How Should Monetary Policy Respond to Housing Inflation?*

Javier Bianchi Alisdair McKay Neil Mehrotra

Federal Reserve Bank of Minneapolis

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Abstract

A surge in rents has kept inflation above target in many countries. In this paper, we examine the optimal monetary policy response to a rise in the demand for housing. In contrast to the conventional assumption in New Keynesian models that output is demand determined, we argue that a more plausible description of the housing market is that it is supply determined. Using a macroeconomic model with a rental housing market subject to search and nominal frictions, we find that the optimal policy is to stabilize the non-housing sector and disregard housing inflation. Our results hold exactly in a version of the model with costless search and demand rationing and quantitatively in a version with housing search costs calibrated to match US data on housing tenure and vacancy rates.

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*Email: javieribianchi@gmail.com, alisdair.mckay@mpls.frb.org, and mehrotra@mpls.frb.org. The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

1 Introduction

Following the Covid pandemic, advanced economies experienced a rapid rise in inflation, which prompted central banks to tighten monetary policy significantly. However, almost two years after peaking, inflation has yet to reach the official targets set by central banks. Notably in the US, as Figure 1 shows, the elevated level of inflation is now driven primarily by housing inflation.[1]

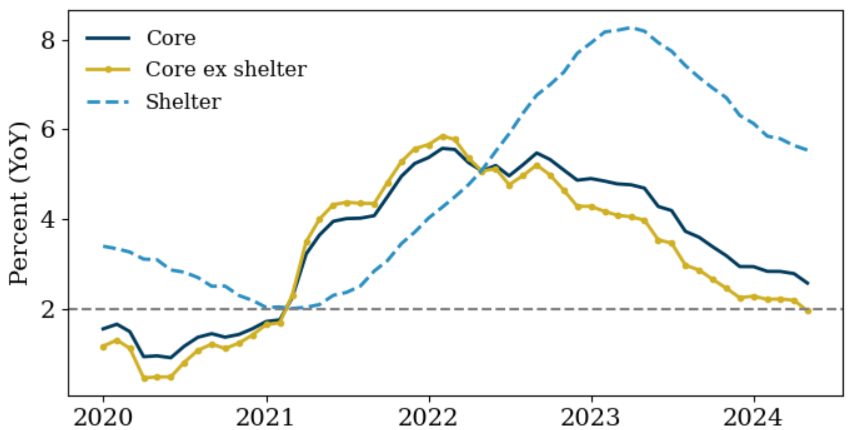

Figure 1: US PCE inflation

Source: Bureau of Economic Analysis. The data are through May 2024.

Given its large and persistent contribution to recent inflation, a key question is how should monetary policy respond to housing inflation? Within the New Keynesian literature, it is well known that relative price changes create trade-offs for monetary policy (see Woodford, 2003, Ch. 6). A central conclusion in this literature is that policy should focus on stabilizing prices in sectors in which prices are stickier (see Aoki, 2001; Benigno, 2004; Eusepi, Hobijn and Tambalotti, 2011). To the extent that rent prices are approximately as sticky as other goods, the implication is that monetary policy should put as much weight on housing as on other goods inflation; therefore keeping inflation on target in response to a housing demand shock.

The premise of our paper is that the canonical New Keynesian model is not an appropriate framework for analyzing shelter inflation. In the New Keynesian literature, a standard assumption is that output is demand determined: if consumers demand more of a good, a firm that does not raise its price must hire factors of production to produce it. Our starting observation is that the flow of new housing produced is a small fraction of the housing

[1]While we focus on the US, shelter inflation has also recently made a large contribution to core inflation in other advanced economies, including the UK and Canada. See Appendix B.1 for details.

services consumed in the economy. Given the time it takes to construct homes, we see it as implausible that housing supply responds quickly to accommodate housing demand at the prevailing price. In the short run, if the demand for the stock of housing is out of line with the available supply, there is no way for the economy to create more. We posit that a more appealing assumption is that the quantity of housing consumed is supply determined. We develop a framework based on this premise and examine the implications for optimal monetary policy. Our quantitative findings show that in the current context where inflation is driven by a surge in rents, optimal policy should largely ignore shelter prices and target price stability in the non-housing sector.

We begin our analysis in a static two-sector model with fixed prices and search frictions, building on Barro and Grossman (1971) and Michaillat and Saez (2015). We assume the two sectors are subject to nominal rigidities but differ in the rationing protocol. In one sector, which we refer to as "goods," output is entirely demand determined, as in the canonical New Keynesian model. When the price is too low to clear the market, firms employ sufficient factors of production to satisfy the desired demand at the rigid price. In the other sector, which we label "housing", output is supply determined. When the price is too low to clear the market, it is households that have to adjust their consumption to be consistent with the available supply. In particular, households increase their search intensity for housing but match with a lower probability in equilibrium.

In this framework, we then study the implications of an increase in the preference for housing. The surge in remote work and the associated desire for more space during the pandemic (see e.g., Mondragon and Wieland, 2022) is the motivation for considering a housing-specific demand shock.

Consider an increase in the preference for housing. With fixed prices, households will devote an excessive search effort to acquire housing units. The central bank then faces a tradeoff between letting the housing market overheat or tightening monetary policy and generating a negative output gap in the goods sector. Ultimately, the optimal policy will balance the housing congestion effects and the cost of the recession. In a limiting case, we show that the optimal policy is to close the output gap in the goods sector and ignore the housing sector.

We then explore the optimal monetary policy in a dynamic quantitative model. We extend the canonical New Keynesian model to include housing that is traded in markets subject to search and nominal frictions. When households come in contact with landlords, they negotiate a rent, which is then fixed for the term of the lease. Although this rigidity affects the measurement of inflation (Adams, Loewenstein, Montag and Verbrugge, 2024), it does not affect the equilibrium allocation—the tenant and the landlord split the surplus the same way regardless of the rigidity. We also include an additional nominal rigidity in the form of imperfect adjustment of new rents, which can distort the equilibrium allocation.

Following a positive housing demand shock, market rents rise less than is needed to achieve the efficient allocation. As a result, households get "too much" of the surplus from a match and search excessively relative to a planner's solution. The monetary authority can depress this search effort by tightening monetary policy and reducing demand for housing. The downside, however, is that a tight monetary policy also inefficiently reduces demand for goods. The question is then how far the monetary policymaker would like to depress the goods market in order to compensate for overheating in the housing market. Our quantitative answer is that they would not want to depress the goods market at all. We compare three monetary policy strategies: stabilize goods inflation, stabilize CPI inflation that includes rents, and the optimal policy. We find that the optimal policy is nearly identical to goods inflation targeting, which allows CPI inflation to rise after a housing demand shock.

Literature. Our paper belongs to the New Keynesian literature emphasizing the importance of asymmetric sectors for optimal monetary policy. Aoki (2001) considers a two-sector model where prices are sticky in one sector and flexible in the other. He shows that the optimal policy is to target inflation in the sector with sticky prices. Woodford (2011) (Ch. 6) shows more generally that when there are multiple sectors with price rigidities, divine coincidence fails and inflation in the stickier sectors should carry more weight in the optimal policy. Eusepi et al. (2011) provide a quantitative analysis of the weights that minimize the welfare costs of nominal distortions. Following these contributions, there has been an active recent literature examining the role of sectoral shifts in understanding recent inflation dynamics and the implications for optimal monetary policy.[2] In contrast to these studies, our analysis considers a model where prices are potentially equally sticky in both sectors, but they crucially differ in the rationing protocol. In particular, we show that the central bank should place less weight on the sector with supply-determined output relative to the one with demand-determined output.

Erceg and Levin (2006) and Barsky, Boehm, House and Kimball (2015) study optimal monetary policy in a two-sector New Keynesian model with a durable goods sector. Both

[2] For production networks, see .e.g, Rubbo, 2023; La'O and Tahbaz-Salehi, 2022; Baqaee, Farhi and Sangani, 2024; Afrouzi and Bhattarai, 2023; for the role of downward wage rigidity and costly reallocation, see .e.g, Guerrieri, Lorenzoni, Straub and Werning, 2020, 2022; for a focus on inflation dynamics post-Covid, see .e.g, Woodford, 2022; Gagliardone and Gertler, 2023; di Giovanni, Kalemli-Özcan, Silva and Yildirim, 2022, 2023; for open economy considerations, see .e.g, Fornaro and Romei, 2023; Bianchi and Coulibaly, 2024.

studies emphasize that demand for new durables is especially sensitive to interest rates and therefore policy needs to take care not to generate large output gaps in the durables production sector. Our argument is that the output gap in the market for housing *services* is small to the extent that it is supply determined. Therefore, monetary policy should be more concerned with stabilizing output gaps in other sectors.

Outline. Section 2 presents the static model. Section 3 presents the dynamic model. Section 4 presents the calibration and Section 5 presents the quantitative results. Section 6 concludes.

2 The static model

This section presents a simplified static version of the model to provide the main theoretical results. Households have preferences over consumption goods and housing services.[3] Goods are produced with labor and are sold in a competitive market. Housing is in fixed supply and is rented in a frictional market where households need to exert search effort to locate houses available for rent. Both housing and goods have a rigid price, but will differ in the rationing protocol that resolves any potential disequilibrium.

2.1 Main elements

Households. The economy is populated by a unit mass of identical households with preferences represented by the utility function

$$(1-\omega)\log(c) + \omega\log(h) + (1-\omega)[\varphi\log(m) - (l+\rho s)].$$

Households derive utility from consumption goods, c, housing h, real money holdings, m, and face a disutility from labor, l, and time spent searching for housing, s. The preference parameter ω captures the relative preference for housing, ρ captures any additional disutility from time spent on search relative to labor, and φ the value of real money holdings (in terms of consumption goods).

