Global Inflation Spillovers and Costly Supply Chains

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Abstract

This paper studies cross-country inflation spillovers arising from a sudden reallocation of household demand from services to goods and the resulting cost pressure on production and international trade, with a particular focus on the role of global production linkages. Using a two-country multi-sector New Keynesian model with input-output linkages whereby firms face asymmetric adjustment costs of expanding employment and international goods shipment, I show that, when both countries experience demand reallocation from services to goods, the cross-country spillover of foreign inflationary pressure accounts for around one-quarter of the peak CPI inflation response, substantially larger than the calibrated size of trade relative to GDP for the United States. Importantly, international trade in intermediate production inputs significantly amplifies the cross-country spillover of inflationary pressure when demand reallocates from services to goods. However, the asymmetries in the adjustment costs and the dominance of goods trade relative to services trade imply that such propagation mechanism is absent when demand reallocation occurs in reverse, shifting from goods to services.

The views expressed in this paper are those of the author, and do not reflect those of the Bank of Canada. Any remaining errors are my own.

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1 Introduction

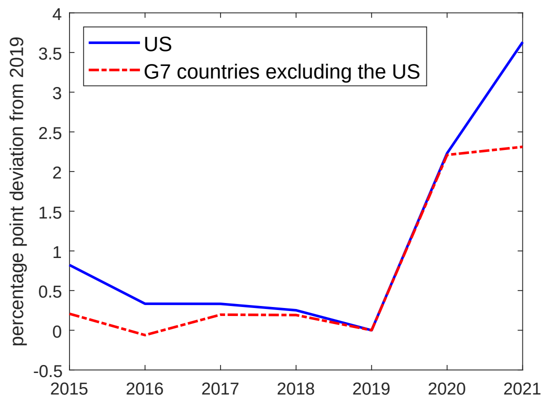
The Covid-19 pandemic brought unprecedented disruptions to the economies around the world, shifting production and distribution of goods and services across sectors and countries. Following the imposition of lockdown measures in March 2020 and the subsequent large contraction in broad economic activity, the social distancing practice led to a sudden shift in consumers' spending patterns away from services toward goods. Ferrante, Graves and Iacoviello (2023) show that such demand reallocation from services to goods as observed in the US becomes inflationary when it is costly for firms to increase employment, explaining a large fraction of the observed US inflation during the pandemic period.

Given the global nature of the pandemic, the sudden, large shift in consumer expenditure was not limited to the United States, and other advanced economies also experienced expenditure reallocation of a similar magnitude. Figure 1 shows the share of final consumption expenditure on goods for the United States and the G6-country aggregate (G7 countries excluding the US), expressed as percentage-point deviations from their respective 2019 levels.[1] In the United States, the goods expenditure share increased 2.2 percentage points in 2020 and further 1.4 percentage points in 2021. Similarly, the G6 aggregate experienced an increase of 2.2 percentage points in 2020 and another 0.1 percentage point in 2021.

An important consequence of this global shift in demand was a drastic shift in the patterns of international trade, with goods trade rebounding and growing more rapidly relative to services trade. Figure 2 shows the evolutions of US exports and imports of goods and services between 2017Q1 and 2023Q3. After the initial large contraction in 2020Q1-Q2, both exports and imports started to recover. Importantly, however, goods trade and services trade exhibited a markedly different speed of recovery over the subsequent periods. Goods trade (blue line) recovered almost immediately to the pre-pandemic level for both exports and imports, and continued a steady growth thereafter. In stark contrast, the recovery of services trade (red dash-dotted line) was significantly more delayed, especially for exports.

[1] In 2019, the share of consumer spending on goods was 32.0 percent for the United States, and 43.9 percent for the G6 aggregate. Data source: OECD Annual National Accounts, final consumption expenditure of households.

Figure 1: Share of final consumption expenditure on goods



Notes: This figure plots the share of consumer expenditures on goods for the United States (blue solid line) and the G6 countries (the G7 countries excluding the US, shown in a red dash-dotted line), expressed as percentage point deviation from the 2019 levels. In 2019, the share of consumer spending on goods was 32.0 percent for the United States, and 43.9 percent for the G6 aggregate. Data source: OECD Annual National Accounts, final consumption expenditure of households.

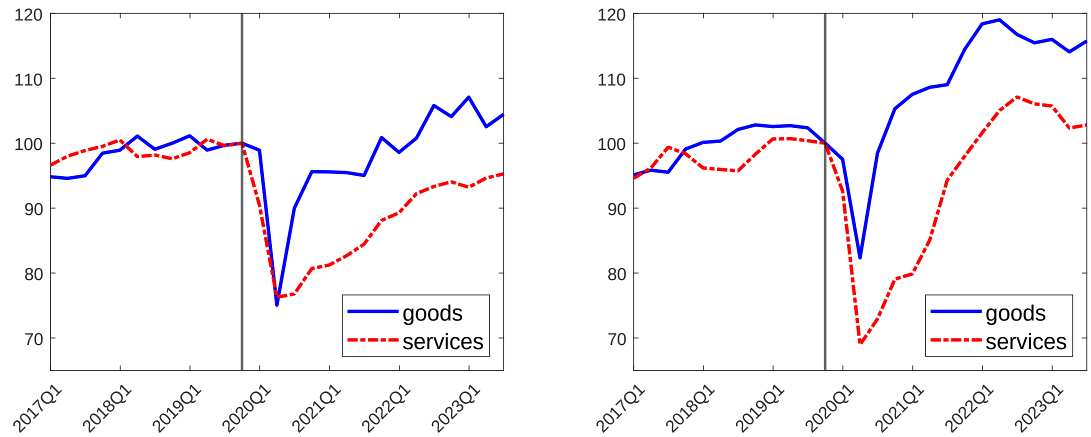
This sharp surge in goods trade, combined with the reduced transportation capacity due to port lockdowns, resulted in an unprecedented pressure on the shipping industry, a vital link that connects production chains around the world. Figure 3 shows the evolutions of the US container import volume and global freight costs around the time of the pandemic. Following the initial drop in early 2020, the container import volume started to increase in June 2020, reaching 2.5 million TEUs by March 2021 (figure 3a), and remained elevated until mid 2022. This strong rise in demand for international goods trade contributed to a rising pressure on shipping costs, and freight costs increased sharply during this period (figure 3b). For example, by mid 2021, the cost of shipping dry bulk materials by sea, measured by the Baltic Dry Index, increased by more than three-fold (blue line), while the cost of ocean freight container, measured by the Freightos index, increased by as much as seven times (red line). The skyrocketing freight costs were often cited as a source of inflationary pressures.[2]

Against this backdrop, this paper studies cross-country inflation spillovers arising from a global demand reallocation and the resulting cost pressure on production and international trade, with a particular focus on the role of production linkages in propagating the inflation dynamics. I

[2] See, for example, “Inflation: Seven reasons the cost of living is going up around the world,” BBC, January 20, 2022. “Biden criticizes ‘foreign owned’ shipping companies for helping to drive inflation as he signs new law,” CNN, June 16, 2022.

Figure 2: Real exports and imports of goods and services, United States (2019Q4=100)

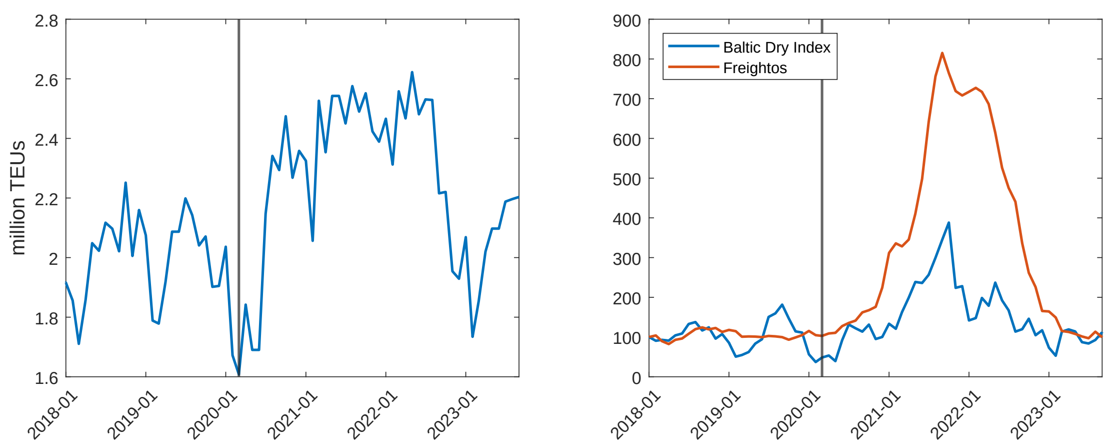
(a) exports (b) imports



Notes: Panel (a): US real exports of goods (blue solid line) and services (red dash-dotted line), in billions of chained 2017 dollars, normalized to their respective 2019Q4 value. Panel (b): US real imports of goods (blue solid) and services (red dot-dashed line), in billions of chained 2017 dollars, normalized to their respective 2019Q4 value. In both panels, the black vertical line indicates 2019Q4, the last period before the beginning of the Covid-19 pandemic. The data series are seasonally adjusted annual rate. Data source: U.S. Bureau of Economic Analysis.

