Inflation Strikes Back: The Role of Import Competition and the Labor Market*

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Abstract

U.S. inflation has recently surged, with inflation reaching its highest readings since the early 1980s. We examine the drivers of this rise in inflation, focusing on supply chain disruptions, labor supply constraints, and their interaction. Using a calibrated two-sector New Keynesian DSGE model with multiple factors of production, foreign competition, and endogenous markups, we find that supply chain disruptions combined with a rise in the disutility of work raised inflation by about 2 percentage points in the 2021-22 period. We show that the combined shock increased price inflation in the model by 0.6 percentage point more than it would have risen if the shocks had hit separately. This amplification arises because the joint shock to labor and imported input prices makes substituting between labor and intermediates less effective for domestic firms. Moreover, the simultaneous foreign competition shock allows domestic producers to increase their pass-through into prices without losing market share. We then show that the benefit of aggressive monetary policy in the model depends on the source of the rise in inflation. If the rise in inflation is demand-driven, then aggressive monetary tightening can contain inflation without a recession later. In contrast, aggressive policy can have a large negative effect on the labor market when inflation is driven by supply chain and labor market disruptions. We use aggregate and industry-level data on producer prices, wages, and input prices to provide corroborating evidence for the key amplification channels in the model.

Keywords: Inflation dynamics, Phillips curve, pass-through, supply chains
JEL Classification: E24, E31

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1 Introduction

> *So we have now experienced an extraordinary series of shocks if you think about it. The pandemic, the response, the reopening, inflation, followed by the war in Ukraine, followed by shutdowns in China, the war in Ukraine potentially having effects for years here. [...] You couldn't get this kind of inflation without a change on the supply side, which is there for anybody to see, which is these blockages and shortages and people dropping out of the labor force and things like that.*
> **Chair Powell—Press Conference on June 15, 2022**

U.S. inflation has recently surged with annual CPI inflation reaching 9.1 percent in June 2022, its highest reading since November 1981, as Figure 1a shows. Many policymakers have attributed this high and persistent level of inflation to supply chain pressures related to several unprecedented developments, such as the COVID-19 pandemic and the war in Ukraine, coupled with a very tight labor market as the unemployment rate retreated back to its pre-pandemic level in fewer than three years (see quote above). To illustrate how the post-COVID recovery differs from earlier expansions, Figure 1b shows the increase in the core CPI price index for the past six expansions, starting at the quarter with the peak level of unemployment of the preceding recession. Price growth in the most recent expansion is markedly higher than in the expansions of the 1990s or 2000s: ten quarters after peak unemployment in 2020:Q2, prices have grown by more than 12 percent, following a trajectory similar to the 1980s expansion rather than the most recent past.

In this paper, we examine how supply chain disruptions and labor supply constraints have contributed to the recent rise of inflation.[1] We consider three shocks to capture these forces: first, supply chain bottlenecks have led to an increase in the prices of imported intermediate inputs, driving up firms' marginal costs and contributing to price increases, in particular in the goods sector.[2] Second, supply chain pressures affected U.S. firms' foreign competitors as well, forcing them to raise their prices and allowing domestic firms to pass through price increases to customers without losing market share. Third, workers' willingness to work declined and there was a rise in reservation wages, defined as the minimum wage that individuals require to work.[3] The decline in labor supply led to a rapid tightening of the

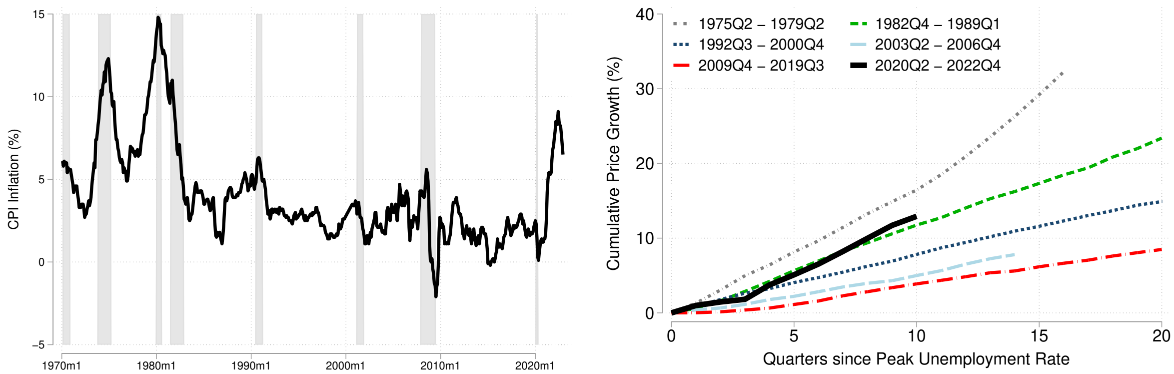
[1] For anecdotal evidence, see NY Times Daily Business Briefing: Supply Chain Snags Continued to Drive Up Prices in December, January 12, 2022 and NY Times: Could Wages and Prices Spiral Upward in America? February 17, 2022.

[2] For example, Amiti et al. (2021) and LaBelle and Santacreu (2022) document that higher import prices were associated with higher producer prices for U.S. output in the recent period.

[3] See for example Crump et al. (2022) and Faberman et al. (2022). Reservation wage increases are documented in the Survey of Consumer Expectations (SCE) of the NYFed: https://www.newyorkfed.org /microeconomics/sce/labor#/expectations-job-search16.

Figure 1: CPI Inflation

(a) Time Series of CPI Inflation (b) Core CPI Price Growth in Expansions



Source: BLS and authors' calculations. Note: The left figure plots the annual rate of CPI inflation. The right figure plots the cumulative core CPI price growth (All items less food and energy, seasonally adjusted) against time, starting at the quarter of peak unemployment of a given recession, for the past six expansions.

labor market and worker shortages, contributing to high wage inflation and price pressures particularly in services.

A careful analysis of the role played by the different forces on goods and services inflation requires a framework with multiple factors of production, simultaneous cost shocks, and multiple sectors. In the first part of the paper, we therefore develop a two-sector New Keynesian model that allows for shocks to import prices, foreign competitors' prices, and workers' disutility of labor. Firms can substitute between domestic labor and intermediate inputs, which are in turn a combination of domestic and foreign inputs that are also substitutable. The substitution margins in our model reduce the effect of an individual cost shock on overall marginal costs, since firms can shift away from any factor experiencing an isolated cost increase (see, e.g., Feenstra et al. (2018)). However, when multiple cost shocks hit at the same time, the scope for substitution is diminished, amplifying the cost pass-through into inflation. To capture the effect of foreign competition on firms' price setting, our model considers a finite number of domestic and foreign producers, which compete in a framework as in Atkeson and Burstein (2008). Markups are variable in this framework, and domestic firms have more pricing power at times when foreign competitors also experience cost pressures since they can raise prices without losing market share. We assume that firms in only the "Goods" sector are subject to foreign competition in their domestic output market, while firms in the "Services" sector compete only domestically. The goods sector also exhibits a lower labor share than services (and hence a higher intermediates share), and accounts for a smaller share in the final consumption basket. These sectoral differences generate heterogeneous responses of inflation across the two sectors.

In the second part of the paper, we calibrate the model to U.S. data and use it to study the effects of supply chain disruptions and labor shortages on inflation. We capture supply chain disruptions by two shocks: first, a 16 percent shock to imported intermediate input prices, calibrated to approximately match the observed increase of these prices in the data. Second, a marginal cost shock to foreign competitors, which we set to match U.S. firms' marginal cost increase. This shock delivers a roughly stable market share of foreign competitors. To proxy labor supply shocks, we use a labor disutility shock that reduces potential hours by 0.3 percentage points, which mimics the negative effects of the pandemic on the participation rate estimated by Hobijn and Şahin (2022). Our quantitative analysis shows that these three shocks together increase aggregate consumer price inflation by 2 percentage points and wage inflation by 4 percentage points. These are sizeable effects on wage and price inflation.

Our model allows us to investigate the mechanisms by which the shocks contribute to the inflation surge. We obtain three key insights. First, the input price shock prompts firms to substitute from imported inputs towards domestic suppliers. This shift generates demand for domestic labor and puts upward pressure on wages even without any separate shock to the labor market. This *substitution effect* due to supply chain disruptions generates both wage and price inflation of about 0.5 percentage point. Second, the foreign competitor shock shifts production from foreign producers to domestic ones, increasing domestic demand for inputs and labor. We refer to this mechanism as the *foreign competition effect*. Lastly, the combination of supply chain shocks and labor disutility shock creates an amplified effect on inflation: the shocks increase wage inflation by 1 percentage point and price inflation by 0.6 percentage point more than they would have increased if the shocks had hit separately. This *amplification* arises because the joint shock to labor and imported input prices makes substituting between labor and intermediates less effective for domestic firms. Moreover, the simultaneous foreign competition shock allows domestic producers to increase their pass-through into prices without losing market share.

While supply chain bottlenecks and labor supply disruptions have had a sizeable impact on inflation, recent work has stressed the additional role of demand-side factors in contributing to the price increases (e.g., Di Giovanni et al. (2022, 2023), De Soyres et al. (2023)). The pandemic period was accompanied by a stark shift in consumption from services to goods, increasing the goods share in personal consumption expenditures from 36 percent before the pandemic to a peak of 42 percent in 2020 and about 38 percent recently. This shift in consumption patterns was accompanied by a large fiscal expansion in the U.S. due to stimulus payments. To capture these shifts, we calibrate a goods-favored demand shock that also generates a 2 percentage point increase of inflation. We then analyze the effectiveness of aggressive monetary policy in addressing inflation when it is either supply- or demand-driven.

Our simulations show that while the rise in inflation is the same in both experiments, the benefit of aggressive monetary policy depends on the source of the rise in inflation. On the one hand, for the demand-driven inflation experiment it is better to raise interest rates early, i.e., to be *ahead of the curve*, to contain inflation early on. This policy can avoid relatively high interest rates later and avoids an associated recession. For the supply-driven inflation experiment with supply chain disruptions and labor disutility shocks, on the other hand, a less aggressive policy is advantageous. The supply shocks generate a substantial boost in labor demand due to the substitution towards domestic inputs, which raises labor demand by about 7 percent in our baseline. If the central bank follows a more aggressive policy rule, the economy contracts and the boost to labor demand is substantially diminished. Our policy implications are somewhat similar to Harding et al. (2022), who argue that the policy trade-off to stabilize inflation becomes larger as baseline inflation increases. In our case, the trade-off is larger if supply constraints are important for the ramp-up in inflation.

In the final part of the paper, we provide corroborating evidence for the key mechanisms in the model using aggregate and industry-level data on prices and wages. First, we estimate pass-through regressions from wages and input prices to producer prices using the local projection method on aggregate data (Jordà, 2005). We find a positive and significant interaction effect, consistent with the model: when wages and input prices go up simultaneously, producer prices rise more strongly. We then turn to industry-level data. While the aggregate analysis is informative, it is limited in scope to time-series variation. We therefore estimate reduced-form regressions derived from the model using prices at the 6-digit NAICS level from the Producer Price Index (PPI) and industry-level wages from the Quarterly Census of Employment and Wages (QCEW), covering about 500 industries over the period 2013-2021. We find a pattern similar to what we see in the aggregate data: a given increase in wages translates into a larger increase in producer prices in industries that experienced a larger increase in input prices, and vice versa. In addition, prices have become more correlated with changes in foreign competitors' prices in 2021, consistent with the foreign competition effect.

Related Literature. Our paper is closely related to recent work on drivers of inflation dynamics in the post-COVID period and macroeconomic effects of supply chain disruptions. Di Giovanni et al. (2022) show that supply chain pressures and labor shortages have contributed to higher inflation in both the Euro area and the U.S. in the recent period, and analyze these effects through an input-output network. Bunn et al. (2022) and Ball et al. (2022) find that energy prices and shortages of labor and materials were important drivers of the rise in inflation both in the UK and the US. Crump et al. (2022) re-examine the Phillips curve for the recent period and project underlying inflation to remain high due to strong wage growth. Our modeling strategy is similar to Harding et al. (2022) who also consider a nonlinear DSGE model to study recent inflation dynamics. They argue that all shocks transmit stronger to inflation when inflation is surging. In particular, they find that cost-push shocks are amplified in booms and muted in recessions—a result that is supported with our industry-level empirical analysis.

We also build on a recent literature that emphasized the global nature of inflation dynamics. Several studies such as Forbes (2019), Obstfeld (2019) and Heise et al. (2022) argue that foreign competition and firms' ability to outsource have weakened the link between wage pressures and prices in the U.S. over the past two decades. This substitution mechanism has also been highlighted by Elsby et al. (2013) and Feenstra et al. (2018), and has been used to explain the low inflation in the U.S. and the decline in the labor share. Relatedly, Heise et al. (2022) show that the lack of goods inflation in the U.S. in the last two decades can be linked to increased foreign competition that constrained firms' ability to pass through domestic wage shocks. We view pandemic-related disruptions as a partial reversal of these disinflationary factors in the economy and argue that large and simultaneous inflationary shocks to both labor and intermediate inputs contributed to the rise in inflation and overheating in the labor market in the recent period.

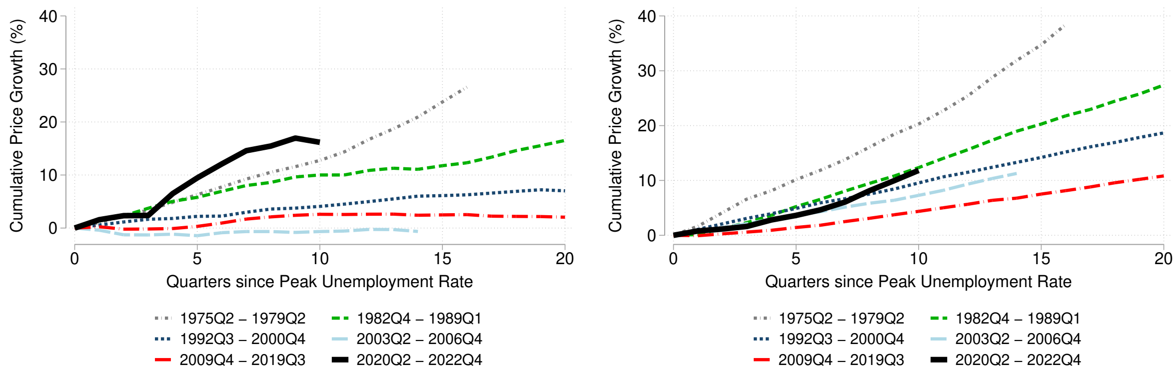
The rest of the paper is organized as follows. Section 2 documents some aggregate facts regarding behavior of inflation, import prices, and wages. Section 3 introduces our New Keynesian DSGE model, which we calibrate and analyze quantitatively in Section 4. Section 5 uses aggregate data to provide corroborating evidence for the model, and Section 6 provides further support with industry-level data. Finally, Section 7 concludes.

2 Why is This Time Different?

The pick-up of inflation after nearly three decades of subdued price increases has surprised many. In this section, we document four key differences in the evolution of aggregates in the 2020-2022 period compared to earlier expansions. First, goods inflation, which averaged around zero in the last two decades, accounted for roughly half of the rise in inflation in 2021. Second, there has been a notable shift towards goods from services in aggregate consumption. Third, workers' willingness to work has declined and reservation wages have increased, contributing to the unprecedented tightness in the labor market. Finally, we show

Figure 2: Evolution of Cumulative Core Goods and Services CPI Inflation

(a) Core Goods (b) Core Services



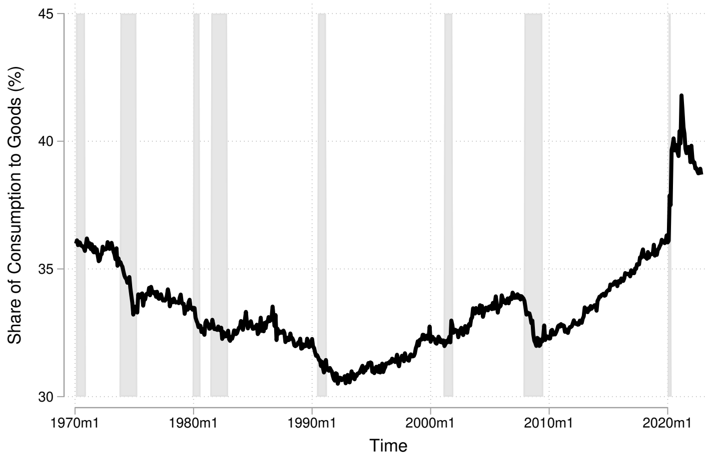
Source: BLS and authors' calculations. Note: The left panel plots the cumulative core goods CPI price growth (All items less food and energy, seasonally adjusted) against time, starting at the quarter of peak unemployment of a given expansion. The right panel plots the cumulative core services price growth (All items less energy services) against time.

that there has been a sharp rise in both wages and input prices in the current period that far exceeds earlier expansions. These facts motivate our modelling choices below.

Re-emergence of Goods Inflation. The left panel of Figure 2 shows the cumulative price growth of the core consumer price index for goods (core goods CPI) in the U.S. starting from the business cycle trough for each of the past six economic expansions. As the figure shows, the pick-up in core goods prices in the current expansion is the strongest across all expansions, including even the 1970s and the 1980s expansions. After only ten quarters since the unemployment peak, goods prices have risen by 16 percent. The right panel of Figure 2 shows the analogous figure for core services. The pick-up in services prices is significant but more modest initially. These inflation dynamics stand in sharp contrast to the typical pattern in the last 20 years, which consisted of procyclical services price inflation and essentially no pick-up in goods prices despite declining unemployment (see, Heise et al. (2022)). On the contrary, goods inflation picked up briskly in 2021 and far exceeded services inflation. Services inflation has accelerated recently while goods prices have started to moderate.

Consumption share of goods increased relative to services. A defining feature of the pandemic period was the stark shift in the composition of consumption from services to goods. The lockdowns which have been followed by a still ongoing period of extended remote work triggered a shift away from services such at restaurants, travel, and entertainment to durable goods. Figure 3 shows the share of real personal consumption expenditures that is attributed to goods since 1970. This share was at around 36% before the pandemic and

Figure 3: Consumption Share of Goods



Source: BEA and authors' calculations. Note: This figure plots the monthly share of real personal consumption expenditures attributed to goods.

peaked at 42% in 2020. Since then it has declined but is still 2 percentage points above its pre-pandemic level. Given the differences in goods and services production and the differential role of imports in these two categories of consumption, the shift towards goods is an important factor in understanding inflationary developments. Imported goods account for about one third of manufactured goods consumption, while services are mostly produced domestically.

Labor supply and willingness to work declined. The COVID pandemic was a major disruption for the U.S. labor market with the unemployment rate rising from 3.5 percent in February 2020 to a peak of 14.7 percent in April 2020. While the elevated unemployment rate was short-lived compared to earlier recessions, labor force participation has not returned to its pre-pandemic level. In addition to this persistent decline in labor force participation, which is mostly due to demographic trends, the desired number of work hours also declined according to Faberman et al. (2022). Another measure that captures changes in the work-leisure trade-off is the reservation wage, which is periodically reported by the Survey of Consumer Expectations (SCE) Labor Market Survey. According to this survey, the reservation wage, defined as the *Average lowest wage a respondent would be willing to accept for a new job*, was relatively stable at around $60,000 from March 2016 to March 2020 but has increased by roughly 20% to around $73,000 since then. We view the decline in the participation rate and desired work hours, and the increase in reservation wages, as indicative of a negative labor supply shock that potentially contributed to the increase in wage growth we turn to next.

Table 1: Wage and Input Price Growth and Prices

	Average 4-Quarter Change				
		1992:Q2-2000:Q4	2003:Q2-2006:Q4	2009:Q4-2019:Q3	2020:Q2-2022:Q4
(1)	Wage Growth (ECI)	3.5%	3.2%	2.3%	4.5%
(2)	Import prices (excl. petroleum)	−0.1%	2.5%	0.2%	5.7%
(3)	- *Industrial supplies excl. petroleum*	*1.5 %*	*9.5 %*	*0.6%*	*20.0%*
(4)	Intermediate PPI (excl. food and energy)	1.4%	6.1%	1.4%	16.0%
(5)	Core CPI	2.6%	2.2%	1.9%	5.3%

Source: BLS and authors' calculations. Notes: Table shows the average 4-quarter change in the listed variable for each of the past four economic expansions shown in the header.

Wages and Input Prices Have Risen Sharply. Two important factors that are often referred to as drivers of high inflation in the post-COVID period are strong wage growth and rising input prices, caused by supply chain bottlenecks. Table 1 shows the average four-quarter change of different variables during the past four expansions. In row 1, we present wage growth from the Employment Cost Index (ECI), a measure of labor costs that includes benefits and takes into account compositional shifts in industry and occupation. According to the ECI, average four-quarter wage growth in the most recent expansion was 4.5 percent, exceeding the previous three expansions by about 1-2 percentage points.

Row 2 shows the four-quarter growth in import prices from the Bureau of Labor Statistics (BLS). Import prices have grown at a rate of around 6 percent recently. However, import prices combine both intermediate inputs and final goods. The third row therefore focuses on imported intermediate inputs, specifically industrial supplies, such as metals, rubber, chemicals, and so on. These inputs are especially important because when the price of inputs increases, these costs are passed through into the prices of the goods that use them. The price of imported industrial supplies has grown at a rate of about 20 percent in the current expansion, far higher than in the previous periods.

A rise in import prices affects domestic producers both by raising their marginal costs (due to higher imported intermediate prices) and due to a competition effect. Since foreign producers are increasing their prices, domestic firms can raise prices without losing market share. Consistent with these two forces, row 4 shows the average price growth for domestically produced intermediate inputs from the *core* Producer Price Index (PPI) for intermediates, which excludes food and energy inputs. The average input price growth in the most recent expansion was 16 percent, significantly higher than in the previous expansions.

Taking stock. The behavior of inflation following the pandemic recession has been an exception to the subdued inflationary environment the U.S. experienced since the 1990s. Moreover, the composition of inflation was different with goods inflation leading the inflationary pressures. The pandemic also triggered a reversal in the declining trend of the goods share in consumption. These inflationary pressures were accompanied by stark increases in input prices, reflecting global disruptions in supply chains, and a rapid tightening of the labor market. We next develop a model to evaluate how these joint shocks have contributed to the drastic surge in inflation.

3 A New Keynesian DSGE Model with Two Sectors and Import Competition

Our starting point is the standard New Keynesian DSGE model with two sectors: *goods* and *services*. The goods sector has a lower labor share than services, and is subject to foreign competition while all services are provided by domestic firms. We allow for strategic interactions between firms by assuming that there is only a finite number of firms as in Heise et al. (2022). On the production side, we assume that labor and intermediate inputs are combined via a CES production function. Intermediates are in turn a CES aggregate of domestic and foreign inputs. This structure allows for substitution between the different production factors.

The economy consists of four sets of agents. Households consume final consumption goods provided by a perfectly competitive final output firm. This firm aggregates differentiated products from two sectors: the goods-producing sector, which we also refer to as manufacturing, and services. The final output firm sources differentiated products from monopolistically competitive retailers subject to Rotemberg pricing frictions. Retailers aggregate inputs from a continuum of industries. Finally, the industries are populated by a finite number of producers, which combine labor and an intermediate input to produce a differentiated product. The intermediate input is produced using imported intermediates and domestic intermediates produced in a roundabout production structure. We next describe these building blocks of the model in more detail.

3.1 The Household Sector

The household side follows closely Smets and Wouters (2003). There is a continuum of households, indexed by τ. Households supply differentiated labor at nominal wage $W_t^{s,\tau}$ to the goods and services sectors, indexed by $s \in \{M, S\}$. Each household τ maximizes the present discounted value of utility given by:

$$E_0 \sum_{t=0}^{\infty} \mathcal{B}_0^t U_t^\tau,$$

where $\mathcal{B}_0^t$ indicates the discount factor, which is defined as $\mathcal{B}_0^t = \prod_{t'=0}^{t-1} \beta_{t'}$ with the convention $\mathcal{B}_0^0 = 1$. The discount factor follows the exogenous process

$$\ln(\beta_{t+1}) = (1 - \omega_\beta)\ln(\beta) + \omega_\beta \ln(\beta_t) + \epsilon_{t+1}^\beta,$$

where β is the discount factor in steady state and ϵ_t^β is a discount factor shock.

Household τ's period utility is

$$U^\tau(C_t^\tau, \ell_t^{M,\tau}, \ell_t^{S,\tau}) = \frac{1}{1-\sigma}(C_t^\tau - H_t)^{1-\sigma} - \frac{\kappa_t^M}{1+\varphi}(\ell_t^{M,\tau})^{1+\varphi} - \frac{\kappa_t^S}{1+\varphi}(\ell_t^{S,\tau})^{1+\varphi}.$$

In this equation, C_t^τ is the household's consumption, $\sigma > 0$ is the coefficient of relative risk aversion, $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply, and $H_t = hC_{t-1}$ is the habit stock of the household. The labor supply is additively separable across the two sectors and given by $\ell_t^{s,\tau}$ for sector s. The parameters κ_t^s govern the disutility of labor and follow an exogenous process

$$\kappa_{t+1}^s = (1 - \omega_\kappa)\kappa^s + \omega_\kappa \kappa_t^s + \epsilon_{t+1}^{\kappa,s}, \tag{1}$$

where κ^s is the disutility parameter in steady state and $\epsilon_t^{\kappa,s}$ is a labor disutility shock in sector s.

Households maximize their consumption subject to the intertemporal budget constraint

$$C_t^\tau P_{f,t} + b_t B_t^\tau + Q_{t+1} A_{t+1}^\tau \le W_t^{M,\tau}\ell_t^{M,\tau} + W_t^{S,\tau}\ell_t^{S,\tau} + B_{t-1}^\tau + A_t^\tau + P_{f,t}\Pi_t^\tau,$$

where $P_{f,t}$ is the price index of the final good. Household τ invests B_t^τ into a one-period bond with price b_t at time t. Following Christiano et al. (2005), households also purchase A_{t+1}^τ of state-contingent securities with price Q_{t+1}. The state-contingent securities insure the households against fluctuations in household-specific labor income, and hence the labor income of household τ will be equal to aggregate labor income. Households own the firms and receive nominal dividends $P_{f,t}\Pi_t^\tau$.

We next discuss the household decisions in turn. We delegate all derivations of the model solutions to Appendix A.

Consumption and Savings Behavior. The solution to the household consumption-savings problem leads to the standard Euler equation

$$(C_t - hC_{t-1})^{-\sigma} = \beta_t E_t \left[\frac{1+R_t}{1+\pi_{t+1}} (C_{t+1} - hC_t)^{-\sigma} \right], \tag{2}$$

where R_t is the nominal interest rate on bonds and $\pi_t \equiv P_{f,t}/P_{f,t-1} - 1$ is the rate of consumer price inflation.

Labor Supply Decisions and Wage Setting. Households are wage setters in the labor market as in Smets and Wouters (2003). They face a labor demand curve of

$$l_t^{s,\tau} = \left(\frac{W_t^{s,\tau}}{W_t^s} \right)^{-\eta^s} L_t^s, \tag{3}$$

where labor demand L_t^s and the nominal wage in sector s, W_t^s, are given by

$$L_t^s = \left[\int_0^1 (\ell_t^{s,\tau})^{\frac{\eta^s - 1}{\eta^s}} d\tau \right]^{\frac{\eta^s}{\eta^s - 1}}$$

and

$$W_t^s = \left(\int_0^1 (W_t^{s,\tau})^{1-\eta^s} d\tau \right)^{1-\eta^s}.$$

The parameter η^s governs the wage markup in sector s.

