is switched off. Therefore, some parameters are recalibrated to obtain two comparable models as Subsection 3.1 explains. Moreover, parameters in the policy rule in both variants are optimized to abstract from possible inadequate historical monetary policy from the model's perspective as Subsection 3.2 describes. Since the calibration hinges on the seminal contribution by Iacoviello (2005), one can rightfully argue that it omits a large part of data available since the paper was published, in particular – it does not include the Global Financial Crisis period. In order to verify if and how longer time series would affect the model parametrization, I

Table 1: Calibrated parameters (the same in the model with and without the housing shock)

Description	Parameter	Value
Discounting rates:		
Patient households	β'	0.99
Impatient households	β''	0.95
Entrepreneurs	β	0.98
Preferences:		
Weight on housing services	j	0.1
Labor supply aversion	η	1.01
Factors of production:		
Patient households wage share	α	0.64
Variable capital share	μ	0.3
Housing share	ν	0.03
Other production parameters:		
Variable capital adjustment cost	ψ	2
Capital depreciation rate	δ	0.03
Sticky prices		
Steady-states gross markup	X	1.05
Probability of not changing prices	θ	0.75
Loan-to-values		
Entrepreneur	m	0.89
Household	m''	0.55
Autocorrelation of shocks		
Technology	ρ_A	0.03
Mark-up	ρ_u	0.59
Standard deviation of shocks		
Technology	σ_A	2.24
Mark-up	σ_u	0.17

Table 2: Variance decomposition of selected variables

	Model with the housing shock					Model without the housing shock			
	technology	mark-up	housing	policy		technology	mark-up	housing	policy
$\hat{y}$	1.01	9.79	26.28	62.93	$\hat{y}$	0.81	7.85	0	91.34
$\hat{\pi}$	30.33	31.80	20.86	17.01	$\hat{\pi}$	32.65	34.23	0	33.12
$\hat{q}$	3.74	1.88	89.54	4.85	$\hat{q}$	26.00	13.05	0	60.95
$\hat{R}$	10.27	10.70	6.94	72.09	$\hat{R}$	6.79	7.07	0	86.14

apply Bayesian methods to estimate the log-linearized approximation of both models: with and without the housing shock around the steady state. Including data on real GDP, nominal house prices (S&P/Case-Shiller 20-City Composite Home Price

Index), Fed fund rate and PCE inflation in the United States in 1987q2-2020q1 downloaded from Fred I run standard estimation procedure using the Metropolis-Hastings algorithm with 2 chains (each consisting of 200 000 draws) and burn the first half of each. Basing on Brooks and Gelman (1998) diagnostic tests I confirm the stability and convergence of the obtained parameters.

Prior assumptions that follow Iacoviello (2005) calibration together with posterior estimates are presented in Table 3. Three parameter values stand out. First, household loan-to-value ratio is higher in the estimated model than in the original paper which implies that the financial friction is stronger in the extended sample. This should not come as a surprise given that it covers the worst financial crisis in advanced economies since the Great Depression. Second and third, the wage share of patient households and productivity shock variance are significantly higher in the estimated model with the housing shock and lower in the estimated model without the housing shock as compared with its prior.

As a robustness I verify that using models with estimated parameters (instead of the calibration based on Iacoviello, 2005) does not change qualitatively the paper conclusions. This notwithstanding, in what follows I keep the parameter values from the seminal paper. First, it is a better-grounded calibration in literature and does not require choosing the model estimation (with/without the housing shock) to set the value of some parameters that should be robust to policy changes (such as wage share of households). Second, the proper estimation with Bayesian methods based on the current state-of-the-art techniques would require utilizing much larger model or applying occasionally constraint assumption which are beyond the scope of this paper (see e.g. Guerrieri and Iacoviello, 2017; Iacoviello and Neri, 2010).

3.1 Calibration

Both models – with and without housing shock – share the vast majority of parameter values (Table 4), with the exception of shock variances and autoregressive parameters that are recalibrated in the model without the housing shock so that it can be meaningfully compared with the model with the housing shock. Since in the model without the housing shock it is effectively assumed that the housing shock variance equals zero, main macroeconomic variables are less volatile than in the model with the housing shock ceteris paribus. This feature would be undesirable as one could expect models to be observationally equivalent in the same way as both model variants were estimated on the same set of variables as explained in the previous section. To address this issue I adjust the interest rate shock variance in the model without the housing shock to obtain output and inflation volatilities as close to their counterparts from the model with the housing shock as possible (see Table 5).

