

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

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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 to study the persistently high inflation during the post-COVID-19 period. We include multiple shocks as well as several amplification channels of these shocks in a parsimonious model to quantify the relative importance of each factor. We calibrate the model to match the pre-COVID-19 data and alter parameters governing 1) the fiscal rule, 2) inflation feedback in the monetary policy rule, 3) elasticity of substitution among intermediary inputs in production, and 4) the size of a sectoral demand shift shock to explain the post-COVID-19 data. We obtain estimates of shocks in the model to fit goods inflation data during the post-COVID-19 period and use aggregate inflation to test the model's ability to explain the recent inflationary episode. Although aggregate demand shocks and a sectoral demand shift shock have played a significant role in the initial inflation surge during 2021, the propagation of these shocks into the persistently high aggregate inflation was also helped by lower inflation feedback in the monetary policy response relative to the pre-COVID-19 period. Compared with other changes in parameters, this alteration of the monetary policy rule best fits the level and persistence of the post-COVID-19 aggregate inflation. While lowering the elasticity of substitution among intermediary inputs can match the level of inflation, it does a poorer job of explaining the persistence of inflation compared with allowing changes in the monetary policy rule.

JEL classification: E53; E62; E63

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

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1 Introduction

As the U.S. economy emerged from the pandemic-driven restrictions on economic activities of early 2021, inflation started to pick up. Figure 1 shows the historical behavior of inflation and consumption both at the disaggregated level (goods sector and services sector) and aggregated level. After a prolonged period of low inflation before the pandemic shock hit the economy in 2020, U.S. inflation, measured by the twelve month change in the personal consumption expenditures (PCE) price index, first rose above 3 percent in early 2021, peaked near 7 percent in the summer of 2022. Policymakers viewed the initial rise of inflation in 2021 as largely “transitory” due to the one-time pressure on the supply side as the economy reopened while inflation expectations remained stable (FOMC, 2021). However, they changed this view and began to signal impending policy tightening later in 2021 as inflation remained persistently high. With the substantial tightening of monetary policy in 2022, inflation came down somewhat but still remained well over 4 percent as of December 2022, much higher than the Federal Reserve’s inflation target of 2 percent. As consumption rotated toward services, which were depressed during the pandemic-period, goods inflation started to come down. The decline in goods inflation is also observed when we look at the core goods component in the right panel of Figure 1, which strips away volatile food and oil components. Nonetheless, the decline was largely offset by the opposite movement in services inflation that remained elevated both in core and non-core measures.

There are many factors that could contribute to the persistent rise in inflation. The pandemic disrupted both the demand side (e.g., a large shift of consumption from services to goods) and

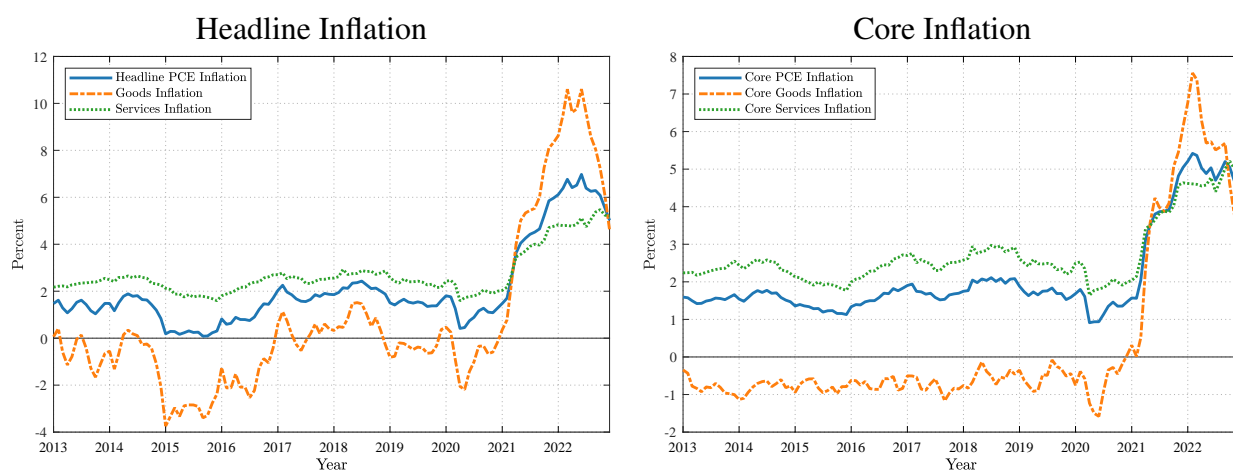


Figure 1: AGGREGATED AND SECTORAL INFLATION: 2013-2022

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 dashed 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

the supply side (e.g., supply chain disruptions) and triggered extraordinary policy responses (e.g., a series of fiscal support packages as well as the Federal Reserve’s low interest rate policy and asset purchases). In addition, the Federal Reserve announced a new framework in the midst of the pandemic (August 27, 2020) that targets the average inflation over time at 2 percent, which was criticized by some researchers for abandoning the pre-emptive policy tightening against inflation (Sargent and Silber, 2022). With multiple factors operating at the time, quantifying the relative importance of each factor is challenging.

This paper takes this challenge and calibrates a two-sector New Keynesian model with input-output linkages buffeted by multiple aggregate and sectoral shocks. The model also includes the friction on the production side of the economy through the imperfect substitution among production factors across sectors. It also captures the Federal Reserve’s new framework of the average inflation targeting as well as the fiscal regime in which inflation is driven by the fiscal rule and the monetary policy authority accommodates the fiscal action. Finally, the model considers the increased volatility of a sectoral demand shift shock to capture the pandemic-driven shift to goods consumption from services consumption.

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, similar to Gagliardone and Gertler (2023).

We focus on identifying determinants of level and persistence of inflation during the pandemic period. We re-calibrate the model based on the pre-pandemic data to introduce the respective channel (shock, friction, and policy regime) used to explain the post-pandemic inflation. Given re-calibrated parameters, we obtain shock estimates using the historical decomposition of goods inflation and other non-inflation variables during the post-pandemic period (March 2020-December 2022). We evaluate alternative specifications of the baseline model based on the model fit for the level and persistence of aggregate inflation, which was not directly used in the re-calibration exercise.

We draw several conclusions from our quantitative analysis. First, allowing changes in parameters governing the monetary policy rule by lengthening the targeting horizon for inflation and lowering the inflation feedback parameter can best fit the level and persistence of aggregate inflation. While increasing the friction on the production side through a lower elasticity of substitution among the intermediary inputs similarly increases the correlation between the model-implied inflation and the data, changing the monetary policy rule fits the volatility of inflation better. In addition, a

less aggressive monetary policy response to inflation makes the inflationary effect of the aggregate demand shock more persistent at the same time that it makes shocks with higher persistence more important in determining the volatility of inflation. For other specifications, the model fit is not much different from the baseline calibration (a higher volatility for a sectoral demand shift shock) or worse in terms of over-predicting inflation volatility (fiscal regime).

Second, the historical decomposition of aggregate inflation under our favored calibration shows that fiscal support packages implemented during 2020-2021 played a significant role in the initial inflation surge during 2021. In 2022, the inflationary pressures from fiscal policy shocks faded, but a negative goods-sector technology shock seems to explain a bulk of the persistent rise in inflation. Our model does not have a direct role for the commodity input but the rise in the oil price with the war in Ukraine can be proxied as a goods sector technology shock in the model.

Third, we find that the real interest rate has remained relatively low in the first half of 2022 in spite of the rapid policy tightening of the Federal Reserve, contributing to inflation. In the model, an inter-temporal preference shock that reduces the real interest rate and boosts consumption and inflation accounts for this pattern. A positive monetary policy shock is found to decrease aggregate inflation only from the late 2022.

The final point is that the pandemic did not necessarily increase the degree of friction on the production side but exacerbated the influence of the existing friction by subjecting the economy to an unusually large demand and supply imbalance. To the extent large shocks dissipate, inflation is likely to return to the pre-COVID-19 level over time. Our analysis suggests that the return might have been faster if the monetary policy had responded to inflation to the same degree as in the pre-COVID-19 period.

Related Literature: Our paper is closely related to the literature that uses dynamic macro models to understand the post-COVID-19 inflation (e.g., [Amiti, Heise, Karahan and Şahin 2023](#); [Bhattarai, Lee and Yang 2023](#); [Benigno and Eggertsson 2023](#); [Bianchi, Faccini and Melosi 2023](#); [Comin, Johnson and Jones 2023](#); [Ferrante, Graves and Iacoviello 2023](#); [Gagliardone and Gertler 2023](#); [Harding, Lindé and Trabandt 2023](#)). 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 attempts to explain the post-COVID-19 inflation by the combination of both policy-driven factors and various frictions.

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 a persistent inflation because the lower real interest rate stimulates borrowing and household spending. [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 the future tax increase and accommodated by the non-response of the monetary policy to inflation can explain the persistent rise in inflation. While this channel certainly helps to amplify the rise in inflation during 2021, in our alternative calibration of the fiscal regime, it implies overly volatile aggregate inflation when the model's shock estimates are obtained to perfectly fit the goods inflation data. In other words, the fiscal regime may suggest the counterfactually large pass-through from goods inflation to services inflation during the post-COVID-19 period.

Although [Bianchi et al. \(2023\)](#) and [Bhattarai et al. \(2023\)](#) provide detailed descriptions of monetary and fiscal policies, they do not 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 because they do not consider the input-output network in a multi-sector model. Hence, they cannot distinguish a sharp rise and fall in goods inflation from a more muted but more persistent variation in services inflation. [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. In [Amiti et al. \(2023\)](#) and [Comin et al. \(2023\)](#), supply disruptions play an important role in creating a rapid increase in goods inflation while [Ferrante et al. \(2023\)](#) emphasizes the sectoral demand reallocation during the COVID-19 period (from services to goods) as a main factor of goods inflation. In contrast to [Bianchi et al. \(2023\)](#) and [Bhattarai et al. \(2023\)](#), they 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. We find that the increased friction on the production side helps to match the rise in aggregate inflation but underpredicts the volatility and persistence of the aggregate inflation.

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](#)). However, 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, 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 as inflation increases. Unlike [Benigno and Eggertsson \(2023\)](#), [Harding et al. \(2023\)](#) derives the nonlinear Phillips curve from 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 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. Our favored version of the re-calibration that features a less aggressive response of monetary policy to inflation extends the one-sector models. We find that the steepening Phillips curve improves the model fit for change in the fiscal rule but not for our favored specification.

Our paper is also 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.

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 \(2014\)](#) considers 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 network structure. 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.

2 Model

We build a multi-sector new Keynesian model with input-output linkage 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 2020.¹ There are N sectors in the economy. Each sector $i \in \{1, \dots, N\}$ 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.

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:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \xi_{D,t} \left[\frac{(C_t)^{1-\gamma}}{1-\gamma} - \chi \frac{L_t^{1+\varphi}}{1+\varphi} \right],$$

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

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

¹[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.

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:

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

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

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

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

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

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

where $L_{i,t}$ is the household's labor supply for sector i , Γ_i^L 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:

$$\begin{aligned} \xi_{D,t} C_t^{-\gamma} &= \beta R_t E_t \left[\xi_{D,t+1} C_{t+1}^{-\gamma} \frac{1}{\Pi_{t+1}} \right], \\ (1 - \tau_t) \frac{W_{i,t}}{P_t} &= \chi (L_t)^\varphi (C_t)^\gamma \left(\frac{1}{\Gamma_i^L} \frac{L_{i,t}}{L_t} \right)^{\frac{1}{\varepsilon_L}} \text{ for each } i \in \{1, \dots, N\}, \\ \lim_{t \rightarrow \infty} \left[\beta^t \xi_{D,t} C_t^{-\gamma} \frac{B_t}{P_t} \right] &= 0. \end{aligned}$$

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

$$\begin{aligned} \max \quad & P_{i,t} Y_{i,t} - \int_0^1 P_{i,t}(j) Y_{i,t}(j) dj, \\ \text{s.t.} \quad & Y_{i,t} = \left[\int_0^1 (Y_{i,t}(j))^{\frac{\sigma_i-1}{\sigma_i}} dj \right]^{\frac{\sigma_i}{\sigma_i-1}}. \end{aligned}$$

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

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

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 , $\Gamma_{i,k}$ is the relative share of k sector output for sector i 's composite material.

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

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

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

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

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

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

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:

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

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

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

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

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

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:

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

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

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

where

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

2.4 Government

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

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

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:

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

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 $Q_t^G = \prod_{i=1}^N (Q_{i,t})^{\Gamma_i^G}$.

With debt, the government budget constraint is

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

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.

Monetary policy follows a Taylor rule with average inflation targeting:

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

where $\bar{\Pi}_{t-T,t} = \left[\prod_{j=1}^T (\Pi_{t-j+1}) \right]^{1/T}$ for $T \geq 1$ is T -period average inflation and $\zeta_{R,t}$ is the monetary policy shock. 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 ($\psi_L \gg 0$).

2.5 Market clearing, aggregation, and resource constraints

Labor market clearing conditions are given by

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

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:

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

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

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

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

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

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:

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

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

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

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:

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

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 $\varepsilon_t^{z,S}$).

3 Channels of High and Persistent Inflation

This section inspects the main channels of high and persistent inflation with a linearized version of the model described in Section 2. We derive a sectoral Phillips curve in the model and decompose it to look at the source of high inflation. In addition, we introduce an 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.