Households set wages subject to Rotemberg pricing frictions with a utility cost of changing price that is governed by a parameter ψ_w. The maximization problem leads to the following markup equation:

$$(\eta^s - 1)(C_t - hC_{t-1})^{-\sigma} w_t^s = \kappa_t^s \eta^s (L_t^s)^\varphi - \psi_w \pi_t^{s,w}(1 + \pi_t^{s,w}) + E_t \beta_t \psi_w \pi_{t+1}^{s,w}(1 + \pi_{t+1}^{s,w}), \tag{4}$$

where $w_t^s \equiv W_t^s / P_{f,t}$ is the real wage and $\pi_t^{s,w} \equiv W_t^s / W_{t-1}^s - 1$ is the rate of wage inflation in sector s.

3.2 Final Output Firm

The final output good $Y_{f,t}$ consumed by the households is a Cobb-Douglas aggregate of two sectoral goods, manufacturing and services:

$$Y_{f,t} = (Y^M_{f,t})^{\gamma^M_t} (Y^S_{f,t})^{\gamma^S_t}, \tag{5}$$

where γ^M_t and γ^S_t is the share of expenditures in each sector. We assume that the share of expenditures in the goods sector follows

$$\ln(\gamma^M_{t+1}) = (1 - \omega_\gamma)\ln(\gamma^M) + \omega_\gamma \ln(\gamma^M_t) + \epsilon^{\gamma,M}_{t+1},$$

where γ^M is the steady state share of expenditures in the goods sector and $\epsilon^{\gamma,M}_{t+1}$ is an expenditure share shock. By definition, $\gamma^M_t + \gamma^S_t = 1$, and hence the evolution of γ^M_t also determines the value of γ^S_t. We will analyze below a shock that shifts the composition of expenditures towards goods, motivated by the empirical evidence above.

Both manufacturing and services are a CES aggregate of a continuum of products $j \in [0, 1]$:

$$Y^s_{f,t} = \left(\int_0^1 y^s_{f,t}(j)^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}}. \tag{6}$$

where θ is the elasticity of substitution across products j. Cost minimization implies that the final demand for product j is

$$y^s_{f,t}(j) = \gamma^s_t \left(\frac{P^s_{f,t}(j)}{P^s_{f,t}} \right)^{-\theta} \left(\frac{P_{f,t}}{P^s_{f,t}} \right) Y_{f,t}, \tag{7}$$

where $P^s_{f,t} = (\int_0^1 P^s_{f,t}(j)^{1-\theta} dj)^{1/(1-\theta)}$ is the sectoral price index. The consumer price index $P_{f,t}$ is a combination of the sectoral price indices

$$P_{f,t} = \left(\frac{1}{\gamma^M_t} \right)^{\gamma^M_t} \left(\frac{1}{\gamma^S_t} \right)^{\gamma^S_t} (P^M_{f,t})^{\gamma^M_t} (P^S_{f,t})^{\gamma^S_t}. \tag{8}$$

Note that the aggregate price index may fluctuate as the shares γ^M_t and γ^S_t on each sector vary.

3.3 Retailers

Each product is sold by a retailer j. Retailers aggregate a continuum of industries $i \in [0,1]$ according to

$$y^s_{f,t}(j) = \left(\int_0^1 x^s_t(j,i)^{\frac{v-1}{v}} di \right)^{\frac{v}{v-1}}, \tag{9}$$

where v is the elasticity of substitution between industries and $x^s_t(j,i)$ is the quantity of industry i used by retailer j in sector s. The retailers are monopolistic competitors, taking price indices as given, and face a quadratic price adjustment cost proportional to sectoral output with price adjustment parameter ψ_p. We denote the cost of the input of industry i by $P_{x,t}(j,i)$. Given demand (7) and solving for a symmetric equilibrium with $j = j'$ and $i = i'$, maximization of real profits results in the first order condition

$$(\theta - 1) = \theta \frac{p^s_{x,t}}{p^s_{f,t}} - \psi_p \left(1 + \pi^s_t\right) \pi^s_t + \beta_t \psi_p E_t \left[\frac{\gamma^s_{t+1}}{\gamma^s_t} \frac{(C_{t+1} - hC_t)^{-\sigma}}{(C_t - hC_{t-1})^{-\sigma}} \frac{Y_{f,t+1}}{Y_{f,t}} \left(1 + \pi^s_{t+1}\right) \pi^s_{t+1} \right], \tag{10}$$

where $p^s_{x,t} \equiv P^s_{x,t}/P_{f,t}$, $p^s_{f,t} \equiv P^s_{f,t}/P_{f,t}$, sectoral inflation is $\pi^s_t = P^s_{f,t}/P^s_{f,t-1} - 1$, and we have omitted the i and j indices due to symmetry.

3.4 Intermediate Goods Firms

Each industry i consists of a finite number of intermediate goods firms indexed by k that produce for retailer j in sector s. The finite number of firms allows for strategic interactions, which will generate potentially incomplete pass-through of shocks. We build on the canonical model by Atkeson and Burstein (2008) and its application in Heise et al. (2022). Firms can either be domestic, D, or foreign, F, and the total number of these firms in sector s is N^s_D and N^s_F, respectively. The number of domestic firms relative to foreign firms will govern the importance of foreign competition for the transmission of domestic shocks.

The production of intermediate goods firms is aggregated to the industry level according to

$$x^s_t(j,i) = (N^s)^{\frac{1}{1-\mu}} \left(\sum_{k=1}^{N^s_D} x^s_t(j,i,k)^{\frac{\mu-1}{\mu}} + \sum_{k=1}^{N^s_F} x^s_t(j,i,k)^{\frac{\mu-1}{\mu}} \right)^{\frac{\mu}{\mu-1}} \tag{11}$$

where μ is the elasticity of substitution between firms and $N^s = N^s_D + N^s_F$. As in Jaimovich and Floetotto (2008), we include the scale term $(N^s)^{1/(1-\mu)}$ to ensure that there is no variety effect, which implies that, in an equilibrium in which all firms are symmetric, $N^s x^s_t(j,i,k) = x^s_t(j,i) = x^s_t(j)$. As in Atkeson and Burstein (2008), we assume that $\mu > \nu > 1$ so that it is easier to substitute across firms within industries than across industries.

Demand

Firms engage in Bertrand competition, and set a producer price of $P^s_{x,t}(j,i,k)$. Demand for firm k's output is

$$x^s_t(j,i,k) = \left(\frac{P^s_{x,t}(j,i,k)}{P^s_{x,t}(j,i)}\right)^{-\mu} \frac{x^s_t(j,i)}{N^s}, \tag{12}$$

where $P^s_{x,t}(j,i,k) = P^s_{x,t}(j,i) = P^s_{x,t}(j) \equiv P^s_{x,t}$ in a completely symmetric equilibrium, and

$$P^s_{x,t}(j,i) = (N^s)^{\frac{1}{\mu-1}} \left(\sum_{k=1}^{N^s_D} P^s_{x,t}(j,i,k)^{1-\mu} + \sum_{k=1}^{N^s_F} P^s_{x,t}(j,i,k)^{1-\mu}\right)^{\frac{1}{1-\mu}} \tag{13}$$

is the industry price index. We will analyze the behavior of this producer price index at the industry-level in our empirical analysis below.

Production

We assume that firms combine two factors of production: intermediate inputs and labor. These factors of production are imperfectly substitutible via a CES production structure. Our setup will allow us to analyze the substitution patterns in response to a cost shock to one or both of the factors.

Domestic intermediate firm k supplying retailer j in sector s has a production function

$$x^s_t(j,i,k) = \left[(A_t L^s_t(j,i,k))^{\frac{\rho_s-1}{\rho_s}} + \Lambda_s^{\frac{1}{\rho_s}} D^s_t(j,i,k)^{\frac{\rho_s-1}{\rho_s}}\right]^{\frac{\rho_s}{\rho_s-1}}, \tag{14}$$

where A_t is aggregate labor productivity, which is common across sectors, and $L^s_t(j,i,k)$ and $D^s_t(j,i,k)$ are labor and intermediate inputs used by the firm. The parameter ρ_s is the sector-specific elasticity of substitution between the inputs. When one of the factors of production increases in cost, firms substitute towards the other factor, where the strength of the effect is governed by ρ_s. The parameter Λ_s is a constant that we will use to match the share of intermediates in production in steady state.

The intermediate input $D^s_t(j,i,k)$ is a composite of domestic and foreign inputs, which are combined according to

$$D^s_t(j,i,k) = \left[M^s_t(j,i,k)^{\frac{\xi-1}{\xi}} + Z^s_t(j,i,k)^{\frac{\xi-1}{\xi}}\right]^{\frac{\xi}{\xi-1}} \tag{15}$$

where $M^s_t(j,i,k)$ is an imported intermediate input and $Z^s_t(j,i,k)$ is an aggregate of domestic intermediate inputs. The equation highlights that firms can adjust to a change in imported input costs by substituting towards the domestic input with an elasticity of substitution that is governed by ξ.

The imported intermediate input $M_t^s(j,i,k)$ is supplied with a sector-specific price $P^s_{x,imp,t}$. We assume that the relative import price $p^s_{x,imp,t} \equiv P^s_{x,imp,t}/P_{f,t}$ follows an exogenous process

$$\ln(p^s_{x,imp,t+1}) = (1-\omega_P)\ln(p^s_{x,imp}) + \omega_P \ln(p^s_{x,imp,t}) + \epsilon^{P,s}_{t+1}, \tag{16}$$

where $p^s_{x,imp}$ is the relative import price in sector s in steady state and $\epsilon_t^{P,s}$ is an import price shock. We will calibrate $p^s_{x,imp}$ below to match the empirically observed imported input share in each sector.

The domestic input $Z_t^s(j,i,k)$ is assembled using all industries' output via a roundabout production technology that combines all industries as in equation (9), and combines sectors in the same way as the consumer good in equations (5) and (6). We assume that the domestic input is produced with the same weights γ_t^M, γ_t^S as the consumer good. This structure leads to a price index for domestic inputs of

$$P_{x,dom,t} = \left(\frac{1}{\gamma_t^M}\right)^{\gamma_t^M} \left(\frac{1}{\gamma_t^S}\right)^{\gamma_t^S} (P^M_{x,t})^{\gamma_t^M} (P^S_{x,t})^{\gamma_t^S}, \tag{17}$$

analogous to the equation for the consumer price index (8), but using the sectoral producer prices $P^s_{x,t}$ defined above. Since both sectors use the same input basket, the domestic input price index is the same in both sectors. We assume that only domestic firms demand domestic intermediates, and thus our model does not include exports.

Domestic intermediate input producers optimally choose their input bundle of domestic and foreign intermediates, and then optimize over intermediates and labor to minimize costs. Cost minimization implies that marginal costs of domestic firm k are

$$MC^s_{D,t} = \left[(W_t^s/A_t)^{1-\rho_s} + \Lambda_s (P^s_{x,input,t})^{1-\rho_s}\right]^{1/(1-\rho_s)}, \tag{18}$$

where $P^s_{x,input,t}$ is the intermediate input price index. This price index aggregates the prices of domestic and foreign inputs according to

$$P^s_{x,input,t} = \left[(P_{x,dom,t})^{1-\xi} + (P^s_{x,imp,t})^{1-\xi}\right]^{1/(1-\xi)}. \tag{19}$$

Real marginal costs are defined as $mc^s_{D,t} \equiv MC^s_{D,t}/P_{f,t}$.

We assume that foreign intermediate firms face an exogenous process for real marginal costs, $mc^s_{F,t} \equiv MC^s_{F,t}/P_{f,t}$, given by

$$\ln(mc^s_{F,t+1}) = (1-\omega_F)\ln(mc^s_F) + \omega_F \ln(mc^s_{F,t}) + \epsilon^F_{t+1}, \tag{20}$$

where mc^s_F is the foreign firm's real marginal cost in steady state and ϵ^F_t is a marginal cost shock. Foreign intermediates are produced abroad and do not use any domestic resources.

Profit maximization implies that producers set producer prices as

$$P_{x,t}(j,i,k) = \frac{\mathcal{E}^s_t(j,i,k)}{\mathcal{E}^s_t(j,i,k)-1} MC^s_{D,t}, \tag{21}$$

where $\mathcal{E}^s_t(j,i,k) = \mu(1 - S^s_t(j,i,k)) + \nu S^s_t(j,i,k)$ is the effective elasticity of substitution faced by the firm, which depends on the market share

$$S^s_t(j,i,k) = \left(\frac{1}{N^s}\right) \frac{P^s_{x,t}(j,i,k)^{1-\mu}}{P^s_{x,t}(j,i)^{1-\mu}}. \tag{22}$$

Equation (21) highlights that firms set a variable markup $\mathcal{M}_t(j,i,k) \equiv \mathcal{E}^s_t(j,i,k)/(\mathcal{E}^s_t(j,i,k)-1)$ over marginal costs. Since $\mu > \nu$, firms with a higher market share face a lower effective elasticity of substitution, and hence set higher markups.

3.5 Monetary Authority

We close the model by assuming that a central bank sets monetary policy based on a Taylor rule. This rule is given by

$$R_t = \varrho R_{t-1} + (1-\varrho)R + (1-\varrho)[\Phi_\pi \pi_t + \Phi_y(\ln(Y_{f,t}) - \ln(Y_f))] + \epsilon^M_t, \tag{23}$$

where Φ_π and Φ_y are the central bank's weights on inflation and on final output, respectively, and Y_f is the steady state value of final output. Monetary policy shocks are represented by ϵ^M_t.

3.6 Aggregation

We consider an equilibrium in which all domestic and foreign firms are symmetric, but allow the two groups to differ in terms of their marginal costs. Thus, a domestic producer will set price $P^s_{D,x,t}$ and a foreign producer sets price $P^s_{F,x,t}$. Gross output by domestic producers in sector s, $Y^s_{g,t}$, is equal in equilibrium to the total demand for domestic output by consumers, from other firms, and for the price adjustment cost:

$$Y^s_{g,t} = \frac{N^s_D}{N^s}\left(\frac{P_{D,x,t}}{P_{x,t}}\right)^{-\mu}\left(\gamma^s_t\left(\frac{P_{f,t}}{P^s_{f,t}}\right)C_t + \gamma^s_t\frac{\psi_p}{2}(\pi^s_t)^2 C_t + \gamma^s_t\left(\frac{P_{x,dom,t}}{P^s_{x,t}}\right)Z^s_t + \gamma^s_t\left(\frac{P_{x,dom,t}}{P^s_{x,t}}\right)Z^{s'}_t\right).$$

The first term, $(N^s_D/N^s)(P_{D,x,t}/P_{x,t})$, represents the share of total demand that is satisfied by domestic producers. This share depends on the number of domestic producers in sector s, N^s_D, and their price relative to the industry price index, which also includes foreign firms. The term in parentheses represents the output demand from four sources. The first term in parentheses is the demand from consumers, where in equilibrium $Y_{f,t} = C_t$. The second term is the output needed by retailers to cover the price adjustment. The third and fourth term are the input demands by sector s and s' from sector s, which depend on the price of sector s relative to the domestic input price index. The total demand for intermediates by sector s is given by

$$Z^s_t = \Lambda_s\left(\frac{P_{x,dom,t}}{P^s_{x,input,t}}\right)^{-\xi}\left(\frac{P^s_{x,input,t}}{MC^s_{D,t}}\right)^{-\rho_s} Y^s_{g,t}.$$

Total gross output is

$$Y_{g,t} = Y^M_{g,t} + Y^S_{g,t}.$$

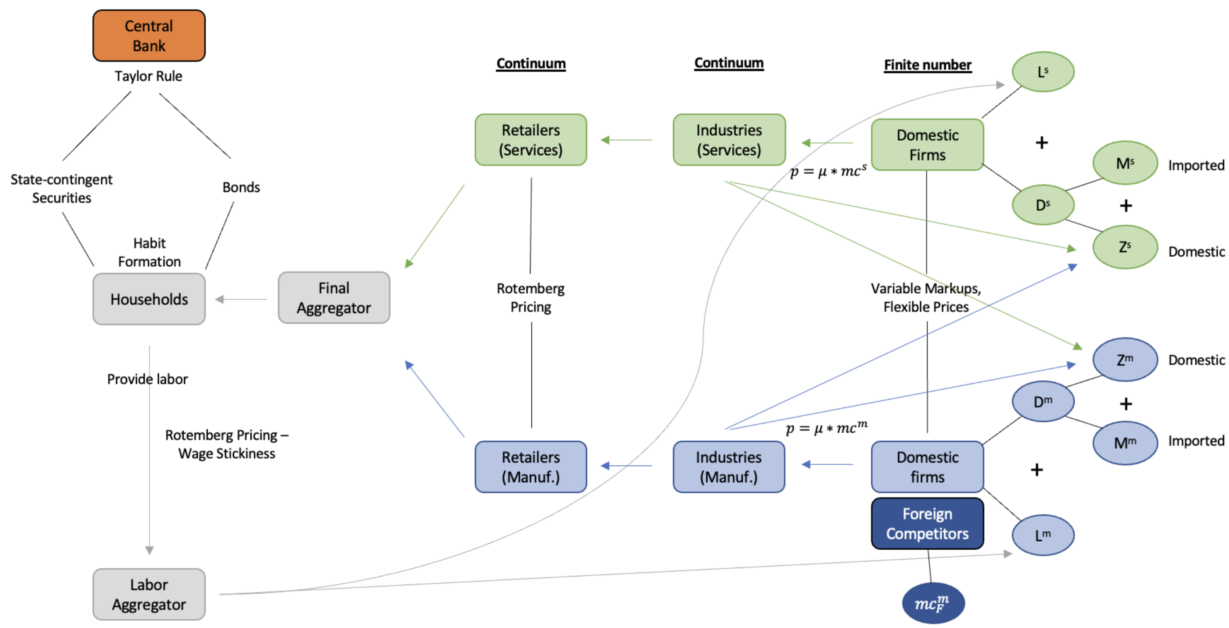
Aggregate labor demand in sector s is equal to

$$L^s_t = A_t^{\rho_s - 1}\left(\frac{W^s_t}{MC^s_{D,t}}\right)^{-\rho_s} Y^s_{g,t},$$

which must equal the total supply of labor to that sector given by (4).

Going forward, we assume that foreign firms operate only in the goods sector, while the services sector contains only domestic firms. This assumption is consistent with the empirical analysis below, where a number of industries, mostly in services, do not record any imports and hence no competition by foreign firms. Figure 4 summarizes the components of the model. The gray cells show the household side. Households face a trade-off between consumption of final goods and savings, and base their decision on the interest rate set by the monetary authority. The central bank sets monetary policy using a Taylor rule. The blue and green cells show the goods and services sectors, respectively. Both sectors are populated by a continuum of retailers, which aggregate a continuum of industries that are populated by a finite number of producers. The producers assemble labor and intermediate inputs, where the latter are a combination of domestic inputs, produced using a roundabout production structure, and imported inputs in both sectors. Firms in the goods sector face competition

Figure 4: Model Diagram



Note: This figure summarizes key components of the model. Households are represented by gray cells, the central bank in orange, while the green and blue cells show the manufacturing and services sector, respectively. The dark blue box highlights foreign competitors.

from foreign firms, which set prices based on an exogenous marginal cost process. We list all equilibrium conditions of the final model in Appendix A.6.

4 Quantitative Analysis

In this section, we calibrate our two-sector model and analyze the effects of supply chain disruptions and the labor disutility shock. Our calibrated model implies that the supply-side shocks can account for about 2 percentage points of the rise in inflation in the pandemic period. We analyze the interactions of the shocks and show that they amplify each other. We then compare the inflationary effects of these supply shocks to the effects of a goods-biased demand shock. Finally, we examine the effect of monetary policy in response to the shocks and show that aggressive policy can reduce the risk of a recession in the case of a demand shock, but is less advantageous in the case of the supply shocks.

4.1 Calibration

We calibrate our model using some standard parameters in the DSGE literature and also a dataset of disaggregated industry-level data, which we assemble at the 6-digit NAICS level from publicly available data from the Census Bureau and from the BLS. We describe this dataset in more detail in Section 6.2. We solve the model via a third-order approximation in Dynare to capture non-linear effects.

Standard parameters based on the DSGE literature. We set standard values for a number of parameters, and summarize the parameter values in Table 2. We choose the risk aversion parameter, inverse of the Frisch elasticity of labor supply, steady state discount factor, wage markup, and habit parameter as in Smets and Wouters (2003), and obtain $\sigma = 1.371$, $\varphi = 2.491$, $\beta = 0.99$, $\eta_M = \eta_S = 3$, and $h = 0.595$.

We calibrate the adjustment cost parameter for prices following Keen and Wang (2007). Assuming a steady state markup of 20%, they find a value of $\psi_p = 72$. At that value, a simple model with Rotemberg adjustment costs corresponds to a Calvo model with a price adjustment frequency of 12 to 15 months, consistent with empirical evidence. Given the rapid adjustment of wages in the recent period, we do not assume that wages are more sluggish than prices. Instead, we set $\psi_w = 72$. We specify the Taylor rule based on estimates by Carvalho et al. (2021), who follow a similar procedure as Clarida et al. (2000). For the Greenspan-Bernanke era, they find a Taylor rule persistence parameter of $\varrho = 0.8$, a weight on inflation of $\Phi_\pi = 1.4$, and a weight on the output gap of $\Phi_y = 0.95$.

Labor share in goods and services sectors. Our model implies that the labor share in sector s in steady state is

$$\lambda_s \equiv \frac{(w^s/A)^{1-\rho_s}}{(w^s/A)^{1-\rho_s} + \Lambda_s (p^s_{i,input})^{1-\rho_s}}, \tag{24}$$

where variables are without a time subscript to indicate a steady state. Given a calibrated λ_s, we can back out the parameter values Λ_s from this equation. We set the labor share in goods and services from the average share of labor costs relative to total costs in our disaggregated industry-level data. We obtain $\lambda_M = 0.31$ and $\lambda_S = 0.60$, and hence labor is significantly more important in services than in goods.

Table 2: Calibration Summary

Parameter	Description	Value	Source
σ	Risk aversion	1.371	Smets and Wouters (2003)
φ	Inverse elasticity of labor supply	2.491	Smets and Wouters (2003)
β	Steady state discount factor	0.99	Smets and Wouters (2003)
η_M, η_S	Wage markup	3	Smets and Wouters (2003)
h	Habit parameter	0.595	Smets and Wouters (2003)
ψ_p	Adjustment costs prices	72	Keen and Wang (2007)
ψ_w	Adjustment costs wages	72	Assumed same as prices
ϱ	Taylor rule persistence	0.8	Carvalho et al. (2021)
Φ_π	Taylor rule weight on inflation	1.4	Carvalho et al. (2021)
Φ_y	Taylor rule weight on output	0.95	Carvalho et al. (2021)
λ_M, λ_S	Labor share goods (services)	0.31 (0.6)	Census Bureau, authors' calculations
γ_M, γ_S	Consumption share goods (services)	0.35 (0.65)	Bureau of Economic Analysis
κ_M, κ_S	Steady state disutility of labor in goods (services)	122 (1)	Census Bureau, authors' calculations
N_D^M, N_D^S	Domestic firms goods (services)	13 (20)	Atkeson and Burstein (2008)
N_F^M	Foreign firms goods	7	Census Bureau, authors' calculations
α_M, α_S	Imported input share in goods (services)	0.17 (0.04)	Census Bureau, authors' calculations
θ	Elasticity final goods	6	Christiano et al. (2005)
μ	Elasticity across firms	3	Atkeson and Burstein (2008)
ν	Elasticity across industries	1	Atkeson and Burstein (2008)
ρ_M, ρ_S	Elasticity labor v. intermediates	2 (1.5)	Chan (2021)
ξ	Elasticity domestic v. foreign	2	Feenstra et al. (2018)

Consumption share in goods and services sectors. The steady state consumption share of goods is obtained from the BEA's real personal consumption expenditures (PCE) data. We average the goods share over time from 1970 to 2022 and obtain approximately $\gamma_M = 0.35$ and $\gamma_S = 0.65$.

Disutility of labor. We normalize the steady state disutility of labor in the services sector to $\kappa_S = 1$. To set the disutility in the goods sector, we obtain the average monthly earnings of workers in goods and in services from the Quarterly Workforce Indicators (QWI) for 2013-2021.[4] On average, wages in the goods sector are 17% higher than in services. We then set κ_M to match this wage gap in steady state, yielding $\kappa_M = 122$.

Number of firms—domestic and foreign. We calibrate the number of firms based on Atkeson and Burstein (2008). They set the number of firms to 20. To set the number of foreign competitors in the good sector, we use the import share in total domestic sales from our disaggregated industry-level data. We find an import share in the goods sector of 0.3. We therefore set $N_D^M = 13$, $N_F^M = 7$, and $N_D^S = 20$.

[4]We define the manufacturing and mining sectors as the goods sector, and set utilities, construction, wholesale and retail trade, transportation, and all other services as services.

Relative import price. To calibrate the steady state relative import price, $p^s_{x,imp}$, we define the imported input share in sector s, α_s, in steady state as

$$\alpha_s \equiv \frac{(p^s_{x,imp})^{1-\xi}}{(p_{x,dom})^{1-\xi} + (p^s_{x,imp})^{1-\xi}}, \tag{25}$$

where $p_{x,dom} \equiv P_{x,dom}/P_f$. We set the imported input share α_s to match the average share of imported input costs in intermediate costs in our disaggregated industry-level data. We obtain an imported input share in goods of $\alpha_M = 0.17$, and in services of $\alpha_S = 0.04$. Given these values, we can then back out $p^s_{x,imp}$ in steady state.

Key elasticities. Given the rich structure of our model, there are a number of elasticities that we need to calibrate.

First, for *the elasticity of substitution across final goods*, we follow Christiano et al. (2005) and set $\theta = 6$.

Second, since all domestic and all foreign firms are symmetric, the parameter μ essentially governs the *elasticity of substitution between the domestic and foreign firm groups*, rather than substitution between individual firms. We therefore set this elasticity towards the lower end of the range of 1 to 10 discussed by Atkeson and Burstein (2008), and follow estimates on the elasticity of substitution between foreign and domestic varieties from the trade literature. Feenstra et al. (2018) estimate this elasticity to be in the range of 1 to 4. We therefore set $\mu = 3$. We follow the conventional calibration from Atkeson and Burstein (2008) and Amiti et al. (2019) and set the elasticity of substitution across industries to $\nu = 1$.

The third parameter is *the elasticity of substitution between labor and intermediates*, ρ_s. This parameter is important because it governs to what extent firms can substitute between inputs when hit by a shock, and hence the importance of the substitution channel. We set this parameter based on Chan (2021), who estimates using disaggregated Danish data that labor and intermediates are gross substitutes. He estimates the elasticities by regressing the labor-to-intermediate ratio on the ratio of input prices and wages, instrumenting for wages to induce exogenous wage variation. Chan (2021) estimates elasticities of substitution in the range of 1.5 to 4, and we therefore choose an elasticity in the goods sector of $\rho_M = 2$. We assume a lower elasticity between labor and intermediates in services, and set $\rho_S = 1.5$.

Fourth is *the elasticity of substitution between domestic and foreign intermediates*, ξ. This parameter governs to what extent firms can switch to domestic intermediates in the event of a shock to foreign inputs. We again build on the estimated value of 1 to 4 in Feenstra et al. (2018). Since we prefer this elasticity to be at least as high as the elasticity of substitution between labor and intermediates, we set it to $\xi = 2$.

Our calibration implies that the model contains four key differences between the goods and the services sector. First, services account for a larger share of the consumption basket and of firms' inputs, $\gamma_S > \gamma_M$. Second, the labor share is lower in the goods sector, $\lambda_M < \lambda_S$, making intermediates more important. As a result, shocks to input prices will have a larger direct effect on goods. Third, it is easier to substitute between labor and intermediates in the goods sector, $\rho_M > \rho_S$. Finally, only the goods sector contains foreign competitors. The presence of foreign competition dampens the response of domestic producers to domestic shocks since these firms partially adjust their markups to preserve market share.

