Monetary Policy Transmission amid Demand Reallocations*

Julien Bengui† Lu Han‡ Gaelan MacKenzie§

October 2024

Abstract

Large swings in the expenditure shares of goods and services at the start of the pandemic have contributed to the inflation surge, posing new challenges for monetary policy. Using a multi-sector model featuring upward labor adjustment frictions, we analyze the transmission of monetary policy during a demand reallocation episode, focusing on sectoral heterogeneity in inflation and output responses. Following an unexpected contractionary monetary policy shock, expanding sectors primarily respond by lowering prices, while contracting sectors reduce output more significantly. At the aggregate level, monetary policy is thus more effective at curbing inflation when a larger proportion of sectors are expanding or expected to be expanding in the near future.

JEL classification: E31, E52

Keywords: Demand reallocation, monetary policy, pandemic, inflation, labor adjustment frictions

---

*We thank Giancarlo Corsetti, José Dorich, Daniela Hauser, Alessandro Lin, Stefano Neri, Enrico Sette, Frank Smets, Ben Tomlin, Chris Waller, as well as seminar and conference participants at the Bank of Canada and the 2024 International Journal of Central Banking Annual conference for feedback and comments. The views expressed herein are those of the authors and not necessarily those of the Bank of Canada or the Swiss National Bank.

†Swiss National Bank and CEPR; email: jbengui@gmail.com.

‡Bank of Canada and CEPR; email: hanlulong@gmail.com.

§Bank of Canada; email: gmackenzie@bank-banque-canada.ca.

1 Introduction

The Covid-19 pandemic and associated policy responses triggered major reallocations of consumer spending in many economies. In the United States, the goods expenditure share rose by nearly 3 percentage points between the first quarter of 2020 and the second quarter of 2021 (see Figure 1). This demand reallocation has contributed to a surge in inflation that at first was driven by increases in goods prices during the pandemic and then, once the economy began reopening, was sustained by price rises in services (see Figure 2). The rapid and substantial increase in inflation has presented many challenges for monetary policymakers. Initially, central banks looked through the inflation surge, but they ultimately began raising interest rates in what has turned out to be the most aggressive tightening cycle in decades.

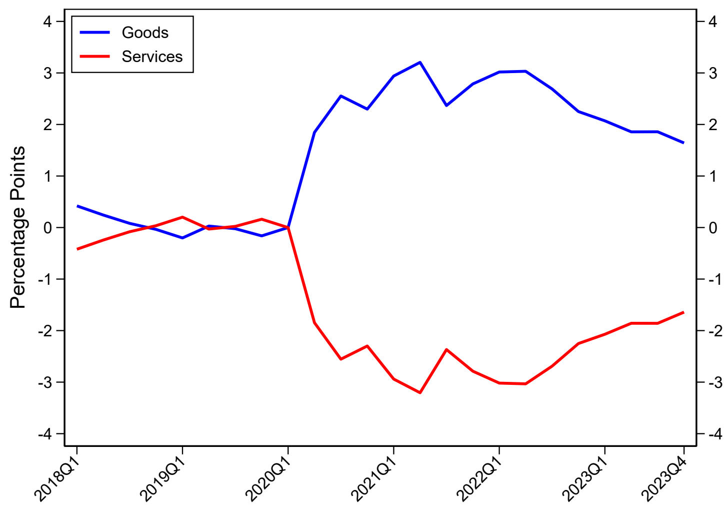


Figure 1: Recent US PCE share changes relative to 2020Q1

The initial hesitancy of central banks to raise rates can be traced to several factors, among which were the belief that price pressures were temporary and localized and the assessment that the economy as a whole was still operating well below capacity. Notably, large sectoral imbalances, wherein some sectors were overheating and others showed significant signs of slack, appear to have posed novel challenges for policymakers. An important outstanding question for research on monetary policy is to assess the extent to which the severity of the 2021–2023 inflation spell could have been lessened had central banks raised interest rates earlier. To answer this, it is critical to understand whether monetary policy transmits differently in times of demand reallocation featuring large sectoral imbalances. Yet, despite recent advances in the analysis of the state-dependent transmission of monetary policy, relatively little is known about transmission of monetary policy during such episodes. Our objective in this paper is to focus on this issue.

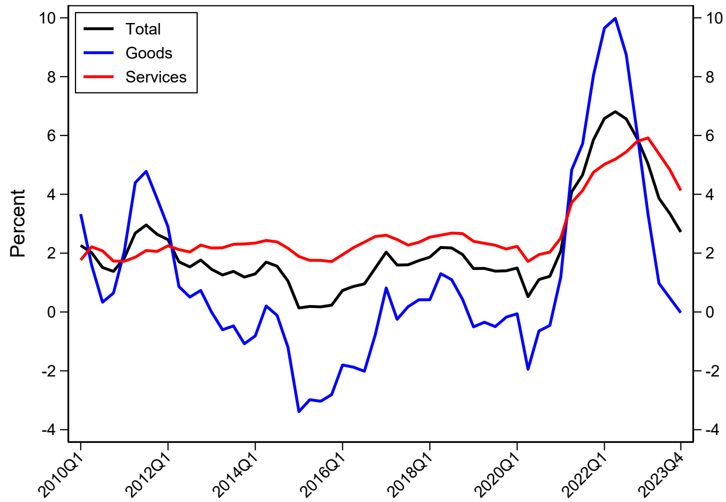


Figure 2: Year-on-year US PCE Inflation

We analyze the transmission of monetary policy during a time of sectoral reallocation using a multi-sector New Keynesian model augmented with factor reallocation frictions in the spirit of Ferrante, Graves and Iacoviello (2023) that account for several features of recent US data. An asymmetric reallocation friction, featuring a convex cost of raising labor in a given sector, implies that sectoral reallocations are inflationary in the short-term because they raise costs in expanding sectors without significantly altering costs in contracting sectors.[1] This feature means that the model can account for the cross-sectoral sequencing of the recent inflation surge, depicted in Figure 2, where inflation initially rose for goods before rising for services.

To study how monetary policy transmission interacts with demand reallocations, we proceed in two steps. First, we present a simple two-sector New Keynesian model featuring upward labor adjustment costs at the sector level. We then characterize the economy's adjustment to a reallocation of expenditures from services to goods in the model and show analytically how monetary policy shocks transmit in different states of the reallocation process. Second, we pursue the same exercise in a more detailed quantitative model featuring multiple sectors, sectoral heterogeneity in price stickiness and a rich input-output production structure calibrated to the US economy.

The main advantage of working with a simple two-sector framework is that we are able

[1] Ilut, Kehrig and Schneider (2018) find that industry- and firm-level U.S. employment growth is negatively skewed both in the cross section and the time series and that firms adjust employment to a greater degree in response to negative idiosyncratic productivity shocks than to positive shocks of the same size. These facts are consistent with the presence of asymmetric labor adjustment costs that could result from hiring costs that are larger than firing costs, financial market frictions, or capacity constraints (e.g., Boehm and Pandalai-Nayar 2022 and Comin, Johnson and Jones 2023).

to derive closed-form solutions and thus cleanly identify the key factors that influence the transmission of a monetary policy shock amid demand reallocations.[2] We show that, during a reallocation process, monetary policy transmits more or less powerfully in a given sector depending on whether the sector expands or is expected to do so in the future. Specifically, we find that a contractionary monetary policy is more effective at curbing inflation in sectors that are induced to expand by a demand reallocation. Intuitively, sectors seeing higher demand attempt to raise their production by hiring more labor. But in the presence of hiring frictions, marginal costs in expanding sectors rise steeply, which results in higher prices. In this context, a contractionary monetary policy shock suppresses demand and eases firms' hiring pressure, effectively lowering their marginal costs and desired prices. And since expanding sectors are already operating at full capacity, the monetary policy shock only has a minor effect on their activity. In contrast, a contractionary monetary policy shock does not influence as strongly marginal costs in contracting sectors, since their hiring frictions are not active. Therefore, monetary policy transmits to prices and outputs in those sectors as in a standard model without hiring frictions.

A key insight from our closed-form expressions is that the effectiveness of monetary policy depends not only on the current state of a sector, but also on the full trajectory of all future states. For example, our model predicts different effects of a contractionary monetary policy for a sector that is currently contracting but expected to expand in the future (e.g., the case of the services sector during the pandemic) relative to another sector that is expected to continue contracting in the future. Our model suggests that monetary policy is more effective at curbing inflation in a sector that is expected to expand in the future (despite currently contracting). Intuitively, anticipating the need to raise employment in the near future, the sector optimally does not cut back production by as much in response to the monetary policy shock today, which results in a larger drop in prices.

During a demand reallocation episode, the economy goes through distinct adjustment phases, and the effectiveness of monetary policy in controlling aggregate output and inflation varies across these phases. In certain phases, which we label *rebalancing phases*, one sector is expanding while the other is contracting. This is the case at the beginning of a demand reallocation episode, for instance. In other phases, both sectors are growing—in one sector because supply gradually increases over time to meet an elevated demand and in the other sector because the expectation of a future demand recovery calls for a gradual build-up

[2] Analyses of the transmission of monetary policy shocks in models featuring non-linearities often rely on numerical solutions. While numerical solutions can provide useful insights on the transmission mechanism, responses are necessarily sensitive to the calibrations of the models and shock processes. A key contribution of our paper is to provide an analytical characterization of the transmission of a monetary policy shock during the reallocation process.

of capacity. We label this second type of adjustment period as an *expansion phase*. A contractionary monetary policy reduces demand in all sectors to similar extents. But because it has a larger effect on inflation in expanding sectors than in contracting sectors, it is more effective at reducing aggregate inflation during expansion phases than during rebalancing phases. Furthermore, when rebalancing phases are long-lasting, employment reductions in the contracting sector become more frontloaded in response to a contractionary monetary policy, which results in an even smaller inflation response in that sector as well as in the aggregate.

These insights carry over to the multi-sector model with input-output linkages calibrated to the US economy that we analyse in the second part of the paper. In that model, we find significant differences in the effect of monetary policy at different stages of the reallocation process. Moreover, we find that allowing for input-output linkages diminishes the potency of monetary policy in tempering inflation. Intuitively, this is because with input-output linkages, nominal rigidities are compounded along the production network (as in Rubbo, 2023), which reduces the effect of monetary policy on final prices. Meanwhile, accounting for asymmetries in price stickiness across different sectors markedly enhances the disparities in sectoral responses to monetary policy shocks.

Related literature Our investigation of the effects of monetary policy during a demand-driven sectoral reallocation with adjustment frictions is related to Guerrieri, Lorenzoni, Straub and Werning (2021). They focus on the degree to which monetary policy encourages or discourages reallocation of labor across sectors during the rebalancing phase of a reallocation episode and discuss the implications for the optimal conduct of monetary policy. A key difference between their work and ours is that nominal and real frictions remain present throughout the reallocation episode in our setting. This allows us to evaluate the effectiveness of monetary policy across different phases of the adjustment of the economy to demand reallocations with arbitrary persistence. Additionally, it implies that the ability of monetary policy to stabilize output and inflation depends on the anticipated paths of employment in different sectors. The modelling framework we use to shed light on these issues is Ferrante, Graves and Iacoviello (2023)'s model of sectoral reallocations. Relative to their work, our contribution is to study the transmission of monetary policy. Our paper also relates to a recent literature on the state-dependent effects of monetary policy (e.g., Alpanda, Granziera and Zubairy, 2021, Ascari and Haber, 2021, McKay and Wieland, 2021, or Eichenbaum, Rebelo and Wong, 2022). Relative to this work, the novelty of our analysis is to focus on a notion of states related to imbalances in sectoral dynamics of particular relevance during reallocation episodes.

2 Simple model with labor reallocation frictions

This section describes a simple two-sector New Keynesian model featuring sticky prices and an asymmetric labor adjustment friction that enables us to characterize how monetary policy transmits through the economy during a demand reallocation episode.[3] The formulation of the labor adjustment frictions follows that of Ferrante, Graves and Iacoviello (2023). Time is discrete and lasts forever. In each sector, a representative competitive producer purchases inputs from a continuum of monopolistically competitive intermediate input producers. Intermediate firms hire sector-specific labor that is supplied to them by labor agencies. In turn, labor agencies in each sector hire labor from a representative household subject to convex hiring costs. In addition, monetary policy targets nominal expenditures.

2.1 Households

A representative household has preferences over consumption, C_t, and labor supply, N_t, given by

$$U_t = \sum_{t=0}^{\infty} \beta^t \left[ln(C_t) - N_t \right],$$

where $\beta < 1$ is a discount factor. Consumption C_t is a Cobb-Douglas aggregate of goods and services consumption:

$$C_t = \left(\frac{C_t^g}{\omega_t} \right)^{\omega_t} \left(\frac{C_t^s}{1-\omega_t} \right)^{1-\omega_t},$$

where g and s denote goods and services, respectively.[4] The preference parameter $\omega_t \in (0,1)$ is time-varying.

The household faces a budget constraint:

$$P_t^g C_t^g + P_t^s C_t^s + B_{t+1} + M_{t+1} = W_t N_t + (1 + i_{t-1}) B_t + M_t + D_t,$$

where P_t^g and P_t^s are, respectively, the price of goods and services, W_t is the nominal wage, B_t are nominal bond holdings that pay interest at rate i_{t-1}, M_t denotes cash holdings, and

[3]For the quantitative exercises in Section 4, we expand the framework to allow for additional sectors and a more realistic production structure in which sectors are connected in an input-output network (see Appendix B.1 for the details of the quantitative model).

[4]In this simple framework, consumption categories and production sectors are equivalent, and so we use these terms interchangeably. Because the data used to discipline the consumption and production sides of the quantitative model of Section 4 use different classifications, there, these two concepts are distinct.

D_t are dividends paid out from the profits of the monopolistically competitive firms and labor agencies that we describe later. The household also faces a cash-in-advance constraint:

$$P_t^g C_t^g + P_t^s C_t^s \leq M_t.$$

The solution to the household's intra-temporal expenditure minimization problem implies the following exogenous expenditure shares on the two consumption categories:

$$\frac{P_t^g C_t^g}{P_t C_t} = \omega_t,$$
$$\frac{P_t^s C_t^s}{P_t C_t} = 1 - \omega_t,$$

where $P_t \equiv (P_t^g)^{\omega_t} (P_t^s)^{1-\omega_t}$ is the (expenditure-based) consumer price index (CPI).

