Shocks, Frictions, and Policy Regimes: Understanding Inflation after the COVID-19 Pandemic*

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Abstract

We set-up a two-sector New Keynesian model with input-output linkages and monetary-fiscal policy interactions to study the post-COVID-19 inflation. We test alternative calibrations of the model based on the fit of aggregate inflation, using shock estimates obtained by fitting goods inflation. Our preferred model suggests that fiscal shocks not offset by monetary policy account for the initial inflation surge in the first half of 2021 while supply-side shocks have emerged as main drivers of inflation since then. Multiple factors ("supply-side disruption", "expansionary policy", and "sectoral reallocation shock") played an important role at different phases of the recent inflationary episode.

JEL classification: E53; E62; E63

Keywords: Inflation persistence, COVID-19, Sectoral reallocation, Inflation feedback, Production friction.

*We thank seminar participants at the Federal Reserve Bank of Kansas City and the Federal Reserve Board for helpful comments. All the remaining errors are ours. Taeyoung Doh thanks the Center for Advancement of Data and Research in Economics (CADRE) at the Federal Reserve Bank of Kansas City (FRB-KC) for providing essential "computational/data" resources that contributed to the results reported in this paper. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors and the Federal Reserve Bank of Kansas City of the Federal Reserve System or of anyone else associated with the Federal Reserve System. This version: September 2024

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1 Introduction

As the U.S. economy emerged from the pandemic-driven restrictions on economic activities in early 2021, inflation started to rise. Figure 1 illustrates the historical behavior of inflation at both the disaggregated level (goods sector and services sector) and the aggregated level. After a period of low inflation prior to the pandemic shock in 2020, U.S. inflation, as measured by the twelve-month change in the personal consumption expenditures (PCE) price index, exceeded 3 percent in early 2021 and peaked near 7 percent in the summer of 2022. Initially, policymakers considered the rise in inflation in 2021 to be "transitory," attributing it to temporary supply-side pressures as the economy reopened, while inflation expectations remained stable (FOMC, 2021). However, as inflation remained persistently high, policymakers shifted their view and began signaling future policy tightening in 2021. Despite significant monetary policy tightening in 2022, inflation remained well above 4 percent as of December 2022, significantly surpassing the Federal Reserve's 2 percent inflation target. As consumption shifted towards services, which were suppressed during the pandemic, goods inflation began to decline. This decline is also evident in the core goods component shown in the right panel of Figure 1, which excludes volatile food and oil components. However, the decline in goods inflation was largely offset by the persistent elevation in services inflation, both in core and non-core measures.

There are several factors contributing to the persistent rise in inflation. The COVID-19 pandemic disrupted both the demand side (*e.g.*, a significant shift in consumption from services to goods) and the supply side (*e.g.*, supply chain disruptions), while also triggering extraordinary policy responses

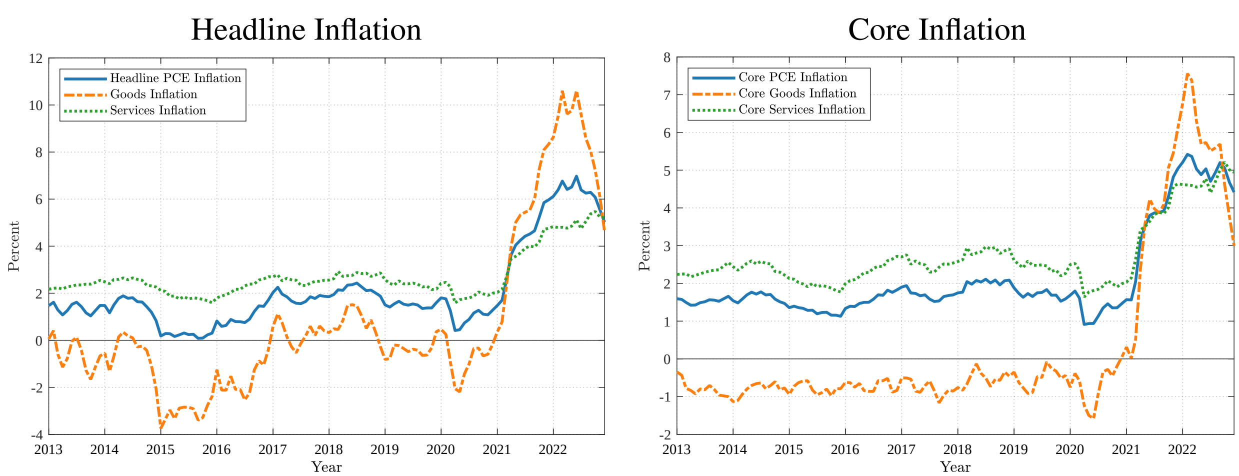

Figure 1: AGGREGATED AND SECTORAL INFLATION: 2013-2022

Notes: This figure shows the 12-month changes in headline (left panel) and core (right panel) PCE prices (blue solid line), in goods prices (orange dahsed line), and in services prices (green dotted line).The vintage of the data is as of the March of 2023.

Source: Bureau of Economic Analysis

(*e.g.*, fiscal support packages and the Federal Reserve's low interest rate policy and asset purchases). Additionally, the Federal Reserve introduced a new framework during the pandemic (August 27, 2020) that targets an average inflation rate of 2 percent over time, which has been subject to criticism for potentially abandoning pre-emptive policy tightening against inflation (Sargent and Silber, 2022). At the same time, the size of fiscal support packages was unprecedented during peacetime and led to the highest deficit-to-GDP ratio since World War II in 2021 (CBO, 2022). With multiple factors at play, it is challenging to quantify the relative importance of each factor.

This paper addresses the challenge by calibrating a two-sector New Keynesian model with input-output linkages that incorporates multiple aggregate and sectoral shocks. The model includes a friction on the production side of the economy, capturing the imperfect substitution among production factors across sectors. It also incorporates the Federal Reserve's new framework of average inflation targeting and the fiscal regime, where the monetary policy authority accommodates potentially inflationary fiscal actions. The new framework for monetary policy reinterprets the maximum employment mandate as responding to "shortfalls in employment" rather than "deviations" from the maximum employment level, which can be partially captured as a lower feedback for inflation when the policy rule is supposed to respond to only inflation as in our specification.[1] Such a lower inflation feedback is shown to raise inflation persistence in Davig and Doh (2014). In addition, motivated by Bianchi, Faccini and Melosi (2023), we consider a temporary shift to the fiscal regime by distinguishing between transfer shocks funded by future primary surpluses and those that are unfunded. Finally, the model accounts for the increased volatility of a sectoral demand shift shock, capturing the pandemic-driven shift from services consumption to goods consumption, which has been identified as an important factor for the persistently high inflation during the post-pandemic period (*e.g.,* Ferrante, Graves and Iacoviello, 2023).

We estimate the model parameters to match the model-implied impulse responses of inflation, consumption, and the monetary policy stance measure to a sectoral demand shift shock with those from a structural vector autoregression (SVAR) model using pre-pandemic data. Our method of impulse-response matching is similar to what Christiano, Eichenbaum and Evans (2005) do for a monetary policy shock. We deliberately use only the pre-pandemic period data in calibrating model parameters to avoid the possibility that the pandemic shock affects parameters governing the pre-pandemic dynamics, as Gagliardone and Gertler (2023) do.

We focus on identifying the determinants of the level and persistence of inflation during the post-pandemic period. To do this, we re-calibrate the model using post-pandemic data to incorporate the relevant channels (shocks, frictions, and policy regimes) that can explain the post-pandemic

[1] Bundick and Petrosky-Nadeau (2021) examine the implications of this change in the context of the zero lower bound. Since firms would expect higher prices on average under the shortfall rule instead of the deviation rule, they show that the average interest rate would be also higher, giving a more policy space to address the zero lower bound constraint. But their paper does not quantitatively analyze the role of the shortfall rule in the post-pandemic inflation.

inflation. With the re-calibrated parameters, we obtain the shocks estimates by conducting a historical decomposition of goods inflation and other non-inflation variables during the post-pandemic period (March 2020–December 2022). We then evaluate different specifications of the baseline model based on how well they fit the level and persistence of aggregate inflation, which was not directly used in the re-calibration process.

We draw several conclusions from our quantitative analysis. First, incorporating a temporary shift to the fiscal regime by introducing unfunded transfer shocks fits the level and persistence of inflation better than other specifications. Allowing changes in parameters governing the monetary policy rule by lengthening the targeting horizon for inflation and lowering the inflation feedback parameter is the closest next option since it matches the volatility of inflation better than all the other specifications. However, allowing only shifts in monetary policy without a shift to the fiscal regime implies a negative output effect of transfer shocks because people reduce labor supply in response to labor income tax increases to finance transfers. The fiscal regime in which taxes do not respond to transfer shocks mutes this channel and highlights a more plausible demand-side nature of transfer shocks.[2] Hence, incorporating changes in both fiscal and monetary policy parameters is our preferred version. For other specifications (a higher volatility for a sectoral demand shift shock or increasing the friction on the production side through a lower elasticity of substitution among the intermediary inputs), the model fit is not much different from the baseline calibration. Our findings illustrate the crucial role of policy regime shifts in explaining the persistently high inflation during the post-pandemic period.

Second, the historical shock decomposition of aggregate inflation under our favored calibration reveals that fiscal support packages implemented during 2020-2021 played a significant role in the initial inflation surge in 2021. However, a negative goods-sector technology shock increasingly explains the bulk of the persistent rise in inflation in 2022. Although our model does not directly incorporate a role for commodity inputs, the rise in oil prices due to the war in Ukraine can be proxied as a goods sector technology shock in the model.

The final point is that the COVID-19 pandemic did not necessarily increase the level of friction on the production side, but it did amplify the impact of existing frictions by creating a significant imbalance between demand and supply. As the economy adjusts and the effects of the large shocks dissipate, it is expected that inflation will gradually return to pre-pandemic levels. Our analysis suggests that the magnitude of demand and supply imbalances would have been smaller if there were no shifts in fiscal and monetary policies.

Related Literature: Our paper is closely related to the literature that uses dynamic macro models

[2]Using high-frequency credit and debit card spending data, Chetty, Friedman and Stepner (2024) show that the government cash transfer to households during the pandemic period had an immediate effect on consumer spending, consistent with the demand-side effect from fiscal actions.

to understand the post-COVID-19 inflation (*e.g.*, Afrouzi, Bhattarai and Wu 2024; Amiti, Heise, Karahan and Şahin 2023; Bhattarai, Lee and Yang 2023; Benigno and Eggertsson 2023; Bianchi et al. 2023; Comin, Johnson and Jones 2023; Ferrante et al. 2023; Gagliardone and Gertler 2023; Harding, Lindé and Trabandt 2023; Montag and Villar 2023; Smets and Wouters 2024). Each of these papers emphasizes either policy-driven factors or real and nominal frictions in the economy but rarely consider all the features at the same time. Our paper includes both policy-driven factors and production-side frictions as potentially competing amplification channels to explain the post-COVID-19 inflation.

One prominent factor highlighted in the literature to explain the post-COVID-19 inflation is the role of extraordinary policy responses to the COVID-19 recession. For example, Bianchi et al. (2023) show that a fiscal stimulus financed by debt which is not funded by future tax increases creates fiscal inflation because the real value of the nominal government debt must decline through inflation in equilibrium. In addition, if the monetary authority decides not to respond to this increase in fiscal inflation, it can generate persistent inflation because the lower real interest rate stimulates borrowing and household spending further. Bianchi et al. (2023) argue that the persistent rise in inflation during the post-COVID-19 period can be explained by the passage of the American Rescue Plan Act (ARPA) in 2021 and the Federal Reserve's adoption of the new policy framework which allowed inflation to overshoot the 2% target after the COVID-19 recession. Using a two-agent New Keynesian model, Bhattarai et al. (2023) similarly show that a large fiscal transfer not financed by future tax increases and accommodated by the non-response of the monetary policy to inflation can explain the persistent rise in inflation.[3] Regarding monetary policy, Bocola, Dovis and Kirpalani (2024) provide empirical evidence that the bond market view of the Federal Reserve's reaction function significantly changed after the announcement of the new framework. They found that the revisions in the expected nominal interest rate responded less sensitively to the revisions in the expected inflation compared to the pre-COVID-19 period. According to their analysis, about half of the increase in inflation during the post-pandemic period (2020-2022) can be attributed to the changed perception of the Federal Reserve's reaction function. While they did not specifically discuss a shift in the fiscal side, their emphasis on the policy shift aligns with our findings.

Although all these papers focus on monetary and/or fiscal policies, they do not explicitly consider supply chain disruptions and sectoral reallocation frictions that have drawn a lot of attention as the main driver of inflation during the post-COVID-19 period. This is because their one-sector model cannot incorporate the input-output network as in a multi-sector model. Hence, they cannot distinguish the sharp rise and fall in goods inflation from the more muted but persistent variation in

[3] Smets and Wouters (2024) estimate a medium-scale New Keynesian model with temporary fiscal regimes and show that fiscal stimulus in 2021 might have contributed to inflation. However, they argue that this inflationary effect largely offset the dis-inflationary force by other demand shocks such as intertemporal preference shocks. In our preferred calibration of the model, this dis-inflationary force was present mostly in 2020 but not much thereafter.

services inflation.

In contrast, papers such as Amiti et al. (2023), Comin et al. (2023), and Ferrante et al. (2023) set up a multi-sector New Keynesian model and explain the disparity between goods inflation and services inflation. They highlight the role of supply disruptions in creating a rapid increase in goods inflation, while also emphasizing the sectoral demand reallocation during the COVID-19 period (from services to goods) as a main factor of goods inflation. These papers largely abstract from the fiscal side of the economy and do not explicitly consider the change in the monetary policy framework during the COVID-19 period. In our analysis, we find that the increased friction on the production side underpredicts the volatility and persistence of aggregate inflation compared to specifications that allow for policy shifts.[4] While the increased friction on the production side increases the contribution of a service-sector technology shock to aggregate inflation in early 2021, it does not explain the overall trajectory of inflation better than models with policy shifts. Our results suggest that policy shifts remain important for explaining the post-pandemic inflation, even when we consider production-side frictions through input-output linkages, which are not included in previous studies such as Bianchi et al. (2023) and Bhattarai et al. (2023).

Besides the sectoral linkage and supply chain disruptions, the nonlinearity of the Phillips curve was suggested as a main factor behind the surge in inflation during the COVID-19 period. Before COVID-19, the slope of the Phillips curve was largely believed to be flat, implying that inflation is not sensitive to a change in the resource slack (*e.g.*, Hazell, Herreno, Nakamura and Steinsson 2022). The rapid acceleration in inflation in the context of the tight labor market during the post-COVID-19 period raised the possibility that the slope of the Phillips curve might have changed. Benigno and Eggertsson (2023) introduce real wage rigidity which is binding only when there is slack in the labor market. But if the labor market is tight with vacancy postings exceeding the number of unemployed people, real wage becomes flexible and rises to balance labor demand with labor supply. This downward real wage rigidity makes the Phillips curve steeper when the labor market is tight due to either demand stimulus from fiscal and monetary policies or a decline in labor supply, which explains the sharp rise in inflation as the resource slack diminishes during the post-COVID-19 period. Harding et al. (2023) also explains the post-COVID-19 inflation surge by the nonlinear Phillips curve that amplifies the effect of a cost push shock due to quasi-kinked demand for goods in which price elasticity increases as the price rises. Hence, for the same magnitude of an upward shift in the marginal cost, firms have to raise price more when the initial price is high, making inflation more sensitive to output gap or a cost push shock when the level of inflation is high. Monetary and fiscal policies that stimulate demand can cause persistently higher inflation in an economy

[4]Without input-output linkages, sectoral technology shocks would have smaller impacts on aggregate inflation as shown in Montag and Villar (2023). Our model attributes a substantial portion of service-sector inflation to goods-sector technology shocks even in the baseline calibration, suggesting that input-output linkages are strong.

with a nonlinear Phillips curve than in an economy with a flat, linear Phillips curve. Nonetheless, one-sector models used in these papers still cannot explain significant difference in sectoral price inflation. We shorten the average price duration to make the Phillips curve steeper compared to our baseline calibration but this does not improve the model fit for the level and persistence of inflation compared to our favored model specification with policy shifts.[5]

Our paper is closely related to Gagliardone and Gertler (2023). They develop a New Keynesian model in which oil is an intermediary input and interpret the post-COVID-19 inflation as driven by an accommodative monetary policy that did not react aggressively to oil price shocks in 2021 and 2022. The easy monetary policy is represented by large negative deviations from a standard Taylor rule. The conclusion is somewhat similar to our paper in which monetary policy less aggressive to inflation generates persistently high inflation during the post-COVID-19 period. But they focus on unanticipated monetary easing while we emphasize changes in the systematic response of monetary policy to inflation as a main factor driving the post-COVID-19 inflation.[6]

Our paper is also related to Davig and Doh (2014) who show that monetary policy regime shifts can affect inflation persistence by changing weights of inflation on shocks with different persistence. In Davig and Doh (2014), a less aggressive monetary policy response to inflation in a Taylor rule can increase the weight on the most persistent shock in inflation, raising inflation persistence which is the weighted average of shock persistence. While Davig and Doh (2014) consider a purely forward-looking model in which the persistence of inflation response to a shock is a monotonic function of shock persistence, we consider a more generalized model with inertia in which the persistence of the inflation impulse response is not the same as the persistence of the shock. In this paper, inflation persistence is the weighted average of the persistence of inflation response conditional on the realization of a particular shock. Changes in monetary policy parameters can affect both weights and conditional persistence of inflation unlike Davig and Doh (2014).

The rest of the paper is organized as follows. In Section 2, we describe the multi-sector New Keynesian model with input-output linkages. Section 3 explains the channels of high and persistent inflation in the model and introduces the empirical framework of a reference structural vector autoregression (SVAR) model whose impulse responses to a sectoral reallocation shock we want to match by our model-implied impulse responses. Section 4 describes the main empirical results, focusing on the decomposition of the post-pandemic period rise of inflation into various factors. Section 5 discusses implications of our analysis. Section 6 provides concluding remarks.

[5]A part of reason for this is that the average price duration in our baseline calibration (6 months for goods sector, 12 months for service sector) might be already shorter than values considered in the flat Phillips curve literature.

[6]Afrouzi et al. (2024) highlight the inflationary effect of the change in the relative price of the upstream sector (*e.g.*, energy sector) when monetary policy does not respond. By considering the systematic component of monetary policy, their model is more similar to ours than Gagliardone and Gertler (2023) although they do not detail monetary/fiscal policy interactions as we do in our preferred calibration.

2 Model

We build a multi-sector new Keynesian model with input-output linkages similar to the one in Carvalho, Lee and Park (2021). However, unlike Carvalho et al. (2021), we include the imperfect substitution of labor across sectors and model the monetary policy in terms of average inflation targeting to accommodate the new framework announced in 2020.[7] There are N sectors in the economy. Each sector $i \in \{1, \cdots, N\}$ consists of a final output producer and a unit measure of intermediate output producers which produce differentiated varieties. In each sector, the final output producer aggregates the output of a continuum of monopolistically competitive intermediate output producers. Intermediate output producers combine labor and intermediate inputs to make their differentiated products. They are subject to Calvo (1983)-type nominal price rigidity and can change prices infrequently according to the exogenously given probability. We describe the optimal behavior of households and firms first and discuss monetary and fiscal policies of the government sector before providing equilibrium conditions.[8]

2.1 Household

The representative household consumes final goods/services, supplies labor, and saves nominal bonds. The household's optimization problem is to maximize the lifetime utility:

$$\max_{\{C_t, L_t, B_t, \{C_{i,t}, L_{i,t}\}_{i\in\{1,2,\cdots,N\}}\}} \quad E_0 \sum_{t=0}^{\infty} \beta^t \xi_{D,t} \left[\frac{(C_t)^{1-\gamma}}{1-\gamma} - \chi \frac{L_t^{1+\varphi}}{1+\varphi} \right],$$

subject to a standard No-ponzi-game constraint and sequence of flow budget constraints:

$$P_t C_t + B_t = \sum_i (1-\tau_t) W_{i,t} L_{i,t} + R_{t-1} B_{t-1} + P_t T_t + \Phi_t,$$

where $\xi_{D,t}$ is a preference shock, γ is risk aversion, φ is the inverse of Frisch elasticity, C_t is the aggregate consumption, L_t is aggregate hours, τ_t is the labor tax rate, B_t is the nominal government bond, P_t is the price level, $W_{i,t}$ is the nominal wage for sector i, R_t is the nominal interest rate, T_t is transfers, and Φ_t is nominal aggregate profits.

Here C_t is a CES/Armington-type aggregator ($\varepsilon > 0$) of the consumption good/service produced in each sector:

$$C_t = \left(\sum_{i=1}^{N} \left(\Gamma_{i,t}^c\right)^{\frac{1}{\varepsilon}} (C_{i,t})^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}},$$

where $C_{i,t}$ is the consumption for sector i output and $\Gamma_{i,t}^c$ is the consumption share for sectoral output i. Notice that we assume that the consumption share can be varying over time. This gives

[7] Carvalho et al. (2021) consider either the economy-wide labor market or the sector-specific labor market but do not address the intermediate case in which the inter-sector labor mobility is limited but not completely shut down.

[8] A complete set of equilibrium conditions is presented in Appendix A.1.

the following composite price index and demand functions from a standard static expenditure minimization problem:

$$C_{i,t} = \Gamma^c_{i,t} \left(\frac{P_{i,t}}{P_t} \right)^{-\varepsilon} C_t \text{ and } 1 = \sum_{i=1}^{N} \Gamma^c_{i,t} \left(Q_{i,t} \right)^{1-\varepsilon},$$

with $Q_{i,t} = \frac{P_{i,t}}{P_t}$. Note that if $\varepsilon = 1$, then $C_t = \prod_{i=1}^{N} \left(\frac{C_{i,t}}{\Gamma^c_{i,t}} \right)^{\Gamma^c_{i,t}}$ and $1 = \prod_{i=1}^{N} \left(Q_{i,t} \right)^{\Gamma^c_{i,t}}$.

Moreover, L_t is also a CES aggregator of the hours supplied for each sector:

$$L_t = \left(\sum_{i=1}^{N} \left(\Gamma^L_i \right)^{-\frac{1}{\varepsilon_L}} \left(L_{i,t} \right)^{\frac{\varepsilon_L+1}{\varepsilon_L}} \right)^{\frac{\varepsilon_L}{\varepsilon_L+1}},$$

where $L_{i,t}$ is the household's labor supply for sector i, Γ^L_i is the share of labor supply for sector i, and ε_L is the elasticity of substitution in labor supply across sectors. A similar specification is used in Horvath (2000), Katayama and Kim (2018), and vom Lehn and Winberry (2021). The lower ε_L implies a higher degree of friction in the sectoral reallocation of labor.

Then, we describe optimality conditions from the intertemporal consumption choice and the labor supply choice for each sector as well as the transversality condition as follows:

$$\xi_{D,t} C_t^{-\gamma} = \beta R_t E_t \left[\xi_{D,t+1} C_{t+1}^{-\gamma} \frac{1}{\Pi_{t+1}} \right],$$

$$\left(1 - \tau_t\right) \frac{W_{i,t}}{P_t} = \chi \left(L_t \right)^{\varphi} \left(C_t \right)^{\gamma} \left(\frac{1}{\Gamma^L_i} \frac{L_{i,t}}{L_t} \right)^{\frac{1}{\varepsilon_L}} \quad \text{for each } i \in \{1, \cdots, N\},$$

$$\lim_{t \to \infty} \left[\beta^t \xi_{D,t} C_t^{-\gamma} \frac{B_t}{P_t} \right] = 0.$$

2.2 Final Output Producers

A representative final output producer in sector i buys intermediate output, indexed by $j \in [0, 1]$. We assume that the final output firm produces a sectoral output, $Y_{i,t}$, using a CES production function with an elasticity of substitution across differentiated products $\sigma_i > 1$. Then, the profit maximization problem of the final good producer is given by

$$\max_{\{\{Y_{i,t}(j)\}_{j \in [0,1]}, Y_{i,t}\}} P_{i,t} Y_{i,t} - \int_0^1 P_{i,t}(j) Y_{i,t}(j)\, dj,$$

$$\text{s.t. } Y_{i,t} = \left[\int_0^1 \left(Y_{i,t}(j) \right)^{\frac{\sigma_i - 1}{\sigma_i}} dj \right]^{\frac{\sigma_i}{\sigma_i - 1}}.$$

The solution of this problem gives the following optimal demand for intermediate product j and the price index in sector i:

$$Y_{i,t}(j) = \left(\frac{P_{i,t}(j)}{P_{i,t}} \right)^{-\sigma_i} Y_{i,t}, \text{ and } P_{i,t} = \left[\int_0^1 \left(P_{i,t}(j) \right)^{1-\sigma_i} dj \right]^{\frac{1}{1-\sigma_i}}.$$

2.3 Intermediate Output Producers

Each sector i has a unit measure of intermediate output producers, indexed by $j \in [0,1]$. An intermediate output producer j in sector i has a CES production function:

$$Y_{i,t}(j) = Z_{i,t}\left((\alpha_i)^{\frac{1}{\varepsilon_Y}}(M_{i,t}(j))^{\frac{\varepsilon_Y-1}{\varepsilon_Y}} + (1-\alpha_i)^{\frac{1}{\varepsilon_Y}}(L_{i,t}(j))^{\frac{\varepsilon_Y-1}{\varepsilon_Y}}\right)^{\frac{\varepsilon_Y}{\varepsilon_Y-1}},$$

where $L_{i,t}(j)$ is labor demand for firm j in sector i, and $M_{i,t}(j)$ is a composite material input which is a CES bundle of the outputs of the N sectors of the economy:

$$M_{i,t}(j) = \left(\sum_{k=1}^{N}(\Gamma_{i,k})^{\frac{1}{\varepsilon_M}}(M_{i,k,t}(j))^{\frac{\varepsilon_M-1}{\varepsilon_M}}\right)^{\frac{\varepsilon_M}{\varepsilon_M-1}},$$

where $M_{i,k,t}(j)$ is the intermediate firm j in sector i's demand for material input produced by sector k, and $\Gamma_{i,k}$ is the relative share of sector k output in sector i's composite material.