Households receive labor income, firm profits, and lump-sum transfers from the government.

[3] Goods should be understood as all goods and services ex-housing. In the quantitative model in Section 3, we take this approach to calibrate the model.

Their budget constraint is:

$$Rh + Pc + M \leq Wl + d + T,$$

where R and P denote the prices of housing (rents) and consumption, and W denotes wages. All prices are denominated in money.

To rent housing, households must engage in costly search effort. Specifically, every household is divided into a continuum of identical members who spend time searching for housing units. We assume a constant returns to scale matching function such that the probability of a member finding one unit of housing per unit of time spent searching is $f(\Theta)$, where Θ is a measure of market tightness and denotes the ratio of the total number of hours that households are searching to vacant houses. We assume that f satisfies $f' < 0, \lim_{\Theta\to 0} f(\Theta) = 1, \lim_{\Theta\to\infty} f(\Theta) = 0$. By the law of large numbers, a household where its members spend s hours searching is able to rent $sf(\Theta)$ units.

Taking prices and market tightness as given, the household's problem is choosing consumption of goods and housing, money holdings, labor, and search effort to maximize their utility. That is,

$$\max_{c,h,s,l,m} \left\{(1-\omega)\log(c) + \omega\log(h) + (1-\omega)\left[\varphi\log(m) - (l+\rho s)\right]\right\}, \tag{1}$$

$$\text{subject to}$$

$$Rh + Pc + Pm = Wl + d + T,$$

$$h = sf(\Theta).$$

The second constraint imposes that the amount of housing the household can rent depends on its search effort and the market tightness. Thus, in addition to the monetary cost of renting, there is an additional marginal cost from searching. The optimality conditions lead to

$$\frac{\omega}{h} = \frac{1-\omega}{c}\left(\frac{R}{P}\right) + (1-\omega)\frac{\rho}{f(\Theta)}. \tag{2}$$

That is, at the optimum, the household has to be indifferent between its current bundle and selling one unit of consumption to buy R/P units of housing while spending $\frac{1}{f(\Theta)}R/P$ units of time to acquire the extra housing units.

In addition, optimality also implies

$$\frac{W}{P} = c,$$
$$m = \varphi c.$$

These conditions equate the marginal rate of substitution between consumption and leisure to the real wage and the marginal utility of consumption to the marginal utility of real money balances.

Firms. There are two types of firms: those that produce goods ("firms") and real estate firms that rent their available stock of housing units ("landlords").

Goods prices are fixed at $P = \overline{P}$. Following the standard assumption in the New Keynesian literature, we assume that output of goods is demand determined. That is, once prices are set, firms must produce to satisfy the consumers' demand at that price. Given a production function $y = zl$, the labor demanded by firms in a symmetric equilibrium is given by $l^d = c/z$.

Rent prices are also fixed at $R = \overline{R}$. For simplicity, we assume that landlords face no costs from posting vacancies and rent out their entire stock of housing, which we denote by $\bar{h}$. Market tightness is therefore given by $\Theta = s/\bar{h}$. Given a constant-returns to scale matching function, the probability that a landlord rents out its one unit of housing is $g(\Theta) = f(\Theta)\Theta$.

Total profits from firms and landlords are then given by

$$d = zl - Wl + Rg(\Theta)\bar{h}. \tag{3}$$

Government. The government injects the money supply M via transfers. That is, the government budget constraint is $M = T$.

Competitive equilibrium. We now define a competitive equilibrium, given the fixed prices.

Definition 1. Given fixed prices $\{\overline{P}, \overline{R}\}$ and a government policy $\{M, T\}$, a *competitive equilibrium* in this economy is given by $\{c, h, l, s, l^d, W, \Theta\}$ such that: (i) Households policies solve (1); (ii) Firms' profits are given by (3); (iii) Labor markets clear, implying $l^d = l$; (iv) Landlords supply $\bar{h}$ units of housing; and (v) Matching probabilities are given by $f(\Theta)$ and $g(\Theta)$ where $\Theta = s/\bar{h}$.

Figure 2 shows the determination of the equilibrium in the housing market for a given monetary policy. Let us define an effective rent as $\frac{R}{P} + \frac{c\rho}{f(\Theta)}$. The effective rent depends on Θ because this determines the probability of finding a house and the amount of search effort that needs to be devoted. Using that the amount of housing traded satisfies $h = g(\Theta)\bar{h}$, we then obtain an upward sloping curve for the effective rent as a function of h. As h increases, it becomes more and more difficult for households to find housing units available. Moreover, as h approaches $\bar{h}$, the probability of finding a unit $f(\Theta)$ goes to zero, raising sharply the effective rent. Equation (2) equalizes the marginal rate of substitution to the relative price of housing. The marginal rate of substitution gives us a downward-sloping demand curve. The intersection of the two curves represents the equilibrium in the housing market. Notice that as the preference for housing ω increases, the demand curve shifts up and to the right and the equilibrium features a higher amount of housing occupied and higher effective rents.

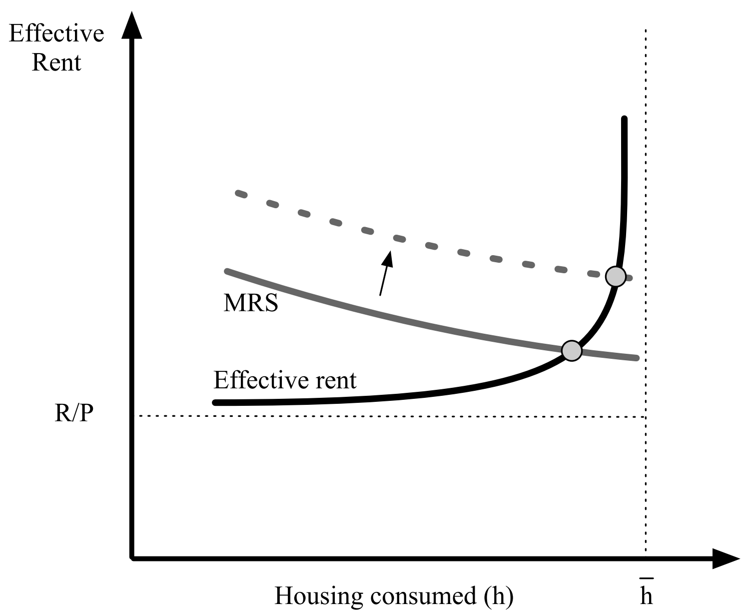

Figure 2: Equilibrium in the housing market

2.2 Optimal Policy

Toward our analysis of optimal monetary policy, we first present the constrained-efficient allocation in this economy. We then study the optimal monetary policy. Throughout, we will abstract from the utility of money balances in the welfare evaluation.

Constrained-efficient allocation. A planner that directly chooses allocations subject to technological constraints and search frictions solves the following problem

$$\max_{c,s} \left\{(1-\omega)\log(c) + \omega \log\left(sf\left(\frac{s}{\bar{\bar{h}}}\right)\right) - (1-\omega)\left[\left(\frac{c}{z} + \rho s\right)\right]\right\}.$$

The first-order conditions yield

$$c = z, \tag{4}$$

$$\frac{\omega}{sf(\Theta)}\left(f(\Theta) + f'(\Theta)\Theta\right) = (1-\omega)\rho. \tag{5}$$

Condition (4) states that optimal consumption of goods equals z, owing to log utility of consumption and linear disutility from labor. Condition (5) states that the planner increases search effort until the marginal utility from the additional housing equals the marginal cost of searching more. Notice that the additional housing that can be consumed is determined by the probability of finding a match minus the infra-marginal effects of additional search on the matching probability.

It is worth highlighting that the efficient allocation does not generally coincide with the flexible-price allocation. This is because search frictions generate standard congestion effects, which may create a wedge between the private and social marginal benefits of searching.[4]

Optimal monetary policy. We now examine optimal monetary policy. The central bank's problem is choosing the level of money supply, M, that maximizes welfare in the competitive equilibrium with fixed prices. The optimal policy problem is

$$\max_{c,s,M} \left\{(1-\omega)\log(c) + \omega \log\left(sf\left(s/\bar{h}\right)\right) - (1-\omega)\left[\left(\frac{c}{z} + \rho s\right)\right]\right\} \tag{6}$$

subject to

$$\frac{\omega}{sf\left(s/\bar{h}\right)} = \frac{1-\omega}{c}\left(\frac{\bar{R}}{\bar{\bar{P}}}\right) + (1-\omega)\frac{\rho}{f\left(s/\bar{h}\right)},$$

$$c = \left(\frac{1}{\varphi}\right)\frac{M}{\bar{\bar{P}}}.$$

Notice that we have used the technological constraints to replace for employment and housing consumption. The first constraint reflects that households choose optimally how they split their income between consumption and housing, as given by (2). Notice that we can ignore

[4] Following Hosios (1990), it is possible to specify a bargaining rule that splits the match surplus to render the flexible-price competitive equilibrium constrained efficient. We follow this approach in the dynamic model in Section 3.

the second implementability constraint. That is, the monetary authority can choose the optimal consumption, c, and then set the level of money supply that implements it. The optimality conditions yield

$$\underbrace{(1-\omega)\rho - \frac{\omega}{h}\left(f(\Theta) + f'(\Theta)\Theta\right)}_{\text{Housing congestion}} = \underbrace{\left(\frac{1}{z} - \frac{1}{c}\right)}_{\text{Output gap}} \frac{-\frac{\omega}{h}(f(\Theta) + f'(\Theta)\Theta) + (1-\omega)\rho\left(\frac{f'(\Theta)\Theta}{f(\Theta)}\right)}{\frac{h}{c^2}\left(\frac{\overline{R}}{\overline{P}}\right)}. \tag{7}$$

The left-hand side represents the deviation from the constrained-efficient search effort per equation (5). The right-hand side is the product of two terms, a measure of the output gap in the goods sector and a term that represents how a change in consumption and housing affects the central bank implementability constraint. Namely, an increase in search lowers the marginal utility of housing and raises the marginal cost of housing (by lowering the probability of a match), therefore requiring an increase in consumption to maintain household optimality. Given that this second term is negative, equation (7) therefore shows that when there is congestion in the housing sector (i.e., when housing exceeds the constrained-efficient level), we must have at the optimum a negative output gap.[5] That is, to cool down the housing market, the central bank is willing to allow for a recession.