Figure 3: Container import volume and shipping costs

(a) US container import volume (b) freight costs indices (2018m1=100)



Notes: Panel (a): US import container volume in the twenty-foot equivalent unit (TEU). Data source: Descartes. Panel (b): Freight cost indices. Data sources: Baltic Dry Index and Freightos. In both panels, the vertical line indicates the beginning of the Covid-19 lockdown in March 2020.

extend the closed-economy, multi-sector New Keynesian model of Ferrante, Graves and Iacoviello (2023) with input-output linkages and frictions in adjusting employment, to a two-country environment, and introduce additional frictions in international trade of goods. The labor market friction arises through labor adjustment costs following Ferrante, Graves and Iacoviello (2023) whereby firms face quadratic adjustment costs when increasing employment relative to last period while reducing employment is costless. In addition to the labor adjustment costs, I introduce additional transportation costs for goods trade that arise when sectoral goods exports exceed their steady-state levels, accounting for the observed cost pressure in international shipping during the pandemic. Because these labor adjustment costs and transportation costs arise only when expanding production or international trade but not when reducing it, and also because the transportation costs apply only to goods trade and not services trade, the aggregate consequences of demand reallocation become asymmetric and depend on whether demand shifts from services to goods or in reverse.

I show that a global demand reallocation shock that shifts the consumer expenditure share from services to goods in both countries leads to a sizable cross-country spillover of inflationary pressures. When the inflation response is decomposed into a part attributed to the demand reallocation within the domestic economy and that attributed to the country's trade partner, I find that the foreign demand reallocation accounts for more than one-quarter of the peak CPI inflation response. This is significantly larger than the calibrated size of imports relative to GDP in the model, which is about 11 percent as observed for the United States. As in Ferrante, Graves and Iacoviello (2023), demand reallocation in Home country generates an inflationary pressure in the domestic economy as employment shifts from services to goods and firms in goods sectors face the costs of increasing employment. In addition, in my open-economy environment, as demand shifts toward goods, the increased imports of goods lead to higher shipping costs, placing an additional upward pressure on prices there. On the other hand, the country's trade partner (Foreign country) experiences inflationary pressures due to the demand reallocation in Home country through two channels. The first is that the higher prices of output in Home country are transmitted directly through the prices of imports into Foreign country, both to consumer spending (through final-goods trade) and local production costs (through intermediate-input trade). The second channel arises as labor in Foreign country reallocates from services to goods in response to the higher demand for its goods exports, which in turn raises the costs of employment and hence prices in the goods sectors of Foreign country.

When I compare the inflation responses in my baseline model and those from an alternative model without international trade in intermediate inputs, I show that the presence of input trade in my baseline model dampens the impact of domestic demand reallocation on domestic inflation, as imported inputs from abroad serve as relatively cheaper substitutes. However, the presence of input trade significantly amplifies the cross-country inflation spillovers to the country's trade partner economy, as the rising prices of imported inputs raise the cost of local production in both goods and services sectors there.

Importantly, however, such propagation channel of cross-country production linkages for inflation spillovers is absent when demand reallocation occurs in reverse, shifting away from goods to services. The demand reallocation from goods to services increases employment and trade in services sectors, while reducing them in goods sectors. Because my model assumes that reducing employment and goods trade is costless while increasing them is costly, the relative reduction in demand for goods sectors does not generate additional inflationary pressure for goods prices. Since international trade is dominated by goods rather than services, this limits the inflation spillovers to the foreign economy, resulting in a fall in the price of local products in the foreign economy relative to the aggregate price index there.

Lastly, I investigate the implications of demand reallocation shocks for the monetary policy stance. Demand reallocation shocks from services to goods induce rising inflation and a contraction in aggregate output, thus posing a policy dilemma for central banks between inflation and output stability. I show that, if the central bank in a country that is hit by a demand reallocation shock responds more strongly to output fluctuations (while keeping its reaction to inflation unchanged), it leads to even higher inflation and a larger output contraction, not only domestically but also in its trade partner economy. This is because, when demand reallocates from services to goods, the first-order impact is the rising upward pressure on production costs, and hence prices, as expanding employment and imports in goods sectors entails adjustment costs. The rising aggregate inflation in turn reduces household wealth and aggregate consumption and output. Therefore, when the central bank follows a less contractionary policy by responding relatively more strongly to the falling output, the resulting higher inflation leads to even lower domestic consumption and output, and also larger inflation spillovers to the foreign economy.

The remainder of the paper is organized as follows. Section 2 discusses existing studies related to my analysis. In section 3, I describe the quantitative model and equilibrium conditions in detail. The calibration of model parameters is explained in section 4, and results are presented in section 5. Section 6 concludes.

2 Related literature

This paper is related to recent studies examining the aggregate implications of demand reallocation shocks. Ferrante, Graves and Iacoviello (2023) develop a closed-economy, multisector New Keynesian model with labor adjustment costs and input-output linkages, and show that a calibrated demand reallocation shock from services to goods can account for a large fraction of US inflation during and following the Covid-19 pandemic. I extend their closed-economy model to a two-country setting, and introduce asymmetric shipping costs that arise when goods trade exceeds the steady-state level. Di Giovanni et al. (2023) develop and estimate a two-period model with multi-countries and multi-sectors, and decompose the drivers of domestic inflation into various types of shocks. They find that the reallocation of consumption from services to goods contributed to transmitting the demand-supply imbalances abroad through trade and production networks.

My inclusion of increasing shipping costs in a dynamic general equilibrium model contributes to the growing literature on the role of shipping frictions and its aggregate implications. Carriere-Swallow et al. (2022) estimate the impact of shocks to global shipping costs, and report that an increase in freight costs induces sizable and statistically significant rises in import prices, inflation and inflation expectations. Alessandria et al. (2022) develop a two-country general equilibrium model with heterogeneous firms, input-output linkages and various supply-chain frictions including shipping delays, and quantify the aggregate effects of supply chain disruptions - an increase in international delivery times as observed in the US following the Covid-19 pandemic. Dunn and Leibovici (2023) document the dynamics of the global shipping industry, and incorporate endogenous demand and supply of global shipping services into a multi-country dynamic general equilibrium model. They show that, in response to an increase in demand for tradable goods, shipping capacity delays a rise in international trade while raising shipping prices on impact. Leibovici and Waugh (2019) introduce shipping delays into a small open economy model, and show that the mismatch between the timing of import payments and deliveries plays an important role in accounting for the observed dynamics of the stochastic discount factor. Ravn and Mazzenga (2004) quantify the effects of transportation costs for international business cycles and welfare, using a model with international transportation services sector.

Finally, my analysis relates to the literature on international spillovers of inflation. Hall, Tavlas and Wang (2023) estimate the spillover effects of inflation for the Unites States, the euro area, and United Kingdom during the post-pandemic period, and find that a shock to US inflation generates large and persistent effects on the price levels in the euro area and the United Kingdom. Baurle et al. (2021) find that the magnitude of spillovers varies significantly depending on the shocks driving inflation abroad. Auer, Levchenko and Saure (2017) examine the role of international input-output linakges in synchronizing producer price inflation across countries, and estimate that input-output linkages account for half of the global component of PPI inflation.

3 Model

There are two symmetric countries: country 1 and country 2. In each country, there are i number of sectors, each with a unit mass of monopolistically competitive firms producing a differentiated product. In any given period, these firms reset the price of their output, but adjusting prices is costly. I assume Rotemberg quadratic price adjustment costs that vary with the deviation of the current price from the last-period price.

Firms' production utilizes labor and a composite of intermediate inputs which consists of domestically produced inputs and imported inputs from various sectors. Therefore, production is roundabout, and individual firms from different sectors and countries are connected through the use of output of firms in other sectors, domestic and abroad.