3.1 Sectoral Phillips Curve and the Decomposition of Marginal Cost

Aggregate inflation can be expressed as the weighted average of sector-level inflation in our model, whose dynamics are in turn determined by the sector-level Phillips curve. As in [Carvalho et al. \(2021\)](#) and [Rubbo \(2023\)](#), the sector-level Phillips curve connects the sector-level price inflation with the expected sector-level price inflation and the sector-level real marginal cost. We describe the sector-level Phillips curve below with all the variables denoting log deviations from steady state values.

$$\begin{aligned}\hat{\Pi}_{i,t} &= \beta E_t(\hat{\Pi}_{i,t+1}) + \frac{(1-\theta_i)(1-\beta\theta_i)}{\theta_i} (\widehat{mc}_{i,t} - \widehat{Q}_{i,t}), \\ \widehat{mc}_{i,t} &= -\frac{\widehat{Z}_{i,t}}{\varepsilon_Y} + \nu_i \widehat{w}_{i,t}^M + (1-\nu_i) \widehat{w}_{i,t}, \quad \nu_i = \frac{\alpha_i (\bar{w}_i^M)^{1-\varepsilon_Y}}{\alpha_i (\bar{w}_i^M)^{1-\varepsilon_Y} + (1-\alpha_i) (\bar{w}_i)^{1-\varepsilon_Y}},\end{aligned}\tag{1}$$

$$\begin{aligned}\widehat{w}_{i,t}^M &= \sum_{k=1}^N \omega_{i,k} \widehat{Q}_{k,t}, \quad \omega_{i,k} = \frac{\Gamma_{i,k} \bar{Q}_k^{1-\varepsilon_M}}{\sum_{j=1}^N \Gamma_{i,j} \bar{Q}_j^{1-\varepsilon_M}}, \quad \widehat{w}_{i,t} = \left(\varphi - \frac{1}{\varepsilon_L}\right) \widehat{L}_t + \frac{1}{\varepsilon_L} \widehat{L}_{i,t} + \gamma \widehat{C}_t - \frac{\bar{\tau}}{1-\bar{\tau}} \widehat{\tau}_t, \\ \widehat{Q}_t^{\text{sector}} &= [\widehat{Q}_{1,t}, \dots, \widehat{Q}_{N,t}]^T, \quad \widehat{L}_t^{\text{sector}} = [\widehat{L}_{1,t}, \dots, \widehat{L}_{N,t}]^T, \quad \widehat{Z}_t^{\text{sector}} = [\widehat{Z}_{1,t}, \dots, \widehat{Z}_{N,t}]^T, \\ \nu^{\text{sector}} &= \text{diag}(\nu_1, \dots, \nu_N), \quad \mathbb{1} = (1, \dots, 1)^T,\end{aligned}$$

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 $\Pi_t^{\text{sector}} = [\Pi_{1,t}, \dots, \Pi_{N,t}]^T$. Then sector-level Phillips curves can be decomposed into four terms as follows:

$$\begin{aligned}\widehat{\Pi}_t^{\text{sector}} &= \underbrace{\beta E_t(\widehat{\Pi}_{t+1}^{\text{sector}})}_{\text{expected inflation}} \\ &+ \underbrace{\Theta(\Omega - I) \widehat{Q}_t^{\text{sector}}}_{\text{intermediary input cost in real terms}} \\ &+ \underbrace{\Theta(I - \nu^{\text{sector}}) \left(\left(\varphi - \frac{1}{\varepsilon_L}\right) \widehat{L}_t \mathbb{1} + \frac{1}{\varepsilon_L} \widehat{L}_t^{\text{sector}} + \gamma \widehat{C}_t \mathbb{1} + \frac{\bar{\tau}}{1-\bar{\tau}} \widehat{\tau}_t \mathbb{1} \right)}_{\text{sectoral real wage}} \\ &- \underbrace{\Theta \frac{\widehat{Z}_t^{\text{sector}}}{\varepsilon_Y}}_{\text{sectoral technology shock}}.\end{aligned}$$

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 the 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 like sectoral wage and aggregate productivity. For example, if the real wage channel were a dominant factor in the 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:

$$\begin{aligned}
\widehat{\Pi}_t &= \underbrace{\beta E_t(\widehat{\Pi}_{t+1})}_{\text{expected inflation}} \\
&+ \underbrace{\bar{\Gamma}^c T [\beta(\widehat{Q}_{t+1}^{\text{sector}} - \widehat{Q}_t^{\text{sector}}) - (\widehat{Q}_t^{\text{sector}} - \widehat{Q}_{t-1}^{\text{sector}}) + \Theta(\Omega - I)\widehat{Q}_t^{\text{sector}}]}_{\text{intermediary input cost in real terms}} \\
&+ \underbrace{\bar{\Gamma}^c T \Theta(I - \nu^{\text{sector}}) \left((\varphi - \frac{1}{\varepsilon_L}) \widehat{L}_t \mathbb{1} + \frac{1}{\varepsilon_L} \widehat{L}_t^{\text{sector}} + \gamma \widehat{C}_t \mathbb{1} + \frac{\bar{\tau}}{1 - \bar{\tau}} \widehat{\tau}_t \mathbb{1} \right)}_{\text{sectoral real wage}} \\
&- \underbrace{\bar{\Gamma}^c T \Theta \frac{\widehat{Z}_t^{\text{sector}}}{\varepsilon_Y}}_{\text{sectoral technology shock}}, \tag{2}
\end{aligned}$$

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

By iterating forward the sectoral Phillips curve in Equation (2), we obtain aggregate inflation as the discounted sum of the current and expected future real marginal cost as follows:

$$\begin{aligned}
\widehat{\Pi}_t &= \underbrace{\sum_{j=0}^{\infty} \beta^j E_t [(\bar{\Gamma}^c)^T (\widehat{Q}_{t+j-1}^{\text{sector}} + [\Theta(\Omega - I) - (1 + \beta)I] \widehat{Q}_{t+j}^{\text{sector}} + \beta E_t(\widehat{Q}_{t+j+1}^{\text{sector}}))]}_{\text{intermediary input cost inflation}} \\
&+ \underbrace{\sum_{j=0}^{\infty} \beta^j E_t [(\bar{\Gamma}^c)^T \Theta(I - \nu^{\text{sector}}) \left((\varphi - \frac{1}{\varepsilon_L}) \widehat{L}_{t+j} \mathbb{1} + \frac{1}{\varepsilon_L} \widehat{L}_{t+j}^{\text{sector}} + \gamma \widehat{C}_{t+j} \mathbb{1} + \frac{\bar{\tau}}{1 - \bar{\tau}} \widehat{\tau}_{t+j} \mathbb{1} \right)]}_{\text{real wage}} \\
&- \underbrace{\sum_{j=0}^{\infty} \beta^j E_t [(\bar{\Gamma}^c)^T \Theta \frac{\widehat{Z}_{t+j}^{\text{sector}}}{\varepsilon_Y}]}_{\text{technology shock}},
\end{aligned}$$

where $\Theta = \text{diag}(\frac{(1-\theta_1)(1-\beta\theta_1)}{\theta_1}, \dots, \frac{(1-\theta_N)(1-\beta\theta_N)}{\theta_N})$ and $\Omega = \text{diag}(\nu_1, \dots, \nu_N)\omega$.

The sector-level price inflation is ultimately determined by the propagation of factors affecting sector-level relative prices (intermediary cost channel), sectoral real wages and sectoral technology shocks. Under our framework, inflation can surge either due to aggregate demand shocks or sector-specific shocks that determine 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 boost the aggregate consumption gap. In addition, fiscal shocks financed by distortionary taxes can negatively affect labor supply and increase inflation through $\widehat{\tau}_t$.² The inflationary effect of

²When fiscal policy does not raise taxes to finance unanticipated government spending or transfer, fiscal shocks

aggregate shocks can be amplified if the monetary policy become less responsive to inflation by lowering ϕ_{Π} .

Second, sector-specific shocks can also have inflation effects by changing the sector-level real marginal cost. A negative sectoral technology shock is a prominent example and can capture the effect of negative supply-side effects from the COVID-19 (e.g., pandemic-related health measures that increased the cost of production). In addition, as highlighted by [Ferrante et al. \(2023\)](#), a sectoral demand shift shock can also affect aggregate inflation especially if the reallocation of resources across sectors is subject to frictions. In [Ferrante et al. \(2023\)](#), labor hiring cost plays such a role while it is the imperfect mobility of labor across sectors in our model. 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}_t^{sector} . In that case, the sectoral real wage is more likely to be affected by aggregate shocks and sector-specific shocks would have small effects than otherwise. In contrast, if labor is not perfectly mobile across sectors, sectoral real wage would be more sensitive to sector-specific shocks. Hence, if large sector-specific shocks coincide with the increasing friction in the sectoral reallocation of labor (e.g., a decline in ε_L), they can increase aggregate inflation significantly.

Another channel that 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 the intermediary input is expected to increase further in the future (e.g., material shortages), 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:

$$\widehat{Q}_{t-1}^{sector} + (\Theta(\Omega - I) - (1 + \beta)I) \widehat{Q}_t^{sector} + \beta E_t[\widehat{Q}_{t+1}^{sector}] = \beta(E_t[\widehat{Q}_{t+1}^{sector}] - \widehat{Q}_t^{sector}) - (\widehat{Q}_t^{sector} - \widehat{Q}_{t-1}^{sector}) - \Theta(I - \Omega)\widehat{Q}_t^{sector}.$$

Intuitively, the above expression implies that the relative price inflation is accelerated more in the flexible sector (e.g., the sector with the steeper slope in the sectoral Phillips curve which corresponds to an element in Θ), it would increase aggregate inflation more than otherwise. Also 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, which leads to the greater acceleration in the relative price inflation than otherwise because the relative price is more responsive to sectoral shocks in this case.

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

increase inflation mostly through the demand side channel. Under our baseline, we assume that taxes adjust. We illustrate this in the appendix by showing impulse-responses functions under both the monetary regime and the fiscal regime.

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 not been just high but also persistent. In particular, although the Federal Reserve started to raise the interest rate in 2022, aggregate inflation has declined only gradually. In particular, service-sector inflation has been persistently high although goods-sector inflation declined significantly. In the model, inflation persistence can increase either when the economy is subject to a more persistent shock or when changes in policy regimes or the degree of market frictions make inflation more sensitive to more persistent shocks than less persistent shocks.

As in the case of the level of inflation, both aggregate factors and sector-specific factors can increase the persistence of inflation in our model. To decompose changes in the persistence of inflation into contributions from various shocks, we first define the persistence of inflation based on the long-run variance and auto-covariance of inflation. Suppose that we have n_k exogenous shocks which are independent with each other. In the linearized model, inflation can be represented by the following vector moving average process with respect to innovations in exogenous shocks based on the model solution. We denote the state vector in the model by s_t :

$$\begin{aligned}
s_t &= \Phi_s s_{t-1} + \Phi_\epsilon \epsilon_t, \\
\Pi_t &= \Pi' s_t = \Pi' \sum_{j=0}^{\infty} \Phi_s^j \Phi_\epsilon \epsilon_{t-j} = \sum_{j=0}^{\infty} \Phi'_{\Pi,j} \epsilon_{t-j}, \\
V(\Pi_t) &= \sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon \Phi_{\Pi,j}, \\
Cov(\Pi_t, \Pi_{t+h}) &= \sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon \Phi_{\Pi,j+h}, \\
AR_h(\Pi_t) &= \sum_{k=1}^{n_k} \left(\frac{\sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon^{(k)} \Phi_{\Pi,j}}{\sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon \Phi_{\Pi,j}} \right) \left(\frac{\sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon^{(k)} \Phi_{\Pi,j+h}}{\sum_{j=0}^{\infty} \Phi'_{\Pi,j} V_\epsilon^{(k)} \Phi_{\Pi,j}} \right) = \sum_{k=1}^{n_k} w_k AR_h^{(k)}(\Pi_t). \quad (3)
\end{aligned}$$

$AR_h^{(k)}(\Pi_t)$ is the persistence of inflation conditional on the realization of the k -th shock while $AR_h(\Pi_t)$ is 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 were set to zero. In case that the model is purely forward-looking and the solution of Π_t is an affine function of exogenous shocks, the first order auto-covariance of Π_t is the weighted average of each shock’s persistence since $AR_h^{(k)}(\Pi_t) = (\rho_k)^h$ where ρ_k is the persistence of the k -th shock. If the model contains the lagged endogenous variables as state variables, the model solution is not as simple as this. Davig and Doh (2014) show that $AR_h^{(k)}(\Pi_t)$ can depend on other model parameters, in particular 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 like the production network and the adjustment cost to the sectoral reallocation. In addition to weights, the long-run variance and the auto-covariance of inflation depend on the persistence and volatility of exogenous shocks. In Davig and Doh (2014), a decrease in the inflation feedback parameter in the monetary policy rule increases the weight on the most persistent shock. We examine if these results can hold in our extended model with the production network.

4 Quantitative Analysis

What were the main drivers of high and persistent inflation during the COVID-19 period? To inspect different channels through which shocks, frictions, and policy affect the dynamics of the post-COVID-19 inflation, we consider the simplified two sector version of the model in Section 2, which consists of a goods-producing sector and a service-producing sector. We calibrate the key model parameters with the pre-COVID-19 US data, and examine four main channels of high and persistent inflation by looking at the historical shock decomposition of aggregate inflation.

4.1 Data and Model Calibration

Table 1 shows baseline model parameters. We divide model parameters into four blocks. The first block is mostly related to household preferences and production technologies. For preference parameters, we take standard values in the literature. The model is calibrated at a monthly frequency with a time discount factor of $\beta = 0.98^{1/12}$. We set the inverse of the Frisch elasticity (φ) to be 1.0 and the inverse of the elasticity of intertemporal substitution (γ) to be 2.0. We set the elasticity of substitution across firms within each sector to be four ($\sigma_G = \sigma_S = 4$), which corresponds to a recent estimate of average markup of 33 percent (Hall, 2018). We assume that the goods and services consumption are substitutes by setting the elasticity (ε) as 2.0, to ensure that our results are not being driven by the assumption of complementarity in the consumption of sectoral goods. The elasticity of substitution between composite materials and labor is set as 1.0 and the steady-state share of goods consumption expenditure is 0.31 as in Ferrante et al. (2023). We use the input-output table (1997-2021) of the Bureau of Economic Analysis (BEA) to set each sector’s relative weight

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)
$\bar{\Gamma}_G^c$	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_G^L	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	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	1.1311	Sectoral Inflation IRFs
ε_L	Degree of labor mobility	0.0139	Sectoral Inflation IRFs
ρ_Γ	Persistence of demand shift shocks	0.99	Sectoral Inflation IRFs
σ_Γ	SD of demand shift shocks	0.0015	Sectoral Inflation IRFs

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

for sectoral composite materials ($\{\Gamma_{i,j}\}_{i,j \in \{G,S\}}$). 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.³ 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.⁴ We set the steady-state debt to GDP ratio to 2.5, which is close to the estimate in [Bianchi et al. \(2023\)](#).⁵ 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 parameter from the data.

The last 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 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).

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 ($\Gamma_{G,t}^c$) and the proxy policy rate (R_t) which is the measure of monetary policy stance explained in [Choi, Doh, Foerster, Martinez et al. \(2022\)](#). 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 has been declining steadily during the sample period, we use the detrended goods consumption weight after subtracting the linear trend from the original measure. We fit the

³The 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.

⁴In 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 \(2020\)](#).

⁵This is the annualized debt-to-GDP ratio estimated using the quarterly data. 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.