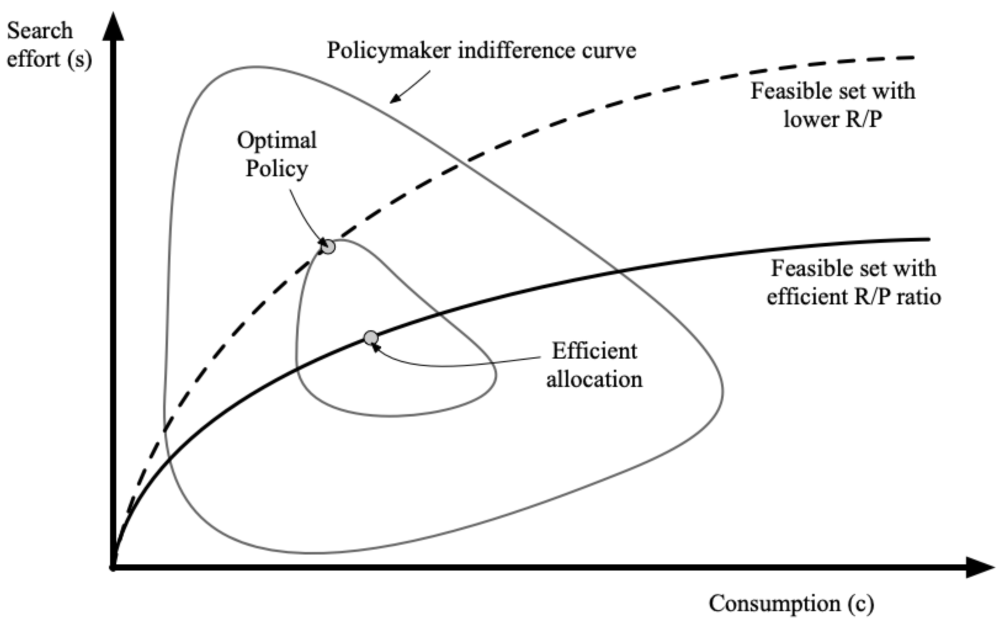

Figure 3: Illustration of tradeoffs for monetary policy

Figure 3 illustrates the tradeoffs for policy. The figure plots the policy indifference curves and the feasible set for the central bank. The implementability constraint reflecting

[5]The fact that the second term is negative follows because f is concave and $f(0) = 0$.

households' optimality implies that search effort is an increasing function of consumption. This constraint is represented by the upward locus. The policymaker can choose to move along the constraint locus by manipulating the money supply. When the R/P ratio is equal to the level implied by the Hosios condition, the constraint passes through the efficient allocation. If the R/P ratio is lower, households will search more at any given level of consumption and the efficient allocation is no longer attainable (i.e., the upward locus shifts up). There is then a tradeoff between inefficiently high search effort and inefficiently low consumption. The optimal policy balances these two inefficiencies, meaning that consumption falls when R/P is too low. The optimum is at the tangency point between the indifference curve and the upward locus.

In a situation where preference for housing goes up, the housing market will overheat as fixed prices imply that households will devote significantly more search effort to acquire housing units. The monetary authority thus faces a tradeoff between letting the market for housing overheat or tightening monetary policy and generating a negative output gap in the goods sector.

To the extent that the housing congestion gets smaller as search costs fall, this suggests that the monetary authority will put more weight on keeping the output gap in the goods sector close to zero. In the next section, we show that the key for this conclusion is that the quantity of housing consumed is not demand determined as in standard New Keynesian models.

2.3 The role of the rationing protocol

A central feature of the theory is that housing does not follow the conventional rationing protocol in New Keynesian models. That is, landlords do not passively provide the amount of housing that households wish to consume at the prevailing rigid prices. The fact that housing is in fixed supply indeed rules out the possibility of adding factors or production to increase the supply of housing. However, we argue in this section that our insights of how optimal monetary policy should respond to a housing demand shock generalize to a situation where housing can be produced.

We assume that housing is produced with labor such that $h^s = \bar{h} l_h^\alpha$. We now use l_h and l_c to distinguish employment in the two sectors The landlords' problem is given by

$\max_{l_h} \left\{ g(\Theta) R\bar{h} l_h^\alpha - W l_h \right\}$. Optimization gives rise to an upward supply schedule for housing:

$$l_h = \left(\frac{\alpha g(\Theta) R\bar{h}}{W} \right)^{\frac{1}{1-\alpha}}. \tag{8}$$

That is, landlords' production of housing is increasing in the rental price and the probability of finding a match and decreasing in the wage. For simplicity, we assume that the latter is fixed at $W = \overline{W}$. That is, households supply labor to meet firms' demand.

We now contrast the results for optimal monetary policy in two stark cases in the absence of search frictions. In the demand-determined case, when there is a mismatch between supply and demand at rigid prices, the demand determines the output. In the supply-determined case, the mismatch is resolved by setting the output equal to the supply. Our model with search frictions represents, in effect, an intermediate case—market tightness adjusts to balance supply and demand of housing.

The case with demand determined output. Let us first inspect the standard case in New Keynesian models where output is entirely demand-determined and there are no search frictions.[6] In this case, we have that firms passively employ enough workers to deliver the desired amount of housing. Using the households' optimality conditions in problem (1) under $\rho = 0$,[7] we obtain that the equilibrium level of housing consumed is given by

$$h = \left(\frac{\omega}{1-\omega} \right) \frac{M}{\overline{R}\varphi}. \tag{9}$$

In the absence of search frictions, the optimal policy problem in this economy is then given by

$$\max_{c,h} (1-\omega)\log(c) + \omega \log(h) + (1-\omega) \left[\frac{c}{z} + \left(\frac{h}{\bar{h}} \right)^{1/\alpha} \right] \tag{10}$$

subject to

$$\frac{\omega}{h} = \frac{1-\omega}{c} \left(\frac{\overline{R}}{\overline{P}} \right)$$

The policy problem (10) is a simple version of optimal monetary policy in the multi-sector New Keynesian model. In our environment with completely rigid prices, the constraint

[6]This is also the standard assumption in most of the general disequilibrium models following Barro and Grossman (1971).

[7]That is, we use (2) and $c = \frac{M}{P\varphi}$.

the central bank faces is that the marginal rate of substitution between consumption and housing must be equal to the relative price. That is, the central bank can alter the levels of employment in both sectors as long as their relative values are consistent with the relative prices.

Consider an initial situation where rigid prices are such that the competitive equilibrium coincides with the efficient allocations. When ω increases, for the same monetary policy, there will be an overheating in the housing market. The optimal policy is then to tighten monetary policy and reduce the demand for both housing and consumption. At the optimum, the monetary authority balances the tradeoff between too little employment in the goods sector and excessive employment in the housing sector.

The case with supply-determined output. Assume now that when there is a mismatch between supply and demand for housing, the equilibrium quantity is the one consistent with the firm's optimality condition and households are demand rationed.[8] In this case, the optimal monetary policy problem is

$$\max_{c,h}(1-\omega)\log(c)+\omega\log(h)+(1-\omega)\left[\frac{c}{z}+\left(\frac{\alpha\bar{R}\bar{h}}{\bar{W}}\right)^{\frac{1}{1-\alpha}}\right] \tag{11}$$

where note that we have used (8) to replace for employment in housing, under $g(\Theta)=1$.

It is apparent from (11) that the optimal policy will imply a *zero output gap in the goods sector*. That is, since housing is supply determined (and is independent of monetary policy), the optimal policy is to keep the output gap in the goods sector at zero. However, this does not mean that the constrained-efficient allocation is obtained because housing output will be inefficiently lower compared to the constrained-efficient level. That is, the monetary authority would like to allocate more labor toward housing, but with fixed prices, monetary policy is unable to induce firms to employ more workers in housing.

Figure 4 illustrates graphically the differences between the two rationing protocols. The supply and demand schedule are given respectively by (8) and (9). The starting point in the figure is a situation with market clearing. An increase in ω shifts the demand for housing to the right. The flex-price allocation is given by the green dot. On the other hand, under rigid prices, we can see that the demand-determined outcome and the supply-determined outcome are given, respectively, by the red and black dots. Notice that in the latter case, the

[8] In the context of our search model, this outcome can be endogeneized by considering the limit where $\rho=0$ and there is a bound on search effort.

production of housing remains at the original allocation.[9]

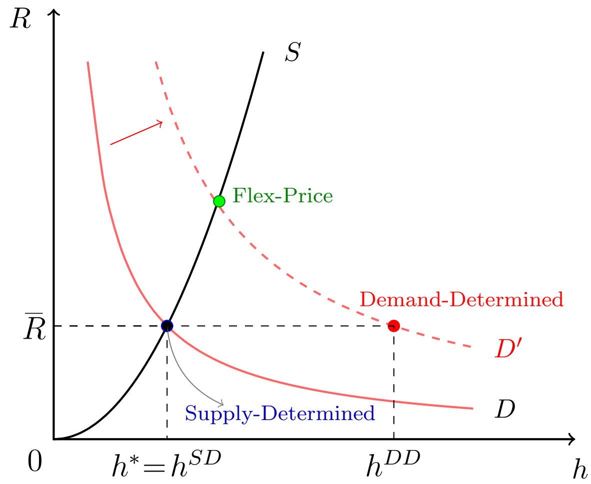

Figure 4: Demand vs. Supply Determined Output

Note: The figure illustrates the comparison between demand-determined and supply-determined rationing protocols. The figure assumes the initial point (R^*, R^*) is at a market clearing price. The curve D' represents the demand for housing after a rise in ω. The quantities h^{DD} and h^{SD} denote respectively the demand-determined and supply-determined output after the shock.

