How Should Monetary Policy Respond to Housing Inflation?*

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Abstract

A persistent rise in rents has kept inflation above target in many advanced economies. Optimal policy in the standard New Keynesian model requires policy to stabilize housing inflation. We argue that the architecture of the New Keynesian model—based on the premise that excess demand is always satisfied by producers—is inappropriate for the housing market, and we develop a matching framework that allows for demand rationing. Our analysis shows that the optimal response to a housing demand shock is to stabilize inflation in the non-housing sector and disregard housing inflation. These findings hold exactly in a version of the model with costless search and quantitatively in a version with housing search costs calibrated to match US data on housing tenure, vacancy rates, and the size of the real estate sector.

JEL classification: E24, E30, E31, E52

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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]

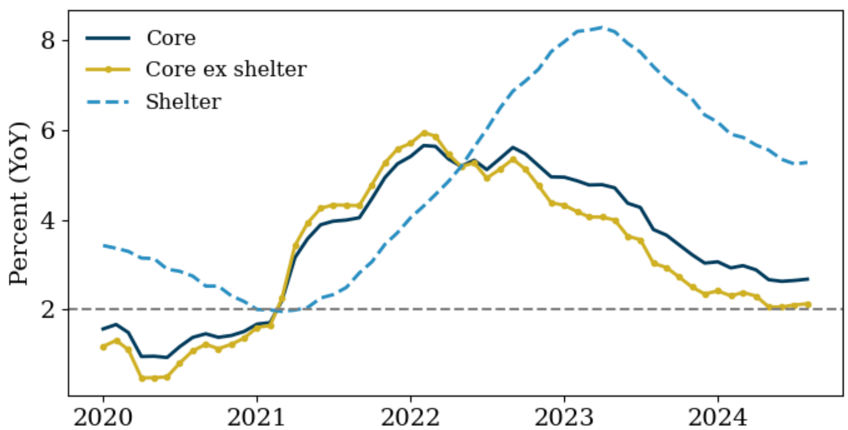

Figure 1: US PCE inflation

Source: Bureau of Economic Analysis. The data are through August 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 changes in relative prices create trade-offs for monetary policy (see Woodford, 2003). A central conclusion in this literature is that policy should focus on stabilizing prices in sectors in which prices are more rigid and in which supply is inelastic (see Aoki, 2001; Benigno, 2004; Eusepi, Hobijn and Tambalotti, 2011). To the extent that rents exhibit similar stickiness to that of other goods and given that the supply of housing is notably inelastic, this suggests that monetary policy should assign considerable weight to housing inflation. Specifically, in response to a housing demand shock, the monetary authority should tighten policy to maintain inflation around the established target.

We argue that the canonical New Keynesian model is not an appropriate framework for analyzing shelter inflation. In New Keynesian theory, a standard assumption is that output is demand-determined: if consumers demand more of a good, a firm that does not raise its

[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 D.1 for details.

price must hire additional factors of production to meet that demand. 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 housing services exceeds the available supply, there is no way for the economy to produce more. We posit that a more appealing assumption is one of demand rationing. We develop a theory based on this premise, showing that it has radically different implications for the costs of inflation and for optimal monetary policy. Our application to housing shows that in contrast to the standard New Keynesian model, the optimal policy involves assigning approximately zero weight to housing inflation.

Preview. As a preview for our results, we show graphically how the two alternative rationing assumptions work to understand the implications for monetary policy. Figure 2 depicts a scenario where, starting from market clearing, demand shifts upward while the price remains rigid. The red solid dot represents the case of *demand-determined output*. In this situation, suppliers would prefer to produce less but are assumed to increase their output to meet the higher demand. In contrast, the blue solid dot illustrates the case of *supply-determined output*, where households wish to consume more at the prevailing price but are instead rationed.

In the figure, the red and blue triangles illustrate the deadweight losses relative to the flexible price allocation. Panel (a) depicts a case where these deadweight losses are approximately equal. Panel (b) shows that when supply becomes more inelastic, the deadweight loss under demand-determined output increases significantly whereas the deadweight loss under supply-determined output is reduced. The larger deadweight loss under demand-determined output is why the New Keynesian model prescribes a greater weight on sectors with low supply elasticity, as emphasized by Eusepi et al. (2011). However, the reversal of this result under supply-determined output suggests that the optimal monetary policy response to housing inflation depends crucially on the rationing mechanism.

Framework and results. We start with a static two-sector model featuring fixed prices and search frictions, building on the seminal work of Barro and Grossman (1971) and Michaillat and Saez (2015). Our framework features two sectors that are subject to nominal rigidities but differ in their rationing mechanisms. In the (non-housing) goods sector, output is entirely demand-determined, consistent with the canonical New Keynesian model. Under a fixed goods price, when goods demand exceeds supply, firms adjust production to meet demand. In contrast, we assume that the housing sector resolves disequilibrium through demand rationing. Specifically, we introduce search frictions, requiring households to exert effort to find housing.

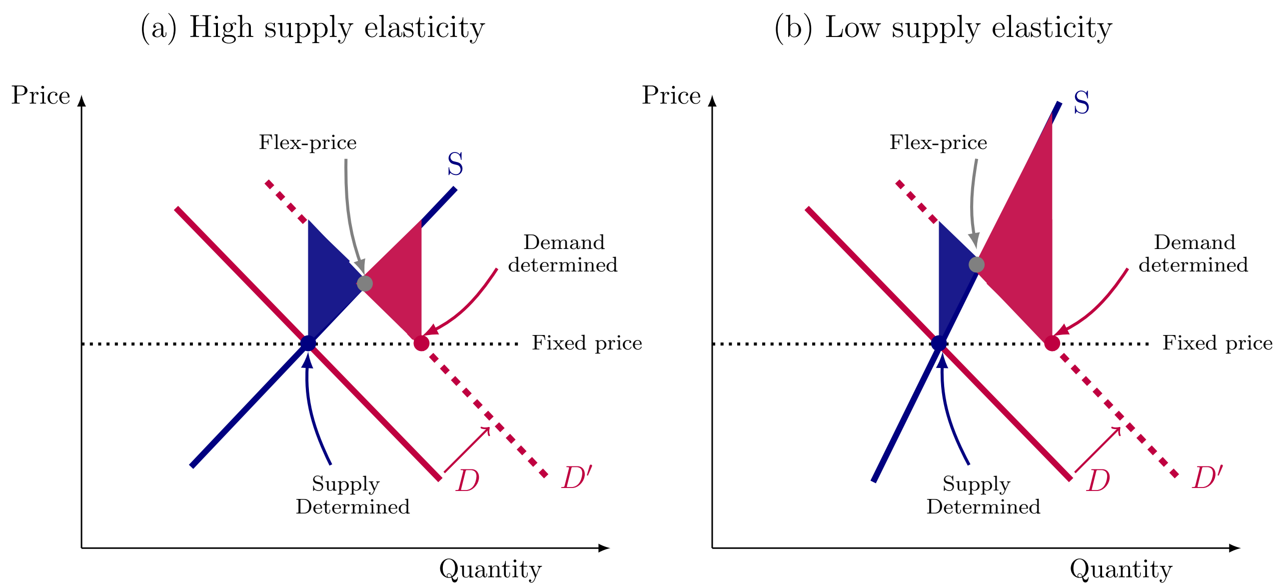

Figure 2: Rationing protocols: supply vs. demand determined

Note: The purple and blue triangles indicate respectively the deadweight losses in case of demand-determined and supply-determined equilibrium.

This framework implies that when the notional demand for housing exceeds supply at the fixed rent, households respond by increasing their search effort, and the market clears through changes in market tightness. Moreover, we show analytically that the presence of a search friction mimics a short-side rule as the search friction vanishes. Namely, when there is excess demand, the allocation is approximated by supply-determined output whereas when supply exceeds demand, the allocation becomes demand-determined.

We characterize optimal monetary policy in this framework. In a supply-determined equilibrium without search costs, the monetary authority ensures a zero output gap in the goods sector at all times. However, when search is costly, the amount of search effort generally deviates from the efficient one. In this case, we derive a targeting rule for optimal policy that shows how the monetary authority trades off the output gap against housing congestion.

We then extend the analysis to a dynamic environment to quantitatively evaluate the optimal monetary policy. The quantitative model features staggered pricing à la Calvo (1983) for goods and long-term rental markets for housing subject to search and nominal frictions. We calibrate our model so that it matches facts on renter mobility, the housing vacancy rate, and spending on the real estate sector.

Our main quantitative experiment consists of evaluating the impact of an increase in the preference for housing. This housing-specific shock is motivated by the surge in remote work and the desire for more space following the pandemic (see, e.g., Mondragon and Wieland, 2022). With market rents rising slowly due to nominal rigidities, households capture a larger share of the surplus from a match and search excessively relative to the constrained-efficient level. The monetary authority can mitigate excessive 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 authority would be willing to depress the goods market to compensate for overheating in the housing market.

Our quantitative answer is that it is not optimal to depress the goods market at all. Specifically, we compute the optimal monetary policy and compare it with two strategies: stabilizing goods inflation and stabilizing overall CPI inflation. We find that the optimal policy is nearly identical to goods inflation targeting. This implies that it is optimal for the monetary authority to allow CPI inflation to rise in response to a housing demand shock and to keep the output gap in the goods sector close to zero.

Our results are robust to alternative parameterizations and extensions. Notably, while our baseline model considers a fixed supply of housing, our result that the central bank should ignore housing inflation also holds when we allow for *production* of housing. That is, the key distinction is not whether housing is in fixed supply or produced, but whether the equilibrium resembles a demand-determined one or a supply-determined one.

Literature. Our paper belongs to the New Keynesian literature examining 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, and shows that the optimal policy is to target inflation in the sector with sticky prices. Woodford (2003) and Benigno (2004) show, more generally, that when there are multiple sectors with price rigidities, divine coincidence fails, and inflation in the stickier sectors should carry more weight under the optimal policy. Eusepi et al. (2011) provide a quantitative analysis of the weights that minimize the welfare costs of nominal distortions and find that these weights are larger for sectors with more rigid prices as well as more inelastic supply.[2]

Our paper is also connected to the literature on monetary policy in economies with durable

[2]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. See, for example, Rubbo (2023), La'O and Tahbaz-Salehi (2022); Baqaee, Farhi and Sangani (2024) for production networks; Guerrieri, Lorenzoni, Straub and Werning (2021, 2022) for the role of downward wage rigidity and costly reallocation; Woodford (2022), Gagliardone and Gertler (2023), di Giovanni, Kalemli-Özcan, Silva and Yildirim (2022, 2023) for inflation dynamics post-COVID; Olivi, Sterk and Xhani (2023) for insights on non-homotheticities and inequality; and Fornaro and Romei (2023); Bianchi and Coulibaly (2024) for discussions on open economy considerations.

goods. Barsky, House and Kimball (2007) develop a model with different price rigidities in non-durable and durable goods, and show that it is the rigidity in durables that plays a more significant role in the monetary transmission. This is because assets like durable goods are more sensitive to changes in interest rates. In line with their insights, Erceg and Levin (2006) and Barsky, Boehm, House and Kimball (2015) show that monetary policy should focus on stabilizing the output gap in the durable goods sector within a standard New Keynesian framework. There are two key differences in our analysis. First, we study the market for the service flow from durables (i.e. the rental market) rather than in the market for newly constructed durables (i.e. the market for new homes). The large interest elasticitities of demand that are emphasized in the durables literature are not a feature of the rental market. Second, we consider demand rationing for housing services, rather than assuming a demand-determined equilibrium. The different rationing protocol leads to our finding that optimal monetary policy should place less emphasis on stabilizing housing inflation.

As mentioned above, we build on Michaillat and Saez (2015), who analyze unemployment fluctuations through a matching approach while preserving the architecture of the general disequilibrium model of Barro and Grossman (1971).[3] In contrast to their work, our study incorporates multiple sectors that differ in their rationing protocols and studies optimal policy. This approach allows us to explore how sectoral shocks and differences in rationing influence the costs of inflation, the dynamics of employment, and the implications for monetary policy.