The household maximizes utility subject to its budget constraint and cash-in-advance constraint. Its optimal savings decision is characterized by the Euler equation:

$$\frac{1}{C_t} = \beta \mathbb{E}_t \left(\frac{1 + i_t}{C_{t+1} \Pi_{t+1}} \right),$$

where $\Pi_t = \frac{P_t}{P_{t-1}}$ is the (gross) CPI inflation rate. As long as the nominal interest rate is positive ($i_t > 0$), the household's cash-in-advance constraint holds with equality:

$$P_t C_t = M_t.$$

2.2 Representative competitive producer

In each sector $i \in \{g, s\}$, a representative competitive producer purchases intermediate inputs from a unit mass of monopolistically competitive firms (indexed by j) and aggregates them according to a constant elasticity of substitution production function:

$$Y_t^i = \left[\int_0^1 Y_t^i(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}, \tag{1}$$

where ϵ is the elasticity of substitution across varieties within a sector. Given prices of each variety, $P_t^i(j)$, cost minimization implies that demand for variety j in sector i is

$$Y_t^i(j) = \left(\frac{P_t^i(j)}{P_t^i} \right)^{-\epsilon} Y_t^i,$$

where the sectoral producer price index is $P_t^i = \left[\int_0^1 P_t^i(j)^{1-\epsilon} dj\right]^{1/(1-\epsilon)}$.

2.3 Monopolistically competitive firms

In each sector i, a continuum of firms supply differentiated intermediate inputs to the sector's representative competitive producer and engage in monopolistic competition subject to price adjustment costs. In the simple framework described here, these firms hire labor services from a sectoral labor agency to produce output using the linear technology $Y_t^i(j) = L_t^i(j)$. Because all intermediate input producers in a sector use the same technology, the marginal costs of production are common across all such firms and are given by $MC_t^i = P_t^{L,i}$, where $P_t^{L,i}$ is the price of labor services in sector i.

Firms set prices subject to quadratic, non-pecuniary adjustment costs. In recursive form, their optimization problem is given by

$$V_t^i\left(P_{t-1}^i(j)\right) = \max_{P_t^i(j)} \left(\frac{P_t^i(j)}{P_t^i}\right)^{-\epsilon} Y_t^i\left(P_t^i(j) - MC_t^i\right) \tag{2}$$

$$- \frac{\psi}{2}\left(\frac{P_t^i(j)}{P_{t-1}^i(j)}\right)^2 P_t^i Y_t^i + \mathbb{E}_t\left[\mathcal{M}_{t+1} V_{t+1}^i\left(P_{t-1}^i(j)\right)\right], \tag{3}$$

where ψ moderates the price adjustment cost, and $\mathcal{M}_{t+1}$ is the stochastic discount factor of the representative household. Since the price-setting problem is symmetric across all intermediate input producers in a sector, its solution implies the following sector-level New Keynesian Phillips curve:

$$1 - \epsilon + \epsilon \frac{P_t^{L,i}}{P_t^i} - \psi\left(\Pi_t^i - 1\right)\Pi_t^i + \psi E_t\left(\mathcal{M}_{t+1}\frac{\left(\Pi_{t+1}^i\right)^2}{\Pi_{t+1}}\left(\Pi_{t+1}^i - 1\right)\frac{Y_{t+1}^i}{Y_t^i}\right) = 0,$$

where $\Pi_t^i = \frac{P_t^i}{P_{t-1}^i}$ denotes the (gross) inflation rate in sector i.

2.4 Labor agencies

A representative labor agency in each sector hires workers from the representative household and supplies labor services to the monopolistically competitive firms. As in Ferrante, Graves and Iacoviello (2023), these agencies face convex hiring costs measured in units of labor. In contrast, they can freely lay off workers and decrease sectoral employment. In recursive form, the sector i labor agency's optimization problem is

$$V_t^i\left(L_{t-1}^i\right) = \max_{L_t^i} P_t^{L,i} L_t^i - W_t L_t^i \left(1 + \mathbb{I}_t^i \frac{c}{2}\left(\frac{L_t^i}{L_{t-1}^i} - 1\right)^2\right) + E_t\left[\mathcal{M}_{t+1} V_{t+1}^i\left(L_t^i\right)\right],$$

where c modulates the hiring cost and $\mathbb{I}_t^i$ is the *expansion state* of sector i at time t, defined as

$$\mathbb{I}_t^i = \begin{cases} 1 & \text{if } L_t^i > L_{t-1}^i \\ 0 & \text{if } L_t^i \leq L_{t-1}^i. \end{cases}$$

By convention, this expansion state is 1 if the sector is expanding and 0 if it is not. Hiring costs are quadratic and increasing in the growth rate of sectoral employment. The solution to this problem implies the following expression for the cost of labor services in a sector:

$$\begin{aligned} P_t^{L,i} = W_t + \mathbb{I}_t^i W_t &\left(\frac{c}{2}\left(\frac{L_t^i}{L_{t-1}^i} - 1\right)^2 + c\left(\frac{L_t^i}{L_{t-1}^i} - 1\right)\frac{L_t^i}{L_{t-1}^i}\right) \\ &- \mathbb{I}_{t+1}^i E_t\left(\mathcal{M}_{t+1} W_{t+1} c\left(\frac{L_{t+1}^i}{L_t^i} - 1\right)\left(\frac{L_{t+1}^i}{L_t^i}\right)^2\right). \end{aligned} \tag{4}$$

When active, labor adjustment costs introduce a wedge between the aggregate wage paid to the household and the price of labor services in a sector. This wedge depends on both the current and expected future hiring costs (the second and third terms on the right-hand side of Equation 4, respectively). The profits associated with this wedge are rebated to the household as a flow of dividends.

2.5 Market clearing

In equilibrium, all product and labor markets clear. In each sector $i \in \{g, s\}$, market clearing implies that the amount of output produced by firms is consumed by the representative household:

$$Y_t^i = C_t^i.$$

Furthermore, labor market clearing requires that the sum of labor inputs used across sectors is supplied by the representative household:

$$\sum_{i\in\{g,s\}} L_t^i \left(1+\mathbb{I}_t^i \frac{c}{2}\left(\frac{L_t^i}{L_{t-1}^i}-1\right)^2\right) = N_t,$$

where $L_t^i = \int_0^1 L_t^i(j)dj$ for $i \in \{g, s\}$ and all t. Finally, bond market clearing requires $B_t = 0$.

3 Sectoral reallocation and monetary policy

We next examine the effects of a sectoral reallocation shock and characterize the transmission of monetary policy to sectoral and aggregate variables in the simple model presented above. Using this characterization, we demonstrate how the strength of monetary policy transmission varies across different stages of the adjustment of the economy to the sectoral reallocation shock.

3.1 A sectoral reallocation episode

We consider a temporary shock to expenditure shares in order to capture an episode, similar to that experienced in the Covid-19 pandemic, during which consumers temporarily shifted their expenditure shares across consumption categories. Suppose that the economy is initially in steady state at time $t = 0$ but is subject to an unanticipated shock to the household's goods expenditure share that arrives at time $t = 1$ and persists for many periods thereafter (see, e.g., Fornaro and Romei, 2022). In particular, let the expenditure share for period $t \geq 1$ be exogenously given by

$$\omega_t = (1-\rho)\overline{\omega} + \rho\omega_{t-1} + v_t,$$

where $\overline{\omega}$ is the steady-state share of spending on goods, $v_1 \in (-\overline{\omega}, 1-\overline{\omega})$, $v_t = 0\ \forall t > 1$, and $\rho \in (0, 1)$ controls the persistence of the shock.[5] For illustration, we set $\overline{\omega} = 0.5$ (so that the economy is symmetric in steady state), $v_1 = 0.05$, and $\rho = 0.9$.[6]

To understand the main forces at work behind the economy's response to such a scenario,

[5] The characterization of the transmission of monetary policy developed below and its implications for aggregate employment and inflation also apply to transitory (finite period) or permanent shocks.

[6] We parameterize the simulations of the simple model discussed throughout this section as follows: $\beta = 0.995$, $\epsilon = 10$, $c = 10$, and $\psi = 54$. The value of ψ is chosen such that the simulated simple model reflects the average degree of price stickiness in Ferrante, Graves and Iacoviello (2023), where price adjustment costs are asymmetric across sectors and which we use in the calibration of the full quantitative model.

it is useful to briefly examine the dynamic response of the economy in versions of the model with and without price and labor adjustment frictions. We first consider a version with flexible prices and absent any labor reallocation frictions and then a version with costly price adjustments but no labor reallocation frictions. Following this, we contrast the responses in these two cases with the economy's adjustments in the model with both sticky prices and labor reallocation frictions. We assume throughout this preliminary discussion that monetary policy plays no active role so that $M_t = \overline{M} > 0 \; \forall t$ and discuss the role of monetary policy in the next subsection.

Flexible price economy Under flexible prices and with no factor reallocation frictions, the prices of goods and services are equal and the allocation of labor to producing goods and services is determined by the ratio of the expenditure shares: $L_t^g/L_t^s = C_t^g/C_t^s = \omega_t/(1-\omega_t)$. Figure 3 illustrates these responses. The economy adjusts to the shock immediately by allocating more labor toward the goods sector. The goods sector temporarily employs more workers and the services sector temporarily employs fewer workers until the expenditure shares converge back to their steady-state levels. Neither aggregate employment nor aggregate consumption change, so wages remain constant. Therefore, firms' marginal costs, markups, and prices also remain constant. Although the shift in relative demand for goods leads to a reallocation of workers across sectors, it generates no inflation and leads to no change in aggregate output or consumption.

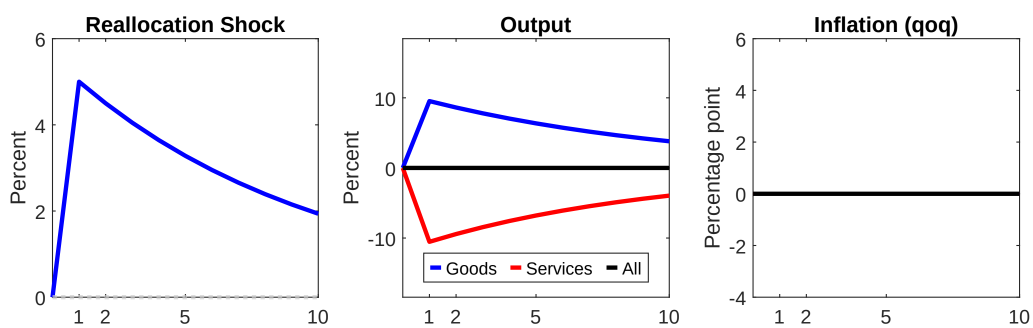


Figure 3: Reallocation episode in frictionless model (no labor adjustment costs).

Economy with sticky prices and no labor reallocation frictions Adding price stickiness does not change the equilibrium responses. Since sectoral supply immediately adjusts to meet the changes in sectoral demand and marginal costs of production remain equal to the common nominal wage in both sectors, there is no need to make price adjustments. More formally, denoting $x_t \equiv log(X_t) - log(\overline{X})$ as the log deviation of a variable from its steady state level $\overline{X}$ and $\hat{\omega}_t \equiv \omega_t - \overline{\omega}$ as the level deviation of the goods consumption share from its steady state, Lemma 1 provides the full dynamics of all variables in the economy without labor reallocation frictions in response to a shift in expenditure shares.

Lemma 1. *In the absence of labor reallocation frictions, and under the assumption of no change the in monetary policy stance (i.e., $m_t = 0$), the output and price dynamics in response to a demand reallocation shock $\widehat{\omega}$ are given by*

$$y_t^g = l_t^g = c_t^g = \frac{1}{\overline{\omega}}\hat{\omega}_t,$$
$$y_t^s = l_t^s = c_t^s = -\frac{1}{1-\overline{\omega}}\hat{\omega}_t,$$
$$p_t^g = p_t^s = p_t^{L,s} = p_t^{L,g} = p_t = w_t = 0.$$

The responses are independent of the degree of price adjustment frictions ψ.
Proof: See Appendix A.1.

Economy with sticky prices and labor reallocation frictions When the hiring frictions are present, the economy adjusts to the shock unevenly and more gradually, which results in more complex responses of sectoral employment and prices (see Figure 4). Because employment rises in the goods sector immediately after the onset of the shock, the costs of the goods sector's labor agency increase as it pays the hiring costs. These higher costs are passed through to goods-producing firms, who, facing higher marginal costs, raise their prices as a result. Higher goods prices lower the quantity of goods demanded, so employment in the goods sector does not expand as much as in the version of the model without the hiring frictions. At the same time, as there are no adjustment costs arising from downsizing, the employment drop in the services sector is more pronounced than the rise in the goods sector, which results in a fall in aggregate employment on impact. Lower aggregate labor demand reduces the equilibrium real wage, which lowers marginal costs and exerts downward pressure on prices in the services sector. However, inflationary pressures in the goods sector initially outweigh the deflationary pressures in the services sector, so aggregate inflation rises on impact. After the initial shock period, employment continues to gradually expand in the goods sector for a few periods before declining as relative demand for goods returns to steady state. Meanwhile, employment recovers in the services sector.

A key implication of these adjustments for inflation dynamics is that the model predicts two consecutive inflation episodes: (1) an initial peak in goods inflation due to the increased marginal costs of goods producers, and (2) subsequent persistent services inflation driven by the gradual increase of employment in the services sector as demand for services recovers.

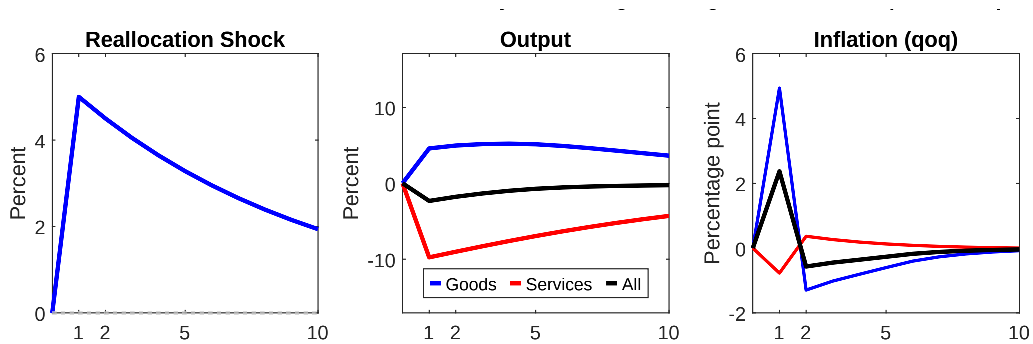


Figure 4: Reallocation episode in model with asymmetric labor adjustment costs.

3.2 Monetary policy transmission

In the presence of nonlinearities, analyzing the transmission of monetary policy often relies on numerical solutions. While numerical solutions can provide useful insights on the transmission mechanism, responses are necessarily sensitive to the calibration of the model and shock processes.

A key contribution of our paper is to provide analytical characterizations of the transmission of small, unexpected monetary policy shocks to sectoral and aggregate output and inflation at any point during a reallocation episode in the model of Section 2. Using an approach similar to Guerrieri and Iacoviello (2015), we analyze a piece-wise linear approximation of the equilibrium dynamics, in which equilibrium conditions are linearized conditional on a small number of state variables summarizing whether the two sectors are expanding or not. Our characterization, presented in Proposition 1, emphasizes the key factors that determine the transmission strength of a monetary policy shock.