Connections with the literature. It is worth highlighting at this point how our findings contrast with existing studies on optimal monetary policy with multiple sectors where the standard assumption is that output in all sectors is demand determined.

In their analysis of optimal monetary policy with heterogeneous sectors, Eusepi et al. (2011) find that the central bank should put more weight on the output gap (or the inflation) of those sectors with a less elastic supply (a lower labor share). From their analysis, one would infer that if housing has a low labor share, the central bank should put a high weight on that sector. Intuitively, when a sector is demand determined and it has a low elasticity of supply, an increase in demand forces the sector to allocate significant resources to deliver the goods that are demanded.[10] Our analysis shows that when a sector is supply-determined, its labor share does not affect the optimal monetary policy.

Another well-known principle in multi-sector models is that the central bank should put more weight on the sectors with relatively more sticky prices (Aoki, 2001; Woodford, 2011).

[9] In case of a negative shock to ω, we obtain the same implications under the assumption that output remains supply determined. If one adopts the "short-side" rule, output would be supply-determined for positive shocks and demand-determined for negative shocks.

[10] In terms of Figure 4 this can be seen by noting that the steeper is the supply schedule, the larger is the deadweight loss from allocation h^{DD}.

Notice here that we have assumed that both sectors are equally rigid and so the classic distinction does not play a role in our analysis.[11]

2.4 Takeaways

We have presented a simple model to illustrate how monetary policy should respond to a change in the demand for housing. We have argued that, if the market for housing is supply determined (and demand is rationed), monetary policy should focus on closing the output gap in the rest of the economy and disregard the housing sector. A market with search frictions is an intermediate case between supply determined and demand determined output. Moreover, to the extent that search is costly and give rise to congestion externalities, monetary policy faces a tradeoff between stabilizing the housing market and the non-housing sector. In the rest of the paper, we develop and calibrate a quantitative model to assess the optimal monetary policy.

3 Dynamic model

We now present an infinite-horizon version of our model that we will use for quantitative evaluation of the tradeoffs in managing an increase in housing inflation.

3.1 Environment

A representative household has preferences given by

$$\sum_{t=0}^{\infty} \beta^t \left\{ (1-\omega_t) \log c_t + \omega_t \log h_{t+1} - \psi (1-\omega_t) \left(\ell_t + s_t \right) \right\},$$

where c_t is consumption of goods, h_{t+1} is the consumption of housing services equal to the number of housing units occupied between t and $t+1$, ℓ_t is labor effort and s_t is search effort.[12] The time-varying parameter ω_t affects the taste for housing relative to goods and leisure. We consider a perfect foresight transition path induced by changes in $\{\omega_t\}_{t=0}^{\infty}$ that are announced at date 0.

[11] Our dynamic model will allow for different price rigidities.

[12] Here we assume search effort is equally costly as labor effort. This is a normalization of the units of search effort that is without loss of generality as we can rescale the efficiency of the matching function accordingly. In addition, we take the cashless limit where the demand for real balances goes to zero.

The economy can produce the consumption good out of intermediate inputs according to a production function

$$c_t = \left(\int_0^1 y_{jt}^{\frac{\eta-1}{\eta}} dj \right)^{\frac{\eta}{\eta-1}}.$$

Intermediate goods are produced out of labor according to $y_{jt} = z\ell_{jt}$ with a resource constraint for labor given by $\ell_t = \int \ell_{jt} dj$. The total supply of housing is fixed at $\bar{h} = 1$.[13] If the household wants to occupy more housing, it must search for vacant units. We now define $\Theta_t = s_t/[1 - h_t + \delta h_t]$ as market tightness, where δ is the probability that a housing unit is exogenously vacated. The number of occupied housing units, $h_t \in [0, 1]$, satisfies

$$h_{t+1} = (1 - \delta)h_t + f(\Theta_t)s_t, \tag{12}$$

where $f(\Theta_t)$ is the probability of finding a housing unit as before. Similarly, $g(\Theta_t) = f(\Theta_t)\Theta_t$ is the probability of a landlord finding a tenant.

Nominal rigidities. A unit continuum of landlords own the housing units and each supplies his or her unit inelastically. When a landlord meets a searching household member, the rent is either determined by Nash bargaining (with probability $1 - \chi$) or set to the average prevailing rent over all the outstanding rent agreements (with probability χ).[14] These rents are denoted respectively by R_t and $\bar{R}_t$ in nominal terms. After a match is formed, the rent is then fixed until either (i) the match is broken which occurs (with probability δ); or (ii) a renegotiation shock occurs which occurs (with probability ξ).

In case a match is broken, the household needs to exert search effort to find a new house. The renegotiation shock is meant to mimic the term of a rental lease that fixes the rent for a given period of time. The fact that rents are sticky within the match does not affect the equilibrium outcome, but the fact that some rents are set to $\bar{R}_t$ rather than being negotiated to R_t does. Therefore, χ controls the degree to which market rents fail to adjust efficiently following shocks.[15]

[13] As argued in Section 2.3, the fixed amount of housing is not crucial for the mechanism. Future work could allow for an upward supply of housing to inspect its quantitative importance.

[14] At the start of each period, after match separations occur, a fraction χ of the vacant housing units are placed in the "sticky" pool while the remaining $1-\chi$ share are placed in the bargaining pool. This assignment is i.i.d. over time. Searching households are randomly assigned to the two pools in the same proportions so the market tightness is the same in each pool.

[15] In general in search models, one may worry that a fixed payment would lead to inefficient separations. For example, if the rent is fixed at too low a level, the landlord may want to break the lease in order to obtain the market rent. We assume that this is not possible as the lease forces both parties to commit to both to the rent and the term of the lease. While such an assumption would be unappealing in labor markets (i.e. forced labor), it provides a good description of housing markets.

Intermediate goods are produced by monopolistic competitors who face Calvo-style nominal rigidities in adjusting their prices. Let θ be the probability that a price is retained each period. Let P_{jt} be the nominal price of good j. The price index for the composite consumption good is

$$P_t = \left(\int_0^1 {P_{jt}}^{1-\eta} dj \right)^{\frac{1}{1-\eta}}.$$

We assume a constant production subsidy corrects the steady state monopoly distortion. Labor is traded in a Walrasian market at nominal wage W_t. A nominal bond trades with nominal interest rate i_t.

3.2 Decision problems

Household's problem

The household's state variabes are the existing matches h (before separations), the existing rent bill X (before separations and renegotiations), and nominal bonds B. The rent paid today is the sum of three components: (i) the rent already committed to $(1-\delta)(1-\xi)X$, (ii) a fraction ξ of the existing housing units renegotiate the rent to R_t leading to a rent bill of $R_t\xi(1-\delta)h$ and (iii) the rent on new matches, which is the product of the number of new matches $f(\Theta_t)s$ and the expected rent on new matches $\chi\overline{R}_t + (1-\chi)R_t$.

The household's problem at date t is then

$$H_t(h, X, B) = \max_{c,h',X',s,\ell,B'} \left\{ (1-\omega_t)\log c + \omega_t \log h' - \psi(1-\omega_t)(\ell + s) + \beta \left[H_{t+1}(h', X', B') \right] \right\}$$

subject to (Lagrange multipliers on the right) <u>mult.</u>

$$P_t c_t + X' + \frac{B'}{1+i_t} = B + W_t \ell_t + P_t d_t \qquad \lambda_t P_t$$

$$h' = (1-\delta)h + f(\Theta_t)s \qquad \mu_t$$

$$X' = (1-\delta)(1-\xi)X + R_t\xi(1-\delta)h + \left(\chi\overline{R}_t + (1-\chi)R_t\right) f(\Theta_t)s \qquad -\upsilon_t P_t$$

where d_t are dividends from intermediate producers and landlords. In writing the problem this way, we see that the household understands that it can send out more searchers to increase its consumption of housing and these searchers, if successful, will agree to an expected rent of $\chi\overline{R}_t + (1-\chi)R_t$.

The first-order conditions of this problem result in the following system of equations,

$$\frac{1-\omega_t}{c_t} = \lambda_t \tag{13}$$

$$\frac{\omega_t}{h_{t+1}} + \beta(1-\delta)\left[\mu_{t+1} - \xi r_{t+1}\upsilon_{t+1}\right] = \mu_t \tag{14}$$

$$\lambda_t + \beta\left[(1-\delta)(1-\xi)\frac{\upsilon_{t+1}}{\Pi_{t+1}}\right] = \upsilon_t \tag{15}$$

$$f(\Theta_t)\left[\mu_t - \left(\chi\bar{r}_t + (1-\chi)r_t\right)\upsilon_t\right] = \psi(1-\omega_t) \tag{16}$$

$$\lambda_t w_t = \psi(1-\omega_t) \tag{17}$$

$$\lambda_t = \frac{(1+i_t)}{\Pi_{t+1}}\beta\lambda_{t+1} \tag{18}$$

where $w_t \equiv W_t/P_t$, $r_t \equiv R_t/P_t$, $\bar{r}_t \equiv \bar{R}_t/P_t$, and $\Pi_{t+1} \equiv P_{t+1}/P_t$.