Table 3: Estimated parameters

Parameter	Calibration	prior mean	model with housing shock			model without housing shock			prior type	prior std dev
			post mean	90% HPD interval		post mean	90% HPD interval			
γ_y	0.13	0.1	0.1144	0.0804	0.1489	0.0315	0.0109	0.0522	normal	0.025
γ_π	0.27	0.25	0.3057	0.2288	0.3843	0.2595	0.1809	0.3353	normal	0.05
γ_R	0.73	0.7	0.6624	0.6181	0.7076	0.5689	0.5253	0.6136	beta	0.05
θ	0.75	0.75	0.7505	0.5923	0.9144	0.7516	0.5905	0.9103	beta	0.1
m	0.89	0.8	0.9119	0.8832	0.9401	0.8340	0.7225	0.9367	beta	0.1
m''	0.55	0.5	0.9138	0.8713	0.9529	0.7477	0.6690	0.8278	beta	0.1
α	0.64	0.64	0.8176	0.7751	0.8589	0.3625	0.3152	0.4106	beta	0.05
ν	0.03	0.03	0.0088	0.0032	0.0143	0.0848	0.0475	0.1251	beta	0.025
μ	0.3	0.3	0.3510	0.2506	0.4394	0.5269	0.4528	0.5963	beta	0.05
ψ	2	2	2.0142	1.8516	2.1756	2.0025	1.8398	2.1687	normal	0.1
ρ_A	0.03	0.05	0.0677	0.0173	0.1159	0.0768	0.0189	0.1305	beta	0.025
ρ_u	0.59	0.6	0.6597	0.5894	0.7282	0.8359	0.8081	0.8650	beta	0.05
ρ_j	0.85	0.8	0.9243	0.9164	0.9319	N/A	N/A	N/A	beta	0.05
σ_A	2.24	2.2	3.5329	2.7498	4.3524	0.9254	0.7661	1.0757	inv gamma	1
σ_u	0.17	0.2	0.1816	0.1432	0.2192	0.1999	0.1471	0.2522	inv gamma	0.1
σ_R	0.29	0.4	0.1724	0.1523	0.1907	0.2011	0.1778	0.2238	inv gamma	0.1
σ_j	24.89	25	23.4563	22.0331	24.8859	N/A	N/A	N/A	inv gamma	1

Table 4: Calibrated parameters (different values in the model with and without housing shock)

Description		Model with the housing shock	Model without the housing shock
Autocorrelation of shocks			
Housing	ρ_j	0.85	0
Standard deviation of shocks			
Monetary policy	σ_R	0.29	0.39
Housing	σ_j	24.89	0

Table 5: Volatility of selected variables over business cycle

Description	Variable	Model with the housing shock	Model without the housing shock
Output	$\hat{y}$	1.8565	2.0723
Inflation	$\hat{\pi}$	0.4822	0.4647
Housing prices	$\hat{q}$	2.6030	0.9870
Nominal interest rates	$\hat{R}$	0.3987	0.4813

I do not change other parameters as they are supposed to be robust to a policy change (Table 1). I choose to manipulate the volatility of interest rate assuming that the central bank beliefs about the housing shock should not affect the assessment of volatility of the productivity or mark-up shocks. It would rather influence the perception of the central bank's own deviations from policy rule. Furthermore, as it turns out in robustness check, this assumption does not affect the main result which holds without recalibration of the model without the housing shock.

3.2 Monetary policy optimization

The parameters in monetary policy rules in both models are optimized using numerical algorithm. I repetitively run Optimal Simple Rule (OSR) in Dynare taking the optimized parameters from the previous step as the initial values for next optimization step. This procedure is repeated unless a decrease in loss function between steps is less than 0.0001 which corresponds to drop of 0.01 percentage point of inflation gap and $0.01/\lambda$ percentage points of output gap. This approach allows to avoid reaching local maxima or unstable policy rule parametrization, i.e. policy from the next step is associated with lower value of loss function as compared with the previous step (which was not always the case for using only one iteration) and Blanchard-Kahn conditions are usually satisfied. This procedure also gives superior results to the grid search.

As the starting point for the parameter optimization in the Taylor rule I take their values from Iacoviello (2005). To check the robustness of results I also performed several exercises such as optimization with different initial values of parameters in the Taylor rule or simulations for different steps between λ. None of these tests did change the main result of the paper. The performance of a policy rule is assessed with a standard loss function in which the central bank minimizes the variance of inflation and output gap with weights of, respectively, 1 and λ:

$$L = \sigma_{\hat{\pi}}^2 + \lambda \sigma_{\hat{y}}^2 \tag{11}$$

Note that potentially, one may consider using other forms of policy optimality e.g. Ramsey optimal policy approach. However, they rely on the welfare measure which is model-dependent. As pointed by Levin et al. (2006) simple policy rules usually provide more robust results with respect to model or parameter uncertainty. Therefore, in order to make central bank target and instrument parsimonious I prefer to consider loss function and Taylor rule.