Cost minimization: The cost minimization problem for the intermediate producer j is given by

$$\min_{\{L_{i,t}(j), M_{i,t}(j), \{M_{i,k,t}(j)\}_{k=1}^{N}\}} W_{i,t}L_{i,t}(j) + \sum_{k=1}^{N}P_{k,t}M_{i,k,t}(j),$$

$$\text{s.t., } M_{i,t}(j) = \left(\sum_{k=1}^{N}(\Gamma_{i,k})^{\frac{1}{\varepsilon_M}}(M_{i,k,t}(j))^{\frac{\varepsilon_M-1}{\varepsilon_M}}\right)^{\frac{\varepsilon_M}{\varepsilon_M-1}},$$

$$Y_{i,t}(j) \leq Z_{i,t}\left((\alpha_i)^{\frac{1}{\varepsilon_Y}}(M_{i,t}(j))^{\frac{\varepsilon_Y-1}{\varepsilon_Y}} + (1-\alpha_i)^{\frac{1}{\varepsilon_Y}}(L_{i,t}(j))^{\frac{\varepsilon_Y-1}{\varepsilon_Y}}\right)^{\frac{\varepsilon_Y}{\varepsilon_Y-1}}.$$

Let $W_{i,t}^{M}(j)$ and $MC_{i,t}(j)$ be the Lagrangian multipliers for the first and the second constraint, respectively. Then, the first-order optimal conditions are given by

$$M_{i,k,t}(j) = \Gamma_{i,k}\left(\frac{P_{k,t}}{W_{i,t}^{M}(j)}\right)^{-\varepsilon_M}M_{i,t}(j),$$

$$L_{i,t}(j) = (1-\alpha_i)\left(\frac{MC_{i,t}(j)}{W_{i,t}}\right)^{\varepsilon_Y}Y_{i,t}(j),$$

$$M_{i,t}(j) = \alpha_i\left(\frac{MC_{i,t}(j)}{W_{i,t}^{M}(j)}\right)^{\varepsilon_Y}Y_{i,t}(j).$$

Then, the firms' aggregate cost for composite material input in sector i is equalized across firms at

$$W_{i,t}^{M}(j) = W_{i,t}^{M} = \left(\sum_{k=1}^{N}\Gamma_{i,k}(P_{k,t})^{1-\varepsilon_M}\right)^{\frac{1}{1-\varepsilon_M}}.$$

Similarly, the firms' marginal cost in sector i is equalized at

$$MC_{i,t}(j) = MC_{i,t} = (Z_{i,t})^{-\frac{1}{\varepsilon_Y}}\left(\alpha_i\left(W_{i,t}^{M}(j)\right)^{1-\varepsilon_Y} + (1-\alpha_i)(W_{i,t})^{1-\varepsilon_Y}\right)^{\frac{1}{1-\varepsilon_Y}}$$

and if $\varepsilon_Y = 1$, $MC_{i,t} = \frac{1}{Z_{i,t}} \left(\frac{W_{i,t}^M}{\alpha_i} \right)^{\alpha_i} \left(\frac{W_{i,t}}{1-\alpha_i} \right)^{1-\alpha_i}$.

Notice that the sectoral real marginal cost can be expressed as a CES aggregate of the sectoral real wage and and sectoral input cost as follows:

$$\frac{M_{i,t}(j)}{L_{i,t}(j)} = \frac{\alpha_i}{1-\alpha_i} \left(\frac{w_{i,t}}{w_{i,t}^M} \right)^{\varepsilon_Y},$$

$$\frac{Y_{i,t}(j)}{L_{i,t}(j)} = (1-\alpha_i)^{\frac{1}{\varepsilon_Y - 1}} Z_{i,t} \left(\frac{\alpha_i}{1-\alpha_i} \left(\frac{w_{i,t}}{w_{i,t}^M} \right)^{\varepsilon_Y - 1} + 1 \right)^{\frac{\varepsilon_Y}{\varepsilon_Y - 1}},$$

$$mc_{i,t} \equiv \frac{MC_{i,t}}{P_t} = (Z_{i,t})^{-\frac{1}{\varepsilon_Y}} \left(\alpha_i \left(w_{i,t}^M \right)^{1-\varepsilon_Y} + (1-\alpha_i)(w_{i,t})^{1-\varepsilon_Y} \right)^{\frac{1}{1-\varepsilon_Y}},$$

where $w_{i,t}^M = \frac{W_{i,t}^M}{P_t}$ and $w_{i,t} = \frac{W_{i,t}}{P_t}$.

Price setting: Intermediate output firms face nominal rigidity. As in Calvo (1983), a firm resets its price optimally with probability $1-\theta_i$ every period. We allow the heterogeneity in the nominal price rigidity across sectors. Flow (real) profits $\Phi_{i,t+k}(j)$ are given by

$$\Phi_{i,t+k}(j) = \left(\frac{P_{i,t}^*}{P_{t+k}} - \frac{MC_{i,t+k}}{P_{t+k}} \right) Y_{i,t,t+k}(j),$$

with

$$Y_{i,t,t+k}(j) = \left(\frac{P_{i,t}^*}{P_{i,t+k}} \right)^{-\sigma_i} Y_{i,t+k}.$$

The profit maximization problem for firms that get to choose optimal prices, $P_{i,t}^*$, is given by

$$\max_{\{P_{i,t}^*\}} E_t \left\{ \sum_{k=0}^{\infty} (\theta_i \beta)^k \left(\frac{C_t}{C_{t+k}} \right)^{\gamma} \left(\frac{P_{i,t}^*}{P_{i,t+k}} Q_{i,t+k} - \frac{MC_{i,t+k}}{P_{t+k}} \right) \left(\frac{P_{i,t}^*}{P_{i,t+k}} \right)^{-\sigma_i} Y_{i,t+k} \right\},$$

where $Q_{i,t+k}$ denotes the relative price of the i-th sector $Q_{i,t+k} = \frac{P_{i,t+k}}{P_{t+k}}$. The first-order condition for the optimal reset price is given by:

$$\frac{P_{i,t}^*}{P_{i,t}} = \frac{\sigma_i}{\sigma_i - 1} \frac{E_t \left\{ \sum_{k=0}^{\infty} (\theta_i \beta)^k \left(\frac{C_t}{C_{t+k}} \right)^{\gamma} (mc_{i,t+k}) \left(\frac{P_{i,t+k}}{P_{i,t}} \right)^{\sigma_i} Y_{i,t+k} \right\}}{E_t \left\{ \sum_{k=0}^{\infty} (\theta_i \beta)^k \left(\frac{C_t}{C_{t+k}} \right)^{\gamma} Q_{i,t+k} \left(\frac{P_{i,t+k}}{P_{i,t}} \right)^{\sigma_i - 1} Y_{i,t+k} \right\}}.$$

We can rewrite this optimality condition in terms of the law of motion of prices as follows:

$$\frac{P_{i,t}^*}{P_{i,t}} = \frac{\sigma_i}{\sigma_i - 1} \frac{X_{i,t}^1}{X_{i,t}^2},$$

$$X_{i,t}^1 = mc_{i,t} Y_{i,t} + \theta_i \beta E_t \left[\left(\frac{C_t}{C_{t+1}} \right)^{\gamma} (\Pi_{i,t+1})^{\sigma_i} X_{i,t+1}^1 \right],$$

$$X_{i,t}^2 = Q_{i,t} Y_{i,t} + \theta_i \beta E_t \left[\left(\frac{C_t}{C_{t+1}} \right)^{\gamma} (\Pi_{i,t+1})^{\sigma_i - 1} X_{i,t+1}^2 \right].$$

2.4 Government

The government sector consumes G_t, which is the CES aggregator of the consumption output produced in different sectors:

$$G_t = \left(\sum_{i=1}^{N} \left(\Gamma_i^G\right)^{\frac{1}{\varepsilon}} \left(G_{i,t}\right)^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}},$$

where Γ_i^G is the government consumption share of i-sector output and $G_{i,t}$ is the government consumption for i-sector output. This gives the following composite price index and demand functions from a standard static expenditure minimization problem:

$$G_{i,t} = \Gamma_i^G \left(\frac{P_{i,t}}{P_t^G}\right)^{-\varepsilon} G_t \,,\; 1 = \sum_{i=1}^{N} \Gamma_i^G \left(\frac{Q_{i,t}}{Q_t^G}\right)^{1-\varepsilon},$$

with $\frac{Q_{i,t}}{Q_t^G} = \frac{P_{i,t}}{P_t}\frac{P_t}{P_t^G} = \frac{P_{i,t}}{P_t^G}$. Note that if $\varepsilon = 1$, then $G_t = \prod_{i=1}^{N} \left(\frac{G_{i,t}}{\Gamma_i^G}\right)^{\Gamma_i^G}$ and $Q_t^G = \prod_{i=1}^{N} \left(Q_{i,t}\right)^{\Gamma_t^G}$.

With debt, the government budget constraint is given by

$$B_t + \tau_t \sum_{i=1}^{N} W_{i,t} L_{i,t} = R_{t-1} B_{t-1} + P_t^G G_t + P_t T_t.$$

To close the fiscal policy block, we consider the following tax rule:

$$\tau_t - \bar{\tau} = \rho_\tau (\tau_{t-1} - \bar{\tau}) + (1-\rho_\tau)\psi_\tau \left(\frac{b_{t-1} - \bar{b}}{\bar{b}}\right),$$

where b_{t-1} and $\bar{b}$ represent the real value of debt $\frac{B_{t-1}}{P_{t-1}}$ and the steady state value of the real debt, respectively.

Monetary policy follows a Taylor rule with average inflation targeting:

$$\frac{R_t}{R^\star} = \left(\bar{\Pi}_{t-T,t}\right)^{\phi_\Pi} \exp\left(\zeta_{R,t}\right),$$

where $\bar{\Pi}_{t-T,t} = \left[\prod_{j=1}^{T} \left(\Pi_{t-j+1}\right)\right]^{1/T}$ for $T \geq 1$ is T-period average inflation and $\zeta_{R,t}$ is the monetary policy shock. Since we assume zero inflation at the steady state, the steady state nominal interest rate is equal to the steady state real interest rate, $R^\star = \frac{1}{\beta}$. Both k and ϕ_Π determine the systematic policy response to inflation.

The fiscally dominant regime can be described by the zero inflation feedback ($\phi_\Pi = 0$) in the monetary policy rule and the low debt feedback ($\psi_L \approx 0$) in the tax rule while the monetary regime implies the relatively high inflation feedback ($\phi_\Pi > 1$) and debt feedback ($\psi_L >> 0$). Following Bianchi et al. (2023), we introduce a temporary shift to the fiscal regime by assuming that only a portion of transfer shocks is unfunded by increases in taxes and the monetary authority also does not respond to inflation incurred by the unfunded transfer shock.[9] For this temporary fiscal regime case, we also introduce the systematic component for government transfer as follows:

$$\frac{T_{b,t}}{\bar{T}} = \left(\frac{Y_t}{\bar{Y}}\right)^{-\psi_{T,y}} \left(\frac{B_{t-1}}{B_{t-1}^U}\right)^{-\psi_T}, \tag{2.1}$$

where B_{t-1}^U is debt issued to finance the unfunded transfer shock. Accordingly, we modify fiscal and monetary policy rules in this specification with a temporary shift to the fiscal regime.

$$\tau_t - \bar{\tau} = \rho_\tau \left(\tau_{t-1} - \bar{\tau}\right) + \left(1 - \rho_\tau\right) \psi_\tau \left(\frac{b_{t-1} - b_{t-1}^U}{\bar{b}}\right),$$

$$\frac{R_t}{R^\star} = \left(\frac{\bar{\Pi}_{t-T,t}}{\bar{\Pi}_{t-T,t}^U}\right)^{\phi_\Pi} \exp\left(\zeta_{R,t}\right),$$

where $\bar{\Pi}_{t-T,t}^U$ is the portion of inflation that is incurred by the unfunded transfer shock for which monetary authority does not respond by adjusting the interest rate.

2.5 Market clearing, aggregation, and resource constraints

Labor market clearing conditions are given by

$$L_{i,t} = \int_0^1 L_{i,t}(j)\, dj = \left(1 - \alpha_i\right) \left(\frac{mc_{i,t}}{w_{i,t}}\right)^{\varepsilon_Y} Y_{i,t} \Xi_{i,t},$$

where $\Xi_{i,t} \equiv \int_0^1 \left(\frac{P_{i,t}(j)}{P_{i,t}}\right)^{-\sigma_i} dj$ is the within-sector price dispersion which is given by:

$$\Xi_{i,t} = \left(1 - \theta_i\right) \left(\frac{P_{i,t}^*}{P_{i,t}}\right)^{-\sigma_i} + \theta_i \Xi_{i,t-1}.$$

The output market clears in each sector $k \in \{1, \cdots, N\}$,

$$Y_{k,t} = C_{k,t} + G_{k,t} + \sum_{i=1}^{N} M_{i,k,t},$$

where sector i's aggregate demand for the sector k's final output, $M_{i,k,t} \equiv \int M_{i,k,t}(j)\, dj$, is given by

$$M_{i,k,t} \equiv \int_0^1 M_{i,k,t}(j)\, dj = \Gamma_{i,k} \left(\frac{Q_{k,t}}{w_{i,t}^M}\right)^{-\varepsilon_M} M_{i,t},$$

and sector i's composite material inputs, $M_{i,t} \equiv \int M_{i,t}(j)\, dj$, is given by

$$M_{i,t} \equiv \int_0^1 M_{i,t}(j)\, dj = \alpha_i \left(\frac{mc_{i,t}}{w_{i,t}^M}\right)^{\varepsilon_Y} \Xi_{i,t} Y_{i,t},$$

[9] To separate inflation incurred by unfunded transfer shocks from overall inflation, we solve the shadow economy model in which unfunded shocks are shut down and fiscal/monetary policy authorities always stabilize debt-to-output ratio/inflation as in Bianchi et al. (2023).

and sector i's output, $Y_{i,t}^s$, is given by

$$Y_{i,t}^s \equiv \int Y_{i,t}(j)\, dj = Y_{i,t}\Xi_{i,t}.$$

We derive the law of motion for sector-i's inflation as:

$$P_{i,t} = \left[\int_0^1 \left(P_{i,t}(j)\right)^{1-\sigma_i} dj\right]^{\frac{1}{1-\sigma_i}} \text{ and } \left(\Pi_{i,t}\right)^{1-\sigma_i} = (1-\theta_i)\left(\frac{P_{i,t}^*}{P_{i,t}}\Pi_{i,t}\right)^{1-\sigma_i} + \theta_i.$$

To derive an aggregate resource constraint, we combine household budget constraint and government budget constraint:

$$C_t + Q_t^G G_t = \sum_{i=1}^N \left[Q_{i,t}Y_{i,t} + (1-\alpha_i)\left(mc_{i,t}\right)^{\varepsilon_Y}\left(w_{i,t}\right)^{1-\varepsilon_Y} Y_{i,t}\Xi_{i,t} - \left(mc_{i,t}\right)Y_{i,t}\Xi_{i,t}\right]$$

where $Q_t^G = \frac{P_t^G}{P_t}$.

2.6 Shocks

We assume that all the exogenous shocks follow AR(1) processes as follows:

$$\begin{aligned}
\frac{Z_{i,t}}{\bar{Z}_i} &= \left(\frac{Z_{i,t-1}}{\bar{Z}_i}\right)^{\rho_{z,i}} \exp\left(\varepsilon_t^{z,i}\right) \text{ for } i \in \{1,2,\cdots,N\},\\
\Gamma_{i,t}^c - \bar{\Gamma}_i^c &= \rho_{\Gamma,i}\left(\Gamma_{i,t-1}^c - \bar{\Gamma}_i^c\right) + \varepsilon_t^{\Gamma} \text{ for } i \in \{1,2,\cdots,N\},\\
\frac{\xi_{D,t}}{\bar{\xi}_D} &= \left(\frac{\xi_{D,t-1}}{\bar{\xi}_D}\right)^{\rho_\xi} \exp(\varepsilon_t^D),\\
\frac{G_t}{\bar{G}} &= \left(\frac{G_{t-1}}{\bar{G}}\right)^{\rho_G} \exp(\varepsilon_t^G),\\
\frac{T_t}{\bar{T}} &= \left(\frac{T_{t-1}}{\bar{T}}\right)^{\rho_T} \exp(\varepsilon_t^T),\\
\zeta_{R,t} &= \rho_R \zeta_{R,t-1} + \varepsilon_{R,t}.
\end{aligned}$$

In our calibrated model, there are four aggregate demand shocks (ε_t^D, ε_t^G, ε_t^T, $\varepsilon_{R,t}$) and one sectoral demand shift shock (ε_t^Γ) with two sectoral technology shocks ($\varepsilon_t^{z,G}$ and $\varepsilon_t^{z,S}$).

For the specification that incorporates a temporary fiscal regime, the government transfer contains the systematic component described in Equation (2.1). We assume that government transfers evolve according to the following process in the specification with a temporary shift to the fiscal regime.

$$\begin{aligned}
\frac{T_t}{\bar{T}} &= \left(\frac{T_{t-1}}{\bar{T}}\right)^{\rho_T}\left(\frac{T_{b,t}}{\bar{T}}\right)^{1-\rho_T} \exp(\zeta_{F,t}^T + \zeta_{U,t}^T),\\
\zeta_{F,t}^T &= \rho_{F,T}\zeta_{F,t-1} + \varepsilon_{F,t}^T,
\end{aligned}$$

$$\zeta_{U,t}^{T} = \rho_{U,T}\zeta_{U,t-1} + \varepsilon_{U,t}^{T}.$$

where $\zeta_{F,t}^{T}$ is the funded transfer shock for which the fiscal authority would adjust the future tax to repay the debt issued to finance spending, and $\zeta_{U,t}^{T}$ is the unfunded transfer shock for which the fiscal authority would not do that. Each shock follows an AR(1) process.

3 Channels of High and Persistent Inflation

This section examines the main channels of high and persistent inflation using a linearized version of the model described in Section 2. We derive a sectoral Phillips curve in the model and decompose it to analyze the sources of high inflation. Additionally, we introduce an empirical framework of a reference structural vector autoregression (SVAR) model, whose impulse responses to a sectoral reallocation shock we aim to match with our model-implied impulse responses.

3.1 Sectoral Phillips Curve and the Decomposition of Marginal Cost

In our model, aggregate inflation can be expressed as the weighted average of sector-level inflation, whose dynamics are in turn determined by the sector-level Phillips curve. In line with standard New Keynesian models with production networks, the sector-level Phillips curve links sector-level price inflation to expected sector-level inflation and sector-level real marginal costs (see *e.g.,* Carvalho et al., 2021; Rubbo, 2023; Afrouzi and Bhattarai, 2023; Minton and Wheaton, 2023). We describe the sector-level Phillips curve below with all the variables denoting log deviations from steady state values.

$$\begin{aligned}
\widehat{\Pi}_{i,t} &= \beta E_t(\widehat{\Pi}_{i,t+1}) + \frac{(1-\theta_i)(1-\beta\theta_i)}{\theta_i}(\widehat{mc}_{i,t} - \widehat{Q}_{i,t}), \\
\widehat{mc}_{i,t} &= -\frac{\widehat{Z}_{i,t}}{\varepsilon_Y} + \nu_i \widehat{w}_{i,t}^{M} + (1-\nu_i)\widehat{w}_{i,t}\,,\ \nu_i = \frac{\alpha_i(\bar{w}_i^M)^{1-\varepsilon_Y}}{\alpha_i(\bar{w}_i^M)^{1-\varepsilon_Y} + (1-\alpha_i)(\bar{w}_i)^{1-\varepsilon_Y}}, \\
\widehat{w}_{i,t}^{M} &= \sum_{k=1}^{N}\omega_{i,k}\widehat{Q}_{k,t}\,,\ \omega_{i,k} = \frac{\Gamma_{i,k}\bar{Q}_k^{1-\varepsilon_M}}{\sum_{j=1}^{N}\Gamma_{i,j}\bar{Q}_j^{1-\varepsilon_M}}\,,\ \widehat{w}_{i,t} = (\varphi - \frac{1}{\varepsilon_L})\widehat{L}_t + \frac{1}{\varepsilon_L}\widehat{L}_{i,t} + \gamma\widehat{C}_t - \frac{\bar{\tau}}{1-\bar{\tau}}\widehat{\tau}_t, \\
\widehat{Q}_t^{\text{sector}} &= [\widehat{Q}_{1,t}, \cdots, \widehat{Q}_{N,t}]^T\,,\ \widehat{L}_t^{\text{sector}} = [\widehat{L}_{1,t}, \cdots, \widehat{L}_{N,t}]^T, \widehat{Z}_t^{\text{sector}} = [\widehat{Z}_{1,t}, \cdots, \widehat{Z}_{N,t}]^T, \\
\nu^{\text{sector}} &= \text{diag}(\nu_1, \cdots, \nu_N)\,,\ \mathbb{1} = (1, \cdots, 1)^T,
\end{aligned} \tag{3.1}$$

where $\text{diag}(\cdot)$ stands for a diagonal matrix whose diagonal elements are described inside the parenthesis. Let's stack the sector-level price inflation by a vector $\Pi_t^{\text{sector}} = [\Pi_{1,t}, \cdots, \Pi_{N,t}]^T$. Then sector-level Phillips curves can be decomposed into four terms as follows:

$$\widehat{\Pi}_t^{\text{sector}} = \underbrace{\beta E_t(\widehat{\Pi}_{t+1}^{\text{sector}})}_{\text{expected inflation}} + \underbrace{\Theta(\Omega - I)\widehat{Q}_t^{\text{sector}}}_{\text{intermediary input cost in real terms}}$$

$$+\underbrace{\Theta(I-\nu^{\text{sector}})((\varphi-\frac{1}{\varepsilon_L})\widehat{L}_t\mathbb{1}+\frac{1}{\varepsilon_L}\widehat{L}_t^{\text{sector}}+\gamma\widehat{C}_t\mathbb{1}+\frac{\bar{\tau}}{1-\bar{\tau}}\widehat{\tau}_t\mathbb{1})}_{\text{sectoral real wage}}$$

$$-\underbrace{\Theta\frac{\widehat{Z}_t^{\text{sector}}}{\varepsilon_Y}}_{\text{sectoral technology shock}},$$

where $\Theta = \text{diag}(\frac{(1-\theta_1)(1-\beta\theta_1)}{\theta_1}, \cdots, \frac{(1-\theta_N)(1-\beta\theta_N)}{\theta_N})$ and Ω is an $N \times N$ matrix whose (i,k) element is $\nu_i\omega_{i,k}$. The sectoral price inflation gap is the sum of the relative price inflation gap and the consumer price inflation gap

$$\widehat{\Pi}_{i,t} = \widehat{Q}_{i,t} - \widehat{Q}_{i,t-1} + \widehat{\Pi}_t.$$

Since the sum of expenditure weights is always equal to one, we can denote aggregate inflation ($\widehat{\Pi}_t$) as follows:

$$\widehat{\Pi}_t = \widehat{\Pi}_t \sum_{i=1}^{N} \bar{\Gamma}_i^c = \sum_{i=1}^{N} \bar{\Gamma}_i^c \widehat{\Pi}_t.$$

Using these two properties, we can decompose the aggregate consumer price inflation gap into three terms: intermediary input cost inflation, sectoral real wage, and sector-specific technology shock, assuming no exogenous shocks to expected inflation. While these terms are not orthogonal to each other, their relative importance can be evaluated by using empirical proxies for each channel, such as sectoral wage and aggregate productivity. For example, if the real wage channel were a dominant factor in price inflation, we should have seen wage inflation peaking before price inflation.

We convert the sectoral Phillips curve into the aggregate price inflation Phillips curve by aggregating the sectoral price inflation by the final consumption weights as follows:

$$\widehat{\Pi}_t = \underbrace{\beta E_t(\widehat{\Pi}_{t+1})}_{\text{expected inflation}} + \bar{\Gamma}^{cT} \underbrace{[\beta(\widehat{Q}_{t+1}^{\text{sector}} - \widehat{Q}_t^{\text{sector}}) - (\widehat{Q}_t^{\text{sector}} - \widehat{Q}_{t-1}^{\text{sector}}) + \Theta(\Omega - I)\widehat{Q}_t^{\text{sector}}]}_{\text{intermediary input cost in real terms}}$$

$$+ \bar{\Gamma}^{cT} \underbrace{\Theta(I-\nu^{\text{sector}})((\varphi-\frac{1}{\varepsilon_L})\widehat{L}_t\mathbb{1}+\frac{1}{\varepsilon_L}\widehat{L}_t^{\text{sector}}+\gamma\widehat{C}_t\mathbb{1}+\frac{\bar{\tau}}{1-\bar{\tau}}\widehat{\tau}_t\mathbb{1})}_{\text{sectoral real wage}}$$

$$- \bar{\Gamma}^{cT} \underbrace{\Theta\frac{\widehat{Z}_t^{\text{sector}}}{\varepsilon_Y}}_{\text{sectoral technology shock}}, \tag{3.2}$$

where $\bar{\Gamma}^c = [\Gamma_1^c, \cdots, \Gamma_N^c]^T$.