3.2.1 Sectoral transmission of monetary policy

To characterize the equilibrium dynamics in response to an unexpected monetary policy shock amid the demand reallocation, we compare the impulse responses from two scenarios: (1) the baseline response of variable x to a demand reallocation shock, denoted as $x_t^{\text{without MP shock}}$ and (2) the response of that same variable x when there is an additional unexpected monetary policy shock at t, denoted as $x_t^{\text{with MP shock}}$. Defining $\widetilde{x}_t \equiv x_t^{\text{with MP shock}} - x_t^{\text{without MP shock}}$, the response of output and inflation to the monetary policy shock are given in Proposition 1.[7] As we make clear below, the key takeaway from this result is that the transmission of the monetary policy shock depends on the current and future expansion states of the sector.

[7]In the proposition, we focus on the sectoral responses. The aggregate responses are simply the average of the sectoral responses we characterized here, weighted by the respective consumption shares of each sector.

Proposition 1. *Consider a monetary policy shock small enough not to alter the sign of the growth rate of output in any sector. Then, the response of output in sector i to an unexpected one-time expansionary monetary policy shock at time t (i.e., $\widetilde{m}_t = 1$ and $\widetilde{m}_{t+\tau} = 0 \; \forall \tau \neq 0$) is given by*

$$\widetilde{y}_t^i = -\frac{z_{t+1}^i + \kappa + \beta\left[\kappa + (1+\beta)(1-\lambda_2^i)z_{t+2}^i\right]}{\beta(z_{t+1}^i)^2 - \left(z_t^i + \kappa + \beta z_{t+1}^i\right)\left[z_{t+1}^i + \kappa + \beta(1-\lambda_2^i)z_{t+2}^i\right]},$$

$$\widetilde{y}_{t+1}^i = \frac{z_t^i + \kappa + \beta z_{t+1}^i}{\beta z_{t+1}^i}\widetilde{y}_t^i - \frac{1+\beta}{\beta z_{t+1}^i},$$

$$\widetilde{y}_{t+\tau}^i = \widetilde{y}_{t+1}^i \Pi_{\iota=2}^{\tau} \lambda_\iota^i \qquad \forall \tau \in \{2, \ldots, T^i\}.$$

The composite parameters λ_ι^i are

$$\lambda_{\iota-1}^i = \frac{z_{t+\iota-2}^i}{\kappa + z_{t+\iota-1}^i + \beta z_{t+\iota}^i(1-\lambda_\iota^i)} \qquad \forall \iota \in \{2, \ldots, T^i\},$$

$$\lambda_{T^i}^i \equiv \frac{\kappa + (1+\beta)z_{t+T^i}^i - \sqrt{[\kappa + z_{t+T^i}^i(1+\beta)]^2 - 4\beta(z_{t+T^i}^i)^2}}{2\beta z_{t+T^i}^i},$$

where $\kappa \equiv (\epsilon - 1)/\psi$ is the slope of the Phillips curve in the model without labor hiring frictions. The parameters $z_{t+\tau}^i \equiv 1 + \kappa c \mathbb{I}_{t+\tau}^i \geq 1$ reflect the expansion state of sector i at time $t+\tau$ and T^i is the terminal period after which $\mathbb{I}_{t+\tau}^i = \mathbb{I}_{t+T^i}^i \; \forall \tau > T^i$. The price and inflation dynamics in sector i are given by

$$\widetilde{p}_{t+\tau}^i = \widetilde{m}_{t+\tau} - \widetilde{y}_{t+\tau}^i \quad \text{and} \quad \widetilde{\pi}_{t+\tau}^i = \Delta\widetilde{m}_{t+\tau} - \Delta\widetilde{y}_{t+\tau}^i.$$

Proof: See Appendix A.2.

These analytical results leverage the fact that, due to the assumed preferences, the dynamics of each sector are independent from each other. It is useful to contrast these model solutions with those in a standard model without hiring frictions, presented in Corollary 1. The key difference in the responses to the monetary policy shock lies in the state-dependent dynamics that are governed by $z_{t+\tau}^i$. Intuitively, when $\mathbb{I}_{t+\tau}^i = 1$ and thus $z_{t+\tau}^i = 1 + \kappa c$, the sector is expanding and hence constrained by the labor hiring friction. Since it is costly for the sector to increase its production capacity, an expansionary monetary policy shock pushes up the sector's price and has a comparatively limited impact on its employment and output.

Corollary 1. *In absence of labor hiring frictions, i.e.,* $z^i_{t+\tau} = 1\ \forall\tau \geq 0$*, we get the standard dynamics:*

$$\widetilde{y}^i_t = -\frac{1+\kappa+\beta\left[\kappa+(1+\beta)(1-\lambda)\right]}{\beta-(1+\kappa+\beta)\left[1+\kappa+\beta(1-\lambda)\right]},$$

$$\widetilde{y}^i_{t+1} = \frac{1+\kappa+\beta}{\beta}\widetilde{y}^i_t - \frac{1+\beta}{\beta},$$

$$\widetilde{y}^i_{t+\tau} = \widetilde{y}^i_{t+1}\lambda^{\tau-1} \quad \forall\tau \geq 1,$$

with

$$\lambda \equiv \frac{1+\kappa+\beta-\sqrt{(1+\kappa+\beta)^2-4\beta}}{2\beta}.$$

Proof: See Appendix A.2.

3.2.2 Dimensionality reduction

The sequence of expansion and contraction periods in a given sector shapes the strength of monetary policy transmission. The nature of this dependence is potentially complicated since, as shown in Proposition 1, the size of the effects of a shock on sectoral output and inflation dynamics depends not only on the current expansion state of the sector, $\mathbb{I}^i_t$, but also the full trajectory of all future states $\{\mathbb{I}^i_{t+\tau}\}_{\tau=1}^{\infty}$. However, because the monetary policy shock considered is temporary, the relevance of states further in the future declines quickly. In Appendix A.3, we show that artificially imposing that the terminal period T^i is as soon as two periods after the monetary policy shock (i.e., assuming that $\mathbb{I}^i_{t+\tau} = \mathbb{I}^i_{t+2}\ \forall\tau > 2$) already provides a reasonably precise approximation to the exact nonlinear solution. Moreover, when $T^i = 2$, knowledge of the path of the first three expansion states, $\mathbb{I}^i_t$, $\mathbb{I}^i_{t+1}$, and $\mathbb{I}^i_{t+2}$, is sufficient to solve for the output and inflation dynamics in sector i in closed form, as is shown in Corollary 2.

Corollary 2. *When* $T^i = 2$*, the output dynamics can be solved in closed-form as*

$$\widetilde{y}^i_t = -\frac{\kappa+z^i_{t+1}+\beta\left[\kappa+(1+\beta)(1-\lambda^i)z^i_{t+2}\right]}{\beta(z^i_{t+1})^2-\left(\kappa+z^i_t+\beta z^i_{t+1}\right)\left[\kappa+z^i_{t+1}+\beta(1-\lambda^i)z^i_{t+2}\right]},$$

$$\widetilde{y}^i_{t+1} = \frac{\kappa+z^i_t+\beta z^i_{t+1}}{\beta z^i_{t+1}}\widetilde{y}^i_t - \frac{1+\beta}{\beta z^i_{t+1}},$$

$$\widetilde{y}^i_{t+\tau} = \widetilde{y}^i_{t+1}(\lambda^i)^{\tau-1},$$

with

$$\lambda^i \equiv \frac{\kappa + (1+\beta)z^i_{t+2} - \sqrt{[\kappa + z^i_{t+2}(1+\beta)]^2 - 4\beta(z^i_{t+2})^2}}{2\beta z^i_{t+2}}.$$

Proof: See Appendix A.2.

To describe how the effects of monetary policy depend on the sequence of (expansion) states in a sector, we evaluate the responses implied by Corollary 2 to a one-time 0.25% contractionary monetary policy shock at t, i.e., $\widetilde{m}_t = -0.25\%$ and $\widetilde{m}_{t+1} = \widetilde{m}_{t+2} = 0\%$. Under the assumptions of our simple model, the output and price responses always sum up to the magnitude of the monetary policy shock, so that $\widetilde{y}^i_{t+\tau} + \widetilde{p}^i_{t+\tau} = \widetilde{m}_{t+\tau}$.

Figure 5 illustrates how the sectoral output and price responses differ depending on the set of expansion states $(\mathbb{I}^i_t, \mathbb{I}^i_{t+1}, \mathbb{I}^i_{t+2})$, where, for example, (0,0,0) means the sector is not expanding in any period from the onset of the shock onwards. The output dynamics in this case are the same as in the model without hiring frictions (cf. Corollary 1). As such, this case provides a useful benchmark against which to compare the dynamics under alternative paths of the expansion states. Quantitatively, the expansion states in period $t+2$ and thereafter play a relatively minor role in determining the effects of the shock on impact.[8] Therefore, we focus our discussion on the importance of the sequence of the first two states $(\mathbb{I}^i_t, \mathbb{I}^i_{t+1})$, assuming $\mathbb{I}^i_{t+2} = 0$.

Regardless of the path of current and future expansion states, output and inflation always drop on impact in response to the contractionary monetary policy shock. However, the magnitude of the impact response varies considerably across different paths. Two main insights can be drawn about the dependence of the time t effect on these paths.

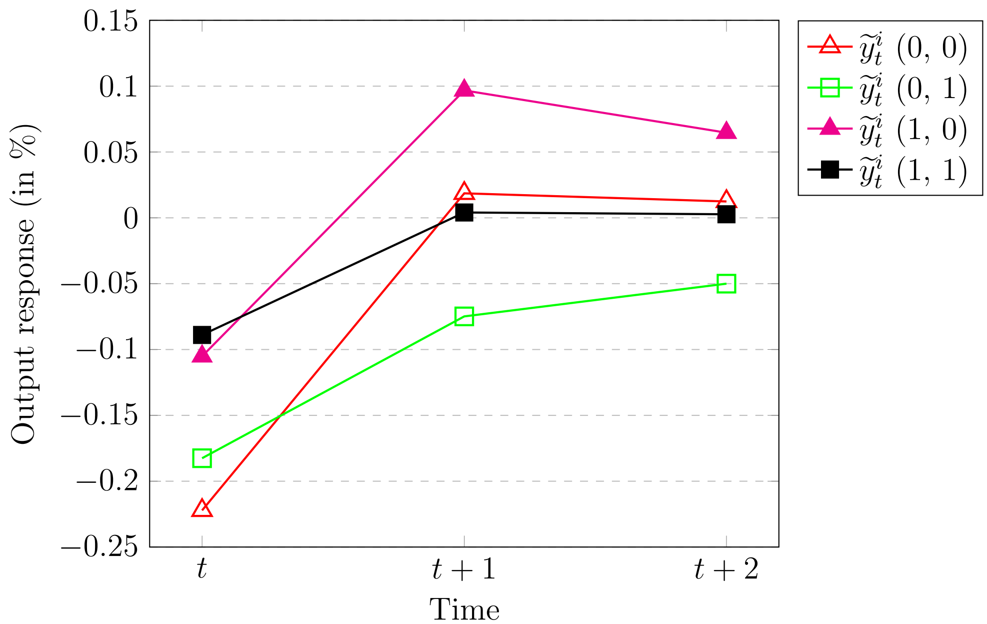
First, if the sector is expanding at the time of the shock, then, all else equal, the contractionary monetary policy has a smaller effect on output and a bigger effect on prices. This pattern can be seen by comparing the response at time t for any pair of paths $(1, \mathbb{I}^i_{t+1})$ and $(0, \mathbb{I}^i_{t+1})$ for a given $\mathbb{I}^i_{t+1}$.[9] Intuitively, the contractionary monetary policy shock depresses demand and relaxes the pressure to raise production in the expanding sector. This reduces the marginal cost of firms in the expanding sector and leads to a bigger drop in prices in the first period.

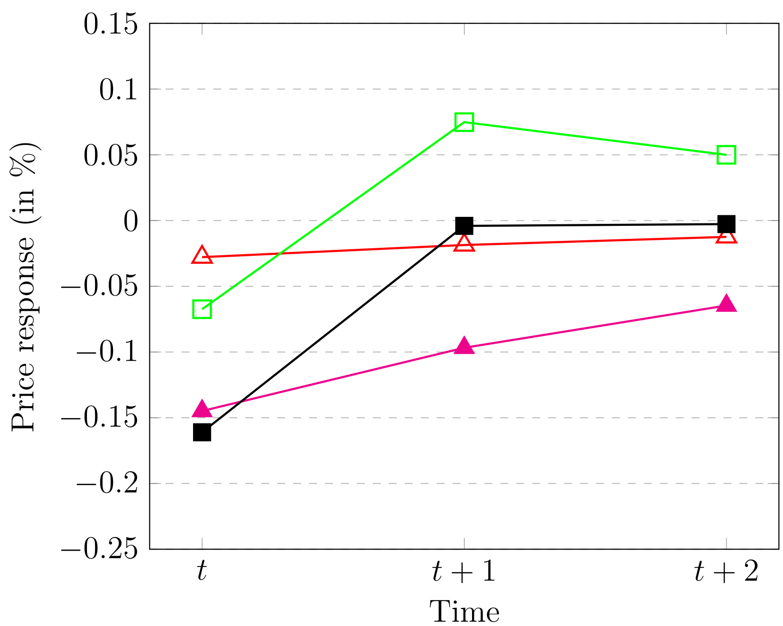
Second, anticipation of a sectoral expansion in the period after the shock dampens the impact effect of the shock on output in period t (and leads to a larger decline in prices), as is clear from comparing time t responses in Figure 5 for any pair of paths $(\mathbb{I}^i_t, 1)$ and $(\mathbb{I}^i_t, 0)$ for a given $\mathbb{I}^i_t$. Because the shock lasts one period, a sector that expects to expand in $t+1$

[8]See Appendix Figure 11 for more details.

[9]In this example, the on-impact effect on output (prices) at time t is smaller (larger) in magnitude for any path over which the sector is initially expanding relative to those over which it is initially contracting.

Figure 5: Responses to a one-time 0.25% contractionary monetary policy shock at t ($c = 10, \kappa = 1/6$)





reduces output by less than if it were to contract in $t+1$, so as to mitigate the rise in the hiring costs required to increase employment in $t+1$.

3.2.3 Monetary policy transmission during a sectoral reallocation

To illustrate how alternative decisions on the timing of monetary policy interventions transmit to sectoral and aggregate inflation during a demand reallocation episode, we use the reallocation episode described in Section 3.1 and leverage the results and intuition discussed in Section 3.2.2. In particular, we evaluate the on-impact effects of monetary policy shocks at different points in time during the reallocation episode.