I follow Ferrante, Graves and Iacoviello (2023) and introduce labor adjustment costs that arise when sectoral employment rises relative to the previous period. These costs are modelled as additional workers that need to be hired in that sector, and arise when current sectoral labor is higher than the level in the previous period. Adjusting labor is costless if the current labor falls below the level from the previous period.

In addition to the labor adjustment costs, I assume additional transportation costs when international goods trade increases. When firms' output is exported abroad, either as final goods consumed by households or as intermediate inputs used by foreign firms, the exports of goods are subject to sectoral shipping costs that increase when the volume of these exports exceed the steady state value. Therefore, these transportation costs generate asymmetries along two dimensions. First, the costs arise only for goods trade but not for service trade. This implies that demand reallocation shocks generate additional inflationary pressures when demand shifts away from services toward goods as observed during the pandemic, but such effects are absent when demand relocates from goods to services. Second, these costs arise only when the trade volume exceeds the steady state level (as opposed to the level from the previous period). Therefore, goods trade becomes costly only during the periods of high demand, and does not incur any additional costs during a trade contraction or a subsequent recovery period.

In the subsections below, I describe optimization problems of agents in country 1. Analogous conditions hold for country 2.

3.1 Monopolistically competitive firms

In each sector in each country, there is a unit mass of monopolistically competitive firms. Firm s in sector i in country 1 produces output with the following production function:

$$Y_t(s,i,1) = A_t(i,1)\left[(\alpha_i)^{\frac{1}{\varepsilon_Y}} M_t(s,i,1)^{\frac{\varepsilon_Y-1}{\varepsilon_Y}} + (1-\alpha_i)^{\frac{1}{\varepsilon_Y}} L_t(s,i,1)^{\frac{\varepsilon_Y-1}{\varepsilon_Y}}\right]^{\frac{\varepsilon_Y}{\varepsilon_Y-1}} \tag{1}$$

where $A_t(i,1)$ is sectoral productivity, $L_t(s,i,1)$ is labor, $M_t(s,i,1)$ is a composite of domestic and imported intermediate inputs (described in section 3.4 below), and ε_Y is the elasticity of substitution between labor and material inputs. Taking as given the sectoral unit labor cost $P^L_t(i,1)$ and the price of the sectoral input bundle $P_t^M(i,1)$, firms choose labor and intermediate-input bundle by minimizing the production cost $P_t^L(i,1)L_t(s,i,1) + P_t^M(i,1)M_t(s,i,1)$ subject to the production function (1).

When firms adjust prices, they face quadratic price-adjustment costs. Firm s in sector i in country 1 chooses $P_t(s,i,1)$ to solve

$$\begin{aligned} V_t^P\left(P_{t-1}(s,i,1)\right) &= \max_{P_t(s,i,1)} \frac{P_t(s,i,1)}{P_t^1} Y_t(s,i,1) - \frac{MC_t(i,1)}{P_t^1} Y_t(s,i,1) \\ &\quad - \frac{\kappa_i}{2}\left(\frac{P_t(s,i,1)}{P_{t-1}(s,i,1)} - 1\right)^2 Y_t(i,1)\frac{P_t(i,1)}{P_t^1} + \mathbf{E}_t\Big[\mu_{t+1} V_{t+1}^P\left(P_t(s,i,1)\right)\Big] \end{aligned}$$

where $MC_t(i,1)$ denotes the marginal cost of production as derived from the static problem above:

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

The first order condition is given by

$$\begin{aligned} 0 &= (1-\epsilon)\left(\frac{P_t(s,i,1)}{P_t(i,1)}\right)^{-\epsilon} + \epsilon MC_t(i,1)\left(\frac{P_t(s,i,1)}{P_t(i,1)}\right)^{-\epsilon}\frac{1}{P_t(s,i,1)} - \kappa_i\left(\frac{P_t(s,i,1)}{P_{t-1}(s,i,1)} - 1\right)\frac{P_t(i,1)}{P_{t-1}(s,i,1)} \\ &\quad + \mathbf{E}_t\left[\mu_{t+1}\kappa_i\left(\frac{P_{t+1}(s,i,1)}{P_t(s,i,1)} - 1\right)\frac{P_{t+1}(s,i,1)}{P_t(s,i,1)}\frac{P_{t+1}(i,1)}{P_t(s,i,1)}\frac{P_t^1}{P_{t+1}^1}\frac{Y_{t+1}(i,1)}{Y_t(i,1)}\right] \end{aligned}$$

where $\pi_t^1 = \frac{P_t^1}{P_{t-1}^1}$ denotes aggregate inflation. In equilibrium, firms in a given sector are identical; therefore, subscript s can be dropped.

3.2 Representative competitive producer

In each sector i, a representative competitive producer aggregates output of each firm s in that sector $Y_t(s,i,1)$ to make a sectoral composite bundle $Y_t(i,1)$ whose price is $P_t(i,1)$:

$$Y_t(i,1) = \left[\int_0^1 Y_t(s,i,1)^{\frac{\epsilon-1}{\epsilon}} ds\right]^{\frac{\epsilon}{\epsilon-1}} \tag{2}$$

The representative competitive producer chooses $Y_t(s,i,1)$ to minimize the costs $\int_0^1 P_t(s,i,1)Y_t(s,i,1)ds$ subject to equation (2). This yields the demand for $Y_t(s,i,1)$:

$$Y_t(s,i,1) = \left(\frac{P_t(s,i,1)}{P_t(i,1)}\right)^{-\epsilon} Y_t(i,1),$$

where the zero-profit condition implies $P_t(i,1) = \left[\int_0^1 P_t(s,i,1)^{1-\epsilon} ds\right]^{\frac{1}{1-\epsilon}}$.

$Y_t(i,1)$ is then used as final goods and intermediate inputs in the domestic market, and also exported abroad as final goods and intermediate inputs.

3.3 Export agencies

In each sector i, there is an export agency that ships abroad sectoral output produced by representative competitive producers. These export agencies charge some costs if the volume of exports today exceeds the steady state volume of exports. These costs are quadratic, and paid as extra sectoral output. Let $Y_t^X(i,1)$ denote the volume of exports from sector i in country 1, and $P_t^X(i,1)$ be the price of the exports, denominated in the currency of the origin country (country 1). The export agency in sector i solves

$$\max_{Y_t^X(i,1)} \frac{P_t^X(i,1)}{P_t^1} Y_t^X(i,1) - \frac{P_t(i,1)}{P_t^1}(1+\overline{\tau})Y_t^X(i,1) - \mathbb{1}_{Y_t^X(i,1)>\overline{Y}^X(i,1)} \frac{P_t(i,1)}{P_t^1}\frac{\tau_i}{2}\left(\frac{Y_t^X(i,1)}{\overline{Y}^X(i,1)} - 1\right)^2 Y_t^X(i,1)$$

The first-order condition implies the following export price:

$$\frac{P_t^X(i,1)}{P_t^1} = (1+\overline{\tau})\frac{P_t(i,1)}{P_t^1} + \mathbb{1}_{Y_t^X(i,1)>\overline{Y}^X(i,1)} \frac{P_t(i,1)}{P_t^1}\left[\frac{\tau_i}{2}\left(\frac{Y_t^X(i,1)}{\overline{Y}^X(i,1)} - 1\right)^2 + \tau_i\left(\frac{Y_t^X(i,1)}{\overline{Y}^X(i,1)} - 1\right)\frac{Y_t^X(i,1)}{\overline{Y}^X(i,1)}\right]$$

Exports are then used as intermediate inputs in sector j, $m_t\Big((i,1),(j,2)\Big)$, or final goods, $f_t\Big((i,1),2\Big)$, in the destination country (country 2): $Y_t^X(i,1) = \sum_{j=1}^K m_t\Big((i,1),(j,2)\Big) + f_t\Big((i,1),2\Big)$.