By iterating forward the sectoral Phillips curve in Equation (3.2), we obtain aggregate inflation as the discounted sum of the current and expected future real marginal cost as follows: [10]

$$\widehat{\Pi}_t = \underbrace{\sum_{j=0}^{\infty} \beta^j E_t[(\bar{\Gamma^c})^T (\widehat{Q}^{\text{sector}}_{t+j-1} + [\Theta(\Omega - I) - (1+\beta)I]\widehat{Q}^{\text{sector}}_{t+j} + \beta E_t(\widehat{Q}^{\text{sector}}_{t+j+1})]}_{\text{intermediary input cost inflation}}$$

$$+ \underbrace{\sum_{j=0}^{\infty} \beta^j E_t[(\bar{\Gamma^c})^T \Theta(I - \nu^{\text{sector}})((\varphi - \frac{1}{\varepsilon_L})\widehat{L}_{t+j}\mathbb{1} + \frac{1}{\varepsilon_L}\widehat{L}^{\text{sector}}_{t+j} + \gamma \widehat{C}_{t+j}\mathbb{1} + \frac{\bar{\tau}}{1-\bar{\tau}}\widehat{\tau}_{t+j}\mathbb{1})]}_{\text{real wage}}$$

$$- \underbrace{\sum_{j=0}^{\infty} \beta^j E_t[(\bar{\Gamma^c})^T \Theta \frac{\widehat{Z}^{\text{sector}}_{t+j}}{\varepsilon_Y}]}_{\text{technology shock}} .$$

The sector-level price inflation is determined by factors that affect sector-level relative prices (intermediary cost channel), sectoral real wages, and sectoral technology shocks. In our framework, inflation can surge due to aggregate demand shocks or sector-specific shocks that influence these factors.

First, aggregate demand shocks can increase the sectoral real wage by boosting the aggregate consumption gap ($\widehat{C}_t$). For example, a positive preference shock and a negative monetary policy shock can increase the aggregate consumption gap. Fiscal shocks financed by distortionary taxes can also affect labor supply and increase inflation through $\widehat{\tau}_t$. The inflationary effect of aggregate shocks can be amplified if monetary policy becomes less responsive to inflation by lowering ϕ_Π.

Second, sector-specific shocks can also impact inflation by changing the sector-level real marginal cost. A negative sectoral technology shock, such as pandemic-related health measures that increased production costs during the COVID-19 pandemic, is a prominent example. Additionally, sectoral demand shift shocks can affect aggregate inflation, especially if there are frictions in the reallocation of resources across sectors. In our model, imperfect mobility of labor across sectors introduces such frictions. If labor can be reallocated across sectors without friction (e.g., $\varepsilon_L = \infty$), there is only one economy-wide real wage and sector-level price inflation does not depend on $\widehat{L}^{\text{sector}}_t$. However, if labor is not perfectly mobile across sectors, sectoral real wages become more sensitive to sector-specific shocks. Therefore, if large sector-specific shocks coincide with increasing friction in the sectoral reallocation of labor (e.g., a decline in ε_L), they can significantly increase aggregate inflation.

Another channel through which sectoral demand shifts propagate into aggregate inflation is the intermediate input cost inflation, which is determined by the relative price. If the relative price of

[10] Sectoral demand shift shocks can affect aggregate inflation through the interaction with sectoral inflation but this is the second-order term that is ignored by the first-order approximation underlying the derivation of the Phillips curve. However, demand shifts shocks can still influence aggregate inflation through relative price changes even in the first-order approximation.

the intermediary input is expected to increase further in the future (*e.g.*, due to material shortages) relative to what we would expect based on the current level of the relative price, that can increase aggregate inflation. To see this more clearly, let's rearrange the term in the intermediary input cost channel in the Phillips curve as follows:

$$\begin{aligned}&\widehat{Q}_{t-1}^{\text{sector}} + (\Theta(\Omega - I) - (1+\beta)I)\,\widehat{Q}_{t}^{\text{sector}} + \beta E_t[\widehat{Q}_{t+1}^{\text{sector}}] = \\ &\qquad \beta(E_t[\widehat{Q}_{t+1}^{\text{sector}}] - \widehat{Q}_{t}^{\text{sector}}) - (\widehat{Q}_{t}^{\text{sector}} - \widehat{Q}_{t-1}^{\text{sector}}) - \Theta(I - \Omega)\widehat{Q}_{t}^{\text{sector}}.\end{aligned}$$

The inflationary impact can be amplified if the elasticity of substitution among intermediary inputs (ε_M) or the elasticity of substitution between the intermediary input and labor (ε_Y) is low. This is because a low elasticity of substitution leads to a greater acceleration in relative price inflation in response to sectoral shocks.

Although we distinguish the amplification of the inflationary effect of aggregate shocks by policy shifts from the amplification of the inflationary effect of sector-specific shocks from the friction on the production side, they are not incompatible. Both factors might have contributed to the surge inflation during the post-COVID-19 period. Also, the heterogeneity in price stickiness can play a role in propagating both types of shocks through Θ. In the quantitative analysis in the next analysis, we calibrate our model to answer a more precise decomposition of inflation into various factors.

3.2 Persistence of Inflation

Inflation during the post-COVID-19 period has been characterized by both high levels and persistence. Despite the Federal Reserve's decision to raise interest rates in 2022, aggregate inflation has only gradually declined. Notably, inflation in the service sector has remained persistently high, while inflation in the goods sector has decreased significantly. In our model, inflation persistence can be influenced by persistent shocks, changes in policy regimes, or variations in market frictions that make inflation more responsive to persistent shocks compared to less persistent shocks.

Both aggregate factors and sector-specific factors can contribute to the persistence of inflation in our model, similar to the level of inflation. To decompose the changes in inflation persistence and identify the contributions from different shocks, we define the persistence of inflation based on the long-run variance and auto-covariance of inflation. Assuming we have n_k independent exogenous shocks in the linearized model, inflation can be represented by a vector moving average process with respect to innovations in these shocks, denoted as s_t, based on the model solution.

$$\begin{aligned}&s_t = \Phi_s s_{t-1} + \Phi_\epsilon \epsilon_t\ ,\ E(\epsilon_t) = 0\ ,\ V(\epsilon_t) = I,\\ &\Pi_t = \Pi' s_t = \Pi' \sum_{j=0}^{\infty} \Phi_s^j \Phi_\epsilon \epsilon_{t-j} = \sum_{j=0}^{\infty} \Phi'_{\Pi,j} \epsilon_{t-j},\end{aligned}$$

$$
\begin{aligned}
V(\Pi_t) &= \sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon \Phi_{\Pi,j}, \\
Cov(\Pi_t, \Pi_{t+h}) &= \sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon \Phi_{\Pi,j+h}, \\
AR_h(\Pi_t) &= \sum_{k=1}^{n_k} \Big(\frac{\sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon^{(k)} \Phi_{\Pi,j}}{\sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon \Phi_{\Pi,j}}\Big)\Big(\frac{\sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon^{(k)} \Phi_{\Pi,j+h}}{\sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon^{(k)} \Phi_{\Pi,j}}\Big) = \sum_{k=1}^{n_k} w_k AR_h^{(k)}(\Pi_t).
\end{aligned} \tag{3.3}
$$

where $AR_h^{(k)}(\Pi_t)$ represents the persistence of inflation conditional on the realization of the k-th shock, while $AR_h(\Pi_t)$ represents the unconditional persistence of inflation. Π is a vector selecting inflation if Π_t is an element of s_t. If not, it represents a decision rule linking Π_t with s_t. $V_\epsilon^{(k)}$ is V_ϵ where columns other than the k-th one are set to zero. In the case that the model is purely forward-looking and the solution of Π_t is an affine function of exogenous shocks, the h-th order autocorrelation of Π_t is the weighted average of each shock's persistence, given by $AR_h^{(k)}(\Pi_t) = (\rho_k)^h$, where ρ_k is the persistence of the k-th shock. If the model contains lagged endogenous variables as state variables, the model solution is not as simple. Davig and Doh (2014) show that $AR_h^{(k)}(\Pi_t)$ can depend on other model parameters, particularly the inflation feedback parameter in the monetary policy rule. In general, the weight may also depend on all the parameters that can potentially affect inflation dynamics, such as the production network and the adjustment cost to sectoral reallocation. Additionally, the autocorrelation of inflation depends on all the model parameters, including those characterizing the monetary policy rule. In Davig and Doh (2014), it is shown that a decrease in the inflation feedback parameter of the monetary policy rule increases the weight on the most persistent shock. We will examine if these results hold in our extended model with the production network and lagged endogenous variables.

4 Quantitative Analysis

What were the main drivers of high and persistent inflation during the COVID-19 period? To investigate the different channels through which shocks, frictions, and policy affect the dynamics of post-COVID-19 inflation, we consider a simplified two-sector version of the model described in Section 2. This version consists of a goods-producing sector and a service-producing sector. We calibrate the key model parameters using pre-COVID-19 US data and examine four main channels of high and persistent inflation by analyzing the historical shock decomposition of aggregate inflation. The model is solved using the first-order perturbation method by linearizing the model around the steady state. The steady-state equilibrium is detailed in Appendix A.2. For variables whose steady state values cannot be obtained analytically such as sectoral relative prices, we solve equilibrium conditions numerically.

4.1 Data and Model Calibration

Table 1 presents the baseline model parameters. The parameters are divided into four blocks. The first block includes parameters related to household preferences and production technologies. For preference parameters, we use standard values from the literature. The model is calibrated at a monthly frequency with a time discount factor of $\beta = 0.98^{1/12}$. The inverse of the Frisch elasticity (φ) is set to 1.0, and the inverse of the elasticity of intertemporal substitution (γ) is set to 2.0. The elasticity of substitution across firms within each sector is set to four ($\sigma_G = \sigma_S = 4$), which corresponds to an average markup of 33 percent (Hall, 2018). We assume that goods and services consumption are substitutes by setting the elasticity (ε) to 2.0. The elasticity of substitution between composite materials and labor is set to 1.0. The relative weights for sectoral composite materials ($\{\Gamma_{i,j}\}_{i,j\in\{G,S\}}$) are determined using the input-output table (1997-2021) from the Bureau of Economic Analysis (BEA). Following Comin et al. (2023), we target the cost-based expenditure share of the sectoral output, which depend on the steady-state values of relative prices as well as input-output parameters.[11] We set the material input shares for each sector (α_G and α_S) to be 0.5 as in Carvalho et al. (2021).

The second block consists of policy parameters. We set the monetary policy reaction coefficient to inflation to 1.5, which is standard in the literature. We set the steady-state government spending to GDP ratio to be 0.15 and the transfer to GDP ratio to be 0.127, which are consistent with the US average observation. We assume that the steady-state gross inflation is 1. The inflation averaging horizon is set to one year in the baseline calibration.[12] We set the steady-state debt to GDP ratio to 2.5, which is close to the annualized debt-to-GDP ratio estimated using the quarterly data in Bianchi et al. (2023). If all the debt is equally distributed for the three months during a quarter, 7.5 might be the corresponding number at the monthly frequency. However, not all the debts mature within a month, this transformation can be too simplistic. We use 7.5 only for our experiment with the fiscal regime scenario in which the steady state debt ratio is likely to be higher than the monetary regime. We set the debt feedback parameter in the tax rule to 0.05, which is the mid-point of values used in Bhattarai et al. (2023) while assuming no smoothing in the tax rule ($\psi_L = 0$).

The third block is the set of parameters describing shock processes other than a sectoral demand shift shock. We draw on the literature which estimated these parameters from the data. The fourth block consists of four parameters related to the sectoral reallocation friction and the nominal price rigidity as well as the process of a sectoral demand shift shock. We calibrate these parameters to minimize the distance between the model-implied moments and the target moments in the data in

[11]The cost-based expenditure share of G-sector input for the G-sector composite material is 0.7 while the corresponding share of the S-sector input for the S-sector composite material is 0.8.

[12]In the later exercise to match the post-COVID-19 data, we extend this to four years, which is the lower bound of the averaging horizon considered in Hebden, Herbst, Tang, Topa and Winkler (2020).

Table 1: MODEL PARAMETERS

	Description	Value	Source
Panel A: Parameters for household and firms' problems			
β	Time preference	$0.98^{\frac{1}{12}}$	Target real rate = 2%
γ	Risk aversion	2	Comin et al. (2023)
φ	Inverse of Frisch elasticity	2	Comin et al. (2023)
ε	ES between goods and services expenditure	2	Carvalho et al. (2021)
$\sigma_G = \sigma_S$	ES across intermediate output in sector i	4	Hall (2018)
ε_Y	ES between composite material and labor	1.0	Carvalho et al. (2021)
$\bar{\Gamma}^c_G$	Steady-state goods consumption expenditure share	0.2692	Comin et al. (2023)
Γ^G_G	Steady-state government goods consumption share	0.3912	Comin et al. (2023)
Γ^L_G	Weight of labor supply to G-sector	0.32	Cardi et al. (2020)
$\Gamma_{G,G}$	Weight of G-sector product for G-sector composite material	0.7013	Comin et al. (2023)
$\Gamma_{S,S}$	Weight of S-sector product for S-sector composite material	0.6987	Comin et al. (2023)
α_G	Share of material input for G-sector output production	0.5	Carvalho et al. (2021)
α_S	Share of material input for S-sector output production	0.5	Carvalho et al. (2021)
θ_G	Calvo sticky price parameter for G-sector	0.8333	Mean price duration=6 months
θ_S	Calvo sticky price parameter for S-sector	0.9167	Mean price duration=12 months
Panel B: Monetary policy and fiscal variables			
ϕ_Π	Inflation feedback parameter	1.5	Standard
$\frac{\bar{G}}{\bar{Y}}$	Steady-state government spending to output ratio	0.15	BEA, Authors' Calculation
$\frac{\bar{T}}{\bar{Y}}$	Steady-state transfers to output ratio	0.127	BEA, Authors' Calculation
$\frac{\bar{b}}{\bar{Y}}$	Steady-state debt to GDP ratio	2.5/7.5	Authors' Calculation/Bianchi et al. (2023)
ψ_L	Debt feedback parameter	0.05	Bhattarai et al. (2023)
Panel C: Shock process			
ρ_{zG}	Persistence of G-sector productivity shocks	0.919	Carvalho et al. (2021)
ρ_{zS}	Persistence of S-sector productivity shocks	0.925	Carvalho et al. (2021)
ρ_ξ	Persistence of preference shocks	0.94	Carvalho et al. (2021)
ρ_G	Persistence of government spending shocks	0.97	Leeper et al. (2010)
ρ_T	Persistence of transfer shocks	0.94	Leeper et al. (2010)
ρ_R	Persistence of monetary policy shocks	0.7	Davig and Doh (2014)
σ_{zG}	SD of G-sector productivity shocks	0.015	Carvalho et al. (2021)
σ_{zS}	SD of S-sector productivity shocks	0.011	Carvalho et al. (2021)
σ_ξ	SD of preference shocks	0.017	Carvalho et al. (2021)
σ_G	SD of government spending shocks	0.031	Leeper et al. (2010)
σ_T	SD of transfer shocks	0.034	Leeper et al. (2010)
σ_R	SD of monetary policy shocks	0.005	Davig and Doh (2014)
Panel D: Parameters calibrated to match impulse responses to a sectoral demand shift shock			
ε_M	ES across sectoral outputs for composite material	1.1809	Sectoral Inflation IRFs
ε_L	Degree of labor mobility	0.0188	Sectoral Inflation IRFs
ρ_Γ	Persistence of demand shift shocks	0.99	Sectoral Inflation IRFs
σ_Γ	SD of demand shift shocks	0.0011	Sectoral Inflation IRFs
Panel E: Parameters for temporary fiscal regime in Bianchi et al. (2023)			
ρ_T	Persistence of transfer rule	0.5394	Bianchi et al. (2023)
ψ_T	Debt feedback parameter	0.0891	Bianchi et al. (2023)
$\psi_{T,y}$	Output feedback parameters	0.0823	Bianchi et al. (2023)
$\rho_{F,T}(= \rho_{U,T})$	Persistence of funded (unfunded) transfer shocks	0.995	Bianchi et al. (2023)
$\frac{\sigma_{U,T}}{\sigma_{F,T}}$	Relative SD of unfunded transfer shocks	0.2	Bianchi et al. (2023)

Notes: This table shows model parameter values used for our baseline simulation.

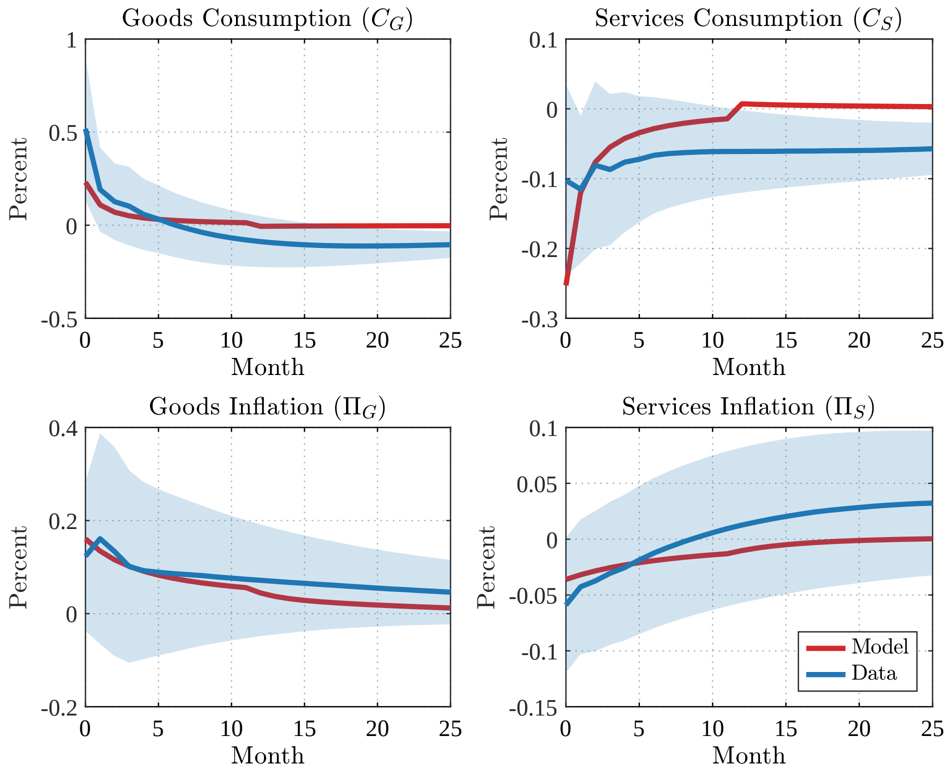

Figure 2: IRFs to Demand Shift Shocks in the Model and Data

Notes: The red line represents the model-implied impulse response to a one-standard deviation increase in $\Gamma^C_{G,t}$ while the blue line represents the corresponding impulse response from the SVAR in Equation (4.1). The shaded area represents the 95% confidence interval.

terms of the percentage deviations and estimate others to match the model-implied impulse response to a sectoral demand shock with those from a reference model (*e.g.*, structural vector-autoregression in which a sectoral demand shock is identified by sign restrictions).

The last block is the set of parameters used only in the specification with a temporary shift to the fiscal regime. We need to pin down five additional parameters related to the transfer feedback rule and funded/unfunded transfer shock processes. We adopt posterior mode estimates from Bianchi et al. (2023) for these parameters.

4.2 Structural Vector-autoregression (SVAR)

We consider a six variable VAR with 3 lags in which the sectoral reallocation shock is identified by sign restrictions on sectoral inflation and output to an unanticipated rise in goods consumption weight. The VAR contains 12 month changes in goods consumption and services consumption as well as changes in the corresponding price level. The VAR also includes the goods consumption weight ($\Gamma^c_{G,t}$) and the proxy policy rate (R_t), which is the measure of monetary policy stance on and off the zero lower bound in Choi, Doh, Foerster and Martinez (2022). We use the proxy policy rate to translate the effect of unconventional policies (*e.g.*, forward guidance and asset purchases) in the space of the short-term interest rate. We use data from July 1976 to December 2019. Since goods consumption weight declined steadily during the sample period, we use the detrended goods consumption weight after subtracting the linear trend from the original measure. We fit the VAR(3) for the vector of six variables ($y_t = [\Delta C_{G,t-12:t}, \Delta C_{S,t-12:t}, \Pi_{G,t-12:t}, \Pi_{S,t-12:t}, \Gamma^c_{G,t}, R_t]$):

$$y_t = A_0 + \sum_{k=1}^{3} A_k y_{t-k} + e_t \,,\; e_t = B\epsilon_t, \tag{4.1}$$

where the structural shocks, ϵ_t, are translated to reduced-form VAR residuals (e_t) through B.

We impose the following sign restrictions to identify a demand shift shock (ε^Γ_t) in the VAR:[13]

$$\frac{\partial \Delta C_{G,t-12+h:t+h}}{\partial \varepsilon^\Gamma_t} > 0 \;\text{ and }\; \frac{\partial \Delta C_{S,t-12+h:t+h}}{\partial \varepsilon^\Gamma_t} < 0 \,,\, \forall h \geq 0$$
$$\frac{\partial \Pi_{G,t-12+h:t+h}}{\partial \varepsilon^\Gamma_t} > 0 \;\text{ and }\; \frac{\partial \Pi_{S,t-12+h:t+h}}{\partial \varepsilon^\Gamma_t} > 0 \,,\, \forall h \geq 0,$$
$$\frac{\partial \Gamma^c_{G,t+h}}{\partial \varepsilon^\Gamma_t} > 0, \;\; \forall h \geq 0.$$

We estimate four parameters, $\mathbf{\Theta} = \{\varepsilon_M, \varepsilon_L, \rho_\Gamma, \sigma_\Gamma\}$, to minimize the distance between the model IRFs of sectoral inflation ($\Pi_{G,t}$ and $\Pi_{S,t}$) and the SVAR's IRFs of sectoral inflation. Figure 2 compares these IRFs in the calibrated model with the SVAR's median IRFs.

4.3 Inspecting Inflation Dynamics through Impulse Responses

Figures 3–6 display the impulse responses of relative price, real wage, marginal cost, and sectoral price inflation to structural shocks in the model under the baseline calibration in Table 1. As expected, aggregate shocks such as fiscal and monetary policy shocks, as well as an intertemporal preference shock, cause real wages and price inflation in different sectors to move in the same direction. Conversely, a sector-specific demand shock leads to a negative comovement in sectoral price inflation. Due to the complementarity in the production network, sector-specific technology shocks do not generate a negative comovement in sectoral price inflation, with real wages in both sectors moving in the same direction shortly after the realization of shocks. In addition, the higher price stickiness in the service sector ($\theta_S > \theta_G$) generates more persistent responses of sectoral prices than in the goods sector.

Figure 7 displays the autocorrelation of the model-implied one-year inflation $\Pi_{12,t}$ at different horizons. The autocorrelation of each shock is overlaid with the autocorrelation of the corresponding impulse response of inflation to that shock. In most cases, the autocorrelation of the impulse response decays more slowly than the autocorrelation of the shock, at least within a horizon of less than a year. The only exception is the demand shift shock, where the autocorrelation of the shock decays

[13] We impose sign restrictions up to 2 months after the realization of a shock. SVAR impulse responses are not sensitive to the maximum horizon of sign restrictions.

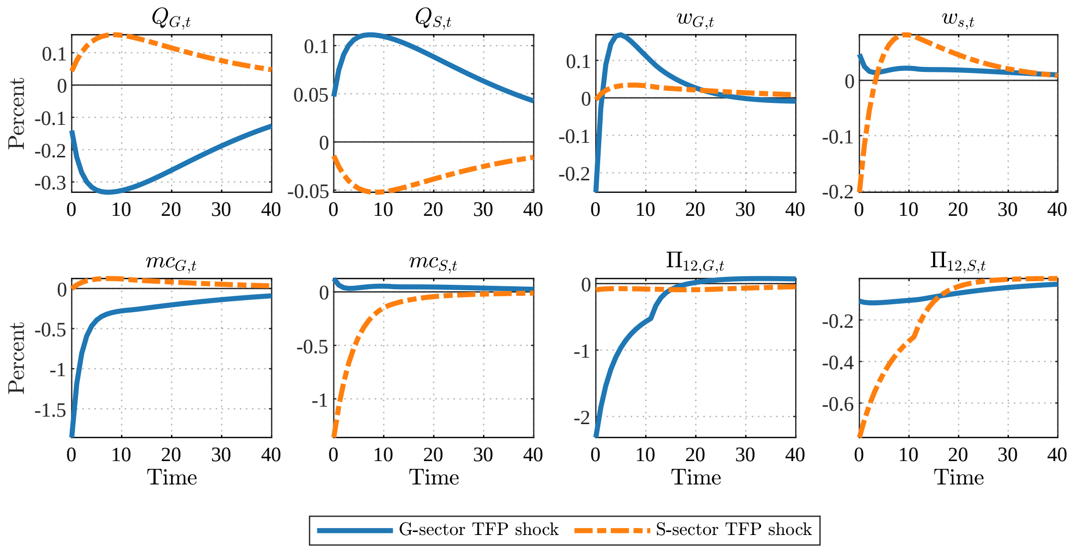

Figure 3: IRFs to Sectoral Technology Shocks

Notes: This figure shows impulse responses of key model variables to a goods sector TFP shock (blue solid line) and to a services sector TFP shock (orange dashed line) in the baseline model.