The marginal value of (real) income at date t is λ_t, which is equal to the marginal utility of consumption, see (13). The marginal value of adding to the occupied housing units is μ_t, which includes the expected discounted service flow from the marginal housing unit and the exposure to future renegotiation shocks, see (14). The marginal cost of increasing the rent bill is υ_t, which is linked to λ_t through (15). Expected inflation reduces the cost of the rent bill because leases are fixed in nominal terms. Finally, equations (16)-(18) give the first-order conditions for search effort, labor supply and bond holdings, respectively.

Landlord's problem

When search and matching is completed, a landlord may have an occupied unit or vacant unit. We denote the value of a landlord with an occupied unit paying real rent r as $L_t^o(r)$ and the value of a landlord with a vacant unit as L_t^v. These satisfy[16]

$$\begin{aligned}
L_t^o(r) = \lambda_t r + \beta\Big[&(1-\delta)(1-\xi)L_{t+1}^o(r/\Pi_{t+1}) && \text{continue}\\
&+\delta g(\Theta_{t+1})\left[\chi L_{t+1}^o(\bar{r}_{t+1}) + (1-\chi)L_{t+1}^o(r_{t+1})\right] && \text{separate and re-match}\\
&+\delta\left[1-g(\Theta_{t+1})\right]L_{t+1}^v && \text{separate and vacant}\\
&+(1-\delta)\xi L_{t+1}^o(r_{t+1})\Big] && \text{renegotiate}
\end{aligned}$$

$$L_t^v = \beta\left[L_{t+1}^v + g(\Theta_{t+1})\left(\chi L_{t+1}^o(\bar{r}_{t+1}) + (1-\chi)L_{t+1}^o(r_{t+1}) - L_{t+1}^v\right)\right].$$

[16]The variable r is a generic argument of L_t^o while r_{t+1} is the real rent that will be negotiated in $t+1$.

The derivative of $L_t^o(r)$ is

$$\frac{dL_t^o(\tilde{r})}{d\tilde{r}}\Big|_{\tilde{r}=r} = \lambda_t + \beta\left[(1-\delta)(1-\xi)\frac{1}{\Pi_{t+1}}\frac{dL_{t+1}^o(\tilde{r})}{d\tilde{r}}\Big|_{\tilde{r}=r/\Pi_{t+1}}\right].$$

Solving forward, we see that the derivative is independent of r so the function L_t^o is linear in r. By comparison with (15), we see that $\frac{dL_t^o(r)}{dr} = \upsilon_t$, which implies the marginal value of rent to the landlord is equal to the marginal cost of rent for the household. Given linearity, we can write $L_t^o(r) = L_t^o(r_t) + \upsilon_t(r - r_t)$ and the value functions yield

$$\begin{aligned} L_t^o(r_t) - L_t^v = \lambda_t r_t + \beta(1-\delta)\Big[&[1-g(\Theta_{t+1})]\left[L_{t+1}^o(r_{t+1}) - L_{t+1}^v\right] \\ &+ (1-\xi)\upsilon_{t+1}(r_t/\Pi_{t+1} - r_{t+1}) \\ &+ g(\Theta_{t+1})\chi\upsilon_{t+1}(r_{t+1} - \bar{r}_{t+1})\Big] \end{aligned} \quad \text{(Landlord)}$$

Intermediate producer's problem

The problem of the intermediate goods producer is to set the reset price P_t^* to maximize profits subject to the production function and the demand curve $y_{jt} = (P_{jt}/P_t)^{-\eta} c_t$. This problem results in the standard New Keynesian reset price, which in its non-linear form is given by

$$p_t^* \equiv \frac{P_t^*}{P_t} = \frac{\sum_{\tau=t}^{\infty}(\beta\theta)^{\tau-t}\Pi_{t,\tau}{}^{\eta+1}\frac{w_\tau}{z}}{\sum_{\tau=t}^{\infty}(\beta\theta)^{\tau-t}\Pi_{t,\tau}{}^{\eta}}. \tag{19}$$

The price index for goods then leads to

$$\Pi_t = \left(\frac{1}{\theta} - \frac{1-\theta}{\theta}(p_t^*)^{1-\eta}\right)^{\frac{1}{\eta-1}}. \tag{20}$$

3.3 Equilibrium

When a rent is bargained, it is set by Nash bargaining to solve

$$\max_{\tilde{r}} \left[\mu_t - \tilde{r}\upsilon_t\right]^{\Psi}\left[L_t^o(\tilde{r}) - L_t^v\right]^{1-\Psi}.$$

The first-order condition imposing $\tilde{r} = r_t$ yields

$$\mu_t - r_t\upsilon_t = \Psi\underbrace{\left[\mu_t - r_t\upsilon_t + L_t^o(r_t) - L_t^v\right]}_{\equiv S_t}, \tag{21}$$

where S_t is the total surplus from the match. Using (14), (15), (16), (21), and (Landlord) we have

$$S_t = \frac{\omega_t}{h_{t+1}} + \beta(1-\delta)\left[S_{t+1} - g(\Theta_{t+1})\left[(1-\Psi)S_{t+1} - \chi\upsilon_{t+1}(r_{t+1} - \bar{r}_{t+1})\right]\right]. \tag{22}$$

The average prevailing rent is given by $\bar{R}_t = X_{t+1}/h_{t+1}$. Defining $x_{t+1} = X_{t+1}/P_t$, we then have

$$\bar{r}_t = x_{t+1}/h_{t+1}. \tag{23}$$

The total rent bill evolves according to

$$x_{t+1} = (1-\delta)(1-\xi)\frac{x_t}{\Pi_t} + r_t\xi(1-\delta)h_t + \left[\chi\bar{r}_t + (1-\chi)r_t\right]f(\Theta_t)s_t. \tag{24}$$

Labor supply depends on the production function aggregated across intermediate input producers

$$\ell_t = \int \ell_j t di = \underbrace{\int \left(\frac{P_{jt}}{P_t}\right)^{-\eta} dj}_{\equiv\Delta_t} \frac{c_t}{z}, \tag{25}$$

where $\Delta_t \geq 1$ is a measure of price dispersion, which evolves as

$$\Delta_t = (1-\theta)\left(p_t^*\right)^{-\eta} + \theta\Pi_t^{\eta}\Delta_{t-1}. \tag{26}$$

An equilibrium of the model consists of sequences for $\{p_t^*, \Pi_t, h_t r_t, w_t, c_t, s_t, \ell_t, S_t, \Theta_t, \lambda_t, \mu_t, \upsilon_t, x_t, \bar{r}_t, \Delta_t, i_t\}$ that satisfy (12)-(26), the definition of $\Theta_t = s_t/[1 - h_t + \delta h_t]$, and a monetary policy rule.

3.4 Constrained planner's problem

In order to establish a benchmark for optimal policy, we study a constrained planner's problem in which the planner is subject to the search friction. The problem is dynamic because the number of occupied houses is a state. The problem is

$$V_t(h) = \max_{c,\ell,s,h'} \left\{(1-\omega_t)\log c + \omega_t \log h' - \psi(1-\omega_t)\left(\ell_t + s_t\right) + \beta\left[V_{t+1}\left(h'\right)\right]\right\}$$

subject to (multipliers on the right)

$$h' = (1-\delta)h + \overline{M}(1-(1-\delta)h)^{1-\gamma}s^{\gamma} \qquad S_t^*$$
$$c = z\ell \qquad \lambda_t^*$$

The first-order conditions, envelope conditions, and constraints lead to

$$\begin{aligned}
(1-\omega_t)\psi &= f(\Theta_t^*)\gamma S_t^* \\
\psi c_t^* &= A \\
S_t^* &= \frac{\omega_t}{h_{t+1}^*} + \beta(1-\delta)\left[S_{t+1}^*\left[1-g(\Theta_{t+1}^*)(1-\gamma)\right]\right] \\
\ell_t &= c_t/z
\end{aligned}$$

In the decentralized economy, equations (16), (17), (21), (22), (25) lead to

$$\begin{aligned}
\psi(1-\omega_t) &= f(\Theta_t)\Psi S_t + \chi f(\Theta_t)\nu_t(r_t - \bar{r}_t) \\
\psi c_t &= w_t \\
S_t &= \frac{\omega_t}{h_t} + \beta(1-\delta)\left[S_{t+1}\left(1-g(\Theta_{t+1})(1-\Psi)\right)\right] \\
\ell_t &= \Delta_t c_t/z
\end{aligned}$$

These two systems of equations will coincide (i.e., the competitive equilibrium will be constrained efficient) provided that the following four conditions hold:

(i) $\Psi = \gamma$. This is the familiar Hosios condition for search models to deliver the efficient equilibrium.

(ii) $\chi = 0$. Even if $\Psi = \gamma$, if rents are sticky, the expected surplus from the match will not align with the Hosios condition.

(iii) $\Delta_t = 1$ so there is no dispersion of relative prices across intermediate inputs.

(iv) $w_t = z$. The wage is equal to the marginal product of labor.

Note that conditions (iii) and (iv) can be achieved by a policy of targeting zero inflation in the goods sector. Therefore, the reasons to move away from this policy are to address conditions (i) and (ii).

Table 1: Calibration of model parameters

Parameter	Target	Value
ψ	Level of activity (normalization)	1
β	Steady state interest rate	$1.02^{-1/12}$
Ψ	Baseline	0.5
γ	Hosios $= \Psi$	0.5
δ	Housing mobility in ACS	0.011
$\overline{M}$	Steady state vacancy rate $h = 0.966$	0.72
ω	Housing expenditure share	0.18
$1 - \theta$	Goods price adjustment frequency	1/12
η	Basu-Fernald (1997)	6
ξ	Annual lease	$(1 - \chi)/12$
χ	Estimated pass-through of new rents to CPI	0.46

4 Calibration

We calibrate to a monthly time period and treat 2019 as a steady state. For a functional form, we use a Cobb-Douglas matching function so $f(\Theta) = \overline{M}\Theta^{\gamma-1}$ and $g(\Theta) = \overline{M}\Theta^{\gamma}$, where $\overline{M}$ is the matching function efficiency. Table 1 summarizes the parameter values.