Outline. Section 2 presents and analyzes 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 static version of the model to highlight the key mechanism and trade-off for monetary policy. The economy has two sectors, goods and housing, both with rigid prices. Goods are produced with labor and are sold in a competitive market.[4] Housing

[3]Other examples integrating search and matching in New Keynesian models include Gertler and Trigari (2009), Christiano, Eichenbaum and Trabandt (2016), Blanco, Drenik, Moser and Zaratiegui (2024). In the disequilibrium literature, a recent contribution is Huo and Ríos-Rull (2020), which explores the quantitative properties of introducing a short-side rule in the labor market, along the lines of Drèze (1975). Flynn, Nikolakoudis and Sastry (2023) explore an alternative to the New Keynesian model where firms choose supply schedules.

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

is in fixed supply and is rented in a frictional market where households must exert search effort to locate available rental properties.

2.1 Main elements

Households. The economy is populated by a representative household with preferences given by the utility function

$$(1-\omega)\log(c) + \omega\log(h) + (1-\omega)\left[\varphi\log\left(\frac{M}{P}\right) - (\ell + \rho s)\right].$$

The household derives utility from consumption goods c, housing h, and real money balances M/P, while facing a disutility from labor ℓ and time spent searching for housing s. The preference parameter ω captures the relative preference for housing compared to consumption; ρ captures the disutility of time spent on searching relative to labor, and φ represents the value of real money holdings in terms of consumption goods.

Households receive labor income, firm profits, and lump-sum transfers from the government, which they use to buy consumption, housing, and accumulate money. Their budget constraint is given by

$$Rh + Pc + M \leq W\ell + d + T, \tag{1}$$

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

To rent housing, the household must engage in costly search effort. Specifically, the household is divided into a continuum of identical members who spend time searching for housing units and match with landlords according to a matching function $\mathbb{H}(s, h^v)$, where s denotes hours searched and h^v denotes housing vacancies. The matching function is continuously differentiable, strictly increasing in both arguments, and has constant returns to scale. Let $\Theta \equiv s/h^v$ denote market tightness (i.e., the ratio of aggregate hours households spend searching to vacant houses). Using that $\mathbb{H}$ is constant returns, we can define $f(\Theta)$ as the probability that a member of the households finds one unit of housing per hour searched. Given the properties of $\mathbb{H}$, it follows that f is decreasing in Θ. We further assume that $\lim_{\Theta\to 0} f(\Theta) = 1, \lim_{\Theta\to\infty} f(\Theta) = 0$. Meanwhile, we denote by $g(\Theta)$ the probability that a landlord rents out a unit of housing, satisfying $g(\Theta) = f(\Theta)\Theta$.

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

$$\max_{c,h,s,\ell,m} \left\{ (1-\omega)\log(c) + \omega\log(h) + (1-\omega)\left[\varphi\log\left(\frac{M}{P}\right) - (\ell+\rho s)\right]\right\}, \tag{2}$$

subject to

$$Rh + Pc + M = W\ell + d + T,$$

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

The second constraint specifies that the amount of housing a household can rent depends on its search effort and market tightness. By the law of large numbers, a household that searches for s hours rents $sf(\Theta)$ units of housing.

The optimality conditions lead to

$$\frac{\omega}{h} = \frac{1-\omega}{c}\left(\frac{R}{P}\right) + (1-\omega)\frac{\rho}{f(\Theta)}. \tag{3}$$

At the margin, the household is indifferent between consuming one more unit of housing and one more unit of goods. If a household gives up one unit of housing, the utility cost is $\frac{\omega}{h}$, while the benefit includes an increase in consumption of goods by $\frac{R}{P}$, which provides a marginal utility of $\frac{1-\omega}{c}$, as well as a reduction in search effort by $\frac{1}{f(\Theta)}$, yielding a marginal utility of $(1-\omega)\frac{\rho}{f(\Theta)}$.

In addition, optimality also implies

$$\frac{W}{P} = c, \tag{4}$$

$$\frac{M}{P} = \varphi c. \tag{5}$$

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 (referred to as "firms"), and real estate firms that rent out their available stock of housing units (referred to as "landlords"). Each type has a measure of one.

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

$$l^d = \frac{c}{z}. \tag{6}$$

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 $\Theta = s/\bar{h}$.

Total profits from firms and landlords are then given by

$$d = Pz\ell - W\ell + Rg(\Theta)\bar{h}. \tag{7}$$

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 monetary policy M, a *competitive equilibrium* in this economy is given by $\{c, h, \ell, s, W, \Theta, d, T\}$ such that (i) households' policies solve (2); (ii) firms' employment satisfies (6) and profits are given by (7); (iii) landlords supply $\bar{h}$ units of housing; (iv) matching probabilities satisfy $f(\Theta)s = g(\Theta)\bar{h}$ with $\Theta = s/\bar{h}$; and (v) the government budget constraint holds, $M = T$.

Given a quantity of money M set by the government, there exists a unique equilibrium for any $\rho > 0$. To see this, notice that (5) uniquely determines the level of consumption for any $(M, \bar{P})$. In addition, given c, equations (3) and $h = g(\Theta)\bar{h}$ uniquely determine the level of Θ and thus pin down the search effort and the quantity of housing consumed.

To illustrate the determination of equilibrium, we rearrange equation (3) and use $h = g(\Theta)\bar{h}$ to obtain:

$$\left(\frac{\omega}{1-\omega}\right)\frac{c}{h} = \frac{\overline{R}}{\overline{P}} + \frac{c\rho}{f\left(g^{-1}\left(h/\bar{h}\right)\right)}.$$

The left-hand side represents the marginal rate of substitution between housing and consumption (MRS), depicted by the downward-sloping curve in Figure 3. The right-hand side denotes an *effective rent*, expressed in terms of consumption goods. The effective rent depends on $h/\bar{h}$ because this ratio determines the probability of finding a house and the amount of search effort required. Given that c is defined by equation (5), we then derive

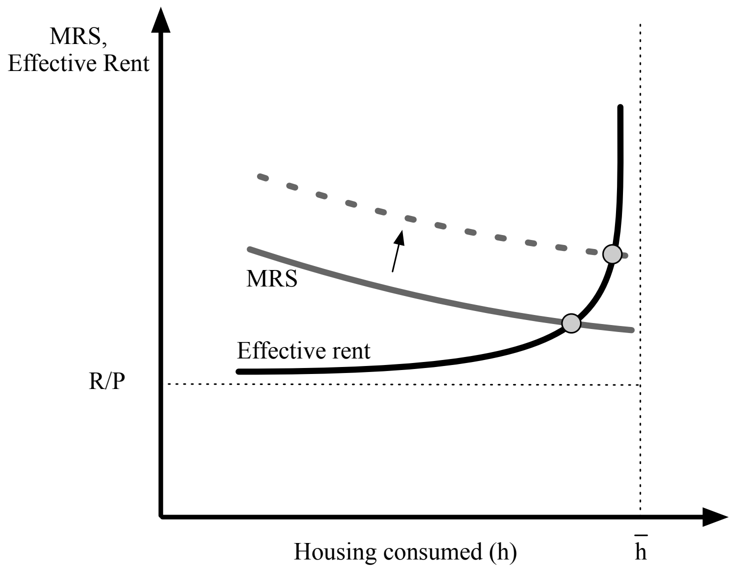

Figure 3: Equilibrium in the housing market

an upward-sloping curve for the effective rent as a function of h, as illustrated in the figure. As h increases, it becomes increasingly costly for households to find available housing units. Moreover, as h approaches $\bar{h}$, the probability of finding a unit $f(\Theta)$ approaches zero, which sharply increases the effective rent. The equilibrium occurs at the intersection of the two curves. Notice that as the preference for housing ω increases, the MRS shifts up, and the equilibrium features a higher amount of housing occupied and higher effective rents.

2.2 Optimal Policy

We first present the constrained-efficient allocation in this economy, which will serve as a benchmark for optimal monetary policy. Throughout, we will abstract from the utility of money balances in the welfare evaluation.[5]

Constrained-efficient allocation. We consider a planner that directly chooses allocations subject to technological constraints and search frictions. The planner's problem can be expressed as follows:

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

[5]This can be rationalized by taking the cashless limit $\varphi \to 0$, following Woodford (2011).

The first-order conditions yield

$$c = z, \tag{8}$$

$$\frac{\omega}{sf(\Theta)}\left(f(\Theta) + f'(\Theta)\Theta\right) = (1-\omega)\rho. \tag{9}$$

Condition (8) states that the optimal consumption of goods equals z, reflecting the log utility of consumption and linear labor disutility. This implies that the labor wedge is zero in the constrained-efficient allocation. Condition (9) 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.

A flexible-price equilibrium in which firms set prices equal to marginal cost results in the constrained-efficient level of employment.[6] However, price flexibility does not generally ensure an efficient level of search. Owing to the standard congestion effects induced by search frictions, there is generally a gap between the private and social marginal costs of searching. Consider an equilibrium with flexible rent prices that are set via Nash-bargaining. Denoting by Ψ the bargaining power for the household, the real rental rate r^* satisfies[7]

$$r^* = \frac{v'(h)}{u'(c)}(1-\Psi)$$

That is, the household obtains a fraction Ψ of the total surplus. Replacing r^* for the relative price in (3), we obtain (9) if the bargaining power is $\Psi = \frac{f(\Theta)+f'(\Theta)\Theta}{f(\Theta)} \equiv \gamma(\Theta)$. Following Hosios (1990), setting the bargaining power equal to the elasticity of the matching function with respect to search effort, renders the flexible-price competitive equilibrium constrained efficient.

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.

[6]This can be seen by noting that combining $P = W/z$ and (4) yields (8).

[7]The Nash-Bargaing solution satisfies $r^* = \text{argmax}_x \left(\frac{v'(h)}{u'(c)} - x\right)^{\Psi} x^{1-\Psi}$.

The optimal policy problem is

$$\max_{c,s,M} \left\{(1-\omega)\log(c) + \omega \log\left(sf\left(\frac{s}{\bar{h}}\right)\right) - (1-\omega)\left(\frac{c}{z} + \rho s\right)\right\}, \tag{10}$$

subject to

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

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

The first constraint reflects that households choose optimally how they split their income between consumption and housing, as given by (3). Notice that we can ignore 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

$$\underbrace{(1-\omega)\rho - \frac{\omega}{h}\left(f(\Theta) + f'(\Theta)\Theta\right)}_{\text{Housing congestion}} = \underbrace{\left(\frac{c-z}{z}\right)}_{\text{Output gap}} \frac{-\frac{\omega}{h}(f(\Theta) + f'(\Theta)\Theta) + (1-\omega)\rho\left(\frac{f'(\Theta)\Theta}{f(\Theta)}\right)}{\frac{h}{c}\left(\frac{\overline{R}}{\overline{P}}\right)}. \tag{11}$$

This condition represents a targeting rule that relates the output gap and housing congestion. The left-hand side reflects the deviation of search effort from the constrained-efficient level, as specified in equation (9). 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 (11) 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.[8] That is, to cool down the housing market, the central bank is willing to allow a recession.[9]

Figure 4 illustrates the trade-offs for monetary policy. The figure plots the policy indif-

[8]To see that the second term is negative, we note that $f(\Theta)+f'(\Theta)\Theta > 0$. For this, we use $\mathbb{M}(s, h^v) = f(\Theta)s$ and $0 < \mathbb{M}_s(s, h^v) = f(\Theta) + f'(\Theta)\Theta$, where the first inequality follows from the assumption that $\mathbb{M}$ increasing in s. Additionally, note that the denominator is positive and that $\rho\left(\frac{f'(\Theta)\Theta}{f(\Theta)}\right)$ is negative.

[9]Conversely, when there is too little housing search, the planner induces a positive output gap.