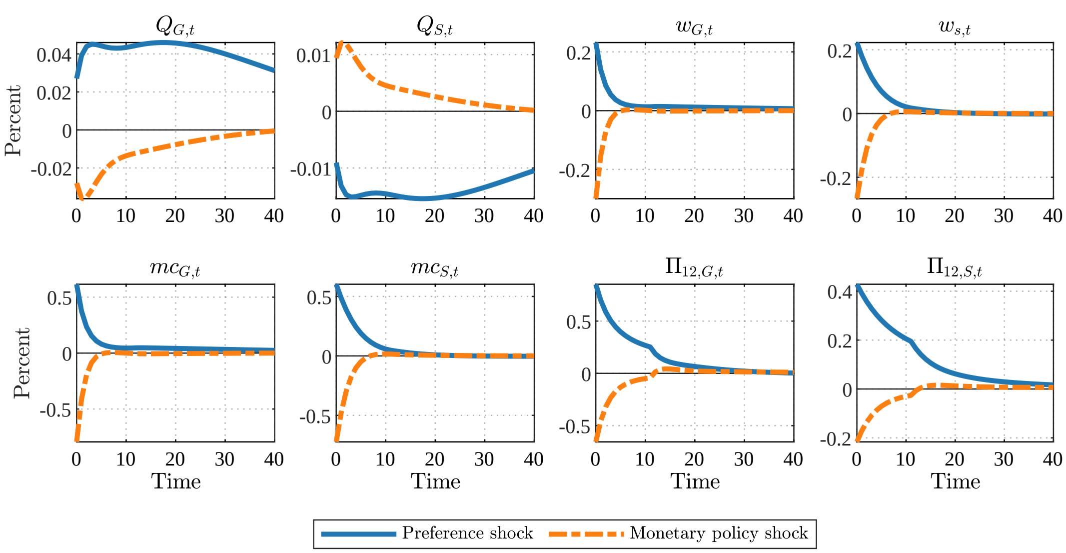

Figure 4: IRFs to Preference and Monetary Policy Shocks

Notes: This figure shows the impulse responses of key model variables to a preference shock (blue solid line) and to a monetary policy shock (orange dashed line) in the baseline model.

more slowly than the autocorrelation of the impulse response. The demand shift shock exhibits high persistence with an autocorrelation coefficient of 0.99, while the impulse response of inflation in the SVAR to a demand shift shock is not as persistent. This discrepancy may be due to the calibration process, where the model is adjusted to match the impulse response from the SVAR, which decays faster than implied by the autocorrelation of the demand-shift shock. Additionally, under the baseline calibration, the strong inflation feedback mitigates the impact of the persistent

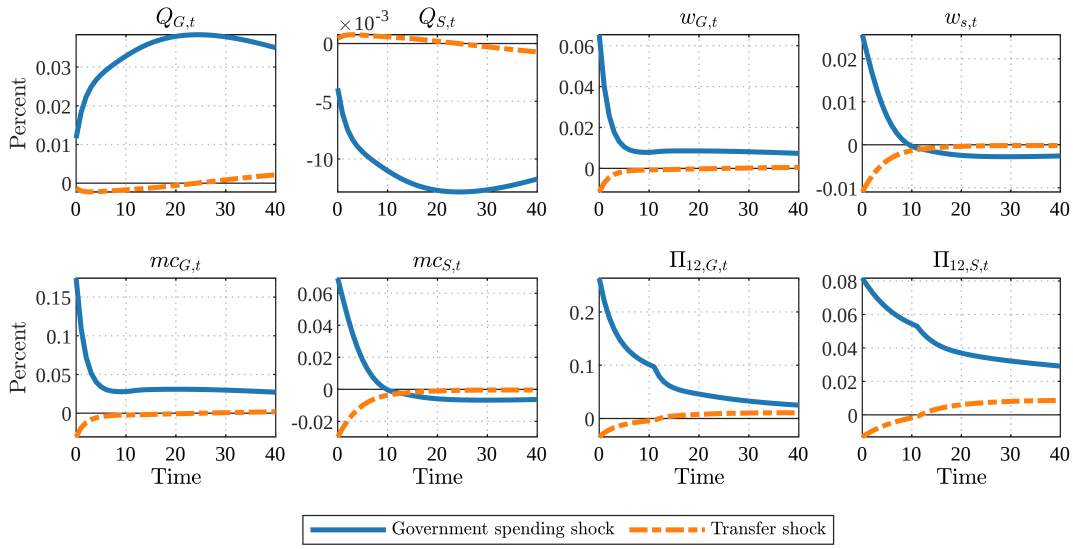

Figure 5: IMPULSE RESPONSES TO FISCAL SHOCKS

Notes: This figure shows impulse responses of key model variables to a government spending shock (blue solid line) and to a transfer shock (orange dashed line) in the baseline model.

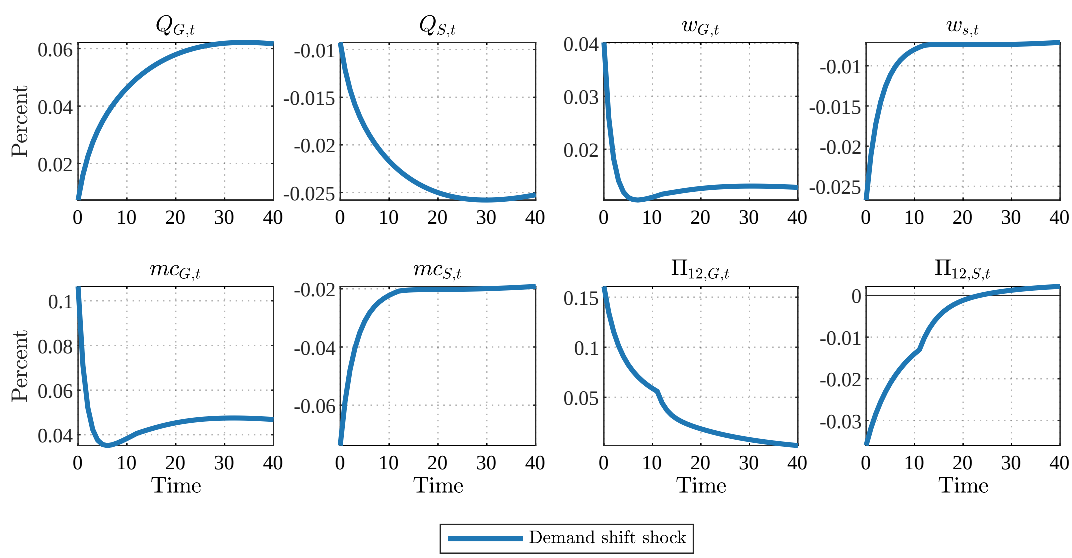

Figure 6: IMPULSE RESPONSES TO A DEMAND SHIFT SHOCK

Notes: This figure shows impulse responses of key model variables to a demand shift shock in the baseline model.

shock on inflation.

Table 2 presents the long-run variance decomposition of one-year inflation into various shocks under the baseline calibration of the model. Sectoral shocks, primarily sector-specific productivity shocks, account for over 60% of the long-run variance of inflation, while aggregate demand shocks explain the remaining portion. The contribution from a sectoral demand shift shock is negligible under the baseline calibration, which aligns with the findings of the SVAR analysis during the

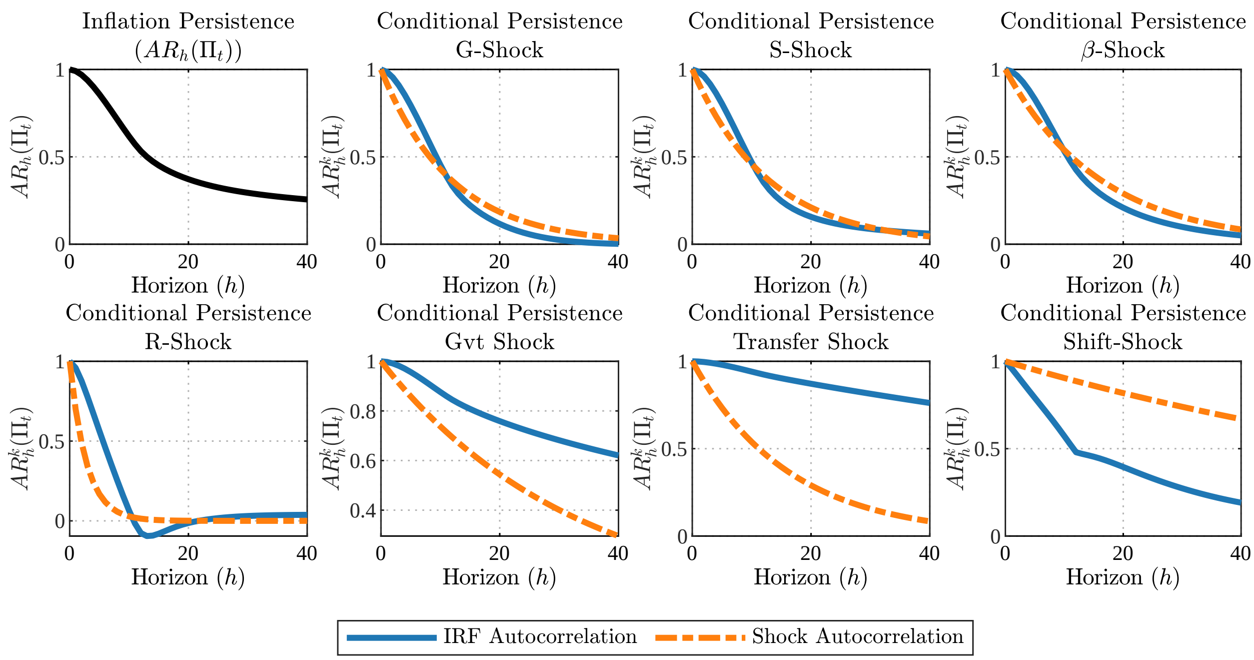

Figure 7: INFLATION PERSISTENCE $(AR_h(\Pi_{12,t}))$

Notes: This figure shows the persistence of inflation in the baseline model. The top left panel shows unconditional inflation persistence for horizon h, $AR_h(\Pi_{12,t})$, in Equation (3.3) and the rest of panels show the conditional inflation persistence in response to each shock k, $AR_h^{(k)}(\Pi_{12,t})$. "G-Shock" is a goods sector TFP shock, "S-Shock" is a services sector TFP shock, "β-Shock" is a preference shock, "R-Shock" is a monetary policy shock, "Gvt Shock" is a government spending shock, and "Shift-Shock" is a demand shift shock. We plot both autocorrelation of inflation response (blue solid lines) and autocorrelation of each shock (orange dashed lines).

pre-pandemic period.

4.4 Understanding the Post-COVID-19 Inflation Dynamics

We use the calibrated model to understand the post-COVID-19 inflation dynamics. To do so, we estimate structural shocks in the model using post-COVID-19 data on goods inflation, cyclical components of goods consumption, government spending and transfers, as well as goods consumption weight and the demeaned proxy funds rate. Shocks are estimated to fit these six variables during the post-COVID-19 period (March 2020–December 2022). To match model variables, we demean inflation and calculate the cyclical components of consumption, government spending, and inflation using the filter in Hamilton (2018). Figure 8 shows the variables used to obtain shock estimates.

Given the shock estimates, we can examine the model's fit for aggregate inflation, which was not used in the shock estimation. In our two-sector model, estimating shocks with goods consumption and goods consumption weight should pin down aggregate consumption. Hence, we measure the model fit by how well it can explain aggregate inflation consistent with aggregate consumption. This allows us to test six alternative channels that have been suggested to explain the post-COVID-19

Table 2: INFLATION VARIANCE DECOMPOSITION

Shock	Rel. Importance (%)	Shock	Rel. Importance (%)
G-sector TFP shock	28.30	Government spending shock	7.37
S-sector TFP shock	33.33	Transfer shock	0.63
Monetary policy shock	1.77	Sectoral demand shift shock	0.07
Preference shock	28.53		

Notes: This table presents the variance decomposition of inflation from the model calibrated based on the pre-COVID-19 period data. The decomposition may not add up to 100% due to rounding.

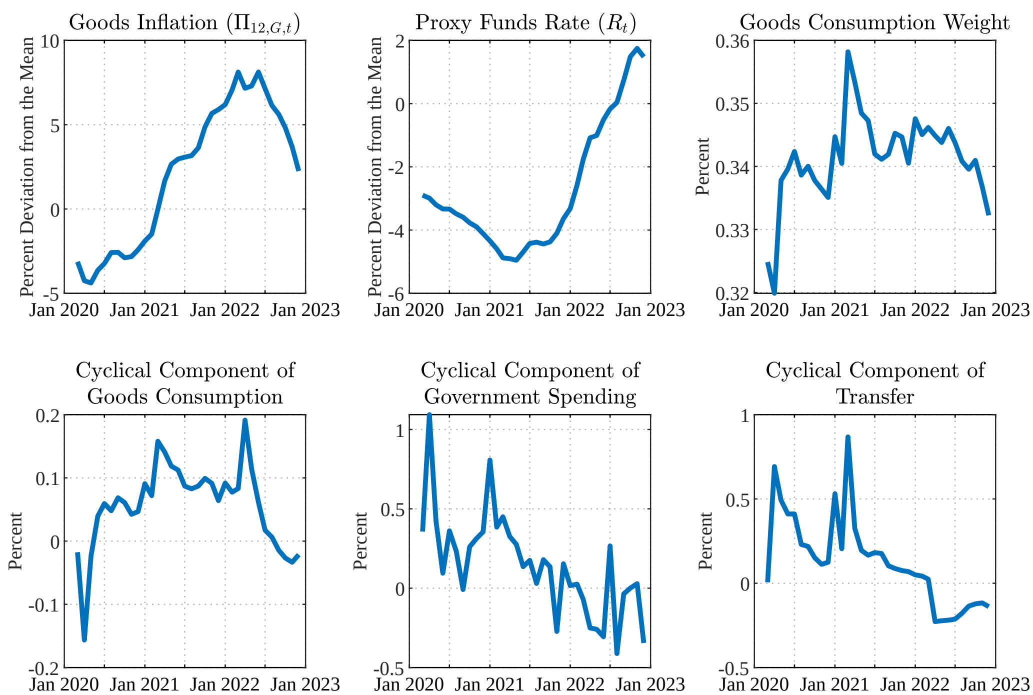

Figure 8: OBSERVED VARIABLES FOR SHOCK ESTIMATES

Notes: This figure displays the observed variables used for shock estimation from March 2020 to December 2022. Goods inflation and proxy funds rates are expressed as percent deviations from historical averages. For goods consumption, government spending, and transfers, the cyclical components are obtained using the Hamilton filter.

inflation dynamics. These alternative channels include (1) a permanent shift to the fiscal regime, (2) frictions to production process, (3) accommodative monetary policy with longer AIT (average inflation targeting) horizons, (4) volatile demand shift disturbances, (5) a temporary shift to the fiscal regime through unfunded transfer shocks, and (6) a temporary shift to the fiscal regime combined with accommodative monetary policy with longer AIT horizons.

Table 3: ALTERNATIVE CALIBRATIONS

	Alternative parameter values
(1) Fiscal regime	$\phi_\Pi = 0\,,\ \psi_L = 0\,,\ \frac{\bar{b}}{\bar{Y}} = 7.5$
(2) Friction to production process	$\varepsilon_M = 0.01$
(3) Accommodative monetary policy with longer AIT horizon	$\phi_\Pi = 1.1, T = 48$
(4) Volatile demand shift shock	$\sigma_\Gamma = 0.015$
(5) BFM funded/unfunded transfer shocks	$\sigma_{F,T} = 0.034\,,\ \sigma_{U,T} = 0.0068\,,\ \rho_{F,T} = \rho_{U,T} = 0.995$
(6) BFM funded/unfunded transfer shocks + accomoodative MP	$\sigma_{F,T} = 0.034,\ \sigma_{U,T} = 0.0068,\ \rho_{F,T} = \rho_{U,T} = 0.995,$ $\phi_\Pi = 1.1,\ T = 48$

Notes: This table presents altered parameter values for six alternative calibration exercises. All other model parameters remain the same as the baseline calibration parameters in Table 1. BFM stands for the baseline model in Bianchi et al. (2023).

Table 4: COMPARISON OF ALTERNATIVE CALIBRATIONS

Specification	Correlation	Relative Std.	Relative Persistence
Baseline	0.9721	0.9743	0.9178
(1) Fiscal regime	0.9783	4.7547	0.9412
(2) Friction to production process	0.9663	0.9249	0.9055
(3) Accommodative monetary policy with longer AIT horizon	0.9836	1.0322	0.9426
(4) Volatile demand shift shock	0.9516	0.8460	0.8761
(5) BFM funded/unfunded transfer shocks	0.9917	1.0909	0.9672
(6) BFM funded/unfunded transfer shocks + accomoodative MP	0.9911	1.0918	0.9672

Notes: This table presents the correlation between model-implied inflation and observed aggregate inflation during the post-COVID-19 period (column 2), the relative volatility of model-implied inflation compared to actual data (column 3), and the relative persistence of model-implied inflation compared to actual data averaged across different horizons shown in Figure 16 (column 4).

4.4.1 Historical Shock Decomposition for Post-COVID-19 Inflation

We show the historical shock decomposition of aggregate inflation based on shock estimates with the recalibrated models to capture six different specifications as well as the results from the baseline calibration. We use the 12-month change in the headline PCE price index as the measure of aggregate inflation. Table 3 shows the parameter values altered from the baseline calibration in the four different recalibration exercises. We discuss how alternative recalibrations of the models improve or worsen the model fit relative to the baseline calibration.

Baseline calibration Figure 9 shows the historical shock decomposition of aggregate inflation during the post-COVID-19 period (March 2020 to December 2022) for the baseline calibration. We use parameter values from Panels A to D in Table 1. The model-implied inflation in the black solid line fits the general contour of service inflation in the data well. The correlation between the model-implied inflation and the realized data and relative volatility of the model implied measure compared to the data in Table 4 confirm this finding. According to the baseline specification, the

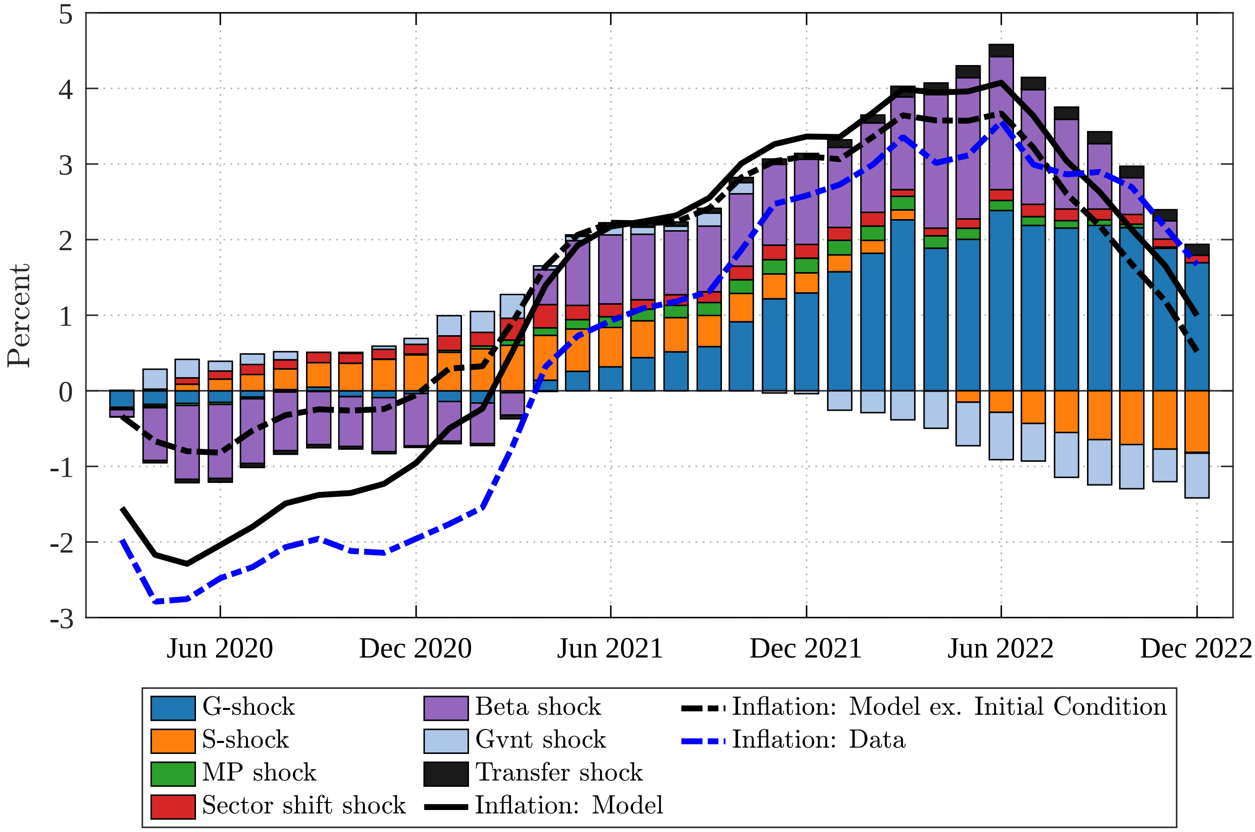

Figure 9: HISTORICAL SHOCK DECOMPOSITION OF $\Pi_{12,t}$: BASELINE CALIBRATION

Notes: This figure shows historical shock decomposition of inflation under the alternative model with more distortions in production process where we set $\varepsilon_M = 0.01$. We use the (demeaned) 12-month change in the headline PCE price index from January 1960 to February 2023 as the measure of aggregate inflation. "G-Shock" is a goods sector TFP shock, "S-Shock" is a services sector TFP shock, "β-Shock" is a preference shock, "R-Shock" is a monetary policy shock, "Gvt Shock" is a government spending shock, and "Shift-Shock" is a demand shift shock.

surge in inflation during the early 2021 is largely driven by a negative service-sector technology shock while the subsequent rise is driven by a negative goods-sector technology shock and a positive intertemporal preference shock. Except for the intertemporal preference shock, demand-side shocks do not play any major role in the recent inflation episode. Since the baseline calibration keeps the aggressive inflation feedback and the passive fiscal regime in which the fiscal authority adjust taxes to stabilize the debt-to-output ratio, there is less room for demand-side shocks to explain the persistently high inflation by construction. We examine if alternative calibrations that allow more meaningful roles for demand-side shocks can better explain the recent episode.

Fiscal regime The first alternative specification that we consider is a permanent shift to the fiscal regime, which might be the polar opposite of the active monetary policy regime in the baseline calibration. In the baseline specification, the monetary authority actively adjusts the interest rate

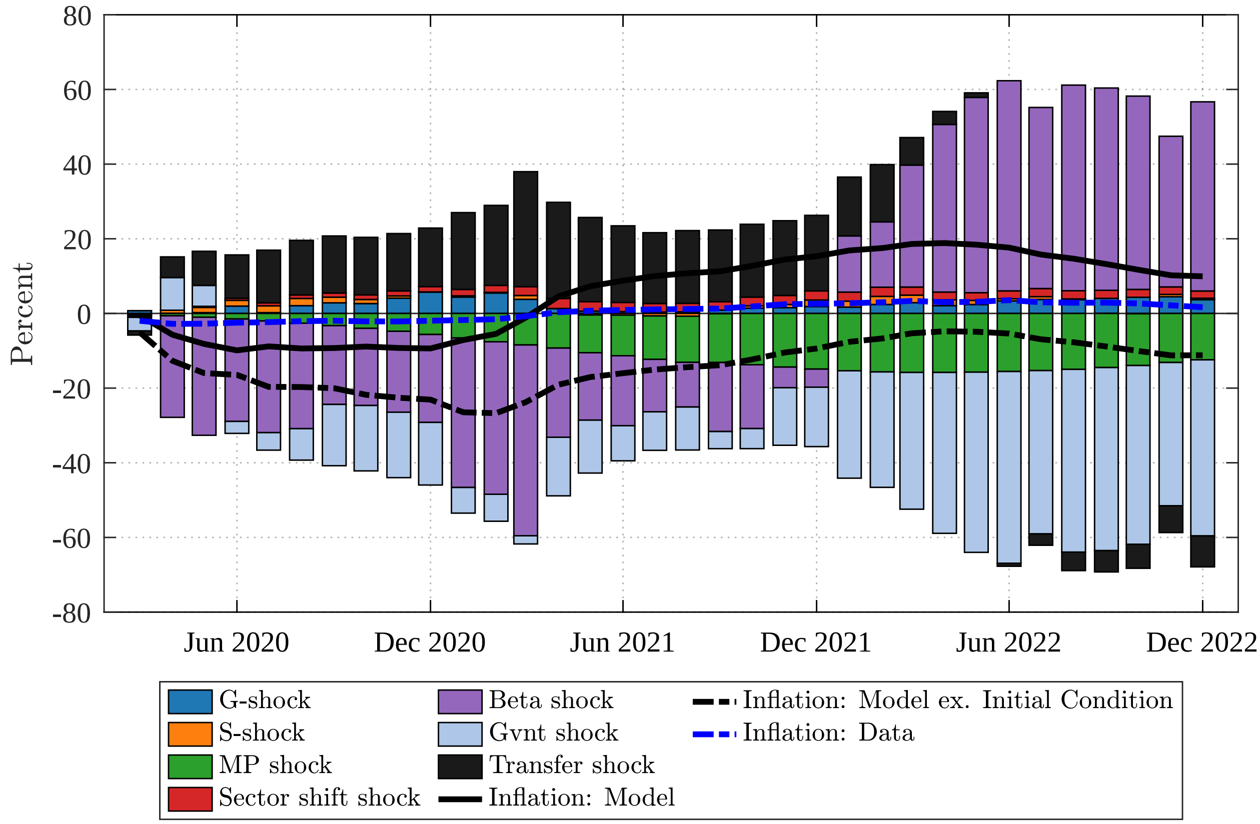

Figure 10: HISTORICAL SHOCK DECOMPOSITION OF $\Pi_{12,t}$: FISCAL REGIME

Notes: This figure shows historical shock decomposition of inflation under the fiscal regime where we set $\phi_\pi = 0.0$ and $\psi_L = 0.0$. We use the (demeaned) 12-month change in the headline PCE price index from January 1960 to February 2023 as the measure of aggregate inflation. "G-Shock" is a goods sector TFP shock, "S-Shock" is a services sector TFP shock, "β-Shock" is a preference shock, "R-Shock" is a monetary policy shock, "Gvt Shock" is a government spending shock, and "Shift-Shock" is a demand shift shock.

in response to inflation and the fiscal authority adjusts the tax rate to stabilize the debt-to-GDP ratio given the interest rate rule set by the monetary authority. To model the fiscal regime, we shut down the inflation feedback in the monetary policy rule ($\phi_\Pi = 0$) and set the debt feedback parameter to be zero ($\psi_L = 0$). We also increase the steady-state debt-to-GDP ratio to 7.5 in this alternative calibration to match the monthly counterpart of the quarterly frequency value in Bianchi et al. (2023).