The optimization and model simulations with suboptimal policy rules are conducted for $\lambda \in [0;1]$ as I look for a policy that will be robust to different λ. In the literature it is frequently assumed that $\lambda = 0.5$ (see e.g. Smets, 2002), thus for illustrative purposes impulse response functions and some results of optimization are reported for this value. However, it has to be stressed that the main result is presented as a frontier and therefore does not depend on λ.

In the paper all agents share the assumption about the presence of the housing shock in the model (or lack of it). The central bank applies the optimal policy in this environment and does not consider changing it. Alternatively, one could consider learning mechanisms of the agents about housing shock or regime switching between two models, as both approaches would make the model more realistic. In this paper I prefer to use two extreme assumptions about the housing shock to consider optimal policies in both models and highlight the mechanism driving the costs of making incorrect assumptions. Nevertheless, I believe alternative modeling approaches would rather attenuate the costs of misperception than change the results. Regime switching, by attaching some positive probability to moving from the model with the housing shock to the model without it (and vice versa), would result in the optimal policy being in between the optimal policies in the extreme cases. Learning would allow for correcting the incorrect policy with the incoming data but would not change the mechanism.

4 Results

This section documents results of monetary policy rule optimization in two models considered in this paper, as well as implications of the central bank incorrect assumption on the presence of the housing shock.

4.1 Optimization results

Optimization significantly improves the performance of monetary policy in the model as compared with the historical rule. As shown in Table 6, relatively stronger improvement occurred in the model without the housing shock. This results from the smaller number of shocks and consequently trade offs that monetary policy has to face in this variant.

Table 6: Central bank loss function in two variants of optimized model

	Model with the housing shock	Model without the housing shock
before optimization	1.96	2.36
after optimization	0.62	0.27

Table 7 presents the optimized parameters in Taylor rules in two models. In both cases, responses to output gap and inflation, i.e. parameters γ_y and γ_π, are higher in the optimized rule than in the historical one. This finding is in line with the literature which points that central banks are cautious in reacting to output gap that is estimated with a substantial level of uncertainty, see e.g. Smets (2002). If the central bank knew the structure of the economy and parameters it would be much more decisive in its actions. At the same time, γ_R, i.e. interest rule persistence, is smaller. It means that the optimal monetary policy puts less weight on interest rate smoothing than it was the case historically.

Table 7: Taylor rule parameters in three variants of the model (historical one and two optimized)

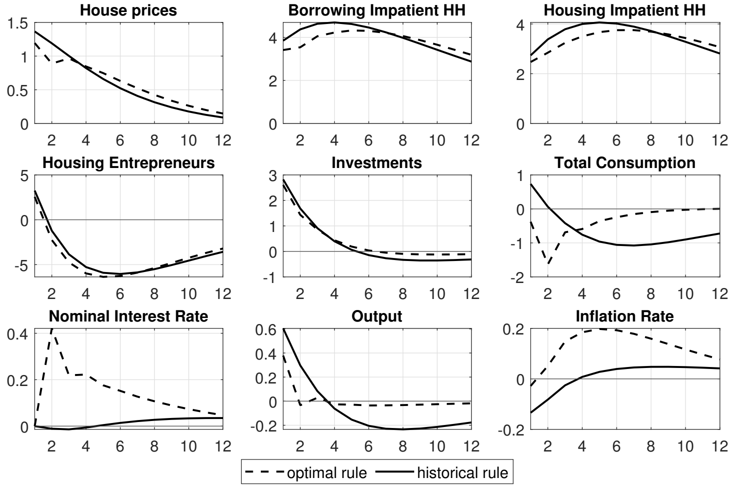
	Historical Taylor rule	Optimized Taylor rules	
		Model with the housing shock	Model without the housing shock
γ_y	0.13	1.28	2.50
γ_π	0.27	0.73	0.58
γ_R	0.73	0.33	0.37
γ_q	0.01*	0.06	-0.30

* In the original calibration the value of γ_q was 0, however, I found through trial and error that a small positive value as a starting point for the optimization procedure allows to obtain more stable numerical results for the optimized parameters (i.e. they more rarely lead to violation of Blanchard-Kahn conditions).