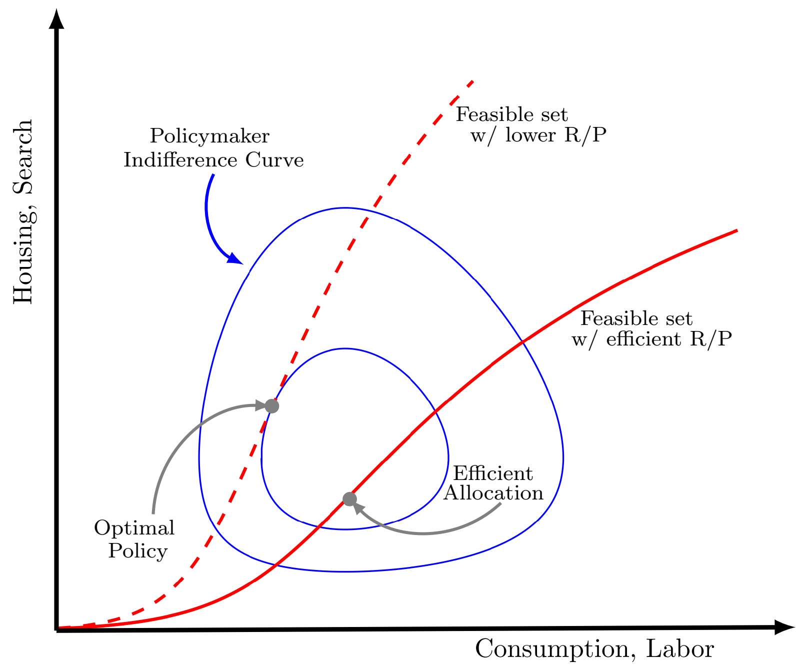

Figure 4: Illustration of trade-offs for monetary policy

ference curves and the feasible set for the central bank.[10] The implementability constraint reflecting households' optimality implies that search effort is an increasing function of consumption. This constraint is represented by the upward red locus, which effectively captures the sacrifice ratio. Namely, the steeper the slope, the lower the amount of consumption the central bank needs to give up to reduce search by one unit. The policymaker can choose to move along this locus by setting the money supply. When the R/P ratio is equal to the level implied by the Hosios condition (red solid line), the constraint passes through the efficient allocation. When 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 trade-off between inefficiently high search effort and inefficiently low consumption. The optimal policy balances these two inefficiencies. At the optimum, depicted by the tangency point between the indifference curve and the dashed red locus, the economy exhibits a negative output gap and more housing than in the constrained-efficient allocation.

In a situation where the preference for housing increases, nominal rigidities will imply that the relative price of shelter is initially too low. As a result, the housing market will overheat, and households will devote more search effort to acquiring housing units. Monetary policy will therefore allow for a contraction of output in the goods sector to mitigate overheating

[10] The numerical illustration uses the matching function $\mathbb{M}(s, h^v) = [s^{-\epsilon} + (h^v)^{-\epsilon}]^{-1/\epsilon}$, as in Michaillat and Saez (2015), and $\gamma = 0.5, \omega = 0.6, \rho = 0.01$.

in the housing sector. The optimal size of the goods recession depends on how costly the misalignment of demand in the housing sector is.

2.3 The role of the rationing mechanism

In the previous section, we examined an economy with search frictions and fixed prices. In this setting, in response to an increase in the preference for housing, equilibrium is restored through an increase in search effort, which is excessive from a social point of view, and a lower probability of matching, which results in demand rationing. The fact that search is costly implies that monetary policy faces a tradeoff between stabilizing the output gap in the goods sector and allowing the housing market to overheat.

In this section, we examine a version of the model without search frictions and extend it to include production of housing so as to highlight the role of the rationing mechanism for optimal monetary policy. In the absence of search costs, (3) gives rise to a notional demand—in the disequilibrium terminology—which will generally differ from the supply of housing. We will contrast the implications for optimal monetary policy of two alternative rationing assumptions, one that is *demand-determined* and one that is *supply-determined*, as we illustrated in Figure 2. We will argue that our model with search frictions represents an "intermediate case" between the two.

We assume here that housing is produced using consumption goods according to $h = \bar{h}x^{\phi}$ where x represents goods devoted to housing production with $\phi \in (0, 1]$. The resource constraint and production function now imply $l = (c + x)/z$. The landlords' problem is given by $\max_x \left\{ R\bar{h}x^{\phi} - Px \right\}$. Optimization gives rise to an upward supply schedule for housing:

$$h = \bar{h}^{\frac{1}{1-\phi}} \left(\frac{\phi R}{P} \right)^{\frac{\phi}{1-\phi}} . \tag{12}$$

That is, landlords' production of housing increases with the rent and decreases with the price of consumption.

Demand determined. Let us first inspect the standard case in New Keynesian models where output is entirely demand determined. In this scenario, firms passively purchase inputs to deliver the desired amount of housing. From the households' optimality conditions in problem (8) under $\rho = 0$, we obtain that the relative demand for the two goods is given by

$$\frac{\omega}{h} = \frac{1-\omega}{c}\left(\frac{\bar{R}}{\bar{\bar{P}}}\right). \tag{13}$$

If we allow firms to hire inputs to meet the demand, which implies that $x = (h/\bar{h})^{1/\phi}$, the optimal policy problem in this economy can be expressed as

$$\max_{c,h}\ (1-\omega)\log(c) + \omega\log(h) - (1-\omega)\left(\frac{c + \left(h/\bar{h}\right)^{1/\phi}}{z}\right), \tag{14}$$

subject to (13). The policy problem (14) is a simple version of optimal monetary policy in the multi-sector New Keynesian model. In our environment with completely rigid prices, the constraint the central bank faces is that the marginal rate of substitution between consumption and housing must be equal to the relative price. Since output in both sectors is demand-determined, the central bank can influence production in each sector by pursuing expansionary or contractionary monetary policy. At the optimum, given constraint (13), the economy must feature too little output in one sector and too much output in the other sector.

Supply-determined. 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. We focus on the case where rents are below the market clearing value, which implies that demand is rationed. In this case, the optimal monetary policy problem is

$$\max_{c,h}\ (1-\omega)\log(c) + \omega\log\left(h\right) + (1-\omega)\left(\frac{c + \left(h/\bar{h}\right)^{1/\phi}}{z}\right), \tag{15}$$

subject to (12). Notice that given fixed prices, the constraint (12) renders the quantity of housing produced and consumed independent of policy. It is then apparent from (15) that the optimal policy would yield $c = z$, as in the constrained-efficient allocation. 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 efficient allocation is obtained, because housing output will be inefficiently low.

Short-side rule. We argue that our environment with search frictions mimics a short-side rule. When there is an imbalance of supply and demand under fixed prices, it is the short side of the market that determines the traded quantity. Specifically, if the price is below the market-clearing price, the economy with search frictions exhibits an output level that is closer to the notional supply than to the notional demand. Furthermore, as $\rho \to 0$, output approaches the supply-determined equilibrium.[11] Conversely, when the price is above the market-clearing price, the search equilibrium is closer to the notional demand, and as $\rho \to 0$, output approaches the demand-determined equilibrium.[12]

Figure 5 illustrates these results. The dashed lines represent the quantity of housing in our equilibrium with search as we vary the sticky rent price for two different values of ρ. As the search friction decreases, indicated by a lower ρ, the equilibrium approaches the short-side rule. See Appendix A for the formal analysis.

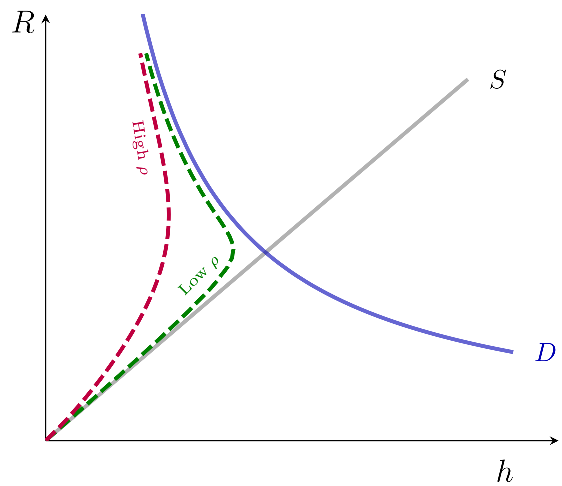

Figure 5: Short-side rule and search equilibrium

Note: The curves "S" and "D" are the notional supply and demand, as given by (12) and (13). The dashed lines represent the equilibrium quanty of housing as we vary the sticky rent price, for two different values of ρ.

Connections with the literature. It is worth emphasizing how our findings contrast with existing studies on optimal monetary policy with multiple sectors, which assume 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 more inelastic supply or with a lower labor share. From their analysis, one would infer that the central bank should put a high weight on housing to the extent that the sector has a low labor share. Intuitively, when a sector is demand determined and it has a low elasticity of supply, an increase in demand forces firms to allocate significant resources

[11] For $\rho = 0$, the equilibrium with search does not exist if the sticky price is below the market-clearing price.

[12] A similar limiting result is derived in Michaillat and Saez (2015). However, their analysis does not address the alternative case where demand exceeds supply.

to deliver the goods that are demanded, giving rise to a larger distortion.[13] 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, 2003). Intuitively, the more sticky is the price in a particular sector, the larger the quantity response to a demand shock and therefore the larger the distortion. Notice that we have assumed here that both sectors are equally rigid, and so this classic distinction does not play a role in our analysis.[14,15]

2.4 Takeaways

We have presented a simple model to analyze how monetary policy should respond to a change in the demand for housing. In contrast to the canonical New Keynesian model, which is based on the premise that output is demand-determined, our model allows for demand rationing in housing. In the absence of search costs, the optimal monetary policy is to close the output gap in the goods sector and disregard housing. However, to the extent that search is costly and gives rise to congestion externalities, monetary policy faces a trade-off between stabilizing the housing and non-housing sectors. In the rest of the paper, we develop and calibrate a quantitative model to assess the optimal monetary policy in response to housing inflation.

3 Dynamic model

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

[13] In terms of Figure 2, this can be seen by noting that the steeper is the supply schedule, the larger is the deadweight loss from the demand-determined equilibrium.

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

[15] A related theme, well-studied in open economy settings, is on the desirability of targeting producer price index (PPI) over consumer price index (CPI) where the latter include imports (see, e.g., Aoki, 2001; Gali and Monacelli, 2005). Our results do not hinge on whether housing is produced or not, but on whether the equilibrium resembles a demand-determined one or a supply-determined one.

3.1 Environment

A representative household has preferences given by

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

where c_t is consumption of goods, ℓ_t is labor effort and s_t is search effort at date t.[16] The total consumption of housing services is $h^o + h_{t+1}$, which is equal to the housing units occupied between t and $t+1$. The parameter h^o reflects a baseline stock of units that are always occupied—for instance, by high-tenure households. 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.

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 $\ell_t = \int \ell_{jt} dj$. We assume a constant production subsidy corrects the steady state monopoly distortion.

The total supply of housing for rent is fixed at $\bar{h}$. To capture housing turnover, we assume that a housing unit is exogenously vacated with probability δ. If the household wants to occupy more housing, it must search for vacant units. Given our normalization of $\bar{h}$, Vacancies are given by $h_t^v = \bar{h} - (1-\delta)h_t$. The number of occupied housing units, $h_t \in [0, \bar{h}]$, evolves according to the equation:

$$h_{t+1} = (1-\delta)h_t + f(\Theta_t)s_t, \tag{16}$$

where market tightness is given by $\Theta_t = s_t/h_t^v$ and $f(\Theta_t)$ is the probability of finding a housing unit. Similarly, $g(\Theta_t) = f(\Theta_t)\Theta_t$ represents the probability of a landlord finding a tenant.

Nominal rigidities. A continuum of landlords owns the housing units, and each supplies his or her unit inelastically. When a landlord meets a searching household member at date t, the rent is set to R_t in nominal terms. This rent remains fixed until either (i) the match is

[16] 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.

broken, which occurs with probability δ, or (ii) a renegotiation shock occurs, which occurs with probability ξ. We assume that these probabilities are exogenous.[17]

We assume that new rents and renegotiated leases are sticky, albeit less so than old rents. Specifically, new rents and renegotiated leases are determined as a convex combination of the current average outstanding rent, $\bar{R}_t$, and the Nash bargaining solution, R_t^*. Using lower case to normalize nominal rents by P_t, we have that

$$r_t = \chi \bar{r}_t + (1 - \chi) r_t^*, \tag{17}$$

where the parameter χ governs the degree of rigidity. The case with $\chi = 0$ corresponds to the fully flexible case and the case with $\chi = 1$ corresponds to the fully rigid one. We note that the fact that rents are sticky within the match does not affect the equilibrium outcome. However, the imperfect adjustment of new rents does have allocative effects.[18]

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

We present the household problem in recursive form. The household's state variables include the housing units rented in the previous period, denoted by h, a committed nominal rent bill (before separations and renegotiations), denoted by X, and nominal bonds, denoted by B. The rent paid today consists of three components: (i) the rent already committed (i.e., the

[17] Notice that 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.