According to the 2019 American Community Survey, 40.5% of households moved into their current home in 2015 or later or in other terms, 59.5% of households at the start of 2015 remained in their home for the next 4 years, implying $(1-\delta)^{4\times 12} = 0.595$ or $\delta = 0.011$. Using the Census Housing Vacancy Survey for 2019, we calculate the ratio of occupied units relative to the sum of occupied units and vacant units for sale or rent to find $h = 0.966$. We set ξ to correspond to an annual lease. In the model, when the renegotiation shock occurs, the landlord renegotiates to the current market rent R_t. In practice, some landlords may not not the current market rent or may be reluctant to raise the rent on tenants to quickly. In calibrating the model, we assume that, at lease expiration, only a fraction $1 - \chi$ of landlords set the rent to the current market rent. Therefore we set $\xi = (1 - \chi)/12$.

The most challenging part of the calibration is to determine the degree of rigidity in new rents, χ. We observe various measures of rents. The CPI-shelter price index measures the current cost of rent for households and can be interpreted as $\overline{R}_t$. The Zillow Observed Rent Index measures rents on units listed for rent on Zillow. As the landlords posting units on Zillow are likely sophisticated, we interpret this index as a measure of R_t. The BLS New Tenant Rent Index measures rent growth among renters who moved into units. We interpret this as a measure of $\chi\overline{R}_t + (1-\chi)R_t$. We then estimate the pass through of R_t to $\overline{R}_t$ (e.g. eq. 24). Given values for δ and ξ, this pass-through coefficient allows us to infer χ. We provide further details in Appendix A, but in short, $\overline{R}_t$ moves slowly relative to what we would expect given 12-month leases and we interpret the extra inertia as nominal rigidity in the form of $\chi > 0$. The resulting value for χ is 0.46.

5 Monetary policy responses to housing inflation

Our main experiment is an increase in rents following an unexpected and permanent increase in the preference weight on housing ω. We consider three alternative monetary policy responses:

(i) CPI-targeting. Under this policy, the monetary authority sets CPI inflation to zero. Gross CPI inflation is defined as $\Pi_t^{1-\omega}(\overline{R}_t/\overline{R}_{t-1})^{\omega}$. Notice that the CPI is a cost-of-living price index and depends on the average rent across all tenants, $\overline{R}_t$.

(ii) Goods inflation targeting. Under this policy, the monetary authority sets goods market inflation to zero (i.e. $\Pi_t = 1$).

(iii) Optimal monetary policy. Under this policy, the monetary authority maximizes the welfare of the representative household subject to the equilibrium dynamics of the economy.[17]

We solve for a perfect-foresight non-linear transtion following each shock under these three different monetary policy strategies.

Housing demand shock We simulate a permanent increase in ω_t from its baseline value of 0.18 to 0.25 at date 0. Figure 5 shows the results. On the impact of the shock, the relative price of (new) rents jumps up because the household now receives more utility from housing and the surplus is larger. Whether or not this relative price movement affects the CPI depends on the monetary policy strategy. Under the goods inflation targeting policy, the central bank allows the CPI to rise in order to stabilize demand in the goods sector. At the other extreme, monetary policy can perfectly stabilize the CPI by lowering goods prices. Doing so creates a recession in the goods sector and consumption of goods falls by 10% on

[17] We compute the optimal policy by stacking the transition path of the equilibrium variables in the vector $\mathcal{X}$. The dimension of $\mathcal{X}$ is nT where we have $n = 16$ variables per time period and a transition of length $T = 300$ months after which we assume the economy has reached the new steady state. The households preferences can be represented as $U(\mathcal{X})$. We then stack the $(n-1)T$ equilibrium equations in $f(\mathcal{X}) = 0$. We then maximize $U(\mathcal{X})$ subject to $f(\mathcal{X}) = 0$. We find the non-linear solution to this problem using Newton's method.

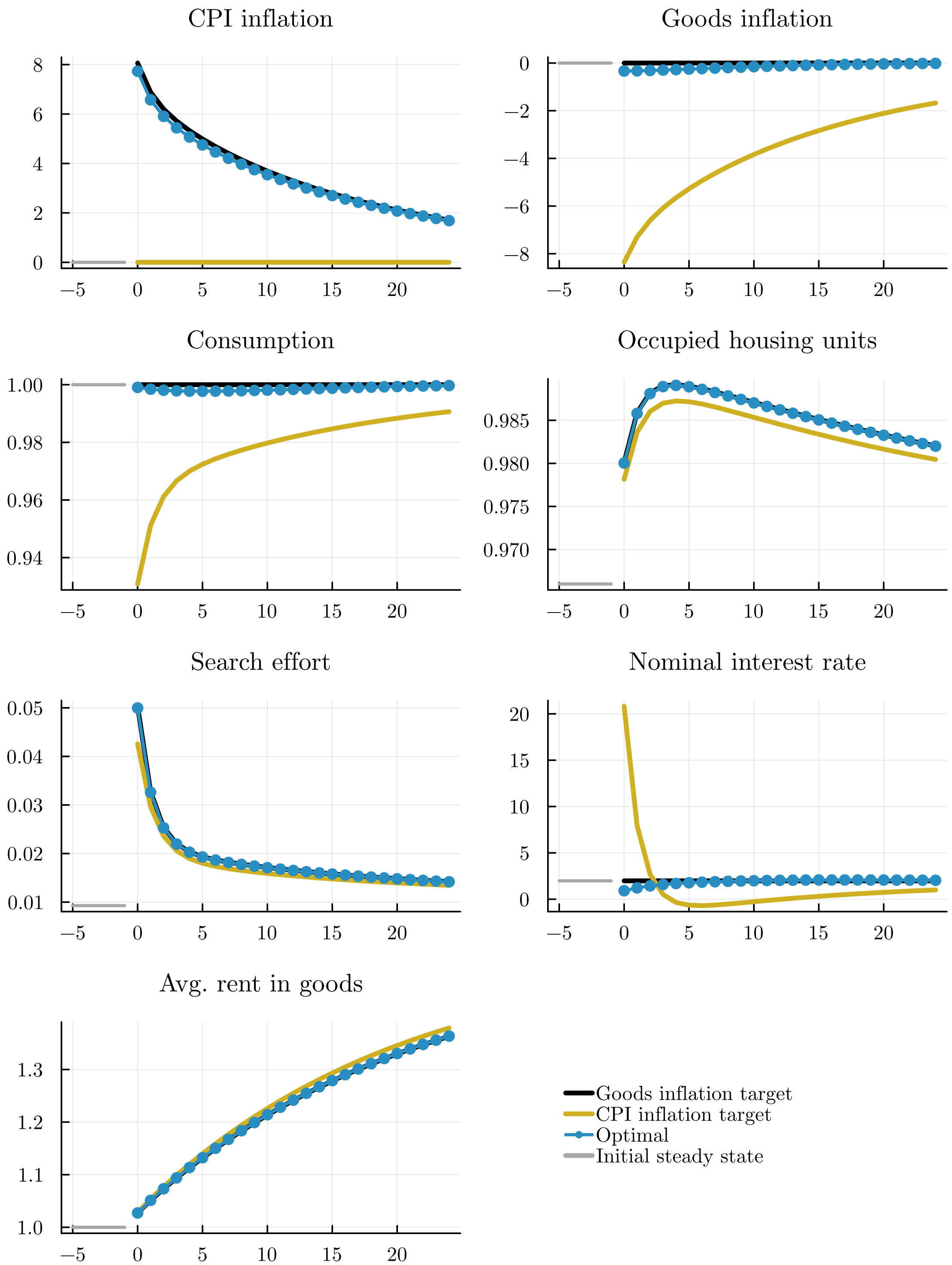

Figure 5: Alternative policy responses to a permanent increase in ω_t.

impact. With less consumption of goods, the marginal rate of substitution between housing and goods changes so as to reduce the relative price of rent in the short-run. Moreover, and more importantly, goods prices decline putting downward pressure on the CPI that balances the increase in rents.

To shed light on the source of the results in the model, define

$$U^{goods} \equiv \sum_{t=0}^{\infty} \beta^t (1-\omega) \left[\log(c_t) - \psi \ell_t\right]$$
$$U^{housing} \equiv \sum_{t=0}^{\infty} \left[\omega \log(h_t) - (1-\omega)\psi s_t\right]$$

so total welfare is $U = U^{goods} + U^{housing}$. At an optimal policy, we have $dU/di_t = 0$ for all t where i_t is the interest rate expected at date t along the transition path. This optimality condition implies $-dU^{goods}/di_t = dU^{housing}/di_t$. Intuitively, at the margin, the welfare loss from distoring the goods market must be balanced by the welfare gain from reducing distortions in the housing market. The top panel of Figure 6 plots U^{goods} and $U^{housing}$ as we vary i_0, the interest rate at the date the shock occuurs. The key feature of this figure is that $U^{housing}$ has a small slope relative to the curvature in U^{goods} so the marginal cost of distoring the goods market rises quickly as we attempt to stabilize the housing market. The lower panel of the figure gives some insight into why this is the case. Most importantly the consumption of housing services is a slow-moving stock so imbalances in the market for housing have little impact on the housing consumed and therefore little impact on welfare.