The important result of the optimization in each model is the value of the parameter γ_Q that describes the direct interest rate reaction to past house prices. Basing on the literature on the optimal monetary policy with respect to asset prices (see references in the introduction) one might expect it to be non-negative. Indeed, this is the case in the model with the housing shock (Table 7). Surprisingly, however, in the model without the shock, the optimal direct response of interest rates to house prices is negative.

This result can be explained by comparing sources of increases in house prices in both variants. In the model with the housing shock a rise in house prices usually results from the positive housing shock. Increasing marginal utility from housing makes impatient agents buy housing and borrow more (see Figure 2). The selling side, i.e. patient households receive additional income that finances their increasing consumption. At the same time, entrepreneurs gradually sell housing substituting it with capital (i.e. with relatively cheap factor of production) which is reflected in growing investments. Therefore, in the case of the model with the housing shock under the historical policy rule, a growth in house prices would usually lead to booming consumption and investments. Once monetary policy is optimized, central bank is more decisive in answering to house price boom both due to its stronger responsiveness to output gap and house prices. It turns out that by rising nominal interest rates it is able to stabilize GDP by causing a fall in consumption (through the patient household intertemporal choice) amidst still robust growth in investments.

Figure 2: Housing shock: historical and optimal calibration of the policy rule

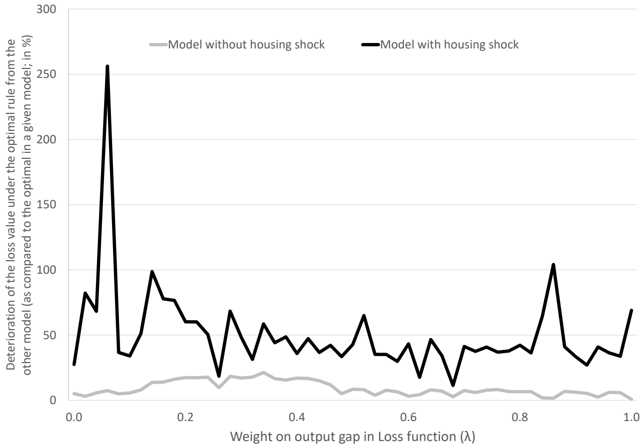


In turn, in the model without the housing shock, an increase in house prices makes housing less desired for impatient households as it becomes relatively more expensive source of utility (as compared with consumption). As impatient households sell off housing, their patient colleagues consume less to absorb house purchases. Therefore, the central bank relaxes collateral constraints of impatient households and entrepreneurs by lowering interest rate path to stabilize output by increasing consumption and investments. In a sense, thanks to the negative γ_Q central bank fixes the inefficiency caused by collateral constraint mechanism and smooths out output gap and inflation over time.

4.2 Comparison of policy rules performance

As the final step I apply both optimal Taylor rules to both models and compare their performance with each other. This allows to check how much the loss function deteriorates (increases) when the monetary authority follows the incorrect policy. The main result of the paper is summarized in Figure 3. It shows that the central bank applying policy rule that incorrectly assumes no housing shock in the economy makes more costly mistake as measured by the per cent deterioration of the loss function under all λ's considered in comparison with the central bank that incorrectly assumes the presence of this shock. To check robustness of the results I also performed several exercises such as optimization with different initial values of parameters in the Taylor rule or simulations for different steps between λ. None of these tests did change the main result of the paper. In the following subsection I focus on the performance of the optimal policy rule from the model without the housing shock in the model with the housing shock and compare it to the optimal rule in this model. Then I present the opposite analysis.

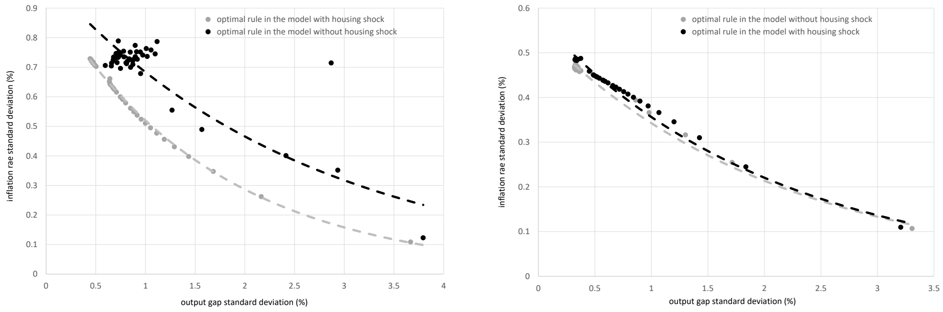
Figure 3: Difference in loss function values of the suboptimal and the optimal Taylor rules in two versions of the model



Model with the housing shock

Figure 4 (left panel) presents standard deviations of inflation and output gap for two Taylor rules applied in the model with the housing shock: the optimal rule in this model and the optimal rule from the model without the housing shock. It turns out that a distance between their outcomes is large. In extreme cases, the application of the latter rule may lead to an increase in standard deviation of quarterly inflation rate by 0.4 pp. and by 1 pp. in case of output gap.