[18] A literature on labor is also concerned with a similar issue regarding the flexibility on wages of new hires (see, in particular Hazell and Taska, 2020 for recent evidence). While the literature on rent rigidity is less developed, considerations like rent control suggest significant rigidity in rents.

rent on units that do not get separated or renegotiated), given by $(1-\delta)(1-\xi)X$; (ii) the rent that is renegotiated, which amounts to $(1-\delta)\xi h R_t$; and (iii) the rent on new matches, which results in a rent bill of $R_t f(\Theta_t) s$.

Each period, the household chooses how many hours to work and search, collects its labor income and dividends, pays the rents due and chooses consumption of goods and housing. We let H_t denote the value function of the household, where the subscript t indexes the evolution of the aggregate states. We can express the problem of the household as follows:

$$H_t(h, X, B) = \max_{\substack{c,h',X',\\ s,\ell,B'}} \Big\{ (1-\omega_t) \log c + \omega_t \log (h^o + h') - \psi(1-\omega_t)(\ell + s) + \beta H_{t+1}(h', X', B') \Big\},$$

subject to the following constraints (with Lagrange multipliers in brackets)

$$P_t c + \frac{B'}{1+i_t} + X' = B + W_t \ell + P_t d_t \qquad [\lambda_t P_t],$$

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

$$X' = (1-\delta)(1-\xi)X + R_t \left[\xi(1-\delta)h + f(\Theta_t)s\right] \qquad -[\upsilon_t P_t],$$

where d_t are dividends from intermediate producers and landlords and i_t denotes the nominal interest rate.

The first-order conditions of this problem with respect to $\{c, h', X', s, \ell, B'\}$ yield the following system of equations:

$$\frac{1-\omega_t}{c_t} = \lambda_t, \tag{18}$$

$$\frac{\omega_t}{h^o + h_{t+1}} + \beta(1-\delta)\left[\mu_{t+1} - \xi r_{t+1} \upsilon_{t+1}\right] = \mu_t, \tag{19}$$

$$\lambda_t + \beta \left[(1-\delta)(1-\xi) \frac{\upsilon_{t+1}}{\Pi_{t+1}} \right] = \upsilon_t, \tag{20}$$

$$f(\Theta_t)\left[\mu_t - r_t \upsilon_t\right] = \psi(1-\omega_t), \tag{21}$$

$$\lambda_t w_t = \psi(1-\omega_t), \tag{22}$$

$$\lambda_t = \frac{(1+i_t)}{\Pi_{t+1}} \beta \lambda_{t+1}, \tag{23}$$

where $w_t \equiv W_t/P_t$, $r_t \equiv R_t/P_t$, 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 (18). 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 (19). The marginal cost of increasing the rent bill is υ_t, which is linked to λ_t through (20). Expected inflation reduces the cost of the rent bill because leases are fixed in nominal terms. Finally, equations (21)-(23) give the first-order conditions for search effort, labor supply and bond holdings, respectively.[19]

Landlord's problem

A landlord may have either an occupied unit or a 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

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

The continuation value for the landlord reflects four possible outcomes: (i) continue renting to the same household at the current rent r adjusted for inflation, with probability $(1-\delta)(1-\xi)$; (ii) separate and rematch at next-period's prevailing rent r_{t+1}, with probability $\delta g(\Theta_{t+1})$; (iii) separate and remain vacant, with probability $\delta(1-g(\Theta_{t+1}))$; or (iv) continue renting to the same household at a renegotiated rent r_{t+1}, with probability $(1-\delta)\xi$. The value of a landlord with a vacant unit is given by

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

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 $y_{jt} = \left(P_{jt}/P_t\right)^{-\eta} c_t$. This is the standard price-setting problem from the New Keynesian literature and results in an

[19]Notice we are assuming that when households choose consumption and search, they do not internalize how this affects the bargained price.

optimal reset price given by

$$p_t^* \equiv \frac{P_t^*}{P_t} = \frac{\sum_{\tau=t}^{\infty}(\beta\theta)^{\tau-t}\Pi_{t,\tau}^{\eta+1}\frac{w_\tau}{z}}{\sum_{\tau=t}^{\infty}(\beta\theta)^{\tau-t}\Pi_{t,\tau}^{\eta}}, \tag{24}$$

where $\Pi_{t,\tau} \equiv \Pi_{t+1} \times \Pi_{t+2} \times \cdots \times \Pi_\tau$. The price index for goods then leads to

$$\Pi_t = \left(\frac{1}{\theta} - \frac{1-\theta}{\theta}\left(p_t^*\right)^{1-\eta}\right)^{\frac{1}{\eta-1}}. \tag{25}$$

3.3 Equilibrium

The Nash bargaining rent solves

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

where recall that the bargaining occurs between an atomistic member of a household and a landlord, and hence the Lagrange multipliers on the household problem stated above, μ and υ, are taken as given by individual member.

The solution to the Nash bargaining problem, which we denote by r_t^*, satisfies

$$\mu_t - r_t^*\upsilon_t = \Psi\mathcal{S}_t, \tag{26}$$

where $\mathcal{S}_t \equiv \mu_t - r_t^*\upsilon_t + L_t^o(r_t^*) - L_t^v$ is the total surplus from the match. Appendix B shows the total surplus satisfies

$$\mathcal{S}_t = \frac{\omega_t}{h^o + h_{t+1}} + \beta(1-\delta)\left\{\mathcal{S}_{t+1} - g(\Theta_{t+1})\left[(1-\Psi)\mathcal{S}_{t+1} + \upsilon_{t+1}(r_{t+1} - r_{t+1}^*)\right]\right\}. \tag{27}$$

In equilibrium, we also have that labor supply must equal the demand for labor across all intermediate input producers:

$$\ell_t = \int \ell_j t di = \frac{c_t}{z}\int\left(\frac{P_{jt}}{P_t}\right)^{-\eta} dj. \tag{28}$$

Defining price dispersion as $\Delta_t \equiv \int\left(\frac{P_{jt}}{P_t}\right)^{-\eta} dj \geq 1$, we have that

$$\Delta_t = (1-\theta)\left(p_t^*\right)^{-\eta} + \theta\Pi_t^{\eta}\Delta_{t-1}. \tag{29}$$

Finally, the total real rent bill evolves according to

$$x_{t+1} = (1-\delta)(1-\xi)\frac{x_t}{\Pi_t} + r_t\left[\xi(1-\delta)h_t + f(\Theta_t)s_t\right]. \tag{30}$$

An equilibrium of the model consists of sequences for $\{p_t^*, \Pi_t, h_t, r_t, r_t^*, w_t, c_t, s_t, \ell_t, \mathcal{S}_t, \Theta_t, \lambda_t, \mu_t, \upsilon_t, x_t, \Delta_t, i_t\}$ that satisfy (16)-(30), the definition of $\Theta_t = s_t/[\bar{h} - (1-\delta)h_t]$, 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

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

subject to

$$h' = (1-\delta)h + f\left(\frac{s}{1-(1-\delta)h}\right)s,$$

$$c = z\ell,$$

The solution to this problem yields

$$\begin{aligned}
(1-\omega_t)\psi &= f(\Theta_t^*)\gamma(\Theta)S_t^*,\\
\psi c_t^* &= z,\\
\mathcal{S}_t^* &= \frac{\omega_t}{h^o + h_{t+1}^*} + \beta(1-\delta)\mathcal{S}_{t+1}^*\left[1 - g(\Theta_{t+1}^*)(1-\gamma)\right],\\
\ell_t^* &= \frac{c_t^*}{z},
\end{aligned}$$

where we denote by $\mathcal{S}^*$ the Lagrange multiplier on the first constraint and recall that $\gamma(\Theta)$ denotes the elasticity of the matching function with respect to search effort.

In the decentralized economy, equations (17),(21),(22),(26),(27), and (28) lead to

$$\psi(1-\omega_t) = f(\Theta_t)\Psi S_t + \chi f(\Theta_t)\nu_t(r_t - \bar{r}_t),$$

$$\psi c_t = w_t,$$

$$\mathcal{S}_t = \frac{\omega_t}{h^o + h_{t+1}} + \beta(1-\delta)\left\{\mathcal{S}_{t+1} - g(\Theta_{t+1})\left[(1-\Psi)\mathcal{S}_{t+1} + \chi\upsilon_{t+1}(\bar{r}_{t+1} - r^*_{t+1})\right]\right\},$$

$$\ell_t = \frac{\Delta_t c_t}{z}.$$

These two systems of equations coincide (i.e., the competitive equilibrium will be constrained efficient) provided that the following four conditions hold: (i) $\Psi = \gamma$; (ii) $\chi = 0$; (iii) $\Delta_t = 1$; and (iv) $w_t = z$.

Condition (i) is the familiar Hosios condition for search models to deliver an efficient equilibrium. The underlying logic is that the searching household does not account for the congestion externality and does not capture the entire surplus of the match. When the bargaining power of the household equals the elasticity of the matching function with respect to search, the amount of search is efficient. However, in our model, this condition alone is not sufficient to ensure the efficiency of the competitive equilibrium. If rents are sticky ($\chi > 0$), the expected surplus from the match will not always align with the Hosios condition, hence condition (ii).

Additionally, condition (iii) specifies that there is no dispersion of relative prices across intermediate inputs, and condition (iv) stipulates that the wage is equal to the marginal product of labor. It is important to note that conditions (iii) and (iv) can be achieved by a policy of targeting zero inflation in the goods sector, as in the standard one-sector New Keynesian model. However, to the extent that condition (i) or (ii) fails, optimal policy may call for a deviation from this policy. We will next calibrate the model and analyze the optimal monetary policy.

4 Calibration

We calibrate the model to a monthly time period and treat 2019 as a steady state.We use a Cobb-Douglas matching function, which implies a constant elasticity γ. We then have $f(\Theta) = \overline{M}\Theta^{\gamma-1}$ and $g(\Theta) = \overline{M}\Theta^{\gamma}$, with $\overline{M}$ representing the efficiency of the matching function. We set $\gamma = \Psi$ so that the equilibrium is constrained efficient in the absence of nominal rigidities. Table 1 summarizes the parameter values.

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	Size of real estate sector	0.782
γ	Hosios $= \Psi$	0.782
ω	Housing expenditure share	0.15
$\overline{M}$	Steady state vacancy rate 6.8%	1.61
$h^o/(h+h^o)$	ACS housing turnover (see text)	0.7077
δ	ACS housing turnover (see text)	0.0355
ξ	Annual lease	1/12
χ	Estimated pass-through of new rents to CPI	0.520
θ	Klenow-Malin (2010)	0.9199
η	Basu-Fernald (1997)	6

The preference for housing, ω, is set to match the housing expenditure share.[20] We set the frequency of the renegotiation shock ξ to correspond to an annual lease. Using the Census Housing Vacancy Survey for 2019, we calculate the ratio of occupied rental units relative to the sum of occupied units and vacant units for rent, finding $h = 0.932$. This target informs the efficiency of the matching function.