For a one-period contractionary monetary policy shock at time $t \in \{1, \ldots, 10\}$, Figure 6 plots the effects of the shock on impact for inflation and output in both the goods and services sectors, as well as for the aggregate consumption bundle. As described above, the magnitude of these effects depends on the sequence of expansion states in each sector, with the first two states, $\mathbb{I}_t^i$ and $\mathbb{I}_{t+1}^i$, being the most important determinants of the on-impact effects in practice. The baseline sequences of states depend on the trajectory of output (and hence employment) depicted in Figure 4.[10]

The combinations of sectoral and aggregate responses can be grouped into categories that reflect the phases of the economy's adjustment during the demand reallocation episode. The first category, which we label as a *rebalancing phase*, is one in which the two sectors are adjusting in opposite directions such that one sector is expanding while the other is contracting. The second category is an *expansion phase* in which both sectors are expanding. In between these phases there can be transitional periods during which one or both sectors are switching between expanding and contracting (or vice versa) and the responses depend on the size and direction of the monetary policy shocks.[11]

At the beginning of the demand reallocation episode in period 1, the economy is in a rebalancing phase. Output in the goods sector increases for multiple periods while output in the services sector declines for that period before increasing thereafter. The relevant expansion states are $\mathbb{I}_1^g = 1$ and $\mathbb{I}_2^g = 1$ for goods and $\mathbb{I}_1^s = 0$ and $\mathbb{I}_2^s = 1$ for services. Based on the discussion in Section 3.2.2, the monetary policy shock has a relatively large impact on output and small impact on inflation in the services sector compared with the goods sector.

The economy is also in a rebalancing phase between periods 5 and 10 when the goods sector is contracting and the services sector is expanding as the economy converges back to steady state while the demand reallocation shock dissipates. In the services sector, this

[10] With some exceptions noted below, the monetary policy shock is sufficiently small that it does not alter the expansion states along the baseline sequence and so the results of Proposition 1 hold.

[11] An additional category, which is not relevant for the demand reallocation shock we focus on, would be a phase during which both sectors are contracting.

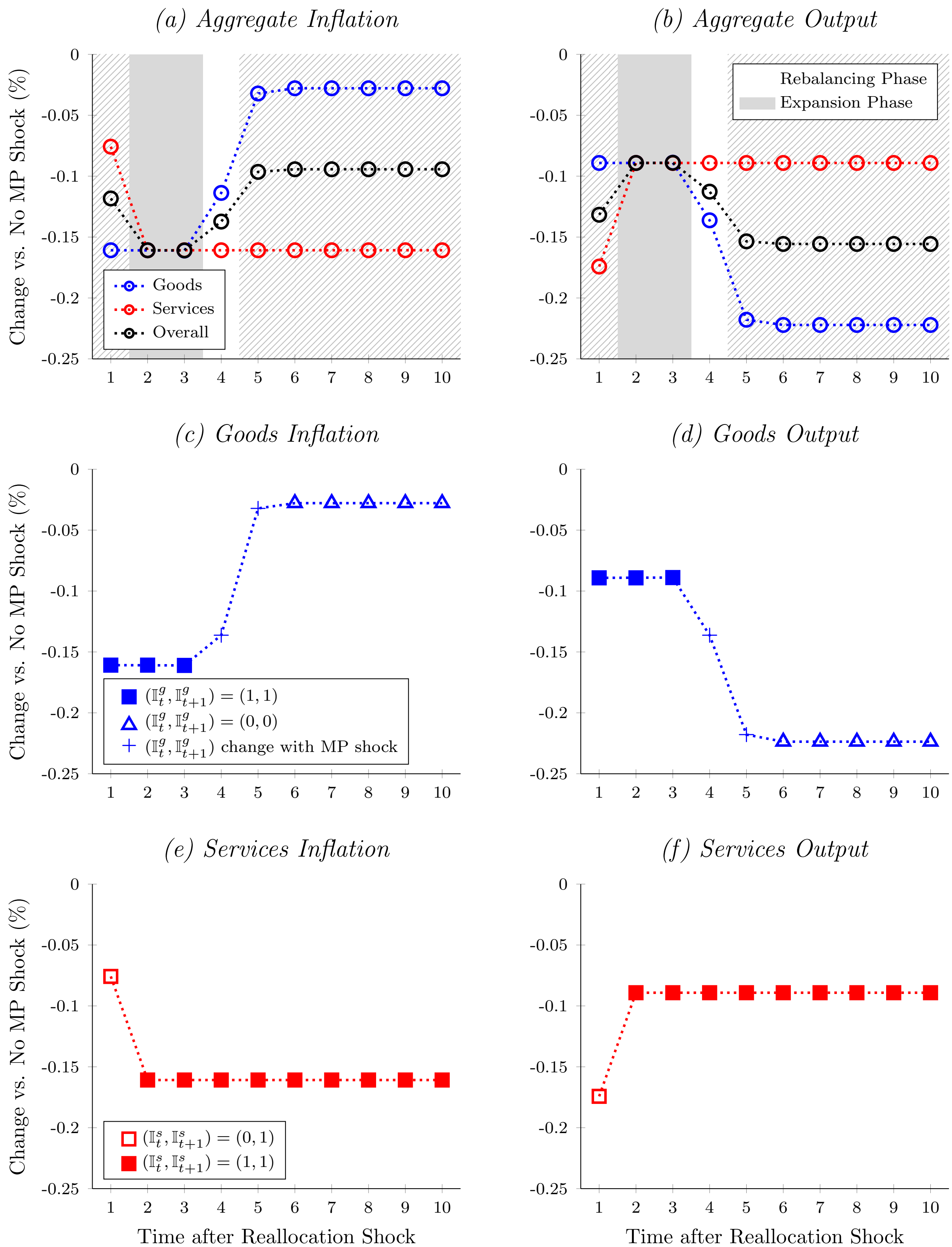


Figure 6: Impact effects of contractionary monetary policy shock at different stages of reallocation episode in model with asymmetric labor adjustment costs

steady growth implies that the relevant expansion states during this phase are $\mathbb{I}^s_t = \mathbb{I}^s_{t+1} = 1\ \forall t \in \{5, \ldots, 11\}$. In the goods sector, the baseline sequence of relevant expansion states in each of these periods is $\mathbb{I}^g_t = \mathbb{I}^g_{t+1} = 0\ \forall t \in \{5, \ldots, 11\}$.[12] Consequently, the effects of a monetary policy shock during this phase are larger (smaller) for output (inflation) in the goods sector than in the services sector. Moreover, as compared with the rebalancing phase in period 1, the aggregate impact of the shock on output is larger and on inflation is smaller in periods 5 through 10 because the anticipation of a future expansion in the services sector in period 1 leads to a smaller impact of the shock on output and larger impact on inflation in services in that period.

In between these two rebalancing phases, there is an expansion phase lasting from period 2 to 3.[13] The relevant expansion states in period 2 are $\mathbb{I}^g_2 = \mathbb{I}^s_2 = 1$ and $\mathbb{I}^g_3 = \mathbb{I}^s_3 = 1$ and in period 3 are $\mathbb{I}^g_3 = \mathbb{I}^s_3 = 1$ and $\mathbb{I}^g_4 = \mathbb{I}^s_4 = 1$, so the impact effects of the monetary policy shock are virtually the same in both sectors.

The differential on-impact responses of aggregate inflation and output in this simple two-sector model shed light on the effectiveness of monetary policy at different points during a reallocation episode. Because contractionary monetary policy has a larger impact on sectoral inflation and smaller impact on sectoral output in sectors that are expanding, the overall effectiveness of monetary policy is larger when the economy is in an expansion phase than when it is in a rebalancing phase. In addition, monetary policy contractions are more effective at reducing inflation while having a smaller impact on output when sectors anticipate expanding in the imminent future.

4 Quantitative analysis

The intuition developed above for the effects of monetary policy in the symmetric two-sector model across different phases of a demand reallocation episode provides a foundation for analyzing monetary policy transmission during an empirically relevant episode, such as during and after the Covid-19 pandemic. In this section, we modify the simple model developed in Section 2 to allow for a quantitative analysis, implement a demand reallocation shock that is calibrated to changes in expenditure patterns since the onset of the pandemic

[12] In this example, the contractionary monetary policy shock in period 5 causes the trajectory of relevant states to switch from $\mathbb{I}^g_5 = 0$ and $\mathbb{I}^g_6 = 0$ to $\mathbb{I}^g_5 = 0$ and $\mathbb{I}^g_6 = 1$, and so the effect lies outside the scope of the characterization given in Proposition 1. The exact effect lies between the approximate effects derived in Corollary 2 for these two cases where, for both trajectories, $\mathbb{I}^g_7 = 0$.

[13] Period 4 is a transitional period between an expansion phase and a rebalancing phase. While the relevant states in the services sector are $\mathbb{I}^s_4 = \mathbb{I}^s_5 = 1$, the monetary policy shock is large enough that the goods sector actually contracts that period before rebounding in the following period and so the relevant states switch from $\mathbb{I}^g_4 = 1$ and $\mathbb{I}^g_5 = 0$ to $\mathbb{I}^g_4 = 0$ and $\mathbb{I}^g_5 = 1$.

in the U.S., and assess the sectoral and aggregate transmission dynamics of monetary policy.

We enrich the two-sector model along multiple dimensions to facilitate the calibration of the model and incorporate features of the economy that are important for evaluating the quantitative effects of the pandemic reallocation shock and monetary policy transmission.[14] The first change is to decompose final demand into consumption categories that reflect key differences in the dynamics of inflation and output in different sectors during the pandemic and permits a realistic calibration of the model's demand reallocation shock to these dynamics. In particular, total consumption comprises bundles of products from five categories—durable goods (d), core non-durable goods (n), core services excluding housing (s), housing (h), and food and energy (f)—that are aggregated according to

$$C_t = \left(\frac{C_t^d}{\omega_t^d}\right)^{\omega_t^d} \left(\frac{C_t^n}{\omega_t^n}\right)^{\omega_t^n} \left(\frac{C_t^s}{\omega_t^s}\right)^{\omega_t^s} \left(\frac{C_t^h}{\omega_t^h}\right)^{\omega_t^h} \left(\frac{C_t^f}{\omega_t^f}\right)^{\omega_t^f},$$

where $\omega_t^d + \omega_t^n + \omega_t^s + \omega_t^h + \omega_t^f = 1$. Second, because the data on consumption and production that are used to calibrate the model group sectors using different classification systems, we introduce a distinction between these five consumption categories and the production industries that sell output that is consumed as a product classified under one or more of these five categories.[15] Third, we incorporate an input-output structure of production into the model to allow demand reallocation shocks to propagate across sectors through production linkages across industries. Fourth, we introduce heterogeneity in the degree of price stickiness across production industries. Fifth, we use a more general specification of preferences over aggregate consumption and labor supply. Finally, we formulate monetary policy through a Taylor rule rather than through a money supply rule.

4.1 Consumer demand reallocation during the pandemic

We start by calibrating the demand reallocation shock to match the changes in the US personal consumption expenditure (PCE) shares of the five consumption categories relative to the shares that prevailed in the first quarter of 2020, which we consider to be the steady-state expenditure shares in our quantitative analysis.[16] In particular, we calibrate AR(1) shock processes separately for durable goods, non-durable goods, and core services sectors.

[14] Appendix B.1 presents the details of the full model.

[15] For example, output produced by a given production industry may be consumed as either durable goods or core services. This separation of consumption and production is a key feature of the calibration of the quantitative framework used in Ferrante, Graves and Iacoviello (2023).

[16] Using the notation developed above, this implies that $\overline{\omega}^d = 10.4\%$, $\overline{\omega}^n = 11.2\%$, $\overline{\omega}^s = 51.2\%$, $\overline{\omega}^h = 15.8\%$, and $\overline{\omega}^f = 11.4\%$.

We do not apply a shock to the food and energy sector, and the shock to the housing sector is calculated as a residual term. To match the dynamics in durable goods, we apply three consecutive shocks at the onset of the pandemic. Table 1 details the calibrated shock processes for each of the sectors.[17]

Industry:	Durables	Non-durables	Core Services	Food & Energy
Persistence:	0.96	0.90	0.915	-
Size of shock:	0.01 (3 shocks)	0.007	-0.04	0

Table 1: Calibration for the reallocation shock processes

To facilitate discussion of the quantitative model, we recategorize the sectors into three groups: (1) core goods, including durable and non-durable goods, (2) core services, and (3) energy, food, and housing. The paths of the expenditure shares for these groups are displayed in Figure 7. As shown by the solid lines, the core goods and core services shares are both converging back to their pre-pandemic levels, but there is a notable difference in the persistence of the shocks in these sectors. The core services share is projected to be close to its pre-pandemic level by early 2026. However, the deviation in the core goods share appears more persistent as it projected to be nearly one percentage point above its pre-pandemic level in the first quarter of 2026.

Before assessing the quantitative importance of the differential impacts of monetary policy at different stages of the reallocation process, it is useful to examine the model responses to the reallocation without monetary policy shocks. As panel (a) of Figure 8 displays, upon receiving a positive demand shock, the goods sector seeks to hire more workers to increase production. However, due to the labor adjustment frictions, it is very costly to do so. As a result, employment in the goods sector increases only gradually, as shown in the second figure. At the same time, the high labor hiring cost causes the production cost to go up in industries that sell intensively to the goods sector, which leads to a price hike for goods, as shown in the third figure. In contrast, there is no cost in laying off workers. Therefore, facing a negative demand shock, firms in the services sector quickly downsize and reduce their workforce. This massive layoff in turn causes wages to drop in equilibrium, which leads to a reduction in production costs and an initial drop in the services price. After the initial shock, the demand gradually rebalances from the goods sector back to the services

[17] Separately calibrating the five PCE categories allows us to closely match the evolution of core goods and core services shares observed in the data using simple AR(1) type processes, rather than more complicated or arbitrary processes. See Figure 17 for a comparison of the data shares and model-implied shares across the five PCE categories. The values of other parameters used in the quantitative model are provided in Appendix B.2.