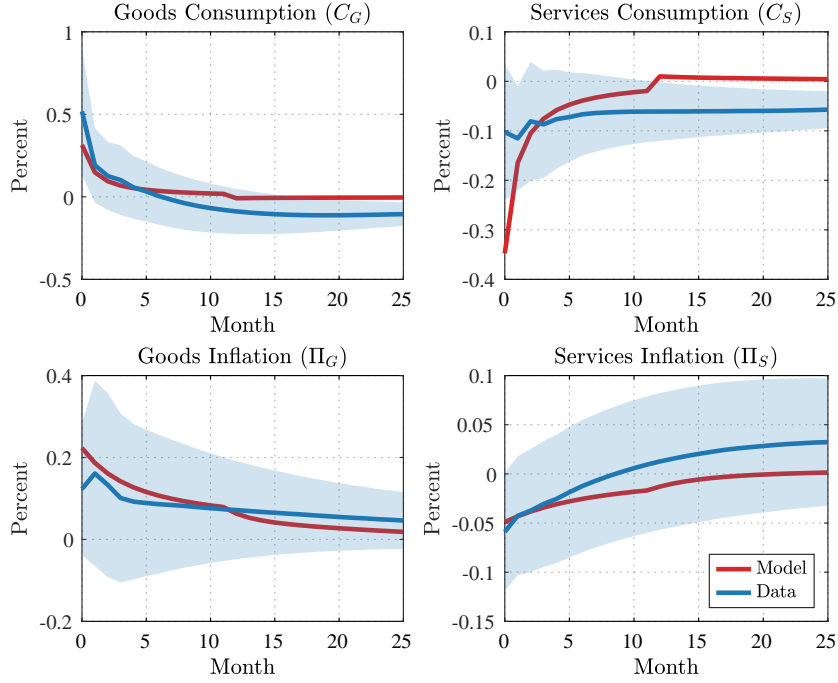


Figure 2: IRFs to Demand Shift Shocks in the Model and Data

Notes: The red line represents the model-implied impulse response to a one-standard deviation increase in $\Gamma_{G,t}^C$ while the blue line does the corresponding impulse response from the SVAR in Equation (4.2). The shaded area is the 95% confidence interval.

VAR(3) for the vector of six variables ($y_t = [\Delta C_{G,t-12:t}, \Delta C_{S,t-12:t}, \Pi_{G,t-12:t}, \Pi_{S,t-12:t}, \Gamma_{G,t}^c, R_t]$):

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

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_t^Γ) in the VAR:⁶

$$\begin{aligned} \frac{\partial \Delta C_{G,t-12+h:t+h}}{\partial \varepsilon_t^\Gamma} &> 0 \quad \text{and} \quad \frac{\partial \Delta C_{S,t-12+h:t+h}}{\partial \varepsilon_t^\Gamma} < 0, \quad \forall h \geq 0 \\ \frac{\partial \Pi_{G,t-12+h:t+h}}{\partial \varepsilon_t^\Gamma} &> 0 \quad \text{and} \quad \frac{\partial \Pi_{S,t-12+h:t+h}}{\partial \varepsilon_t^\Gamma} > 0, \quad \forall h \geq 0, \\ \frac{\partial \Gamma_{G,t+h}^c}{\partial \varepsilon_t^\Gamma} &> 0, \quad \forall h \geq 0. \end{aligned}$$

We estimate four parameters, $\Theta = \{\varepsilon_M, \varepsilon_L, \rho_\Gamma, \sigma_\Gamma\}$, 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

⁶We 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.

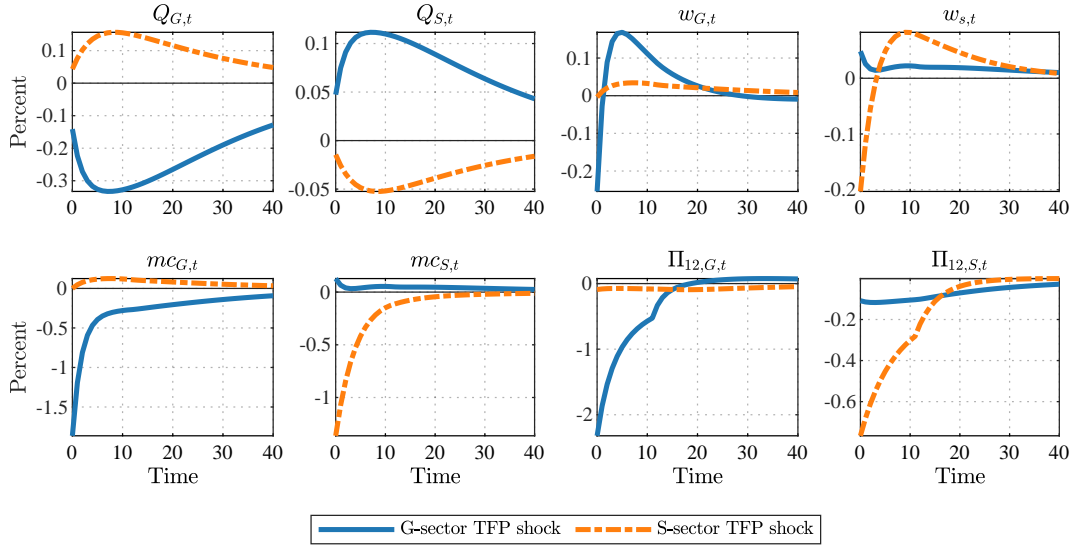


Figure 3: IRFs to Sectoral Technology Shocks

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.

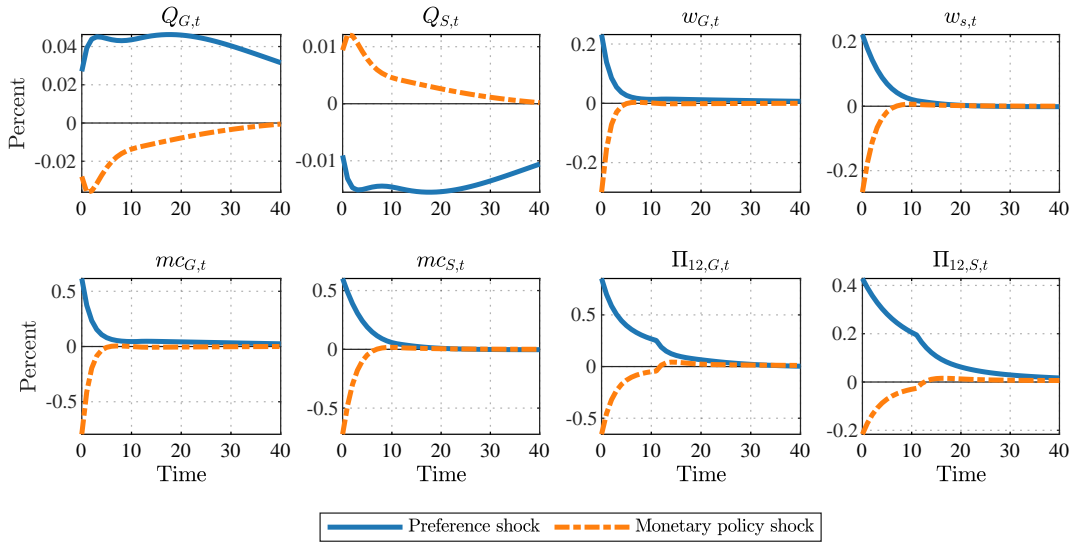


Figure 4: IRFs to Preference and Monetary Policy Shocks

Notes: This figure shows 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.

compares these IRFs in the calibrated model with the SVAR’s median IRFs.

4.3 Inspecting Inflation Dynamics through Impulse Responses

Figures 3–6 show 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,

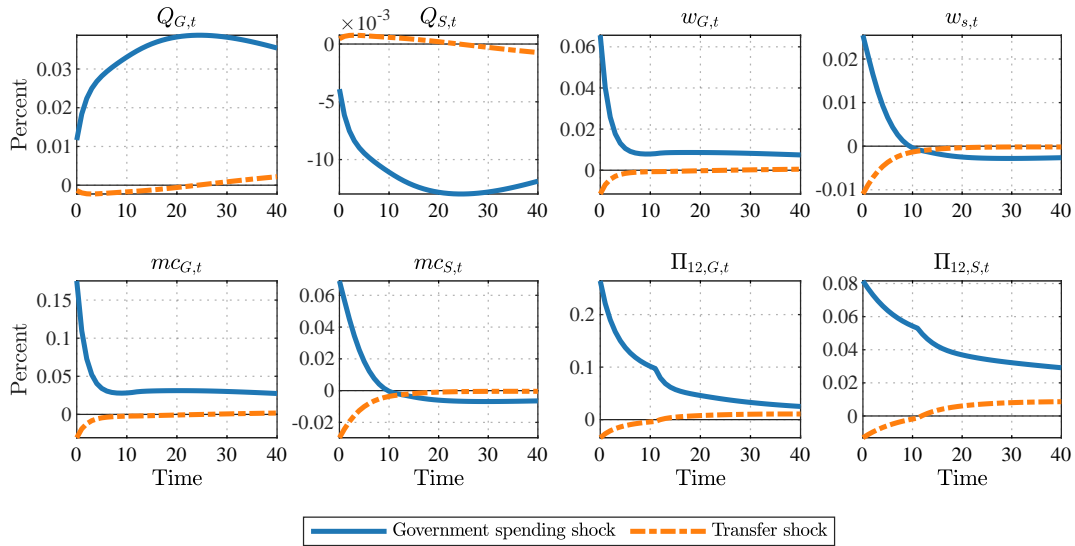


Figure 5: IMPULSE RESPONSES TO FISCAL SHOCKS

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.

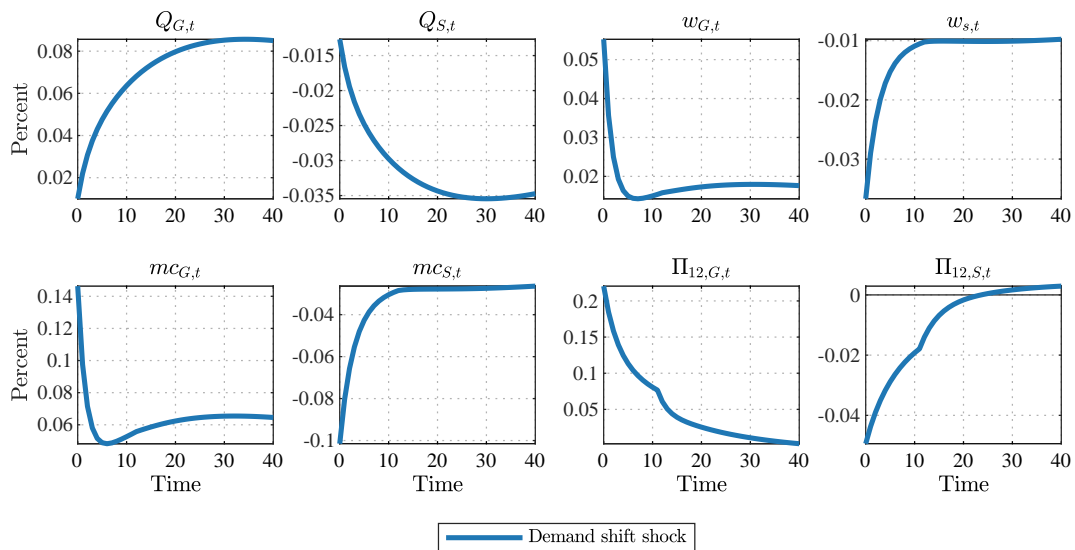


Figure 6: IMPULSE RESPONSES TO A DEMAND SHIFT SHOCK

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

aggregate shocks such as fiscal and monetary policy shocks as well as an intertemporal preference shock move real wage and price inflation of different sectors in the same direction. On the other hand, a sector-specific demand shock creates 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

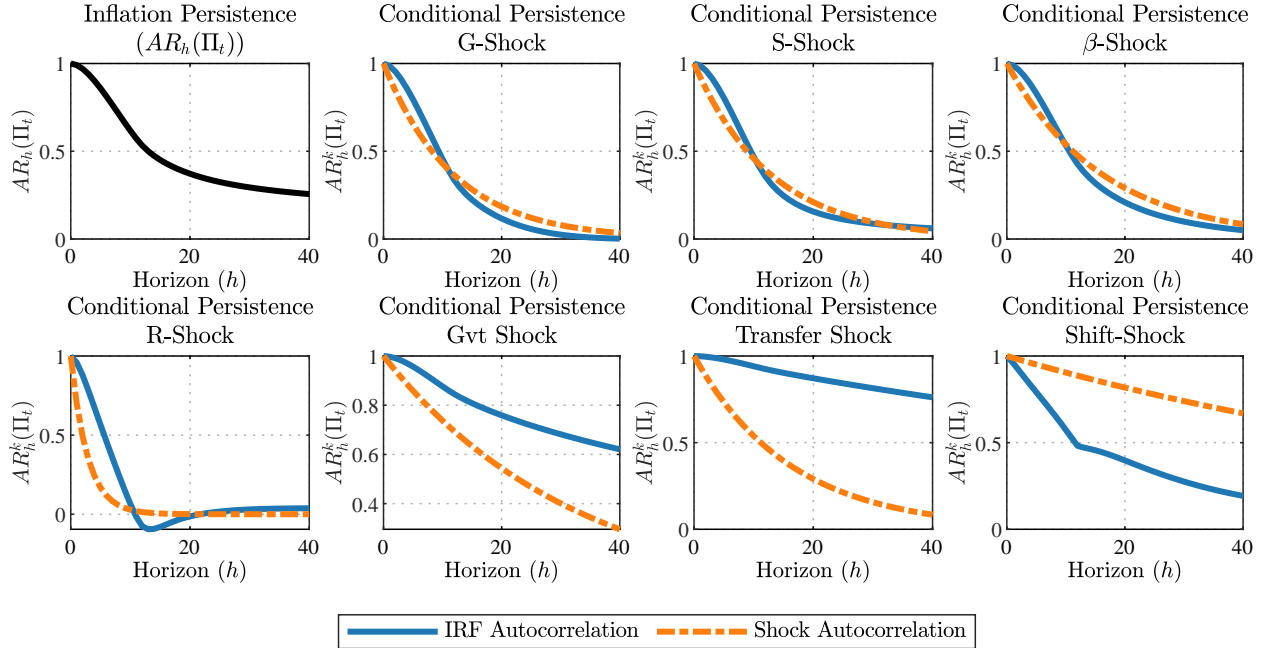


Figure 7: INFLATION PERSISTENCE ($AR_h(\Pi_{12,t})$)

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) 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).

in the same direction shortly after the realization of shocks.