We calibrate δ and h^o using data from the 2019 American Community Survey, in which respondents are asked how long they have lived in their current home. In interpreting the data, we assume they were generated by a population of two types of households with differing mobility patterns. One type is "low mobility," moving each period with probability δ^{low}, while the other type is "high mobility," moving each period with $\delta^{\text{high}} > \delta^{\text{low}}$. We fit the survey data responses, using maximum likelihood estimates for δ^{low}, δ^{high}, and the share of each type of household in the population. The estimation results are $\delta^{\text{low}} = 0.5\%$ (monthly), $\delta^{\text{high}} = 3.5\%$ (monthly), and 71% of households are classified as low mobility. Accordingly, we set $\delta = 3.5\%$ and h^o so that 71% of housing consumed is through the inelastic component.[21]

The most challenging aspect of the calibration is determining the degree of rigidity in new rents—specifically the parameter χ. We observe various measures of rents. The CPI shelter price index reflects the current cost of rent for households and can be interpreted as $\overline{R}_t$. The

[20]Consider the budgeting problem max $(1-\omega)\log c + \omega \log(h^o + h)$ s.t. $Pc + Rh = y$, where y is spending excluding owners' equivalent rent (OER). The solution to this problem is $R(h^o + h) = \omega \times (y + Rh^o)$ so ω is the budget share of rent and OER out of *total* spending.

[21]Appendix D.3 presents an alternative calibration with $h^o = 0$.

Zillow Observed Rent Index measures rents for units listed on Zillow. Since landlords posting units on Zillow are likely more sophisticated, we interpret this index as a measure of R_t^*.[22] The BLS New Tenant Rent Index measures rent growth among renters who have recently moved into units, which we interpret as a measure of R_t. We then estimate the pass-through from R_t^* to $\overline{R}_t$, following (17) and (30). Given the values for δ and ξ calibrated above, this pass-through coefficient allows us to infer χ. We find that $\chi = 0.65$, which implies that $\overline{R}_t$ moves slowly relative to what we would expect given 12-month leases. We interpret the extra inertia as emerging from nominal rigidity. Further details are provided in Appendix C.

Turning to the cost of housing search, we adopt the interpretation that households hire real estate agents to search on their behalf. Following this interpretation, we use data on brokers' commissions to gauge the resources consumed by housing search.[23] NIPA Table 5.4.5U reports expenditure on brokers' commissions and ownership transfer costs as a component of residential investment. In 2019, these costs amounted to 1.2% of total personal consumption expenditures. We treat this as a calibration target for $ws/(c + r(h + h^o))$, where w is the wage in goods and $r(h + h^o)$ is shelter component of personal consumption expenditure. This moment informs the tenant bargaining power: high bargaining power implies that tenants receive a large share of the surplus and therefore are willing to search extensively for housing. We note that this calibration strategy is highly conservative because we include in the cost of search all resources devoted to real estate, including commissions from owner-occupied housing, which are unaffected by the nominal rigidity in rents.

Finally, we set the degree of nominal rigidity for goods producers based on Klenow and Malin (2010), who find a median price duration of 8.3 months when they exclude sales and product substitutions. This frequency of price change corresponds to $\theta = 0.92 \approx 11/12$ (monthly). A median price duration of 8.3 months is on the upper end of the range reported by Klenow and Malin (2010). We use this as our preferred calibration because our model does not include any real rigidities or intermediate input linkages that amplify the effects of nominal rigidities. Appendix D.4 shows that our results are not driven by different degrees of price rigidity in the two sectors.

[22] Park (2024) documents that institutional landlords adjust their asking rents more frequently than small-scale landlords, with larger rent increases in more volatile periods. Genesove (2003) documents a high degree of nominal rigidity in rents, in particular for apartment buildings with fewer units and less tenant turnover.

[23] Certainly, households incur other search costs, such as forgone leisure, but we consider these to be minimal. Using the 2019 American Time Use Survey, we find that the average time spent on real estate search and transactions in a typical day is 10 seconds. In comparison, the average time spent working is 200 minutes.

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 evaluate 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 $\Pi_t^{1-\omega}(\bar{R}_t/\bar{R}_{t-1})^{\omega}$. The weight on housing, ω, reflects total "expenditures" on housing, including owners' equivalent rent (OER). Notice that because the CPI is a cost-of-living price index, it depends on the average rent across all tenants, $\bar{R}_t$.

(ii) Goods inflation targeting. Under this policy, the monetary authority sets goods 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 competitive equilibrium conditions.[24]

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

5.1 Simulation Results

Figure 6 illustrates the results of a permanent increase in ω_t from its baseline value of 0.15 to 0.18 at date 0. In response to the shock, the relative price of (new) rents jumps up because the household now receives more utility from housing, which results in a larger surplus. Whether or not this relative price movement affects the CPI depends on the monetary policy strategy. Under a goods inflation targeting policy, goods inflation is kept at zero; thus, the rise in the relative price of housing implies that the CPI must increase. As the figure shows, this policy maintains consumption at the steady state value. In contrast, under a CPI targeting policy, the increase in the relative price of housing requires a decrease in goods prices to offset the rise in rents. As the figure indicates, this policy results in a recession in the goods sector,

[24] We assume the government has commitment. To compute the optimal policy, we stack the transition path of the equilibrium variables in the vector $\mathcal{X}$. The dimension of $\mathcal{X}$ is nT where we have n 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 household's 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 $f(\mathcal{X}) = 0$ and find the non-linear solution to this problem using Newton's method.

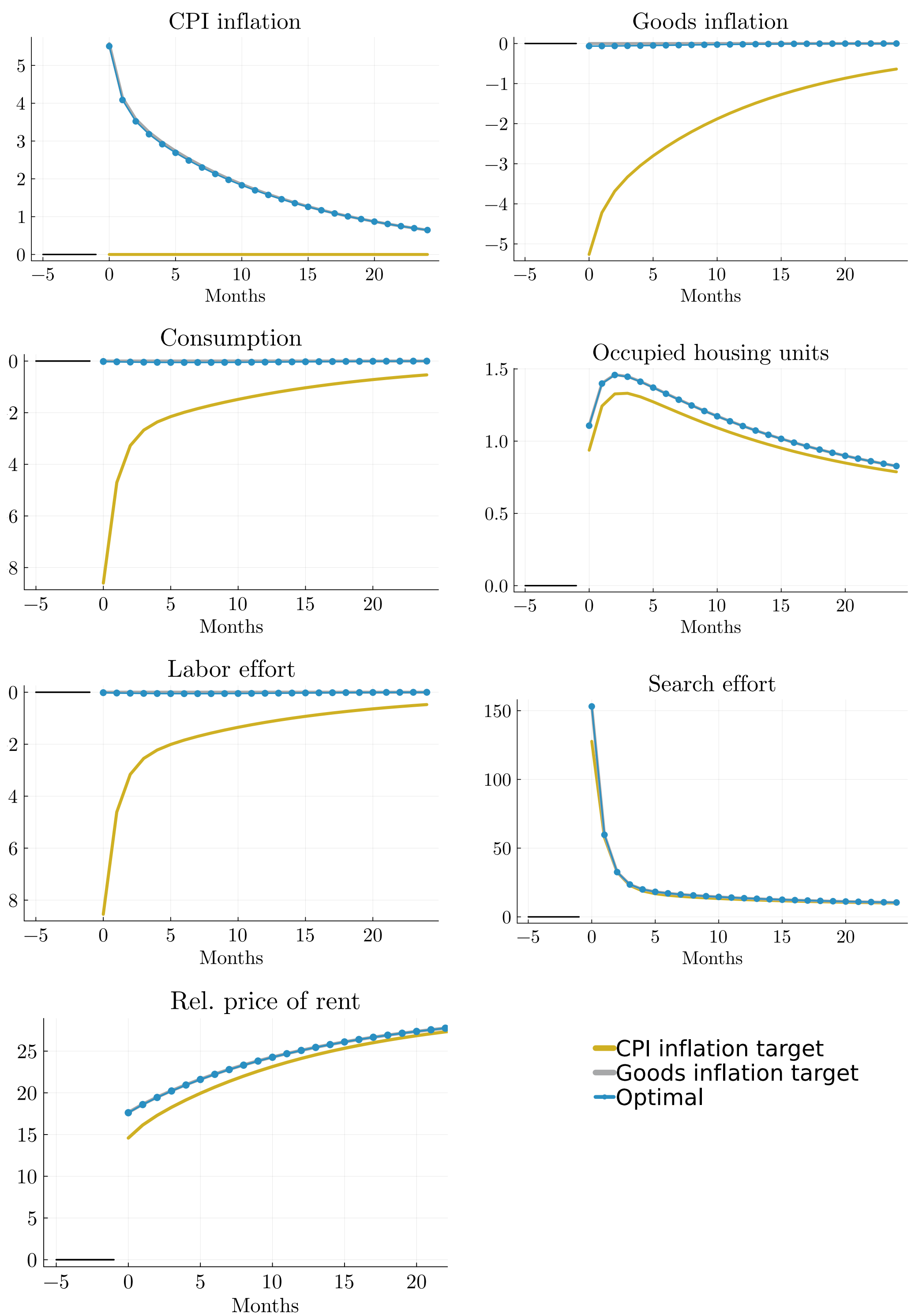

Figure 6: Alternative monetary policy responses to a permanent increase in ω_t.

Note: Inflation is expressed in percent at an annual rate. All other values are expressed in percentage deviations from the initial steady state. Occupied housing is given by $h_t + h^o$.

with consumption of goods falling by about 10% on impact. Under these two policies, we see an increase in search effort and an increase in the occupancy rate, but the increase is higher under goods inflation targeting.

Crucially, the figure shows that the simulations under goods inflation targeting and optimal policy are almost indistinguishable. That is, the optimal policy is very close to goods inflation targeting.

Why ignoring housing inflation is optimal? To inspect our quantitative findings, we now provide a welfare decomposition. We define

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

so total welfare at period 0 is given by $U = U^{\text{goods}} + U^{\text{housing}}$. At 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 $-dU^{\text{goods}}/di_t = dU^{\text{housing}}/di_t$. Intuitively, at the margin, the welfare loss from distorting the goods market must be balanced by the welfare gain from reducing distortions in the housing market.

The top panel of Figure 7 plots U^{goods} and $U^{housing}$ as we vary i_0, keeping the other interest rates fixed at the levels implied by the optimal policy. The key feature of this figure is that $U^{housing}$ has very little curvature relative to U^{goods}. The difference in curvature shows there is much more scope for costly output gaps in the goods market than there is in the housing market. The lower panel of the Figure 7 shows policy has little impact on the housing consumed and therefore little impact on welfare. This finding is reminscent of the case in Section 2.3 in which housing services are fully supply determined and there is little scope for policy to affect the quantity of housing consumed, which results in the central bank focusing on closing the output gap in the goods sector. Although search congestion costs create a trade-off for monetary policy, the optimal policy essentially disregards these costs.

The main takeaway is that the optimal policy is nearly identical to goods inflation targeting. While ignoring housing inflation causes some overheating in the housing market, this cost is far outweighed by the recession needed to counter it.