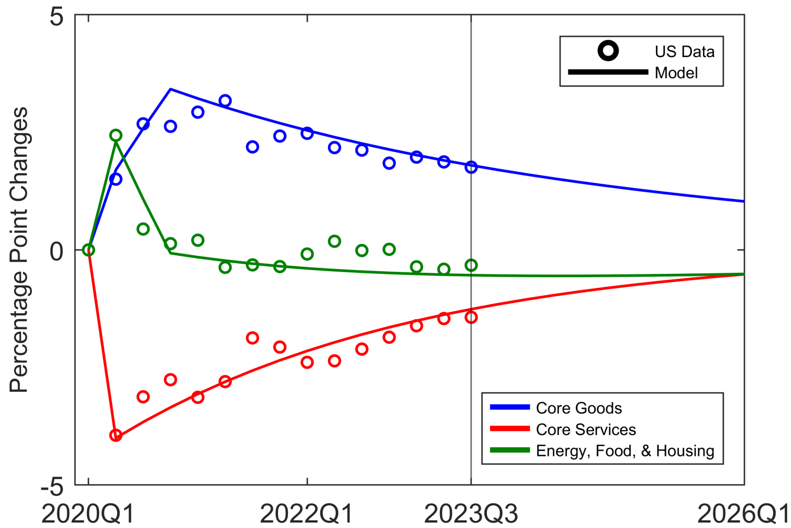


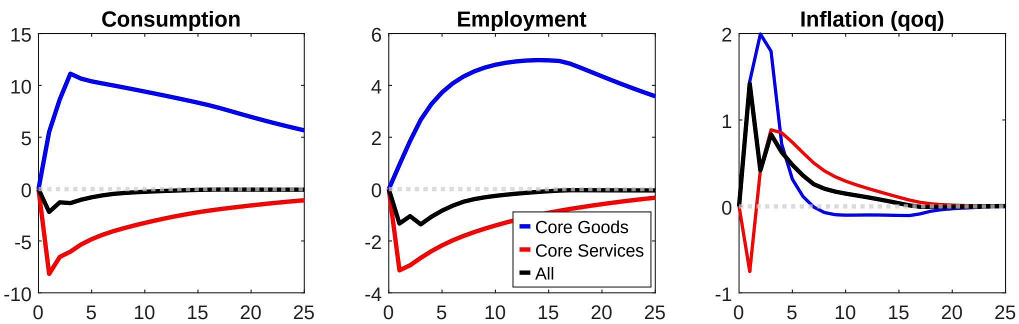
Figure 7: Calibrated demand reallocation shocks

sector. As shown in the first figure, the demand for goods decreases over time. At the same time, supply of goods gradually goes up. As can be seen in the second figure, the goods sector reaches its demand and supply balance in the middle of 2022 (quarter 12), after which employment starts to fall as the demand further decreases.

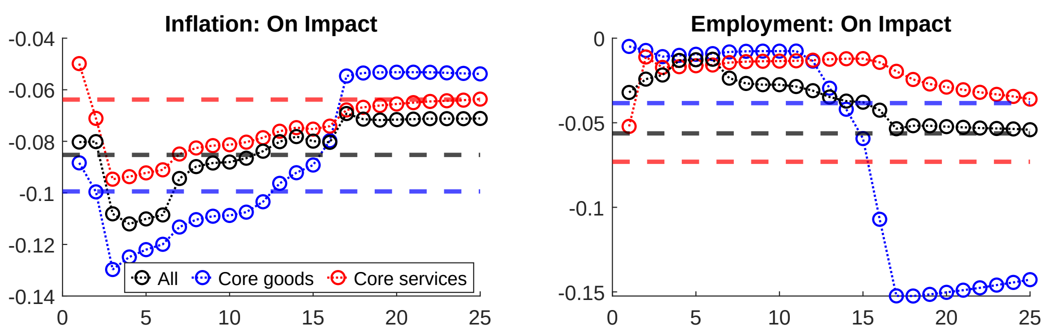
4.2 Effects of monetary policy shocks

Relative to our simple model, the reallocation shock is more persistent, with goods consumption remaining elevated above its steady-state value even after 25 quarters. At the same time, core goods employment takes longer to reach its peak, resulting in a period of expansion for the goods sector. Unlike our simple model with symmetric sectors, the core services sector in our quantitative model is much larger in size than the core goods sector. Therefore, for a similar percentage change in the consumption share, the change in goods employment appears to be higher than that of the service sector.

Panel (b) compares the effect of the monetary policy at different stages of the reallocation shock. Consistent with our findings in the simple model (see Figure 6), the impact of the monetary policy shock differs dramatically depending on the timing of the shock. Focusing on the black dots, we see that a 25 basis point surprise in the interest rate leads to around a 0.08 percentage point reduction in aggregate inflation in the first period of the reallocation shock. However, the deflationary impact quickly enlarges to 0.115 percentage point as goods consumption reaches its peak level in the third period. The deflationary impact remains high and above the steady-state impact until goods employment reaches its peak level around *(a) Reallocation episode*



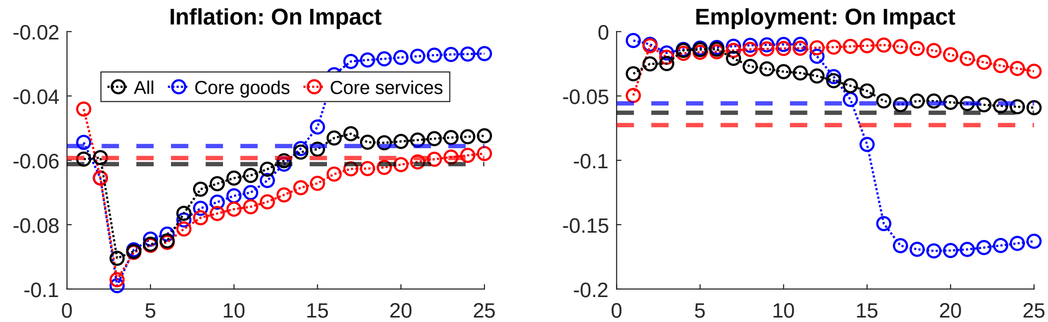
(b) Impact effect of the monetary policy surprise



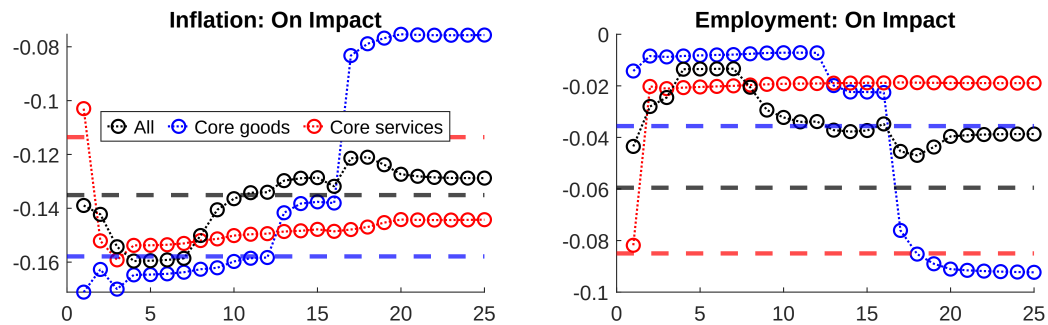
Note: the dashed lines in panel (b) show the responses to a monetary policy shock at the steady state.

Figure 8: Results from the quantitative model

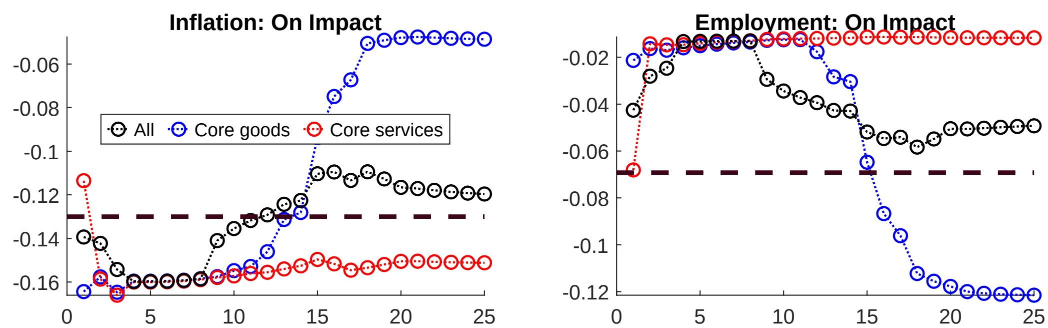
(a) With symmetric price adjustments and input-output linkages



(b) With asymmetric price adjustments and without input-output linkages



(c) With symmetric price adjustments and without input-output linkages



Note: the dashed lines show the responses to a monetary policy shock at the steady state.

Figure 9: Importance of asymmetric price adjustments and input-output linkages

quarter 12. A similar pattern is found in aggregate employment.

As for the sectoral dynamics, we observe that the monetary policy is more effective in curbing inflation in the expanding sector (the goods sector in the first 12 quarters) and the contracting sector (the service sector in the first quarter and the goods sector in later periods). Quantitatively, the deflationary impact of a positive monetary policy shock can be nearly twice as large in the expanding sector than in the contracting sector (e.g., -0.9/-0.5 = 1.8 for a monetary policy shock at period 1). The difference in its impact on employment is more pronounced; monetary policy has little impact on employment in the expanding sector but has a large impact on the contracting sector.

Figure 9 evaluates the importance of asymmetric price adjustments and input-output linkages in generating differential responses to monetary policy shocks at different stages of the reallocation process. Panel (a) shows the impact of the monetary policy shock when we set the price adjustment cost to be the same across all 17 industries in the model.[18] We can see that the difference in sectoral responses is much more muted relative to the baseline model in panel (b) of Figure 8, while the employment responses remain roughly similar. This suggests that asymmetric price adjustment costs across sectors are crucial to explain the differential effects of a monetary policy shock on sectoral inflation. In addition, from the dashed lines, we observe that there is much less difference in the sectoral responses, even if the monetary shock is given at the steady state of the economy.

Panel (b) considers an alternative case where we shut down the input-output linkages while keeping the asymmetric price adjustment costs across sectors. First, compared to panel (b) of Figure 8, we see that input-output linkages amplify the impact on inflation while attenuating the responses of employment. Intuitively, this is because in the baseline model with input-output linkages, nominal rigidity is compounded along the production network (as in Rubbo, 2023), which makes the monetary policy have less impact on final prices. After removing the input-output linkage, the overall nominal rigidity is lower, and the monetary policy has smaller impacts on real variables like employment and output but larger impacts on prices.

Finally, panel (c) shows the response from a model with symmetric price adjustments and no input-output linkages. We see that the responses in this model closely resemble the responses in our simple model discussed in section 3.2.3.

[18] Specifically, we take the value-added share-weighted average of the industry-level price adjustment costs and set it to be the same across all 17 industries.

5 Conclusion

In this paper, we analyze the transmission of monetary policy shocks amidst sectoral demand reallocation. Relying on a simple model with labor reallocation frictions, we show that the effect of monetary policy can have differential sectoral impacts, depending on (1) whether the sector is contracting or expanding and (2) whether the sector is expected to be contracting or expanding in the future. In an expanding (contracting) sector, monetary policy has a higher (lower) impact on prices but a lower (higher) impact on employment and outputs. The expected future status of the sector is helpful in explaining the difference in the magnitude of responses, while the current status remains the same.

Building on intuition from a simple model, we calibrate a quantitative model to assess the transmission of monetary policy shocks during the pandemic in the United States. Consistent with the insights from the simple model, we find significant differences in the effect of monetary policy at different stages of the reallocation process. Moreover, we find that allowing for input-output linkages diminishes the potency of monetary policy in tempering inflation. Conversely, accounting for asymmetries in price stickiness across different sectors markedly enhances the disparity in sectoral responses to monetary policy shocks.

References

Alpanda, Sami, Eleonora Granziera, and Sarah Zubairy. 2021. "State Dependence of Monetary Policy across Business, Credit and Interest Rate Cycles." *European Economic Review*, 140: 103936.

Ascari, Guido, and Timo Haber. 2021. "Non-Linearities, State-Dependent Prices and the Transmission Mechanism of Monetary Policy." *The Economic Journal*, 132(641): 37–57.

Boehm, Christoph E, and Nitya Pandalai-Nayar. 2022. "Convex Supply Curves." *American Economic Review*, 112(12): 3941–3969.

Comin, Diego A, Robert C Johnson, and Callum J Jones. 2023. "Supply chain constraints and inflation." National Bureau of Economic Research.

Eichenbaum, Martin, Sergio Rebelo, and Arlene Wong. 2022. "State-Dependent Effects of Monetary Policy: The Refinancing Channel." *American Economic Review*, 112(3): 721–61.

Ferrante, Francesco, Sebastian Graves, and Matteo Iacoviello. 2023. "The Inflationary Effects of Sectoral Reallocation." *Journal of Monetary Economics*, 140: S64–S81. Inflation: Drivers and Dynamics 2022.

Fornaro, Luca, and Federica Romei. 2022. "Monetary Policy in an Unbalanced Global Economy." Center for Economic Policy Research.

Guerrieri, Luca, and Matteo Iacoviello. 2015. "OccBin: A toolkit for solving dynamic models with occasionally binding constraints easily." *Journal of Monetary Economics*, 70: 22–38.

Guerrieri, Veronica, Guido Lorenzoni, Ludwig Straub, and Iván Werning. 2021. "Monetary Policy in Times of Structural Reallocation." Becker Friedman Institute for Economics Working Paper 2021-111.

Ilut, Cosmin, Matthias Kehrig, and Martin Schneider. 2018. "Slow to Hire, Quick to Fire: Employment Dynamics with Asymmetric Responses to News." *Journal of Political Economy*, 126(5): 2011–2071.

McKay, Alisdair, and Johannes F. Wieland. 2021. "Lumpy Durable Consumption Demand and the Limited Ammunition of Monetary Policy." *Econometrica*, 89(6): 2717–2749.

Rubbo, Elisa. 2023. "Networks, Phillips Curves, and Monetary Policy." *Econometrica*, 91(4): 1417–1455.