Figure 7 shows the autocorrelation of the model-implied one-year inflation $\Pi_{12,t}$ at various horizons. We overlay the autocorrelation of shock with the autocorrelation of the corresponding impulse response of inflation to the respective shock. For most shocks, the autocorrelation of the impulse response decays more slowly than the autocorrelation of the shock at least within a horizon less than a year. The only exception is a demand shift shock, in which the autocorrelation of the shock decays more slowly than the autocorrelation of the impulse response. While the demand shift shock is highly persistent with the autocorrelation coefficient of 0.99, the impulses response of inflation in the SVAR to a demand shift shock is not so persistent. This is likely because we calibrate the model to match the model-implied impulse response with the impulse response from the SVAR, whose autocorrelation decays faster than implied by the autocorrelation of the demand-shift shock. In addition, under our baseline calibration, inflation feedback is strong enough to mitigate the impact of the persistent shock on inflation.

Table 2 shows the long-run variance decomposition of the one-year inflation into various shocks under the baseline calibration of the model. Sectoral shocks (mostly sector-specific productivity

Table 2: INFLATION VARIANCE DECOMPOSITION

Shock	Rel. Importance (%)	Shock	Rel. Importance (%)
G-sector TFP shock	26.12	Government spending shock	13.15
S-sector TFP shock	31.37	Transfer shock	1.44
Monetary policy shock	2.00	Sectoral demand shift shock	0.15
Preference shock	25.77		

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

shocks) account for about 58% of the long-run variance of inflation while aggregate demand shocks explain the rest. Under our baseline calibration, the contribution from a sectoral demand shift shock is negligible. This is not surprising because the SVAR also attributes a small portion of inflation to a sectoral demand shift shock during the 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 variables used to obtain shock estimates.

Given shock estimates, we look at the model’s fit for aggregate inflation, which was not used in the shock estimation, to test four alternative channels suggested to explain the post-COVID-19 inflation dynamics: (1) fiscal dominance and inflation, (2) frictions to production process, (3) accommodative monetary policy with longer AIT horizons, and (4) volatile demand shift disturbances.

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 the four different channels. We use the 12-month change in the headline PCE price index as the measure of aggregate inflation.⁷ Under the baseline calibration, the model-implied aggregate inflation is highly correlated with the data with the correlation coefficient of 0.9514. However, the model under-predicts the volatility of inflation data with the standard

⁷We calculate the mean from January 1960 to February 2023.

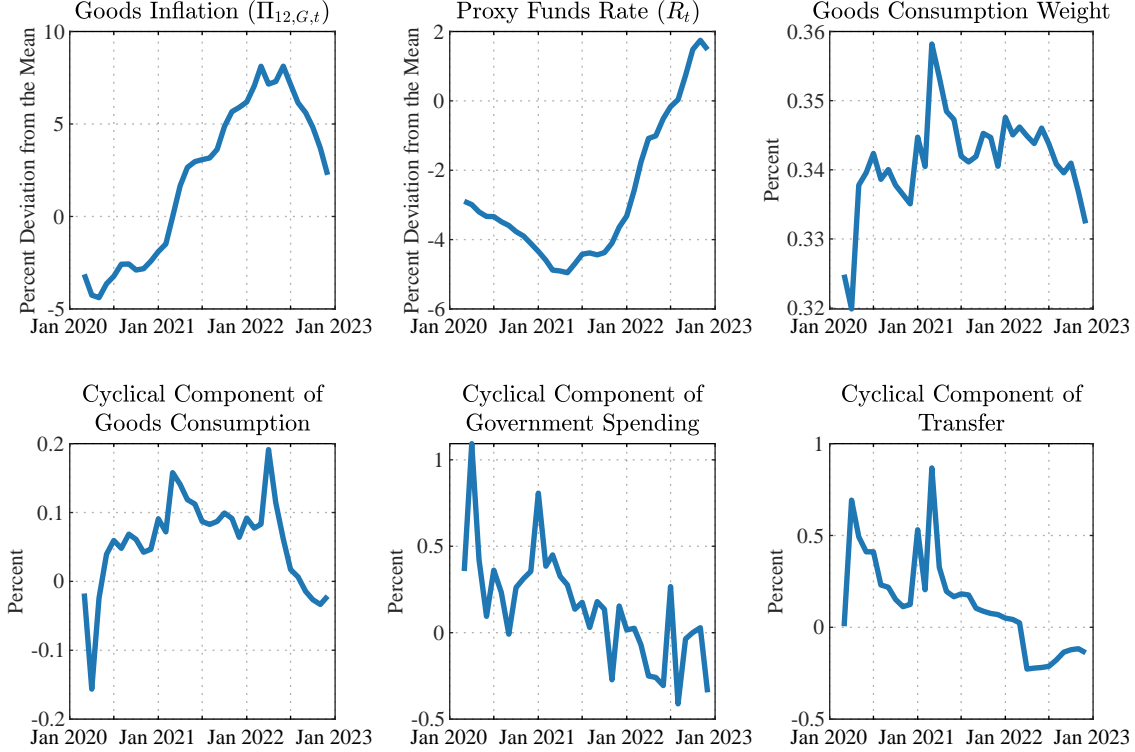


Figure 8: OBSERVED VARIABLES FOR SHOCK ESTIMATES

Notes: This figure shows the observed variables for shock estimates from March 2020 to December 2022. We compute percent deviations from the historical averages for goods inflation and proxy funds rates. For goods consumption, government spending, and transfers, we take cyclical components using the [Hamilton](#) filter.

deviation of the model-implied inflation only 85% of the counterpart in the data. Table 3 shows parameter values altered from the baseline calibration in the four different recalibration exercises. We discuss how alternative recalibrations of models improve or worsen the model fit relative to the baseline calibration.

Table 3: ALTERNATIVE CALIBRATIONS

	Alternative parameter values
(1) Fiscal regime	$\phi_{\Pi} = 0.0, \psi_L = 0.0, \frac{\bar{b}}{\bar{Y}} = 7.5$
(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	$\sigma_{\Gamma} = 0.015$

Notes: This table shows altered parameter values for four alternative calibration exercise. All the other model parameters are identical with the baseline calibration parameters in Table 1.

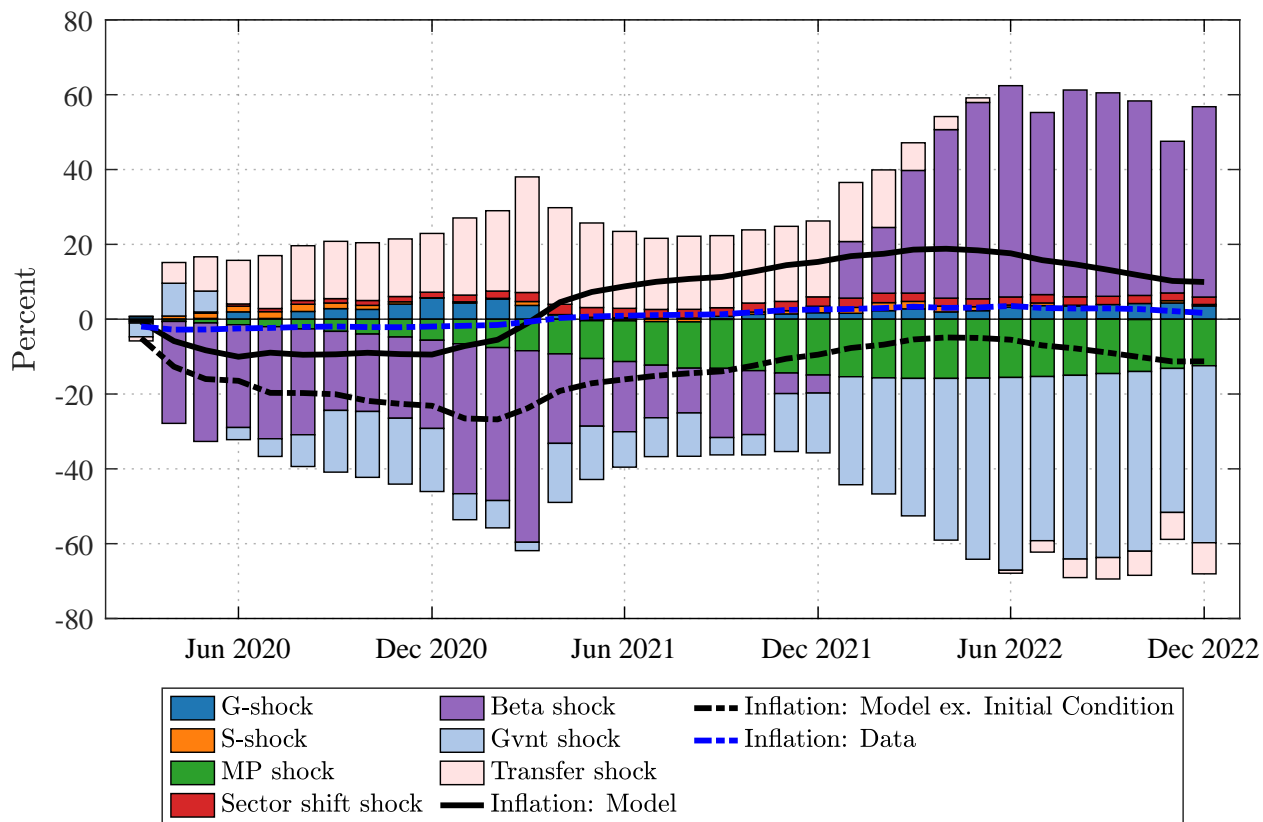


Figure 9: HISTORICAL SHOCK DECOMPOSITION OF $\Pi_{12,t}$: FISCAL REGIME

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.

Fiscal inflation. The first channel captures the fiscal inflation channel highlighted in [Bianchi et al. \(2023\)](#). The baseline calibration implies an active monetary policy regime with $\phi_\Pi > 1$ and a sufficiently large ψ_L , in which the monetary authority adjusts the interest rate 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. We shut down the inflation feedback in the monetary policy rule ($\phi_\Pi = 0$) and set the debt feedback parameter to be zero ($\psi_L = 0$) to model the fiscal regime. We also increase the steady-state debt-to-GDP ratio to 7.5 in this alternative calibration. Figure 9 shows the historical shock decomposition of $\Pi_{12,t}$ in the fiscal regime calibration. Government spending and transfer shocks explain the bulk of inflation up to the early 2022 and then sectoral technology shocks drive inflation in 2022. 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. Although the spike of the contribution of government spending and transfer shocks to inflation in the early 2021 coincides with the passage of a fiscal package (American Rescue Plan), the magnitude of the

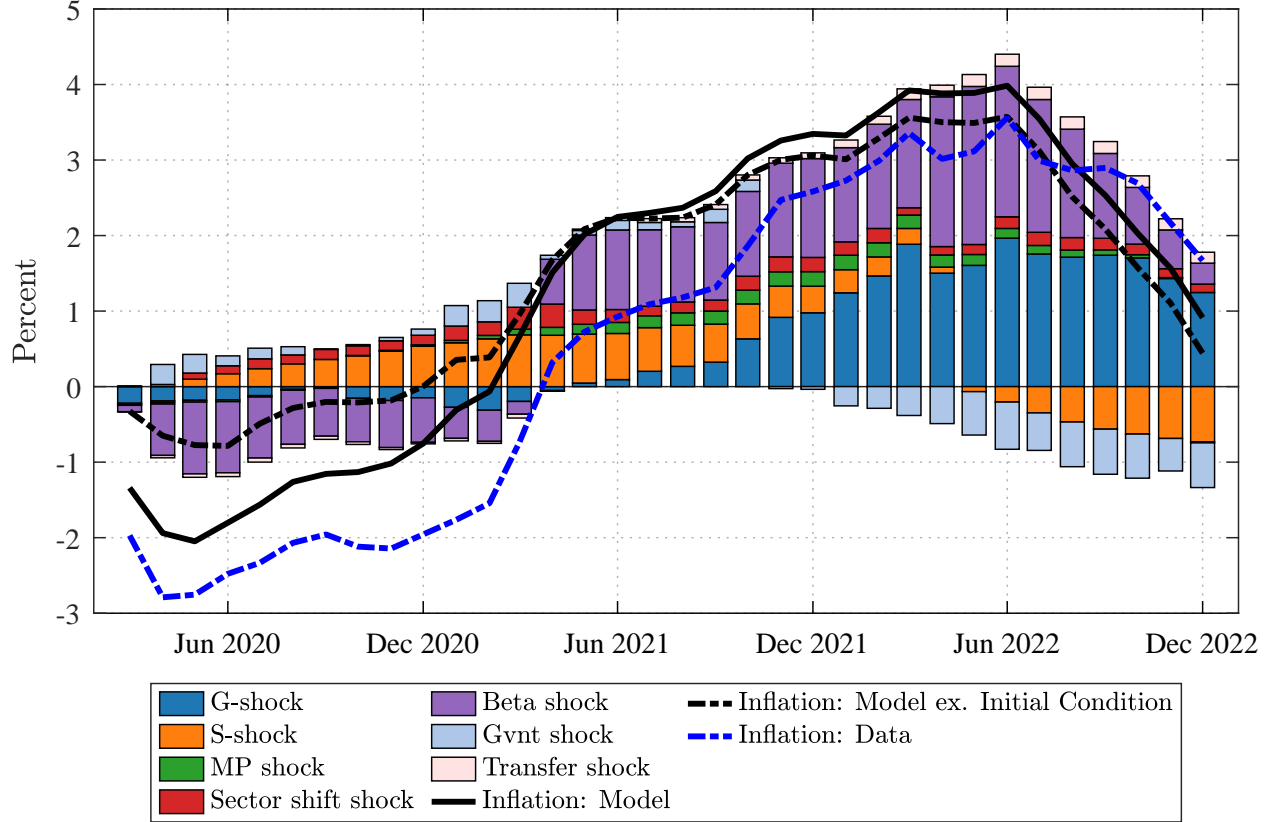


Figure 10: HISTORICAL SHOCK DECOMPOSITION OF $\Pi_{12,t}$: PRODUCTION FRICTION

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.

implied contribution seems to be too high relative to the realized data. Although the model-implied inflation is highly correlated with the data (correlation coefficient = 0.979), the volatility implied by the model estimate is nearly five times bigger than the volatility of the data, which weakens the plausibility of this channel.⁸

Disruption in production process. Another channel that has drawn a lot of attention in terms of explaining the surge in inflation is the 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 production process like a lower elasticity of substitution between the intermediary inputs can capture this channel in a similar way. We recalibrate the model to decrease ε_M to 0.01 from 1.1311 in the

⁸With the fiscal regime recalibration, lowering the nominal price rigidity parameters (θ_G, θ_S) improves the model fit somewhat although it still generates too volatile inflation compared to the data and other recalibration experiments. For all the other recalibration experiments, lowering the nominal price rigidity actually deteriorates the model fit.