3.4 Intermediate input bundle

First, we combine domestic inputs $m_t\Big((i,1),(j,1)\Big)$ and imported inputs $m_t\Big((i,2),(j,1)\Big)$ from the same sector i to be used in sector j in country 1. The price of domestic input is denoted by $P_t(i,1)$, and the price of imported inputs is $P_t^X(i,2)$ which is denominated in the foreign currency. The composite input bundle is $m_t\Big(i,(j,1)\Big)$:

$$m_t\Big(i,(j,1)\Big) = \left[(\theta_{ij})^{\frac{1}{\xi}}\, m_t\Big((i,1),(j,1)\Big)^{\frac{\xi-1}{\xi}} + (1-\theta_{ij})^{\frac{1}{\xi}}\, m_t\Big((i,2),(j,1)\Big)^{\frac{\xi-1}{\xi}}\right]^{\frac{\xi}{\xi-1}} \tag{3}$$

From cost minimization, demand for domestic and intermediate inputs from sector i is given by:

$$\begin{aligned} m_t\Big((i,1),(j,1)\Big) &= \theta_{ij}\left(\frac{P_t(i,1)}{P_t^M\Big(i,(j,1)\Big)}\right)^{-\xi} m_t\Big(i,(j,1)\Big) \\ m_t\Big((i,2),(j,1)\Big) &= (1-\theta_{ij})\left(e_t\frac{P_t^X(i,2)}{P_t^M\Big(i,(j,1)\Big)}\right)^{-\xi} m_t\Big(i,(j,1)\Big) \end{aligned}$$

where the price of sector-i bundle for sector j is given by $P_t^M\Big(i,(j,1)\Big) = \Big[\theta_{ij}P_t(i,1)^{1-\xi} + (1-\theta_{ij})\Big(e_tP_t^X(i,2)\Big)^{1-\xi}\Big]$

Next, intermediate input bundles from all sectors i, are combined to be used in sector j, $m_t\Big(i,(j,1)\Big)$ at price $P_t^M\Big(i,(j,1)\Big)$, to make the input composite $M_t(j,1)$.

$$M_t(j,1) = \left[\sum_{i=1}^{K}(\Gamma_{ij})^{\frac{1}{\varepsilon_M}}\, m_t\Big(i,(j,1)\Big)^{\frac{\varepsilon_M-1}{\varepsilon_M}}\right]^{\frac{\varepsilon_M}{\varepsilon_M-1}} \tag{4}$$

where the price of $m_t\Big(i,(j,1)\Big)$ is $P_t^M\Big(i,(j,1)\Big)$. From cost minimization, demand for $m_t\Big(i,(j,1)\Big)$ is given by

$$m_t\Big(i,(j,1)\Big) = \Gamma_{ij}\left(\frac{P_t^M\Big(i,(j,1)\Big)}{P_t^M(j,1)}\right)^{-\varepsilon_M} M_t(j,1)$$

where $P_t^M(j,1) = \left[\sum_{i=1}^{K}\Gamma_{ij}P_t^M\Big(i,(j,1)\Big)^{1-\varepsilon_M}\right]^{\frac{1}{1-\varepsilon_M}}$. $M_t(j,1)$ is then used by firm s in sector j: $M_t(j,1) = \int_0^1 M_t(s,j,1)ds$

3.5 Final goods bundle

Similar to the intermediate-input bundle, sector i's final-goods bundle $f_t(i,1)$ consists of domestic final goods $f_t\Big((i,1),1\Big)$ and imported final goods $f_t\Big((i,2),1\Big)$:

$$f_t(i,1) = \left[(\zeta_i)^{\frac{1}{\eta}} f_t\Big((i,1),1\Big)^{\frac{\eta-1}{\eta}} + (1-\zeta_i)^{\frac{1}{\eta}} f_t\Big((i,2),1\Big)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{5}$$

The demand for domestic and imported final goods is given by

$$\begin{aligned} f_t\Big((i,1),1\Big) &= \zeta_i \left(\frac{P_t(i,1)}{P_t^f(i,1)}\right)^{-\eta} f_t(i,1) \\ f_t\Big((i,2),1\Big) &= (1-\zeta_i) \left(\frac{e_t P_t(i,2)}{P_t^f(i,1)}\right)^{-\eta} f_t(i,1) \end{aligned}$$

where $P_t^f(i,1) = \Big[\zeta_i P_t(i,1)^{1-\eta} + (1-\zeta_i)\left(e_t P_t(i,2)\right)^{1-\eta}\Big]^{\frac{1}{1-\eta}}$.

3.6 Labor agencies

As in Ferrante, Graves and Iacoviello (2023), there is a labor agency in each sector i. The labor agency faces a quadratic adjustment cost of increasing sectoral employment, and this gives rise to a wedge between the unit cost of labor faced by firms and the wages paid to households. Labor agency in sector i solves the following:

$$\begin{aligned} V_t^L\Big(L_{t-1}(i,1)\Big) &= \max_{L_t(i,1)} \frac{P_t^L(i,1)}{P_t^1} L_t(i,1) - \frac{W_t^1}{P_t^1} L_t(i,1) - \mathbb{1}_{L_t(i,1)>L_{t-1}(i,1)} \frac{W_t^1}{P_t^1} \frac{c}{2} \left(\frac{L_t(i,1)}{L_{t-1}(i,1)} - 1\right)^2 L_t(i,1) \\ &\quad + \mathbf{E}_t\left[\mu_{t+1} V_{t+1}^L\Big(L_t(i,1)\Big)\right] \end{aligned}$$

where $\mu_{t+1} = \beta\left(\frac{C_{t+1}^1}{C_t^1}\right)^{-\gamma}$. The optimal unit price of labor is then given by

$$\begin{aligned} \frac{P_t^L(i,1)}{P_t^1} &= \frac{W_t^1}{P_t^1} + \mathbb{1}_{L_t(i,1)>L_{t-1}(i,1)} \frac{W_t^1}{P_t^1}\left[\frac{c}{2}\left(\frac{L_t(i,1)}{L_{t-1}(i,1)} - 1\right)^2 + c\left(\frac{L_t(i,1)}{L_{t-1}(i,1)} - 1\right)\frac{L_t(i,1)}{L_{t-1}(i,1)}\right] \\ &\quad - \mathbf{E}_t\left\{\mu_{t+1} \frac{W_{t+1}^1}{P_{t+1}^1} \mathbb{1}_{L_{t+1}(i,1)>L_t(i,1)} c \left(\frac{L_{t+1}(i,1)}{L_t(i,1)} - 1\right)\left(\frac{L_{t+1}(i,1)}{L_t(i,1)}\right)^2\right\}. \end{aligned}$$

3.7 Representative household

3.7.1 Consumption aggregators

Households consume final-goods output from sector i as goods or services: $f_t(i,1) = f_t^g(i,1) + f_t^s(i,1)$. The consumption aggregators combine sectoral output as $C_t^{g1} = \prod_{i=1}^{K}\left(\frac{f_t^g(i,1)}{\gamma_i^g}\right)^{\gamma_i^g}$ for goods consumption, and $C_t^{s1} = \prod_{i=1}^{K}\left(\frac{f_t^s(i,1)}{\gamma_i^s}\right)^{\gamma_i^s}$ for services consumption, where $\sum_{i=1}^{K}\gamma_i^g = 1$ and $\sum_{i=1}^{K}\gamma_i^s = 1$. From cost minimization, the demand for goods and services bundles are given by $f_t^g(i,1) = \gamma_i^g\left(\frac{P_t^f(i,1)}{P_t^{g1}}\right)^{-1}C_t^{g1}$ and $f_t^s(i,1) = \gamma_i^s\left(\frac{P_t^f(i,1)}{P_t^{s1}}\right)^{-1}C_t^{s1}$, where $P_t^{g1} = \prod_{i=1}^{K}P_t^f(i,1)^{\gamma_i^g}$ and $P_t^{s1} = \prod_{i=1}^{K}P_t^f(i,1)^{\gamma_i^s}$.

The final consumption bundle C_t^1 consist of goods and services bundles, C_t^{g1} and C_t^{s1}: $C_t^1 = \left(\frac{C_t^{g1}}{\omega_t}\right)^{\omega_t}\left(\frac{C_t^{s1}}{1-\omega_t}\right)^{1-\omega_t}$, where ω_t is the time-varying expenditure share of goods consumption, and follows an AR(1) process: $\omega_t^1 = (1-\rho_{\omega 1})\bar{\omega} + \rho_{\omega 1}(\omega_{t-1}^1) + \epsilon_{\omega,t}^1$. The cost minimization yields the demand for goods and services bundles: $C_t^{g1} = \omega_t^{g1}\frac{P_t^1}{P_t^{g1}}C_t^1$ and $C_t^{s1} = \omega_t^{s1}\frac{P_t^1}{P_t^{s1}}C_t^1$, where $P_t^1 = \left(P_t^{g1}\right)^{\omega_t^{g1}}\left(P_t^{s1}\right)^{\omega_t^{s1}}$.