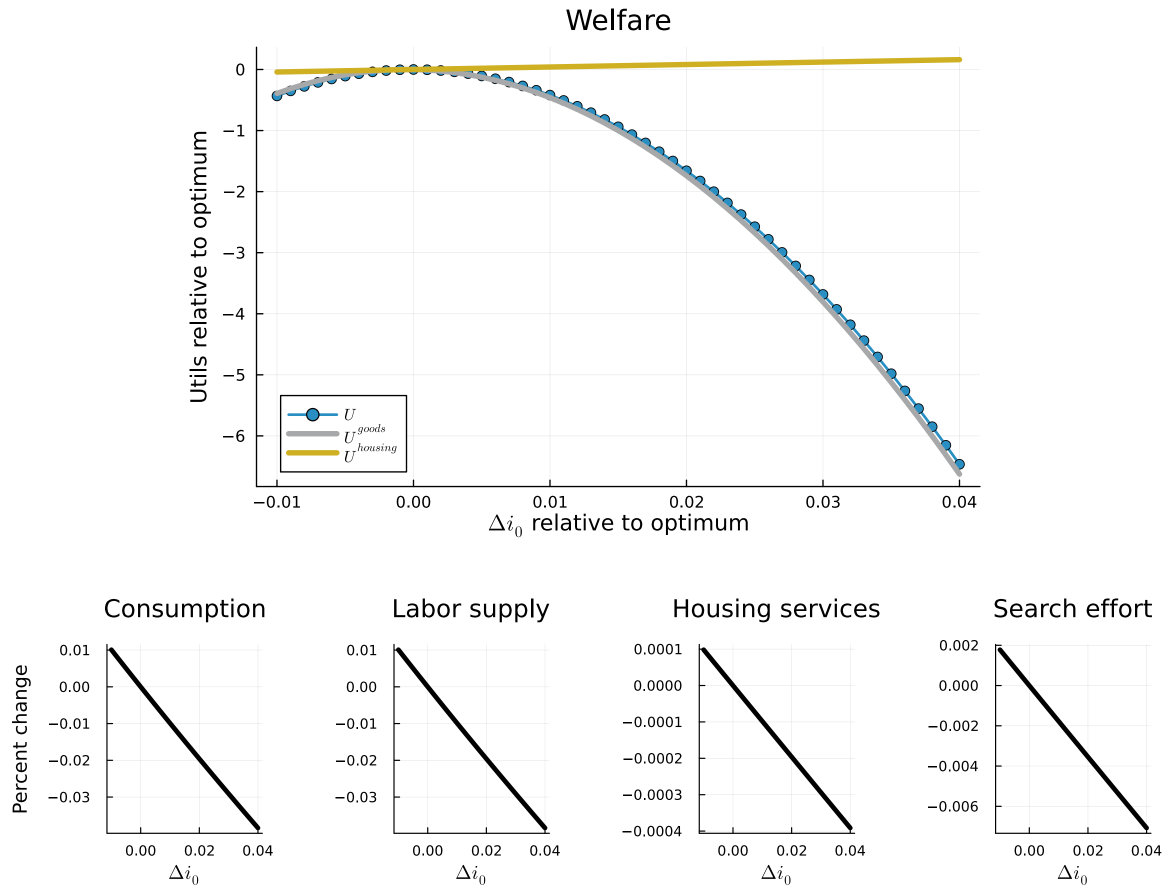

Figure 7: Top panel: change in welfare and its components as we vary i_0 around the optimal policy path. Bottom panels: changes in activity at date 0 as we vary i_0.

5.2 Extensions and Sensitivity

The result that is optimal to ignore housing inflation is robust to alternative calibration and specifications.

Extension with production of housing. Our model assumes an inelastic supply of housing. Appendix D.6 presents an extended version of the model in which housing is produced out of labor and a fixed factor. We calibrate the housing supply elasticity as implied by our housing preference shock to be consistent with the estimates of Baum-Snow and Han (2024). Consistent with our focus on the market for housing *services*, our extended model assumes that the price of new houses is flexible. While the demand for houses by landlords is very sensitive to incentives for intertemporal substitution, there are not large movements in construction in equilibrium in the context of flexible home prices (see Barsky et al., 2007). When we analyze the optimal monetary policy response to the housing preference shock in this extended model, we find results that are very similar to those in Figure 6. This highlights that what is central for our result is that housing is demand rationing, as opposed to demand-determined as in standard New Keynesian models.

Catchup shelter inflation. As Figure D.1 shows, relative shelter prices declined in 2020 and 2021, as rents did not keep pace with the general increase in prices. However, following the initial decline, nominal shelter prices have risen sharply as leases expire and are reset to a higher price level, which brings 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.[25]

Figure D.2 shows the results of this simulation. The increase in the price level reduces existing rents in real terms on impact. Subsequently, average outstanding rents grow faster than goods prices as leases renew and adjust to the higher price level. Under goods inflation targeting, there is upward pressure on the CPI as leases gradually turn over to the new price level while under CPI inflation targeting, goods prices fall to offset the rising rents. As was the case before, we find the optimal policy is nearly identical to the goods inflation targeting policy.

Other sensitivity. Appendix D.4 shows that little changes in the results in a calibration in which the two sectors have the same degree of price flexibility. In addition, one difference between the two sectors is the presence of price dispersion in the goods sector. In Appendix D.5, however, we show that the optimal policy remains close to goods inflation targeting even without the price dispersion consideration. Finally, higher housing turnover (lower h^o or higher δ) increases the level of search effort and make it more responsive to shocks and changes in policy. However, in a calibration with significantly higher turnover (in particular, $h^o = 0$ and $\delta = 0.1$), we still find that the optimal policy is very close to goods inflation targeting.

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 holds prices fixed

[25]We choose a 5% increase in the price level because the relative price of shelter in early 2022 was roughly 5% below its pre-pandemic trend, as can be seen in Figure D.1. 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.

must hire additional factors to meet the rise in demand. We argue that this architecture is a poor description of the market for housing services, where the supply cannot respond in the short run. We develop a theory based on demand rationing and show that it has radically different implications for monetary policy.

We construct a two-sector macroeconomic model with search and nominal frictions. While in the goods sector, an increase in demand leads to an increase in output as in the standard New Keynesian model, an increase in the demand for housing leads to an increase in consumer search and lower vacancy rates. We use our framework to shed light on the optimal monetary policy when inflation is driven by a surge in housing demand. 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 quantitatively in a version with housing search costs calibrated to match US data on housing tenure, vacancy rates, and the size of the real estate sector.

Our findings suggest a reappraisal of the inflation index targeted by central banks. The standard analysis in the New Keynesian literature finds that monetary policy should place more weight on inflation in sectors with stickier prices and more inelastic supply, because these sectors have more potential to generate costly output gaps. The perspective presented here suggests that it is crucial to consider whether the level of activity in a sector is demand-determined or if the market adjusts through demand rationing.

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Appendix

A Additional Results on Section 2

In this appendix, we establish existence and uniqueness of fix-price equilibrium and elaborate on the link between our fix price equilibrium with search and the supply- and demand-determined equilibrium from Section 2.3.

Proposition A1 (Existence and uniqueness)**.** *For any fixed prices $\{\bar{P}, \bar{R}\}$ and monetary policy M, there exists a unique fixed price competitive equilibrium that satisfies Definition 1.*

Proof. We observe first that the problem of the household is strictly concave and thus, the first-order conditions describe the global solution. For any Θ, we have that using (3) and (5), the housing demanded is given by

$$\frac{\omega}{h} = \frac{(1-\omega)\bar{R}\varphi}{M} + (1-\omega)\frac{\rho}{f(\Theta)}$$

Marking clearing requires that $h = g(\Theta)$. Thus, the equilibrium Θ is given by

$$\frac{\omega}{g(\Theta)\,\bar{h}} = \frac{(1-\omega)\bar{R}\varphi}{M} + (1-\omega)\frac{\rho}{f(\Theta)} \tag{A.1}$$

Since $g(\Theta) \in (0,1)$ and increasing in Θ, the left-hand side of (A.1) is strictly positive, monotonically decreasing, and unbounded as $\Theta \to 0$. The right-hand side of (A.1) is strictly positive, monotonically increasing, and unbounded as $\Theta \to \infty$. Therefore, given that both sides are continuous, there exists a unique Θ that satisfies (A.1). Moreover, given the resulting value for Θ, we obtain unique levels of consumption, housing and wages, given by (3) and (14). □

Let us now formally define supply and demand-determined equilibrium in the absence of search frictions.

Definition 2 (Demand-determined equilibrium)**.** Given fixed prices $\{\bar{P}, \bar{R}\}$ and a monetary policy $\{M, T\}$, a *demand-determined equilibrium* in this economy is given by $\{c, h, \ell, m, x, W\}$ such that: (i) Households policies $\{c, h, \ell, m\}$ solve (2); (ii) Firms' employment satisfies (6); (iii) Landlords choose inputs such that $x = (h/\bar{h})^{1/\phi}$, (iv) and the government's budget constraint is satisfied.

Definition 3 (Supply-determined equilibrium)**.** Given fixed prices $\{\bar{P}, \bar{R}\}$ and a monetary policy $\{M, T\}$, *supply-determined equilibrium* in this economy is given by $\{c, h, \ell, s, m, x, W\}$ such that: (i) Household consumption satisfies $c = \frac{1}{\varphi}(M/P)$ and l satisfies (1) with equality; (ii) Firm employment satisfies (6); (iii) Housing production satisfies (12) .

The difference in the two lies in the fact that in the demand-determined equilibrium, firms do not satisfy their optimal input decision and in the supply-determined equilibrium, households do not satisfy their optimal demand for housing.

In Section 2, we defined the fixprice equilibrium in our baseline model without production. With production, the fixprice competitive equilibrium is identical except that condition (iii) is replaced by landlords' housing supply as given by:

$$h_v = \bar{h}^{\frac{1}{1-\phi}} \left(\frac{\phi g(\Theta) \bar{R}}{\bar{P}} \right)^{\frac{\phi}{1-\phi}} \tag{A.2}$$

and condition (iv) becomes $\Theta = s/h_v$. Note that when $\phi = 0$, we recover the case of inelastic housing supply.

We now show that our fixprice competitive equilibrium with search mimics an equilibrium with a "short-side" rule:

Proposition A2 (Short-side rule)**.** *Consider a given monetary policy M. Define h_d and h_s as the housing allocation in the demand and supply determined equilibrium and let h_ρ denote the housing allocation with search frictions. Then $h_\rho \le \min(h_d, h_s)$ and $\lim_{\rho\to 0} h_\rho = min(h_d, h_s)$.*

Proof. Using (3) and (5), the demand-determined housing allocation is given by the following equilibrium condition:

$$h_d = \frac{\omega}{1-\omega} \left(\frac{M}{\bar{R}} \frac{1}{\varphi} \right) \tag{A.3}$$

From (12), the supply-determined housing allocation is given by:

$$h_s = \bar{h}^{\frac{1}{1-\phi}} \left(\frac{\phi \bar{R}}{\bar{P}} \right)^{\frac{\phi}{1-\phi}} \tag{A.4}$$

The housing allocation with search frictions $\{h_v, \Theta, h_\rho\}$ satisfies (A.2), $\Theta = s/h^v$ and

$$h_\rho = \frac{\omega}{\left(\frac{1-\omega}{M}\right) \bar{R} \varphi + (1-\omega) \frac{\rho}{f(\Theta)}}$$

Since $\rho/f(\Theta) \geq 0$, we also have $h_\rho \leq h_d$. In addition, using (A.4) and (A.2), we arrive to

$$h_\rho = g\left(\Theta\right)^{\frac{1}{1-\phi}} h_s.$$

Since the matching function satisfies $0 \leq g\left(\Theta\right) \leq 1$, then $h_\rho \leq h_v \leq h_s$. It thus follows that $h_\rho \leq \min(h_d, h_s)$.

It remains to show that as $\rho \to 0$, $h_\rho \to \min\left(h_d, h_s\right)$. When $h_d > h_s$, it is sufficient to show that $\Theta \to \infty$ as $\rho \to 0$. Combining the equilibrium conditions that determine the housing allocation with search frictions and using the definition of h_d, we have that:

$$\frac{\omega}{g\left(\Theta\right)^{\frac{1}{1-\phi}} h_s} = \frac{1-\omega}{c}\frac{\overline{R}}{\overline{\overline{P}}} + \left(1-\omega\right)\frac{\rho}{f\left(\Theta\right)} \tag{A.5}$$

$$\Rightarrow \frac{\omega}{g\left(\Theta\right)^{\frac{1}{1-\phi}} h_s} - \frac{\omega}{h_d} = \left(1-\omega\right)\frac{\rho}{f\left(\Theta\right)} \tag{A.6}$$

The left-hand side of the equation is strictly positive when $h_d > h_s$, given that $g(\Theta) < 1$ and $\phi \leq 1$. Therefore, for the right-hand side of the equation to remain strictly positive, $f\left(\Theta\right) \to 0$ as $\rho \to 0$. This implies that $\Theta \to \infty$ and $g\left(\Theta\right) \to 1$ as required.