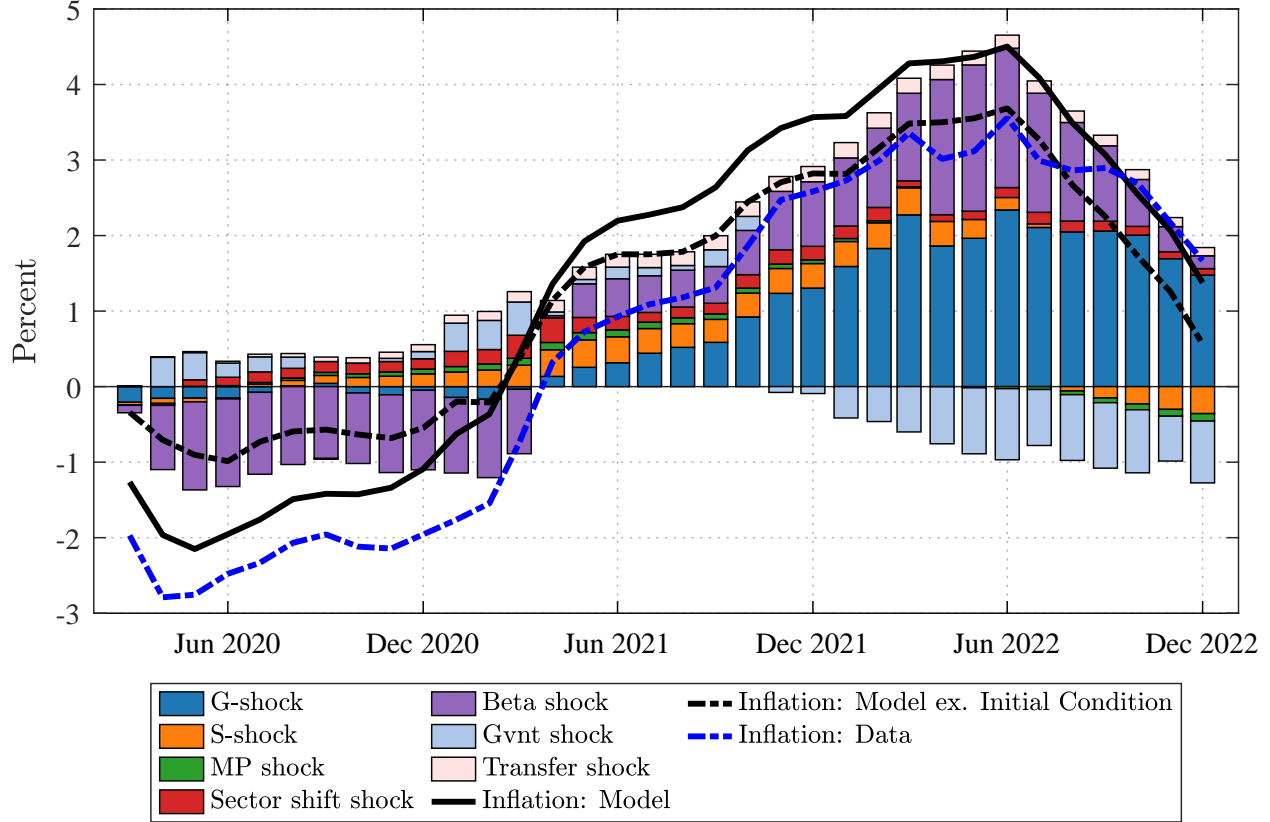


Figure 11: HISTORICAL SHOCK DECOMPOSITION OF $\Pi_{12,t}$: LOWER INFLATION FEEDBACK AND LONGER AIT HORIZON

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.

baseline calibration. In this case, the importance of government spending and transfer shocks plays a small role in the initial surge of inflation while the service sector technology shock and the intertemporal preference shock mostly account for it. Figure 10 shows the results from the historical decomposition. Compared to the fiscal regime case, the volatility of the model-implied inflation is much closer to the data with the model-implied volatility equal to 92% of that in the data and the model-implied inflation is similarly well correlated with the data (correlation coefficient = 0.966).

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 a 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. We capture the lower inflation feedback by decreasing 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 11 shows the results from the historical decomposition. Not only is the model-implied inflation highly correlated with the realized data (correlation coefficient = 0.983) but also it matches the volatility of the data with the model-implied volatility equal to 102% of that in the data. In both dimensions, this alternative calibration improves the previous experiments highlighting the “fiscal channel” or “production friction”. Government spending and transfer shocks as well as a demand shift shock seem to have played an important role for the initial surge in inflation during the first half of 2021. Since then, the model attributes the continued inflation largely to a negative goods sector technology shock. In our simple two-sector model, an oil price shock which was prominent during this period can show up as a goods sector technology shock. Unlike [Gagliardone and Gertler \(2023\)](#), we do not find a significant role for a monetary policy shock in this alternative calibration. Perhaps, lowering the inflation feedback parameter reduces the need for easing monetary policy shocks in accounting for the initial surge in inflation.

Our findings are consistent with [Bhattarai et al. \(2023\)](#), [di Giovanni, Kalemli-Özcan, Silva and Yıldırım \(2023\)](#), and [Santacreu, Young and de Soyres \(2022\)](#) who argue that fiscal support packages exerted significant inflationary pressures. However, the fiscal policy became contractionary in 2022 when the previous support package expired. The model does not find a contractionary monetary policy shock that reduces 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 a 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. Finally, we recalibrate the model to increase the volatility of a demand shift shock as motivated by [Ferrante et al. \(2023\)](#). We make the standard deviation of a demand shift shock (σ_{Γ}) increase to 0.15 from 0.015. Figure 12 shows the historical decomposition of $\Pi_{12,t}$. The model-implied inflation is somewhat correlated with the data (correlation coefficient = 0.82) and the variation of the model-implied inflation is about 92% of the data. In contrast, the volatility of the model-implied inflation was much closer to that of the data in Figure 11, implying that inflation feedback under the baseline calibration was strong enough to undo the amplification of inflation due to a more volatile demand shift shock. The main drivers of the inflation surge in this calibration with a more volatile demand-shift shocks are similar to the calibration with the increased production friction. A negative service sector technology shock coupled with an intertemporal preference shock boosting demand account for the bulk of inflation in 2021. Unlike the change

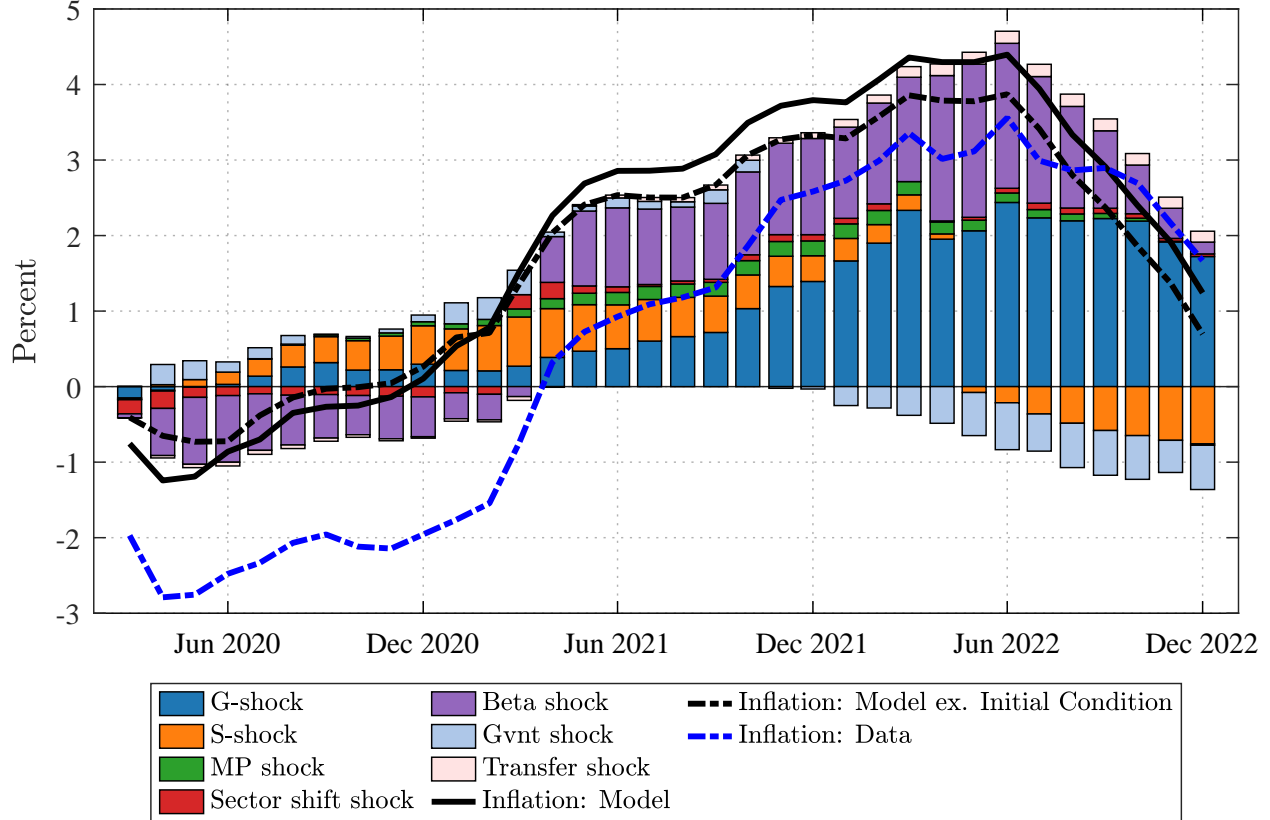


Figure 12: HISTORICAL SHOCK DECOMPOSITION OF $\Pi_{12,t}$: VOLATILE DEMAND SHIFT SHOCK

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.

in the monetary policy rule case in Figure 11, this alternative calibration finds a non-negligible contribution from an easing monetary policy shock in both 2021 and 2022.

Overall, our experiments with alternative calibrations of the baseline model suggest that the change in the monetary policy framework is most consistent with the data. According to this version of the model, demand-side shocks (a demand shift shock and fiscal shocks) played a large role in the initial rise in inflation during the early 2021 but since then, a negative shock to goods sector productivity led to the sustained rise and a sluggish fall in inflation.

4.4.2 Decomposition of Inflation Persistence

One feature of the post-COVID-19 inflation data that was challenging to alternative versions of the model calibration is the persistent rise and slow decline in aggregate inflation while goods inflation declined substantially during the late 2022. Although goods inflation sharply declined

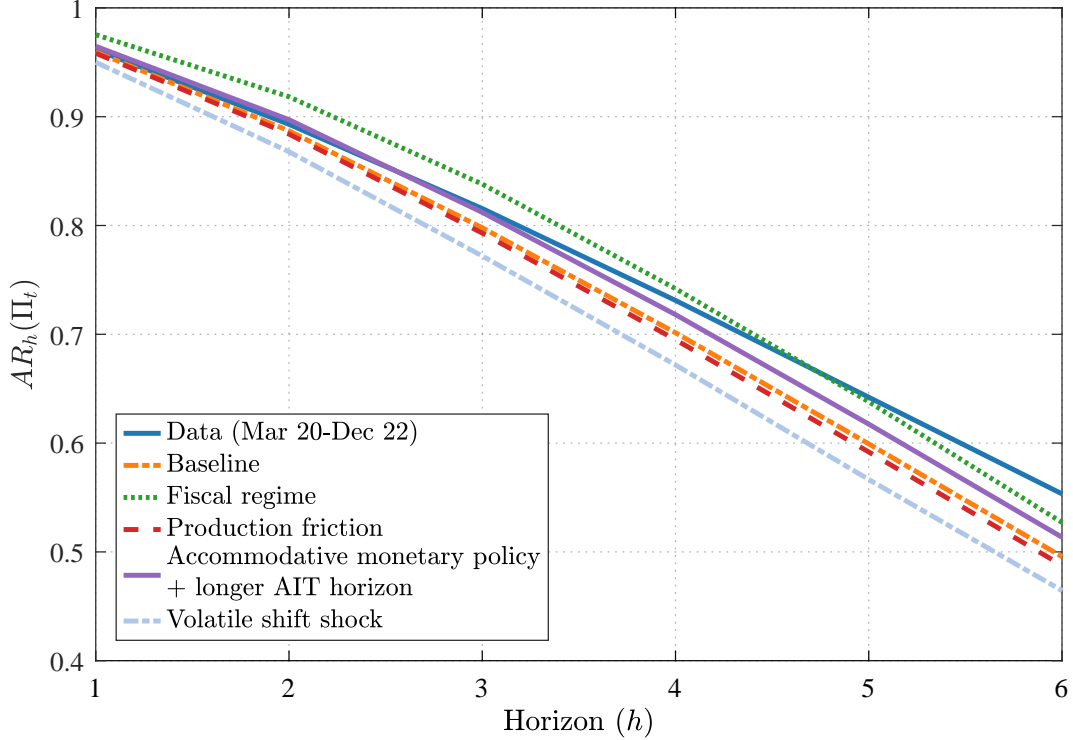


Figure 13: INFLATION PERSISTENCE COMPARISON: MODEL VERSUS DATA

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.

after peaking in the summer of 2022, the decline was more modest in aggregate inflation due to the sluggish decline in services inflation as we see in Figure 1. As we discussed in the previous section, the model-implied persistence of inflation can be represented by a weighted average of the autocorrelations in inflation responses to various structural shocks. Here, 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 13 shows the model-implied persistence of inflation at various horizons using the smoothed estimates of shocks at the alternative calibrations of the model. Again, lengthening the averaging horizon in inflation target to 4 years and lowering the inflation feedback parameter to 1.1 (AIT case) best fits the persistence of inflation in the data. For other versions of the calibration, the autocorrelation of inflation declines much faster than is seen in the data as the horizon lengthens.