A Theoretical Appendix for the Simple Model

For ease of reference, we list here the equilibrium conditions of the simple model:

Sectoral NKPC $$0 = 1 - \epsilon + \epsilon \frac{P_t^{L,i}}{P_t^i} - \psi \left(\Pi_t^i - 1\right) \Pi_t^i + \psi E_t \left(\mathcal{M}_{t+1} \frac{\left(\Pi_{t+1}^i\right)^2}{\Pi_{t+1}} \left(\Pi_{t+1}^i - 1\right) \frac{Y_{t+1}^i}{Y_t^i} \right)$$

Price labor service $$P_t^{L,i} = W_t + W_t \mathbb{I}_t^i \left[\frac{c}{2} \left(\frac{L_t^i}{L_{t-1}^i} - 1 \right)^2 + c \left(\frac{L_t^i}{L_{t-1}^i} - 1 \right) \frac{L_t^i}{L_{t-1}^i} \right] - \mathbb{I}_{t+1}^i E_t \left[\mathcal{M}_{t+1} W_{t+1} c \left(\frac{L_{t+1}^i}{L_t^i} - 1 \right) \left(\frac{L_{t+1}^i}{L_t^i} \right)^2 \right]$$

Product market eqm. $$Y_t^i = C_t^i = L_t^i$$

Goods expenditure $$\omega_t = \frac{P_t^g C_t^g}{P_t C_t}$$

Services expenditure $$1 - \omega_t = \frac{P_t^s C_t^s}{P_t C_t}$$

Consumption $$C_t = \left(\frac{C_t^g}{\omega_t} \right)^{\omega_t} \left(\frac{C_t^s}{1 - \omega_t} \right)^{1 - \omega_t}$$

CPI $$P_t = \left(P_t^g\right)^{\omega_t} \left(P_t^s\right)^{1 - \omega_t}$$

Labor supply $$W_t = P_t C_t$$

Aggregate demand $$M_t = P_t C_t$$

Log-linearized version Denote $x_t \equiv log(X_t) - log(\overline{X})$ as the log deviation of a variable from its steady state and $\hat{\omega}_t \equiv \omega_t - \overline{\omega}$ as the level deviation of the goods consumption share from its steady state. The equilibrium conditions can be expressed as

Sectoral NKPC	$\pi_t^i = \frac{\epsilon - 1}{\psi}\left(p_t^{L,i} - p_t^i\right) + \beta E_t \pi_{t+1}^i \quad \forall i \in \{g, s\}$
Price labor service	$p_t^{L,i} = w_t + c\mathbb{I}_t^i\left(l_t^i - l_{t-1}^i\right) - \beta c \mathbb{I}_{t+1}^i E_t\left[l_{t+1}^i - l_t^i\right] \quad \forall i \in \{g, s\}$
Product market eqm.	$y_t^i = c_t^i = l_t^i \quad \forall i \in \{g, s\}$
Goods expenditure	$\overline{\omega}\left(p_t^g + c_t^g - p_t - c_t\right) = \hat{\omega}_t$
Services expenditure	$\left(1 - \overline{\omega}\right)\left(p_t^s + c_t^s - p_t - c_t\right) = -\hat{\omega}_t$
Consumption	$c_t = \overline{\omega} c_t^g + \left(1 - \overline{\omega}\right) c_t^s$
CPI	$p_t = \overline{\omega} p_t^g + \left(1 - \overline{\omega}\right) p_t^s$
Labor supply	$w_t = p_t + c_t$
Aggregate demand	$m_t = p_t + c_t$

A.1 Dynamics in response to a demand reallocation shock

We first investigate the solutions when the monetary stance is unchanged, i.e., $m_t = 0$. The sectoral New Keynesian Phillips Curves (NKPCs) can be derived from the log-linearized equilibrium conditions as

$$\pi_t^g = \kappa\left[y_t^g - \frac{1}{\overline{\omega}}\hat{\omega}_t + c\mathbb{I}_t^g\left(y_t^g - y_{t-1}^g\right) - \beta c E_t \mathbb{I}_{t+1}^g\left(y_{t+1}^g - y_t^g\right)\right] + \beta E_t \pi_{t+1}^g \tag{5}$$

$$\pi_t^s = \kappa\left[y_t^s + \frac{1}{1 - \overline{\omega}}\hat{\omega}_t + c\mathbb{I}_t^s\left(y_t^s - y_{t-1}^s\right) - \beta c E_t \mathbb{I}_{t+1}^s\left(y_{t+1}^s - y_t^s\right)\right] + \beta E_t \pi_{t+1}^s, \tag{6}$$

where $\kappa \equiv (\epsilon - 1)/\psi$ is the slope of the NKPC in the standard model without labor hiring frictions (see equation 13).

Using the expenditure share relationship, inflation in each sector can be written as

$$\pi_t^g = \Delta m_t + \frac{1}{\overline{\omega}}\Delta\hat{\omega}_t - \Delta y_t^g \tag{7}$$

$$\pi_t^s = \Delta m_t - \frac{1}{1 - \overline{\omega}}\Delta\hat{\omega}_t - \Delta y_t^s. \tag{8}$$

Substituting (7) and (8) into the sectoral NKPCs, we have a system of two second-order difference equations:

$$
\begin{aligned}
\frac{1}{\overline{\omega}}\Delta\hat{\omega}_t - y_t^g + y_{t-1}^g = \kappa &\left[y_t^g - \frac{1}{\overline{\omega}}\hat{\omega}_t + c\mathbb{I}_t^g\left(y_t^g - y_{t-1}^g\right) - \beta c E_t \mathbb{I}_{t+1}^g\left(y_{t+1}^g - y_t^g\right)\right] \\
&+ \beta E_t\left(\frac{1}{\overline{\omega}}\Delta\hat{\omega}_{t+1} - y_{t+1}^g + y_t^g\right) \qquad (9) \\
-\frac{1}{1-\overline{\omega}}\Delta\hat{\omega}_t - y_t^s + y_{t-1}^s = \kappa &\left[y_t^s + \frac{1}{1-\overline{\omega}}\hat{\omega}_t + c\mathbb{I}_t^s\left(y_t^s - y_{t-1}^s\right) - \beta c E_t \mathbb{I}_{t+1}^s\left(y_{t+1}^s - y_t^s\right)\right] \\
&+ \beta E_t\left(-\frac{1}{1-\overline{\omega}}\Delta\hat{\omega}_t - y_{t+1}^s + y_t^s\right). \qquad (10)
\end{aligned}
$$

The system is block recursive: for a given demand reallocation shock process $\{\hat{\omega}_t\}_{t=0}^{\infty}$, the dynamics of activity in the goods and service blocks can be solved independently from each other.

We now discuss two special cases and prove Lemma 1.

Special case 1: Flexible price equilibrium without labor adjustment costs When $\psi \to 0$ and $c = 0$, we have from (5) and (6) that

$$
y_t^g = \frac{1}{\overline{\omega}}\hat{\omega}_t \quad \text{and} \quad y_t^s = -\frac{1}{1-\overline{\omega}}\hat{\omega}_t.
$$

It is easy to verify that $y_t^g = l_t^g = c_t^g$, $y_t^s = l_t^s = c_t^s$, and $p_t^g = p_t^s = p_t^{L,s} = p_t^{L,g} = p_t = w_t = 0$ from the rest of the equilibrium conditions.

Special case 2: Sticky price equilibrium without labor adjustment costs When $\psi \neq 0$ and $c = 0$, we get back to the standard New Keynesian model, where the sectoral NKPCs are given by

$$
\pi_t^g = \kappa\left(y_t^g - \frac{1}{\overline{\omega}}\hat{\omega}_t\right) + \beta E_t \pi_{t+1}^g \qquad (11)
$$

$$
\pi_t^s = \kappa\left(y_t^s + \frac{1}{1-\overline{\omega}}\hat{\omega}_t\right) + \beta E_t \pi_{t+1}^s. \qquad (12)
$$

The total inflation is the consumption share weighted sectoral inflation:

$$
\pi_t = \overline{\omega}\pi_t^g + (1-\overline{\omega})\pi_t^s = \kappa y_t + \beta E_t \pi_{t+1}. \qquad (13)
$$

Similarly, (9) and (10) become

$$\frac{1}{\overline{\omega}}\Delta\hat{\omega}_t - y^g_t + y^g_{t-1} = \kappa\left(y^g_t - \frac{1}{\overline{\omega}}\hat{\omega}_t\right) + \beta E_t\left(\frac{1}{\overline{\omega}}\Delta\hat{\omega}_{t+1} - y^g_{t+1} + y^g_t\right)$$
$$-\frac{1}{1-\overline{\omega}}\Delta\hat{\omega}_t - y^s_t + y^s_{t-1} = \kappa\left(y^s_t + \frac{1}{1-\overline{\omega}}\hat{\omega}_t\right) + \beta E_t\left(-\frac{1}{1-\overline{\omega}}\Delta\hat{\omega}_t - y^s_{t+1} + y^s_t\right).$$

It is straightforward to verify that the solution of the problem is given by $y^g_t = \frac{1}{\overline{\omega}}\hat{\omega}_t$ and $y^s_t = -\frac{1}{1-\overline{\omega}}\hat{\omega}_t$ such that we have the same equilibrium as in the special case 1.

A.2 Effectiveness of monetary policy amid demand reallocations

We next consider the impact of a monetary policy shock and prove Proposition 1 and Corollaries 1 and 2. Denote $\widetilde{x}_t \equiv x_t^{\text{with MP shock}} - x_t^{\text{without MP shock}}$. Assuming MP shocks are sufficiently small so that they do not change the direction of the labor hiring decisions (i.e. $\mathbb{I}_t^{i\text{ with MP shock}} = \mathbb{I}_t^{i\text{ without MP shock}}$), we have

$$\Delta\widetilde{m}_t - \widetilde{y}^i_t + \widetilde{y}^i_{t-1} = \kappa\left[\widetilde{y}^i_t + c\mathbb{I}^i_t\left(\widetilde{y}^i_t - \widetilde{y}^i_{t-1}\right) - \beta c E_t\mathbb{I}^i_{t+1}\left(\widetilde{y}^i_{t+1} - \widetilde{y}^i_t\right)\right] + \beta E_t\left(\Delta\widetilde{m}_{t+1} - \widetilde{y}^i_{t+1} + \widetilde{y}^i_t\right).$$

Rearrange and get

$$(1+\kappa c\mathbb{I}^i_t)\widetilde{y}^i_{t-1} - (1+\beta+\kappa+\kappa c\mathbb{I}^i_t + \kappa c\beta\mathbb{I}^i_{t+1})\widetilde{y}^i_t + \beta(1+\kappa c\mathbb{I}^i_{t+1})\widetilde{y}^i_{t+1} = \beta\Delta\widetilde{m}_{t+1} - \Delta\widetilde{m}_t.$$

Rewrite the dynamics as

$$z_t\widetilde{y}^i_{t-1} - (\kappa + z_t + \beta z_{t+1})\widetilde{y}^i_t + \beta z_{t+1}\widetilde{y}^i_{t+1} = b_t,$$

where $z^i_{t+\tau} \equiv 1 + \kappa c\mathbb{I}^i_{t+\tau}\ \forall\tau \geq 0$ and $b_t \equiv \beta\Delta\widetilde{m}_{t+1} - \Delta\widetilde{m}_t$.

In matrix form, the output dynamics can be written as

$$A\begin{bmatrix}\widetilde{y}^i_t \\ \widetilde{y}^i_{t+1} \\ \widetilde{y}^i_{t+2} \\ \vdots \\ \widetilde{y}^i_{t+T-1}\end{bmatrix} = \begin{bmatrix}b_t \\ b_{t+1} \\ b_{t+2} \\ \vdots \\ b_{t+T-1}\end{bmatrix},$$

where

$$A \equiv \begin{bmatrix} -(\kappa + z_t + \beta z_{t+1}) & \beta z_{t+1} & 0 & \cdots & 0 \\ z_t & -(\kappa + z_{t+1} + \beta z_{t+2}) & \beta z_{t+2} & \cdots & 0 \\ 0 & z_{t+1} & -(\kappa + z_{t+2} + \beta z_{t+3}) & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & -(\kappa + z_{t+T-1} + \beta z_{t+T}(1-\lambda_T)) \end{bmatrix}$$

and T is the breakpoint where after $t+T$, $\mathbb{I}^i_{t+\tau} = \mathbb{I}^i_{t+T}$ $\tau \geq T$; λ_T is the non-explosive root for the dynamics from T onward.

We can solve the system backward:

$$\lambda_{\tau-1} = \frac{z_{t+\tau-2}}{\kappa + z_{t+\tau-1} + \beta z_{t+\tau}(1-\lambda_\tau)} \qquad \forall\, 2 \leq \tau \leq T$$

and

$$\widetilde{y}^i_{t+\tau} = \widetilde{y}^i_{t+1} \Pi^\tau_{\iota=2} \lambda_\iota \qquad \forall\, 2 \leq \tau \leq T.$$

The system can be solved numerically for any arbitrary path of $\mathbb{I}^i_{t+\tau}$ $\forall \tau > 0$.

Full closed-form solution for a one-time monetary shock when $\mathbb{I}^i_{t+\tau} = \mathbb{I}^i_{t+2}$ $\forall \tau > 2$. Consider a one time shock at t (as in our simulations): $\widetilde{m}_t = 1$ and $\widetilde{m}_{t+\tau} = 0$ if $\tau \neq 0$.

Period t:

$$1 - \widetilde{y}^i_t + \widetilde{y}^i_{t-1} = \kappa \left[\widetilde{y}^i_t + c\mathbb{I}^i_t \left(\widetilde{y}^i_t - \widetilde{y}^i_{t-1}\right) - \beta c E_t \mathbb{I}^i_{t+1} \left(\widetilde{y}^i_{t+1} - \widetilde{y}^i_t\right)\right] + \beta E_t \left(-1 - \widetilde{y}^i_{t+1} + \widetilde{y}^i_t\right)$$

Period $t+1$:

$$-1 - \widetilde{y}^i_{t+1} + \widetilde{y}^i_t = \kappa \left[\widetilde{y}^i_{t+1} + c\mathbb{I}^i_{t+1} \left(\widetilde{y}^i_{t+1} - \widetilde{y}^i_t\right) - \beta c E_t \mathbb{I}^i_{t+2} \left(\widetilde{y}^i_{t+2} - \widetilde{y}^i_{t+1}\right)\right] + \beta E_t \left(-\widetilde{y}^i_{t+2} + \widetilde{y}^i_{t+1}\right)$$

Period $t+2$:

$$-\widetilde{y}^i_{t+2} + \widetilde{y}^i_{t+1} = \kappa \left[\widetilde{y}^i_{t+2} + c\mathbb{I}^i_{t+2} \left(\widetilde{y}^i_{t+2} - \widetilde{y}^i_{t+1}\right) - \beta c E_t \mathbb{I}^i_{t+3} \left(\widetilde{y}^i_{t+3} - \widetilde{y}^i_{t+2}\right)\right] + \beta E_t \left(-\widetilde{y}^i_{t+3} + \widetilde{y}^i_{t+2}\right).$$

Note that $\widetilde{y}^i_{t-1} = 0$ is given; from the dynamics of $t+2$ onward, we can solve $\widetilde{y}^i_{t+2}$ as a function of $\widetilde{y}^i_{t+1}$. Thus, equations in periods t and $t+1$ give a system of 2 equations with 2 unknowns, from which $\widetilde{y}^i_t$ and $\widetilde{y}^i_{t+1}$ can be solved. We can see clearly that the impact of the MP on the sectoral output depends on the full path of the labor decisions $\mathbb{I}^i_{t+\tau}$ $\forall \tau \geq 0$.