4.2 Macroeconomics Effects of Supply Chain Disruptions, Rise in Disutility of Work and Goods-Favored Demand Shocks

We consider the effects of four different shocks on macroeconomic aggregates and how they interact with monetary policy. We first consider the joint effect of supply chain and labor supply shocks and end with a discussion of a demand shock that has a bigger effect on goods consumption.

Import price shock. We consider the effect of a positive imported input price shock in both the goods and services sector on inflation by setting $\epsilon_{t+1}^{P,s} = 0.13$ for both $s \in \{M, S\}$. This shock generates an increase in imported input prices of about 16 percent on impact, in the range of the average increase in imported input prices during the current expansion from Table 1. We set $\omega_P = 0.9$ to capture the persistence of the shock.

Labor disutility shock. We interpret the disutility shock as representing workers' increased reservation wage and the tighter labor market conditions in the recent period. We calibrate this shock to match the part of the drop in participation that is due to the pandemic, which Hobijn and Şahin (2022) estimate to be 0.3 percentage points. Since health concerns related to the pandemic have been more prominent in the services sector due to the social proximity of jobs in that sector, we feed in a disutility shock that increases labor disutility κ_t^s in goods and services by 6 percent and 10 percent, respectively. Given the different steady state levels, these values translate into shocks of $\epsilon_{t+1}^{\kappa,S} = 0.10$ in services and of $\epsilon_{t+1}^{\kappa,M} = 8$ in goods. On their own, these shocks lead to a drop in labor demand of slightly more than 0.5 percentage points in services and of 0.3 percentage points in goods at the peak, consistent with the empirical evidence. We set $\omega_\kappa = 0.9$.

Foreign competition shock. The supply chain disruptions also affected U.S. firms' foreign competitors and increased their marginal costs of production. We feed into the model a shock that increases competitors' real marginal costs by 4.2 percent relative to the steady state level, $\epsilon_{t+1}^F = 0.042$. This shock generates an increase in real marginal costs similar to what domestic firms in the goods sector experience due to the import price shock and the labor disutility shock. As a result, foreign competitors' market share remains roughly constant. We set $\omega_F = 0.9$, in line with the persistence of the other shocks.

Goods-favored demand shock. We consider a demand shock that increases consumption but more so for goods than services to capture the shift in consumer demand towards goods at the onset of the pandemic. In particular, we consider a shock $\epsilon_t^\beta = -0.04$ that reduces the discount factor β_t by 0.04, spurring a consumption boom. To capture the goods-biased nature of the shock, we couple this shift with an increase in γ_t^M of 2 percent by setting $\epsilon_t^{\gamma,M} = 0.02$. We assume persistence parameters of $\omega_\beta = 0.9$ and $\omega_\gamma = 0.9$.

4.2.1 Supply Chain Disruptions and Labor Supply.

We now analyze the effects of the three simultaneous supply shocks described above: a rise in imported input prices, an increase in the disutility of work, and a rise in marginal cost of foreign competitors. The magnitudes of the shocks are calibrated as described in the previous subsection.

In Figure 5 we trace out the effects of these shocks over the next 20 quarters. The first and second panel in the top row show the exogenous shocks. The disutility shock raises labor disutility κ_t^s in the goods and services sector by 6 percent and 10 percent, respectively. The imported input shock raises imported input prices in both sectors by about 16 percent on impact. Domestic input prices rise as well due to a rise in equilibrium wages. The second row highlights that the shock leads to a substitution away from intermediates towards labor, particularly in the goods sector due to its higher exposure to imported intermediates. Firms also substitute away from imported intermediates towards domestic intermediates. Gross output rises in both sectors, as more intermediates are now produced domestically. However, consumption only rises slightly on impact and eventually declines, since most of the additional output goes towards the replacement of inputs previously obtained from abroad. The third row illustrates that the substitution effect towards domestic labor increases real wages and therefore marginal costs. The real wage increase is slightly larger in the goods sector than in the services sector due to the stronger substitution towards labor in the former. Foreign firms' marginal costs increase exogenously and decline slowly back to steady state. Based on our calibration, their increase in marginal costs is somewhat in line with the real marginal cost of domestic firms in the goods sector, and thus foreign firms' market share changes little.

Figure 5: Baseline: Supply Chain Disruptions and Labor Supply Constraints

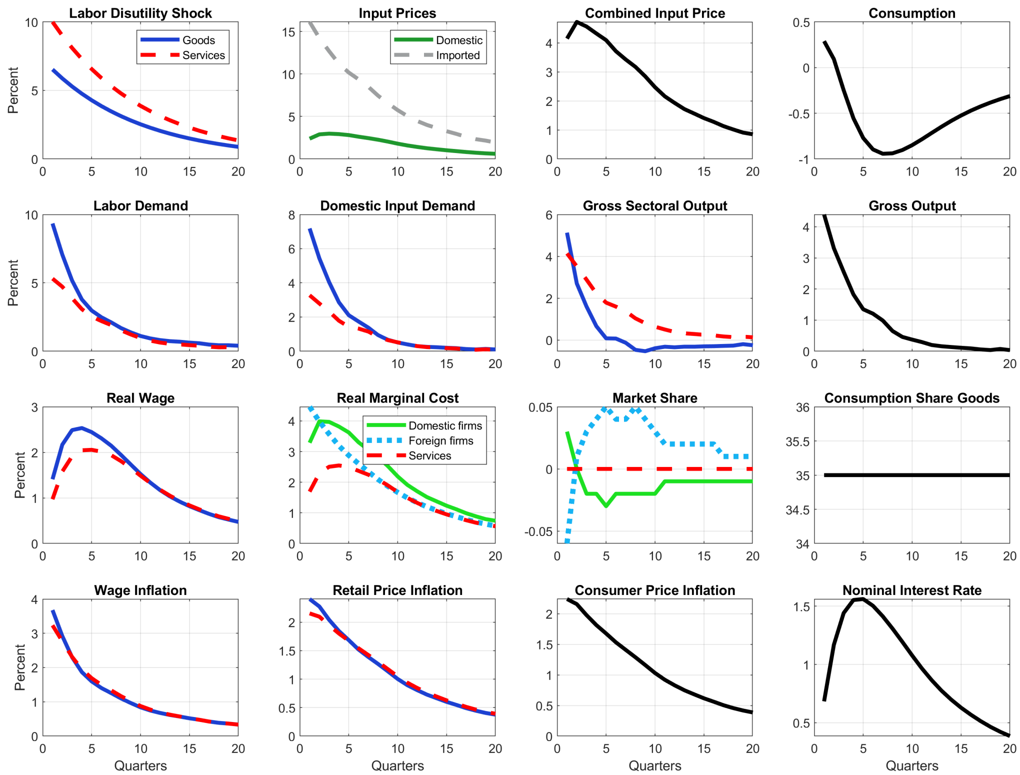


Figure shows the effect of a joint disutility, imported input price, and foreign competitor cost shock. Each panel shows the percent deviation of a variable from its steady state value against the number of quarters passed since the initial shock. For wage and price inflation and the market share, we show percentage point changes from steady state. For the consumption share of goods we show its actual value.

The three shocks together generate a 3.5 percentage point increase in wage inflation and a 2 percentage point rise in consumer price inflation —therefore they account for a notable part of the pick-up in wages and prices. To put this finding into context, headline CPI inflation averaged at 1.8 percent in 2019, 4.7 percent in 2021 and 8 percent in 2022. Thus, the rise in inflation relative to the "steady state" of 2019 was 2.9 percentage points in 2021 and 6.2 percentage points in 2022. Our calculations suggest that supply chain disruptions and labor supply constraints can account for one third to two thirds of the rise in inflation depending on the time period we consider. This finding resonates with the findings of Di Giovanni et al. (2022).

The combination of shocks in our model affects inflation, labor market and consumption dynamics in the economy in a non-trivial manner. To shed light on the role of the individual shocks and how they interact, we next analyze the effects of an imported input price shock and a shock to foreign competitors' marginal costs, respectively, in isolation, and then discuss the interaction of the shocks. We obtain three important insights. First, we demonstrate that an import price shock on its own can lead to substantial wage and price inflation due to the substitution from imported inputs towards labor (*Substitution effect*). Second, we show that a shock to foreign competitors' costs increases the demand for domestic inputs, and allows domestic firms to increase their prices without losing market share (*Foreign competition effect*). Third, we show that a joint shock to import prices, marginal costs of foreign competitors, and wages has an amplified effect on inflation by diminishing firms' ability to reduce costs by substituting across inputs or towards foreign competitors (*Amplification*).

Substitution effect. Figure 6 traces out the effect of the imported input price shock in isolation. The first row shows again the imported input price shock while there is no longer a labor disutility shock. The second row shows that the import price shock leads to a substitution away from intermediates towards labor, particularly in the goods sector due to its higher exposure to imported intermediates. Gross output falls due to a large decline in goods output, which has become more expensive to produce. The third row illustrates that some of this production shifts to foreign firms, which have gained market share since in this experiment they are assumed not to be affected by supply chain disruptions, and hence their real marginal cost stays flat. The substitution effect towards domestic labor increases real wages and therefore marginal costs in the goods sector. Real wages in the services sector actually fall slightly, but real marginal costs in that sector still rise due to the higher cost of intermediate inputs. The real wage increase is larger in the goods sector than in the services sector due to the stronger substitution in goods. The final row highlights that there is significant wage inflation in both sectors of approximately 0.5 percent due to the substitution towards labor. The change in real marginal costs translates into consumer price inflation of about 0.5 percent. Nominal interest rates adjust gradually due to the sluggish Taylor rule. As a result, real interest rates actually decline on impact, leading to a very short-lived consumption boom. This boom is supported by the additional sales of foreign firms.

This experiment highlights that an import price shock *on its own* can generate substantial wage and price inflation due to the substitution effect. If supply chain bottlenecks prompt firms to source more from domestic suppliers, the resulting additional labor demand can put upward pressure on wages. This substitution channel generates a 0.5 percentage point rise in wages—which is around 15% of the rise in the wages in our baseline experiment with three shocks.

Figure 6: Effect of Imported Input Price Shock Only

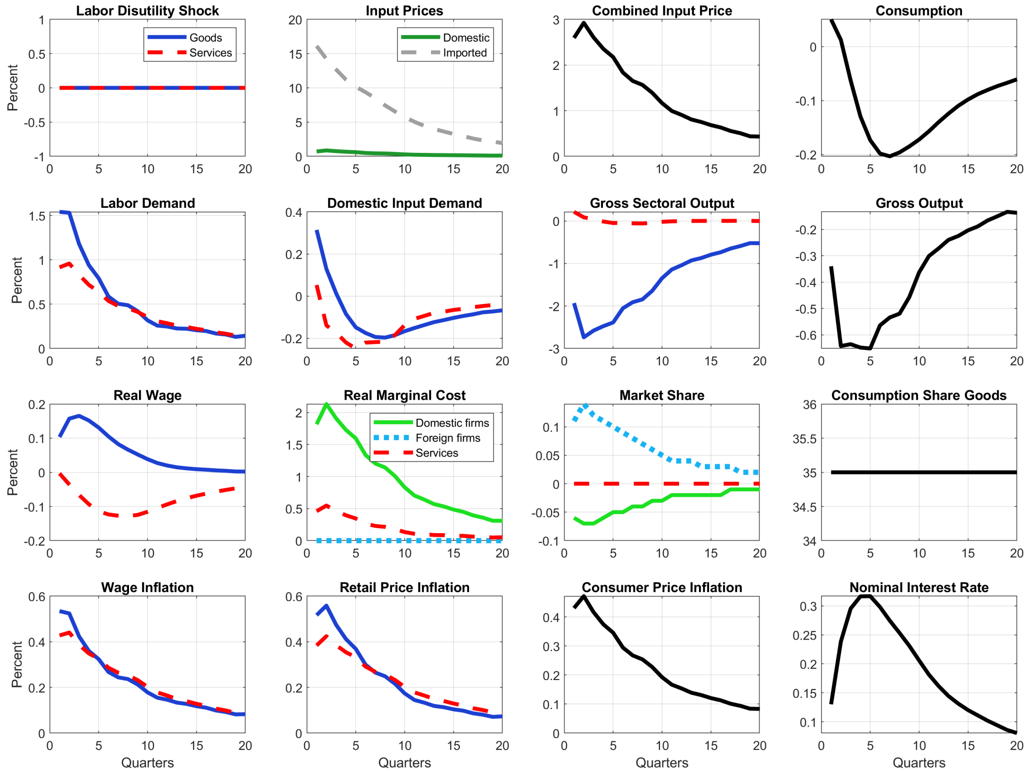


Figure shows the effect of an input price shock on key variables. Each panel shows the percent deviation of a variable from its steady state value against the number of quarters passed since the initial shock. For wage and price inflation and the market share, we show percentage point changes from steady state. For the consumption share of goods we show its actual value.

Foreign competition effect. Figure 7 shows the effect of the increase in foreign competitors' marginal costs by 4.2 percent in isolation. The first row shows that there are no direct domestic shocks to the U.S. producers. However, domestic input prices go up as production shifts from foreign producers towards domestic ones. The second row illustrates the source of this cost increase. When the marginal costs of foreign producers rise, domestic labor demand goes up, especially in the goods sector due to a shift from imports to domestic production. Foreign producers lose market share. As a result of the increase in labor demand, nominal wages rise. The shock generates price inflation of about 0.5 percentage point as the domestic firms' marginal costs rise and they pass these cost increases on to domestic consumers. We refer to this effect as the *foreign competition effect* since it highlights how shocks to relative marginal costs of domestic and foreign firms create inflation. The developments in the two decades before the pandemic were the opposite of this shock: low marginal costs of U.S. firms' foreign competitors, in particular from China, held back price increases by domestic producers. Heise et al. (2022) find that increased import competition during this period

Figure 7: Effect of Foreign Competition Shock Only

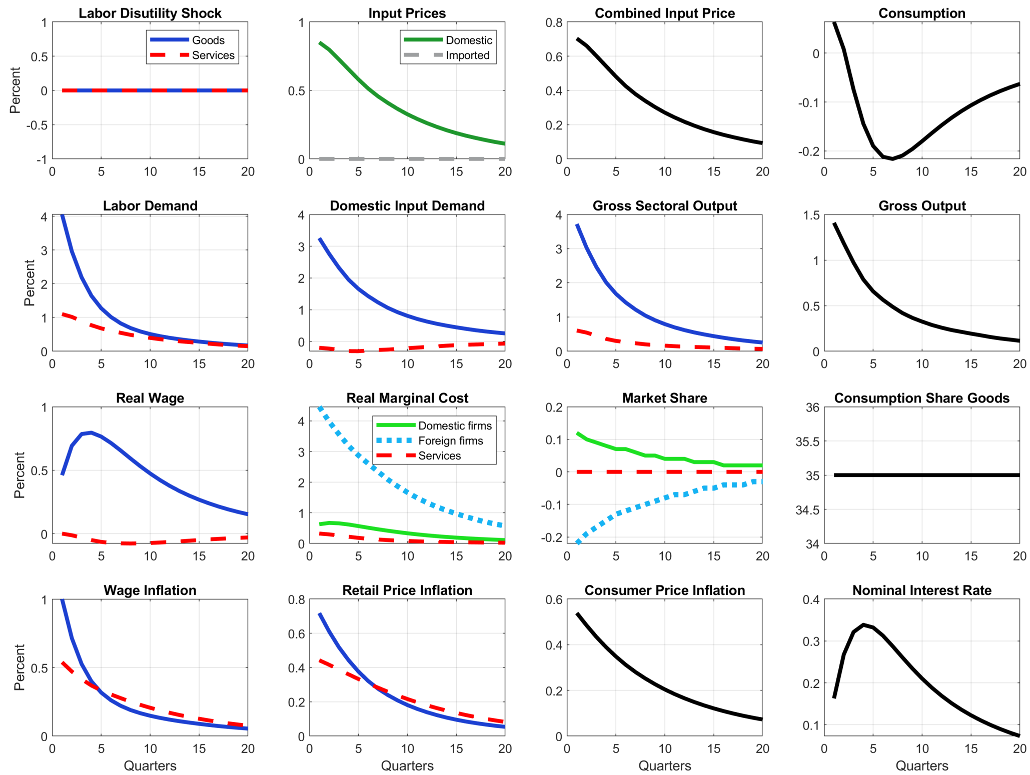


Figure shows the effect of a shock to foreign competitors' real marginal cost on key variables. Each panel shows the percent deviation of a variable from its steady state value against the number of quarters passed since the initial shock. For wage and price inflation and the market share, we show percentage point changes from steady state. For the consumption share of goods we show its actual value.

reduced the pass-through of domestic wage increases to prices in the goods sector, as U.S. firms were unable to raise prices without losing market share.

Amplification. The combination of imported input price shock, foreign competition price shock, and labor disutility shock creates an amplified effect on inflation. First, the combination of a labor disutility and import price shock makes substituting between labor and intermediates less effective for domestic firms. Feenstra et al. (2018) describe that U.S. firms substitute away from labor and towards imported inputs to reduce costs. When the shocks hit jointly, substitution is impaired, which leads to higher inflation compared to when the shocks hit separately. Second, when the labor disutility shock coincides with a price increase by foreign competitors, firms' ability to switch towards foreign products to mitigate the cost shock is weakened. This keeps demand for domestic output high and raises domestic wage pressures. Moreover, the concurrent price increase by foreign competitors allows domestic firms to pass through more of the wage and input price shock into prices without loss of

Figure 8: Effect of Joint Shocks: Amplification

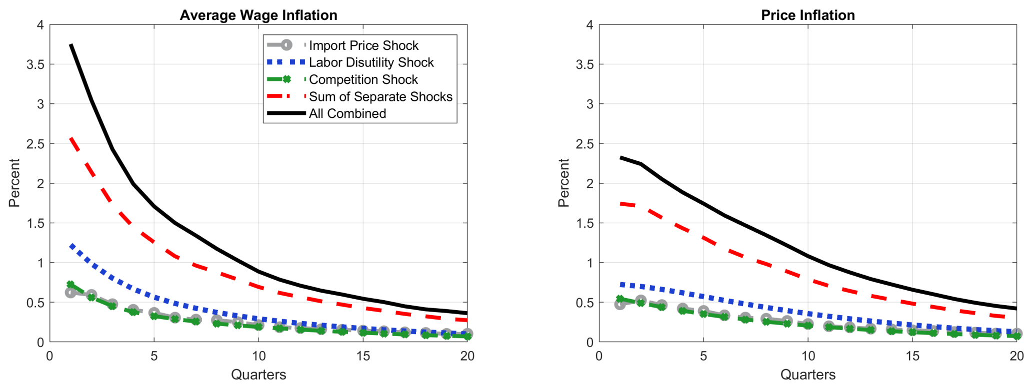


Figure shows the amplification effect of a joint shock compared to the three supply shocks separately. The left panel shows impulse responses of average wage inflation, constructed by averaging across the two sectors' wage growth using each sector's share in consumption. The right panel shows impulse responses of consumer price inflation. The dashed lines trace out the impulse responses to a separate import price shock, labor disutility shock, and competition shock. The black line sums over these impulse responses. The red line shows the joint effect of all three shocks simultaneously.

market share.

Figure 8 illustrates the amplification. The left panel shows the impulse response of the average wage inflation to a specific shock, where wage inflation is constructed by averaging across the two sectors' wage growth using each sector's share in consumption. The right panel shows the impulse response of price inflation. The three lines at the bottom trace out the impulse responses to the import price shock, labor disutility shock, and competition shock separately. We present the sum of these three separate impulse responses by the dashed red line. The solid black line shows the effect of the joint shock, which corresponds to the experiment analyzed in Figure 5 earlier. This line is clearly above the black line: when all three shocks hit together, wage inflation is about 1 percentage point higher and price inflation is about 0.6 percentage points higher at the peak than when all shocks hit separately.

The degree of amplification in the model depends on the elasticity of substitution between labor and intermediates, ρ_s, and on the elasticity of substitution between the domestic and foreign firm groups, μ. When the elasticity of substitution between inputs is higher, producers can substitute more between labor and intermediates when the shocks hit separately than when they hit jointly. Similarly, when the elasticity of substitution between the firm groups is higher, retailers can substitute more between foreign and domestic products. Figure 9 analyzes the difference between the impulse responses of inflation for the joint shock relative to the impulse response of the summed separate shocks on impact (the difference between the red dashed and the black solid line from Figure 8 in quarter one). The left panel of Figure 9 shows the amplification on impact for different values of ρ_s, here assumed to be the same in both sectors. Raising the elasticity of substitution between labor and intermediates

Figure 9: Amplification on Impact: Sensitivity to ρ_s and μ

(a) Sensitivity to ρ_M, ρ_S (b) Sensitivity to μ

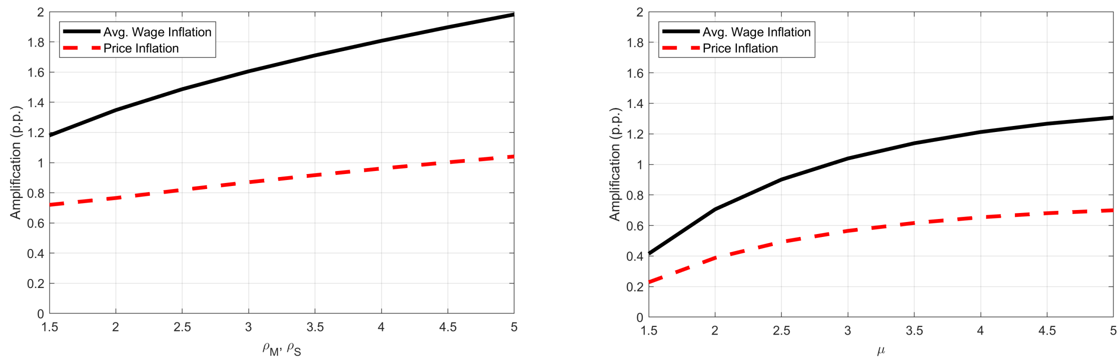


Figure plots the difference between the impulse responses of consumer price inflation and average wage inflation for the joint shock relative to the impulse response of the summed separate shocks on impact (the difference between the red dashed and the black solid line from Figure 8 in quarter one). The left panel shows this amplification as a function of the value of ρ_M and ρ_S. The right panel shows the amplification as a function of μ.

from 1.5 to 5 increases amplification significantly from about 0.6 percentage point to 1 percentage point for price inflation and from 1.2 percentage points to 2 percentage points for wage inflation. The right panel shows the amplification as a function of μ. Reducing this elasticity from its baseline value of 3 to 1.5 would lower wage and price amplification to 0.4 and 0.2 percentage points, respectively.

Additional Results. For completeness, we show the impulse responses of an isolated labor disutility shock in Appendix B.1. We also analyze the sensitivity of amplification to changes in the elasticity of substitution between domestic and imported intermediates, ξ, and find that this variable has only a moderate effect.

In Appendix B.2, we consider a model extension with two types of labor, low-skilled and high-skilled. One less appealing feature of the baseline model is that real wages rise strongly in both goods and services, while empirically real wages of high-skilled workers did not rise. The extended model features significant real wage increases only for low-skilled workers, consistent with the recent U.S. experience, while real wages of other workers are flat. The other patterns are qualitatively similar to the baseline.

4.2.2 Goods-Favored Demand Shock

Supply chain disruptions and labor market interruptions are not the only changes that affected the U.S. economy during the pandemic. While its magnitude is harder to measure, many have argued that the U.S. economy also experienced a shift in aggregate demand. For example, Di Giovanni et al. (2022) and Di Giovanni et al. (2023) attribute roughly 60% of the rise in inflation to demand shocks, and De Soyres et al. (2023) argue that an increase in the demand for consumption goods contributed to inflation. We now analyze the effects of a goods-biased demand shock on the macroeconomy to compare the implications of supply and demand driven inflation for monetary policy.

Figure 10 shows the impulse responses to a demand shock, which we calibrate as described above. We purposefully pick the size of the demand shock so that its effect on inflation, in isolation, is similar to the inflationary effect of the supply chain and labor supply shocks. This exercise is informative to compare the effectiveness of monetary policy in addressing supply and demand driven inflation of the *same size*. While in both cases inflation rises by 2 percentage points, marginal costs increase substantially more in the case of supply disruptions—both a result of increases in intermediate input prices and wages. Interestingly, monetary policy raises the nominal interest rate more strongly in the case of demand-driven inflation, with the nominal interest rate rising by 3 percentage points instead of 1.5 percentage points in the case of supply disruptions. Labor demand and wages remain elevated relative to their steady state level in the case of supply shocks despite the decline in consumption. Demands shocks also initially boost up labor demand and wages, but labor demand declines substantially more in the case of demand shocks. This comparison shows that the overheating of the U.S. labor market is partially a consequence of the supply chain and labor supply disruptions.

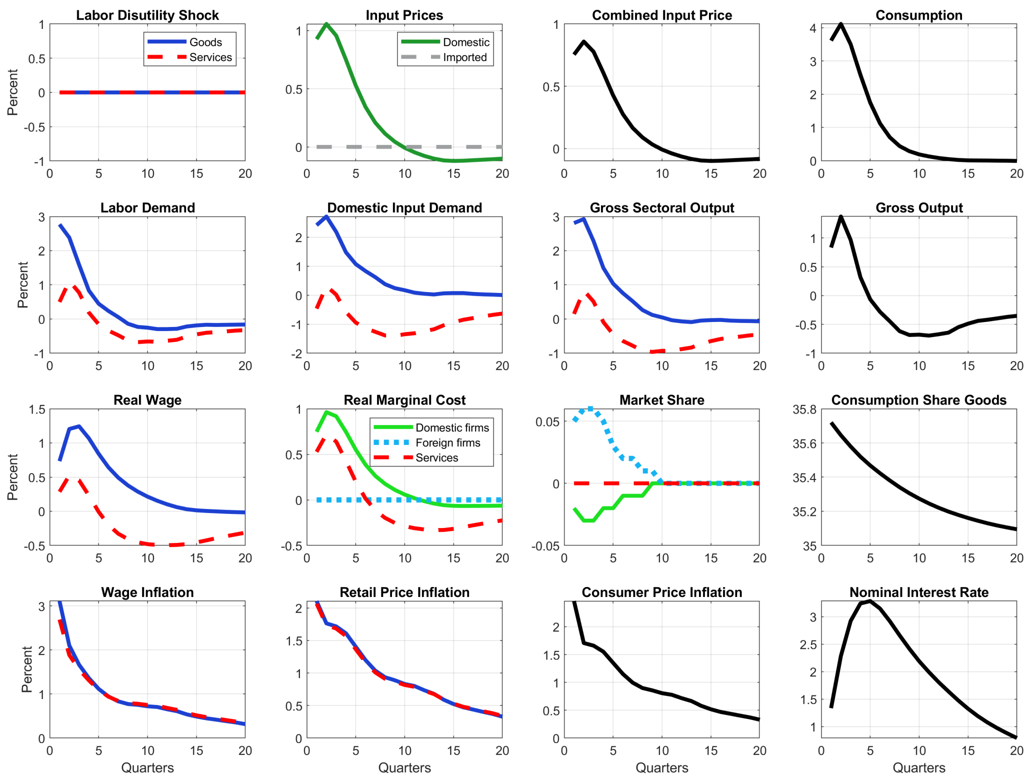
4.3 Aggressive Monetary Policy with Supply and Demand Shocks

Our baseline calibration specifies the Taylor rule with $\varrho = 0.8$, a weight on inflation of $\Phi_\pi = 1.4$, and a weight on the output gap of $\Phi_y = 0.95$. With both supply and demand shocks, nominal interest rates respond sluggishly to the pick-up in inflation in our simulations. This response resembles the developments in 2021. The CPI inflation averaged at 4.7% in 2021 while effective Fed Funds Rate remained close to zero until February 2022. Given the persistence of high inflation, the Fed has been criticized for being *behind the curve* especially in the second half of 2021 and early 2022.[5] In this subsection, we consider the effects of more aggressive monetary policy that responds earlier and more aggressively to inflation.