3.7.2 Intertemporal optimization

A representative household in country 1 chooses consumption and labor to maximize utility $\sum_{t=0}^{\infty}\beta^t\Big[\frac{(C_t^1)^{1-\gamma}}{1-\gamma} - \frac{(N_t^1)}{1+}$ subject to the following budget constraint

$$P_t^1C_t^1 + B_{t+1}^1 + \sum_{s^{t+1}} q(s^{t+1}|s^t)D_1(s^{t+1}) = W_t^1N_t^1 + \left(1+i_{t-1}^1\right)B_t^1 + D_1(s^t) + div_t^1.$$

Similarly, a representative household in country 2 maximizes utility $\sum_{t=0}^{\infty}\beta^t\left(\frac{(C_t^2)^{1-\gamma}}{1-\gamma} - \frac{(N_t^2)^{1+\psi}}{1+\psi}\right)$ subject to the budget constraint

$$P_t^2C_t^2 + B_{t+1}^2 + \sum_{s^{t+1}} q(s^{t+1}|s^t)\frac{D_2\left(s^{t+1}\right)}{e_t} = W_t^2N_t^2 + \left(1+i_{t-1}^2\right)B_t^2 + \frac{D_2(s^t)}{e_t} + div_t^2.$$

As in a standard two-country model with complete international financial markets, the real exchange rate is given by the relative marginal utility of consumption: $Q_t = e_t\frac{P_t^2}{P_t^1} = \left(\frac{C_t^2}{C_t^1}\right)^{-\gamma}$.

Table 1: Parameter values

Subjective discount factor	β	0.995
Household utility function		
intertemporal elasticity of substitution	γ	2
inverse Frisch elasticity of labor supply	ψ	1
Steady-state share of goods expenditures	$\overline{\omega}$	0.31
Persistence of demand reallocation shocks	ρ_ω	0.975
Sectoral good expenditures for final consumption	γ_i^g	0.0005 - 0.4910
Sectoral final-use bundle		
share of domestic final output	ζ_i	0.7089 - 0.9998
elasticity of substitution between domestic and imported final output	η	0.9
Sectoral production function		
elasticity of substitution between labor and material inputs	ε_Y	0.8226
share of material inputs	α_i	0.3692 - 0.6546
Sectoral price adjustment costs	κ_i	2.75-54.84
Labor hiring costs	c	19.0792
Elasticity of substitution across varieties within a sector	ε	10
Steady-state shipping costs	$\overline{\tau}$	0.05
State-dependent shipping costs for goods	τ_i	3.53
Sectoral intermediate input bundle		
share of domestic inputs	θ_{ij}	0.5442 - 1
elasticity of substitution between domestic and imported inputs	ξ	0.9
Sectoral material input bundle		
input shares	Γ_{ij}	0.0022 - 0.5418
elasticity of substitution across inputs from different sectors	ε_M	0.1307
Taylor rule coefficient on inflation	ϕ_π	1.5

3.8 Monetary policy

The central bank in each country sets the nominal interest rate following a Taylor rule that reacts to inflation and the deviation of GDP from the steady state level: $\log(1+i_t^1) = \log\frac{1}{\beta} + \phi_{\pi 1}\log\pi_t^1 + \phi_{y1}\log GDP_t^1$.

4 Calibration

The model is calibrated to the quarterly frequency, and I assume that the two countries are symmetric. There are 9 sectors in each country, with 5 goods sectors and 4 services sectors. A list of sectors is presented in table A1 in Appendix A.

The household subjective discount factor is set equal to 0.995 following Ferrante, Graves and Iacoviello (2023). In the household period utility, the intertemporal elasticity of substitution γ is set equal to 2, and the inverse of the Frisch labor supply elasticity ψ is set to 1. The stead-state share of goods expenditure in households' consumption basket is set equal to 0.31 as observed in the US in 2019 (Ferrante, Graves and Iacoviello, 2023). The consumption shares in goods and services from each sector, γ_i^g and γ_i^s, are calibrated using the spending shares from the BEA's bridge between PCE categories and NAICS industries, as in Ferrante, Graves and Iacoviello (2023). A sector is labeled as a good-producing (services-producing) sector if more of its output is consumed as goods (services): $\gamma_i^g > \gamma_i^s$ ($\gamma_i^g < \gamma_i^s$).

In the final-goods bundle for each sector, the share of domestically produced final goods ζ_i is calibrated using the BEA input-output tables. The elasticity of substitution between domestic and imported final goods η is set to 0.9 as estimated by Heathcote and Perri (2002). Within each sector, the elasticity of substitution between varieties ε is set to 10, following Ferrante, Graves and Iacoviello (2023).

On the firms side, the sectoral production function assumes that the elasticity of substitution between labor and material inputs ε_Y is set to 0.8226 following Ferrante, Graves and Iacoviello (2023). The sectoral share of material inputs in production α_i is calibrated to the BEA input-output tables for 2019. I caliberate the parameter for sectoral price adjustment costs κ_i to the values used by Ferrante, Graves and Iacoviello (2023). The labor hiring cost c is set equal to 19.0792 following Ferrante, Graves and Iacoviello (2023).

In the export sector, I set the steady-state shipping cost $\overline{\tau}$ to 0.05 following Dunn and Leibovici (2023). For the state-dependent shipping cost, the mean freight cost increase between 2019 and 2021 for the Baltic Dry index and the Freightos index was 3.77, while the average growth in the container volume during 2021 relative to the pre-pandemic level in December 2019 was 1.28. Given the steady state shipping cost of $\overline{\tau} = 0.05$, these growths in shipping costs and shipment volume together imply that the extra shipping cost for goods sector is $\tau_i = 3.53$.

In the composite of sectoral intermediate input bundles, the share of domestically produced inputs θ_{ij} is calibrated to the values observed in the BEA's input-output tables. The elasticity of substitution between domestic and imported inputs is set to 0.9 as in the final-goods bundle. In firms' material input bundle, the sectoral input shares Γ_{ij} are calibrated to the BEA's inpu-output table, and the elasticity of substitution between inputs from different sectors ε_M is set to 0.1307 following Ferrante, Graves and Iacoviello (2023).

Finally, in each country's Taylor rule, the coefficient on inflation ϕ_π is set equal to 1.5 as standard in the literature, while the coefficient on output ϕ_{GDP} is set to 0 in the baseline analysis. I explore the cases with $\phi_{GDP} > 0$ in section 5.3. Table 1 summarizes the parameter values.

5 Results

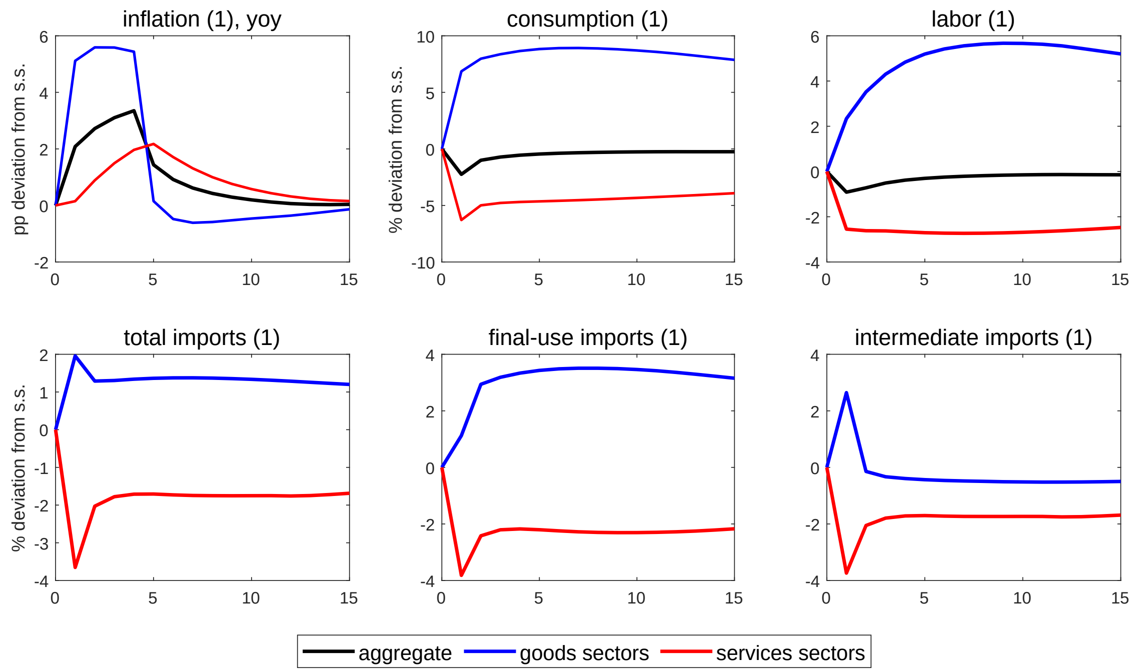
With the model economy described above, I examine the effects of an exogenous shift in expenditure shares from services to goods by increasing ω_t. I begin my analysis by first examining the economy's responses to global expenditure reallocations whereby both countries are hit by a persistent increase in the goods expenditure share in household consumption.