Figure 10 shows the historical shock decomposition of aggregate inflation in the fiscal regime calibration. In this specification, transfer shocks explain the bulk of inflation up until early 2022, after which intertemporal preference shocks drive inflation. Sectoral technology shocks play a smaller role in this calibration. Since the model assumes no systematic response of the interest rate to inflation, the 2022 policy tightening is entirely captured by a series of monetary policy shocks, which have a negative impact on inflation. The correlation between the model-implied inflation and the data is slightly higher than in the baseline calibration, but the model implies inflation that is

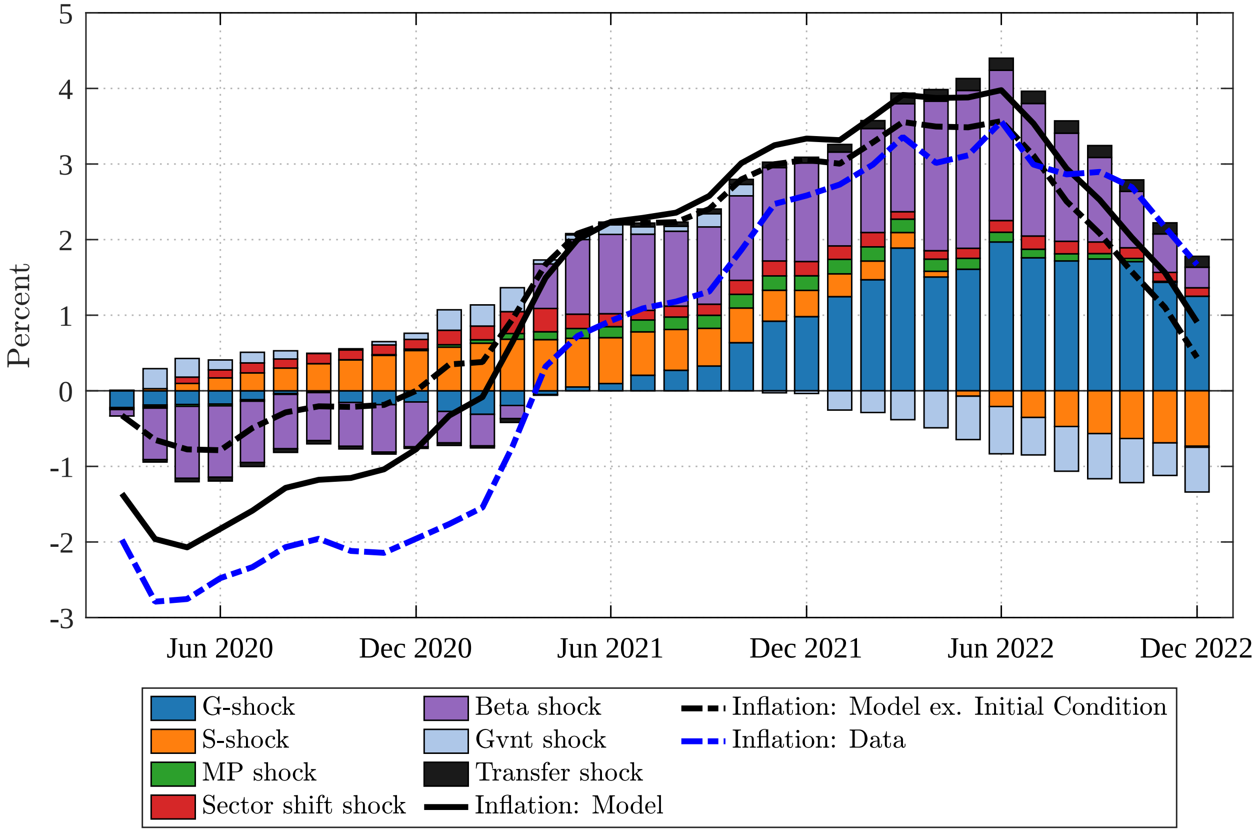

Figure 11: HISTORICAL SHOCK DECOMPOSITION OF $\Pi_{12,t}$: PRODUCTION FRICTION

Notes: This figure shows historical shock decomposition of inflation under the alternative model with more distortions in production process where we set $\varepsilon_M = 0.01$. We use the (demeaned) 12-month change in the headline PCE price index from January 1960 to February 2023 as the measure of aggregate inflation. "G-Shock" is a goods sector TFP shock, "S-Shock" is a services sector TFP shock, "β-Shock" is a preference shock, "R-Shock" is a monetary policy shock, "Gvt Shock" is a government spending shock, and "Shift-Shock" is a demand shift shock.

nearly five times more volatile than the data, as shown in Table 4. While this permanent shift to the fiscal regime may not be realistic due to the counterfactually high volatility of inflation implied by the model, the interpretation of fiscal shocks as the driver of the initial surge in inflation during 2021 is appealing given the timing of the passage of a large fiscal stimulus at that time. We will consider a more realistic alternative specification that includes a temporary shift to the fiscal regime later.

Disruption in production process Another channel that has drawn a lot of attention in terms of explaining the surge in inflation is supply chain disruption. While our model lacks the detailed trade channel in Amiti et al. (2023) and Comin et al. (2023), the increased friction in the production process, such as a lower elasticity of substitution between the intermediary inputs, can capture this channel in a similar way. To incorporate this channel, we can recalibrate the model by decreasing ε_M to 0.01 from 1.1809 in the baseline calibration. This change reflects a higher degree of friction in the production process.

Figure 11 shows the results from the historical decomposition, which is very similar to the baseline calibration case. Negative sectoral technology shocks (service sector in the beginning of the recent inflationary episode and goods-sector later) play a significant role in explaining inflation. The intertemporal shock appears to be the only prominent demand-side shock, and its role is slightly bigger than in the baseline calibration.

However, it is important to note that the model's fit for inflation data deteriorates compared to the baseline calibration, as shown in Table 4. This does not necessarily mean that the production-side friction is not important. Instead, our baseline calibration already has a high degree of friction in the mobility of labor across sectors because ϵ_L is close to 0. As labor accounts for half of the input share, the degree of friction in the sectoral reallocation of labor in the baseline calibration might be enough to generate a significant amount of friction in the production process.

Accommodative monetary policy and new monetary policy framework Beside the fiscal channel, a loose monetary policy was also suggested as a main driver of inflation. For example, Gagliardone and Gertler (2023) argue that the loose monetary policy coupled with an oil price shock explains the surge in inflation during the post-COVID-19 period. Their baseline calibration of the inflation feedback parameter in the Taylor rule is 2, but they note that a weaker monetary policy response would increase inflation further. To capture the lower inflation feedback, we decrease ϕ_Π from 1.5 to 1.1 and increase the averaging horizon in inflation targeting to 4 years from the one year in the baseline calibration.

Figure 12 shows the results from the historical decomposition. The model-implied inflation is more highly correlated with the realized data than in the baseline calibration, as shown in Table 4. In addition, the volatility and persistence of model-implied inflation is closer to actual data. Under this specification, the government spending shock plays a somewhat larger role in the initial surge in inflation during the first half of 2021 than in the baseline specification, as the lower inflation feedback in the monetary policy rule amplifies the inflationary effect of the government spending shock. After that, the model-implied inflation's trajectory is quite similar to the baseline specification, as negative sector technology shocks drive the persistently high inflation.

Unlike Gagliardone and Gertler (2023), we do not find a significant role for a monetary policy shock in this alternative calibration. However, the intertemporal preference shock accounts for a large share of inflation since early 2021. A part of the discrepancy may arise from the fact that Gagliardone and Gertler (2023) assume monetary policy feedback to core inflation instead of headline inflation, which can amplify the effect of an expansionary monetary shock on headline inflation when oil prices are high because the systematic part of monetary policy looks through oil price inflation.

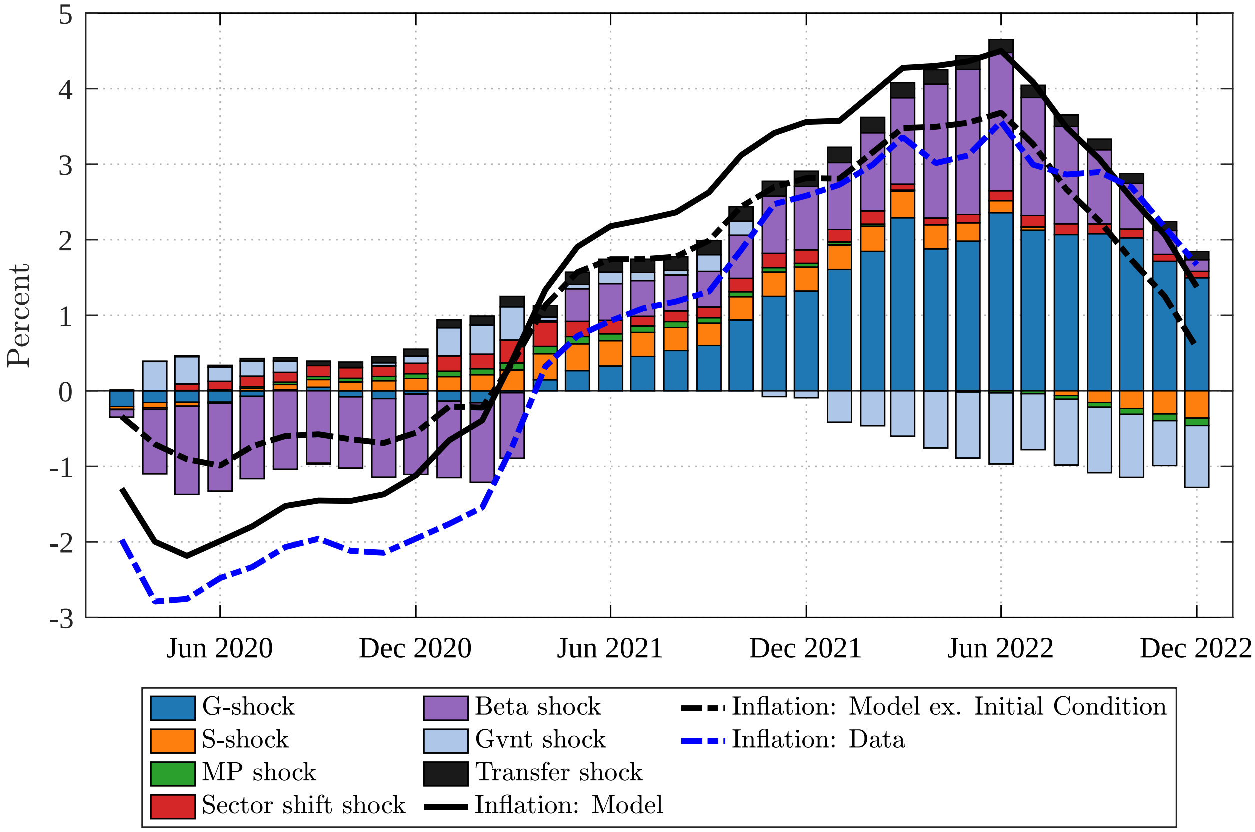

Figure 12: HISTORICAL SHOCK DECOMPOSITION OF $\Pi_{12,t}$: LOWER INFLATION FEEDBACK AND LONGER AIT HORIZON

Notes: This figure shows historical shock decomposition of inflation under the alternative model with a lower inflation feedback ($\phi_\pi = 1.1$) and a longer AIT horizon ($T = 48$). We use the (demeaned) 12-month change in the headline PCE price index from January 1960 to February 2023 as the measure of aggregate inflation. "G-Shock" is a goods sector TFP shock, "S-Shock" is a services sector TFP shock, "β-Shock" is a preference shock, "R-Shock" is a monetary policy shock, "Gvt Shock" is a government spending shock, and "Shift-Shock" is a demand shift shock.

The alternative specification of monetary policy does not find a contractionary monetary policy shock to reduce inflation in 2022, although the Federal Reserve significantly tightened monetary policy. It is not so puzzling if one can take the 2022 rate hike mostly as the systematic response to high inflation as in Aruoba and Drechsel (2022). In fact, the real interest rate was negative for most of 2022 due to high inflation and the model attributes some part of inflation to an intertemporal preference shock that reduces the real interest rate by increasing the convenience yield of government bonds more than otherwise.

Volatile sectoral demand shift shock To consider the case of increasing the volatility of a demand shift shock, we can recalibrate the model by increasing the standard deviation of the demand shift shock (σ_Γ) from 0.015 to 0.15.

Figure 13 shows the historical decomposition of $\Pi_{12,t}$ using this alternative specification.

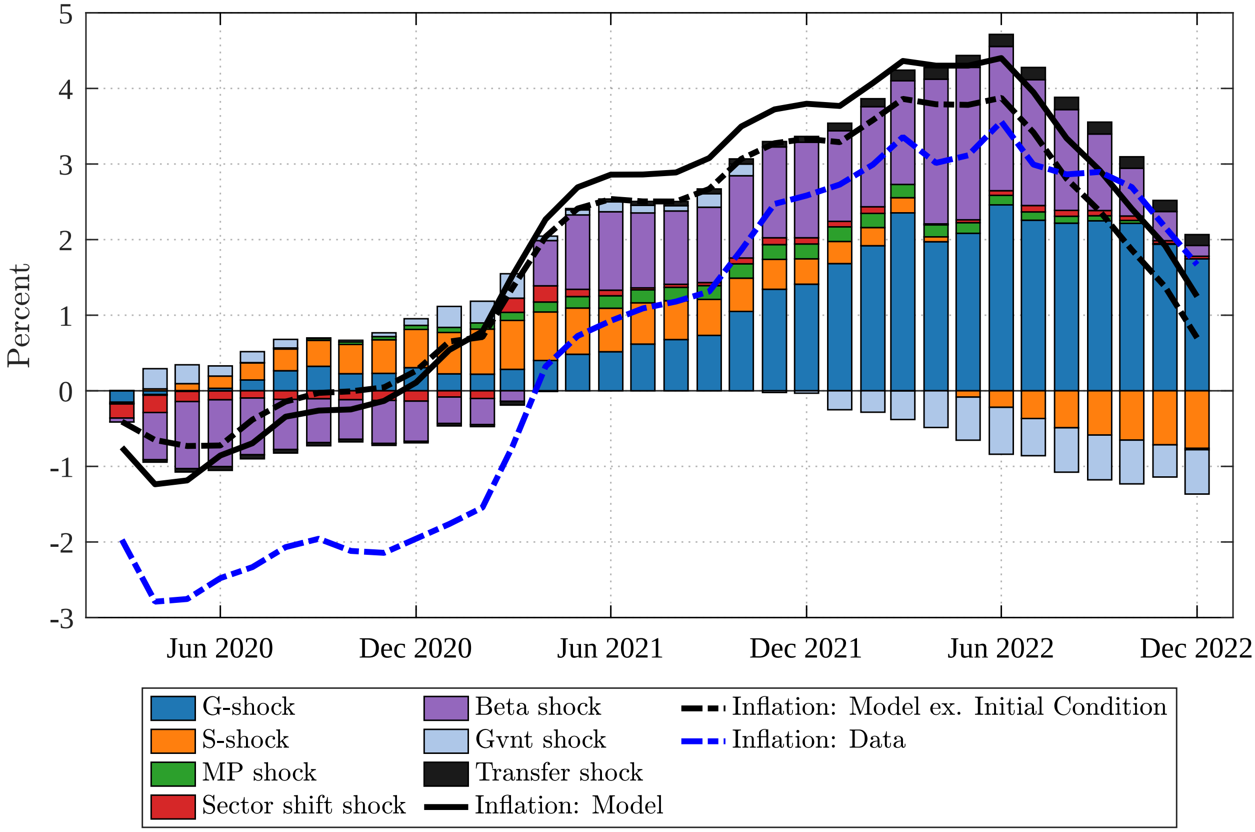

Figure 13: HISTORICAL SHOCK DECOMPOSITION OF $\Pi_{12,t}$: VOLATILE DEMAND SHIFT SHOCK

Notes: This figure shows historical shock decomposition of inflation under the alternative model with a more volatile demand shift shock ($\sigma_\Gamma = 0.15$). We use the (demeaned) 12-month change in the headline PCE price index from January 1960 to February 2023 as the measure of aggregate inflation. "G-Shock" is a goods sector TFP shock, "S-Shock" is a services sector TFP shock, "β-Shock" is a preference shock, "R-Shock" is a monetary policy shock, "Gvt Shock" is a government spending shock, and "Shift-Shock" is a demand shift shock.

However, this modification does not improve the model fit for inflation compared to the baseline calibration, as shown in Table 4. Interestingly, the role of a sectoral demand shift shock in explaining the initial surge of inflation in early 2021 is actually smaller than in the specifications with increased production friction or lower inflation feedback. This suggests that the details of the amplification channel are more important in making this particular shock relevant for explaining the recent inflationary episode.

BFM funded and unfunded transfer shocks The COVID-19 crisis triggered the largest fiscal expansion in the post World War II period as the Congress passed more than \$4 trillion in stimulus packages (\$2.2 trillion from the CARES Act in 2020 and \$1.9 trillion from the ARP Act in 2021). When the fiscal authority does not adjust taxes to repay debt incurred to finance increased spending, these fiscal shocks can be quite inflationary as we see from the alternative specification with a

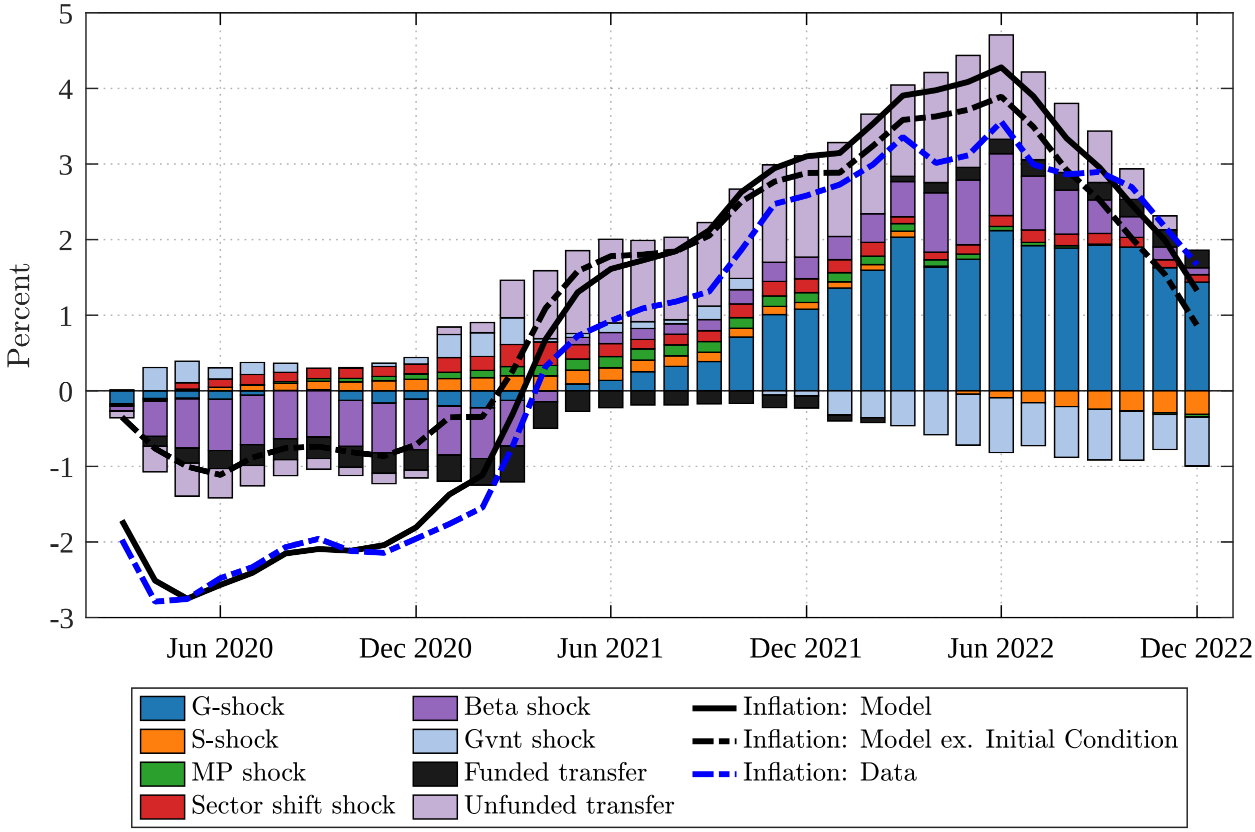

Figure 14: HISTORICAL SHOCK DECOMPOSITION OF $\Pi_{12,t}$: BFM FUNDED/UNFUNDED TRANSFER SHOCKS

Notes: This figure shows historical shock decomposition of inflation under the alternative model with BFM funded and unfunded transfer shocks . We use the (demeaned) 12-month change in the headline PCE price index from January 1960 to February 2023 as the measure of aggregate inflation. "G-Shock" is a goods sector TFP shock, "S-Shock" is a services sector TFP shock, "β-Shock" is a preference shock, "R-Shock" is a monetary policy shock, "Gvt Shock" is a government spending shock, and "Shift-Shock" is a demand shift shock.

permanent shift to the fiscal regime. However, the permanent shift generates volatile inflation that does not fit the post-COVID-19 inflation data. We can consider a middle ground in which only some part of the debt to finance additional fiscal spending is unfunded because the fiscal authority does not raise taxes to repay it while the remaining part of the debt is expected to be repaid through tax increases. Such a model, used in Bianchi et al. (2023), can capture a temporary shift to the fiscal regime. We consider the alternative specification in which transfer shocks are divided into "funded" and "unfunded" parts. Both fiscal policy and monetary policy are assumed not to respond to "unfunded" transfer shocks.

Figure 14 shows the historical shock decomposition of $\Pi_{12,t}$ in the specification with a temporary shift to the fiscal regime. As in the permanent shift to the fiscal regime, fiscal shocks (and a sectoral demand shift shock to a lesser degree) play a dominant role in explaining the initial surge in inflation but the model fits the volatility of inflation in the data reasonably well as shown in Table 4. It also

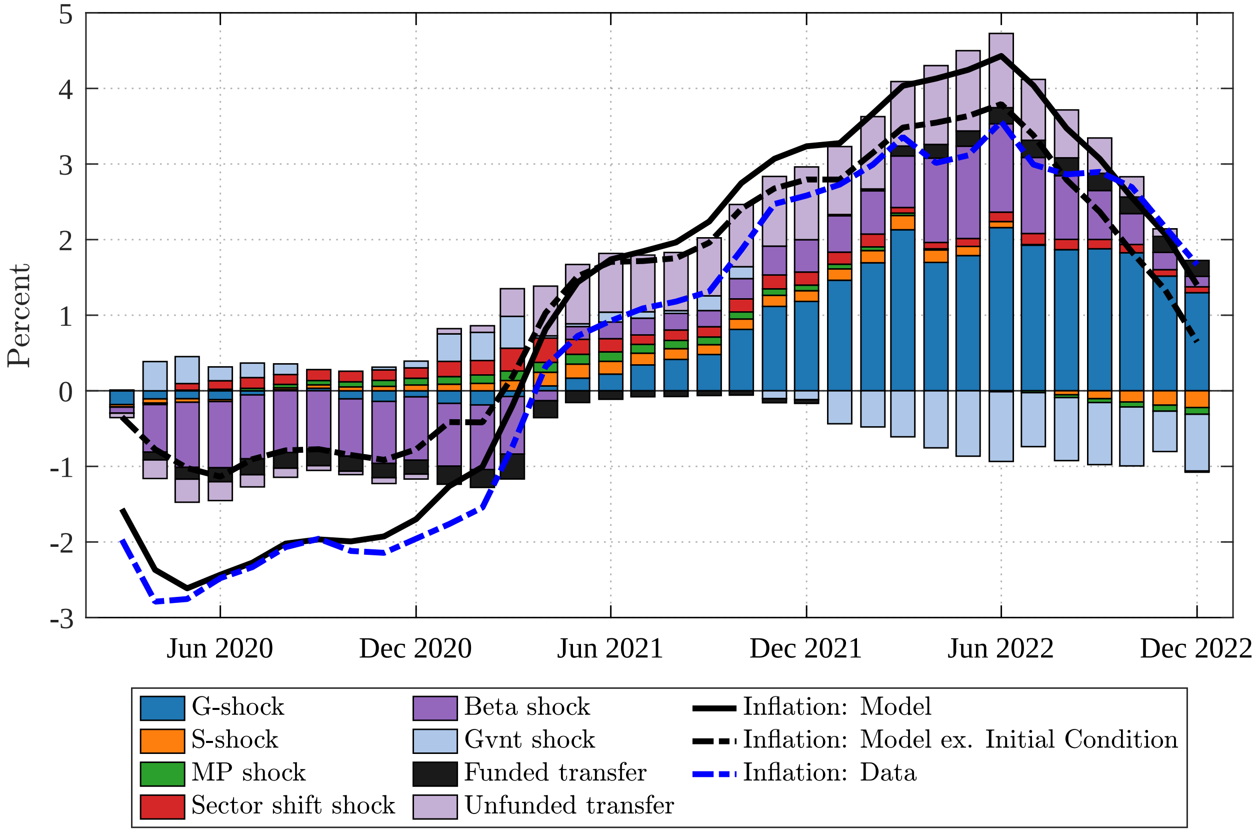

Figure 15: HISTORICAL SHOCK DECOMPOSITION OF $\Pi_{12,t}$: BFM FUNDED/UNFUNDED TRANSFER SHOCKS WITH ACCOMMODATIVE MONETARY POLICY

Notes: This figure shows historical shock decomposition of inflation under the alternative model with BFM funded and unfunded transfer shocks as well as a lower inflation feedback ($\phi_\pi = 1.1$) and a longer AIT horizon ($T = 48$). We use the (demeaned) 12-month change in the headline PCE price index from January 1960 to February 2023 as the measure of aggregate inflation. "G-Shock" is a goods sector TFP shock, "S-Shock" is a services sector TFP shock, "β-Shock" is a preference shock, "R-Shock" is a monetary policy shock, "Gvt Shock" is a government spending shock, and "Shift-Shock" is a demand shift shock.

captures inflation persistence better than any other specification. Under this specification, unfunded transfer shocks account for the largest share of inflation in 2021 and 2022 while other shocks (*e.g.*, intertemporal preference shock, goods-sector technology shock) account for smaller shares relative to other specifications. Our result extends a similar finding in the one-sector model of Bianchi et al. (2023) to a two-sector model in which sectoral technology shocks can compete with fiscal shocks in explaining the post-COVID-19 period inflation.