We consider the two sources of inflation separately as in Figures 5 and 10. Recall that in the first experiment the economy is subject to a combined *supply* shock to (1) import prices; (2) foreign competitors' marginal costs and (3) disutility of work, generating a 2 percentage point increase in inflation. In the second experiment, the economy experiences a *demand* shock that generates again a 2 percentage point rise in inflation. We compare the baseline

[5] See for example, http://larrysummers.com/2021/11/16/on-inflation-its-past-time-for-team-transitory-to-stand-down/

Figure 10: Effect of Goods-Favored Demand Shock

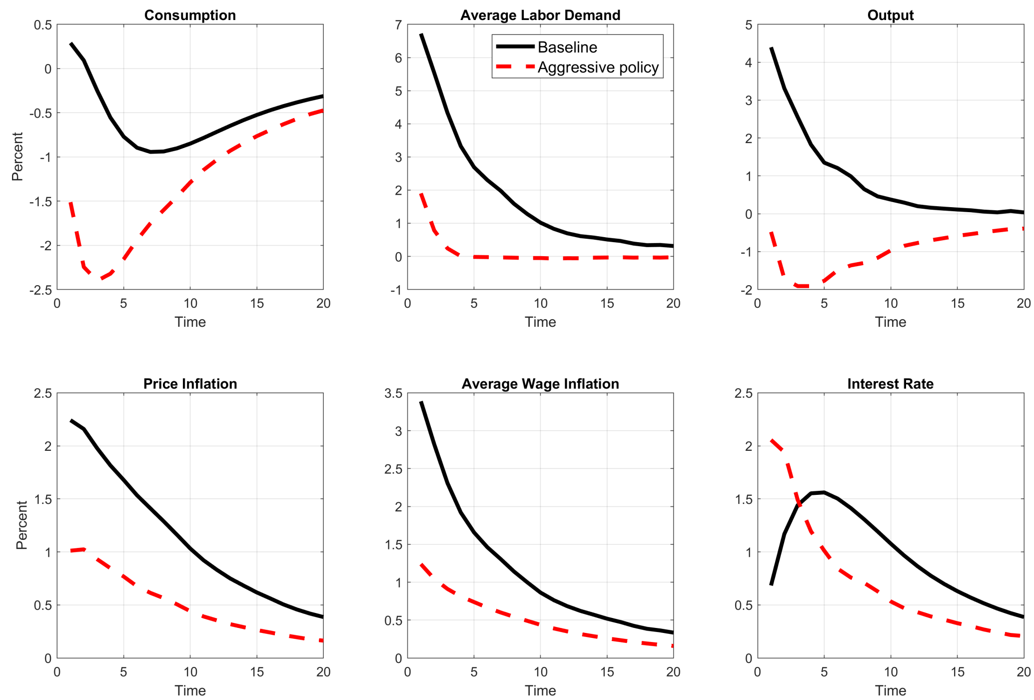


Source: Author's calculations. Figure shows the effect of a goods-biased demand shock on key variables. Each panel shows the percent deviation of a variable from its steady state value against the number of quarters passed since the initial shock. For wage and price inflation and the market share, we show percentage point changes from steady state. For the consumption share of goods we show its actual value.

to a more aggressive policy rule that exhibits less persistence and a stronger response to inflation. Specifically, we set $\varrho = 0.2$ instead of its baseline value of 0.8, and we choose $\Phi_\pi = 4$ instead of its baseline of 1.4.

Figure 11 compares the impulse responses of six key variables under the baseline policy (black solid line) and the more aggressive policy (red dashed) in the case of the supply shocks. Under the more aggressive policy, consumption and output drop significantly on impact, while price and wage inflation are much more moderate than in the baseline at only about 1 percent. Importantly, while aggregate labor demand does not rise as strongly as in the baseline case, it still increases by about 2 percent on impact under the aggressive policy. The lack of an employment decline is due to firms' substitution from intermediate goods to labor, which supports aggregate employment. The large rise in labor demand and inflation under the baseline policy are consistent with an overheating labor market. While aggressive policy could reduce inflation without a decline in employment, there is still a 2 percent drop

Figure 11: Monetary Policy in Response to Supply Shocks



Note: Figure shows the effect of monetary policy on outcomes in response to a supply shock.

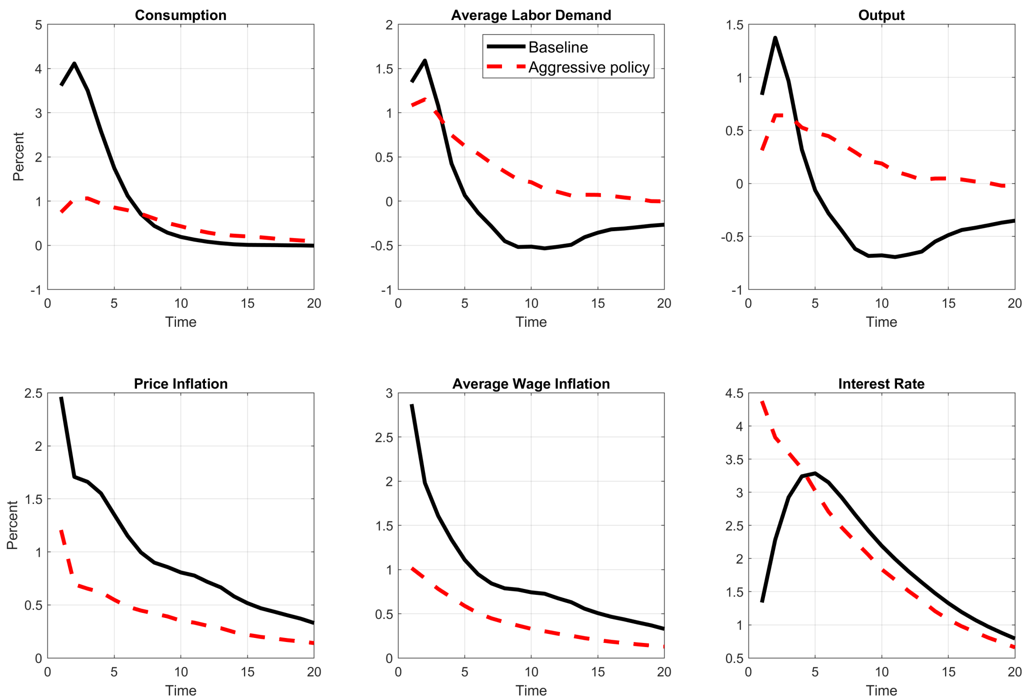
in consumption. Thus, in the presence of a set of these shocks, aggressive monetary policy lowers inflation at the expense of labor demand and wage growth.

Figure 12 shows the effect of monetary policy on the path of inflation, output, and employment with a goods-favored demand shock. Acting more aggressively moderates inflation without creating a recession and has a clear benefit in the case of demand-driven inflation. Aggressive monetary policy moderates wage inflation by reducing labor demand moderately and it avoids the contraction in labor demand in later periods.

Overall, our simulations show that while the rise in inflation of 2 percentage points is the same in both experiments, the benefit of aggressive monetary policy depends on the source of the rise in inflation. For demand-driven inflation it is better to be *ahead of the curve* to reduce inflation, which prevents a contraction in labor demand and output. However, for supply chain disruptions and the labor disutility shock, acting aggressively early on has some disadvantages. If the Central Bank follows the aggressive monetary policy rule in that case, the boost in labor demand is substantially lower, 2 percent instead of 7 percent, which corresponds to roughly 6.5 million jobs.

We next turn towards providing corroborating evidence for the model's key predictions in the aggregate and industry-level data.

Figure 12: Monetary Policy in Response to a Goods-Favored Demand Shock



Note: Figure shows the effect of monetary policy on outcomes in response to a demand shock.

5 Empirical Evidence: Aggregate Analysis

Our quantitative model suggests that supply chain disruptions and labor supply constraints contributed significantly to the rise in inflation in the post-pandemic period. Moreover, the effects of these shocks were amplified since they hit the economy at the same time. This section examines if aggregate data corroborate these findings.

A curious feature of inflation has been the disappearance of goods inflation in the late 1990s and its re-emergence during the pandemic. As Heise et al. (2022) showed, the disinflationary effect of goods inflation can be traced back to lack of pass-through from wages to prices. According to their analysis, there has been a notable decline in the pass-through from wages to producer prices; specifically, firms did not pass through wage increases to prices due to rising import competition. Our analysis implies that this trend should have reversed after the pandemic due to the rise in import prices and the decline in foreign competition.

We investigate this implication of the model by estimating pass-through regressions using aggregate data and the local projection method following Jordà (2005). In particular, we estimate the impulse response of price inflation to changes in wage and input price inflation

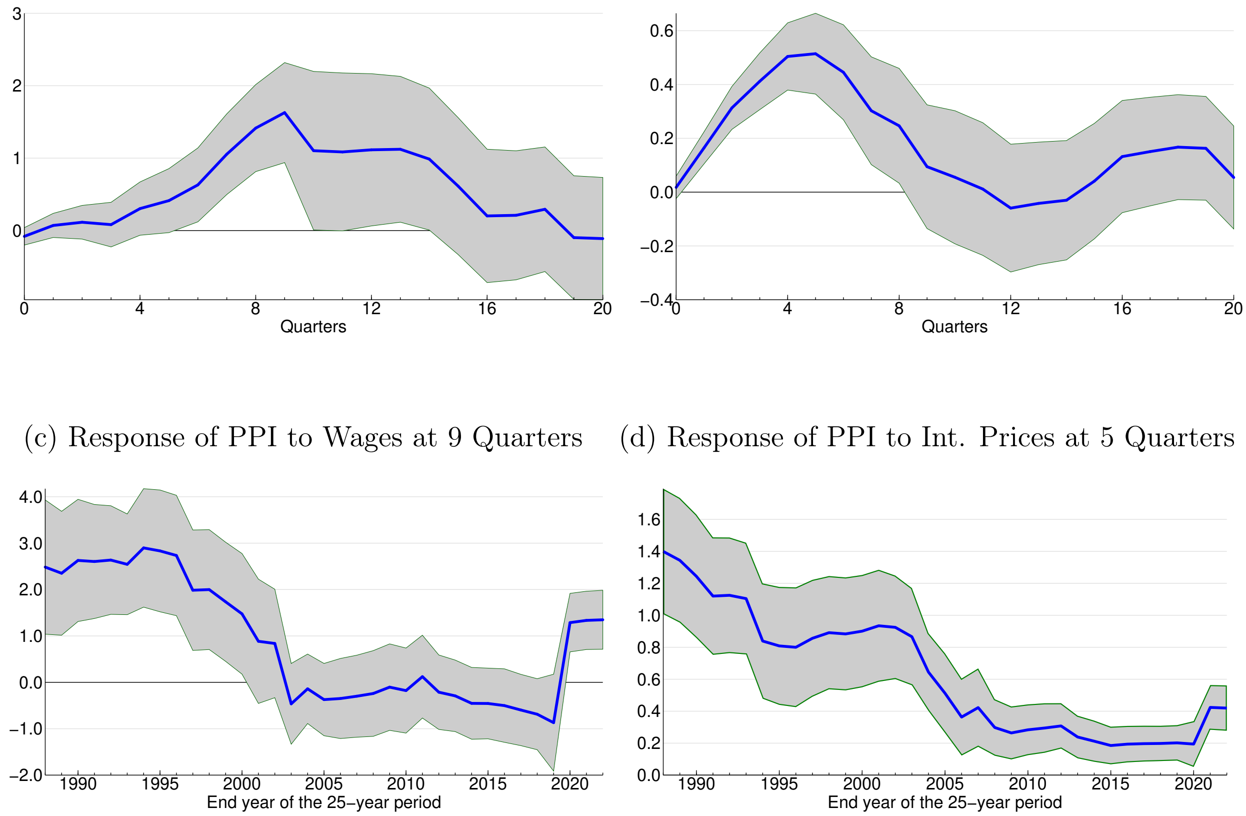
Figure 13: Response of Producer Price Inflation to Wages and Intermediate Input Prices

(a) Response of Finished PPI to Wages

(b) Response of Finished PPI to Int. Prices

(c) Response of PPI to Wages at 9 Quarters

(d) Response of PPI to Int. Prices at 5 Quarters



Source: BLS and authors' calculations. Note: The top two panels present the estimated coefficients β_h and γ_h and their 90 percent confidence intervals from specification (26) run at quarterly frequency, for horizons $h = 0, ..., 20$ quarters. In the top left panel, we present the coefficients β_h showing pass-through from wage inflation and producer price inflation. Wages are average hourly earnings of production and non-supervisory employees. Producer prices are the producer price index (PPI) of finished goods less food and energy. All variables are transformed into a quarterly series by taking a simple average across the months in each quarter. In the top right panel, we show the coefficients γ_h of the pass-through from intermediate prices into producer prices. Intermediate prices are the PPI of intermediate goods less food and energy inputs. The bottom two panels estimate specification (26) over 25-year rolling windows for $h = 9$ for wages and $h = 5$ for intermediate prices, where the ending year of the 25-year period is indicated on the x-axis.

for each quarter $h = 0, ..., 20$ by running a series of regressions of the form

$$\pi_{t+h}^{\text{price}} = \alpha + \beta_h \pi_t^{\text{wage}} + \gamma_h \pi_t^{\text{input}} + \sum_{j=1}^{8} \delta_j \pi_{t-j}^{\text{price}} + \sum_{j=1}^{8} \zeta_j \pi_{t-j}^{\text{wage}} + \sum_{j=1}^{8} \xi_j \pi_{t-j}^{\text{input}} + \epsilon_t, \tag{26}$$

where π_{t+h}^{price} is the inflation rate of prices in quarter $t+h$, π_t^{wage} is wage inflation in quarter t, and π_t^{input} is input price inflation in quarter t. We also include eight lags of the price inflation rate π_{t-j}^{price}, wage inflation rate π_{t-j}^{wage}, and input price inflation π_{t-j}^{input}.

We measure price inflation using the core PPI capturing the inflation of finished goods

Figure 14: Interaction Effect of Wage Inflation and Input Price Inflation

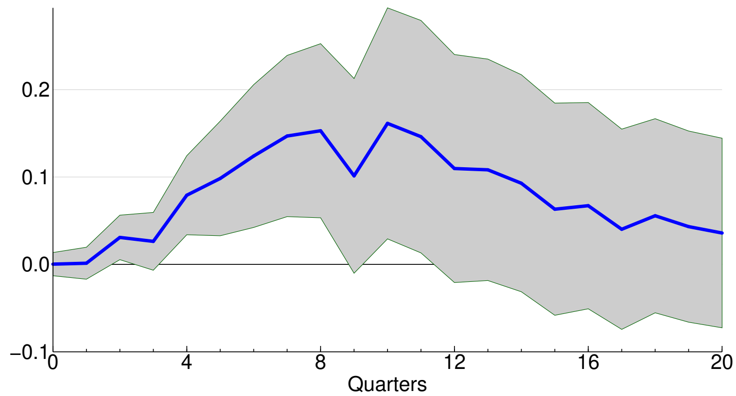


Figure shows the estimated coefficient on the interaction term $\pi_t^{\text{wage}} \pi_t^{\text{input}}$ and its 90 percent confidence interval from an augmented version of specification (26) which includes interactions run at quarterly frequency, for horizons $h = 0, \ldots, 20$ quarters.

less food and energy.[6] We measure wage inflation as average hourly earnings of production and supervisory workers. We measure intermediate input price inflation using the core intermediate PPI, capturing intermediates less food and energy inputs. All inflation measures have been annualized to facilitate the interpretation of the results. Our sample starts in 1988.

Figures 13a and 13b present the impulse response of core finished PPI to an innovation in wages and core intermediate PPI, respectively. We find a strong positive pass-through from both wages and intermediate input prices to producer prices. Pass-through rises for about nine quarters and peaks around 2 for wages. Pass-through rises faster for intermediate prices, and peaks after five quarters at around 0.5.

To examine if pass-through has increased after the pandemic, we estimate equation (26) over 25-year rolling windows and plot the estimate at the peak lag length ($h = 9$ for wages and $h = 5$ for intermediate prices) over time. As shown in Heise et al. (2022), wage-to-price pass-through has significantly declined over time until the beginning of the pandemic. However, it has picked up again following the onset of the pandemic and became significantly positive (see Figure 13c). We find a qualitatively similar, though less strong, pattern for intermediates (Figure 13d). Pass-through declined until the 2010s, and slightly increased in the recent period.

The recent emergence of pass-through could be an outcome of the simultaneous increase in wages and input prices as suggested by our model. We investigate this possible interaction by adding an interaction term between wage inflation and input price inflation to equation (26), both contemporaneously and with eight lags as for the other variables. Figure 14

[6]Since the BLS started collecting services prices only in 2004, we do not have a comprehensive series covering both goods and services.

shows the estimated impulse response to the contemporaneous interaction term. We find a positive and significant interaction effect on producer price inflation. When wages and input prices go up simultaneously, producer prices rise more strongly, consistent with our model's implications. We analyze this interaction in more detail using disaggregated industry-level data in the next section.

6 Empirical Evidence: Industry-level Analysis

While the aggregate analysis is informative, it is limited in scope to time-series variation. In the remainder of this section we exploit rich industry-level panel data on wages, import and producer prices to run within-industry panel regressions. These regressions have the advantage that they can control for any aggregate trends, such as changes in inflation expectations. We derive an estimating equation from the model, and use industry-level data to provide empirical evidence for the key implications of the model.

6.1 Linking the Theory to Data

The firms' price setting equation (21) implies that domestic producers set prices equal to marginal cost times a variable markup $\mathcal{M}_t(j,i,k) \equiv \mathcal{E}_t(j,i,k)/(\mathcal{E}_t(j,i,k)-1)$. Taking logs and differentiating this equation for a domestic firm, we obtain

$$d\ln(P_{x,t}(j,i,k)) = d\ln(MC^s_{D,t}) + d\ln(\mathcal{M}_t(j,i,k)), \tag{27}$$

which is a log-linear approximation of a price change. Using the expression for marginal costs, (18), a log-linear approximation yields

$$d\ln(MC^s_{D,t}) = \lambda_s \left[d\ln W^s_t - d\ln A_t\right] + (1-\lambda_s)d\ln P^s_{x,input,t},$$

where λ_s is the labor share defined in (24), and the input price $P^s_{x,input,t}$ is itself a combination of imported and domestic input prices. It can be approximated from equation (19) as

$$d\ln(P^s_{x,input,t}) = (1-\alpha_s)d\ln(P_{x,dom,t}) + \alpha_s d\ln(P^s_{x,imp,t}), \tag{28}$$

where α_s is the imported input share from (25).

For the markup, given our functional form of the demand elasticity $\mathcal{E}^s_t(j,i,k)$, we obtain

$$d\ln(\mathcal{M}_t(j,i,k)) = -\Gamma_t(j,i,k)\left[d\ln P_{x,t}(j,i,k) - d\ln P_{x,t}(j,i)\right],$$

where $\Gamma_t(j,i,k) = -(\partial \log \mathcal{M}_t(i,j,k)/\partial \log P_{x,t}(j,i,k)) \geq 0$ is the elasticity of the markup with respect to a firm's own price.[7] Plugging the expression for marginal costs and the markup into (27) and re-arranging, we obtain a firm's price change as a function of changes in the components of marginal costs and of changes in competitors' prices

$$\begin{aligned} d\ln(P_{x,t}(j,i,k)) = {} & \frac{\lambda_s}{1+\Gamma_t(j,i,k)}\left[d\ln W_t^s - d\ln A_t\right] + \frac{(1-\lambda_s)}{1+\Gamma_t(j,i,k)} d\ln P_{x,input,t}^s \\ & + \frac{\Gamma_t(j,i,k)}{1+\Gamma_t(j,i,k)} d\ln P_{x,t}(j,i). \end{aligned} \tag{29}$$

Equation (29) illustrates how producers' prices are related to wages and input prices. The first and second terms in the equation reflect the direct effect of input costs on prices, i.e., the effect of marginal costs. An increase in wages W_t^s that exceeds productivity growth passes through into prices with an elasticity that is proportional to the labor share in marginal costs, λ_s. Wage increases only raise prices to the extent that they exceed productivity growth. Changes in input costs pass through to prices with an elasticity that is proportional to $(1-\lambda_s)$, where the pass-through of imported input prices in turn depends on the imported input share α_s. The third term in equation (29) captures the indirect effect on pass-through that operates via firms' markup adjustment. An increase in a firm's competitors' prices $P_{x,t}(j,i)$ allows the firm to raise its prices itself by increasing its markup. The relative strength of this channel relative to the marginal cost channel is modulated by the markup elasticity $\Gamma_t(j,i,k)$. Firms with a higher markup elasticity put a higher weight on the aggregate price index. As shown in Appendix A.7, the markup elasticity is increasing in a firm's market share holding everything else fixed, $d\Gamma_t(j,i,k)/dS_t(j,i,k) > 0$, and satisfies $\Gamma_t(j,i,k) = 0$ if $S_t(j,i,k) = 0$.

Equation (29) is a version of a standard pass-through equation (see, e.g., Amiti et al., 2019). One shortcoming of this specification is that due to the log-linearization, it does not account for the non-linearity of the response arising from the substitution between labor and intermediates. In particular, in our model the labor share adjusts in response to a shock: when import prices rise, firms substitute towards labor, raising the labor share. We therefore also perform a second-order approximation to the marginal cost term to derive the following

[7] See Appendix A.7 for the derivations in this section.

alternative non-linear estimating equation

$$
\begin{aligned}
d\ln(P_{x,t}(j,i,k)) = {} & \frac{\lambda_s}{1+\Gamma_t(j,i,k)}\left[d\ln W_t^s - d\ln A_t\right] + \frac{(1-\lambda_s)}{1+\Gamma_t(j,i,k)} d\ln P_{x,input,t}^s \\
& + \frac{(\rho_s-1)\lambda_{s,t}(1-\lambda_s)}{1+\Gamma_t(j,i,k)}\Big\{ (d\ln W_t^s - d\ln A_t)\, d\ln P_{x,input,t}^s \qquad (30) \\
& - \frac{(d\ln W_t^s - d\ln A_t)^2}{2} - \frac{(d\ln P_{x,input,t}^s)^2}{2}\Big\} + \frac{\Gamma_t(j,i,k)}{1+\Gamma_t(j,i,k)} d\ln P_{x,t}(j,i).
\end{aligned}
$$

This equation contains in the second row the interaction between the wage change and the input price change and in the third row quadratic terms of the wage change and the input price change. The negative sign of the quadratic terms highlights that, absent the interaction effect, the response of producer prices to a shock is smaller than that implied by the linear effect, due to the possibility to substitute. The importance of the substitution rises with the elasticity of substitution ρ_s and with the product of the steady state shares of the two inputs, $\lambda_s(1-\lambda_s)$. We will estimate both the standard linear equation and this specification with non-linear terms.

6.2 Data

Estimating equations (29) and (30) requires industry-level data on input prices, wages, productivity and detailed controls for worker characteristics. We utilize various publicly available data sources to construct our dataset.

Prices: We construct the industry-level producer prices P_{it} from the Producer Price Index (PPI), which we have at the 6-digit North American Industrial Classification System (NAICS) level. The PPI measures the price received by domestic producers for their goods and services, comprising both final goods and intermediate goods. It is constructed by the Bureau of Labor Statistics (BLS) from a monthly survey of establishments representing nearly the entire goods sector and 70 percent of services. We aggregate the monthly PPI data to the quarterly level. We drop the bottom 5 percent of industries in terms of 2012 shipment value from all regressions to eliminate very small and noisy industries.[8] Our sample comprises 497 industries for the period 2013:Q1 to 2021:Q3.[9]

Wages: We obtain quarterly industry wages, W_{it}, as the average weekly earnings per quarter from the Quarterly Census of Employment and Wages (QCEW) from the BLS. In principle,

[8] Our regression results are similar if we include these industries.

[9] We do not include earlier years due to revisions in the Census trade codes and NAICS codes, which make a consistent mapping from import prices to 6-digit PPI codes over longer time horizons more difficult.

hourly earnings would be preferable to account for changes in hours worked. In practice, however, using the QCEW has several advantages over other datasets, such as greater coverage of establishments and industries (see Heise et al., 2022).

Input Prices: We construct an industry's input cost index, $P_{it,input}$, as a weighted average of the domestic input price index and the imported input price index, consistent with equation (28). Specifically, the four quarter change in industry input prices is

$$\Delta \ln(P_{it,input}) = \alpha_{i,2012} \sum_n w_{n,i,2012} \Delta \ln(P_{nt,imp}) + (1 - \alpha_{i,2012}) \sum_n w_{n,i,2012} \Delta \ln(P_{nt}). \quad (31)$$

where $\alpha_{i,2012}$ is the industry's share of intermediate imported inputs in total material costs in 2012. The four quarter change in the domestic input price ΔP_{nt} is constructed as the change in the log PPI across all industries n that provide inputs to industry i, where the weights $w_{n,i,2012}$ are the time-invariant cost shares from the 2012 input-output table from the BEA.[10] We omit the domestic input industry n that is the same as industry i since we cannot disentangle the own industry's input prices from its output prices using our industry-level data.[11] We construct the imported input price index of industry i analogously as a weighted average over the import price indices $P_{nt,imp}$ of all industries n that provide inputs to industry i. Since the import price indices provided by the BLS are too aggregated for our purposes, we construct our own measures using disaggregated import data from the Census Bureau. Our 6-digit NAICS industry-level import price index is a weighted average of the log change in import unit values (equal to import values divided by quantities) across all 10-digit Harmonized Tariff Schedule (HTS10)-country observations, h, c, within each NAICS industry i, where the weights are lagged annual import value weights

$$\Delta \ln(P_{it,imp}) = \sum_{h,c} w_{h,c,year-1} \Delta \ln(\text{import unit values}_{h,c,t}). \quad (32)$$

We construct a mapping between HTS10 codes and 6-digit NAICS industries throughout our sample period using the concordance by Pierce and Schott (2012).

Productivity: We construct industry-level labor productivity, A_{it}, using industries' real value added from the Bureau of Economic Analysis (BEA). While the BLS provides disaggregated industry-level productivity measures, these are only available at an annual basis and with significant delay. We obtain quarterly real value added for 50 2-digit and 3-digit

[10] The latest input-output table with sufficiently disaggregated industries available is 2012. It comprises 405 BEA industries, which are mapped to 6-digit NAICS codes.

[11] As an example, if the auto industry uses 70 percent rubber and 30 percent steel, its domestic input price index will be constructed as 0.7 times the change in the log rubber price plus 0.3 times the price of the log steel price.

industries from the BEA, and divide by each industry's number of workers from the QCEW to obtain real value added per worker. For each 6-digit NAICS industry in our sample, we assign the real value added per worker of the corresponding 2-digit or 3-digit industry.

6.3 Price Dynamics in the Industry Data

It is useful to examine the changes in input prices and wages at the industry level to see whether the facts we have reported in Table 1 also apply to industry-level data. Table 3 provides summary statistics on the average four-quarter change in wages and input prices in our sample of industries. The first two columns present statistics for industries in the *Goods* sector.[12] The last two columns present statistics for the *Services* sector, comprising all industries that are non-traded, mostly services.[13]

The first panel presents statistics for the pre-COVID period. We find that the average industry's change in input prices is virtually zero in this period, with average nominal wage growth between 2 and 3 percent. The raw correlation between wage growth and input price changes is also negligible prior to COVID (row 4). In the fifth row, we residualize the four-quarter wage and input price changes with industry fixed effects, and find similar results.[14]

The second panel shows the same statistics for 2020. Input prices declined in that year, while wages grew slightly faster growth than in the earlier period. What stands out most, however, is the significantly higher correlation between wage and input price changes in 2020 compared to the pre-COVID period. The last panel shows the statistics for 2021 when both wages and input prices have risen significantly. Moreover these changes were highly correlated across industries. This observation reinforces the interaction effect we have seen in the aggregate analysis. It also suggests that there is scope for amplification: our model predicts that simultaneous wage and input price increases would lead to bigger increases in prices.