5.1 Global demand reallocation shocks and inflation spillovers

The Covid-19 pandemic was undoubtedly a global phenomenon, and, with the introduction of public health restrictions, the shift in demand away from services to goods was observed widely across countries. In this subsection, I examine the impact of global demand reallocation shocks, and how much of the rise in domestic CPI inflation may be attributed to spillovers from the foreign demand reallocation shock.

Figure 4 presents the impulse responses of country 1 to a simultaneous 4 percentage point increase in the share of household expenditures in goods in both country 1 and country 2 ($\omega_{1,t}$ and $\omega_{2,t}$), with the persistence of 0.975. As demand shifts away from services consumption toward goods consumption, firms in goods sectors increase employment, while employment in the services sectors declines. As in the closed-economy analysis of Ferrante, Graves and Iacoviello (2023), the increase in labor in the goods sectors involves adjustment costs, leading to a substantial increase in the marginal costs of production in the goods sectors and contributing to the goods-price inflation. In my open-economy framework, the increase in demand for goods consumption also increases

Figure 4: Impulse responses to global demand reallocation shocks

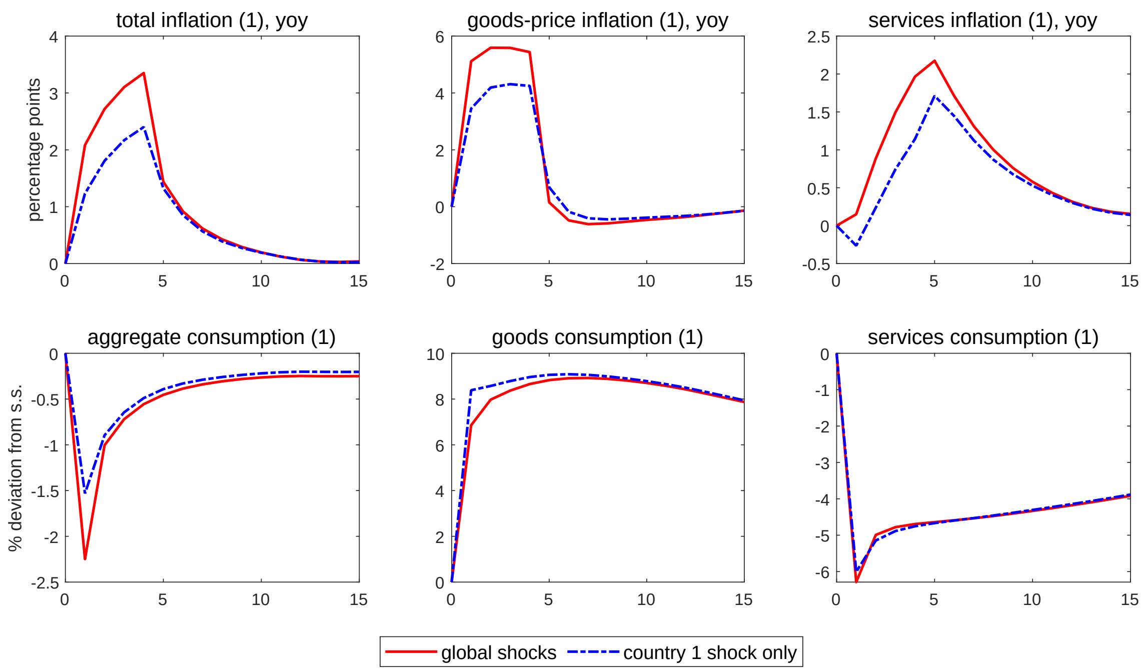


Notes: This figure presents the impulse responses of country 1 to a 4 percentage point reallocation shock to goods expenditure share in country 1 and country 2.

imports, particularly the imports of final goods, while the imports of services experience sizable contractions. As imports of goods increase from their steady state levels, the increased trade volume exerts an upward pressure on shipping costs, making the imports of goods more expensive than in normal times. Combined with the labor adjustment costs in the goods sector, this further places an upward pressure on the goods sector inflation.

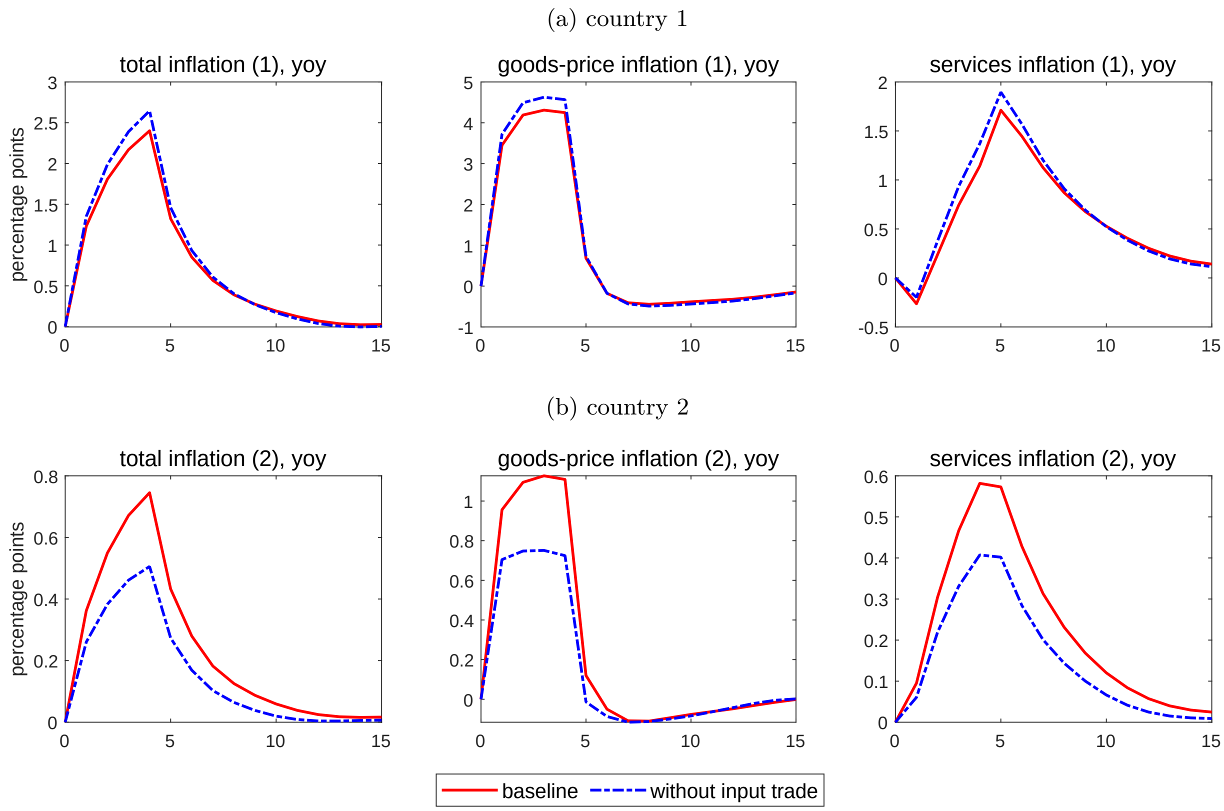
The shock impact shown in figure 4 is the combined impact of the demand reallocation taking place in the domestic economy and that hitting its trade partner economy. To examine the cross-country spillovers of the shock impact, I next decompose the responses to global shocks into the impact attributed to a domestic demand reallocation shock and that resulting from a foreign shock. In figure 5, I plot the impulse responses of inflation (top row) and consumption (bottom row) to the same global demand shock to goods (red solid lines) and an alternative scenario where only country 1 is hit by a goods demand reallocation shock (blue dash-dot lines). Therefore, the difference between the two lines can be interpreted as the extent to which the demand reallocation shock in a trade-partner country (country 2) affects inflation and consumption in country 1.

Figure 5: Impact of a foreign demand allocation shock on domestic inflation and consumption



Notes: This figure presents the impulse response of inflation (top row) and consumption (bottom row) in country 1 to (i) 4 percentage point reallocation shocks to goods expenditure share in both country 1 and country 2 (red lines) and (ii) a 4 percentage point reallocation shock to goods expenditure share in country 1 only (blue dashed lines).

Figure 6: Inflation spillovers through production chains



Notes: This figure compares the impulse response of inflation to a 4 percentage point reallocation shock to goods expenditure share in country 1 from my baseline model (red lines) and those from an alternative model without international trade in intermediate inputs (blue lines).