BFM funded and unfunded transfer shocks with accommodative monetary policy The specification with a temporary shift to the fiscal regime fits the inflation data overall better than other specifications and provides the narrative consistent with other empirical works (*e.g.*,Santacreu, Young and de Soyres (2022)). Nonetheless, we would like to evaluate a potential independent role played by the Federal Reserve's announcement of the new monetary policy framework, which was emphasized by Bocola et al. (2024), for example. Hence, we lower the inflation feedback parameter in the monetary policy rule to 1.1 and lengthen the averaging horizon in target inflation to 48 months in addition to a temporary shift to the fiscal regime in this alternative specification. Table 4 shows the model fit barely changes.

As Figure 15 shows, the historical shock decomposition of $\Pi_{12,t}$ is also little changed as we add changes in the monetary policy rule to the specification with a temporary shift to the fiscal regime. Since monetary policy already changes in the specification with a temporary shift to the fiscal regime in the form of responding to the gap between realized inflation and inflation incurred by unfunded transfer shocks, the additional change to the monetary policy does not appear to be material for explaining the post-COVID-19 inflation.

4.4.2 Decomposition of Inflation Persistence

One feature of the post-COVID-19 inflation data that is challenging to explain is the persistent rise and slow decline in aggregate inflation while goods inflation declined substantially during the late 2022. Although goods inflation sharply declined after peaking in the summer of 2022, the decline was more modest in aggregate inflation due to the sluggish decline in services inflation as shown in Figure 1. The model-implied persistence of inflation can be represented by a weighted average of the autocorrelations in inflation responses to various structural shocks. To analyze this, we compute the autocorrelations of $\Pi_{12,t}$ at horizons from one month to six months and compare them with the model-implied persistence of inflation.

Figure 16 presents the model-implied inflation persistence at different horizons using the smoothed estimates of shocks for the alternative model calibrations. The results show that incorporating a shift in monetary or fiscal regimes provides a better fit for the persistence of inflation in the data compared to other specifications. In the absence of such a shift, the autocorrelation of inflation decreases at a faster rate than observed in the data as the horizon lengthens.

What can explain the relatively slow decay in inflation in the case with policy shifts? Figure 17 illustrates the relationship between changes in monetary policy parameters and the model-implied inflation persistence, as well as the long-run variance decomposition of inflation. When the value of the inflation feedback parameter is lowered, the weight of the government spending shock increases in the long-run variance of inflation, as it is more persistent than other shocks. Consequently, inflation persistence also increases. A shift to the fiscal regime can have similar effects on government spending shocks, either by accompanying no feedback to all shocks (permanent shift) or by introducing an unfunded transfer shock (temporary shift). On the other hand, lowering the elasticity of substitution among intermediary inputs (ϵ_M) or lengthening the averaging horizon

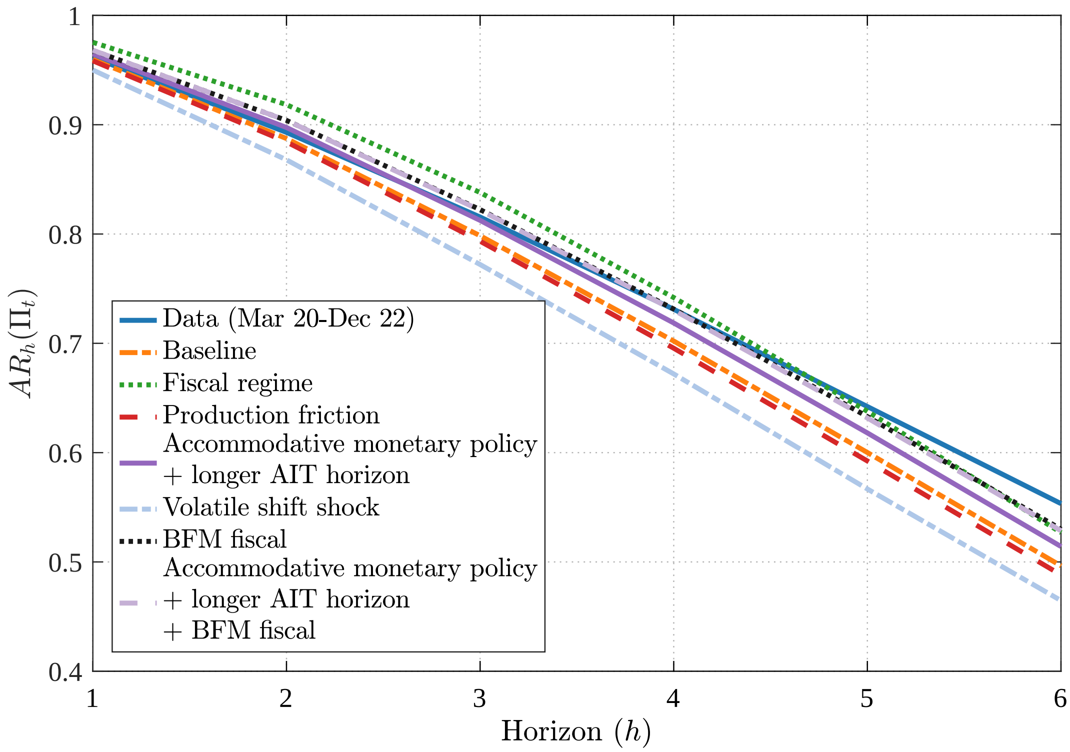

Figure 16: INFLATION PERSISTENCE COMPARISON: MODEL VERSUS DATA

Notes: This figure compares unconditional inflation persistence for horizon h, $AR_h(\Pi_{12,t})$, in the data from March 2020 through December 2022 (blue solid line) and that in the baseline (orange dashed line) and in the four alternative models. We use the fitted inflation of each model for the Post-COVID-19 period to calculate the model-implied inflation persistence.

in the inflation target (T) does not increase inflation persistence.[14]

5 Discussion

Our analysis of the post-COVID-19 inflation suggests that the initial surge in inflation during the first half of 2021 was driven by demand-side shocks, including both aggregate demand driven by fiscal shocks and a sectoral demand shift shock. These shocks may have been amplified by a shift in monetary and/or fiscal policy. However, the persistent rise in inflation since then has been largely driven by a negative technology shock, which has offset the impact of the monetary policy tightening.

While the increased friction in the production process has been suggested as an explanation

[14]Figures in the appendix also show that changing the inflation feedback parameter can greatly dampen inflation persistence conditional on a transfer shock. Hence, although our recalibration with the BFM regime increase the persistence of a transfer shock, the increase in the model-implied inflation with this change is not purely driven by the change in the exogenous shock persistence.

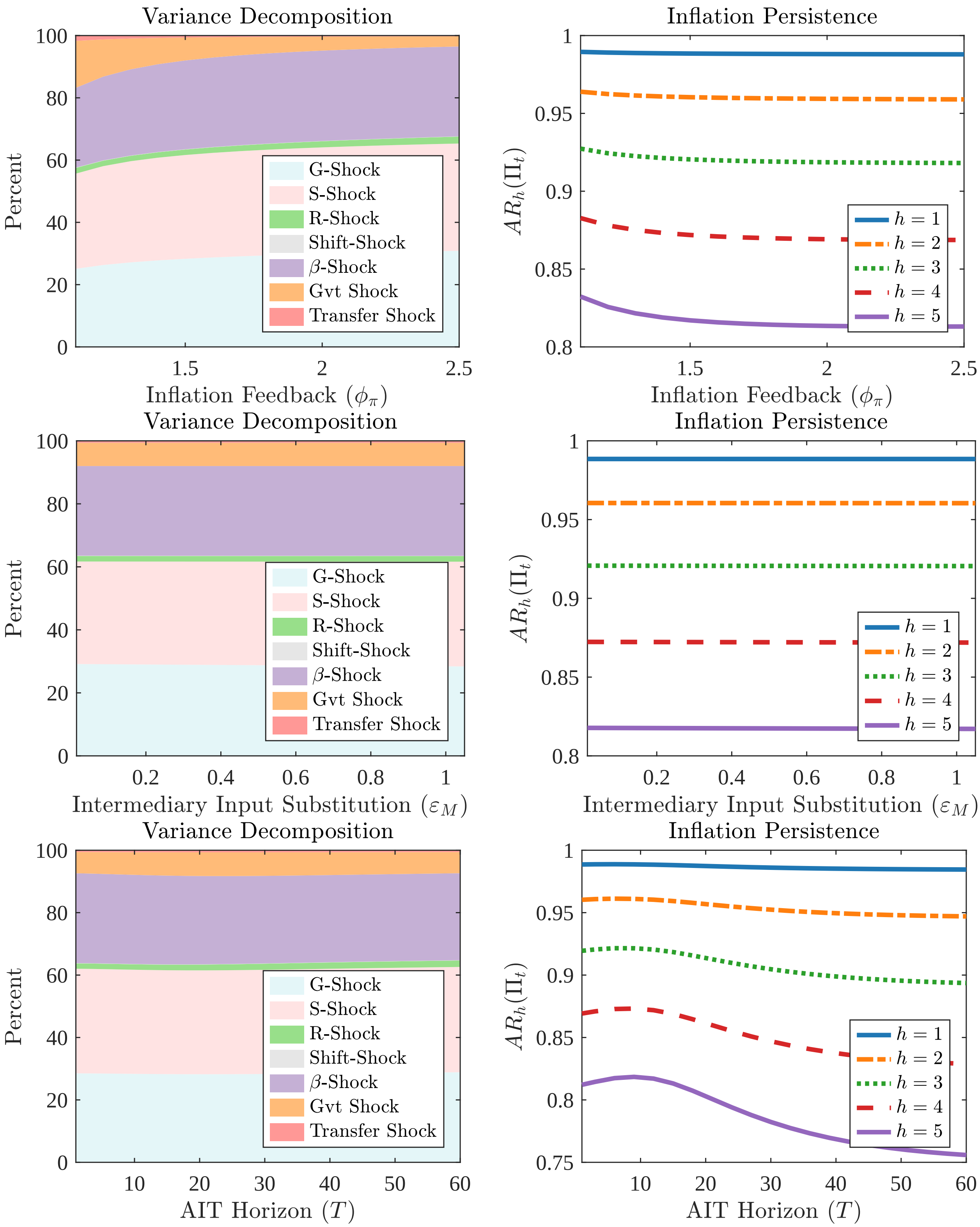

Figure 17: Model-implied Inflation Persistence by Monetary Policy Parameters

Notes: This figure shows the connection between changes in monetary policy parameters and the model-implied inflation persistence as well as the long-run variance decomposition of inflation.

for the persistent rise in inflation during the post-COVID-19 period, our analysis does not favor this mechanism over specifications with policy shifts. There are two reasons for this result. First, even under the baseline calibration using pre-COVID-19 data, we find that the substitution ability among production factors is not particularly high. The elasticity of substitution among intermediary inputs is somewhat elastic ($\epsilon_M = 1.1809$), but the elasticity of substitution of labor across sectors is quite low ($\epsilon_L = 0.0188$). Lowering the inflation feedback parameter increases the model-implied inflation at multiple horizons by reducing the weight of less persistent shocks (such as sectoral technology shocks) in the long-run variance of inflation. On the other hand, lowering the elasticity of substitution among intermediary inputs has little effect on inflation persistence, as shown in Figure 17.

Our interpretation is that the degree of friction in the production process did not change significantly during the post-COVID-19 period. Instead, a large shock that created a significant imbalance in supply and demand exposed the pre-existing vulnerability. It is worth noting that our model does not include a detailed international trade channel to capture supply chain disruptions, as done in studies like Comin et al. (2023) and Amiti et al. (2023). Therefore, it would be interesting to see if our results hold in an extended version of the model that incorporates the international trade channel. Nonetheless, our analysis suggests caution in generalizing the role of supply chain disruptions without considering the corresponding changes in monetary and fiscal policies.

Like Bianchi et al. (2023) and Bhattarai et al. (2023), we find that the fiscal shock played a significant role in the initial surge in inflation accompanied by an accommodative monetary policy. In this case, allowing a temporary instead of permanent shift fits the data better because the permanent shift to the fiscal regime implies too much pass-through from goods inflation to services inflation, which generates counterfactually volatile inflation. Unfunded transfer shocks appear to reduce the role of intertemporal preference shocks in the post-pandemic period because both of them increase inflation by boosting aggregate demand. Our favored version is to incorporate a temporary shift to the fiscal regime along the lines of Bianchi et al. (2023). It is interesting that we find a significant role of a termporary shift to the fiscal regime in the recent inflationary episode even if our model allows room for supply-side disruptions as well as sectoral demand shift shocks, which are absent in Bianchi et al. (2023).

A sectoral demand shift shock emphasized by Ferrante et al. (2023) to explain the post-COVID-19 inflation is an important factor in driving the initial surge in inflation but plays a negligible role in explaining the sluggish declines in services inflation even as goods inflation decreases. One reason that we obtain a different conclusion from Ferrante et al. (2023) is that they focus on the inflation at the more disaggregated sectoral level while we evaluate the model fit in terms of the co-movement between goods inflation and services inflation.

Gagliardone and Gertler (2023) emphasize the oil price shock amplified by a loose monetary

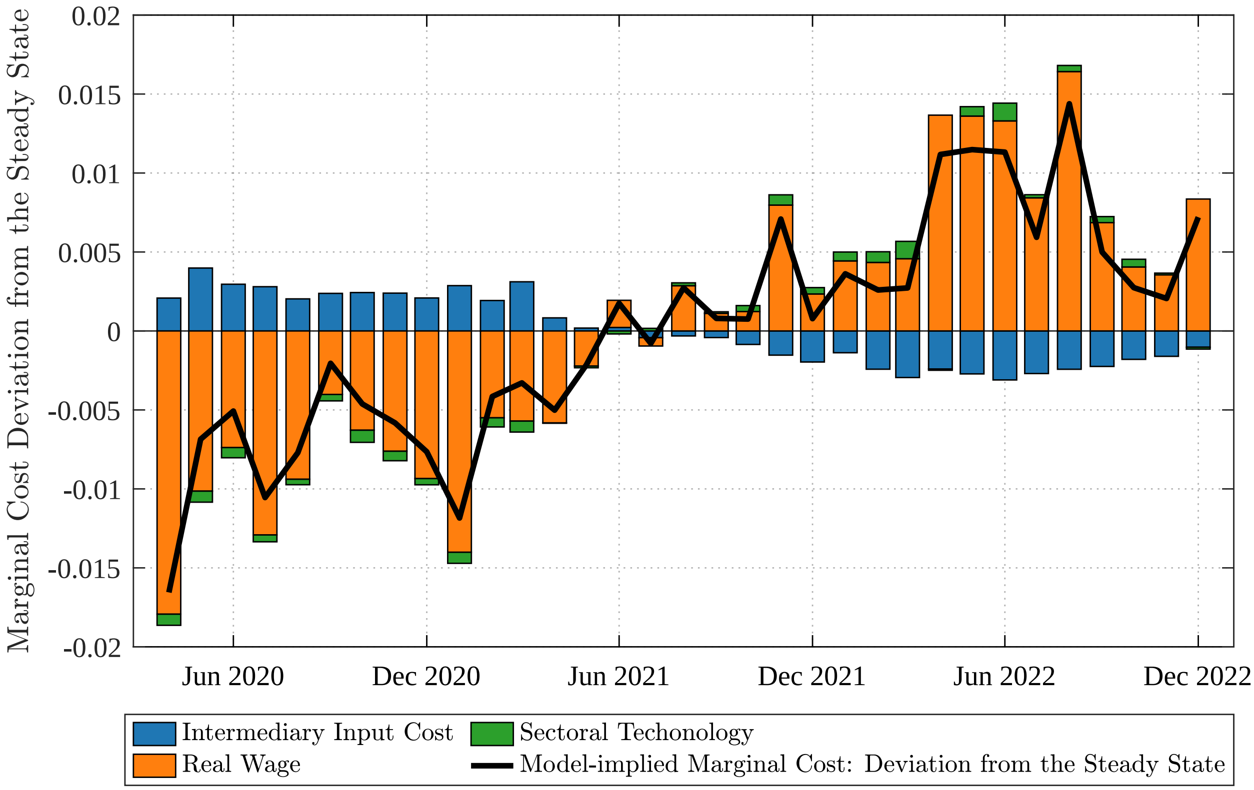

Figure 18: DECOMPOSITION OF THE MODEL-IMPLIED MARGINAL COST GAP

Notes: This figure shows the model decomposition of the deviation of marginal costs from the steady state value under the alternative model with a more accommodative monetary policy ($\phi_\pi = 1.1$) and a longer AIT horizon ($T = 48$). We decompose it into the three channels, intermediary input cost (blue bar), real wage (orange bar), and sectoral technology (green bar), as in Equation (3.1).

policy to explain the inflation surge. The role of energy prices was also highlighted in Blanchard and Bernanke (2023). While we do not directly model the commodity input, the energy price shock may show up as a goods-sector technology shock in our model and can explain inflation from the second half of 2021 to 2022, which is largely consistent with their results. Under our favored model with a temporary shift to the fiscal regime in Table 3, the deviation of the marginal cost from the steady state value can be decomposed into the three channels (intermediary input cost, real wage, and sectoral technology) as in Equation (3.2). Figure 18 shows the three way decomposition of the model-implied marginal cost gap during the post-COVID-19 period. The intermediary input cost channel played a large role during the initial surge of inflation but was overtaken by the real wage channel and the sectoral technology shock channel after the mid 2021.[15] In our decomposition, both

[15] Glover, del Rio and von Ende-Becker (2023) note that while the profit in publicly listed firms rose significantly in 2020:Q3 and the first half of 2021 due to higher prices, this has more to do with higher expectations of future input costs. Our intermediary input cost channel that was prominent during the early stage of the Post-COVID-19 period seems to be consistent with their interpretation. Also, notice that this channel is not immune from aggregate demand shocks because with frictions on the sectoral reallocation, even aggregate demand shocks can move relative prices.

the intermediary input cost channel and the sectoral technology shock channel can be affected by the commodity price. Based on this interpretation, our results are qualitatively similar to Gagliardone and Gertler (2023) and Blanchard and Bernanke (2023), in which the commodity price shock largely drives inflation up to the mid 2021 and the labor market tightening starts to affect price inflation from the late 2021. But relative to their results, our model estimates attribute a larger role to the real wage channel in explaining inflation during 2022.

6 Conclusion

In this paper, we use a calibrated two-sector sticky price model with real and nominal frictions to understand the persistent rise in inflation during the post-COVID-19 period. Given the size of disruption to the economy and extra-ordinary policy responses to the pandemic shock, isolating the contribution of a single factor to the recent inflationary episode is challenging without such a model. Our findings suggest that large fiscal support packages implemented during 2020 and 2021 have exerted inflationary pressures in 2021 but the supply side shocks are increasingly responsible for the elevated level of inflation in 2022. Our results indicate that a temporary shift to the fiscal regime in which monetary policy does not respond to some part of inflation fits the level and persistence observed during the post-COVID-19 period better than alternative specifications without policy shifts. Incorporating the new framework announced by the Federal Reserve in 2020 in the form of lower inflation feedback and longer averaging horizon in inflation target helps the model fit the level and persistence of inflation but without a temporary shift to the fiscal regime, such a specification does not generate the demand-side effect of transfer shocks because household reduce labor supply with tax increases to repay debt to finance transfer spending.

Our emphasis on policy shifts as a key factor in explaining the post-COVID-19 inflation does not deny a significant role for the supply side force. In particular, the continued increase in inflation in spite of policy tightening until the mid-2022 might be explained by the realization of negative sector-specific productivity shocks. Our preferred interpretation of the recent inflationary episode is that the pandemic did not alter the degree of the friction in the economy substantially but large demand and supply imbalances created by the pandemic and policy responses to it exacerbated the inflationary effect of the existing friction. With large shocks dissipating over time and monetary policy responding to inflation as aggressively as in the pre-pandemic period, inflation is likely to return to the level that prevailed during the pre-COVID-19 period in the absence of another bout of supply shocks and inflationary fiscal shocks.

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Supplementary Appendix (Not for Publication)

Section A details the quantitative model presented in Section 2 of the main text. Section B presents additional figures and tables.

A Model Appendix

A.1 System of Equilibrium Conditions

- Marginal cost

$$mc_{i,t} = \begin{cases} (Z_{i,t})^{-\frac{1}{\varepsilon_Y}} \left(\alpha_i \left(w^M_{i,t}\right)^{1-\varepsilon_Y} + (1-\alpha_i)\left(w_{i,t}\right)^{1-\varepsilon_Y}\right)^{\frac{1}{1-\varepsilon_Y}} & \text{if } \varepsilon_Y \neq 1 \\ \frac{1}{Z_{i,t}} \left(\frac{w^M_{i,t}}{\alpha_i}\right)^{\alpha_i} \left(\frac{w_{i,t}}{1-\alpha_i}\right)^{1-\alpha_i} & \text{if } \varepsilon_Y = 1 \end{cases}$$

- Philips curve 1

$$p^*_{i,t} \equiv \frac{P^*_{i,t}}{P_{i,t}} = \frac{\sigma_i}{\sigma_i - 1} \frac{X^1_{i,t}}{X^2_{i,t}}$$

- Philips curve 2

$$X^1_{i,t} = mc_{i,t} Y_{i,t} + \theta_i \beta E_t (\frac{C_t}{C_{t+1}})^{\gamma} \left(\Pi_{i,t+1}\right)^{\sigma_i} X^1_{i,t+1}$$

- Philips curve 3

$$X^2_{i,t} = Q_{i,t} Y_{i,t} + \theta_i \beta E_t (\frac{C_t}{C_{t+1}})^{\gamma} \left(\Pi_{i,t+1}\right)^{\sigma_i - 1} X^2_{i,t+1}$$

- Price dispersion

$$\Xi_{i,t} = (1-\theta_i)\left(p^*_{i,t}\right)^{-\sigma_i} + \theta_i \Xi_{i,t-1}.$$

- Aggregate price index

$$\left(\Pi_{i,t}\right)^{1-\sigma_i} = (1-\theta_i)\left(p^*_{i,t}\Pi_{i,t}\right)^{1-\sigma_i} + \theta_i$$

- Inflation relationship

$$\Pi_{i,t} = \frac{Q_{i,t}}{Q_{i,t-1}} \Pi_t$$

- Sector i's composite material inputs:

$$M_{i,t} = \alpha_i \left(\frac{mc_{i,t}}{w_{i,t}^M}\right)^{\varepsilon_Y} Y_{i,t}\Xi_{i,t}$$

- Sector i's aggregate demand for the final good of sector k:

$$M_{i,k,t} = \Gamma_{i,k} \left(\frac{Q_{k,t}}{w_{i,t}^M}\right)^{-\varepsilon_M} M_{i,t}$$

- i sector output

$$\begin{aligned} Y_{i,t} &= C_{i,t} + G_{i,t} + \sum_{k=1}^{N} \Gamma_{k,i}\alpha_k \left(\frac{Q_{i,t}}{w_{k,t}^M}\right)^{-\varepsilon_M} \left(\frac{mc_{k,t}}{w_{k,t}^M}\right)^{\varepsilon_Y} Y_{k,t}\Xi_{k,t} \\ &= C_{i,t} + G_{i,t} + \sum_{k=1}^{N} M_{k,i,t} \end{aligned}$$

- i sector output:

$$Y_{i,t}^s \equiv \int Y_{i,t}\left(j\right) dj = Y_{i,t}\Xi_{i,t}$$

- Consumer demand for good i

$$C_{i,t} = \Gamma_{i,t}^c \left(Q_{i,t}\right)^{-\varepsilon} C_t$$

- Relative factor prices within sector i

$$\left(w_{i,t}^M\right)^{1-\varepsilon_M} = \left(\sum_{k=1}^{N} \Gamma_{i,k} \left(Q_{k,t}\right)^{1-\varepsilon_M}\right)$$

- HH - Intertemporal EE

$$C_t^{-\gamma} = \beta R_t E_t \left[C_{t+1}^{-\gamma} \frac{1}{\Pi_{t+1}}\right]$$

- HH - Intratemporal EE

$$\chi \left(L_t\right)^{\varphi} \left(\frac{1}{\Gamma_i^L} \frac{L_{i,t}}{L_t}\right)^{\frac{1}{\varepsilon_L}} \left(C_t\right)^{\gamma} = \left(1-\tau_t\right) w_{i,t}$$

- Labor market clearing

$$L_{i,t} = (1-\alpha_i)\left(\frac{mc_{i,t}}{w_{i,t}}\right)^{\varepsilon_Y} Y_{i,t}\Xi_{i,t}$$