We exploit a reduced-form version of (29) to examine the relationship between labor costs, input prices and producer prices and whether the predictions of our model has empirical support in the cross-industry data. Specifically, we estimate

$$\Delta \ln(P_{it}) = \beta_1 \Delta \ln W_{it} + \beta_2 \Delta \ln A_{it} + \beta_3 \Delta \ln P_{it,input} + \beta_4 \Delta \ln P_{it,imp} + \alpha X_{it} + \delta_i + \psi_t + \epsilon_{it}, \quad (33)$$

[12] We define that sector to comprise all industries with positive imports in at least one year, i.e., there is some import competition. These industries are predominantly in manufacturing, with a few industries in agriculture and mining. Manufacturing accounted for about 63% of employment in goods-producing industries in the last decade.

[13] Import prices can still affect non-traded industries through imported intermediate inputs. For example, a dentist may use a computer that was manufactured abroad.

[14] In Appendix D.1, we repeat the same table using wage and input price changes residualized by industry fixed effects for all statistics.

Table 3: Changes in Input Prices and Wages in Goods and Services

	Goods		Services	
2013:Q1 - 2019:Q4	$\Delta\ln(P_{it,input})$	$\Delta\ln(Wage_{it})$	$\Delta\ln(P_{it,input})$	$\Delta\ln(Wage_{it})$
Mean	0.001	0.022	-0.005	0.028
P50	0.005	0.024	0.005	0.029
Mean of 4th quartile	0.062	0.078	0.077	0.072
Correlation	0.045		0.077	
Correlation (Ind. FE)	0.046		0.076	
2020				
Mean	-0.023	0.035	-0.064	0.051
P50	-0.014	0.028	-0.024	0.044
Mean of 4th quartile	0.028	0.116	0.004	0.128
Correlation	0.296		0.205	
Correlation (Ind. FE)	0.312		0.205	
2021				
Mean	0.148	0.049	0.170	0.061
P50	0.124	0.051	0.124	0.056
Mean of 4th quartile	0.296	0.130	0.390	0.149
Correlation	0.226		0.165	
Correlation (Ind. FE)	0.229		0.192	

Notes: The table shows summary statistics on the average four-quarter change in wages and input prices for goods (first two columns) and services (last two columns). Each panel focuses on changes in a specific time period. The first row shows the mean of the four-quarter change. The second row presents the median, and the third row the average over industries in the 4th quartile. The fourth row shows the correlation between wage and industry price changes. The fifth row presents the correlation between wage and input price changes after they have been residualized by industry fixed effects.

where P_{it} denotes the PPI and Δ indicates four quarter changes. W_{it} and $P_{it,input}$ are wages and the input price index, respectively and capture components of marginal costs. The term $\Delta\ln(P_{it,imp})$ picks up the effect of competition on U.S. firms' price setting.[15] The controls X_{it} include the shares of prime-age and 55+ old workers, the share of women, and the shares of workers with a high-school degree, associates degree, and bachelors degree or higher.[16] Finally, δ_i is an industry fixed effect and ψ_t is a time fixed effect which captures any aggregate variation that affects all industries, such as changes in aggregate inflation expectations or general business cycle trends. We estimate our regression specification (33) separately for goods and for services. Our regressions use Driscoll-Kraay standard errors with bandwidth

[15] Since we use industry-level data we do not have domestic competitors' prices within the same industry. We therefore estimate the effect of competition on U.S. producer prices using only an industry's foreign competitors' prices. These are given by the import price index $P_{it,imp}$ constructed above. In contrast to the imported input price index, which is a weighted average of import prices across all industries that provide inputs to i, the competitors' price index is simply the import price index of industry i, e.g., the price of imported cars for the car industry.

[16] We obtain these variables from the Census Bureau's Quarterly Workforce Indicators (QWI).

two quarters to account for cross-sectional and time series correlation. We also estimate the regression interacted with a dummy for 2021 to examine whether the predictions of our model is consistent with the data.

Note that in this regression β_1 to β_4 cannot be interpreted as structural coefficients since we do not generate plausibly exogenous variation in input costs and wages. Instead, we interpret our estimation results as conditional correlations that are informative about the model's predictions. We also note that we cannot compare the coefficients with the model's implications since the model includes general equilibrium effects while the regression exploits within-time, within-industry variation. Nevertheless, we find our results useful to detect changes in wage and price dynamics after the pandemic.

Price Dynamics in the Goods Sector We first estimate our baseline regression for the goods sector, i.e., traded industries, and report the results in Table 4. Column 1 presents the coefficients from specification (33) for the entire sample period 2013:Q1 - 2021:Q3. Since different industries have different degrees of import penetration, we multiply the foreign competitors' price index, $P_{it,imp}$, by the industry's import share, s_i, in 2013. Focusing first on the coefficient on the import price index in the first row, we find that for an industry with the average import share of 31 percent, a 10 percent increase in import prices leads to an increase in producer prices of 0.7 percent. The following coefficients show a positive and significant correlation between producer prices and input costs. A 10 percent increase in input prices is associated with a 3.5 percent rise in producer prices. We also find a positive pass-through from wages to producer prices, although the effect is small. A 10 percent increase in wages is associated with a 0.4 percent rise in producer prices. This small pass-through from wages to prices in the goods sector is consistent with earlier work (Heise et al. (2022)). Finally, productivity improvements have a negative impact on producer prices, as expected.

Our model implies that correlated shocks should have bigger effects on price inflation. Since wage and input prices increased drastically in 2021, it is informative to consider 2021 separately. In particular, the foreign competition effect implies that U.S. producer prices should have become more strongly correlated with foreign competitors' prices in the recent period since all firms are experiencing similar shocks due to global supply chain disruptions. Therefore, U.S. firms can raise their prices by more without losing market share. Similarly, the amplification result in the model implies that the effects of wages and input prices on producer prices should have increased in 2021. Since the cost of both input factors rose at the same time in that year, the inflation impact should be larger. Column 2 re-estimates the regression by interacting the variables with a dummy for the year 2021.

First, we find that U.S. and foreign firms' price changes have become more synchronized.

Table 4: Pass-Through for Goods, 2013:Q1 - 2021:Q3

	(1) $\Delta\ln(p_{it})$	(2) $\Delta\ln(p_{it})$	(3) $\Delta\ln(p_{it})$	(4) $\Delta\ln(p_{it})$
$s_i \times \Delta\ln(p_{it,imp})$	0.238***	0.189***	0.190***	0.172***
	(0.045)	(0.026)	(0.026)	(0.026)
$s_i \times \Delta\ln(p_{it,imp}) \times$ Year=20				0.097**
				(0.044)
$s_i \times \Delta\ln(p_{it,imp}) \times$ Year=21		0.488***	0.502***	0.518***
		(0.137)	(0.136)	(0.136)
$\Delta\ln(p_{it,input})$	0.353***	0.280***	0.316***	0.334***
	(0.030)	(0.026)	(0.027)	(0.032)
$\Delta\ln(p_{it,input}) \times$ Year=20				-0.101**
				(0.038)
$\Delta\ln(p_{it,input}) \times$ Year=21		0.156***	-0.115	-0.119
		(0.029)	(0.094)	(0.099)
$\Delta\ln(Wage_{it})$	0.036**	0.017	0.011	0.003
	(0.015)	(0.013)	(0.011)	(0.012)
$\Delta\ln(Wage_{it}) \times$ Year=20				0.033
				(0.028)
$\Delta\ln(Wage_{it}) \times$ Year=21		0.121***	-0.038	-0.031
		(0.020)	(0.044)	(0.044)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input})$			-0.464*	-0.511
			(0.241)	(0.316)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input}) \times$ Year=20				-0.294
				(0.497)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input}) \times$ Year=21			1.887***	1.939***
			(0.297)	(0.338)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input}) \times$ HH $\times$ Year=20				1.216*
				(0.714)
$\Delta\ln(A_{it})$	-0.160***	-0.157***	-0.145***	-0.145***
	(0.024)	(0.023)	(0.022)	(0.029)
Time Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Worker Composition	Yes	Yes	Yes	Yes
Nonlinear Effects	No	No	Yes	Yes
R2	0.153	0.169	0.173	0.175
Observations	9,549	9,549	9,549	9,549

Notes: The table shows the results from running the baseline regression (33) for goods. The first column shows the results for the baseline regression. The second column includes interactions for 2021. The third column includes an interaction between wage changes and intermediate input price changes. The fourth column includes additional interactions for 2020. All regressions include time and industry fixed effects and controls for the log share of workers 25-54, log share of workers 55+, log share of women, and log shares of workers with a high-school degree, associates degree, and bachelors degree or higher. The last two columns additionally include non-linear terms from (30), i.e., an interaction term between wage changes and input price changes, an interaction between productivity and input price changes, and squared wage and input price terms. We interact all terms with dummies for 2021. The last column contains additionally interactions of competitors' prices, input prices, wages, and productivity with a dummy for 2020, as well as interactions between wages, input price changes, a dummy for 2020, and dummies for whether both wage and input price change were above median (HH), the wage change was below median and the input price change above median (LH), and the wage change was above median and the input price change below median (HL). We only report in the table the main coefficients of interest.

The correlation between foreign competitors' prices and U.S. producer prices was around 5 percent in an industry with the average import share in the pre-2021 period, but rose to around 21 percent in 2021. Second, simultaneous wage and input price changes have a higher correlation with producer price inflation. In particular, a 10 percent rise in input prices was associated with a 2.8 percent rise in producer prices in the pre-2021 period, but led to a 4.4 percent increase in 2021. Even more strikingly, we find that the entire positive correlation between wage changes and producer prices is accounted for by 2021. While in earlier years the pass-through from wages to producer prices was insignificant, it rose to 13.8 percent in 2021.

In column 3 we run the specification with additional non-linear marginal cost terms using (30). This specification includes an interaction term between wage changes and input price changes, an interaction between productivity and input price changes, and squared wage and input price terms. We interact all terms with dummies for 2021 to examine changes in the coefficients.[17] We find a positive and highly significant effect of the product of wage and input price changes on producer prices in 2021. Moreover, once this term is included in the regression, the 2021 interaction terms on wages and input prices become insignificant. This result suggests that the interaction between wages and input prices can completely explain the pick-up in the pass-through of costs in 2021.

The non-linear regression results indicate a positive and significant interaction effect in 2021, but not for earlier years. As shown in Table 3, changes in wages and input prices were small until 2021, and the changes were virtually uncorrelated until 2020. This could explain the lack of an effect in prior years if smaller changes have a lower pass-through. As a robustness check, we next exploit the high correlation between wage and input price shocks in 2020, and construct dummies for whether an industry was above the median of the wage change distribution and above the median of the input price change distribution in our sample period. For industries that exhibited large changes in wages and input prices, we should pick up an interaction effect. Column 4 re-runs our non-linear specification with additional interactions for 2020, where the interaction between wages, input price changes, and the 2020 dummy is additionally interacted with a dummy for whether an industry was in the top half of both the wage and the input price change distribution. We call this dummy "HH". The positive and significant coefficient on the quadruple interaction with the "HH" dummy indicates that there was a positive and significant interaction between wage changes and input price changes for this group of industries. This finding is consistent with our hypothesis that both large and positively correlated shocks are needed.

As we have stated earlier, we do not interpret our estimates of β_1 to β_4 as structural

[17] We show only a subset of the regression coefficients in Table 4.

pass-through coefficients. In Appendix C, we consider pass-through regressions using an instrumental variable local projection (IV-LP) approach following Ramey (2016) and find strong pass-through from wages and import prices to producer prices. While this approach measures the pass-through in a way that properly accounts for dynamics and endogeneity, it is not easily applicable to the specification we consider in equation (29). Instead, to alleviate concerns that our results only hold at one specific time horizon, we re-estimate our regressions where, instead of 4-quarter changes, we use 8-quarter changes or 12-quarter changes for all variables. The results in Appendix D show that our findings are robust over longer time periods.[18]

Price Dynamics in the Services Sector The evolution of goods and services inflation have been different since the onset of the pandemic as we discussed earlier. Services industries are not directly affected by foreign competitors' prices. However, these industries can still be indirectly affected by imported input prices. We next turn to services and show analogous results in Table 5. Column 1 shows that there is a significant and positive correlation of both input prices and wages with producer prices. A 10 percent increase in input prices is associated with a 1 percent rise in producer prices on average. Similarly, a 10 percent rise in wages is associated with a 1.1 percent increase in producer prices. Column 2 shows that, in contrast to the goods sector, there was no increase in input price pass-through in 2021 for the services sector. However, the correlation between wages and prices rose significantly. A 10 percent rise in wages is associated with price growth of 0.7 percent in the earlier years, but with a 2.4 percent rise in prices in 2021. This rise in correlation between wages and producer prices is consistent with our model, since the substitution towards labor and domestically produced intermediates, especially in the goods sector, drives up wages at the same time as prices rise. The last column shows that the coefficient on the interaction between wages and input prices is actually *negative* in services in 2021. This absence of an amplification effect in services is consistent again with the model because the substitutability between labor and intermediates in services is low, and hence there is no change in substitution patterns when both labor and intermediates' costs rise.

[18] In Appendix D, we perform several additional robustness checks of our findings. First, our structural equation (29) indicates that the effect of wages and productivity on prices should be of equal and opposite sign. We therefore run a constrained regression which imposes this requirement. Second, we introduce a proxy for domestic competitors, using the prices of the more aggregated 4-digit NAICS industry, to attempt to capture the competition that is missing from our baseline analysis. Third, we attempt to control for demand shocks by re-running our regression with 3-digit NAICS industry by quarter fixed effects. This specification absorbs all factors that are common to the same 3-digit industry and quarter, and identifies our coefficients of interest from variation within broad industries. If demand shocks are common within 3-digit industries, then the remaining variation can be attributed to the shocks we focus on. The results in Appendix D indicate that our results continue to hold with these alternative specifications.

Table 5: Pass-Through for Services, 2013:Q1 - 2021:Q3

	(1) $\Delta\ln(p_{it})$	(2) $\Delta\ln(p_{it})$	(3) $\Delta\ln(p_{it})$
$\Delta\ln(p_{it,input})$	0.097***	0.097***	0.079***
	(0.011)	(0.016)	(0.027)
$\Delta\ln(p_{it,input}) \times$ Year=21		0.001	0.129**
		(0.027)	(0.061)
$\Delta\ln(Wage_{it})$	0.112***	0.073**	0.072**
	(0.035)	(0.033)	(0.030)
$\Delta\ln(Wage_{it}) \times$ Year=21		0.165***	0.352***
		(0.047)	(0.102)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input})$			0.086
			(0.183)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input}) \times$ Year=21			-1.092***
			(0.294)
$\Delta\ln(A_{it})$	-0.030	-0.029	-0.012
	(0.020)	(0.019)	(0.012)
Time Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Worker Composition	Yes	Yes	Yes
Nonlinear Effects	No	No	Yes
R2	0.047	0.050	0.059
Observations	5,012	5,012	5,012

Notes: The table shows the results from running the baseline regression (33) for services. The first column shows the results for the baseline regression. The second column includes interactions for 2021. The third column includes an interaction between wage changes and intermediate input price changes. All regressions include time and industry fixed effects and controls for the log share of workers 25-54, log share of workers 55+, log share of women, and log shares of workers with a high-school degree, associates degree, and bachelors degree or higher. The last column additionally includes non-linear terms from (30), i.e., an interaction term between wage changes and input price changes, an interaction between productivity and input price changes, and squared wage and input price terms. We interact all terms with dummies for 2021. We only report in the table the main coefficients of interest.

7 Conclusion

In this paper, we have developed and calibrated a DSGE model to quantify the effects of supply chain and labor market disruptions on inflation. Our analysis delivers three key insights: first, supply chain disruptions on their own can generate significant wage and price inflation due to the substitution from imported intermediates to domestic labor (*substitution effect*). Second, the marginal cost shock to foreign competitors shifts production from foreign producers to domestic ones, increasing demand for domestic inputs and labor, which raises price and wage inflation (*foreign competition effect*). Third, a joint supply chain and labor disutility shock has an *amplified* effect on inflation because the joint shock to labor and imported input prices makes substituting between labor and intermediates less effective for domestic firms. Moreover, the simultaneous foreign competition shock allows domestic producers to increase their pass-through into prices without losing market share. Since firms cannot shift towards foreign producers to mitigate the increase in costs, demand for domestic inputs and labor remains high, which may lead to an overheating of the labor market. Using aggregate data and disaggregated industry-level data, we provide empirical support for our predictions.

We use our framework to analyze the effectiveness of monetary policy in the face of supply- versus demand-driven shocks. For demand-driven shocks, our model suggests that it is better to raise interest rates early, i.e., to be *ahead of the curve*, to contain inflation early on. This policy can avoid relatively high interest rates later and avoids an associated recession. In contrast, for supply chain disruptions and labor disutility shocks, a less aggressive policy is advantageous in our model. The supply shocks generate a substantial boost in labor demand due to the substitution towards domestic inputs. If the central bank follows a more aggressive policy rule, the model shows that the economy contracts and the boost to labor demand is substantially diminished.

Our analysis helps shed light on the changing dynamics of inflation. We interpret the supply chain disruptions during the COVID-19 pandemic as a partial reversal of disinflationary effects of globalization on U.S inflation. Better and more interconnected supply chains and improvements in trade allowed firms to substitute between labor and imported labor-intensive intermediate inputs in the past decades, thus cushioning any cost shock due to one of the two input factors. Moreover, foreign competition in output markets affected firms' pricing decisions significantly. The pandemic-related disruptions weakened firms' ability to optimize across domestic and imported input factors, raised demand for domestic inputs and labor, and increased firms' pricing power. These effects contributed significantly to the rise in inflation and the overheating of the labor market.

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Appendix

A Theory

In this section we derive the main equations of the theoretical model in Section 3.

A.1 Households

A.1.1 Consumption-Savings Problem

Here, we derive the solution to the household consumption-savings problem. The first-order condition with respect to consumption implies

$$E_0 \mathcal{B}_0^t (C_t - H_t)^{-\sigma} = \lambda_t P_{f,t}. \tag{34}$$

The first-order condition for assets is, for any state,

$$\lambda_t Q_{t+1} = \lambda_{t+1},$$

which can be re-written as

$$\begin{aligned} \frac{\mathcal{B}_0^t (C_t - H_t)^{-\sigma}}{P_{f,t}} Q_{t+1} &= \frac{\mathcal{B}_0^{t+1} (C_{t+1} - H_{t+1})^{-\sigma}}{P_{f,t+1}} \\ Q_{t+1} &= \beta_t \frac{(C_{t+1} - H_{t+1})^{-\sigma}}{(C_t - H_t)^{-\sigma}} \frac{P_{f,t}}{P_{f,t+1}}. \end{aligned}$$

Taking expectations on both sides yields

$$E_t[Q_{t+1}] = \frac{1}{1+R_t} = \beta_t E_t \left[\frac{(C_{t+1} - H_{t+1})^{-\sigma}}{(C_t - H_t)^{-\sigma}} \frac{P_{f,t}}{P_{f,t+1}} \right],$$

which is the Euler equation. Rewriting H_t in terms of previous consumption

$$\frac{1}{1+R_t} = \beta_t E_t \left[\frac{(C_{t+1} - hC_t)^{-\sigma}}{(C_t - hC_{t-1})^{-\sigma}} \frac{P_{f,t}}{P_{f,t+1}} \right]. \tag{35}$$

A.1.2 Labor and Wage Setting

Households supply labor to a labor bundler, whose problem is

$$\max_{\ell_t^s} \{ W_t^s L_t^s - \int_0^1 W_t^{s,\tau} \ell_t^{s,\tau} d\tau \}.$$

This problem implies the standard demand equation shown in the text,

$$\ell_t^{s,\tau} = \left(\frac{W_t^{s,\tau}}{W_t^s}\right)^{-\eta^s} L_t^s,$$

where

$$W_t^s = \left(\int_0^1 (W_t^{s,\tau})^{1-\eta^s}\right)^{1-\eta^s}.$$

Since the labor supply to each sector is additive, we can solve the wage setting problem separately for each sector. Household τ's wage setting problem for sector s is

$$\max_{W_t^{s,\tau}} E_0 \sum_{t=0}^{\infty} \mathcal{B}_0^t \Big\{ \frac{(C_t - hC_{t-1})^{-\sigma}}{P_{f,t}} W_t^{s,\tau} \ell_t^{s,\tau} - \frac{\kappa_t^s}{1+\varphi}(\ell_t^{s,\tau})^{1+\varphi} - \frac{\psi_w}{2}\left(\frac{W_t^{s,\tau}}{W_{t-1}^{s,\tau}} - 1\right)^2 L_t^s \Big\}, \quad (36)$$

where the first term uses the marginal utility of consumption, $\lambda_t = \mathcal{B}_0^t (C_t - H_t)^{-\sigma}/P_{f,t}$, from the household problem (34) to translate wage income into utility. Plugging in for labor demand $\ell_t^{s,\tau}$ we get

$$\begin{aligned} \max_{W_t^{s,\tau}} E_0 \sum_{t=0}^{\infty} \mathcal{B}_0^t \Big\{ & \frac{(C_t - hC_{t-1})^{-\sigma}}{P_{f,t}} (W_t^{s,\tau})^{1-\eta^s} (W_t^s)^{\eta^s} L_t^s \\ & - \frac{\kappa_t^s}{1+\varphi} (W_t^{s,\tau})^{-\eta^s(1+\varphi)} (W_t^s)^{\eta^s(1+\varphi)} (L_t^s)^{1+\varphi} - \frac{\psi_w}{2}\left(\frac{W_t^{s,\tau}}{W_{t-1}^{s,\tau}} - 1\right)^2 L_t^s \Big\}. \end{aligned} \quad (37)$$

The first order condition of this problem is

$$\begin{aligned} (\eta^s - 1)\frac{(C_t - hC_{t-1})^{-\sigma}}{P_{f,t}} (W_t^{s,\tau})^{-\eta^s} (W_t^s)^{\eta^s} L_t^s = {} & \kappa_t^s \eta^s (W_t^{s,\tau})^{-\eta^s(1+\varphi)-1} (W_t^s)^{\eta^s(1+\varphi)} (L_t^s)^{1+\varphi} \\ & - \psi_w \left(\frac{W_t^{s,\tau}}{W_{t-1}^{s,\tau}} - 1\right) \frac{1}{W_{t-1}^{s,\tau}} L_t^s + E_t \beta_t \psi_w \left(\frac{W_{t+1}^{s,\tau}}{W_t^{s,\tau}} - 1\right)\left(\frac{W_{t+1}^{s,\tau}}{W_t^{s,\tau}}\right) \frac{1}{W_t^{s,\tau}} L_t^s, \end{aligned} \quad (38)$$

Since in equilibrium there is perfect risk sharing, we have $W_t^{s,\tau} = W_t^s$. Defining the real wage as $w_t^s \equiv W_t^s / P_{f,t}$, we obtain

$$(\eta^s - 1)(C_t - hC_{t-1})^{-\sigma} w_t^s L_t^s = \kappa_t^s \eta^s (L_t^s)^{1+\varphi} - \psi_w \pi_t^{s,w}(1+\pi_t^{s,w}) L_t^s + E_t \beta_t \psi_w \pi_{t+1}^{s,w}(1+\pi_{t+1}^{s,w}) L_t^s, \quad (39)$$

where $1 + \pi_t^{s,w} = W_t^s / W_{t-1}^s$. Rearranging, we obtain

$$(\eta^s - 1)(C_t - hC_{t-1})^{-\sigma} w_t^s = \kappa_t^s \eta^s (L_t^s)^{\varphi} - \psi_w \pi_t^{s,w}(1+\pi_t^{s,w}) + E_t \beta_t \psi_w \pi_{t+1}^{s,w}(1+\pi_{t+1}^{s,w}). \quad (40)$$

If there are no adjustment frictions, then the real wage is a markup over the ratio of the disutility of labor and the marginal utility of consumption.

A.2 Final Output Firm

Profit maximization within each sector implies demand for each differentiated product j of

$$y^s_{f,t}(j) = \left(\frac{P^s_{f,t}(j)}{P^s_{f,t}}\right)^{-\theta} Y^s_{f,t},$$

where the sectoral price index is

$$P^s_{f,t} = \left(\int_0^1 P^s_{f,t}(j)^{1-\theta} dj\right)^{\frac{1}{1-\theta}}.$$

Profit maximization across sectors yields the relative demand for each sector s aggregate

$$Y^s_{f,t} = \frac{\gamma^s_t}{\gamma^{s'}_t} \frac{P^{s'}_{f,t}}{P^s_{f,t}} Y^{s'}_{f,t}. \tag{41}$$

From the production function, $Y_{f,t} = (Y^M_{f,t})^{\gamma^M_t} (Y^S_{f,t})^{\gamma^S_t}$, we can substitute for $Y^S_{f,t}$ from the previous equation and solve for $Y^M_{f,t}$ as a function of total output:

$$Y_{f,t} = Y^M_{f,t} \left(\frac{\gamma^S_t}{\gamma^M_t}\right)^{\gamma^S_t} \left(\frac{P^M_{f,t}}{P^S_{f,t}}\right)^{\gamma^S_t},$$

and hence

$$\begin{aligned} Y^M_{f,t} &= (\gamma^M_t)^{\gamma^S_t} (\gamma^S_t)^{-\gamma^S_t} (P^M_{f,t})^{-\gamma^S_t} (P^S_{f,t})^{\gamma^S_t} Y_{f,t} \\ &= (\gamma^M_t)^{1-\gamma^M_t} (\gamma^S_t)^{-\gamma^S_t} (P^M_{f,t})^{-\gamma^S_t} (P^s_{f,t})^{\gamma^S_t} Y_{f,t}. \end{aligned} \tag{42}$$

This expression gives the demand for the manufacturing output as a function of total final output.

The cost function of the final output firm is

$$C(Y_{f,t}) = P^M_{f,t} Y^M_{f,t} + P^S_{f,t} Y^S_{f,t}. \tag{43}$$

Plugging in for $Y^S_{f,t}$ from (41), we obtain

$$\begin{aligned} C(Y_{f,t}) &= P^M_{f,t}Y^M_{f,t} + \frac{\gamma^S_t}{\gamma^M_t}P^M_{f,t}Y^M_{f,t} \\ &= \frac{1}{\gamma^M_t}P^M_{f,t}Y^M_{f,t}. \end{aligned} \tag{44}$$

Plugging (42) into the cost function, we get

$$C(Y_{f,t}) = \left(\frac{1}{\gamma^M_t}\right)^{\gamma^M_t}\left(\frac{1}{\gamma^S_t}\right)^{\gamma^S_t}(P^M_{f,t})^{\gamma^M_t}(P^S_{f,t})^{\gamma^S_t}Y_{f,t}. \tag{45}$$

Therefore, we can define the aggregate price index as

$$P_{f,t} = \left(\frac{1}{\gamma^M_t}\right)^{\gamma^M_t}\left(\frac{1}{\gamma^S_t}\right)^{\gamma^S_t}(P^M_{f,t})^{\gamma^M_t}(P^S_{f,t})^{\gamma^S_t}. \tag{46}$$

We can obtain the aggregate inflation rate as a function of the sectoral inflation rates. Dividing (46) by $P_{f,t-1}$, we get

$$1 + \pi_t = \Theta_t(\gamma)(1+\pi^M_t)^{\gamma^M_t}(1+\pi^S_t)^{\gamma^S_t}, \tag{47}$$

where $\pi_t = (P_{f,t}/P_{f,t-1}) - 1$ is the inflation rate and

$$\Theta_t(\gamma) \equiv \frac{(\gamma^M_{t-1})^{\gamma^M_{t-1}}(\gamma^S_{t-1})^{\gamma^S_{t-1}}}{(\gamma^M_t)^{\gamma^M_t}(\gamma^S_t)^{\gamma^S_t}}(P^M_{f,t-1})^{\gamma^M_t-\gamma^M_{t-1}}(P^S_{f,t-1})^{\gamma^S_t-\gamma^S_{t-1}} \tag{48}$$

is an adjustment factor that takes into account that the shares of goods and services can fluctuate. In steady state, $\Theta_t(\gamma) = 1$. Hence, aggregate inflation is a combination of inflation in the two sectors.