We see that the country 1 inflation rises significantly more with global shocks, as the shock in country 2 raises the prices of its exports (or, put differently, country 1's imports). The cross-country spillovers of the country 2 inflationary pressure raise country 1 inflation by about 0.7 percentage points, from 2.5 percent to 3.2 percent. The rise in the price of imported products into country 1 affects not only the increase in the price of imported final goods, but also the price of imported intermediate inputs. The rising costs of production, in turn, raise the prices of domestically produced products as well, thereby further contributing to the inflationary pressure in country 1.

5.2 Inflation spillovers through production chains

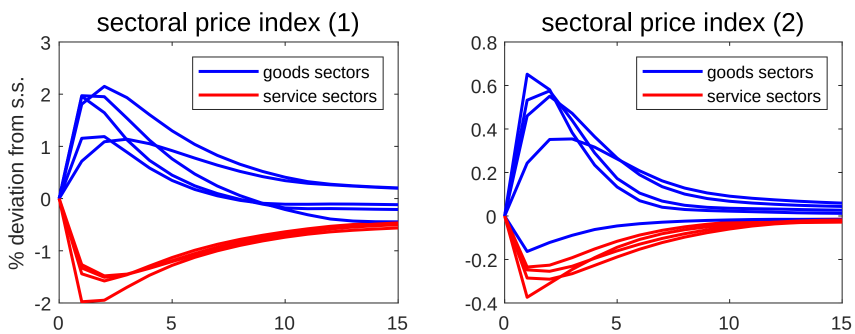
The important link between the two countries in my model economy is international trade in intermediate inputs that connect individual firms through production across the two countries. In this subsection, I examine the role of cross-country input-output linkages in transmitting inflationary pressures across borders.

Figure 6 compares the impulse responses of inflation in country 1 (figure 6a) and country 2 (figure 6b) to a 4 percentage-point goods expenditure share shock in country 1, from my baseline model (red solid lines) and those from an alternative model where there is no international trade in intermediate inputs, $\theta_{ij} = 1$ for all i and j (blue dash-dot lines). Starting first with the role of input trade for the domestic economy (figure 6a), we see that the presence of input trade in my baseline model dampens the impact of the domestic demand reallocation shock on inflation, especially in the goods sector. When only country 1 is hit by the demand reallocation shock, the use of imported inputs from country 2, which is not directly affected by the shock, serves as relatively cheaper substitutes, and thus alleviates the rise in the costs of intermediate inputs and hence the marginal costs of production. Further, as country 1 experiences a larger contraction in aggregate consumption relative to country 2, the real exchange rate for country 1 appreciates, which in turn helps to lower the local prices of imported inputs.

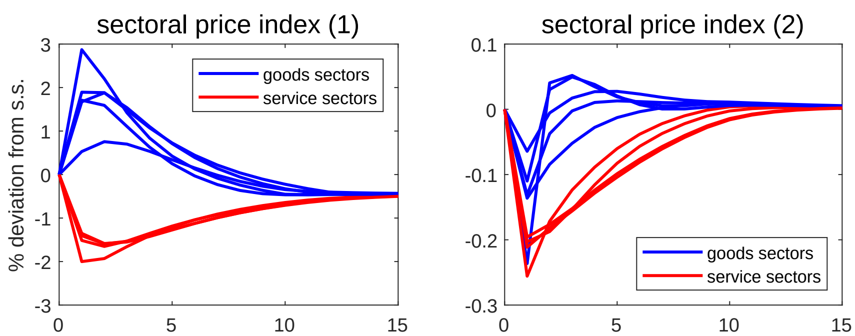
In contrast, we see in figure 6b that the presence of input trade significantly amplifies the inflation responses in country 2, in response to a demand reallocation shock in its trade partner economy (country 1). When country 1 is hit by a demand reallocation shock, the prices of country 1 products increase. For country 2, as the prices of imported intermediate inputs from country 1 rise, the cost of domestic production also increases, contributing to a larger increase in inflation. Figure 7 further illustrates the propagation channel through which foreign inflation pressures spill over into domestic production costs. The figure compares the responses of sectoral prices (relative to the aggregate price index) from my baseline model (panel a) and those from the alternative model without international trade in intermediate inputs (panel b). Focusing first on the sectoral price responses in country 1 (left panels), we see that the inflationary pressure is stronger for most of the goods sectors in the alternative model without international trade in intermediate input,

Figure 7: Sectoral price responses: demand reallocation from services to goods

(a) Baseline model



(b) Model without international trade in intermediate inputs



Notes: This figure presents the impulse response of sectoral prices (relative to the aggregate price index) for country 1 (left) and country 2 (right) in response to a demand reallocation shock in country 1. Panel (a) is from my baseline model, and panel (b) is from an alternative model without international trade in intermediate inputs.

relative to my baseline model. As discussed above, the presence of imported inputs from country 2, which are relatively cheaper than domestically produced inputs, helps to dampen the rise in production costs in my baseline model. The responses in services sectors are largely similar across the two models, reflecting the fact that the use of imported intermediate inputs is relatively limited in these sectors.

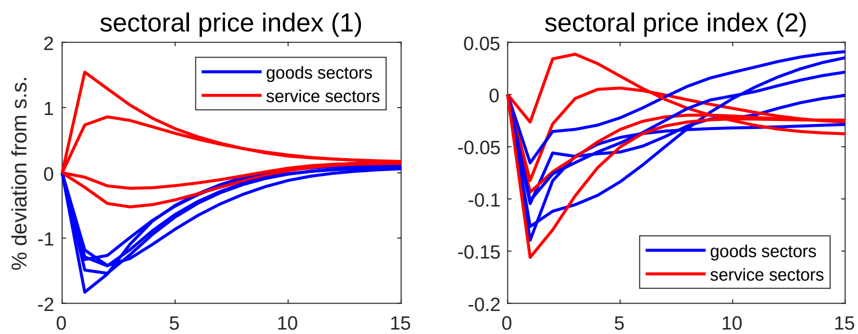
For country 2 (right panels), the impact of the country 1 shock on domestic prices are in stark contrast between the two models. In my baseline model, the domestic sectoral prices rise for goods sectors relative to the aggregate price index, while those for services sectors experience a persistent fall. In the alternative model without input trade, we see instead that domestic prices are relatively lower than the aggregate price for both goods and services sectors. Without the use of imported inputs from country 1, which are now relatively more expensive due to the inflationary pressure in country 1, the prices of domestic production are now lower relative to the aggregate price index.

Importantly, such propagation mechanism through input-output linkages is absent when the demand reallocation shock occurs in reverse, shifting away from goods towards services. Figure 8 shows the impulse responses of sectoral price index (relative to the aggregate price index) in the two countries from my baseline model (panel a) and the alternative model without input trade (panel b) in response to a demand reallocation shock from goods to services, a counterpart of figure 7. Comparing the price responses in country 2 across the two models, we see here that the presence of input trade does not alter the domestic price responses in country 2, in contrast to the reverse shock case we saw in figure 7.

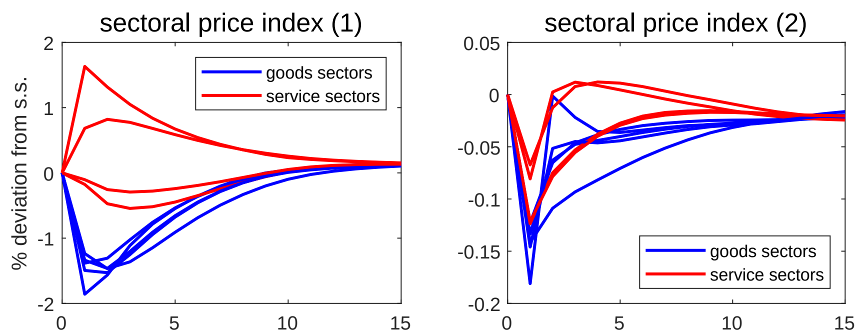
A reallocation shock that shifts demand from goods to services increases employment and trade in services sectors, while it reduces them in goods sectors. Because my model assumes that increasing employment and goods trade is costly but reducing them is costless, the relative reduction in demand for goods sectors does not create additional inflationary pressures. This limits the inflation spillovers to the foreign economy, since international trade is dominated by goods rather than services. This leads to the fall in the price of domestic production in the foreign economy relative to the aggregate price index there, even in the presence of trade in intermediate

Figure 8: Sectoral price responses: demand reallocation from goods to services

(a) Baseline model



(b) Model without international trade in intermediate inputs



Notes: This figure presents the impulse response of sectoral prices (relative to the aggregate price index) for country 1 (left) and country 2 (right) in response to a demand reallocation from goods to services in country 1. Panel (a) is from my baseline model, and panel (b) is from an alternative model without international trade in intermediate inputs.