Consider the alternative case with $h_s > h_d$, and consider equation (A.6) above. For given $\rho > 0$, the search cost term $\left(1-\omega\right)\rho/f\left(\Theta\right)$ is strictly positive. Since $0 \leq g\left(\Theta\right) \leq 1$ and $h_d < h_s$, there exists a unique Θ_d such that:

$$g\left(\Theta_d\right)^{\frac{1}{1-\phi}} h_s = h_d$$

Rearranging (A.6), the limit for Θ as $\rho \to 0$ requires that either $f\left(\Theta\right) \to 0$ or:

$$\frac{\omega}{g\left(\Theta\right)^{\frac{1}{1-\phi}} h_s} - \frac{\omega}{h_d} \to 0$$

By contradiction, assume $f\left(\Theta\right) \to 0$. Then $\Theta \to \infty$. However, then it must be the case that if $\Theta > \Theta_d$, then $g\left(\Theta\right)^{\frac{1}{1-\phi}} h_s > h_d$, a contradiction. Thus, the only possibility is $\Theta \to \Theta_d$ and, therefore, $h_\rho \to h_d$ as required. □

B Additional results for Section 3

Derivation of eq. (27)

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. Using (20), we obtain 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 landlord surplus can be expressed as

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

Using the definition of $\mathcal{S}_t$ we have

$$\begin{aligned} \mathcal{S}_t = \mu_t - r_t^*\upsilon_t + \lambda_t r_t^* + \beta(1-\delta)\Big[&\left[1 - g(\Theta_{t+1})\right]\left[L_{t+1}^o(r_{t+1}) - L_{t+1}^v\right] \\ &+ (1-\xi)\upsilon_{t+1}(r_t^*/\Pi_{t+1} - r_{t+1}). \end{aligned}$$

Using (19) and (20) yields

$$\mathcal{S}_t = \frac{\omega_t}{h^o + h_{t+1}} + \beta(1-\delta)\left[\mu_{t+1} - \upsilon_{t+1} r_{t+1}\right] + \beta(1-\delta)\Big\{\left[1 - g(\Theta_{t+1})\right]\left[L_{t+1}^o(r_{t+1}) - L_{t+1}^v\right]\Big\}.$$

And using (26), we have eq. (27).

C State-space model of rent pass through

The heart of the system to be estimated is

$$\begin{aligned}
X_{t+1} &= (1-\delta)(1-\xi)X_t + \left(\chi\overline{R}_t + (1-\chi)R_t^*\right)\left[\xi(1-\delta)h_t + f(\Theta_t)s_t\right], \\
\overline{R}_t &= X_{t+1}/h_{t+1}, \\
h_{t+1} &= (1-\delta)h_t + f(\Theta_t)s_t.
\end{aligned}$$

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

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

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

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

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 (C.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:

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

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

$\log R^*_t - \log R^*_{t-1} - \pi)$. The state transition equations are then

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

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

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

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 $\bar{R}_t$:

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

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

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 $\pi^{NTR}_t \equiv \log N_t - \log N_{t-12}$. In all, we have

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

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

In summary, (C.3)-(C.4) are the main state transition equations, and (C.6) encompasses the observation equations. Constructing $\pi^{shelter}_t$ requires six lags of $\hat{\bar{R}}_t$ and construction π^{NTR}_t 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 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.

D Additional data and results

D.1 Shelter inflation in G7 countries

Table D.1 shows core inflation and housing inflation across advanced economies. Shelter inflation has also made outsized contributions in other advanced economies. Excluding shelter inflation, core inflation in Canada would be close to zero; 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 D.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

D.2 Catch-up shelter inflation

In our baseline simulations, the increase in rent prices arise because of a shock to the preference for housing ω. As we describe in Section 3, we also conduct simulations when rent prices increase because of a catch-up effect.

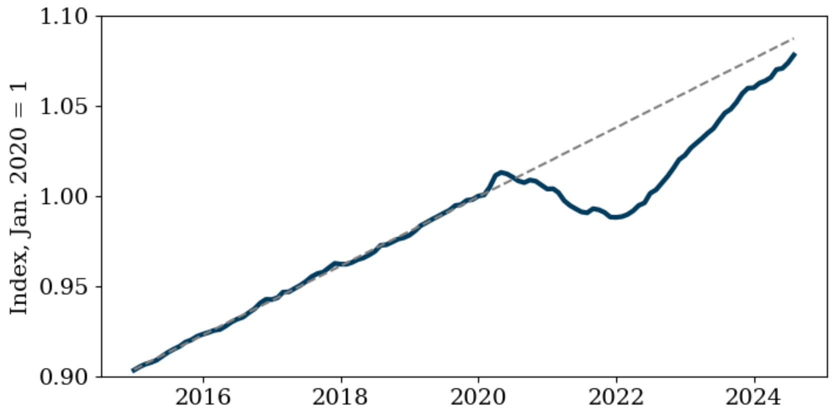


Figure D.1: Relative price of shelter

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 August 2024.

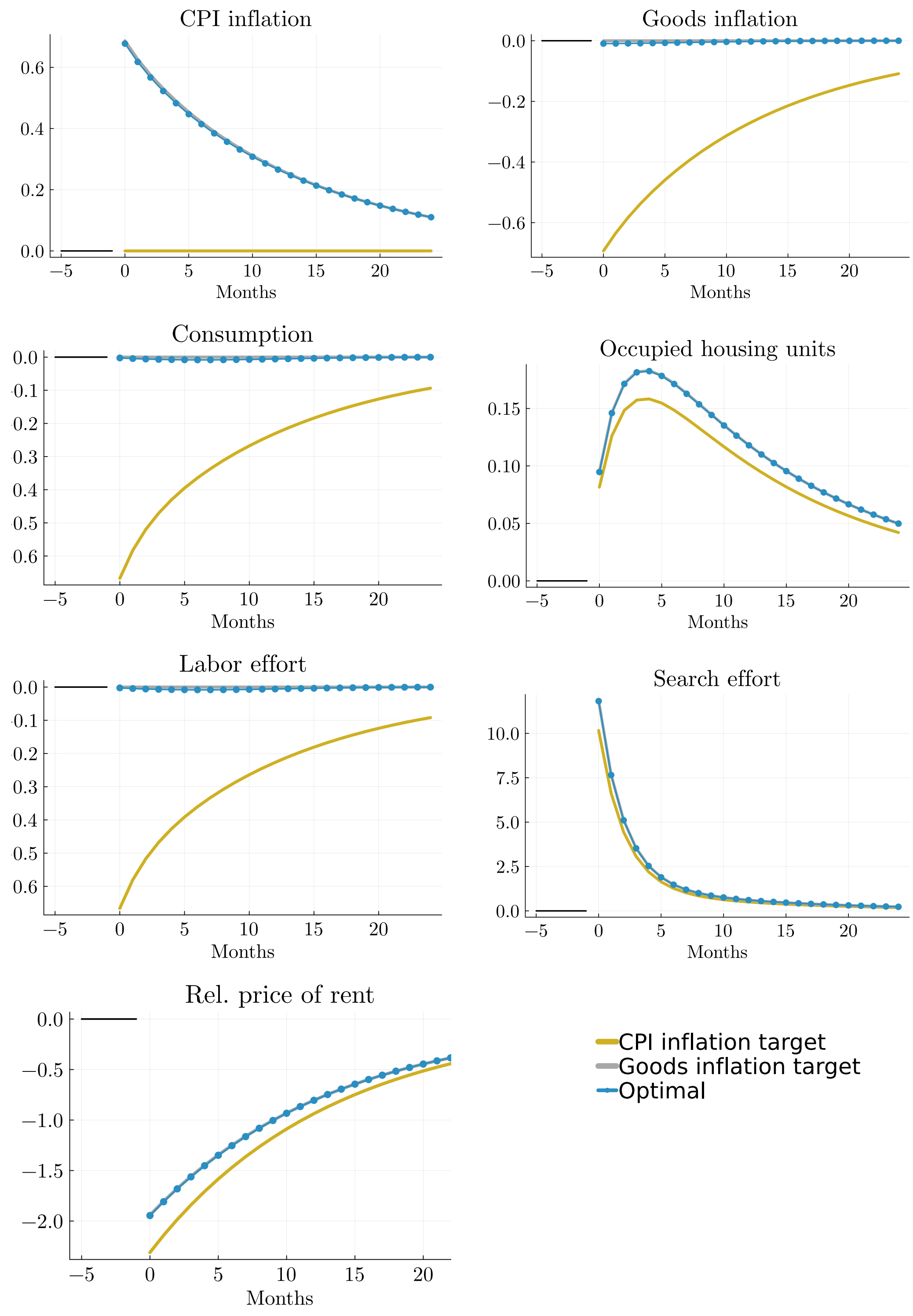


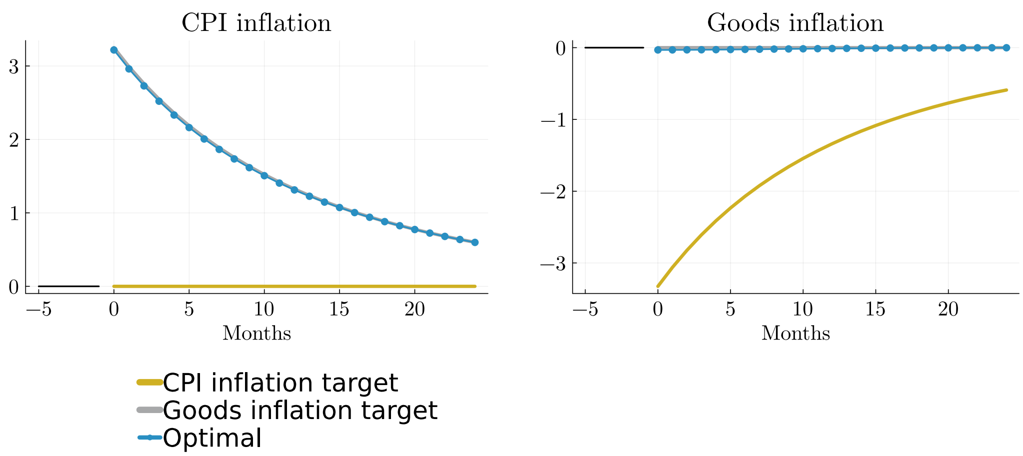
Figure D.2: Alternative monetary policy responses to catch-up shelter inflation.

Note: Inflation is expressed in percent at an annual rate. All other values are expressed in percentage deviations from the initial steady state. Occupied housing units is given by $h + h^o$.

D.3 Alternative calibration without h^o

In our baseline calibration, some households consume housing inelastically as parameterized by h^o. These households never separate from their home and never search. Here, we consider an alternative case in which all households must search for housing so $h^o = 0$. With this change, we recalibrate δ based on the same evidence as in our baseline but now assuming that there is just one common value of δ across all households. This leads to $\delta = 0.007$. We also recalibrate Ψ lower to 0.55 so that model continues match the amount of effort spent on search in steady state. As Figure D.3 shows, our results are largely unchanged in this alternative calibration.

Figure D.3: A permanent increase in ω_t with $h^o = 0$.



D.4 Calibration with common price rigidity across sectors

In this alternative calibration, we would like the flexibility in new rents to be the same as the flexibility in goods prices. To accomplish this, we make several changes to our baseline model to facilitate a more direct comparison with the Calvo frequency of price adjustment in the goods sector. First, here we assume that when a rent is renegotiated, it is set to the Nash bargained rent. Second, we set $\chi = 1$ so all new leases are set to the average outstanding rent. Finally, we set the frequency of renegotiation to match the frequency of price changes in goods. Specifically, renegotiation occurs with probability $(1 - \delta)\xi$ while goods price changes occur with probability $1 - \theta$ so we set $\xi = (1 - \theta)/(1 - \delta)$. With these changes, outstanding rents update towards the Nash rent at the same speed that goods prices update towards the optimal reset price. Moreover, all new leases are set to the prevailing rent just as in the

Calvo model purchases occur at the prevailing price. By this logic, the rigidity in rents is now comparable to the rigidity in goods prices. Figure D.4 shows that our results continue to hold in this "equal stickiness" calibration. This shows that our findings are due to the difference in rationing mechanisms not differences in price rigidity.