Finally, using equation (42), total spending in sector s is

$$\begin{aligned} P^s_{f,t}Y^s_{f,t} &= (\gamma^s_t)^{1-\gamma^s_t}(\gamma^{s'}_t)^{-\gamma^{s'}_t}(P^s_{f,t})^{\gamma^s_t}(P^{s'}_{f,t})^{\gamma^{s'}_t}Y_{f,t} \\ &= \gamma^s_t P_{f,t}Y_{f,t}, \end{aligned} \tag{49}$$

where the second line follows from (46). Therefore, demand for product j as a function of final output is

$$y^s_{f,t}(j) = \left(\frac{P^s_{f,t}(j)}{P^s_{f,t}}\right)^{-\theta}Y^s_{f,t} = \gamma^s_t\left(\frac{P^s_{f,t}(j)}{P^s_{f,t}}\right)^{-\theta}\left(\frac{P_{f,t}}{P^s_{f,t}}\right)Y_{f,t}. \tag{50}$$

A.3 Retailers

Retailers face producer prices $P^s_{x,t}(j,i)$ for their input from industry i. Cost minimization implies that retailers have demand for each industry i of

$$x^s_t(j,i) = \left(\frac{P^s_{x,t}(j,i)}{P^s_{x,t}(j)}\right)^{-\nu} y^s_{f,t}(j), \tag{51}$$

where

$$P^s_{x,t}(j) = \left(\int_0^1 P^s_{x,t}(j,i)^{1-\nu} di\right)^{\frac{1}{1-\nu}} \tag{52}$$

is the producer price index faced by retailer j.

The retailers are monopolistic competitors, taking price indices as given, and face final demand from (7) of

$$y^s_{f,t}(j) = \gamma^s_t \left(\frac{P^s_{f,t}(j)}{P^s_{f,t}}\right)^{-\theta} \left(\frac{P_{f,t}}{P^s_{f,t}}\right) Y_{f,t}. \tag{53}$$

Retailers face a quadratic adjustment cost of $\gamma^s_t \frac{\psi_p}{2}(\frac{P^s_{f,t}(j)}{P^s_{f,t-1}(j)} - 1)^2 P_{f,t} Y_{f,t}$. Their real profits are

$$\begin{aligned}\Pi^s_t(j) = \gamma^s_t P^s_{f,t}(j)^{1-\theta}(P^s_{f,t})^{\theta-1} Y_{f,t} - p^s_{x,t}(j)\gamma^s_t P^s_{f,t}(j)^{-\theta}(P^s_{f,t})^{\theta-1} P_{f,t} Y_{f,t} \\ - \gamma^s_t \frac{\psi_p}{2}\left(\frac{P^s_{f,t}(j)}{P^s_{f,t-1}(j)} - 1\right)^2 Y_{f,t},\end{aligned} \tag{54}$$

where $p^s_{x,t}(j) \equiv P^s_{x,t}(j)/P_{f,t}$ are real marginal costs. The firms' maximization problem is

$$\begin{aligned}\max_{P^s_{f,t+k}(j)} E_t \Bigg\{ \sum_{k=0}^{\infty} \mathcal{B}^{t+k}_t \left(\frac{U'(C_{t+k})}{U'(C_t)}\right) \Bigg[\left(\frac{P^s_{f,t+k}(j)}{P^s_{f,t+k}} - p^s_{x,t+k}(j)\frac{P_{f,t+k}}{P^s_{f,t+k}}\right)\gamma^s_{t+k} P^s_{f,t+k}(j)^{-\theta}(P^s_{f,t+k})^{\theta} Y_{f,t+k} \\ - \gamma^s_t \frac{\psi_p}{2}\left(\frac{P^s_{f,t+k}(j)}{P^s_{f,t+k-1}(j)} - 1\right)^2 Y_{f,t+k}\Bigg]\Bigg\}.\end{aligned} \tag{55}$$

Under the assumption that all retailers are symmetric, the solution to the maximization problem is

$$\begin{aligned}\gamma^s_t(\theta - 1)\frac{Y_{f,t}}{P^s_{f,t}} = \gamma^s_t \theta p^s_{x,t}\left(\frac{P_{f,t}}{P^s_{f,t}}\right)\frac{Y_{f,t}}{P^s_{f,t}} - \gamma^s_t \psi_p \left(\frac{P^s_{f,t}}{P^s_{f,t-1}} - 1\right)\frac{1}{P^s_{f,t-1}} Y_{f,t} \\ + \beta_t \psi_p E_t\left[\gamma^s_{t+1}\frac{(C_{t+1} - H_{t+1})^{-\sigma}}{(C_t - H_t)^{-\sigma}}\left(\frac{P^s_{f,t+1}}{P^s_{f,t}} - 1\right)\left(\frac{P^s_{f,t+1}}{P^s_{f,t}}\right)\frac{1}{P^s_{f,t}} Y_{f,t+1}\right],\end{aligned} \tag{56}$$

which becomes

$$(\theta-1)=\theta\frac{p^s_{x,t}}{p^s_{f,t}}-\psi_p(1+\pi^s_t)\pi^s_t+\beta_t\psi_pE_t\left[\frac{\gamma^s_{t+1}}{\gamma^s_t}\frac{(C_{t+1}-hC_t)^{-\sigma}}{(C_t-hC_{t-1})^{-\sigma}}\frac{Y_{f,t+1}}{Y_{f,t}}(1+\pi^s_{t+1})\pi^s_{t+1}\right], \quad (57)$$

where $\pi^s_t=P^s_{f,t}/P^s_{f,t-1}-1$, and $p^s_{f,t}=P^s_{f,t}/P_{f,t}$.

A.4 Intermediate Goods Firms

A.4.1 Firm and Industry Demand

In this section, we derive the demand faced by producer k. Given price $P^s_{x,t}(j,i,k)$, the first order condition for demand of firm k's output is

$$(N^s)^{\frac{1}{1-\mu}}x^s_t(j,i,k)^{-\frac{1}{\mu}}\left(\sum_{k=1}^{N^s_D}x^s_t(j,i,k)^{\frac{\mu-1}{\mu}}+\sum_{k=1}^{N^s_F}x^s_t(j,i,k)^{\frac{\mu-1}{\mu}}\right)^{\frac{\mu}{\mu-1}-1}=P^s_{x,t}(j,i,k),$$

implying

$$x^s_t(j,i,k)=\left(\frac{P^s_{x,t}(j,i,k)}{P^s_{x,t}(j,i,k')}\right)^{-\mu}x^s_t(j,i,k').$$

Plugging this expression into the aggregator (11) and re-arranging, we get

$$x^s_t(j,i,k)=(N^s)^{\frac{\mu}{\mu-1}}\left(\sum_{k=1}^{N^s_D}P^s_{x,t}(j,i,k)^{1-\mu}+\sum_{k=1}^{N^s_F}P^s_{x,t}(j,i,k)^{1-\mu}\right)^{\frac{\mu}{1-\mu}}P^s_{x,t}(j,i,k)^{-\mu}\frac{x^s_t(j,i)}{N^s}.$$

Thus, the demand faced by firm k is

$$x^s_t(j,i,k)=\left(\frac{P^s_{x,t}(j,i,k)}{P^s_{x,t}(j,i)}\right)^{-\mu}\frac{x^s_t(j,i)}{N^s}, \quad (58)$$

where

$$P^s_{x,t}(j,i)=(N^s)^{\frac{1}{\mu-1}}\left(\sum_{k=1}^{N^s_D}P^s_{x,t}(j,i,k)^{1-\mu}+\sum_{k=1}^{N^s_F}P^s_{x,t}(j,i,k)^{1-\mu}\right)^{\frac{1}{1-\mu}},$$

and $P^s_{x,t}(j,i,k)=P^s_{x,t}(j,i)=P^s_{x,t}(j)$ in a completely symmetric equilibrium.

A.4.2 Roundabout Production Technology

In this section, we describe the roundabout production technology and derive the sectoral demand for domestic intermediates.

The domestic inputs are assembled using all industries' output via a roundabout production technology. The domestic input aggregate $Z_t^s(j,i,k)$ used by firm k in industry i for retailer j in sector s combines inputs from the manufacturing and service sector according to

$$Z_t^s(j,i,k) = (Z_t^{s,M}(j,i,k))^{\gamma_t^M} (Z_t^{s,S}(j,i,k))^{\gamma_t^S}.$$

The sectoral aggregates are in turn combined from all industries using

$$Z_t^{s,s'}(j,i,k) = \left[\int_0^1 z_t^{s,s'}(j,i,k,i')^{\frac{\nu-1}{\nu}} di'\right]^{\frac{\nu}{\nu-1}},$$

where $z_t^{s,s'}(j,i,k,i')$ is the output from intermediate industry i' in sector s' used as input by firm k in industry i in sector s. This output is produced by firms k' in industry i' according to

$$z_t^{s,s'}(j,i,k,i') = (N^s)^{\frac{1}{1-\mu}} \left(\sum_{k=1}^{N_D^s} x_t^s(j,i,k,i',k')^{\frac{\mu-1}{\mu}} + \sum_{k=1}^{N_F^s} x_t^s(j,i,k,i',k')^{\frac{\mu-1}{\mu}}\right)^{\frac{\mu}{\mu-1}}.$$

The demand for producer (k')'s output by industry i' for use as intermediate is, as shown in Appendix A.4.1 for the consumer side

$$z_t^{s,s'}(j,i,k,i',k') = \left(\frac{P_{x,t}^{s'}(j,i',k')}{P_{x,t}^{s'}(j,i')}\right)^{-\mu} \frac{z_t^{s,s'}(j,i,k,i')}{N_t^s},$$

where $P_{x,t}^{s'}(j,i',k')$ is the price charged by firm k'.

The demand for industry i' as input for firm k in industry i in sector s for retailer j is obtained from cost minimization as

$$z_t^{s,s'}(j,i,k,i') = \left(\frac{P_{x,t}^{s'}(j,i')}{P_{x,t}^{s'}(j)}\right)^{-\nu} Z_t^{s,s'}(j,i,k),$$

similar to the demand from retailers derived in (51), where $P_{x,t}^{s'}(j)$ is as before the producer price index, which by symmetry is $P_{x,t}^{s'}$. For the choice of inputs by sector, we have

$$Z_t^{s,s'}(j,i,k) = \gamma_t^{s'} \left(\frac{P_{x,dom,t}}{P_{x,t}^{s'}}\right) Z_t^s(j,i,k), \tag{59}$$

where

$$P_{x,dom,t} = \left(\frac{1}{\gamma_t^M}\right)^{\gamma_t^M} \left(\frac{1}{\gamma_t^S}\right)^{\gamma_t^S} (P_{x,t}^M)^{\gamma_t^M} (P_{x,t}^S)^{\gamma_t^S} \tag{60}$$

is the domestic input price index.

A.4.3 Producers' Marginal Costs

Cost minimization across domestic and foreign intermediates implies

$$M_t^s(j,i,k) = Z_t^s(j,i,k)\left(\frac{P_{x,imp,t}^s}{P_{x,dom,t}}\right)^{-\xi}.$$

Plugging this into the CES aggregator for domestic and foreign inputs, equation (15), yields

$$D_t^s(j,i,k) = Z_t^s(j,i,k)(P_{x,input,t}^s)^{-\xi}(P_{x,dom,t})^{\xi},$$

where

$$P_{x,input,t}^s = [(P_{x,dom,t})^{1-\xi} + (P_{x,imp,t}^s)^{1-\xi}]^{\frac{1}{1-\xi}}$$

is the input price index. It follows that

$$Z_t^s(j,i,k) = \left(\frac{P_{x,dom,t}}{P_{x,input,t}^s}\right)^{-\xi} D_t^s(j,i,k)$$

and

$$M_t^s(j,i,k) = \left(\frac{P_{x,imp,t}^s}{P_{x,input,t}^s}\right)^{-\xi} D_t^s(j,i,k).$$

The expenditure share on imported inputs is

$$\frac{P_{x,imp,t}^s M_t^s(j,i,k)}{P_{x,input,t}^s D_t^s(j,i,k)} = \frac{(P_{x,imp,t}^s)^{1-\xi}}{(P_{x,input,t}^s)^{1-\xi}} = \frac{(P_{x,imp,t}^s)^{1-\xi}}{(P_{x,dom,t})^{1-\xi} + (P_{x,imp,t}^s)^{1-\xi}} \equiv \alpha_s,$$

where α_s is the import share in sector s.

Cost minimization across labor and intermediates implies

$$L_t^s(j,i,k) = \frac{1}{\Lambda_s} A_t^{\rho_s - 1} D_t^s(j,i,k)\left(\frac{W_t^s}{P_{x,input,t}^s}\right)^{-\rho_s}.$$

Plugging this into the CES aggregator for labor and intermediates, equation (14), yields

$$x_t^s(j,i,k) = \frac{1}{\Lambda_s} D_t(j,i,k)(P_{x,input,t}^s)^{\rho_s}(MC_{D,t}^s)^{-\rho_s},$$

where

$$MC_{D,t}^s \equiv \left[\left(\frac{W_t^s}{A_t}\right)^{1-\rho_s} + \Lambda_s (P_{x,input,t}^s)^{1-\rho_s}\right]^{\frac{1}{1-\rho_s}}. \tag{61}$$

It follows that the demand for the intermediate good is

$$D_t^s(j,i,k) = \Lambda_s \left(\frac{P^s_{x,input,t}}{MC^s_{D,t}} \right)^{-\rho_s} x_t^s(j,i,k). \tag{62}$$

Similarly, the demand for labor is

$$L_t^s(j,i,k) = A_t^{\rho_s - 1} \left(\frac{W_t^s}{MC^s_{D,t}} \right)^{-\rho_s} x_t^s(j,i,k). \tag{63}$$

Plugging these two expressions into the firm's cost function yields

$$\begin{aligned} C(x_t^s(j,i,k)) &= W_t L_t^s(j,i,k) + P^s_{x,input,t} D_t^s(j,i,k) \\ &= MC^s_{D,t} \cdot x_t^s(j,i,k). \end{aligned} \tag{64}$$

Thus, $MC^s_{D,t}$ are the firm's marginal costs.

The share of labor in total costs is

$$\begin{aligned} \lambda_t^s &= \frac{A_t^{\rho_s-1}(W_t^s)^{1-\rho_s} MC^{\rho_s}_{D,t}(x_t^s(j,i,k))}{A_t^{\rho_s-1}(W_t^s)^{1-\rho_s} MC^{\rho_s}_{D,t}(x_t^s(j,i,k)) + \Lambda_s (P^s_{x,input,t})^{1-\rho_s} MC^{\rho_s}_{D,t}(x_t^s(j,i,k))} \\ &= \frac{(W_t^s/A_t)^{1-\rho_s}}{(W_t^s/A_t)^{1-\rho_s} + \Lambda_s (P^s_{x,input,t})^{1-\rho_s}}. \end{aligned} \tag{65}$$

This equation links the parameter Λ_s to the labor share in steady state, λ^s.

A.4.4 Price Setting Problem

In this section we find the solution for the firm's profit maximization problem. We first derive the firms' effective elasticity of demand. We then solve the profit maximization problem and obtain firms' prices.

Demand Elasticity

Each producer faces final demand as well as demand for its output as inputs into other industries. Each retailer also demands some output $\gamma_t^s \frac{\psi_p}{2} (\pi_t^s)^2 Y_{f,t}$ to cover its price adjustment cost. From the demand equation (12), each producer thus faces total demand of

$$x^s_{tot,t}(j,i,k) = \frac{1}{N^s}\left(\frac{P^s_{x,t}(j,i,k)}{P^s_{x,t}(j,i)}\right)^{-\mu}\left(\frac{P^s_{x,t}(j,i)}{P^s_{x,t}(j)}\right)^{-\nu}$$
$$\times\left(y^s_{f,t}(j) + \gamma^s_t\frac{\psi_p}{2}(\pi^s_t)^2 Y_{f,t} + \int_0^1 \sum_{k'\in D} Z^{s,s}_t(j,i',k')di' + \int_0^1 \sum_{k'\in D} Z^{s',s}_t(j,i',k')di'\right),$$

where the first term is the final demand by the associated retailer, the second term are the resources needed for price changes, and the third and fourth terms are the demands for inputs by all other domestic firms in all other industries to produce for the retailer. Plugging in the demand for inputs (59) we get

$$x^s_{tot,t}(j,i,k) = \frac{1}{N^s}\left(\frac{P^s_{x,t}(j,i,k)}{P^s_{x,t}(j,i)}\right)^{-\mu}\left(\frac{P^s_{x,t}(j,i)}{P^s_{x,t}(j)}\right)^{-\nu}\times\left(\gamma^s_t\left(\frac{P^s_{f,t}(j)}{P^s_{f,t}}\right)^{-\theta}\left(\frac{P_{f,t}}{P^s_{f,t}}\right)Y_{f,t} + \gamma^s_t\frac{\psi_p}{2}(\pi^s_t)^2 Y_{f,t}\right.$$
$$\left. + \gamma^s_t\left(\frac{P_{x,dom,t}}{P^s_{x,t}}\right)\int_0^1\sum_{k'\in D} Z^s_t(j,i',k')di' + \gamma^s_t\left(\frac{P_{x,dom,t}}{P^s_{x,t}}\right)\int_0^1\sum_{k'\in D} Z^{s'}_t(j,i',k')\right).$$

We denote by $Z^s_t(j) \equiv \int_0^1 \sum_{k'\in D} Z^s_t(j,i',k')di'$ the demand of inputs to produce for retailer j in sector s to re-write

$$x^s_{tot,t}(j,i,k) = \frac{1}{N^s}\left(\frac{P^s_{x,t}(j,i,k)}{P^s_{x,t}(j,i)}\right)^{-\mu}\left(\frac{P^s_{x,t}(j,i)}{P^s_{x,t}(j)}\right)^{-\nu}\times\left(\gamma^s_t\left(\frac{P^s_{f,t}(j)}{P^s_{f,t}}\right)^{-\theta}\left(\frac{P_{f,t}}{P^s_{f,t}}\right)Y_{f,t}\right.$$
$$\left. + \gamma^s_t\frac{\psi_p}{2}(\pi^s_t)^2 Y_{f,t} + \gamma^s_t\left(\frac{P_{x,dom,t}}{P^s_{x,t}}\right)Z^s_t(j) + \gamma^s_t\left(\frac{P_{x,dom,t}}{P^s_{x,t}}\right)Z^{s'}_t(j)\right). \quad (66)$$

Each producer faces an effective elasticity of demand of

$$\mathcal{E}^s_t(j,i,k) \equiv -\frac{d\log x^s_{tot,t}(j,i,k)}{d\log P^s_{x,t}(j,i,k)} = \mu - (\mu-\nu)\frac{\partial\log P^s_{x,t}(j,i)}{\partial\log P^s_{x,t}(j,i,k)}.$$

From the definition of an industry's price index (13), we have that

$$\frac{\partial\log P^s_{x,t}(j,i)}{\partial\log P^s_{x,t}(j,i,k)} = \frac{P^s_{x,t}(j,i,k)^{1-\mu}}{\sum_{k=1}^{N^s_D} P^s_{x,t}(j,i,k)^{1-\mu} + \sum_{k=1}^{N^s_F} P^s_{x,t}(j,i,k)^{1-\mu}}. \quad (67)$$

We can define a firm's market share as

$$
\begin{aligned}
S_t^s(j,i,k) &\equiv \frac{P_{x,t}^s(j,i,k)x_{tot,t}^s(j,i,k)}{\sum_{k'=1}^{N_D^s} P_{x,t}^s(j,i,k')x_{tot,t}^s(j,i,k') + \sum_{k'=1}^{N_F^s} P_{x,t}^s(j,i,k')x_{tot,t}^s(j,i,k')} \\
&= \left(\frac{1}{N^s}\right)\frac{P_{x,t}^s(j,i,k)^{1-\mu}}{P_{x,t}^s(j,i)^{1-\mu}}.
\end{aligned} \tag{68}
$$

Using this expression, we can re-express the demand elasticity as

$$
\mathcal{E}_t^s(j,i,k) = \mu - (\mu-\nu)S_t^s(j,i,k) = \mu(1 - S_t^s(j,i,k)) + \nu S_t^s(j,i,k). \tag{69}
$$

Thus, the firm's demand elasticity is a weighted average of the within-industry and across-industry elasticities of substitution.

Prices

Producer k in industry i in sector s sets prices $P_{x,t}^s(j,i,k)$ to solve

$$
\max_{P_{x,t}^s(j,i,k)} [P_{x,t}^s(j,i,k) - MC_{D,t}^s]x_{tot,t}^s(j,i,k),
$$

where $x_{tot,t}^s(j,i,k)$ is given by (66). The first-order condition of this problem is

$$
\begin{aligned}
&[(1-\mu)P_{x,t}^s(j,i,k)^{-\mu} + \mu P_{x,t}^s(j,i,k)^{-\mu-1}MC_{D,t}^s]P_{x,t}^s(j,i)^{\mu-\nu}P_{x,t}^s(j)^{\nu} \\
&+ \left[(\mu-\nu)P_{x,t}^s(j,i,k)^{-\mu}P_{x,t}^s(j,i)^{\mu-\nu-1}P_{x,t}^s(j)^{\nu}\frac{\partial P_{x,t}^s(j,i)}{\partial P_{x,t}^s(j,i,k)}\right][P_{x,t}^s(j,i,k) - MC_{D,t}^s] = 0.
\end{aligned}
$$

The derivative of the price index is equal to

$$
\frac{\partial P_{x,t}^s(j,i)}{\partial P_{x,t}^s(j,i,k)} = \left(\frac{1}{N^s}\right)\left(\frac{P_{x,t}^s(j,i,k)}{P_{x,t}^s(j,i)}\right)^{-\mu} = S_t^s(j,i,k)\frac{P_{x,t}^s(j,i)}{P_{x,t}^s(j,i,k)},
$$

where we have used equation (67) and the expression for the market share (68). Plugging in, the first-order condition becomes

$$
(1-\mu)P_{x,t}^s(j,i,k) + \mu MC_{D,t}^s + (\mu-\nu)S_t^s(j,i,k)[P_{x,t}^s(j,i,k) - MC_{D,t}^s] = 0,
$$

which can be rearranged to

$$
P_{x,t}^s(j,i,k) = \frac{\mu - (\mu-\nu)S_t^s(j,i,k)}{(\mu-1) - (\mu-\nu)S_t^s(j,i,k)}MC_{D,t}^s.
$$

Using the definition of the demand elasticity, the producer price is thus

$$P^s_{x,t}(j,i,k) = \frac{\mathcal{E}^s_t(j,i,k)}{\mathcal{E}^s_t(j,i,k)-1} MC^s_{D,t}, \tag{70}$$

which can be re-written with real marginal costs by dividing both sides by $P_{f,t}$. We will denote by $P^s_{D,x,t}$ the price of a domestic producer and by $P^s_{F,x,t}$ the price of a foreign producer.

A.5 Aggregation

In this section we derive the aggregate resource constraints. Using equation (66) and symmetry of producers of the same origin, each domestic producer supplying retailer j faces total demand of

$$\begin{aligned} x^s_{tot,t}(j,i,k) = \frac{1}{N^s}\left(\frac{P^s_{D,x,t}}{P^s_{x,t}}\right)^{-\mu} \Bigg(\gamma^s_t \left(\frac{P_{f,t}}{P^s_{f,t}}\right) Y_{f,t} \\ + \gamma^s_t \frac{\psi_p}{2}(\pi^s_t)^2 Y_{f,t} + \gamma^s_t \left(\frac{P_{x,dom,t}}{P^s_{x,t}}\right) Z^s_t(j) + \gamma^s_t \left(\frac{P_{x,dom,t}}{P^s_{x,t}}\right) Z^{s'}_t(j) \Bigg). \end{aligned}$$

We aggregate across domestic producers and integrate across industries and retailers, and use $Y_{f,t} = C_t$, to get gross output by domestic firms in sector s:

$$Y^s_{g,t} = \frac{N^s_D}{N^s}\left(\frac{P_{D,x,t}}{P_{x,t}}\right)^{-\mu} \left(\gamma^s_t \left(\frac{P_{f,t}}{P^s_{f,t}}\right) C_t + \gamma^s_t \frac{\psi_p}{2}(\pi^s_t)^2 C_t + \gamma^s_t \left(\frac{P_{x,dom,t}}{P^s_{x,t}}\right) Z^s_t + \gamma^s_t \left(\frac{P_{x,dom,t}}{P^s_{x,t}}\right) Z^{s'}_t \right).$$

The demand for intermediates by domestic firm k can be derived as

$$\begin{aligned} Z^s_t(j,i,k) &= \left(\frac{P_{x,dom,t}}{P^s_{x,input,t}}\right)^{-\xi} D^s_t(j,i,k) \\ &= \Lambda_s \left(\frac{P_{x,dom,t}}{P^s_{x,input,t}}\right)^{-\xi} \left(\frac{P^s_{x,input,t}}{MC^s_{D,t}}\right)^{-\rho_s} x^s_{tot,t}(j,i,k). \end{aligned}$$

Since only domestic firms demand domestic intermediates, we can obtain the total domestic demand in sector s by summing across domestic firms and using symmetry to obtain

$$Z^s_t = \Lambda_s \left(\frac{P_{x,dom,t}}{P^s_{x,input,t}}\right)^{-\xi} \left(\frac{P^s_{x,input,t}}{MC^s_{D,t}}\right)^{-\rho_s} Y^s_{g,t}.$$

The total demand for labor by firm k is, from (63),

$$L_t^s(j,i,k) = A_t^{\rho_s - 1}\left(\frac{W_t^s}{MC_{D,t}^s}\right)^{-\rho_s} x_{tot,t}^s(j,i,k).$$

Aggregating across firms, industries, and retailers, we obtain

$$L_t^s = A_t^{\rho_s - 1}\left(\frac{W_t^s}{MC_{D,t}^s}\right)^{-\rho_s} Y_{g,t}^s.$$

A.6 Equilibrium Conditions

We now list the equilibrium conditions of the model. We incorporate here our assumption that the services sector consists only of domestic firms, and will write $mc_t^S = mc_{D,t}^S$, and so on.

Our equilibrium consists of 38 endogenous variables: C_t, Z_t^M, Z_t^S, π_t, π_t^M, π_t^S, $\pi_t^{M,w}$, $\pi_t^{S,w}$, $p_{f,t}^M$, $p_{f,t}^S$, $p_{x,t}^M$, $p_{x,t}^S$, $p_{D,x,t}^M$, $p_{F,x,t}^M$, $mc_{D,t}^M$, mc_t^S, $mc_{F,t}^M$, $p_{x,input,t}^M$, $p_{x,input,t}^S$, $p_{x,imp,t}^M$, $p_{x,imp,t}^S$, $p_{x,dom,t}$, w_t^M, w_t^S, L_t^M, L_t^S, $Y_{g,t}$, $Y_{g,t}^M$, $Y_{g,t}^S$, A_t, κ_t^M, κ_t^S, R_t, $S_{D,t}^M$, $S_{f,t}^M$, γ_t^M, γ_t^S, and β_t.