Table 2: Peak response of inflation and GDP under various monetary policy rules

	(1) Baseline	(2) $\phi_{\pi,1} \uparrow$	(3) $\phi_{y,1} \uparrow$	(4) $\phi_{\pi,2} \uparrow$	(5) $\phi_{y,2} \uparrow$
Country 1					
inflation	2.40	1.87	5.94	2.40	2.40
GDP	-1.65	-1.69	-1.88	-1.65	-1.63
Country 2					
inflation	0.74	0.75	0.85	0.59	0.92
GDP	-0.34	-0.35	-0.39	-0.35	-0.31

Notes: This table summarizes the peak responses of inflation and GDP in the two countries under various parameterization of monetary policy rules. "$\phi_{\pi,i} \uparrow$" indicates $\phi_{\pi,i}$ increasing from 1.5 to 1.8, for $i = 1, 2$. "$\phi_{y,i} \uparrow$" indicates $\phi_{y,i}$ increasing from 0 to 0.7, for $i = 1, 2$.

inputs as in my baseline model.

5.3 Implications for monetary policy

As we saw in figure 4, demand reallocation shocks from services to goods induce rising inflation and at the same time a contraction in aggregate consumption. For central banks, this poses a policy dilemma of bringing inflation under control and reducing the output contraction. Given this inflation-output tradeoff for the monetary authority, this subsection investigates how the stance of monetary policy in each country influences the responses of inflation and GDP in a country that is hit by a demand reallocation shock and their spillovers to its trade partner economy. Specifically, central banks in my model economy follow a Taylor rule reaction function that may react to inflation and GDP. In my baseline analysis above, the central banks are assumed to react only to inflation ($\phi_\pi = 1.5$, $\phi_y = 0$). From this baseline specification, I change one of the monetary policy parameters in one country at a time, and compare the peak responses of inflation and GDP under each case.

Table 2 summarizes the peak responses of inflation and GDP, in country 1 (rows 1 and 2) and country 2 (rows 3 and 4), to a demand reallocation shock in country 1 under various parameterization of the monetary policy rule. In my baseline calibration where $\phi_{\pi,i}$=1.5 and $\phi_{y,i}$=0 (column 1), inflation rises and output falls in both countries; therefore, central banks in both countries face a policy dilemma of tightening to reduce inflation or stimulating to support output. When the central bank in the shock hit country (country 1) responds more strongly to the rising inflation (column 2), we see that the inflation response in that country is dampened, but this comes at the cost of slightly deepening the output contraction.

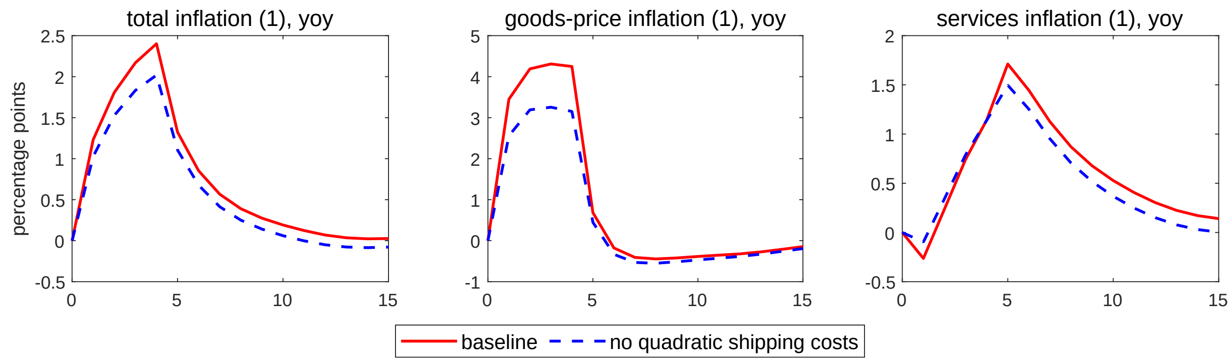
If instead the central bank in country 1 responds more strongly to output fluctuations (column 3), we see that this policy is counterproductive for both inflation and output, not only domestically but also in the spillover country (country 2). Under this scenario, the peak response of inflation rises substantially by 5.94 percentage points, and the trough of the GDP response falls 1.88 percent. At the same time, the international spillover to country 2 amplifies, and the peak inflation there rises 0.85 percentage points while GDP falls 0.39 percent. These larger inflation and output responses under this policy specification (higher ϕ_{y1}) can be attributed to the fact that the main source of high inflation and low output lies in the inflationary pressure coming from the labor and shipping adjustments. When demand reallocates from services to goods, the first-order impact of the shock is the rising pressure on production costs, and hence prices, as increasing employment and imports in goods sectors entails adjustment costs. The rising prices in the goods sectors in turn reduce the household wealth and hence aggregate consumption and output. Therefore, when monetary policy responds more strongly to output relative to the baseline case without changing its stance to inflation, the policy is not reacting to the direct source of fluctuations – the rising production costs –, and by following a less contractionary policy, the resulting higher inflation leads to even lower consumption and output. As country 1 experiences higher inflation, we see stronger inflation spillovers to country 2 through the rise in the price of its imports from country 1, which in turn amplifies the output contraction there.

5.4 Role of state-dependent shipping costs

An important feature of my model economy is the additional sectoral shipping costs that arise when the volume of sectoral goods trade exceeds their respective steady-state level. In this subsection, I examine the role of these goods-import costs for the inflation dynamics.

Figure 9 compares the impulse responses of country 1 inflation from my baseline model (red solid lines) and those from an alternative model without state-dependent shipping costs (blue

Figure 9: Role of state-dependent shipping costs



Notes: This figure presents the impulse response of country 1 inflation to a 4 percentage point reallocation shock to goods expenditure share in country 1.

dashed lines). We see that the presence of state-dependent shipping costs raises total inflation by 0.43 percentage point, from 2.02 percent to 2.45 percent, mostly attributed to the goods-price inflation. The presence of state-dependent shipping costs substantially increases the goods-price inflation, particularly during the first 4 periods following the shock when country 1 imports of goods increase with the expenditure reallocation toward goods consumption. The peak inflation for goods-price inflation is 4.53 percent in my baseline model, whereas it is 3.26 percent in the alternative model without state-dependent shipping costs.

On the other hand, the services inflation is less affected by the presence of quadratic shipping costs, as these cost only apply to goods imports. Nonetheless, there is a slight amplification in the services inflation, by about 0.2 percentage points after 5 periods following the shock, as the rising wages start to also affect the cost of production in these sectors as well.

6 Conclusion

This paper studied cross-country inflation spillovers arising from a sudden demand reallocation from services to goods, and the resulting cost pressures on production and international trade, with a particular focus on the role of production linkages in propagating such spillovers. Using a two-country multi-sector New Keynesian model with input-output linkages whereby firms face costs of increasing employment and international trade in goods, I have shown that cross-country spillovers of foreign inflationary pressures raise domestic inflation by about 1.5 times. This is sizable given that the calibrated size of imports relative to GDP is about 11 percent. A key underlying channel here is that trade in intermediate inputs significantly amplifies cross-country spillovers of inflationary pressure arising from a country's trade partner economy. Importantly, however, because the assumed adjustment costs arise only when increasing labor and goods trade, and because international trade is dominated by goods trade rather than services trade, such propagation mechanism through input-output linkages is absent when the demand reallocation shock occurs in reverse, shifting away from goods towards services.

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Appendix

A Industry aggregation

There are 66 industries in the BEA's input-output tables. In calibrating my model economy, I aggregate some industries to make a 9-industry economy, of which 5 are goods-producing and 4 are services-producing.

Table A1: Sector classification

	BEA codes
Goods sectors	
Natural resources, mining and construction	111,113,211,212,213,23
Manufacturing (wood, mineral and metals)	321,327,331,332
Manufacturing (other durable)	333,334,335,3361,3364,337,339
Manufacturing (non-durable)	311,313,315,322,323,324,325,326
Trade and transportation	42,441,445,452,4A0,481,482,483,484
	485,486,487,493
Services sectors	
Information and professional services	511,512,513,514,5411,5412,5415
Financial activities	521,523,524,525,HS,ORE,532
Education, health, leisure, hospitality and utilities	61,621,622,623,624,711,713,721,722,22
Business and other services	55,561,562,81