The main takeaway is that the optimal policy is nearly identical to goods inflation targeting. Even though, there are nominal rigidities in the housing market that lead to excessive search relative to the planner's solution, this cost is small relative to the recession in the goods market that is needed to counter it.[18]

[18] One difference between the goods market and housing market is that there is the possibility of price dispersion between varieties of intermediate goods while all housing units are perfect substitutes. One may then wonder if this difference in the sectors leads to optimal policy stabilizing goods inflation. In Appendix B.2 we explore this question and find the optimal policy remains close to goods inflation targeting even without the price dispersion consideration.

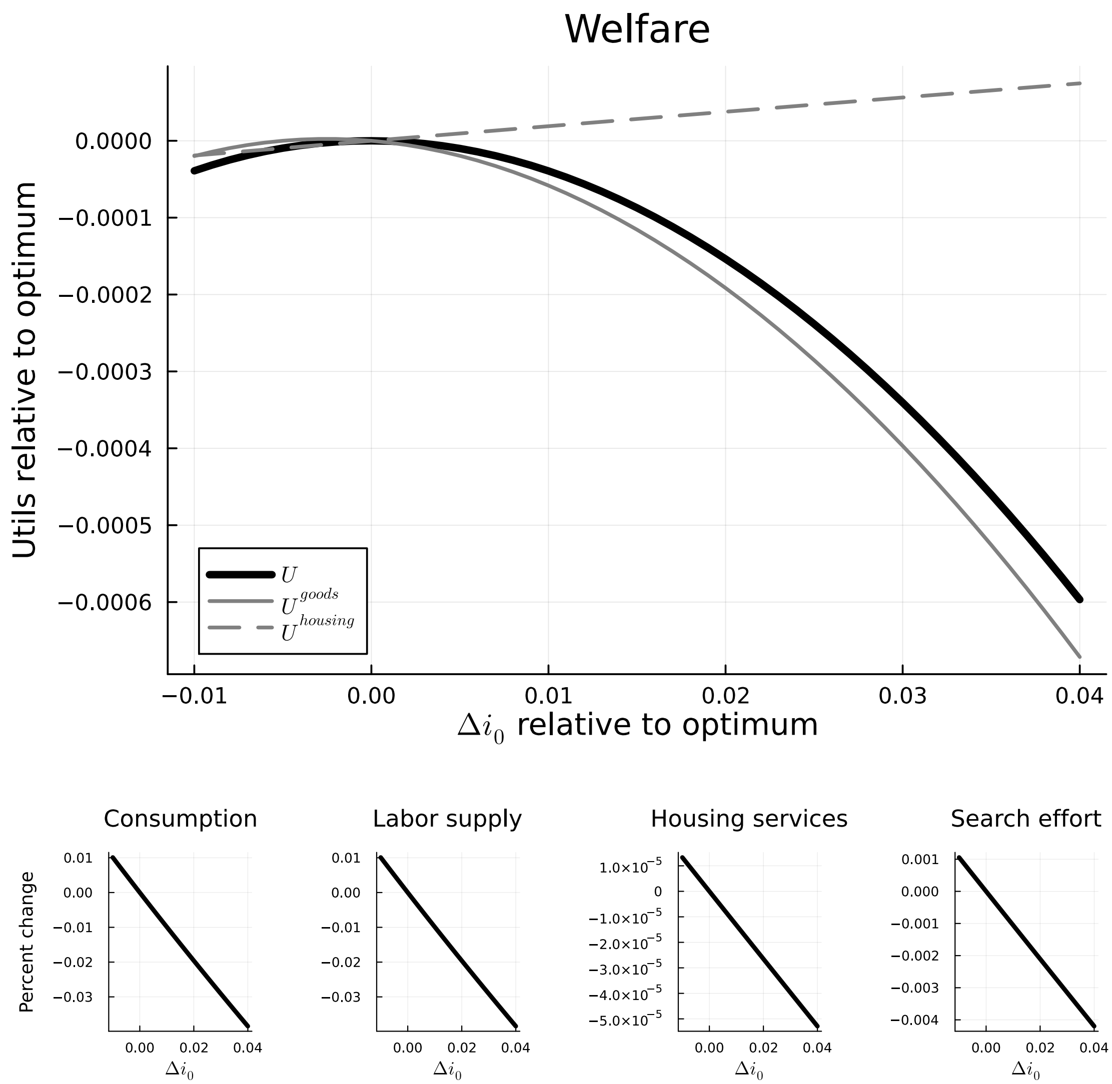

Figure 6: Top panel: change in welfare and its components as we vary i_0 around the optimal policy path. Bottom panels: changes in activity at date 0 as we vary i_0.

Catchup shelter inflation. Figure 7 shows the relative price of shelter. In 2020 and 2021, shelter prices did not keep pace with those in the rest of the economy leading to a decline in the relative price. In recent years, as leases expire and are reset to a higher price level, nominal shelter prices have grown strongly to return the relative price close to its pre-pandemic trend. Motivated by these observations, we now simulate a period of catchup shelter inflation, which we model as an unexpected sudden 5% increase in goods prices at date 0. The increase in the price level lowers existing rents in real terms. Thereafter, average outstanding rents grow faster than goods prices as leases renew and catchup with the higher price level. We choose a 5% increase in the price level because, looking at Figure 7, the relative price of shelter in early 2022 was roughly 5% below its pre-pandemic trend.[19]

Figure 8 shows the results of this simulation. Under goods inflation targeting, there is upward pressure on the CPI as leases gradually turnover to the new price level. Under CPI inflation targeting, goods prices fall to offset the rising rents. As before, the optimal policy is nearly identical to the goods inflation targeting policy.

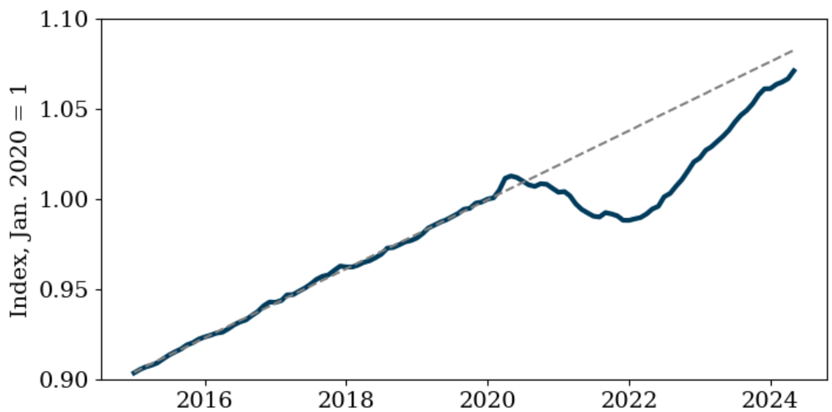

Figure 7: Relative price of shelter

Note: The relative price is calculated as the ratio of the PCE housing price index and the PCE core excluding housing price index. The data are through May 2024.

[19] In our simulation, we start the economy from an initial condition in which real rent commitments, x_t, are 5% below their steady-state level and then simulate the transition back to steady state. Substantively, we begin each period with some rent contracts with fixed nominal values and some goods prices with fixed nominal prices. In our simulation, we change the ratio of these fixed prices that we inherit from the past.

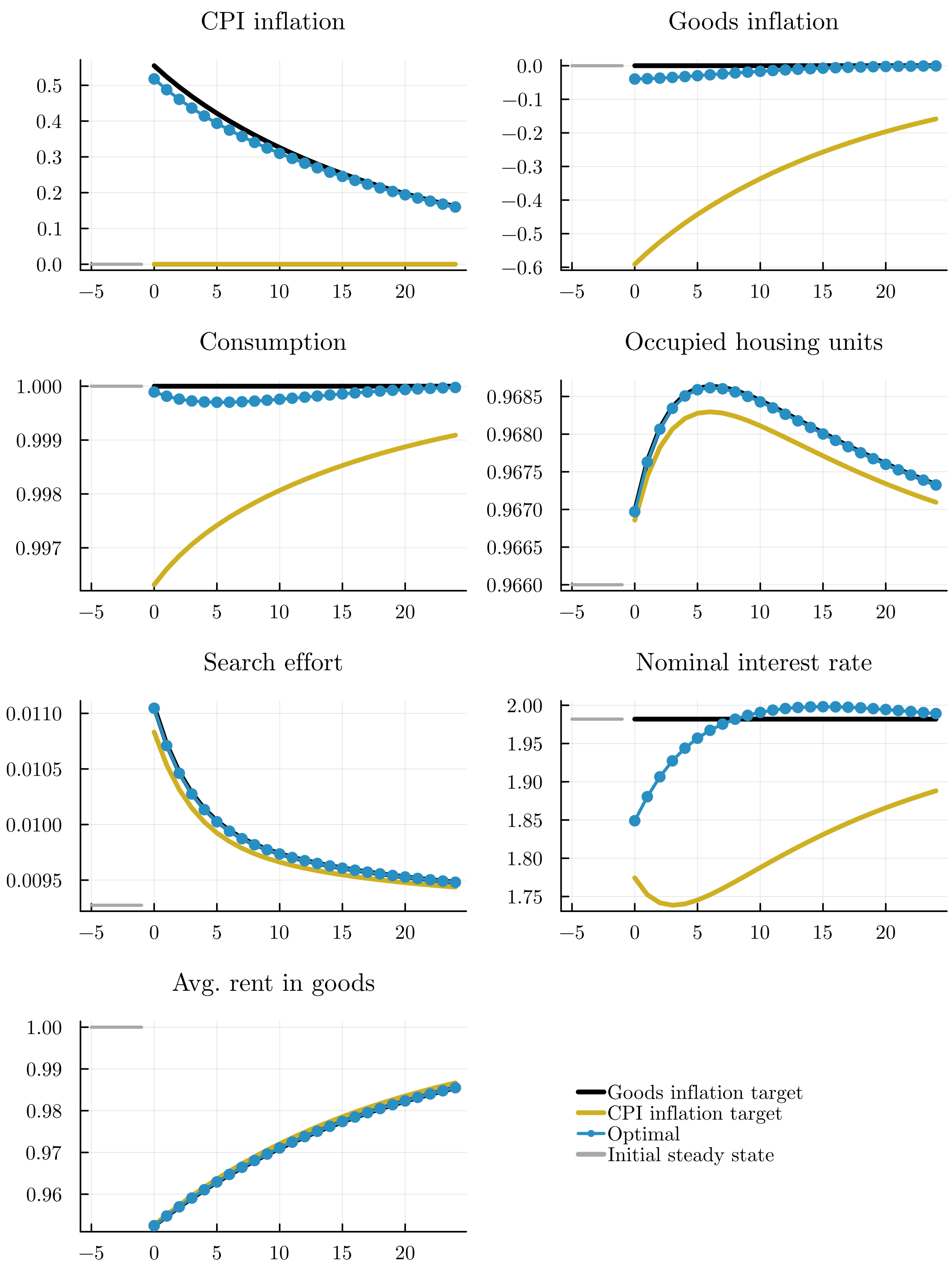

Figure 8: Alternative policy responses to catchup shelter inflation.