We have the following conditions that describe the system:

1. Euler equation:

$$(C_t - hC_{t-1})^{-\sigma} = \beta E_t\left[\frac{1+R_t}{1+\pi_{t+1}}(C_{t+1} - hC_t)^{-\sigma}\right] \tag{71}$$

2. Demand for domestic intermediates:

$$Z_t^s = \Lambda_s (p_{x,dom,t})^{-\xi}(p_{x,input,t}^s)^{\xi-\rho_s}(mc_{D,t}^s)^{\rho_s} Y_{g,t}^s \tag{72}$$

3. Aggregate inflation:

$$1+\pi_t = \Theta_t(\gamma)(1+\pi_t^M)^{\gamma_t^M}(1+\pi_t^S)^{\gamma_t^S} \tag{73}$$

4. Sectoral inflation:

$$(\theta - 1) = \theta\frac{p_{x,t}^s}{p_{f,t}^s} - \psi_p(1+\pi_t^s)\pi_t^s + \beta\psi_p E_t\left[\frac{\gamma_{t+1}^s}{\gamma_t^s}\frac{(C_{t+1} - hC_t)^{-\sigma}}{(C_t - hC_{t-1})^{-\sigma}}\frac{C_{t+1}}{C_t}(1+\pi_{t+1}^s)\pi_{t+1}^s\right] \tag{74}$$

5. Sectoral wage inflation:

$$1+\pi_t^{s,w} = \frac{w_t^s}{w_{t-1}^s}(1+\pi_t) \tag{75}$$

6. Sectoral prices:
$$p^s_{f,t} = p^s_{f,t-1}\frac{1+\pi^s_t}{1+\pi_t} \tag{76}$$

7. Retailers' real marginal costs in the goods sector
$$p^M_{x,t} = (N^M)^{\frac{1}{\mu-1}}\left(N^M_D(p^M_{D,x,t})^{1-\mu} + N^M_F(p^M_{F,x,t})^{1-\mu}\right)^{\frac{1}{1-\mu}} \tag{77}$$

8. Retailers' real marginal costs in the services sector
$$p^S_{x,t} = \frac{\mu-(\mu-\nu)S^S_t}{(\mu-1)-(\mu-\nu)S^S_t}mc^S_t \tag{78}$$

9. Domestic manufacturer's price
$$p^M_{D,x,t} = \frac{\mu-(\mu-\nu)S^M_{D,t}}{(\mu-1)-(\mu-\nu)S^M_{D,t}}mc^M_{D,t} \tag{79}$$

10. Foreign manufacturer's price
$$p^M_{F,x,t} = \frac{\mu-(\mu-\nu)S^M_{F,t}}{(\mu-1)-(\mu-\nu)S^M_{F,t}}mc^M_{F,t} \tag{80}$$

11. Domestic producers' real marginal costs:
$$mc^s_{D,t} = \left[\left(\frac{w^s_t}{A_t}\right)^{1-\rho_s} + \Lambda_s(p^s_{x,input,t})^{1-\rho_s}\right]^{\frac{1}{1-\rho_s}} \tag{81}$$

12. Foreign goods producers' real marginal costs:
$$\ln(mc^M_{F,t+1}) = (1-\omega_F)\ln(mc^M_F) + \omega_F\ln(mc^M_{F,t}) + \epsilon^F_{t+1} \tag{82}$$

13. Relative input price index:
$$p^s_{x,input,t} = \left[(p_{x,dom,t})^{1-\xi} + (p^s_{x,imp,t})^{1-\xi}\right]^{\frac{1}{1-\xi}} \tag{83}$$

14. Relative domestic input price index:
$$p_{x,dom,t} = \left(\frac{1}{\gamma^M_t}\right)^{\gamma^M_t}\left(\frac{1}{\gamma^S_t}\right)^{\gamma^S_t}(p^M_{x,t})^{\gamma^M_t}(p^S_{x,t})^{\gamma^S_t} \tag{84}$$

15. Sectoral labor supply:

$$(\eta^s - 1)(C_t - hC_{t-1})^{-\sigma} w_t^s = \kappa_t^s \eta^s (L_t^s)^{\varphi} - \psi_w \pi_t^{s,w}(1 + \pi_t^{s,w}) + \beta_t \psi_w E_t \pi_{t+1}^{s,w}(1 + \pi_{t+1}^{s,w}) \tag{85}$$

16. Sectoral labor demand

$$L_t^s = A_t^{\rho_s - 1} \left(\frac{w_t^s}{mc_{D,t}^s} \right)^{-\rho_s} Y_{g,t}^s \tag{86}$$

17. Goods market clearing:

$$\begin{aligned} Y_{g,t}^M = \frac{N_D^M}{N^M} \left(\frac{p_{D,x,t}^M}{p_{x,t}^M} \right)^{-\mu} \Bigg\{ & \gamma_t^M \left(\frac{1}{p_{f,t}^M} \right) C_t \\ & + \gamma_t^M \frac{\psi_p}{2} (\pi_t^M)^2 C_t + \gamma_t^M \left(\frac{p_{x,dom,t}}{p_{x,t}^M} \right) Z_t^M + \gamma_t^M \left(\frac{p_{x,dom,t}}{p_{x,t}^M} \right) Z_t^S \Bigg\} \end{aligned} \tag{87}$$

18. Services market clearing:

$$Y_{g,t}^S = \gamma_t^S \left(\frac{1}{p_{f,t}^S} \right) C_t + \gamma_t^S \frac{\psi_p}{2} (\pi_t^S)^2 C_t + \gamma_t^S \left(\frac{p_{x,dom,t}}{p_{x,t}^S} \right) Z_t^M + \gamma_t^S \left(\frac{p_{x,dom,t}}{p_{x,t}^S} \right) Z_t^S \tag{88}$$

19. Aggregate market clearing:

$$Y_{g,t} = Y_{g,t}^M + Y_{g,t}^S \tag{89}$$

20. Domestic firm market shares in goods:

$$S_{D,t}^M = \left(\frac{1}{N^M} \right) \frac{(p_{D,x,t}^M)^{1-\mu}}{(p_{x,t}^M)^{1-\mu}} \tag{90}$$

21. Foreign firm market shares in goods:

$$S_{F,t}^M = \left(\frac{1}{N^M} \right) \frac{(p_{F,x,t}^M)^{1-\mu}}{(p_{x,t}^M)^{1-\mu}} \tag{91}$$

22. Technology process:

$$\ln(A_{t+1}) = \omega_A \ln(A_t) + \epsilon_{t+1}^A \tag{92}$$

23. Relative input price process:

$$\ln(p_{x,imp,t+1}^s) = (1 - \omega_P) \ln(p_{x,imp}^s) + \omega_P \ln(p_{x,imp,t}^s) + \epsilon_{t+1}^{P,s}, \tag{93}$$

24. Labor disutility shocks:

$$\kappa_{t+1}^{s} = (1-\omega_\kappa)\kappa^{s} + \omega_\kappa \kappa_t^{s} + \epsilon_{t+1}^{\kappa,s} \tag{94}$$

25. Monetary policy:

$$R_t = \varrho R_{t-1} + (1-\varrho)R + (1-\varrho)[\Phi_\pi \pi_t + \Phi_y(\ln(Y_{f,t}) - \ln(Y_f))] + \epsilon_t^{M} \tag{95}$$

26. Discount factor process:

$$\ln(\beta_{t+1}) = (1-\omega_\beta)\ln(\beta) + \omega_\beta \ln(\beta_t) + \epsilon_{t+1}^{\beta} \tag{96}$$

27. Goods share process:

$$\ln(\gamma_{t+1}^{M}) = (1-\omega_\gamma)\ln(\gamma^{M}) + \omega_\gamma \ln(\gamma_t^{M}) + \epsilon_{t+1}^{\gamma,M} \tag{97}$$

28. Services share process:

$$\gamma_t^{S} = 1 - \gamma_t^{M} \tag{98}$$

A.7 Price Change Equation

The change in the markup, $d\ln \mathcal{M}_t(j,i,k)$ is given by

$$\begin{aligned}
d\ln \mathcal{M}_t(j,i,k) &= d\ln\left[\mu - (\mu-\nu)S_t^{s}(j,i,k)\right] - d\ln\left[(\mu-1) - (\mu-\mu)S_t^{s}(j,i,k)\right] \\
&= \left[-\frac{\mu-\nu}{\mu-(\mu-\nu)S_t^{s}(j,i,k)} + \frac{\mu-\nu}{(\mu-1)-(\mu-\nu)S_t^{s}(j,i,k)}\right] \\
&\times \frac{\partial S_t^{s}(j,i,k)}{\partial \log S_t^{s}(j,i,k)} d\ln S_t^{s}(j,i,k) \\
&= \frac{(\mu-\nu)S_t^{s}(j,i,k)}{\left[\mu-(\mu-\nu)S_t^{s}(j,i,k)\right]\left[(\mu-1)-(\mu-\nu)S_t^{s}(j,i,k)\right]} \\
&\times \left[(1-\mu)d\ln P_{x,t}^{s}(j,i,k) - (1-\mu)d\ln P_{x,t}^{s}(j,i)\right] \\
&= \frac{S_t^{s}(j,i,k)}{\left[\frac{\mu}{\mu-\nu} - S_t^{s}(j,i,k)\right]\left[1 - \frac{\mu-\nu}{\mu-1}S_t^{s}(j,i,k)\right]}\left[d\ln P_{x,t}^{s}(j,i) - d\ln P_{x,t}^{s}(j,i,k)\right] \\
&= -\Gamma_t(j,i,k)\left[d\ln P_{x,t}^{s}(j,i,k) - d\ln P_{x,t}^{s}(j,i)\right],
\end{aligned}$$

where $\Gamma_t(j,i,k) = -(\partial \ln \mathcal{M}_t(j,i,k)/\partial \ln P^s_{x,t}(j,i,k)) \geq 0$ is the elasticity of the markup with respect to a firm's own price. From

$$\Gamma_t(j,i,k) = \frac{S^s_t(j,i,k)}{\left[\frac{\mu}{\mu-\nu} - S^s_t(j,i,k)\right]\left[1 - \frac{\mu-\nu}{\mu-1} S^s_t(j,i,k)\right]}, \tag{99}$$

it follows that $\Gamma_t(j,i,k) = 0$ if $S^s_t(j,i,k) = 0$.

Finally, the derivative of the markup elasticity with respect to the market share $S(i,j)$ is given by

$$\frac{d\Gamma_t(j,i,k)}{dS^s_t(j,i,k)} =$$

$$\frac{\left[\frac{\mu}{\mu-\nu} - S^s_t(j,i,k)\right]\left[1 - \frac{\mu-\nu}{\mu-1} S^s_t(j,i,k)\right] + \left[1 - \frac{\mu-\nu}{\mu-1} S^s_t(j,i,k)\right] + \frac{\mu-\nu}{\mu-1}\left[\frac{\mu}{\mu-\nu} - S^s_t(j,i,k)\right]}{\left\{\left[\frac{\mu}{\mu-\nu} - S^s_t(j,i,k)\right]\left[1 - \frac{\mu-\nu}{\mu-1} S(i,j)\right]\right\}^2} > 0.$$

B Additional Quantitative Results

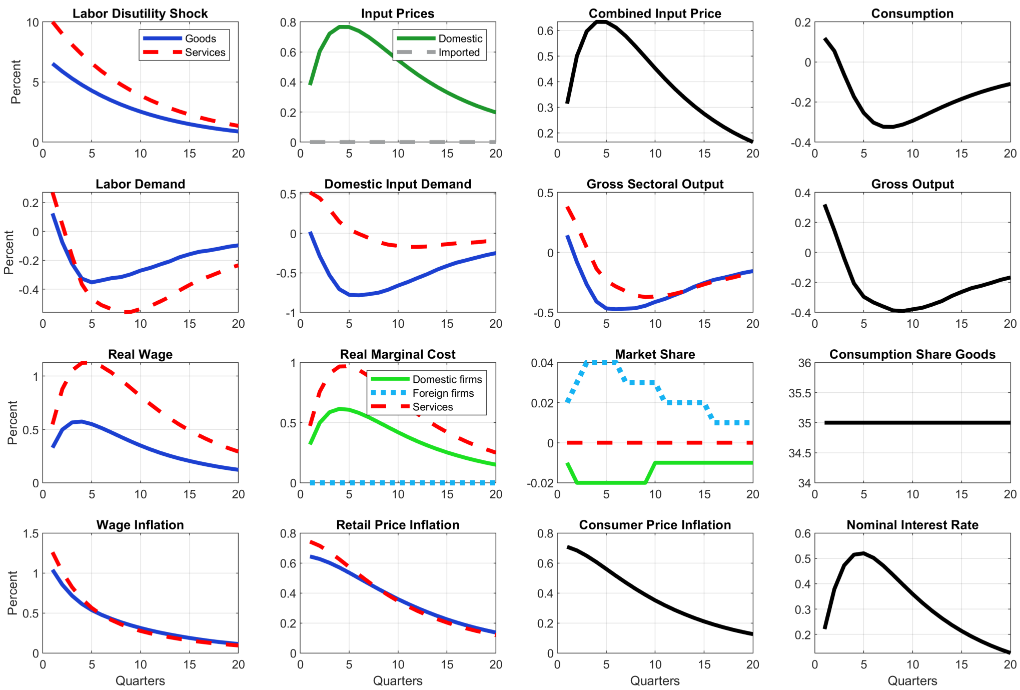
B.1 Additional Results

In this section, we present some additional results from the quantitative analysis.

Figure A.1 shows the impulse responses to our calibrated labor disutility shock in isolation. The first row of panels shows that the shock raises the domestic input price. The second row illustrates that labor demand falls in both goods and in services by about 0.3 percent and 0.5 percent at its peak, respectively, as described in the calibration. The increase in labor demand raises the real wage in particular in services, where the disutility shock is larger, as shown in the third row. The rise in real wages leads to a relative shift from labor towards domestic intermediates in services. Foreign firms gain market share as a result of the higher domestic costs and gross output contracts. The last row shows that the shock raises wage inflation by slightly above 1 percentage point and price inflation by about 0.7 percentage point.

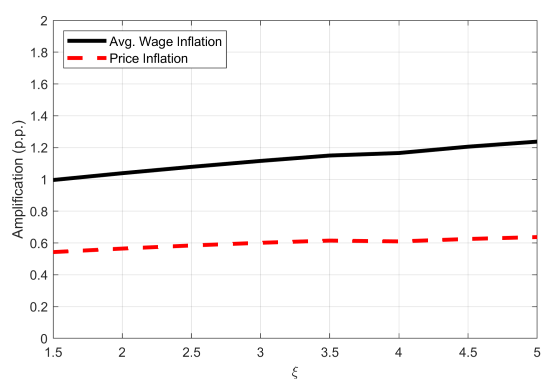
Figure A.2 shows the amplification as a function of the elasticity of substitution between domestic and imported intermediate inputs, ξ, similar to Figure 9 in the main text. This elasticity has a more moderate effect, but still increases amplification from 0.5 to 0.6 percentage point for price inflation and for 1 to 1.2 percentage point for wage inflation.

Figure A.1: Effect of Labor Disutility Shock Only



Source: Author's calculations. Figure shows the effect of a shock to labor disutility on key variables. Each panel shows the percent deviation of a variable from its steady state value against the number of quarters passed since the initial shock. For wage and price inflation and the market share, we show percentage point changes from steady state. For the consumption share of goods we show its actual value.

Figure A.2: Amplification on Impact: Sensitivity to ξ



Source: Author's calculations. Figure plots the difference between the impulse responses of consumer price inflation and average wage inflation for the joint shock relative to the impulse response of the summed separate shocks on impact (the difference between the red dashed and the black solid line from Figure 8 in quarter one) as a function of ξ.

B.2 Heterogeneous Labor

In this section, we consider an extension of the baseline model where we allow for two types of labor in both sectors: high-skilled (H) and low-skilled (L). To incorporate heterogeneous labor, we modify the firms' production function (14) to

$$x_t^s(j,i,k) = \left[\left(A_t L_t^{sH}(j,i,k)\right)^{\frac{\vartheta_s-1}{\vartheta_s}} + \Lambda_s^{\frac{1}{\vartheta_s}} \left(\Xi_t^s(j,i,k)\right)^{\frac{\vartheta_s-1}{\rho_s}} \right]^{\vartheta_s/(\vartheta_s-1)},$$

where L_t^{sH} is high-skilled labor used in sector s, and Ξ_t^s is a composite of low-skilled labor, L_t^{sL} and intermediates

$$\Xi_t^s(j,i,k) = \left\{ D_t^s(j,i,k)^{\frac{\rho_s-1}{\rho_s}} + \left(A_t L_t^{sL}(j,i,k)\right)^{\frac{\rho_s-1}{\rho_s}} \right\}^{\frac{\rho_s}{\rho_s-1}}.$$

Here, ρ_s now represents the elasticity of substitution between low-skilled labor and intermediates.

We set the constant Λ_s to match the labor share in each sector in steady state, which is now given by a modified version of (24)

$$\begin{aligned} \lambda_s &= \frac{W^{sL}L^{sL}(j,i,k) + W^{sH}L^{sH}(j,i,k)}{W^{sL}L^{sL}(j,i,k) + P^s_{i,input}D^s(j,i,k) + W^{sH}L^{sH}(j,i,k)} \\ &= \frac{\Lambda_s (W^{sL}/A)^{1-\rho_s}(P^s_W)^{\rho_s-\vartheta_s} + (W^{sH}/A)^{1-\vartheta_s}}{\Lambda_s (P^s_W)^{1-\vartheta_s} + (W^{sH}/A)^{1-\vartheta_s}}, \end{aligned}$$

where P^s_W is the composite price index of intermediates and low-skilled labor,

$$P^s_{W,t} \equiv \left\{ (P^s_{i,input,t})^{1-\rho_s} + (W_t^{sL}/A_t)^{1-\rho_s} \right\}^{\frac{1}{1-\rho_s}}.$$

On the household side, the utility function is modified to capture the four types of labor

$$U^\tau = \frac{1}{1-\sigma}(C_t^\tau - H_t)^{1-\sigma} - \sum_{o\in\{L,H\}} \frac{\kappa_t^{Mo}}{1+\varphi}(\ell_t^{Mo,\tau})^{1+\varphi} - \sum_{o\in\{L,H\}} \frac{\kappa_t^{So}}{1+\varphi}(\ell_t^{So,\tau})^{1+\varphi},$$

where the disutility parameter for each sector s and labor type o follows an exogenous process of the form (1). The budget constraint becomes

$$C_t^\tau P_{f,t} + b_t B_t^\tau + Q_{t+1} A_{t+1}^\tau \leq \sum_{o\in\{L,H\}} W_t^{Mo,\tau}\ell_t^{Mo,\tau} + \sum_{o\in\{L,H\}} W_t^{So,\tau}\ell_t^{So,\tau} + B_{t-1}^\tau + A_t^\tau + P_{f,t}\Pi_t^\tau.$$

Households' labor of type o in sector s is combined via a Dixit-Stiglitz aggregator

$$L_t^{so} = \left[\int_0^1 (\ell_t^{so,\tau})^{\frac{\eta^s-1}{\eta^s}} d\tau\right]^{\eta^s/(\eta^s-1)}.$$

The household's wage setting problem now implies the wage setting equation

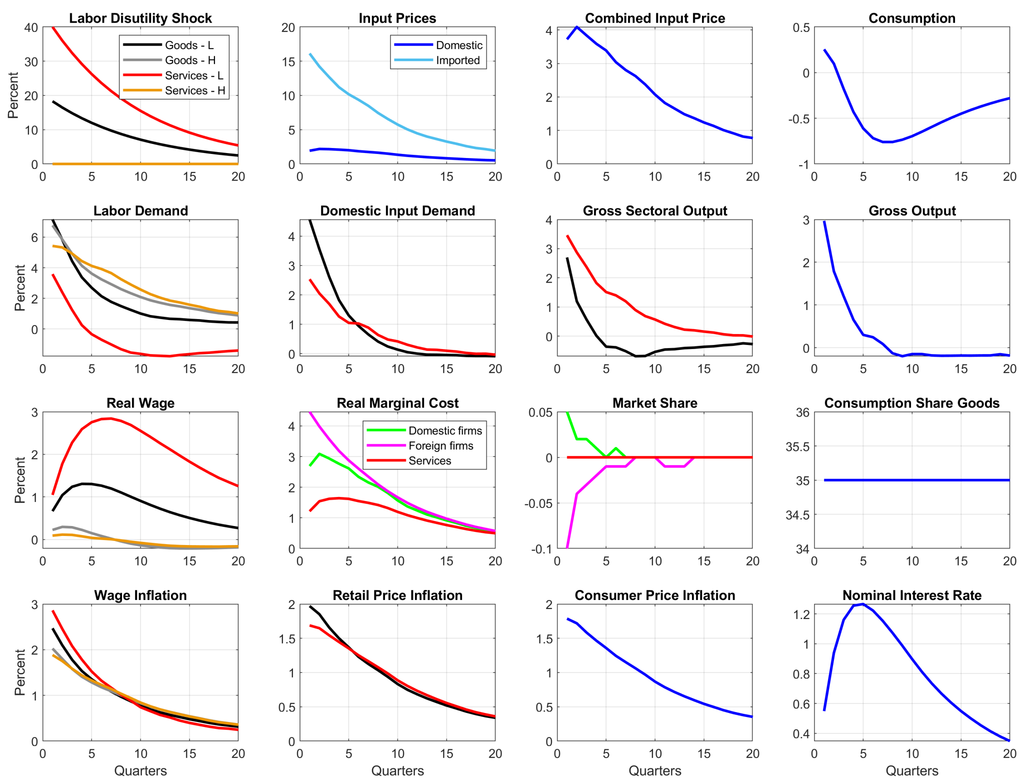
$$(\eta^s-1)(C_t - hC_{t-1})^{-\sigma} w_t^{so} = \kappa_t^{so}\eta^{so}(L_t^{so})^{(1+\varphi)-1} - \psi_w \pi_t^{so,w}(1+\pi_t^{so,w}) + E_t\beta_t\psi_w\pi_{t+1}^{so,w}(1+\pi_{t+1}^{so,w})$$

for each sector and labor type.

We calibrate ρ_s as in the baseline. We set $\vartheta_s = 1.5$ in both sectors to capture that there is a relatively low elasticity of substitution between intermediates and high-skilled labor. We set the disutility parameter $\kappa_{SL} = 1$, and set the other disutilities to match the wage gaps between low- and high-skilled labor and between manufacturing and services from the QWI. We define low-skilled workers as those with at most a high-school degree and high-skilled workers as those with at least some college. The wage gaps are $w^{ML}/w^{SL} = 1.28$, $w^{SH}/w^{SL} = 1.68$, and $w^{MH}/w^{SL} = 1.97$.

We simulate the model with a joint imported input, labor disutility, and foreign competitor shock as in the main text. We assume that the labor disutility shock only affects low-skilled labor, reflecting workers' inability to work remotely in these sectors during the pandemic. The first panel in the first row of Figure A.3 shows the disutility shock to low-skilled goods and services labor. We assume a larger shock than in the baseline since only one type of labor is affected. The second row shows that there is a shift towards domestic labor as in the baseline model, but relatively less so for low-skilled services, which experienced the largest disutility shock. In the third row, we find that real wages strongly increase in low-skilled services and goods, while real wages in high-skilled goods and services are relatively unchanged. The final row shows that price inflation is around 2 percent in this extended model as in the baseline. Overall, the patterns are qualitatively similar to the baseline, but generate heterogeneous responses of real wages.

Figure A.3: Impulse Responses with Heterogeneous Labor



Source: Author's calculations. Figure shows the effect of a joint disutility, input price, and competitor shock in the extended model with heterogeneous labor. Each panel shows the percent deviation of a variable from its steady state value against the number of quarters passed since the initial shock. For wage and price inflation and the market share, we show percentage point changes from steady state. For the consumption share of goods we show its actual value.

C IV-LP Pass-Through Regressions

We construct impulse response functions of a change in wages or input prices on prices using an instrumental variables local projection (IV-LP) approach following Ramey (2016). Specifically, we estimate

$$\sum_{j=1}^{k}(\ln(P_{i,t+j})-\ln(P_{it}))=\beta_k\sum_{j=1}^{k}(\ln(W_{i,t+j})-\ln(W_{it}))+\alpha X_{it}+\delta_i+\psi_t+\epsilon_{it} \tag{100}$$

for wages and

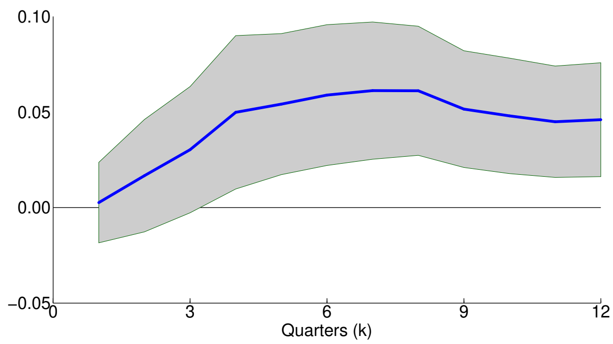
$$\sum_{j=1}^{k}(\ln(P_{i,t+j})-\ln(P_{it}))=\gamma_k\sum_{j=1}^{k}(\ln(P_{i,t+j,input})-\ln(P_{it,input}))+\alpha X_{it}+\delta_i+\psi_t+\epsilon_{it} \tag{101}$$

for input prices, where P_{it} is the producer price index in industry i and quarter t, W_{it} is the industry's wage index, and $P_{it,input}$ is the industry's input price as constructed in the main text. We instrument for both the cumulative wage term $\sum_{j=1}^{k}(\ln(W_{i,t+j})-\ln(W_{it}))$ and for the cumulative input price term $\sum_{j=1}^{k}(\ln(P_{i,t+j,input})-\ln(P_{it,input})$ with two instruments: the contemporaneous, 12-quarter change in wages, $\ln(W_{it})-\ln(W_{i,t-12})$ and the contemporaneous, 12-quarter change in input prices, $\ln(P_{it,input})-\ln(P_{i,t-12,input})$ to obtain the impact of a contemporaneous shock. The choice of these instruments is driven by the first stage of the regression. We found that 12-quarter changes have a better first stage than 4-quarter changes.

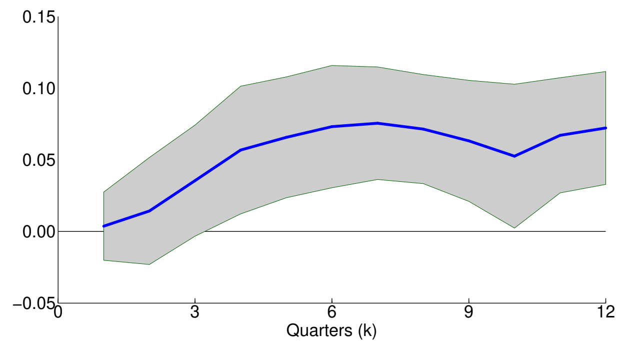
The top left panel of Figure A.4 shows the estimated IV coefficients on the cumulative wage term, β_k, for $k=1,...,12$ using all industries in our dataset for the period 2013:q1 to 2021:q3. Pass-through of wage shocks increases steadily over time until about 8 quarters, peaking at about 6%. The right panel of Figure A.4 presents results for the goods sector only, and the bottom panel presents results for the services sector. Pass-through is relatively similar in both sectors. We note that our findings differ quantitatively from the results in Heise et al. (2022) since we use 6-digit NAICS industries as opposed to 5-digit in our earlier paper and due to the different time period considered.

Figure A.5 shows the estimated IV coefficients on the cumulative input price term, γ_k. Pass-through is significantly stronger for input prices than for wages. Moreover, pass-through is higher in goods than in services.