Figure 4: Volatility of inflation and output gap



(a) Model with the housing shock

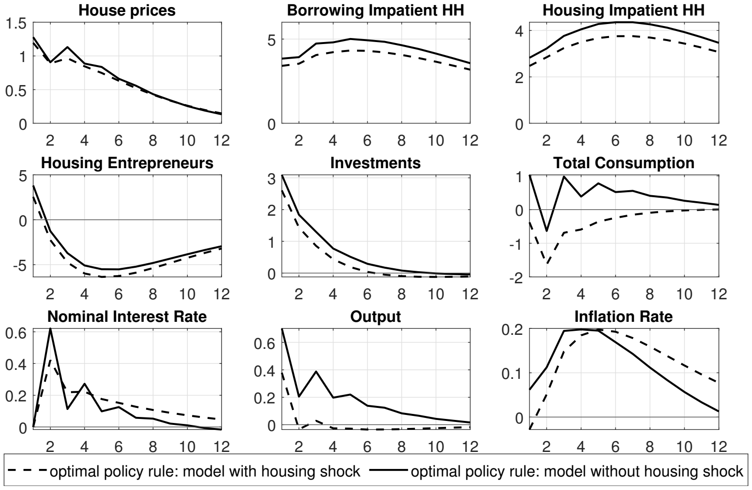
(b) Model without the housing shock

This result is associated with additional reaction to house prices in both rules, i.e. with the parameter γ_Q. As it was discussed, it is negative in the optimal rule in the model without the housing shock. Applying such policy in the model with the housing shock leads to a strong increase in the output gap volatility when the housing shock hits the economy (Figure 5). This result is intuitive – the most harmful is the shock that monetary policy was not prepared for. Expectations of less restrictive policy after an increase in house prices lead to stronger growth of output gap and inflation rate. For other shocks differences in policy performance are very small.

Model without the housing shock While comparing policy rules in the model without this shock, it is noteworthy that their performance is not so much different as in the previous case (Figure 4, right panel). Following the incorrect rule central bank would increase inflation and output volatility to a very limited extent as compared to the optimal policy. It means that the optimal rule in the model with the housing shock is more robust than the optimal rule in the model without the shock.

Alternative Taylor rule specifications In order to check whether the outcome depends on calibration method or the comparison of models with different number of

Figure 5: Housing shock: optimal and suboptimal policy rules



shocks, I performed the same analysis as described above assuming that the Taylor rule does not include additional reaction to house prices (i.e. $\gamma_Q = 0$). It turns out that if the central bank is not allowed to additionally respond to house prices, its wrong assumptions about the housing shock will have little effect in terms of the loss function decrease. Therefore, the main result of the simulation stems from the additional reaction to house prices in the Taylor rule.

5 Conclusions

Despite several spectacular episodes of booms and busts, each time house prices exhibit long-lasting growth trend with little volatility around it, it is argued that this pattern is a "new normal". This paper shows that a central bank following this view would conduct too loose monetary policy significantly increasing output gap and inflation fluctuations as compared to a policy that assumes high volatility of house prices.

To obtain these results I use a medium-scale DSGE model with a financial accelerator mechanism based on a collateral constraint. Model is calibrated in two versions that reflect the uncertainty concerning the presence of the housing shock. First, the model with the housing shock includes four types of shocks: productivity, mark-up, housing and interest rate. In this model the housing shock is to a large extent responsible for volatility in house prices. In the second framework, the housing shock is switched off. Parameters in the policy rule are optimized in both models to abstract from possible inadequate historical monetary policy from the model's perspective. Optimization

significantly improves performance of monetary policy in the model as compared with the historical rule.
Having optimized policy parameters, I compare the performance of the optimal rules in both models utilizing a standard loss function. This allows to check how much the loss function increases when the monetary authority follows the policy that would be correct under the opposite assumption about the housing shock. Simulations of two policy rules in the model with and without the shock reveal that the central bank applying policy rule that incorrectly assumes no housing shock makes more costly mistake as measured by the loss function in comparison with the central bank that incorrectly assumes the presence of this shock. In order to explain this result I analyze the performance of policies after the housing shock. It turns out that the optimal rule from the model without the housing shock is too accomodative in the model with the shock leading to higher output gap and inflation fluctuations. It means that the central bank should not act as if house price volatility is low by historical standards.

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