The output change for the periods $t+2$ onward can be solved as

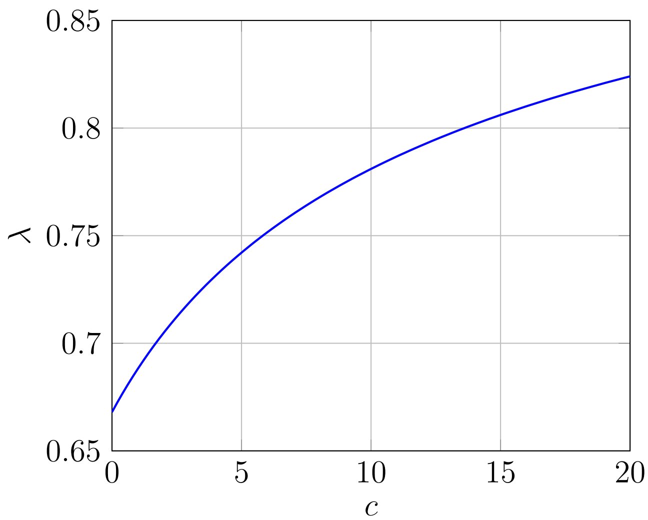
$$\widetilde{y}^i_{t+\tau} = \widetilde{y}^i_{t+1}\lambda^{\tau-1} \quad \forall \tau \geq 2, \tag{14}$$

with the non-explosive root for the dynamics of $t+2$ onward given by

$$\lambda \equiv \frac{\kappa + (1+\beta)z^i_{t+2} - \sqrt{[\kappa + z^i_{t+2}(1+\beta)]^2 - 4\beta(z^i_{t+2})^2}}{2\beta z^i_{t+2}}. \tag{15}$$

Figure (10) illustrates how λ varies with c when $\mathbb{I}^i_{t+2} = 1$ and thus $z^i_{t+2} = 1 + \kappa c$ with $\kappa = 1/6$ and $\beta = 0.995$.

Figure 10: λ as a function of c, when $\mathbb{I}^i_{t+2} = 1$



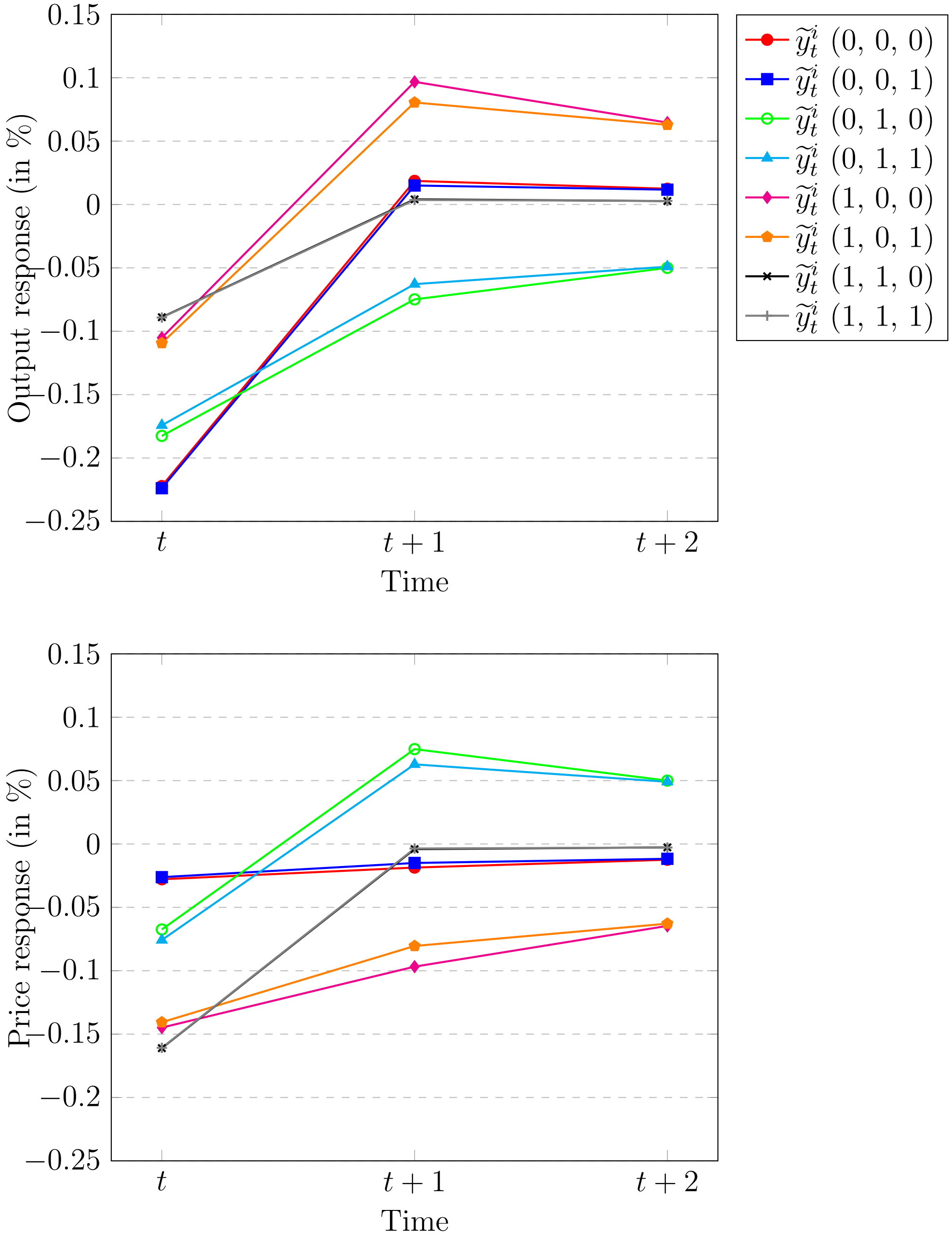
Substituting $\widetilde{y}^i_{t+2}$ in (14) into period t and $t+1$ equations, we can solve the system of equations as

$$\widetilde{y}^i_t = -\frac{\kappa + z^i_{t+1} + \beta\left[\kappa + (1+\beta)(1-\lambda)z^i_{t+2}\right]}{\beta(z^i_{t+1})^2 - \left(\kappa + z^i_t + \beta z^i_{t+1}\right)\left[\kappa + z^i_{t+1} + \beta(1-\lambda)z^i_{t+2}\right]}, \tag{16}$$

$$\widetilde{y}^i_{t+1} = \frac{\kappa + z^i_t + \beta z^i_{t+1}}{\beta z^i_{t+1}}\widetilde{y}^i_t - \frac{1+\beta}{\beta z^i_{t+1}}. \tag{17}$$

Output maps one-to-one to prices. The inflation dynamics can be easily derived according to (7) and (8). The aggregate output and inflation dynamics are the expenditure share weighted sectoral output and inflation dynamics derived here.

Figure 11: Responses to a one-time 0.25% contractionary monetary policy shock at t
($c = 10, \kappa = 1/6$)

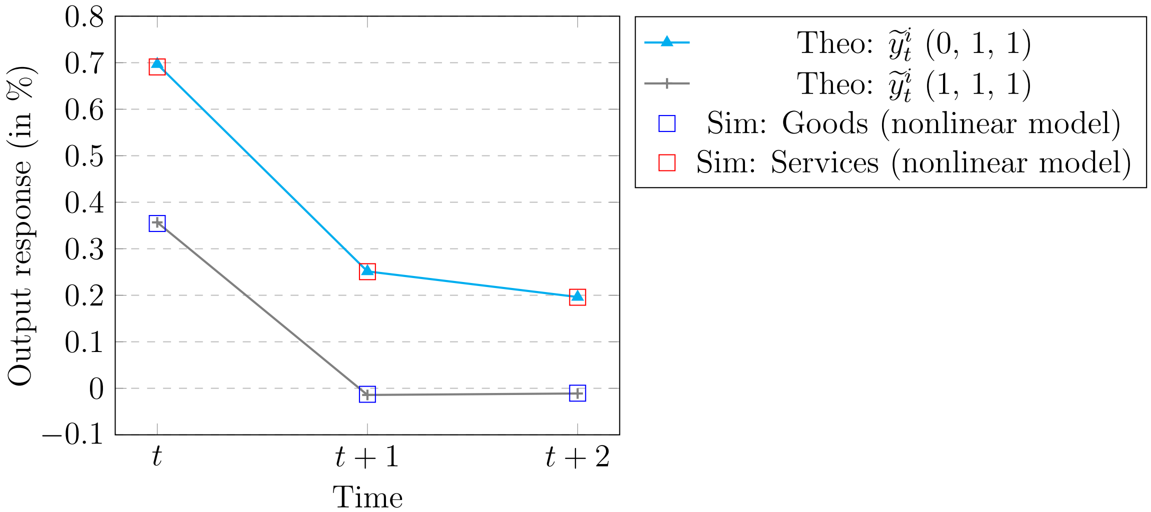


A.3 Verification of theoretical solutions

In this appendix, we compare our theoretical solutions to the simulated responses by numerically solving the fully nonlinear model. Figure 12 compares the theoretical vs. simulated output responses under the demand reallocation process discussed in section 3.1, where $c = 10$, $\kappa = 1/6$, and the persistence of the demand reallocation shock is set to $\rho = 0.9$. On top of the demand reallocation shock, we give an additional one-time 1% expansionary monetary policy shock at period 1. The triangle and plus points give the theoretical predictions from Corollary 2, whereas the empty squares show the simulated responses. The first two rows of the legend indicate the identified reallocation states of the sector. We can see that our theoretical predictions perform really well in capturing the true model responses.

Subsection A.3.1 conducts robustness checks for different types of demand reallocation shocks and different sizes of the labor adjustment costs.

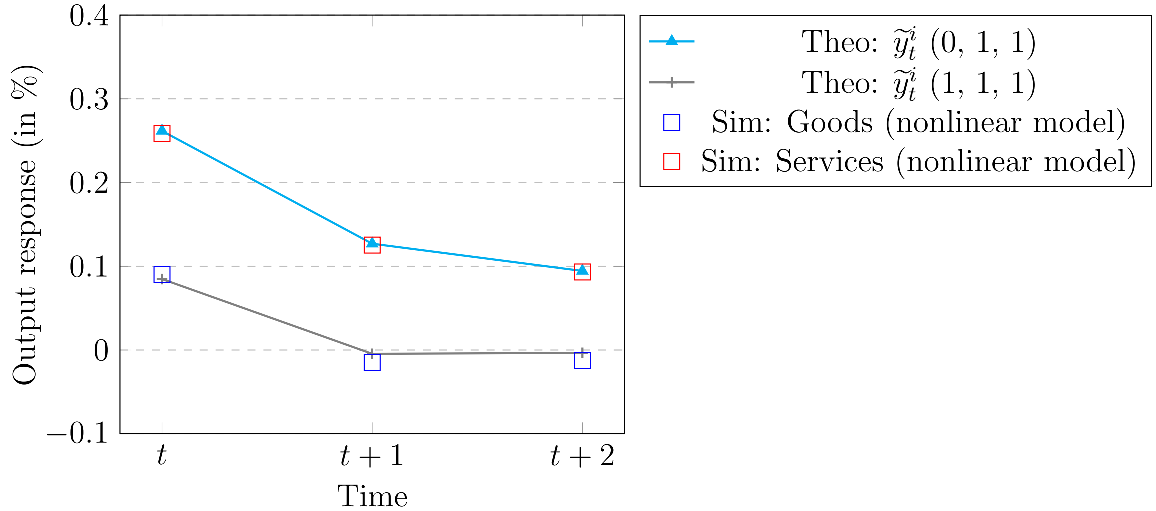
Figure 12: Comparing theoretical vs simulated output responses to a 1% one-time expansionary monetary policy shock at $t = 1$
($c = 10$, AR1 reallocation shock $\rho = 0.9$)



A.3.1 Alternative shock and cost settings

Figure 13: Comparing theoretical vs simulated responses
($c = 10$, AR1 reallocation shock $\rho = 0.7$)

(a) Output responses to a one-time 1% monetary policy shock at $t = 1$



(b) Baseline employment and inflation dynamics without the monetary policy shock

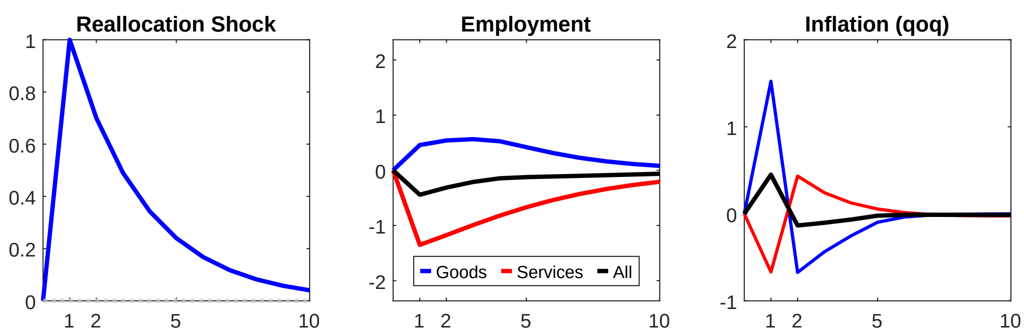
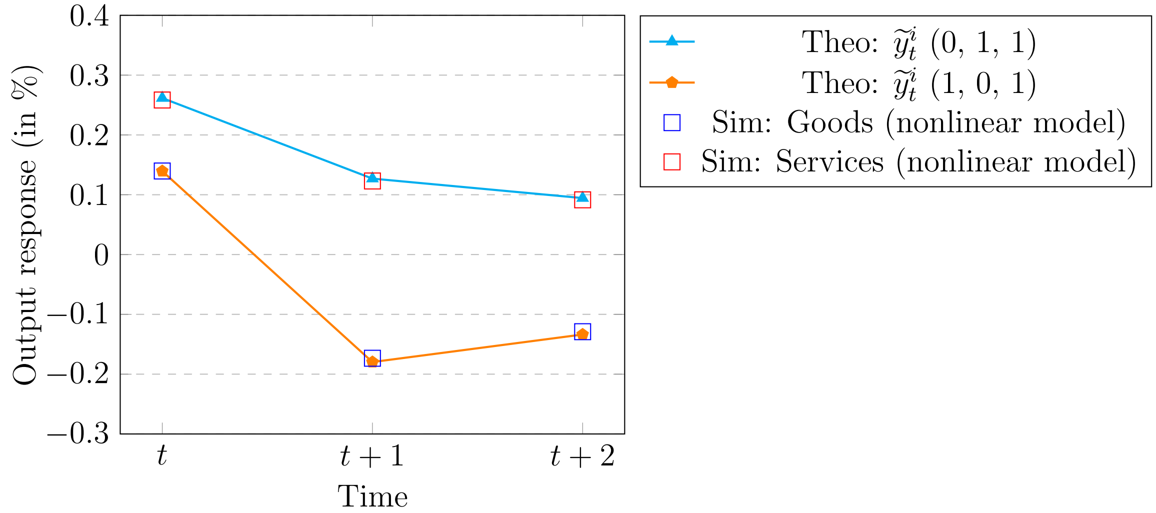