- Government consumption

$$G_{i,t} = \Gamma_i^G \left(\frac{Q_{i,t}}{Q_t^G}\right)^{-\varepsilon} G_t$$

- Labor market clearing

$$L_t = \left(\sum_{i=1}^{N} \left(\Gamma_i^L\right)^{-\frac{1}{\varepsilon_L}} \left(L_{i,t}\right)^{\frac{\varepsilon_L+1}{\varepsilon_L}}\right)^{\frac{\varepsilon_L}{\varepsilon_L+1}}$$

  or

$$(\chi L_t^{\varphi} C_t^{\gamma})^{\varepsilon_L+1} = \sum_{i=1}^{N} \Gamma_i^L \left((1-\tau_t)\, w_{i,t}\right)^{\varepsilon_L+1}$$

- Relative price

$$Q_t^G = \begin{cases} \left(\sum_{i=1}^N \Gamma_i^G \left(Q_{i,t}\right)^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}} & \text{if } \varepsilon \neq 1 \\ \prod_{i=1}^N \left(Q_{i,t}\right)^{\Gamma_i^G} & \text{if } \varepsilon = 1 \end{cases}$$

- GBC

$$\tau_t \sum_{i=1}^{N} w_{i,t} L_{i,t} = Q_t^G G_t + T_t$$

- Monetary policy

$$R_t = \left(\bar{\Pi}_{t-k,t}\right)^{\phi_\Pi} \exp\left(\varepsilon_{R,t}\right)$$

- Average inflation

$$\bar{\Pi}_{t-k,t} = \left[\prod_{j=1}^{k} \left(\Pi_{t-j+1}\right)\right]^{1/k}$$

- Relative price across different sectors

$$1 = \begin{cases} \sum_{i=1}^N \Gamma_{i,t}^c \left(Q_{i,t}\right)^{1-\varepsilon} & \text{if } \varepsilon \neq 1 \\ \prod_{i=1}^N \left(Q_{i,t}\right)^{\Gamma_{i,t}^c} & \text{if } \varepsilon = 1 \end{cases}$$

and the resource constraint

$$C_t + Q_t^G G_t = \sum_{i=1}^{N} \left[Q_{i,t} Y_{i,t} + \frac{1}{\alpha_i} \left\{ (1-\alpha_i) (w_{i,t})^{1-\varepsilon_Y} - (mc_{i,t})^{1-\varepsilon_Y} \right\} \left(w_{i,t}^M \right)^{\varepsilon_Y} M_{i,t} \right]$$

A.2 Steady-State

- Marginal cost

$$\bar{mc}_i = \begin{cases} \left(\frac{1}{\bar{Z}_i}\right)^{\frac{1}{\varepsilon_Y}} \left(\alpha_i \left(\bar{w}_i^M\right)^{1-\varepsilon_Y} + (1-\alpha_i) (\bar{w}_i)^{1-\varepsilon_Y} \right)^{\frac{1}{1-\varepsilon_Y}} & \text{if } \varepsilon_Y \neq 1 \\ \frac{1}{\bar{Z}_i} \left(\frac{\bar{w}_i^M}{\alpha_i}\right)^{\alpha_i} \left(\frac{\bar{w}_i}{1-\alpha_i}\right)^{1-\alpha_i} & \text{if } \varepsilon_Y = 1 \end{cases}$$

- Philips curve 1

$$\bar{mc}_i = \frac{\sigma_i - 1}{\sigma_i}$$

- Philips curve 2

$$\bar{X}_i^1 = \frac{1}{1-\theta_i \beta} \bar{mc}_i \bar{Y}_i$$

- Philips curve 3

$$\bar{X}_i^2 = \frac{1}{1-\theta_i \beta} \bar{Q}_i Y_i$$

- Price dispersion

$$\bar{\Xi}_i = 1$$

- Aggregate price index

$$\bar{p}_i^* = 1$$

- Sector i's composite material inputs:

$$\bar{M}_i = \alpha_i \left(\frac{\bar{mc}_i}{\bar{w}_i^M} \right)^{\varepsilon_Y} \bar{Y}_i$$

- Sector i's aggregate demand for the final good of sector k:

$$\bar{M}_{i,k} = \Gamma_{i,k} \left(\frac{\bar{Q}_k}{\bar{w}_i^M} \right)^{-\varepsilon_M} \bar{M}_i$$

- i sector output

$$\bar{Y}_i = \bar{C}_i + \bar{G}_i + \sum_{k=1}^{N} \bar{M}_{k,i}$$

- i sector output:

$$\bar{Y}_i^s = \bar{Y}_i$$

- Consumer demand for good i

$$\bar{C}_i = \bar{\Gamma}_i^c \left(\bar{Q}_i\right)^{-\varepsilon} \bar{C}$$

- Relative factor prices within sector i

$$\left(\bar{w}_i^M\right)^{1-\varepsilon_M} = \left(\sum_{k=1}^{N} \Gamma_{i,k} \left(\bar{Q}_k\right)^{1-\varepsilon_M}\right)$$

- HH - Intertemporal EE

$$\bar{R} = \frac{1}{\beta}$$

- HH - Intratemporal EE

$$\chi \left(\bar{L}\right)^{\varphi} \left(\bar{C}\right)^{\gamma} \left(\frac{1}{\Gamma_i^L} \frac{\bar{L}_i}{\bar{L}}\right)^{\frac{1}{\varepsilon_L}} = (1 - \bar{\tau})\, \bar{w}_i$$

- Labor market clearing

$$\bar{L}_i = (1 - \alpha_i) \left(\frac{\bar{mc}_i}{\bar{w}_i}\right)^{\varepsilon_Y} \bar{Y}_i$$

- Labor market clearing

$$\bar{L} = \left(\sum_{i=1}^{N} \left(\Gamma_i^L\right)^{-\frac{1}{\varepsilon_L}} \left(\bar{L}_i\right)^{\frac{\varepsilon_L+1}{\varepsilon_L}}\right)^{\frac{\varepsilon_L}{\varepsilon_L+1}}$$

  or

$$\left(\chi \bar{L}^{\varphi} \left(\bar{C}\right)^{\gamma}\right)^{\varepsilon_L+1} = \sum_{i=1}^{N} \Gamma_i^L \left((1 - \bar{\tau})\, \bar{w}_i\right)^{\varepsilon_L+1}$$

- Government consumption

$$\bar{G}_i = \Gamma_i^G \left(\frac{\bar{Q}_i}{\bar{Q}^G}\right)^{-\varepsilon} \bar{G}$$

- Relative price

$$\bar{Q}^G = \begin{cases} \left(\sum_{i=1}^N \Gamma_i^G \left(\bar{Q}_i\right)^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}} & \text{if } \varepsilon \neq 1 \\ \prod_{i=1}^N \left(\bar{Q}_i\right)^{\Gamma_i^G} & \text{if } \varepsilon = 1 \end{cases}$$

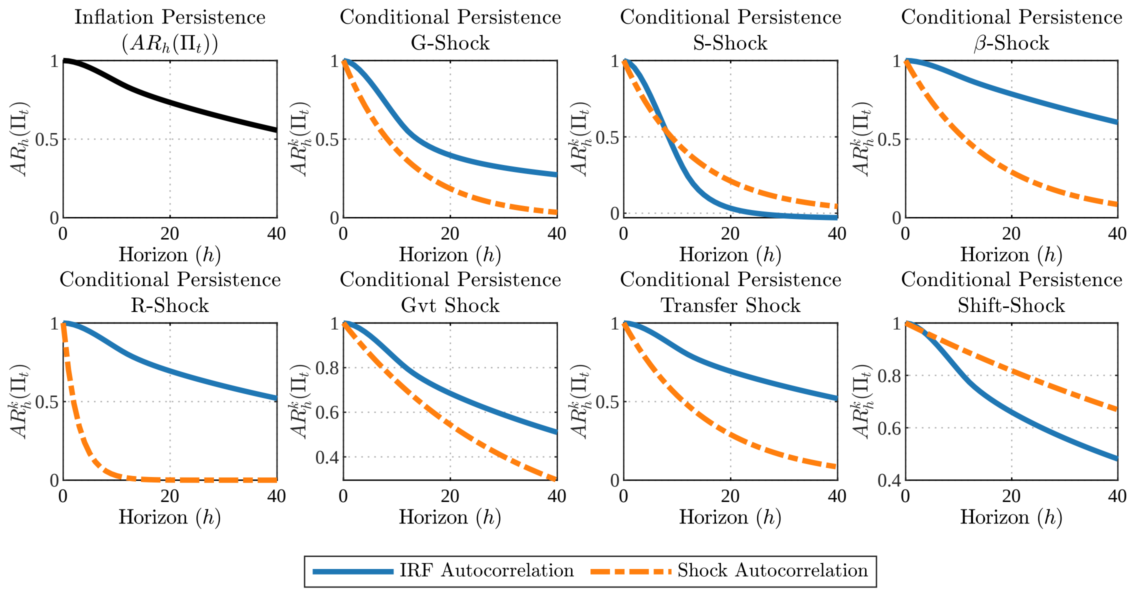
- GBC

$$\bar{\tau}_t \sum_{i=1}^N \bar{w}_i \bar{L}_i = \bar{Q}^G \bar{G} + \bar{T}$$

- Resource constraint

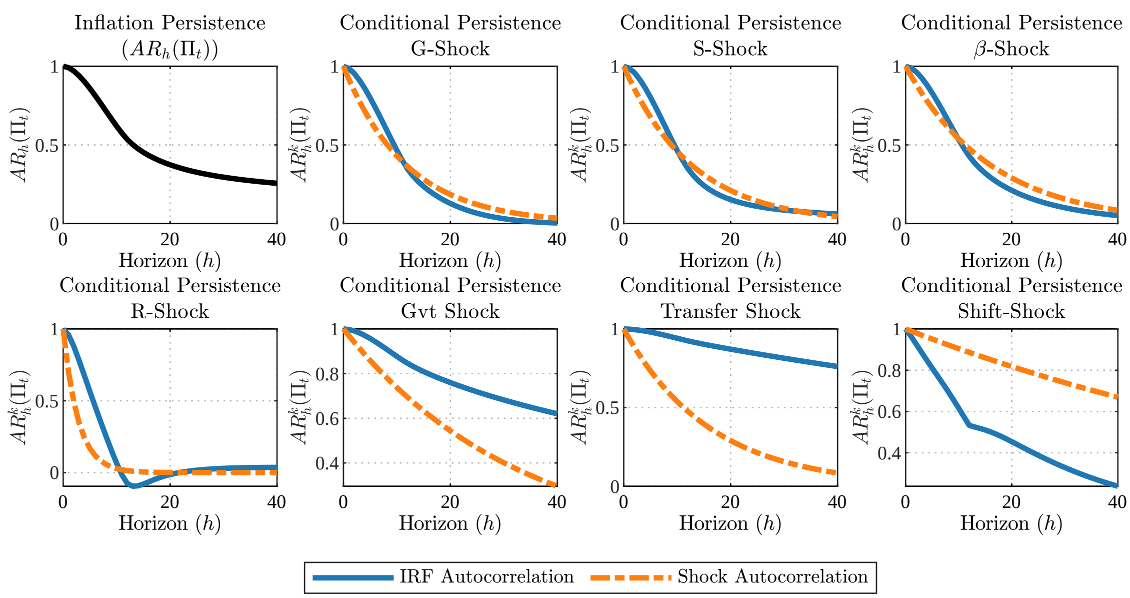
$$C_t + Q_t^G G_t = \sum_{i=1}^N \left[Q_{i,t} Y_{i,t} + \frac{1}{\alpha_i} \left\{(1-\alpha_i)\left(w_{i,t}\right)^{1-\varepsilon_Y} - \left(mc_{i,t}\right)^{1-\varepsilon_Y}\right\} \left(w_{i,t}^M\right)^{\varepsilon_Y} M_{i,t}\right]$$

B Appendix Figures



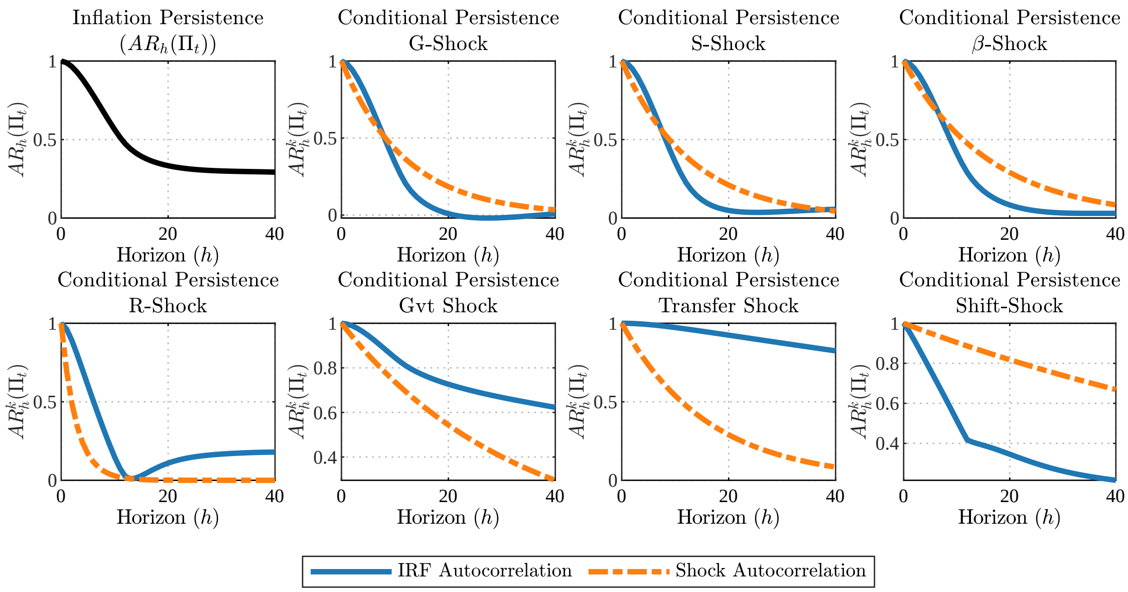
Appendix Figure A.1: MODEL-IMPLIED INFLATION PERSISTENCE: FISCAL REGIME

Notes: This figure shows inflation persistence in the alternative model with a fiscal regime ($\phi_\pi = 0.0$ and $\psi_L = 0.0$). The top left panel displays unconditional inflation persistence over horizon h ($AR_h(\Pi_{12,t})$), while the remaining panels present conditional persistence for each shock k ($AR_h^{(k)}(\Pi_{12,t})$). Both the inflation response (solid blue lines) and shock autocorrelation (dashed orange lines) are plotted.



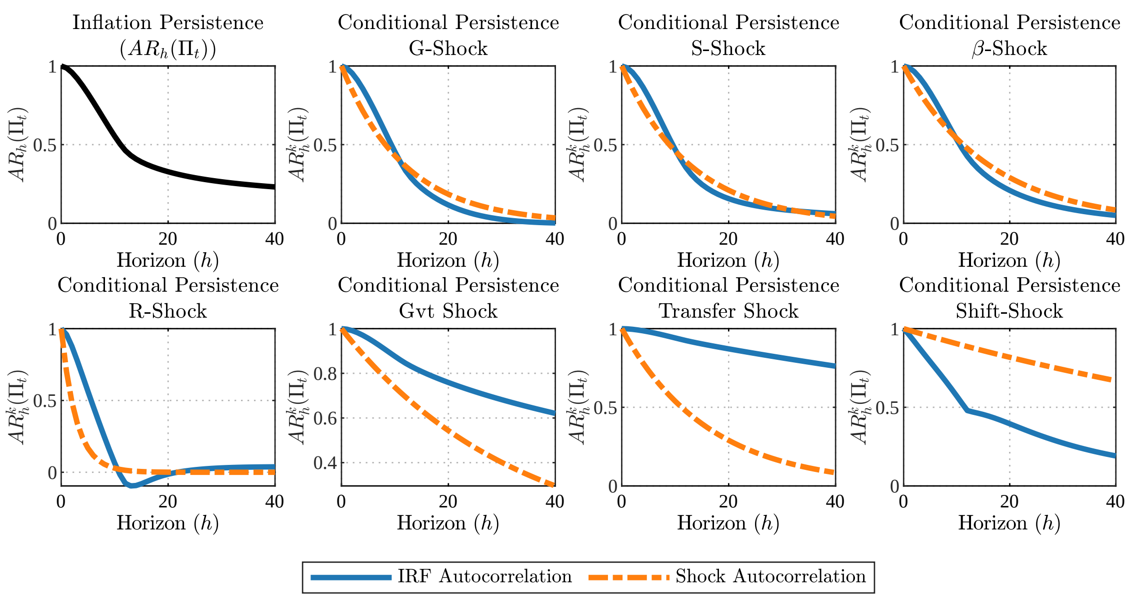
Appendix Figure A.2: MODEL-IMPLIED INFLATION PERSISTENCE: PRODUCTION FRICTION

Notes: This figure shows inflation persistence in an alternative model with increased production friction ($\varepsilon_M = 0.01$). The top left panel presents unconditional inflation persistence over horizon h ($AR_h(\Pi_{12,t})$), while the remaining panels show conditional persistence for each shock k ($AR_h^{(k)}(\Pi_{12,t})$). Both the inflation response (blue solid lines) and shock autocorrelation (orange dashed lines) are plotted.



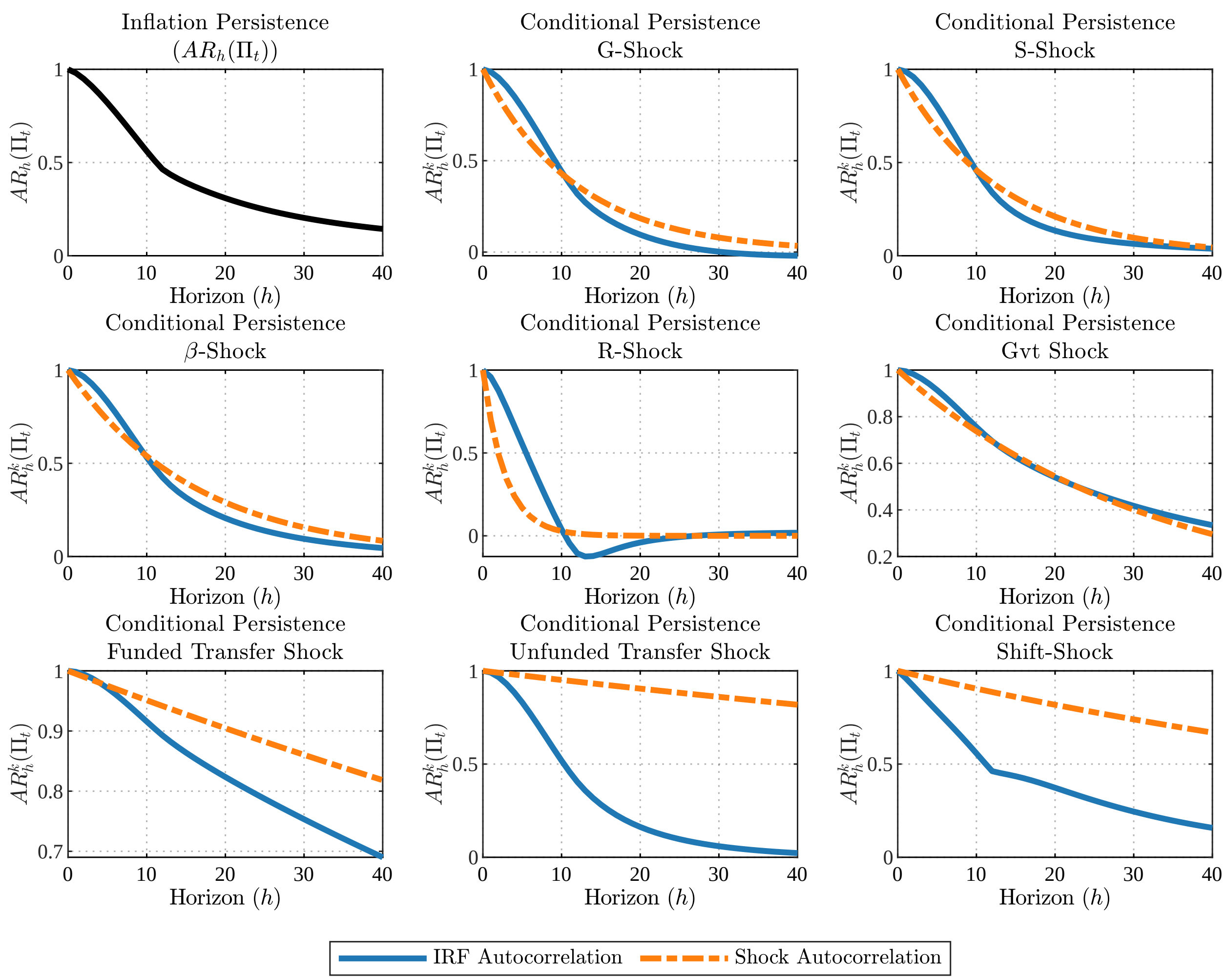
Appendix Figure A.3: MODEL-IMPLIED INFLATION PERSISTENCE: ACCOMMODATIVE MONETARY POLICY + LONGER AVERAGING HORIZON

Notes: This figure illustrates inflation persistence in the alternative model with a lower inflation feedback ($\phi_\pi = 1.1$) and a longer AIT horizon ($T = 48$). The top left panel shows unconditional inflation persistence over horizon h $(AR_h(\Pi_{12,t}))$, while the remaining panels depict conditional persistence for each shock k $(AR_h^{(k)}(\Pi_{12,t}))$. Both the inflation response (solid blue lines) and shock autocorrelation (dashed orange lines) are plotted.



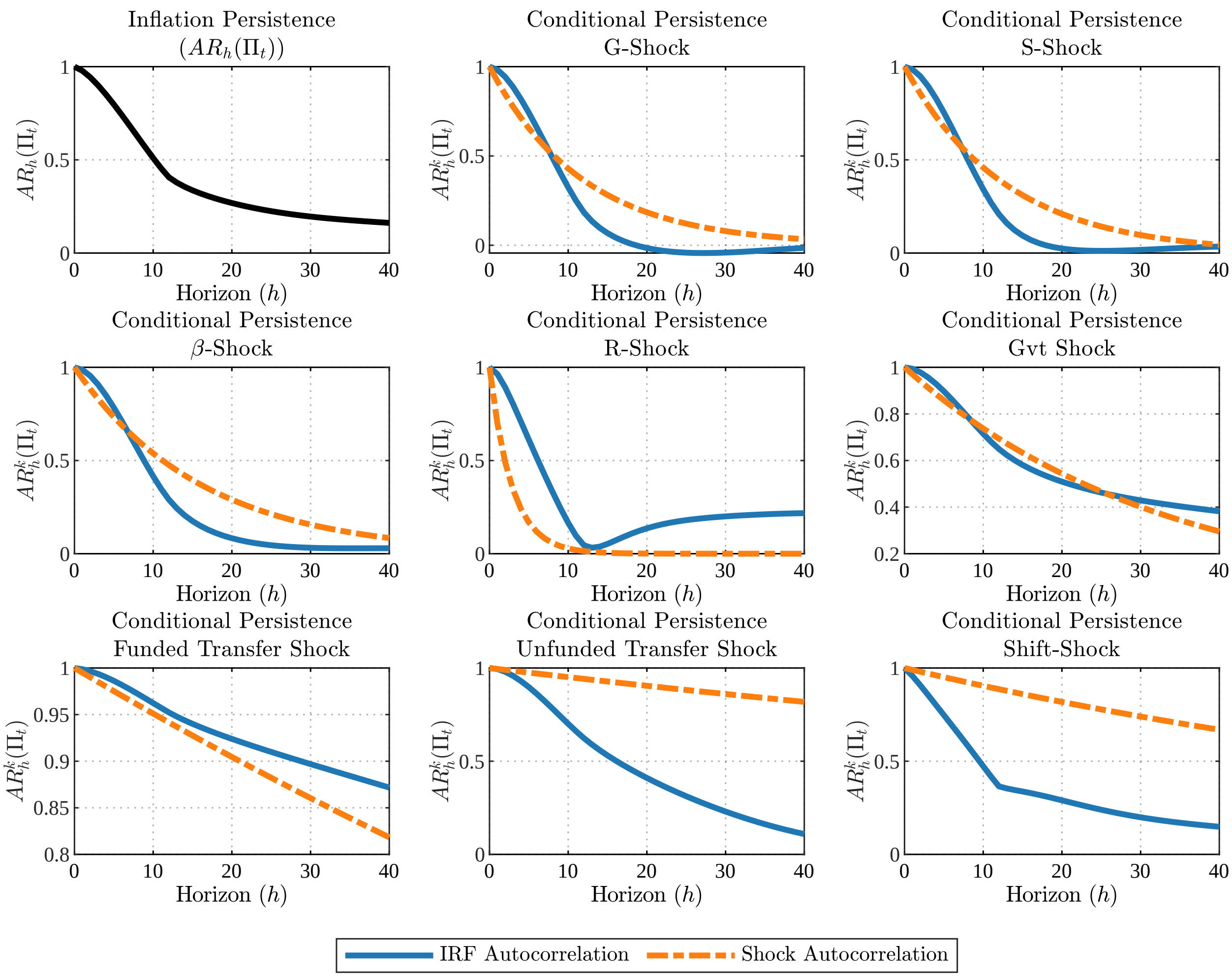
Appendix Figure A.4: MODEL-IMPLIED INFLATION PERSISTENCE: VOLATILE DEMAND SHIFT SHOCK

Notes: This figure shows inflation persistence in the alternative model with a more volatile demand shift shock ($\sigma_\Gamma = 0.015$). The top left panel presents unconditional inflation persistence over horizon h $(AR_h(\Pi_{12,t}))$, while the remaining panels display conditional persistence for each shock k $(AR_h^{(k)}(\Pi_{12,t}))$. Both the inflation response (solid blue lines) and shock autocorrelation (dashed orange lines) are plotted.