6 Conclusions

The standard architecture in New Keynesian models is based on the premise that output is demand-determined: if consumers demand more of a good, a firm that does not raise its price must hire enough production factors to produce it. We argue that this architecture is a poor description of the housing market where the supply is likely to be fixed in the short run or determined by supply-side factors.

Motivated by this disconnect, we develop a two-sector macroeconomic model with search and nominal frictions in the housing sector. In this environment, an increase in demand for housing does not lead to an increase in the quantity of housing but rather an increase in consumer search and lower vacancy rates. In contrast, an increase in the demand for other goods leads to an increase in output, as in the standard New Keynesian model. We use our framework to shed light on the optimal monetary policy in the current juncture where inflation is driven by a surge in rent prices. We find that optimal policy should largely ignore shelter prices and target price stability in the non-housing sector. This conclusion is obtained exactly in a version of the model with costless search and demand rationing and quantitatively in a version with housing search costs calibrated to match US data on housing tenure and vacancy rates.

Our findings suggest a reappraisal of the measure of inflation targeted by central banks. The standard analysis in the New Keynesian litarature finds that monetary policy should place more weight on the inflation in sectors with stickier prices because these sectors have more potential for misallocation. From our perspective, because the market for housing services is largely supply-determined, changes in prices are disconnected from the consumption of housing and are therefore less relevant for welfare.

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Appendix

A State-space model of rent pass through

The heart of the system to be estimated is

$$X_{t+1} = (1-\delta)(1-\xi)X_t + R_t\xi(1-\delta)h_t + \left[\chi\overline{R}_t + (1-\chi)R_t\right] f(\Theta_t)s_t$$
$$\overline{R}_t = X_{t+1}/h_{t+1}$$
$$h_{t+1} = (1-\delta)h_t + f(\Theta_t)s_t$$

To simplify the estimation, we will fix h_t at steady state, which implies $f(\Theta_t)s_t = \delta h$. We may then rewrite the system as

$$\overline{R}_t = \frac{(1-\delta)(1-\xi)}{1-\delta\chi}\overline{R}_{t-1} + \frac{\xi(1-\delta)+\delta(1-\chi)}{1-\delta\chi}R_t.$$

Define $z_t = R_t/\overline{R}_t$ and $\lambda = \frac{\xi(1-\delta)+\delta(1-\chi)}{1-\delta\chi}$. We then have

$$\frac{\overline{R}_t}{\overline{R}_{t-1}} = \lambda\frac{R_t}{R_{t-1}}z_{t-1} + (1-\lambda). \tag{A.1}$$

Now consider a steady state in which all rents grow at $\Pi = \exp\{\pi\}$. We then have

$$\bar{z} = \frac{1}{\lambda} - \frac{1-\lambda}{\lambda\Pi}.$$

Define hat variables such that for some scale s, $R_t = s\bar{z}\Pi^t exp\{\hat{R}_t\}$, $\overline{R}_t = s\Pi^t\exp\{\hat{\overline{R}}_t\}$, and $z_t = \bar{z}\exp\{\hat{z}_t\}$. We can then write (A.1) as

$$\exp\{\hat{\overline{R}}_t - \hat{\overline{R}}_{t-1} + \pi\} = \lambda\bar{z}\exp\{\hat{R}_t - \hat{R}_{t-1} + \pi + \hat{z}_{t-1}\} + 1 - \lambda$$

Now take logs and linearize with respect to the hat variables

$$\hat{\overline{R}}_t - \hat{\overline{R}}_{t-1} = \lambda\bar{z}\left(\hat{R}_t - \hat{R}_{t-1} + \hat{z}_{t-1}\right). \tag{A.2}$$

Empirical model We treat z_t and $\overline{R}_t$ as unobserved states. The state transition for $\overline{R}_t$ is (A.2). For z_t, we specify an AR(1) for the growth rate of market rents (denoted

$m_t = \log R_t - \log R_{t-1} - \pi$). The state transition equations are then

$$m_t = \rho_m m_{t-1} + \varepsilon_t \tag{A.3}$$

$$\hat{\bar{R}}_t = \hat{\bar{R}}_{t-1} + \lambda \bar{z} \left(m_t + \hat{z}_{t-1}\right) \tag{A.4}$$

where ε is distributed $N(0, \sigma_\varepsilon^2)$.

The BLS CPI Housing Survey records the rent on housing units at six-month intervals and constructs the monthly inflation rate. We define monthly shelter inflation as the sixth-root of the six-month change in $\bar{R}_t$

$$\Pi_t^{shelter} = \left(\frac{\bar{R}_t}{\bar{R}_{t-6}}\right)^{1/6}$$

$$\pi_t^{shelter} = \frac{1}{6}\left(\hat{\bar{R}}_t - \hat{\bar{R}}_{t-6}\right) + \pi \tag{A.5}$$

We use the Zillow Observed Rent Index (ZORI) as a measure of $\log R_t - \log R_{t-1} = m_t + \pi^{Zillow}$. We allow the ZORI to have a different mean growth rate π^{Zillow}. Finally, we use the 4-quarter change in the BLS New Tenant Rent Index as a measure of new rent growth. We define new rents as $N_t \equiv \chi \bar{R}_t + (1-\chi) R_t$. Then $\pi_t^{NTR} \equiv \log N_t - \log N_{t-12}$. In all we have

$$\boldsymbol{y}_t = \begin{pmatrix} \Delta \log \left(\text{CPI-shelter Index}\right) \\ \Delta \log \left(\text{Zillow Observed Rent Index}\right) \\ \Delta_{12} \log \left(\text{BLS New Tenant Rent Index}\right) \end{pmatrix} = \begin{pmatrix} \pi_t^{shelter} \\ m_t + \pi^{Zillow} \\ \pi_t^{NTR} \end{pmatrix} + \boldsymbol{\omega}_t \tag{A.6}$$

where $\boldsymbol{\omega}$ is a 3×1 i.i.d. Gaussian random variable.

In summary, (A.3)-(A.4) are the main state transition equations. (A.6) are the observation equations. Constructing $\pi_t^{shelter}$ requires six lags of $\hat{\bar{R}}_t$ and construction π_t^{NTR} requires 12 lags of $\log N_t$ so we create an expanded system to keep track of those lags. The model has 10 parameters: ρ and 4 standard deviations, 2 means, δ, χ, and ξ. We calibrate δ and ξ and estimate χ. We calibrate π^{Zillow} to the mean growth rate of the ZORI before the 2020. The remaining seven parameters are estimated by maximum likelihood.

We use monthly data on the CPI-shelter price index from 1/2005 to 4/2024 and the Zillow Observed Rent Index from 1/2015 to 4/2024. We use quarterly data on the 4-quarter change in the New Tenant Rent Index from 2005Q21 to 2024Q1.

B Additional data and results

B.1 Shelter inflation in G7 countries

Table B.1 shows core inflation and housing inflation across advanced economies. Shelter inflation has also made outsized contributions in other advanced economies. Core inflation in Canada would be close to zero excluding shelter inflation; UK inflation would also be significantly lower excluding shelter despite excluding owners' equivalent rent. By contrast, the contributions are much more modest in both the Eurozone and Japan due to a combination of lower weights and lower shelter inflation.

Table B.1: Core inflation and shelter inflation for the G7

	Core inflation (yoy)	Shelter inflation (yoy)	Shelter weight in core (%)	Contribution to core inflation (pp)	Inflation ex shelter (yoy)
US (PCE)	2.8	5.6	17%	1.0	2.2
US (CPI)	3.4	5.4	45%	2.4	1.9
UK	3.8	7.0	10%	0.7	3.5
Canada	2.7	6.4	37%	2.5	0.3
Japan	2.4	0.2	21%	0.0	3.0
Eurozone	2.9	3.3	11%	0.4	2.8

B.2 The role of price dispersion

Stabilizing goods prices eliminates price dispersion between intermediate goods varieties. Is this an important consideration in our optimal policy calculation? To answer this question we perform a simple alternative calculation in which we fix $\Delta_t = 1$ and solve for the optimal policy response to the permanent increase in ω_t as in Figure 5. As Figure B.1 shows, the optimal policy remains close to goods inflation targetting. From this experiment, we conclude that the optimality of goods inflation targeting is not primarily driven by concerns over price dispersion within the goods sector.

Figure B.1: A permanent increase in ω_t in the absence of goods price dispersion ($\Delta_t = 1$).