What can explain this relatively slow decay in inflation in the AIT case? Figure 14 shows that the change in the monetary policy rule parameters significantly increases the persistence of inflation response to a transfer shock. No other calibration raises the autocorrelations of inflation response to

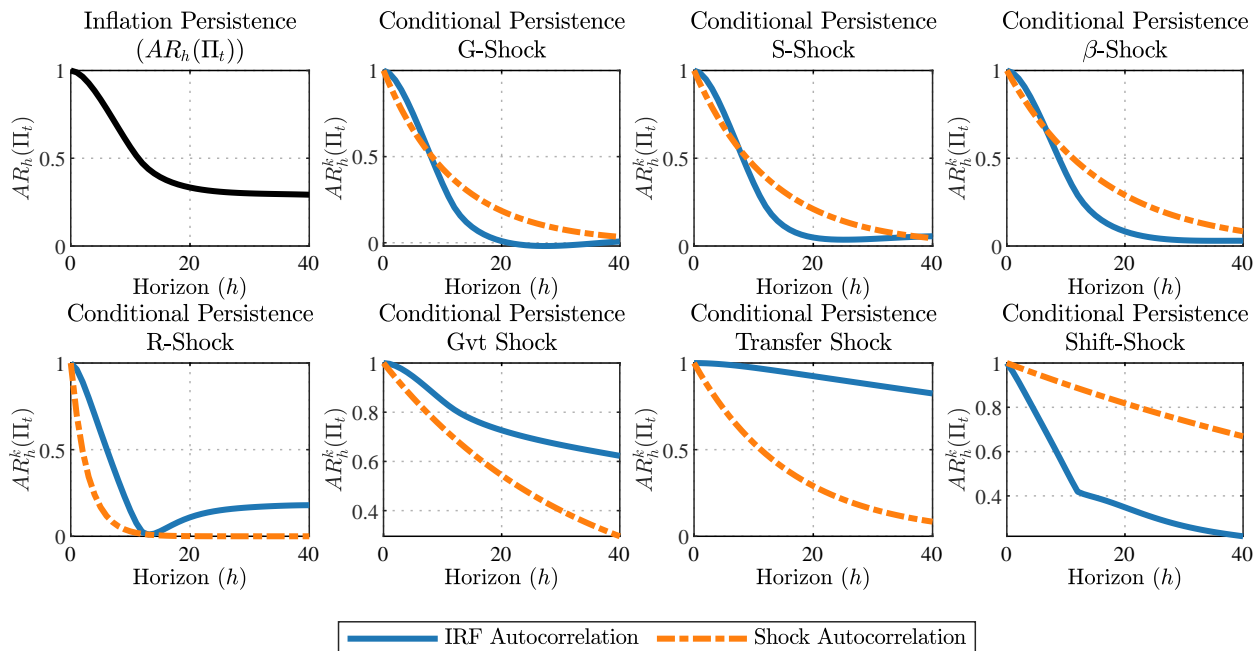


Figure 14: MODEL-IMPLIED INFLATION PERSISTENCE: ACCOMMODATIVE MONETARY POLICY AND LONGER AIT HORIZON

Notes: This figure shows the persistence of inflation in the alternative model with accommodative monetary policy ($\phi_\pi = 1.1$) and longer AIT horizon ($T = 48$). The top left panel shows unconditional inflation persistence for horizon h , $AR_h(\Pi_{12,t})$, in Equation (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 for inflation response (blue solid lines) and autocorrelation of each shock (orange dashed lines).

a transfer shock compared to the autocorrelations of the shock more than the AIT case.⁹

5 Discussion

Our analysis of the post-COVID-19 inflation suggests that the demand-side shocks (both aggregate demand driven by fiscal shocks and a sectoral demand shift shock) were important for the initial surge in inflation during the first half of 2021 and the impact might have been amplified by the loose monetary policy response to inflation relative to the pre-pandemic period.¹⁰ Since then, the

⁹The appendix provides the model-implied persistence of inflation at various horizons with alternative values of ϵ_M and ϕ_Π . These are the model-implied persistence based on Equation (3). The persistence in Figure 13 is based on the estimated shocks which do not necessarily correspond to the long-run distribution of shocks used in Equation (3).

¹⁰Bundick and Petrosky-Nadeau (2021) discuss implications of changing the FOMC’s employment objective from “deviations” to “shortfalls” in the new monetary policy framework. They note that such a change would lead to higher inflation and output on average because people expect more accommodative future policy. Lowering inflation feedback in our model can have a similar effect with respect to inflation.

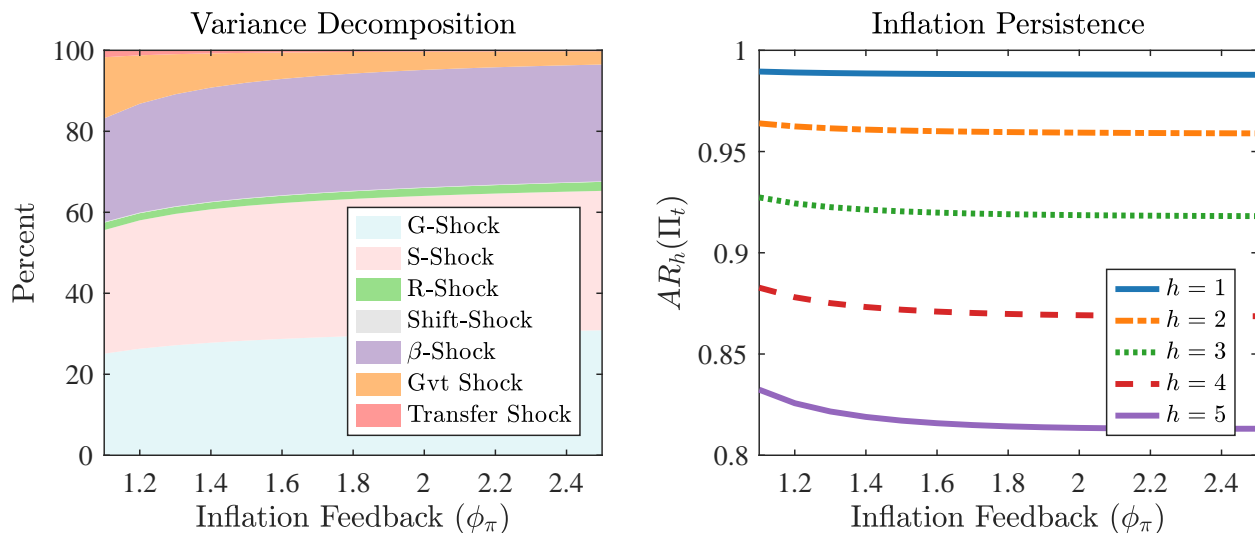


Figure 15: LONG-RUN VARIANCE DECOMPOSITION AND THE MODEL-IMPLIED INFLATION PERSISTENCE WITH ALTERNATIVE VALUES OF THE INFLATION FEEDBACK PARAMETER

Notes: This figure shows long-run variance decomposition (left panel) and the persistence of inflation for each horizon h (right panel) under the baseline model with different inflation feedback parameters. The inflation measure is the 12-month change in headline PCE price index. “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.

persistent rise in inflation was helped by a negative technology shock, which offset the impact of the monetary policy tightening.

While the increased friction on the production process was often suggested to explain the persistent rise in inflation during the post-COVID-19 period, we do not find that this particular mechanism is favored over other amplification channels. There are two reasons for the result. First, even under the baseline calibration using the pre-COVID-19 period data, we find the substitution ability among production factors is not particularly high. While the elasticity of substitution among intermediary inputs is somewhat elastic ($\epsilon_M = 1.1311$), the elasticity of substitution of labor across sectors is pretty low ($\epsilon_L = 0.0139$). Lowering ϵ_M helps the model’s fit for the post-COVID-19 inflation somewhat, but without the change in the monetary policy framework it predicts a counterfactually rapid decline in services inflation when goods inflation declines. In addition, lowering the inflation feedback parameter increases the model-implied inflation at multiple horizons by lowering the weight of the long-run variance of inflation on less persistent shocks (e.g., sectoral technology shocks) while lowering the elasticity of substitution among the intermediary inputs barely changes this as shown in Figures 15 and 16.

Our interpretation is that the degree of the friction did not necessarily change much during the post-COVID-19 period but a large shock that created a huge imbalance in supply and demand exposed the pre-existing vulnerability. Second, although our model includes the input-output

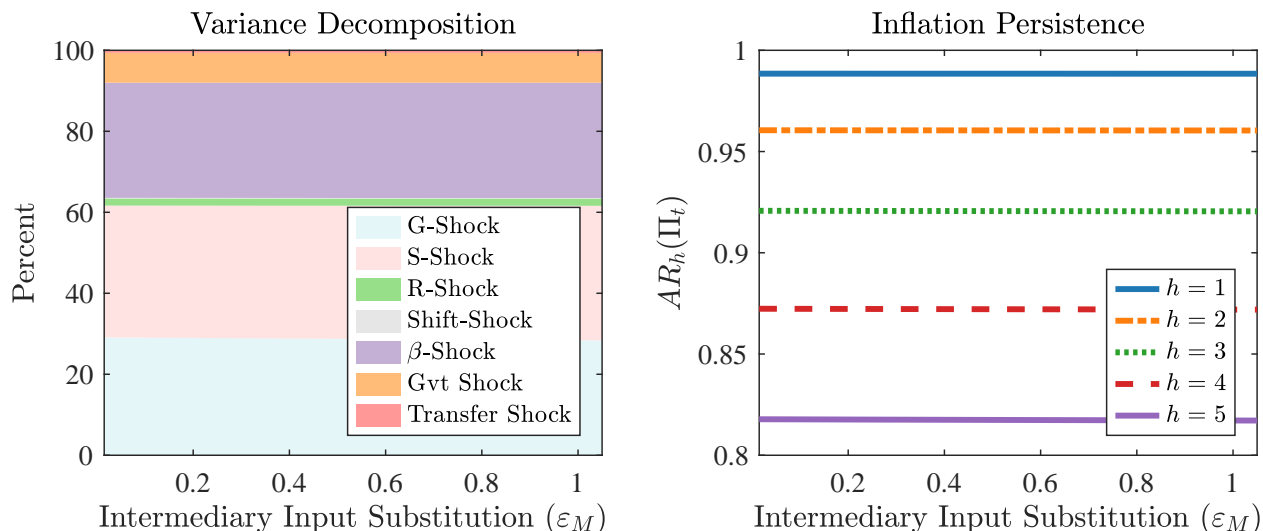


Figure 16: LONG-RUN VARIANCE DECOMPOSITION AND THE MODEL-IMPLIED INFLATION PERSISTENCE WITH ALTERNATIVE VALUES OF THE ELASTICITY OF SUBSTITUTION AMONG THE INTERMEDIARY INPUTS

Notes: This figure shows long-run variance decomposition (left panel) and the persistence of inflation for each horizon h (right panel) under the baseline model with different elasticity of substitution among the intermediary inputs (ε_M). The inflation measure is the 12-month change in headline PCE price index. “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.

linkage, we do not have the detailed international trade channel that can capture supply chain disruptions in a more realistic way like [Comin et al. \(2023\)](#) and [Amiti et al. \(2023\)](#). It would be interesting if our results can survive in this more extended version with the international trade channel. At a minimum, our analysis suggests caution against over-generalizing the role of supply chain disruptions without considering the corresponding changes in the 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. However, relying on the fiscal regime alone may imply too much pass-through from goods inflation to services inflation, which generates counterfactually too volatile inflation. Finally, 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 mode 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 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 (accommodative monetary policy and longer AIT horizon 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 (2). Figure 17 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 2021.¹¹ In our decomposition, both 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.

Our finding that the pandemic might have exacerbated the inflationary effect of the existing friction on the production side from a large shock has an interesting implications for the future trajectory of inflation. With the large shock mostly dissipated over time and a monetary policy responding to inflation as strongly as in the pre-COVID-19 period, the economy is likely to return the pre-COVID-19 “normal” level of inflation. The return might have been faster if the policy responded as strongly to inflation as in the Pre-COVID-19 period.¹²

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 many factors 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 mostly responsible for the elevated level of inflation in 2022. In addition, our model indicates the new framework announced

¹¹Glover, 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.

¹²Increasing the averaging horizon of inflation does not increase inflation persistence much. Figure A.8 in the appendix shows that the longer averaging horizon actually lowers inflation persistence.

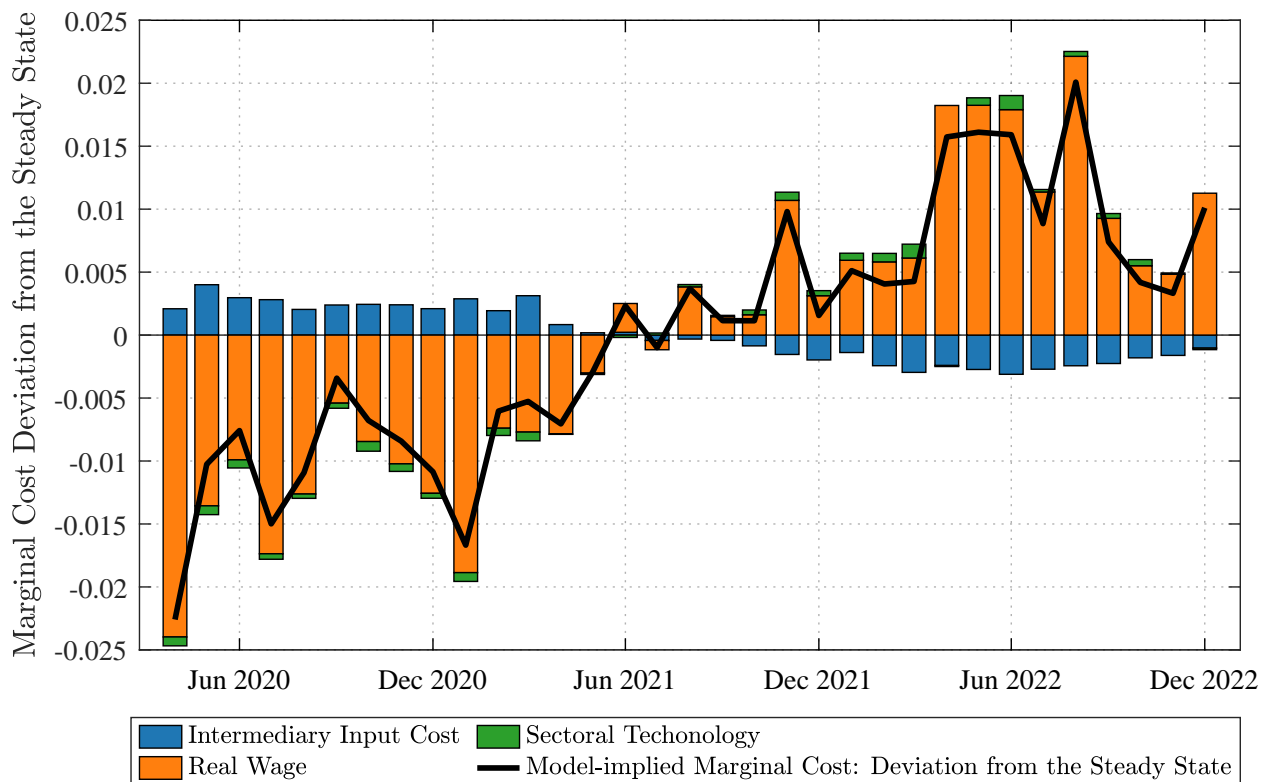


Figure 17: DECOMPOSITION OF THE MODEL-IMPLIED MARGINAL COST GAP

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 (1).

by the Federal Reserve in 2020 might have amplified the contribution of fiscal policy shocks to inflation persistence by lowering the inflation feedback parameter. For example, the announcement of the new framework stated that policy would respond to only the “employment shortfall” instead of “employment deviations” as well as lengthening the averaging horizon of inflation target, which might have reduced a room for the “pre-emptive” policy tightening. Nonetheless, policy has tightened significantly in 2022 and 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 analysis suggests that understanding the sources of the post-pandemic inflation behavior may require a rich model that allows the interaction among shocks, frictions, and policy regime changes.