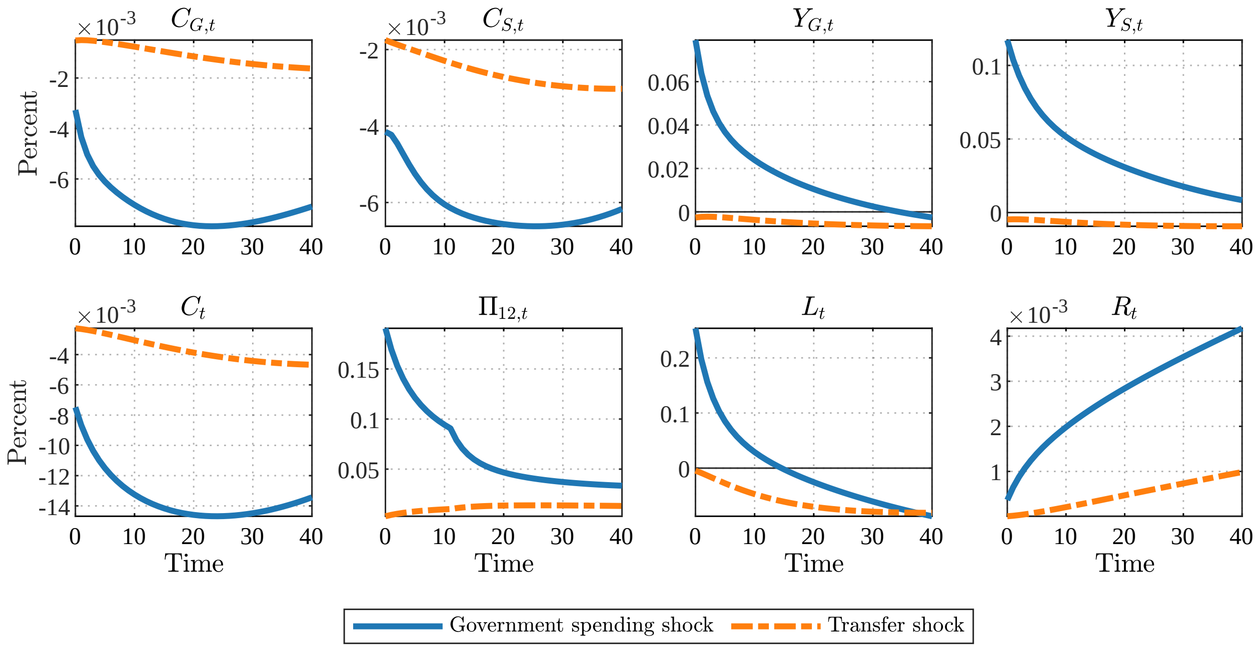
Appendix Figure A.5: MODEL-IMPLIED INFLATION PERSISTENCE: BFM FUNDED/UNFUNDED TRANSFER SHOCKS

Notes: This figure illustrates inflation persistence in the alternative model with BFM funded/unfunded transfer shocks. The top left panel displays unconditional inflation persistence over horizon h $(AR_h(\Pi_{12,t}))$, while the remaining panels present conditional persistence for each shock k $(AR_h^{(k)}(\Pi_{12,t}))$. 'G-Shock' represents a goods sector TFP shock, 'S-Shock' a services sector TFP shock, 'β-Shock' a preference shock, 'R-Shock' a monetary policy shock, 'Gvt Shock' a government spending shock, and 'Shift-Shock' a demand shift shock. Both the inflation response (solid blue lines) and shock autocorrelation (dashed orange lines) are plotted.



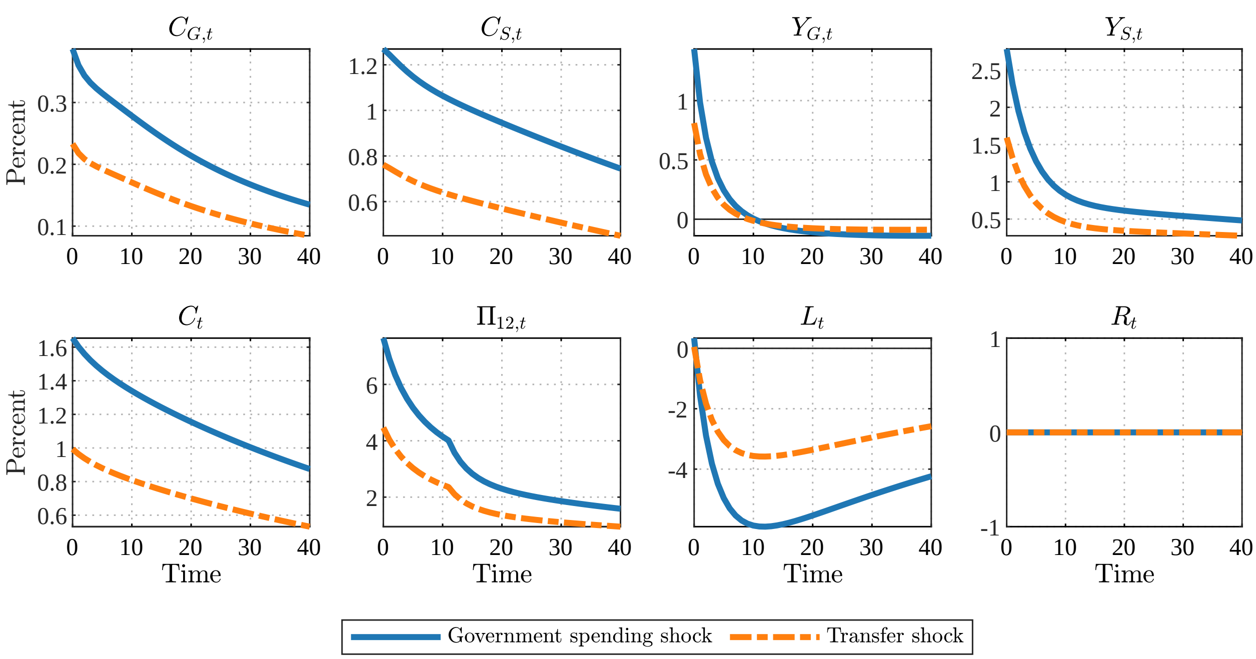
Appendix Figure A.6: Model-implied Inflation Persistence: BFM Funded/Unfunded Transfer Shocks + Accommodative Monetary Policy

Notes: This figure shows inflation persistence in the alternative model with BFM funded/unfunded transfer shocks, a lower inflation feedback ($\phi_\pi = 1.1$), and a longer AIT horizon ($T = 48$). The top left panel presents unconditional inflation persistence over horizon h ($AR_h(\Pi_{12,t})$), while the remaining panels display conditional persistence for each shock k ($AR_h^{(k)}(\Pi_{12,t})$). 'G-Shock' refers to a goods sector TFP shock, 'S-Shock' to a services sector TFP shock, 'β-Shock' to a preference shock, 'R-Shock' to a monetary policy shock, 'Gvt Shock' to a government spending shock, and 'Shift-Shock' to a demand shift shock. Both the inflation response (solid blue lines) and the shock autocorrelation (dashed orange lines) are plotted.



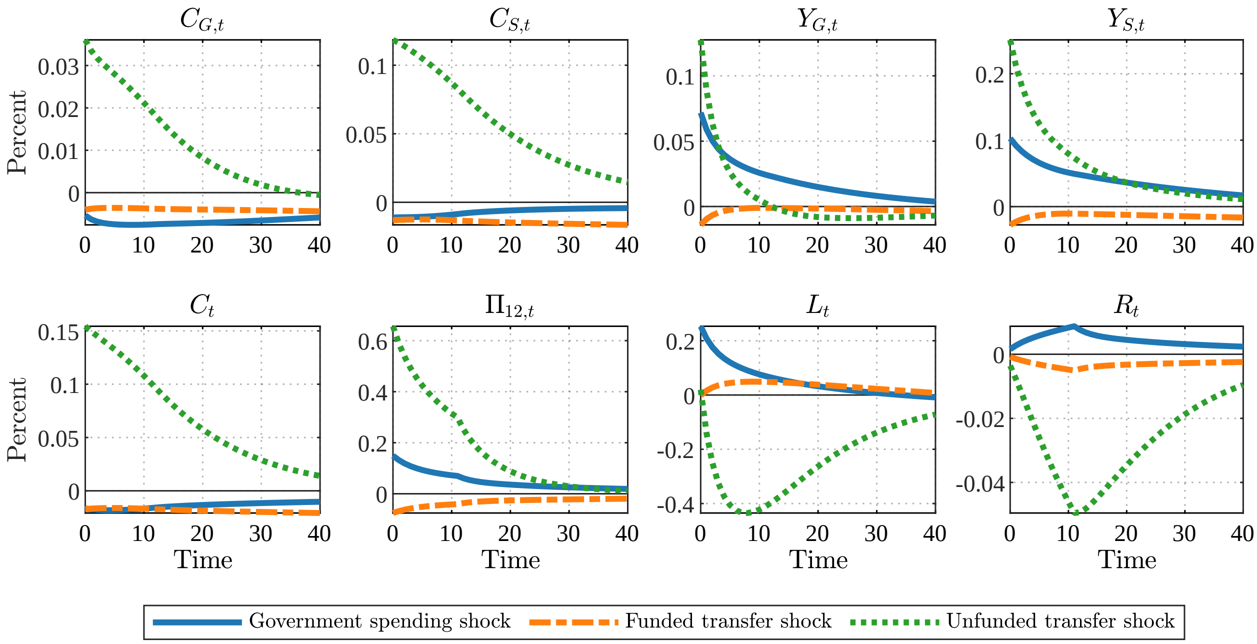
Appendix Figure A.7: IMPULSE RESPONSES TO FISCAL SHOCKS: ACCOMMODATIVE MONETARY POLICY AND LONGER AIT HORIZON

Notes: This figure presents impulse responses of key model variables to a government spending shock (solid blue line) and a transfer shock (dashed orange line) in the alternative model, which features a lower inflation feedback ($\phi_\pi = 1.1$) and an extended AIT horizon ($T = 48$).



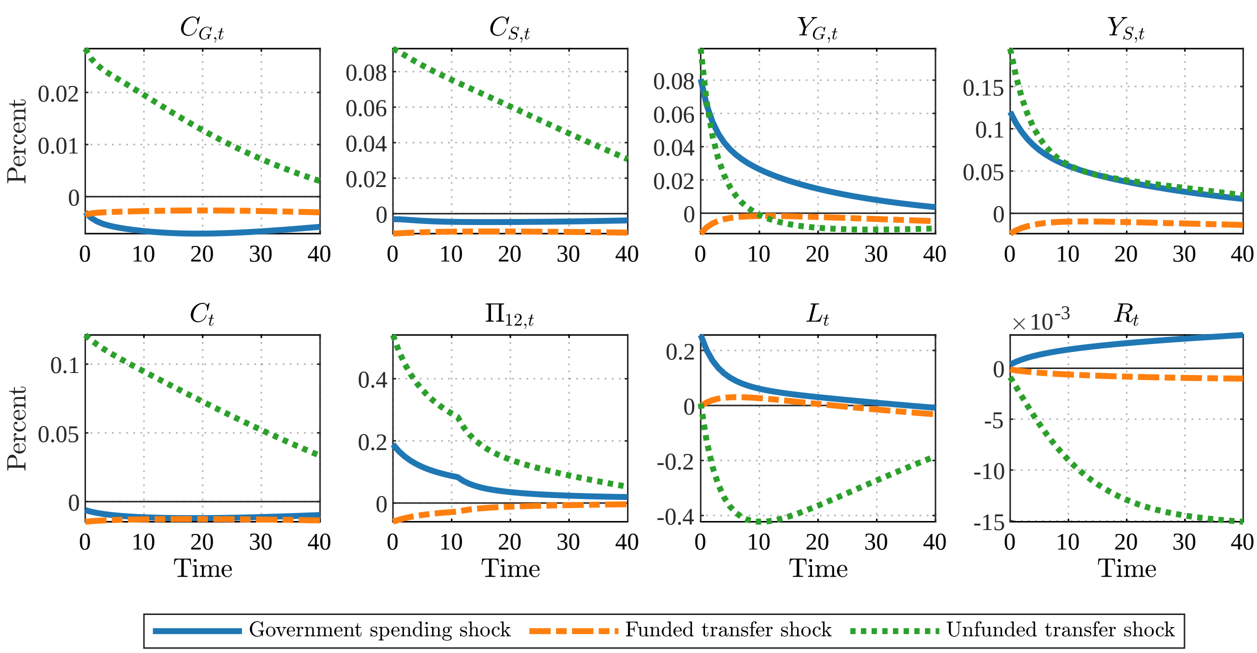
Appendix Figure A.8: IMPULSE RESPONSES TO FISCAL SHOCKS: FISCAL REGIME

Notes: This figure presents impulse responses of key model variables to a government spending shock (solid blue line) and a transfer shock (dashed orange line) in the alternative model under a fiscal regime ($\phi_\pi = 0.0$ and $\psi_L = 0.0$).



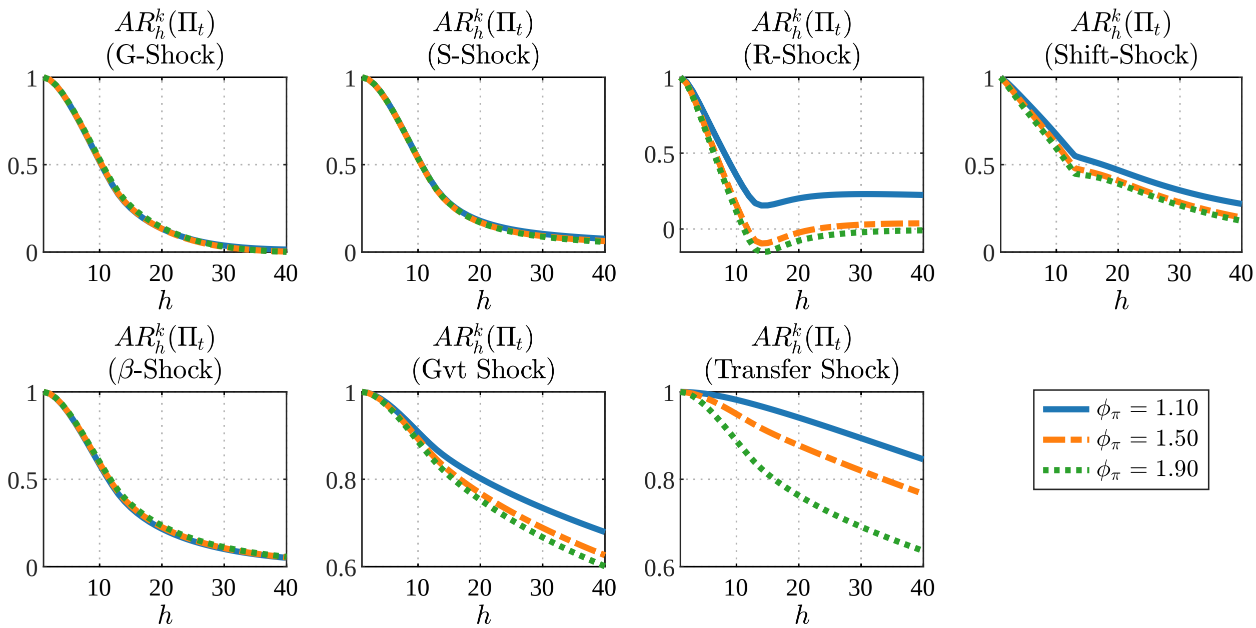
Appendix Figure A.9: IMPULSE RESPONSES TO FISCAL SHOCKS: BFM FUNDED/UNFUNDED TRANSFER SHOCKS

Notes: This figure presents impulse responses of key model variables to a government spending shock (solid blue line) and a transfer shock (dashed orange line) in the alternative model with BFM funded and unfunded transfer shocks.



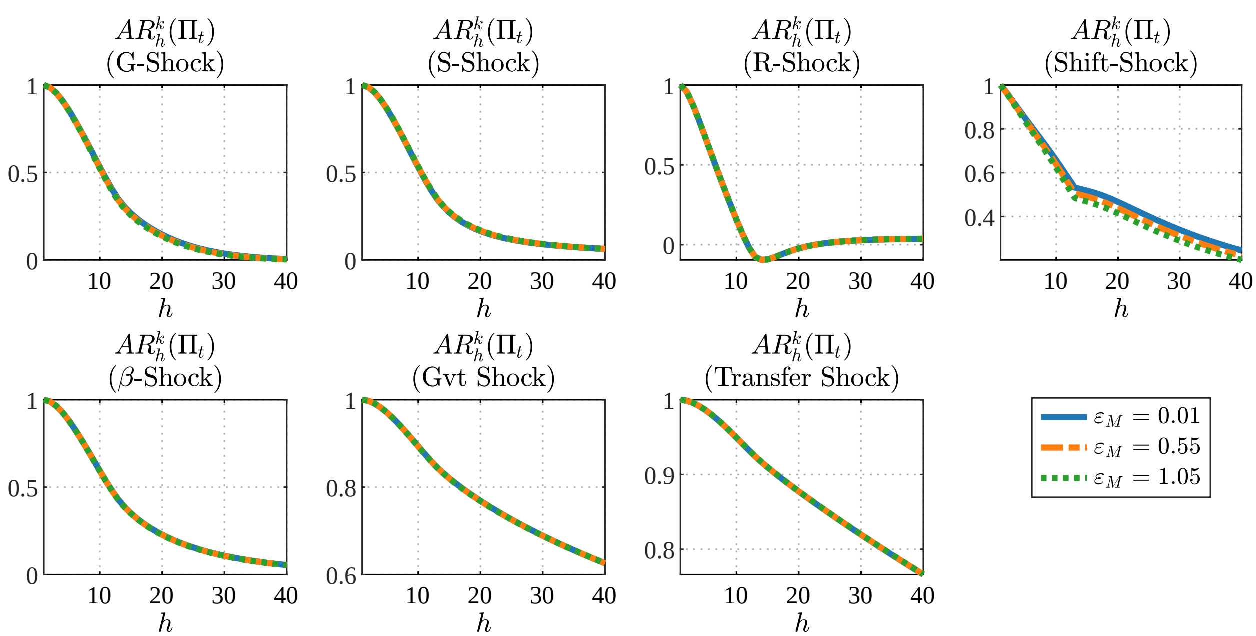
Appendix Figure A.10: IMPULSE RESPONSES TO FISCAL SHOCKS: BFM FUNDED/UNFUNDED TRANSFER SHOCKS WITH ACCOMMODATIVE MONETARY POLICY

Notes: This figure presents impulse responses of key model variables to a government spending shock (solid blue line) and a transfer shock (dashed orange line) in the alternative model, which includes BFM funded/unfunded transfer shocks, a lower inflation feedback ($\phi_\pi = 1.1$), and an extended AIT horizon ($T = 48$).



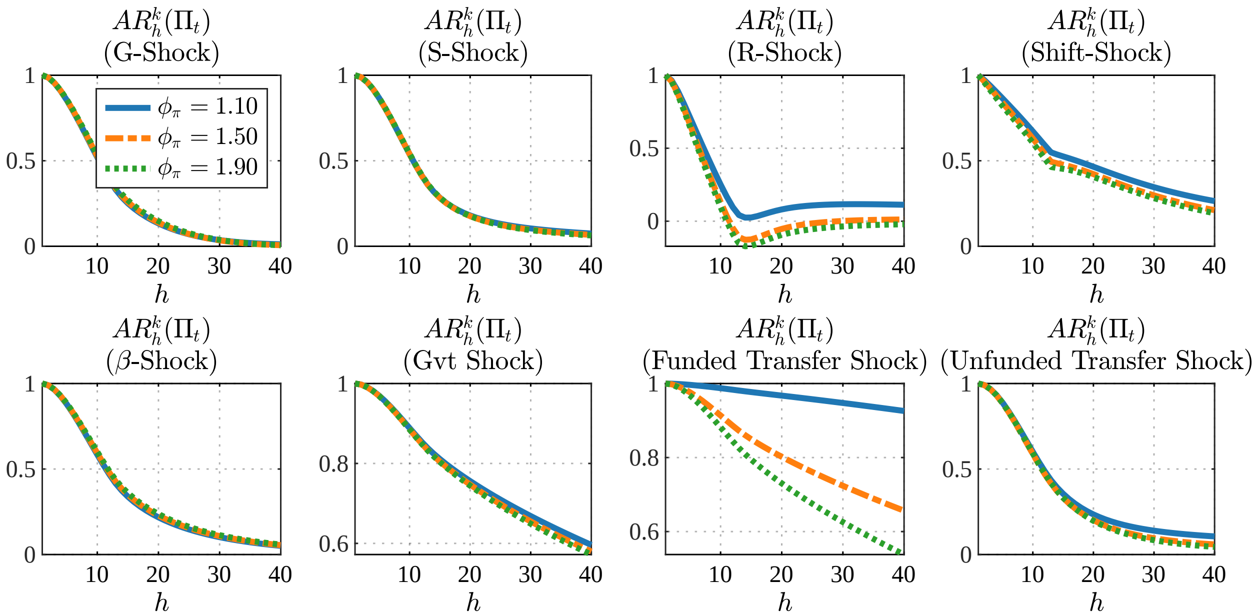
Appendix Figure A.11: MODEL-IMPLIED INFLATION PERSISTENCE CONDITIONAL ON A STRUCTURAL SHOCK AT DIFFERENT VALUES OF ϕ_π

Notes: This figure shows inflation persistence in the baseline model. Each panel presents conditional inflation persistence in response to shock k ($AR_h^{(k)}(\Pi_{12,t})$). Autocorrelations of the inflation response are plotted for different values of ϕ_π.



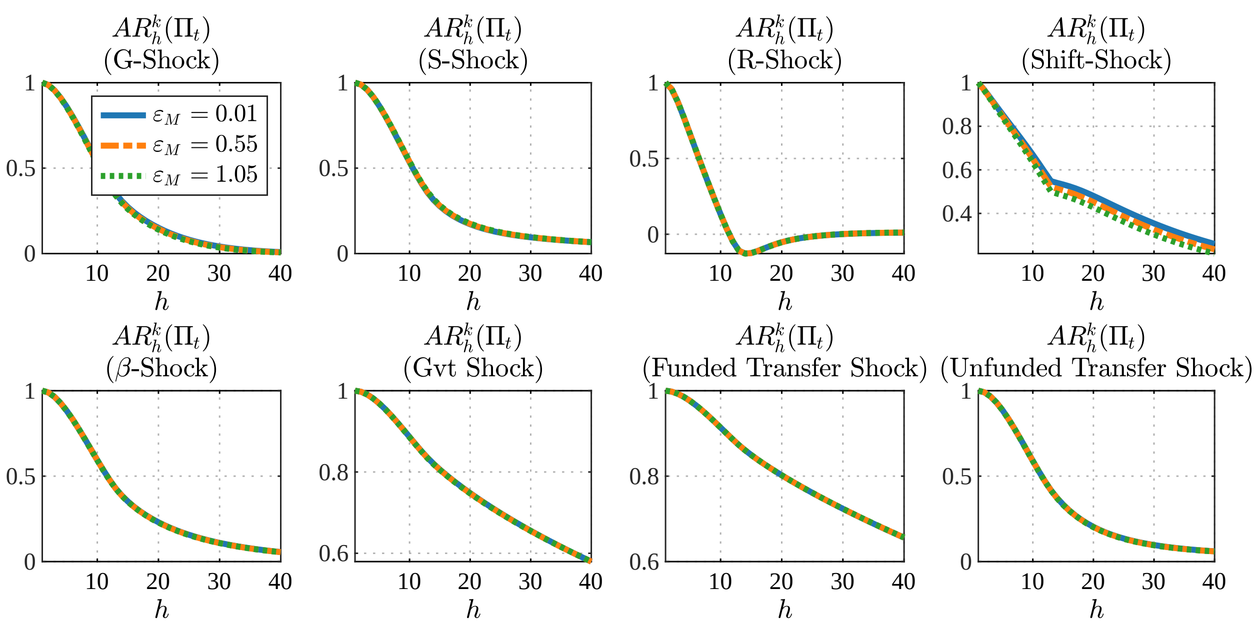
Appendix Figure A.12: MODEL-IMPLIED INFLATION PERSISTENCE CONDITIONAL ON A STRUCTURAL SHOCK AT DIFFERENT VALUES OF ε_M

Notes: This figure illustrates inflation persistence in the baseline model. Each panel shows conditional inflation persistence in response to shock k ($AR_h^{(k)}(\Pi_{12,t})$). Autocorrelations of the inflation response are plotted for different values of ε_M.



Appendix Figure A.13: MODEL-IMPLIED INFLATION PERSISTENCE CONDITIONAL ON A STRUCTURAL SHOCK AT DIFFERENT VALUES OF ϕ_π IN THE MODEL WITH BFM FUNDED/UNFUNDED TRANSFER SHOCKS

Notes: This figure illustrates inflation persistence in the alternative model with BFM funded/unfunded transfer shocks. Each panel presents conditional inflation persistence in response to shock k ($AR_h^{(k)}(\Pi_{12,t})$). Autocorrelations of the inflation response are plotted for different values of ϕ_π.



Appendix Figure A.14: MODEL-IMPLIED INFLATION PERSISTENCE CONDITIONAL ON A STRUCTURAL SHOCK AT DIFFERENT VALUES OF ε_M IN THE MODEL WITH BFM FUNDED/UNFUNDED TRANSFER SHOCKS

Notes: This figure illustrates inflation persistence in the alternative model with BFM funded/unfunded transfer shocks. Each panel presents conditional inflation persistence in response to shock k ($AR_h^{(k)}(\Pi_{12,t})$). Autocorrelations of the inflation response are plotted for different values of ε_M.