We can now demonstrate that if goods prices are sufficiently more flexible than rents, then our results can be overturned. Keeping $\chi = 1$ and ξ fixed at the level from the paragraph above, we now reduce θ to a median price duration of 1.8 months, which is the price rigidity reported by Klenow and Malin (2010) for durable goods—the most flexible major category of spending. For reference, our baseline calibration assumes a median price duration of 8.3 months, so here we are making goods prices *much* more flexible than rents. Figure D.5 shows that optimal policy is now about midway between CPI targeting and goods inflation targeting. In this case, optimal policy does not focus only on goods inflation, but it is still not optimal to put as much weight on rents as the CPI does.

Figure D.4: A permanent increase in ω_t with equal price rigidity in both sectors.

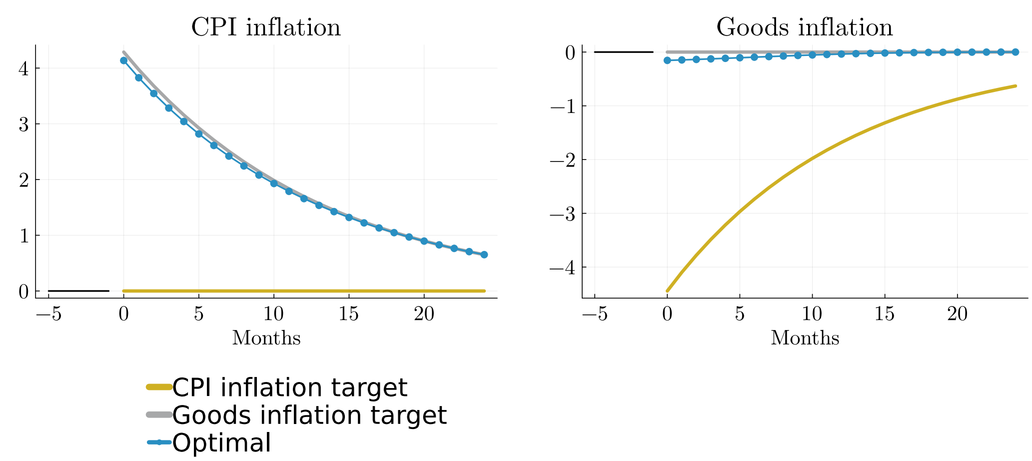
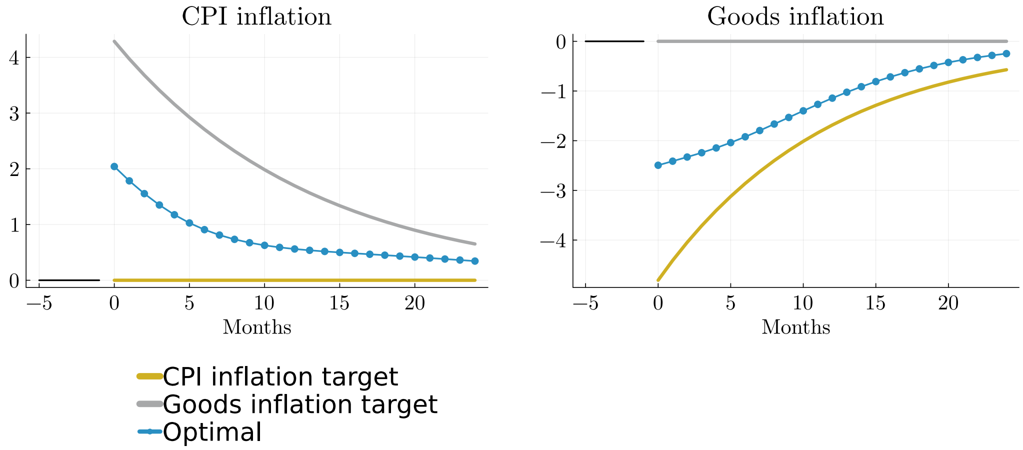


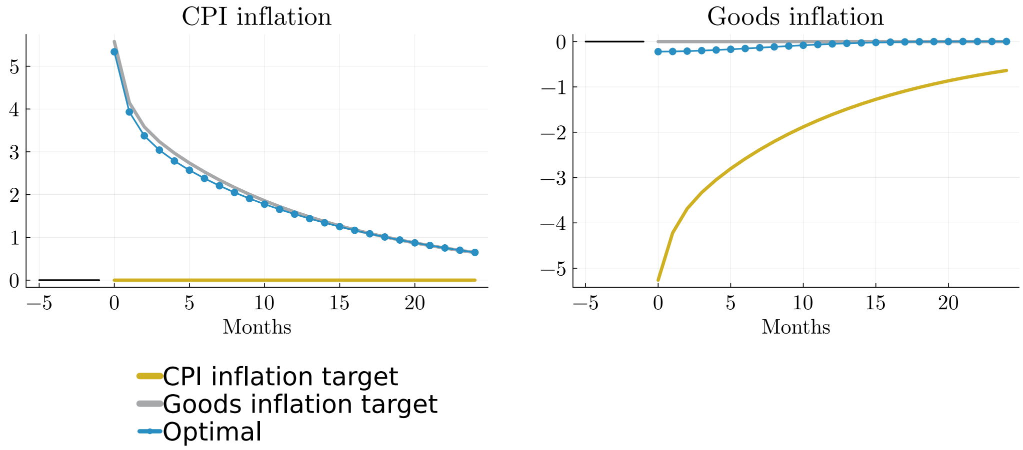
Figure D.5: A permanent increase in ω_t with more flexible good prices (1.8 months duration).



D.5 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 6. As Figure D.6 shows, the optimal policy remains close to goods inflation targeting. From this experiment, we conclude that the optimality of goods inflation targeting is not driven primarily by concerns over price dispersion within the goods sector.

Figure D.6: A permanent increase in ω_t in the absence of goods price dispersion ($\Delta_t = 1$).



D.6 Extended model with production of housing

This appendix describes an extended version of our quantitative model that allows for housing construction. We assume houses are constructed by a representative firm that combines labor with a fixed factor. Letting I_t be gross investment in housing and m be labor devoted to housing production we have the production function

$$I_t = z_h m_t^{1-\tilde{\Phi}}$$

where z_h is a constant construction productivity. Letting q_t be the value of a vacant unit of housing denominated in goods. The profit maximization problem of the construction firm results in a housing supply curve of

$$q_t = \frac{1+\Phi}{z_h^{1+\Phi}} w_t I_t^{\Phi},$$

where $\Phi \equiv \tilde{\Phi}/(1-\tilde{\Phi})$. Landlords will purchase vacant units from the construction firm until $L_t^v = \lambda_t q_t$. Therefore we have

$$L_t^v = \lambda_t \frac{1+\Phi}{z_h^{1+\Phi}} w_t I_t^{\Phi}.$$

The housing stock depreciates at rate κ. We view houses as infinitesimal units of floor space and each unit has a probability κ of disappearing each period. The depreciation shock is one reason a lease might end (i.e. let $1-\delta = (1-\kappa)(1-\tilde{\delta})$ where $\tilde{\delta}$ represents the other reasons for housing turnover) so this does not affect the renter's decision problem. We also assume that the houses occupied by inelastic owner occupiers are maintained so gross investment in the rental stock is $I_t - \kappa h^o$. The supply of homes to the rental market then evolves as

$$\bar{h}_t = (1-\kappa)\bar{h}_{t-1} + I_t - \kappa h^o \tag{D.1}$$

and the number of vacant homes is given by by $h_t^v = \bar{h}_t - (1-\delta)h_t$.

We calibrate the inverse housing supply elasticity, Φ, so that the model matches the measured supply response from Baum-Snow and Han (2024). The empirical elasticity of 0.35 is measured using 10-year changes in available housing units and home prices. As the model counterpart, we compute 10-year changes from our experiment with a permanent shock to housing demand. We set the housing depreciation rate, κ, based on the depreciation rate implied by the BEA fixed assets table from 2019. Finally, we set the productivity of the housing sector, z_h, so that the model matches the steady state supply of housing from our

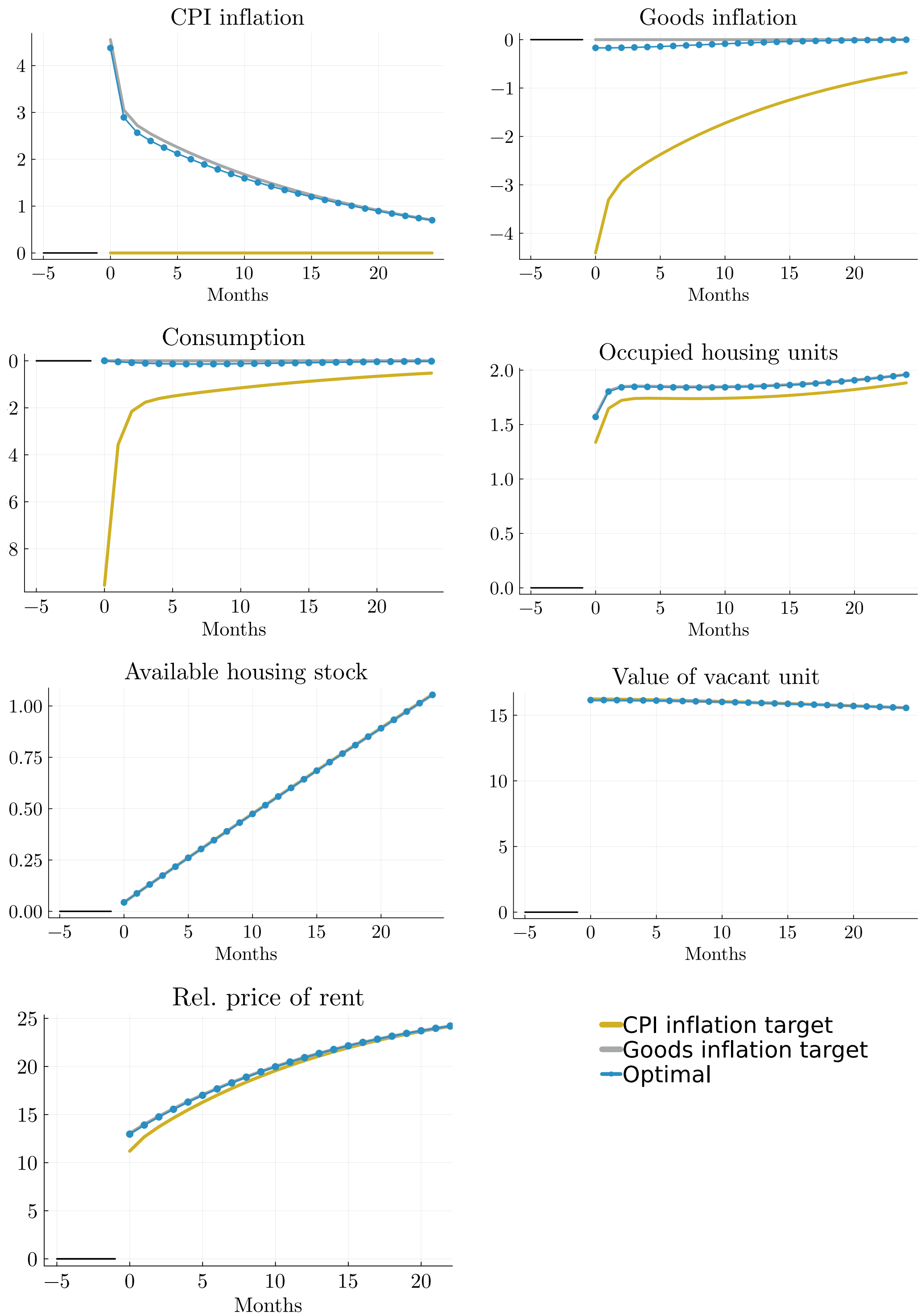


Figure D.7: A permanent increase in ω_t in the extended model with housing construction.

Note: Inflation is expressed in percent at an annual rate. All other values are expressed in percentage deviations from the initial steady state. Housing quantities are reported inclusive of the inelastic component, e.g. occupied housing units are $h_t + h^o$.

baseline model. This is a normalization of the definition of a unit of housing. The calibrated parameter values are $\Phi = 0.475$, $\kappa = 0.023/12$, and $z_h = 0.039$.

Figure D.7 shows our three policy responses to a permanent increase in housing preference, ω_t. As in the baseline model, the optimal monetary policy response is very close to goods inflation targeting.