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. While this outcome can be achieved without a substantial deterioration on the labor market is hotly debated, our analysis suggests that monetary policy needs to remain as strongly responsive to inflation as in the pre-COVID-19 period to achieve that outcome because the loose monetary policy was one of main factors that drove post-COVID-19 inflation.

The pandemic shock disrupted both demand and supply sides of multiple sectors. Understanding not just the aggregate outcomes but also the disparate outcomes across multiple sectors is important. Our two sector model is the first-step toward that task but may be simplistic in understanding the large dispersion of outcomes across multiple sectors during the post-pandemic period. Scaling up the baseline model used in this paper is an important future research task.

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Appendix

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

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

- Philips curve 1

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

- Philips curve 2

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

- Philips curve 3

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

- Price dispersion

$$\Xi_{i,t} = (1 - \theta_i) (p_{i,t}^*)^{-\sigma_i} + \theta_i \Xi_{i,t-1}.$$

- Aggregate price index

$$(\Pi_{i,t})^{1-\sigma_i} = (1 - \theta_i) (p_{i,t}^* \Pi_{i,t})^{1-\sigma_i} + \theta_i$$

- 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:

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

- Consumer demand for good i

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

- Relative factor prices within sector i

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

- 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

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

- 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

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

or

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

- Relative price

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

- GBC

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

- Monetary policy

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

- Average inflation

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

- Relative price across different sectors

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

OR use resource constraint

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

A.2 Steady-State

- Marginal cost

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

- Philips curve 1

$$\bar{m}c_i = \frac{\sigma_i - 1}{\sigma_i}$$

- Philips curve 2

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

- 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:

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

- 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

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

- Relative factor prices within sector i

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

- HH - Intertemporal EE

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

- HH - Intratemporal EE

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

- Labor market clearing

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

- Labor market clearing

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

or

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

- Government consumption

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

- Relative price

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

- GBC

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

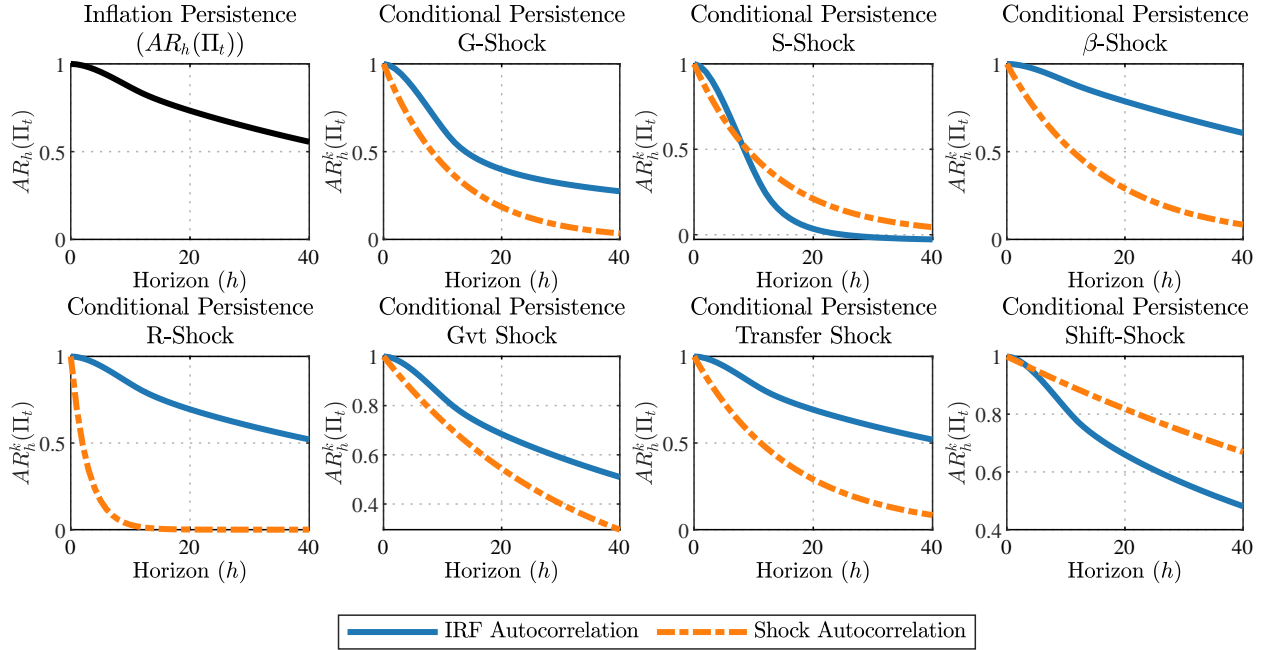
- (Redundant?) Relative price across different sectors

$$1 = \begin{cases} \sum_{i=1}^N \bar{\Gamma}_i^c (\bar{Q}_i)^{1-\varepsilon} & \text{if } \varepsilon \neq 1 \\ \prod_{i=1}^N (\bar{Q}_i)^{\bar{\Gamma}_i^c} & \text{if } \varepsilon = 1 \end{cases}$$

use resource constraint

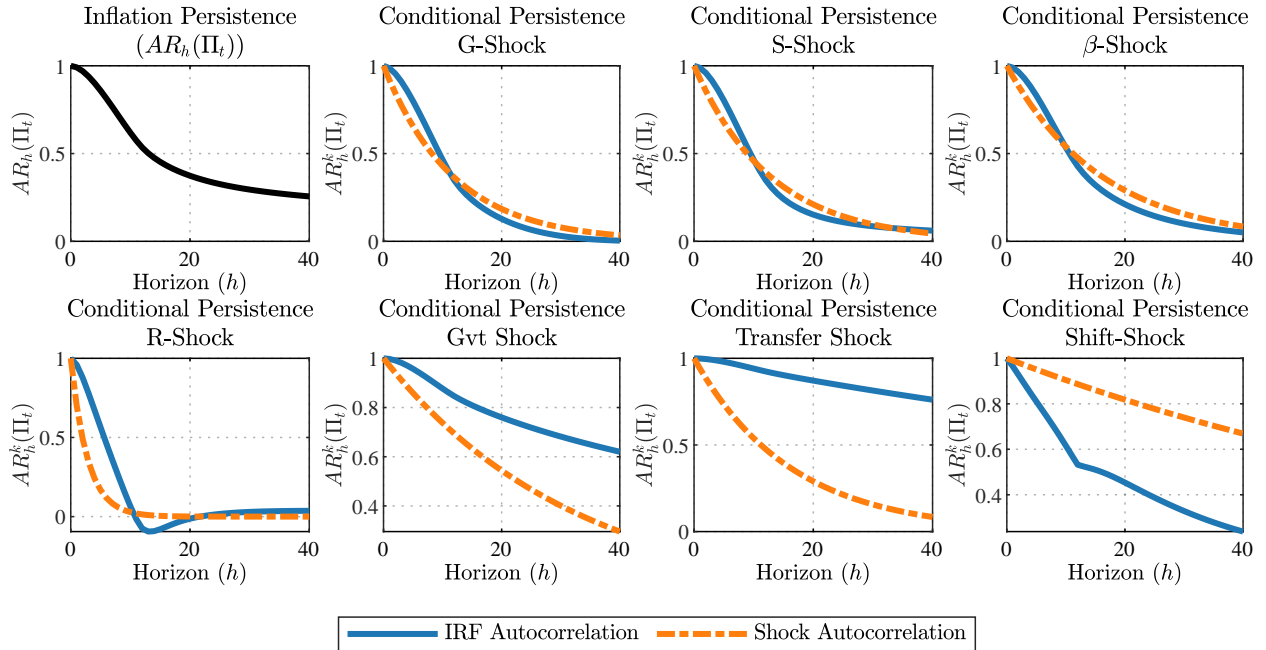
$$C_t + Q_t^G G_t = \sum_{i=1}^N \left[Q_{i,t} Y_{i,t} + \frac{1}{\alpha_i} \left\{ (1 - \alpha_i) (w_{i,t})^{1-\varepsilon_Y} - (m_{i,t})^{1-\varepsilon_Y} \right\} (w_{i,t}^M)^{\varepsilon_Y} M_{i,t} \right]$$

B Appendix Figures



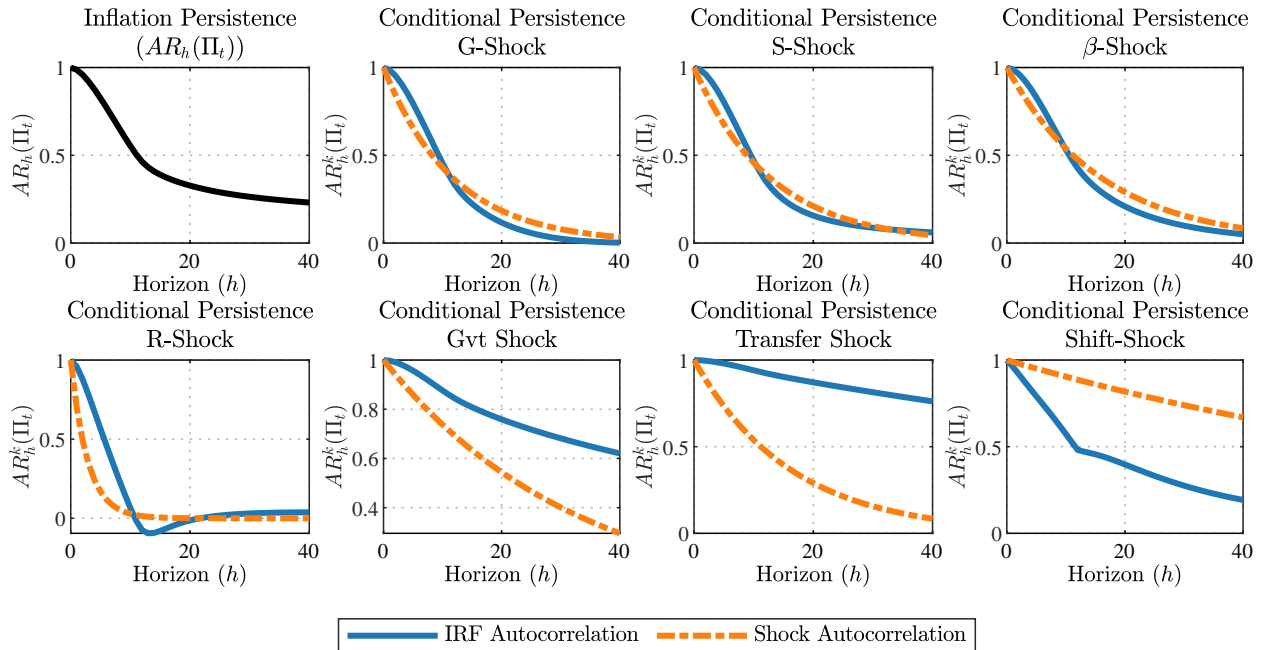
Appendix Figure A.1: MODEL-IMPLIED INFLATION PERSISTENCE: FISCAL REGIME

Notes: This figure shows the persistence of inflation in the alternative model with fiscal regime ($\phi_\pi = 0.0$ and $\psi_L = 0.0$). The top left panel shows unconditional inflation persistence for horizon h , $AR_h(\Pi_{12,t})$, in Equation (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 for inflation response (blue solid lines) and autocorrelation of each shock (orange dashed lines).



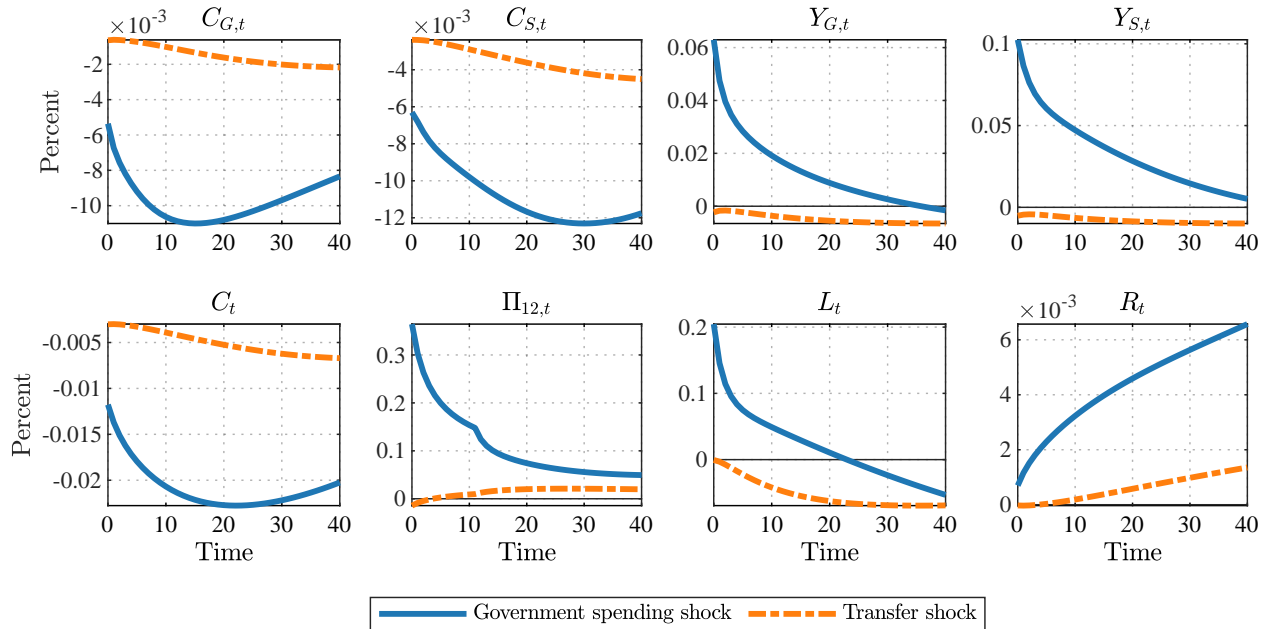
Appendix Figure A.2: MODEL-IMPLIED INFLATION PERSISTENCE: PRODUCTION FRICTION

Notes: This figure shows the persistence of inflation in the alternative model with more friction to production process ($\varepsilon_M = 0.01$). The top left panel shows unconditional inflation persistence for horizon h , $AR_h(\Pi_{12,t})$, in Equation (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 for inflation response (blue solid lines) and autocorrelation of each shock (orange dashed lines).