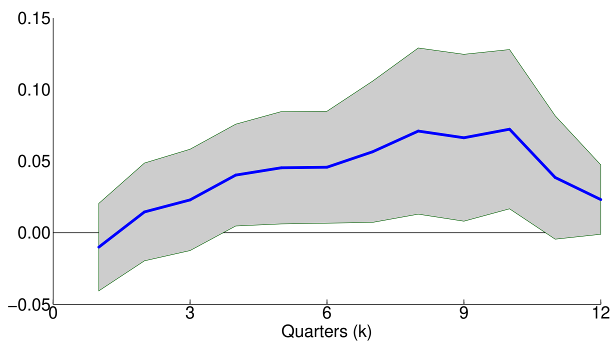
Figure A.4: Impulse Response Functions of Wages using the IV-LP Approach



(a) All Industries



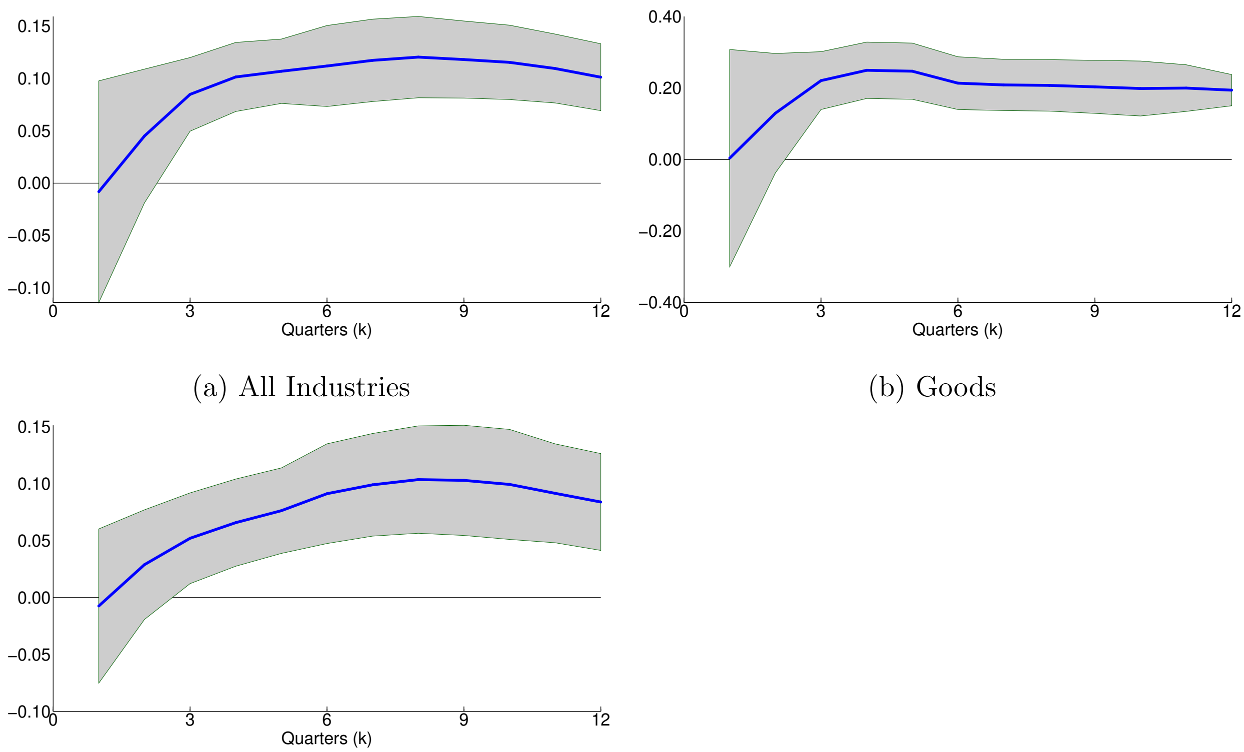
(b) Goods



(c) Services

Source: BLS, Census Bureau Quarterly Census of Employment and Wages, authors' calculations. Note: The figure presents the estimated coefficients β_k from specification (100) and their 90 percent confidence intervals for $k = 1, ..., 20$ quarters. Prices are the seasonally-adjusted producer price indices and wages are the seasonally-adjusted average weekly wages of 6-digit NAICS industries. All data are at the quarterly frequency. Controls in the regression are employment shares of middle-aged and older workers, employment shares of those with high school, associate's, or bachelor's degrees, and employment share of female workers. Panel (a) presents the estimated coefficients β_k based on a regression using all industries in our sample. Panels (b) uses only goods industries and Panel (c) uses only service industries.

Figure A.5: Impulse Response Functions of Input Prices using the IV-LP Approach



(a) All Industries

(b) Goods

(c) Services

Source: BLS, Census Bureau Quarterly Census of Employment and Wages, authors' calculations. Note: The figure presents the estimated coefficients γ_k from specification (101) and their 90 percent confidence intervals for $k = 1, ..., 20$ quarters. Prices are the seasonally-adjusted producer price indices and wages are the seasonally-adjusted average weekly wages of 6-digit NAICS industries. All data are at the quarterly frequency. Controls in the regression are employment shares of middle-aged and older workers, employment shares of those with high school, associate's, or bachelor's degrees, and employment share of female workers. Panel (a) presents the estimated coefficients γ_k based on a regression using all industries in our sample. Panels (b) uses only goods industries and Panel (c) uses only service industries.

D Additional Empirical Results

In this section, we present some additional empirical results using our industry-level data.

D.1 Summary Statistics

We recompute the summary statistics in Table 3, but residualize all wage and input price changes with industry fixed effects. The results are in Table A.1. Here, the fourth row of each panel corresponds to the fifth row of each panel in Table 3. As in the text, the correlation between wage and input price changes in both goods and services rises in 2020.

D.2 Longer Time Horizons

To check whether our results hold over longer time horizons, we re-run our baseline analysis in the goods and services sectors using eight and twelve quarter differences for all variables. Column 1 of Table A.2 shows that we still see a positive correlation of prices in the goods sector with input prices, wages, and foreign competitors' prices. In Column 2, we see similar results as in the baseline specification, with stronger correlations between foreign competitors' prices, input prices and wage changes in 2021. Column 3 includes additional interactions and continues to find that the interaction of wages and input prices completely explains the increase in the pass-through of costs in 2021. The final column includes additional interactions for 2020 and whether an industry was in the top quartile of the wage and input price change distribution. In contrast to our baseline specification, we find that the coefficient on the quadruple interaction becomes insignificant.

Table A.3 repeats the analysis using twelve quarter differences. Column 2 shows that, in contrast to our baseline regression, we do not see evidence that the correlation between competitors' prices and producer prices increased in 2021. The remaining results are similar to the eight quarter analysis.

In Tables A.4 and A.5, we do the same for services and find similar results to our baseline regression.

D.3 Constrained Regression

One concern with our findings in the main text is that we did not impose the restriction that the coefficient on the wage and the coefficient on labor productivity are of equal and opposite signs, as implied by the theory. We therefore re-run our baseline regression (33), but impose the restriction $\beta_1 + \beta_2 = 0$. The results, in column 1 of Table A.6, are similar to those in the main text. In the second column, we additionally include interactions with 2021.

We also interact productivity with a 2021 dummy, and impose the additional constraint that the coefficients on the wage and productivity terms interacted with 2021 are of equal and opposite signs. We still find that the correlation of wages with prices increases in 2021, as in the baseline. In column 3, we additionally include the interaction between wage changes and input price changes. While we still find a positive interaction effect in 2021, this effect is no longer significant once we impose the constraint.

D.4 Domestic Competitors

One issue with our findings in the main text is that we do not control for domestic competitors. Some of the correlation of prices with input costs and wages could be due to a response to domestic competitors' price changes. While our industry-level data do not permit us to take into account within-industry competition, we construct a measure of domestic competition using the price index at the more aggregated 4-digit NAICS industry level. Specifically, we compute for each 6-digit industry a 4-quarter producer price change of the associated 4-digit industry in each quarter by taking a weighted average across the 4-quarter PPI changes of all associated 6-digit industries, using total shipments in 2021 as weight. We include the resulting variable $\Delta \ln(p_{it}^{PPI4})$ in the regression, interacted with industry i's domestic share, $1 - s_i$. To be consistent, we construct the foreign competitors' price change analogously.

The results in column 1 of Table A.7 still indicate a positive correlation of prices in the goods sector with input prices, wages, and foreign competitors' prices. In addition to that, we also find a positive correlation with our proxy for domestic competitors. In column 2, we further add interactions with 2021 and find that pass-through of input prices and wages increased in that year, as before. While we do find a strengthening correlation of producer prices with foreign competitors' prices, we do not find a similar strengthening of the correlation with domestic competitors' prices. Column 3 presents our non-linear specification results. As before, we find a positive and significant interaction between wage changes and input price changes in 2021.

D.5 Regression With Shift in Demand

A concern with our analysis is that while we focus on changes in input costs, demand factors could also be responsible for our findings. To examine whether an increase in demand could be behind our results, we re-run our baseline analysis in the goods sector with time-by-3-digit NAICS industry fixed effects. These fixed effects sweep out any variation that occurs at the broad 3-digit industry level. If demand shocks affect all industries that are part of a broader 3-digit aggregate equally, then the remaining variation is due to supply factors. Since the productivity measure is at most at the 3-digit level, this regression does not separately identify a productivity effect.

Column 1 of Table A.8 shows pass-through coefficients very similar to those in our baseline regression. Thus, most of the variation we pick up is due to variation within 3-digit industries. Column 2 shows that as before we find a significant pick-up in the correlation between domestic prices, wages, and input prices in 2021. The final column shows the results from the non-linear specification. As in the baseline, we find a significant and positive interaction effect in 2021.

Table A.1: Changes in Input Prices and Wages in Goods and Services, Residualized by Industry Fixed Effects

	Goods		Services	
2013:Q1 - 2019:Q4	$\Delta \ln(P_{it,input})$	$\Delta \ln(Wage_{it})$	$\Delta \ln(P_{it,input})$	$\Delta \ln(Wage_{it})$
Mean	-0.011	-0.004	-0.009	-0.006
P50	-0.007	-0.004	-0.003	-0.004
Mean of 4th quartile	0.050	0.051	0.077	0.037
Correlation	0.046		0.076	
2020				
Mean	-0.035	0.008	-0.068	0.016
P50	-0.027	0.003	-0.036	0.007
Mean of 4th quartile	0.014	0.089	-0.009	0.090
Correlation	0.312		0.205	
2021				
Mean	0.136	0.022	0.166	0.027
P50	0.112	0.025	0.111	0.022
Mean of 4th quartile	0.283	0.099	0.399	0.110
Correlation	0.229		0.192	

Notes: The table shows summary statistics on the average four-quarter change in wages and input prices for goods (first two columns) and services (last two columns), where these changes are residualized by industry fixed effects. Each panel focuses on changes in a specific time period. The first row shows the mean of the four-quarter change. The second row presents the median, and the third row the average over industries in the 4th quartile. The fourth row shows the correlation between wage and industry price changes.

Table A.2: Pass-Through for Goods with 8Q Differences, 2013:Q1 - 2021:Q3

	(1) $\Delta\ln(p_{it})$	(2) $\Delta\ln(p_{it})$	(3) $\Delta\ln(p_{it})$	(4) $\Delta\ln(p_{it})$
$s_i \times \Delta\ln(p_{it,imp})$	0.279***	0.256***	0.257***	0.242***
	(0.038)	(0.031)	(0.031)	(0.035)
$s_i \times \Delta\ln(p_{it,imp}) \times$ Year=20				0.068
				(0.041)
$s_i \times \Delta\ln(p_{it,imp}) \times$ Year=21		0.202***	0.187***	0.203***
		(0.043)	(0.049)	(0.049)
$\Delta\ln(p_{it,input})$	0.334***	0.290***	0.303***	0.312***
	(0.041)	(0.023)	(0.025)	(0.032)
$\Delta\ln(p_{it,input}) \times$ Year=20				-0.003
				(0.029)
$\Delta\ln(p_{it,input}) \times$ Year=21		0.228***	0.070	0.050
		(0.042)	(0.052)	(0.064)
$\Delta\ln(Wage_{it})$	0.022**	0.008	0.007	-0.004
	(0.010)	(0.014)	(0.013)	(0.013)
$\Delta\ln(Wage_{it}) \times$ Year=20				0.023
				(0.029)
$\Delta\ln(Wage_{it}) \times$ Year=21		0.092**	-0.082**	-0.072**
		(0.044)	(0.033)	(0.033)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input})$			-0.083	0.063
			(0.174)	(0.182)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input}) \times$ Year=20				-0.970
				(0.961)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input}) \times$ Year=21			1.775***	1.633***
			(0.271)	(0.301)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input}) \times \times$HH $\times$ Year=20				0.192
				(1.015)
$\Delta\ln(A_{it})$	-0.168***	-0.168***	-0.183***	-0.179***
	(0.022)	(0.022)	(0.022)	(0.026)
Time Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Worker Composition	Yes	Yes	Yes	Yes
Nonlinear Effects	No	No	Yes	Yes
R2	0.152	0.160	0.165	0.166
Observations	8,240	8,240	8,240	8,240

Notes: The table shows the results from running the baseline regression (33) for goods, but replacing 4-quarter differences with 8-quarter differences. The first column shows the results for the baseline regression. The second column includes interactions for 2021. The third column includes an interaction between wage changes and intermediate input price changes. The fourth column includes additional interactions for 2020. All regressions include time and industry fixed effects and controls for the log share of workers 25-54, log share of workers 55+, log share of women, and log shares of workers with a high-school degree, associates degree, and bachelors degree or higher. The last two columns additionally include non-linear terms from (30), i.e., an interaction term between wage changes and input price changes, an interaction between productivity and input price changes, and squared wage and input price terms. We interact all terms with dummies for 2021. The last column contains additionally interactions of competitors' prices, input prices, wages, and productivity with a dummy for 2020, as well as interactions between wages, input price changes, a dummy for 2020, and dummies for whether both wage and input price change were above median (HH), the wage change was below median and the input price change above median (LH), and the wage change was above median and the input price change below median (HL). We only report in the table the main coefficients of interest.

Table A.3: Pass-Through for Goods with 12Q Differences, 2013:Q1 - 2021:Q3

	(1) $\Delta \ln(p_{it})$	(2) $\Delta \ln(p_{it})$	(3) $\Delta \ln(p_{it})$	(4) $\Delta \ln(p_{it})$
$s_i \times \Delta \ln(p_{it,imp})$	0.226***	0.232***	0.231***	0.235***
	(0.022)	(0.023)	(0.021)	(0.023)
$s_i \times \Delta \ln(p_{it,imp}) \times$ Year=20				-0.023
				(0.027)
$s_i \times \Delta \ln(p_{it,imp}) \times$ Year=21		-0.025	-0.037	-0.043
		(0.049)	(0.044)	(0.049)
$\Delta \ln(p_{it,input})$	0.337***	0.306***	0.306***	0.310***
	(0.040)	(0.025)	(0.031)	(0.036)
$\Delta \ln(p_{it,input}) \times$ Year=20				-0.000
				(0.047)
$\Delta \ln(p_{it,input}) \times$ Year=21		0.204***	0.085	0.077
		(0.050)	(0.072)	(0.084)
$\Delta \ln(Wage_{it})$	0.008	-0.017	-0.011	-0.017
	(0.013)	(0.015)	(0.013)	(0.014)
$\Delta \ln(Wage_{it}) \times$ Year=20				0.047**
				(0.019)
$\Delta \ln(Wage_{it}) \times$ Year=21		0.138***	0.019	0.025
		(0.036)	(0.024)	(0.024)
$\Delta \ln(Wage_{it}) \times \Delta \ln(p_{it,input})$			0.055	0.079
			(0.110)	(0.110)
$\Delta \ln(Wage_{it}) \times \Delta \ln(p_{it,input}) \times$ Year=20				-0.816
				(0.714)
$\Delta \ln(Wage_{it}) \times \Delta \ln(p_{it,input}) \times$ Year=21			1.083***	1.063***
			(0.135)	(0.143)
$\Delta \ln(Wage_{it}) \times \Delta \ln(p_{it,input}) \times \times$HH $\times$ Year=20				0.218
				(0.688)
$\Delta \ln(A_{it})$	-0.136***	-0.136***	-0.162***	-0.185***
	(0.032)	(0.033)	(0.026)	(0.025)
Time Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Worker Composition	Yes	Yes	Yes	Yes
Nonlinear Effects	No	No	Yes	Yes
R2	0.147	0.154	0.160	0.162
Observations	6,960	6,960	6,960	6,960

Notes: The table shows the results from running the baseline regression (33) for goods, but replacing 4-quarter differences with 12-quarter differences. The first column shows the results for the baseline regression. The second column includes interactions for 2021. The third column includes an interaction between wage changes and intermediate input price changes. The fourth column includes additional interactions for 2020. All regressions include time and industry fixed effects and controls for the log share of workers 25-54, log share of workers 55+, log share of women, and log shares of workers with a high-school degree, associates degree, and bachelors degree or higher. The last two columns additionally include non-linear terms from (30), i.e., an interaction term between wage changes and input price changes, an interaction between productivity and input price changes, and squared wage and input price terms. We interact all terms with dummies for 2021. The last column contains additionally interactions of competitors' prices, input prices, wages, and productivity with a dummy for 2020, as well as interactions between wages, input price changes, a dummy for 2020, and dummies for whether both wage and input price change were above median (HH), the wage change was below median and the input price change above median (LH), and the wage change was above median and the input price change below median (HL). We only report in the table the main coefficients of interest.

Table A.4: Pass Through for Services with 8Q Differences, 2013:Q1 - 2021:Q3

	(1) $\Delta\ln(p_{it})$	(2) $\Delta\ln(p_{it})$	(3) $\Delta\ln(p_{it})$
$\Delta\ln(p_{it,input})$	0.089***	0.084***	0.108***
	(0.009)	(0.011)	(0.018)
$\Delta\ln(p_{it,input}) \times$ Year=21		0.140***	0.218***
		(0.029)	(0.048)
$\Delta\ln(Wage_{it})$	0.084**	0.055*	0.035
	(0.032)	(0.029)	(0.030)
$\Delta\ln(Wage_{it}) \times$ Year=21		0.144***	0.238
		(0.049)	(0.147)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input})$			-0.108*
			(0.061)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input}) \times$ Year=21			-1.198*
			(0.650)
$\Delta\ln(A_{it})$	0.003	0.005	0.007
	(0.014)	(0.012)	(0.014)
Time Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Worker Composition	Yes	Yes	Yes
Nonlinear Effects	No	No	Yes
R2	0.059	0.064	0.068
Observations	4,522	4,522	4,522

Notes: The table shows the results from running the baseline regression (33) for services but replacing 4-quarter differences with 8-quarter differences. The first column shows the results for the baseline regression. The second column includes interactions for 2021. The third column includes an interaction between wage changes and intermediate input price changes. All regressions include time and industry fixed effects and controls for the log share of workers 25-54, log share of workers 55+, log share of women, and log shares of workers with a high-school degree, associates degree, and bachelors degree or higher. The last column additionally includes non-linear terms from (30), i.e., an interaction term between wage changes and input price changes, an interaction between productivity and input price changes, and squared wage and input price terms. We interact all terms with dummies for 2021. We only report in the table the main coefficients of interest.

Table A.5: Pass Through for Services with 12Q Differences, 2013:Q1 - 2021:Q3

	(1) $\Delta \ln(p_{it})$	(2) $\Delta \ln(p_{it})$	(3) $\Delta \ln(p_{it})$
$\Delta \ln(p_{it,input})$	0.095***	0.094***	0.136***
	(0.008)	(0.008)	(0.018)
$\Delta \ln(p_{it,input}) \times$ Year=21		0.075	0.106
		(0.076)	(0.166)
$\Delta \ln(Wage_{it})$	0.067**	0.042	0.022
	(0.030)	(0.029)	(0.034)
$\Delta \ln(Wage_{it}) \times$ Year=21		0.106**	0.214
		(0.042)	(0.155)
$\Delta \ln(Wage_{it}) \times \Delta \ln(p_{it,input})$			-0.100*
			(0.050)
$\Delta \ln(Wage_{it}) \times \Delta \ln(p_{it,input}) \times$ Year=21			-1.212
			(1.232)
$\Delta \ln(A_{it})$	0.013	0.012	0.012
	(0.017)	(0.017)	(0.016)
Time Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Worker Composition	Yes	Yes	Yes
Nonlinear Effects	No	No	Yes
R2	0.072	0.074	0.079
Observations	3,802	3,802	3,802

Notes: The table shows the results from running the baseline regression (33) for services but replacing 4-quarter differences with 12-quarter differences. The first column shows the results for the baseline regression. The second column includes interactions for 2021. The third column includes an interaction between wage changes and intermediate input price changes. All regressions include time and industry fixed effects and controls for the log share of workers 25-54, log share of workers 55+, log share of women, and log shares of workers with a high-school degree, associates degree, and bachelors degree or higher. The last column additionally includes non-linear terms from (30), i.e., an interaction term between wage changes and input price changes, an interaction between productivity and input price changes, and squared wage and input price terms. We interact all terms with dummies for 2021. We only report in the table the main coefficients of interest.

Table A.6: Pass Through for Traded Industries with Constraints, 2013:Q1 - 2021:Q3

	(1) $\Delta\ln(p_{it})$	(2) $\Delta\ln(p_{it})$	(3) $\Delta\ln(p_{it})$
$s_i \cdot \Delta\ln(p_{it,imp})$	0.241***	0.191***	0.192***
	(0.029)	(0.026)	(0.026)
$s_i \cdot \Delta\ln(p_{it,imp}) \times$ Year=21		0.484***	0.488***
		(0.119)	(0.121)
$\Delta\ln(p_{it,input})$	0.360***	0.286***	0.315***
	(0.025)	(0.019)	(0.022)
$\Delta\ln(p_{it,input}) \times$ Year=21		0.143**	-0.034
		(0.057)	(0.085)
$\Delta\ln(Wage_{it})$	0.103***	0.087***	0.084***
	(0.010)	(0.009)	(0.009)
$\Delta\ln(Wage_{it}) \times$ Year=21		0.093*	0.084
		(0.047)	(0.055)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input})$			-0.310
			(0.272)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input}) \times$ Year=21			0.760
			(0.650)
$\Delta\ln(A_{it})$	-0.103***	-0.087***	-0.084***
	(0.010)	(0.009)	(0.009)
$\Delta\ln(A_{it}) \times$ Year=21		-0.093*	-0.084
		(0.047)	(0.055)
Time Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Worker Composition	Yes	Yes	Yes
Nonlinear Effects	No	No	Yes
Observations	9,549	9,549	9,549

Notes: The table shows the results from running the baseline regression (33) for goods but imposing that $\beta_1 + \beta_2 = 0$. The first column shows the results for the baseline regression. The second column includes interactions for 2021, where we impose for these terms as well that the coefficients on wage changes and productivity changes add to zero. The third column includes an interaction between wage changes and intermediate input price changes. All regressions include time and industry fixed effects and controls for the log share of workers 25-54, log share of workers 55+, log share of women, and log shares of workers with a high-school degree, associates degree, and bachelors degree or higher. The last column additionally includes non-linear terms from (30), i.e., an interaction term between wage changes and input price changes, an interaction between productivity and input price changes, and squared wage and input price terms. We interact all terms with dummies for 2021. We only report in the table the main coefficients of interest.

Table A.7: Pass Through for Domestic Competitors, 2013:Q1 - 2021:Q3

	(1) $\Delta\ln(p_{it})$	(2) $\Delta\ln(p_{it})$	(3) $\Delta\ln(p_{it})$
$s_i \times \Delta\ln(p_{it,imp}^{PPI4})$	0.242***	0.179***	0.175***
	(0.050)	(0.021)	(0.019)
$s_i \times \Delta\ln(p_{it,imp}^{PPI4}) \times$ Year=21		0.537***	0.551***
		(0.114)	(0.119)
$(1-s_i) \times \Delta\ln(p_{it}^{PPI4})$	0.531***	0.491***	0.491***
	(0.022)	(0.043)	(0.043)
$(1-s_i) \times \Delta\ln(p_{it}^{PPI4}) \times$ Year=21		0.036	0.030
		(0.045)	(0.046)
$\Delta\ln(p_{it,input})$	0.155***	0.119***	0.145***
	(0.023)	(0.023)	(0.024)
$\Delta\ln(p_{it,input}) \times$ Year=21		0.097***	-0.073
		(0.022)	(0.064)
$\Delta\ln(Wage_{it})$	0.040**	0.019	0.015
	(0.016)	(0.013)	(0.010)
$\Delta\ln(Wage_{it}) \times$ Year=21		0.160***	0.071
		(0.020)	(0.049)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input})$			-0.358
			(0.258)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input}) \times$ Year=21			1.058***
			(0.310)
$\Delta\ln(A_{it})$	-0.096***	-0.099***	-0.093***
	(0.013)	(0.015)	(0.016)
$\Delta\ln(A_{it}) \times$ Year=21		0.019	-0.036
		(0.032)	(0.044)
Time Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Worker Composition	Yes	Yes	Yes
Nonlinear Effects	No	No	Yes
R2	0.231	0.241	0.243
Observations	9,857	9,857	9,857

Notes: The table shows the results from running the baseline regression (33) for goods but incorporating an additional control for the price change of domestic competitors, $\Delta\ln(p_{it}^{PPI4})$, constructed as the weighted average PPI change of the corresponding 4-digit NAICS industry. We interact this price change with the domestic share, $1 - s_i$. The first column shows the results for the baseline regression. The second column includes interactions for 2021. The third column includes an interaction between wage changes and intermediate input price changes. All regressions include time and industry fixed effects and controls for the log share of workers 25-54, log share of workers 55+, log share of women, and log shares of workers with a high-school degree, associates degree, and bachelors degree or higher. The last column additionally includes non-linear terms from (30), i.e., an interaction term between wage changes and input price changes, an interaction between productivity and input price changes, and squared wage and input price terms. We interact all terms with dummies for 2021. We only report in the table the main coefficients of interest.

Table A.8: Pass Through with Time-by-Industry Fixed Effects, 2013:Q1 - 2021:Q3

	(1) $\Delta\ln(p_{it})$	(2) $\Delta\ln(p_{it})$	(3) $\Delta\ln(p_{it})$
$s_i \cdot \Delta\ln(p_{it,imp})$	0.215***	0.173***	0.174***
	(0.041)	(0.029)	(0.029)
$s_i \cdot \Delta\ln(p_{it,imp}) \times$ Year=21		0.407***	0.422***
		(0.130)	(0.139)
$\Delta\ln(p_{it,input})$	0.308***	0.234***	0.276***
	(0.054)	(0.042)	(0.046)
$\Delta\ln(p_{it,input}) \times$ Year=21		0.166***	-0.044
		(0.060)	(0.091)
$\Delta\ln(Wage_{it})$	0.032*	0.014	0.007
	(0.018)	(0.015)	(0.012)
$\Delta\ln(Wage_{it}) \times$ Year=21		0.100***	-0.030
		(0.018)	(0.056)
$\Delta\ln(Wage_{it}) \times \ln(p_{it,input})$			-0.662*
			(0.355)
$\Delta\ln(Wage_{it}) \times \Delta\ln(p_{it,input}) \times$ Year=21			1.844***
			(0.435)
Time by 3-digit Industry Fixed Effects	Yes	Yes	Yes
Worker Composition	Yes	Yes	Yes
Nonlinear Effects	No	No	Yes
R2	0.065	0.078	0.081
Observations	9,549	9,549	9,549

Notes: The table shows the results from running the baseline regression (33) for goods but replacing quarter and 6-digit NAICS industry fixed effects by quarter-by-3-digit NAICS fixed effects. The first column shows the results for the baseline regression. The second column includes interactions for 2021. The third column includes an interaction between wage changes and intermediate input price changes. All regressions include controls for the log share of workers 25-54, log share of workers 55+, log share of women, and log shares of workers with a high-school degree, associates degree, and bachelors degree or higher. The last column additionally includes non-linear terms from (30), i.e., an interaction term between wage changes and input price changes, an interaction between productivity and input price changes, and squared wage and input price terms. We interact all terms with dummies for 2021. We only report in the table the main coefficients of interest.