Figure 14: Comparing theoretical vs simulated responses
($c = 10$, one-time reallocation shock)

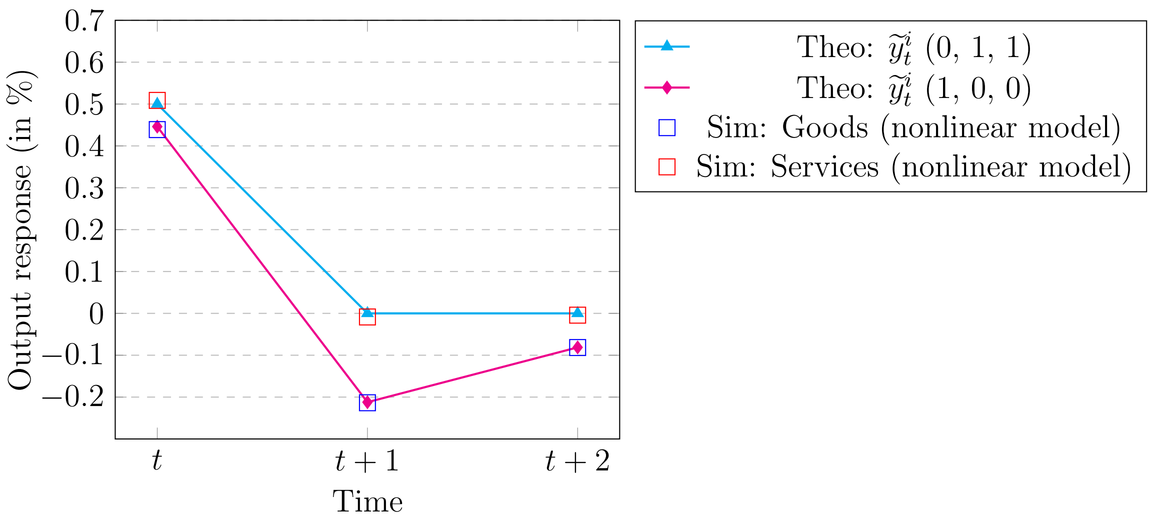
(a) Output responses to a one-time 1% monetary policy shock at $t = 1$



(b) Baseline employment and inflation dynamics without the monetary policy shock

Figure 15: Comparing theoretical vs simulated responses
($c = 1$, AR1 reallocation shock $\rho = 0.7$)

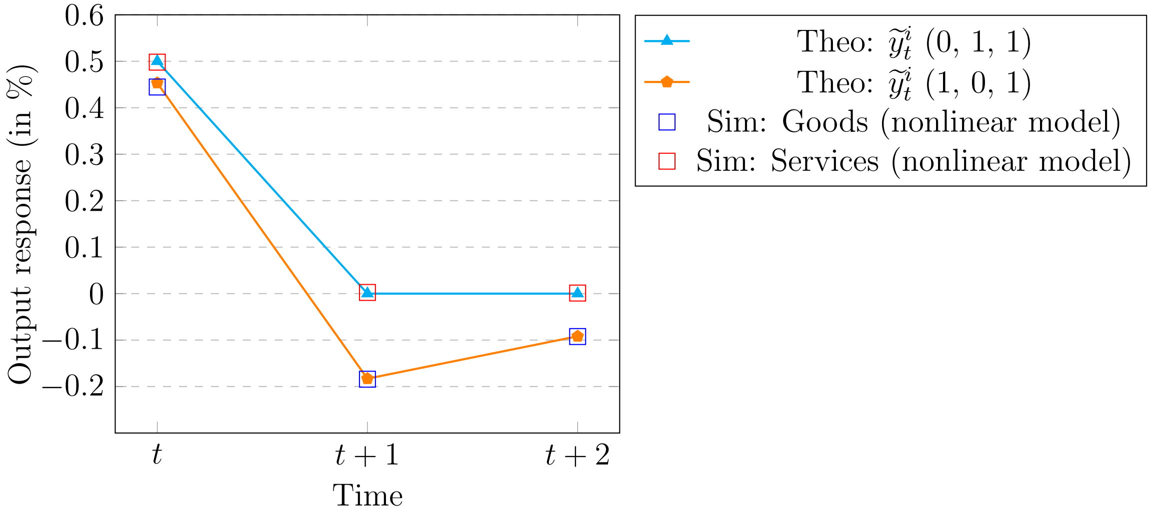
(a) Output responses to a one-time 1% monetary policy shock at $t = 1$



(b) Baseline employment and inflation dynamics without the monetary policy shock

Figure 16: Comparing theoretical vs simulated responses
($c = 1$, one-time reallocation shock)

(a) Output responses to a one-time 1% monetary policy shock at $t = 1$



(b) Baseline employment and inflation dynamics without the monetary policy shock

B Supplementary materials of the full model

B.1 Full model with input-output linkages

To examine the quantitative implications of monetary policy transmission during a demand reallocation, we enrich the simple model developed in Section 2 along multiple dimensions.

The first augmentation is to decompose final demand into consumption categories that reflect key differences in the dynamics of inflation and output in different sectors during the pandemic and allow for a realistic fit of the model's demand reallocation shock to these dynamics. In particular, total consumption comprises bundles of products from five categories—durable goods (d), core non-durable goods (n), core services excluding housing (s), housing (h), and food and energy (f)—that are aggregated according to

$$C_t = \left(\frac{C_t^d}{\omega_t^d}\right)^{\omega_t^d} \left(\frac{C_t^n}{\omega_t^n}\right)^{\omega_t^n} \left(\frac{C_t^s}{\omega_t^s}\right)^{\omega_t^s} \left(\frac{C_t^h}{\omega_t^h}\right)^{\omega_t^h} \left(\frac{C_t^f}{\omega_t^f}\right)^{\omega_t^f},$$

where $\omega_t^d + \omega_t^n + \omega_t^s + \omega_t^h + \omega_t^f = 1$.

Second, we separate the consumption and production sides of the model by introducing a distinction between consumption categories and production industries. Let K^C and K^P be the set of consumption categories and production industries, respectively. For each consumption category $a \in K^C$, the consumption bundle C_t^a is a Cobb-Douglas combination of output produced by different production industries:

$$C_t^a = \prod_{i \in K^P} \left(\frac{C_t^i}{\gamma^{i,a}}\right)^{\gamma^{i,a}},$$

where $\sum_{i \in K^P} \gamma^{i,a} = 1$. In each production industry $i \in K^P$, there is a representative competitive producer that bundles intermediate inputs using the production technology in Equation 1.

To allow demand reallocation shocks to propagate across consumption categories and production industries, we incorporate production input-output linkages across industries. Input suppliers in industry i combine labor and intermediate inputs to produce differentiated output according to the following production function:

$$Y_t^i(z) = A_t^i \left(\alpha_i^{\frac{1}{\epsilon_Y}} \left(M_t^i(z)\right)^{\frac{\epsilon_Y - 1}{\epsilon_Y}} + (1-\alpha_i)^{\frac{1}{\epsilon_Y}} \left(L_t^i(z)\right)^{\frac{\epsilon_Y - 1}{\epsilon_Y}}\right)^{\frac{\epsilon_Y}{\epsilon_Y - 1}},$$

where ϵ_Y is the elasticity of substitution across labor and a bundle of intermediate inputs,

$M_t^i(z)$, and α_i is the sector-specific weight of intermediate inputs in production. The intermediate input bundle is itself a constant elasticity of substitution combination of inputs purchased from other sectors $j \in K^P$:

$$M_t^i(z) = \left(\sum_{j \in K^P} \Gamma_{i,j}^{\frac{1}{\epsilon_M}} \left(M_t^{i,j}(z) \right)^{\frac{\epsilon_M - 1}{\epsilon_M}} \right)^{\frac{\epsilon_M}{\epsilon_M - 1}},$$

where ϵ_M is the elasticity of substitution across different inputs, $\Gamma_{i,j}$ reflects the importance of the output of sector j as an input of production for intermediate firms in sector i, and $\sum_{j \in K^P} \Gamma_{i,j} = 1$. The parameters $\Gamma_{i,j}$ encode the economy's input-output matrix.

This third addition to the model alters the marginal costs of intermediate input producers. Since all such producers within an industry are identical, the cost minimization problem implies that marginal costs for each firm in industry i are

$$MC_t^i = \frac{1}{A_t^i} \left(\alpha_i \left(P_t^{M,i} \right)^{1-\epsilon_Y} + (1 - \alpha_i) \left(P_t^{L,i} \right)^{1-\epsilon_Y} \right)^{\frac{1}{1-\epsilon_Y}},$$

where the sector i price index for intermediate inputs is $P_t^{M,i} = \left[\sum_{j \in K^P} \Gamma_{i,j} \left(P_t^j \right)^{1-\epsilon_M} \right]^{1/(1-\epsilon_M)}$.

Incorporating input-output linkages changes the market clearing conditions for the representative competitive producers in each industry. Now, these conditions are

$$Y_t^i = C_t^i + \sum_{j \in K^P} M_t^{j,i} \quad \forall i \in K^P,$$

where $M_t^{j,i} = \int_0^1 M_t^{j,i}(z) dz$.

The fourth modification to the simple model is to introduce heterogeneity in price stickiness across production industries. To do so, we assume that the price adjustment cost parameter in the intermediate input producers' dynamic problem in Equation 2 is specific to each sector, leading to the following Phillips curve in industry i:

$$1 - \epsilon + \epsilon \frac{MC_t^i}{P_t^i} - \psi_i \left(\Pi_t^i - 1 \right) \Pi_t^i + \psi_i E_t \left(\mathcal{M}_{t+1} \frac{\left(\Pi_{t+1}^i \right)^2}{\Pi_{t+1}} \left(\Pi_{t+1}^i - 1 \right) \frac{Y_{t+1}^i}{Y_t^i} \right) = 0.$$

The fifth generalization is to allow for a more general utility function, where the household's preference is specified as

$$U_t = \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\gamma}}{1-\gamma} - \frac{N_t^{1+\eta}}{1+\eta} \right).$$

The household maximizes utility subject to the following nominal inter-temporal budget constraint:

$$P_t C_t + B_{t+1} = W_t N_t + (1 + i_{t-1}) B_t + D_t. \tag{18}$$

The solution to the household's inter-temporal maximization problem implies

$$C_t^{-\gamma} = \beta \mathbb{E}_t \left(C_{t+1}^{-\gamma} \frac{1 + i_t}{\Pi_{t+1}} \right),$$
$$N_t^{\eta} = C_t^{-\gamma} \frac{W_t}{P_t},$$

where $\Pi_t = \frac{P_t}{P_{t-1}}$ is the aggregate inflation rate.

Unlike in the simple model of Section 2, the budget constraint in Equation 18 does not include cash holdings M_t. Instead, in the quantitative model we introduce an active role for monetary policy by removing the cash-in-advance constraint facing the representative household and assuming that the monetary authority sets interest rates according to a Taylor rule that is subject to shocks:

$$i_t = \overline{r} + \phi \pi_t + \nu_t,$$

where $\overline{r}$ is the natural rate of interest and ν are monetary policy shocks.

B.2 Calibration

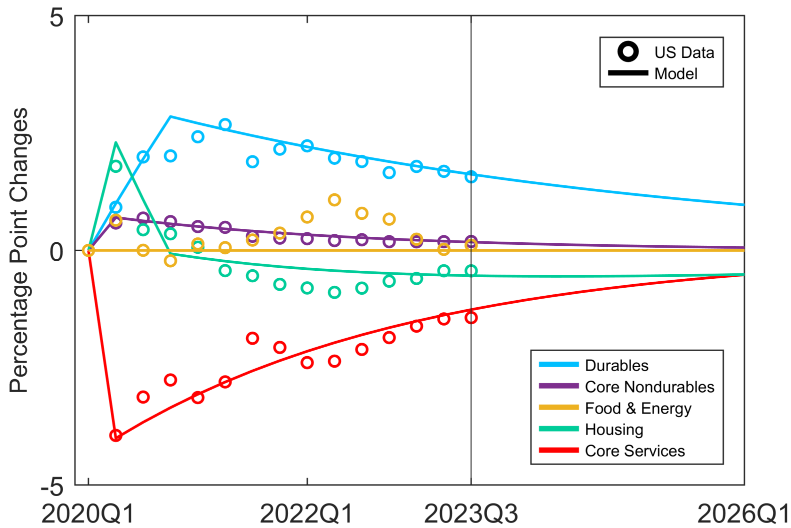


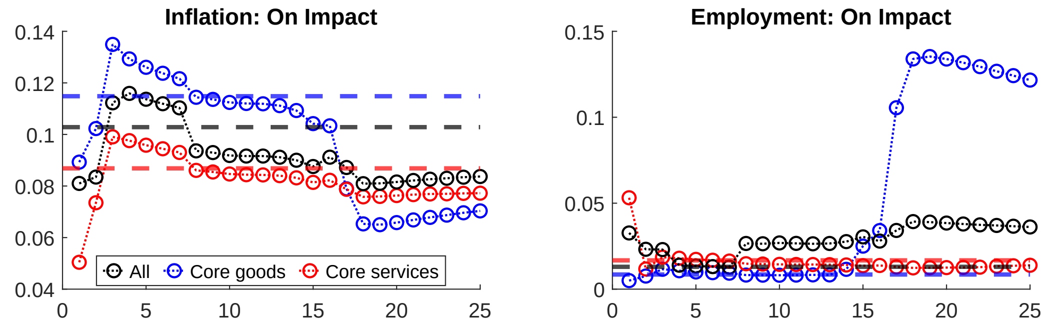
Figure 17: Calibrated demand reallocation shocks for all 5 PCE categories

Table 2: Calibration for Model Parameters

Calibrated Parameters	Symbol	Value/Range	Target/Source
Inverse Elasticity of Substitution	γ	2	Standard
Labor Supply Disutility	$\bar{\chi}$	1	Normalization
Inverse Labor Supply Elasticity	η	1	Standard
Taylor Rule Coefficient on Inflation	ϕ	1.5	Standard
Discount Factor	β	0.995	Standard
Elasticity Across Varieties	ϵ	10	Standard
Intermediate Input Share (Range)	α_i	0.11 to 0.83	BEA
Price Adjustment Cost (Range)	ψ_i	0.05 to 99.9	Pasten et al. (2020)
Hiring Cost	c	18.8 (12.4)	FGI (2023)
Elasticity Across Intermediates	ϵ_M	0.13 (0.24)	FGI (2023)
Elasticity Between Intermediates & Labor	ϵ_Y	0.82 (0.08)	FGI (2023)

B.3 Response to negative MP shocks

withIO + calibrated shock + asym price stickiness + taylor + neg shock (diff)



withIO + calibrated shock + sym price stickiness + taylor + neg shock (diff)