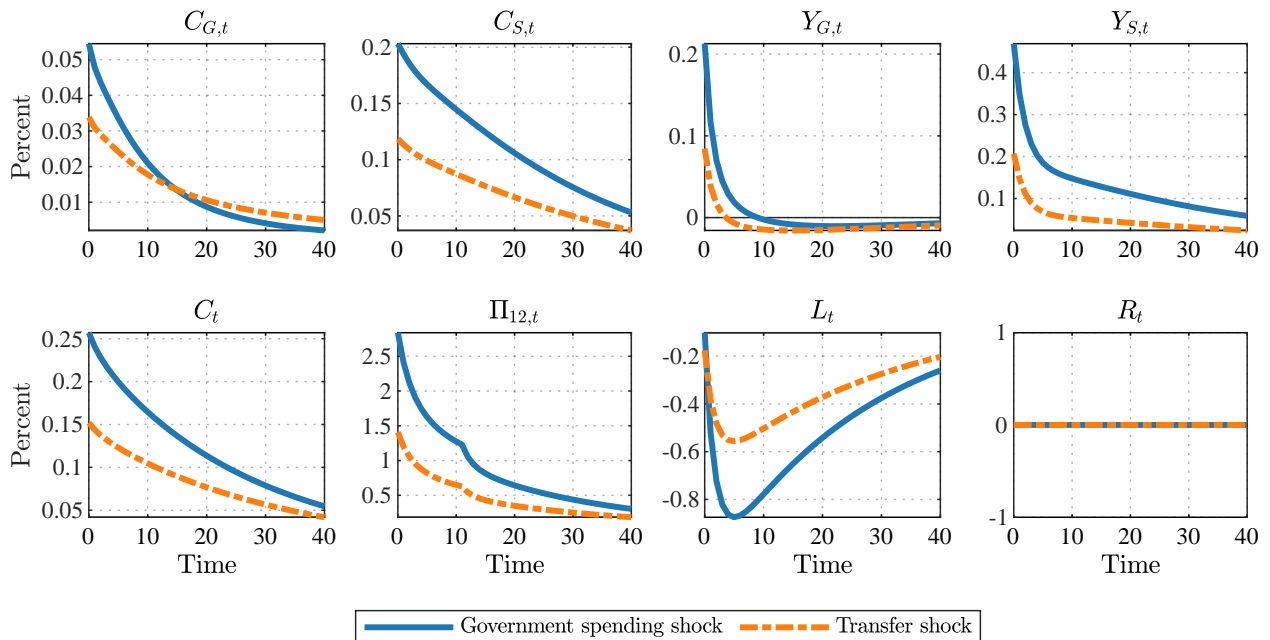
Appendix Figure A.3: MODEL-IMPLIED INFLATION PERSISTENCE: VOLATILE DEMAND SHIFT SHOCK

Notes: This figure shows the persistence of inflation in the alternative model with a more volatile demand shift shock ($\sigma_{\Gamma} = 0.015$). The top left panel shows unconditional inflation persistence for horizon h , $AR_h(\Pi_{12,t})$, in Equation (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 for inflation response (blue solid lines) and autocorrelation of each shock (orange dashed lines).



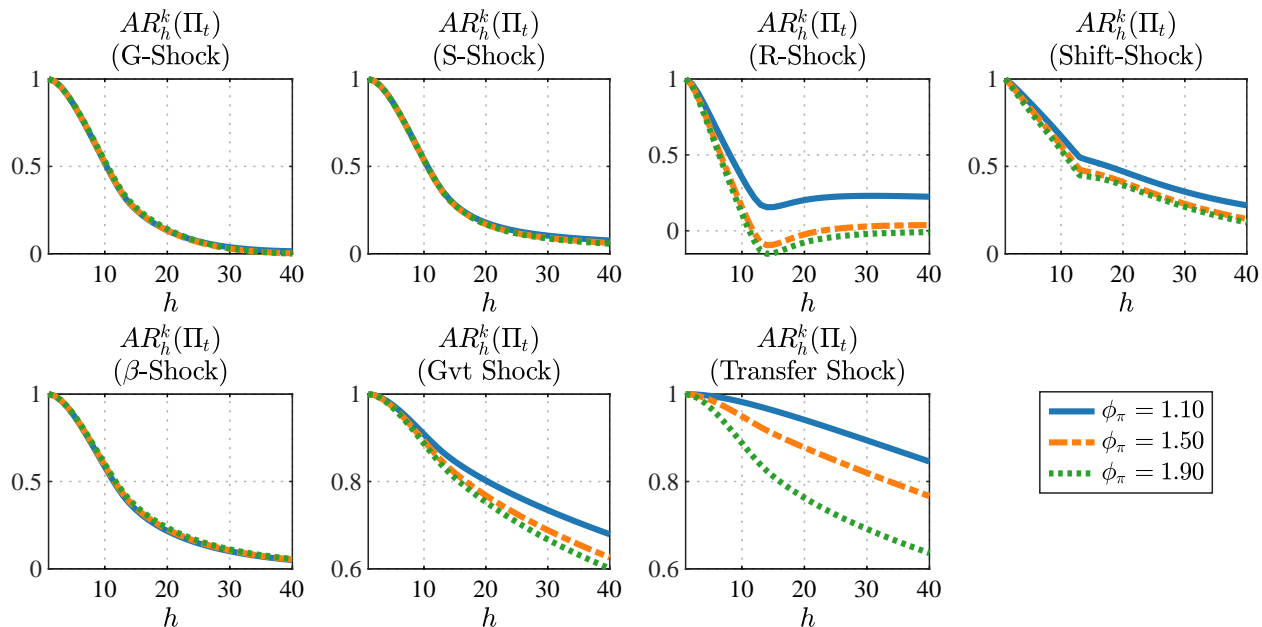
Appendix Figure A.4: IMPULSE RESPONSES TO FISCAL SHOCKS: ACCOMMODATIVE MONETARY POLICY AND LONGER AIT HORIZON

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 alternative model with the accommodative monetary policy ($\phi_\pi = 1.1$) and a longer AIT Horizon (T).

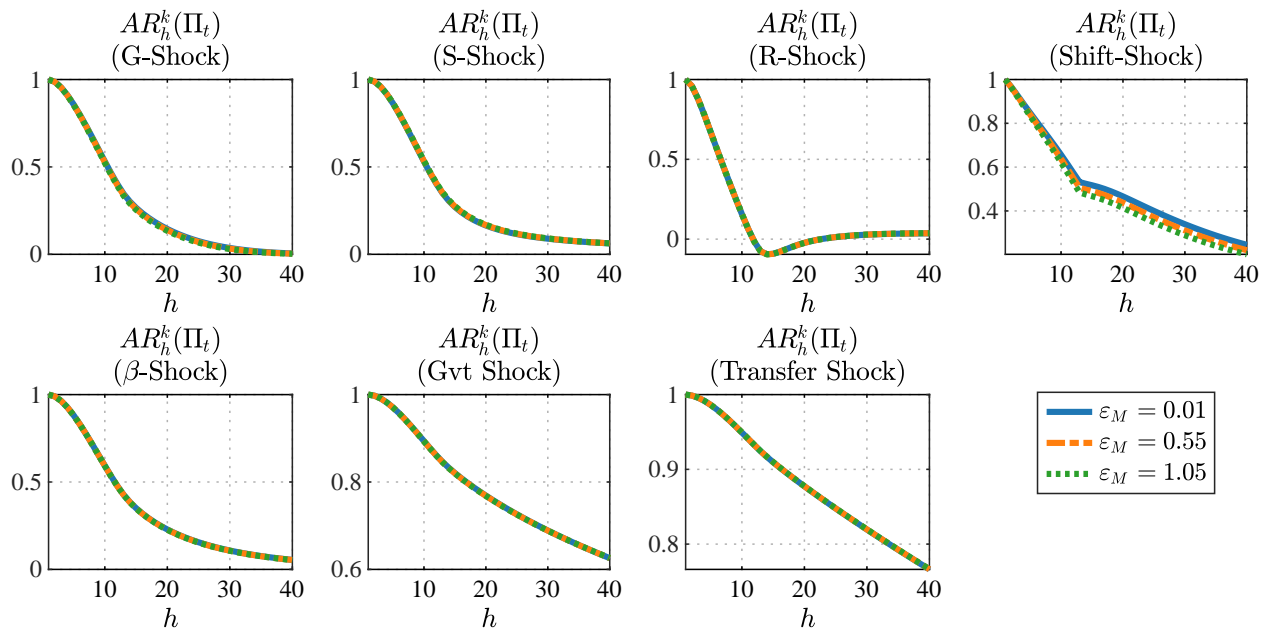


Appendix Figure A.5: IMPULSE RESPONSES TO FISCAL SHOCKS: FISCAL REGIME

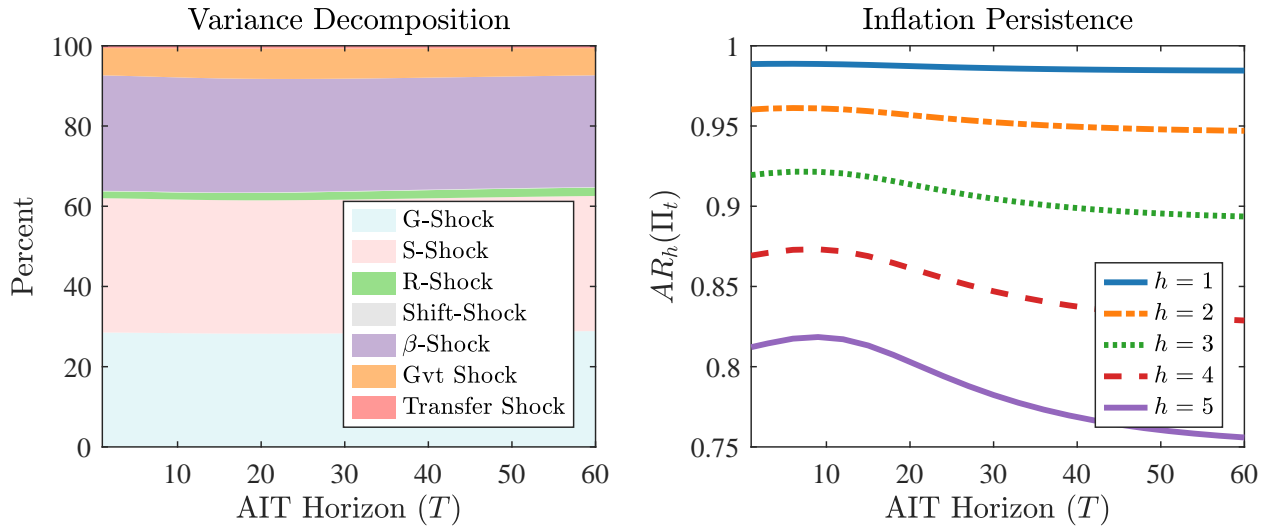
Notes: This figure shows impulse responses of key model variables to a government spending shock (blue solid line) and to a transfer shock (orange dashed line) in the alternative model with a fiscal regime ($\phi_\pi = 0.0$ and $\psi_L = 0.0$).



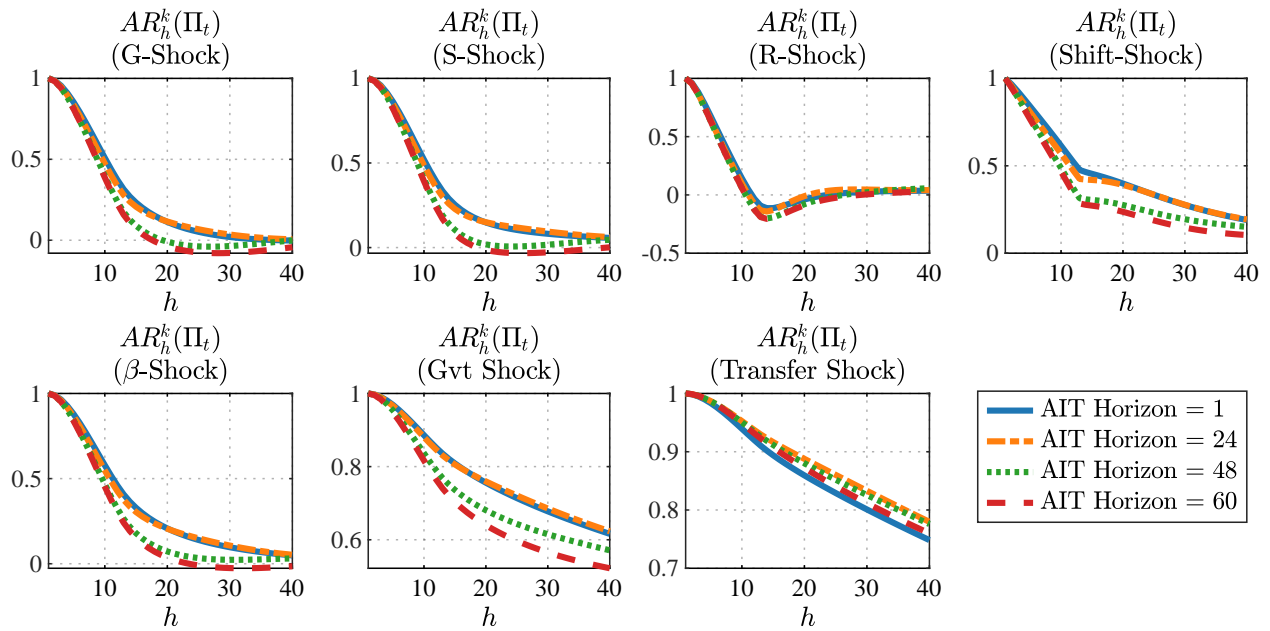
Appendix Figure A.6: MODEL-IMPLIED INFLATION PERSISTENCE CONDITIONAL ON A STRUCTURAL SHOCK AT DIFFERENT VALUES OF ϕ_{Π}



Appendix Figure A.7: MODEL-IMPLIED INFLATION PERSISTENCE CONDITIONAL ON A STRUCTURAL SHOCK AT DIFFERENT VALUES OF ϵ_M



Appendix Figure A.8: LONG-RUN VARIANCE DECOMPOSITION AND THE MODEL-IMPLIED INFLATION PERSISTENCE WITH DIFFERENT AIT HORIZONS



Appendix Figure A.9: MODEL-IMPLIED INFLATION PERSISTENCE CONDITIONAL ON A STRUCTURAL SHOCK AT DIFFERENT AIT HORIZONS