Trade Costs and Inflation Dynamics*

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Abstract

We explore how shocks to trade costs affect inflation dynamics in a global economy. We identify trade costs by exploiting bilateral trade flows for final and intermediate goods and the structure of static trade models that deliver structural gravity equations. We then use a local projections approach to assess the effects of estimated trade cost shocks on countries' consumer price (CPI) inflation and other macroeconomic variables. Higher trade costs lead to increases in inflation and dampen economic activity. We propose a multi-country New-Keynesian model featuring international trade in final and intermediate goods that can replicate the macroeconomic responses we identify in the data. We show that a global increase in trade costs can lead to a global surge in inflation. We also show that the degree of trade integration and the elasticity of substitution between production inputs play an important role in shaping the response of inflation to trade cost shocks. We use the model to explore counterfactual paths of U.S. inflation in the aftermath of the COVID-19 pandemic.

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1 Introduction

Over the past half-century, the world economy experienced a prominent process of globalization. Countries are now markedly more interconnected than fifty years ago, particularly in terms of the amount of goods and services that they trade with each other. For instance, world exports as a share of world GDP almost doubled over this period, going from an average of 16 percent in the 1970s to 29 percent in the late 2010s.[1] This surge in trade was not entirely driven by countries actively trading in the 1970s. Emerging economies played a prominent role in the globalization process as they experienced high growth rates and became increasingly open to trade.[2] China is a clear example of such an economy. The Chinese economy experienced fast economic growth starting in the 1990s and increased its presence in world markets by joining the World Trade Organization (WTO) in 2001. Thus, globalization has led to clear changes in the structure of the world economy over the past fifty years.

The current global economic landscape implies that shocks to trade linkages can have important macroeconomic consequences. Clearly, in a world encompassed by a larger number of countries engaged in sizable transactions, the scope for large effects of disruptions to trade relationships increases. That is, shocks to trade costs can potentially affect various macroeconomic outcomes and further transmit across countries over time. Recent examples of trade cost shocks with important macroeconomic consequences include changes in trade policies—particularly in the case of the U.S. during the Trump administration—and the effects of the COVID-19 epidemic on shipping costs. It is evident that these shocks had important implications for inflation dynamics in many countries. However, studies on the macroeconomic consequences, those on inflation in particular, of trade cost shocks broadly speaking, are scarce.[3] Recent work has aimed at understanding how trade costs can affect particular macroeconomic outcomes (Fitzgerald, 2012; Eaton et al., 2016b; Reyes-Heroles, 2017; Alessandria and Choi, 2021), but the literature has pretty much overlooked the effects on inflation. While this fact may seem puzzling given the policy relevance of inflation, it is also understandable given the focus of existing trade models on real outcomes and the divergence of these models from the New-Keynesian framework that provides the benchmark approach to studying inflation dynamics.[4]

In this paper, we study how shocks to trade costs affect inflation dynamics in a global economy. Our study proceeds in two steps. First, we exploit final and intermediate goods' bilateral trade flows and the structure of static gravity-type models of trade (Head and Mayer, 2014) to identify bilateral trade

[1] World Development Indicators (WDI), World Bank: https://data.worldbank.org/indicator/NE.EXP.GNFS.ZS.

[2] Reyes-Heroles et al. (2020) document the rise of Emerging Market Economies in trade since the mid-1990s.

[3] A large literature has focused on the transmission and implications of productivity shocks (Backus et al., 1992; Heathcote and Perri, 2002), and some works have added demand shocks (Stockman and Tesar, 1995; Bai and Ríos-Rull, 2015).

[4] Some important exceptions to this dichotomy include the works by Comin and Johnson (2020) and Barattieri et al. (2021).

costs. Armed with our estimates, we then empirically assess the effects of trade cost shocks on countries' consumer price inflation and other macroeconomic variables. Our estimates show that increases in trade costs translate into higher inflation. In the second part of the paper, we propose a multi-country New-Keynesian model featuring international trade in final and intermediate goods to explore the mechanisms through which trade cost shocks transmit into inflation and other macroeconomic variables. We show that the model can replicate the response of inflation and other macroeconomic variables to trade cost shocks. Moreover, we show that the degree of trade integration at the time of the shock plays an important role in shaping the response of inflation to trade shocks. Hence, monetary policy trade-offs depend on an economy's degree of trade integration with the rest of the world.

Section 2 constructs bilateral trade costs and presents some stylized facts on the evolution of trade costs over time and their correlation with CPI inflation. We construct bilateral trade flows for intermediate and final goods for a set of 41 countries considered in the World Input-Output Database (WIOD) over the period 1995-2014. Given the data for bilateral trade flows, we rely on the ratio-type estimation proposed by Head and Ries (2001), which delivers measures of structural trade costs—more precisely, measures of trade integration between any two countries—under the assumption of symmetric trade costs. We refer to these measures of trade costs for any pair of countries in any given year as Head-Ries indices Head and Mayer (2014). We rely on these indices to construct country-specific trade costs and show that our estimated trade costs for final and intermediate goods (i) declined significantly from 1995 to 2014 and (ii) that they correlate positively with CPI inflation.

In Section 3, we move on to explore a causal relationship between changes in trade costs, inflation, and other macroeconomic variables. To do so, we follow the local-projections method approach by Jordà (2005). We focus on the effects of trade costs on inflation and find that higher trade costs in both goods and intermediate goods translate to an increase in inflation that persists for two years after the shock. More precisely, we provide estimates for the elasticity of changes in sourcing shares—the share of total expenditure for a given type of good spent on goods domestically produced—on inflation for the ten years after the time of the shock. We also estimate contemporaneous responses in inflation to higher trade costs and find that a 1 percentage point increase in the sourcing share for final (intermediate) goods leads to an increase in CPI inflation ranging from 0.8 to 1.2 (0.2 to 0.8) percentage points. The higher estimates for the case of final goods are in line with these goods entering directly into the final consumption basket that determines CPI prices. Furthermore, for a given trade elasticity considered in our gravity approach, we document how observed changes in sourcing shares translate into changes in our measure of trade costs. We also show that higher trade costs lead to persistent declines in GDP, real exports, real imports, and an appreciation of the real exchange rate. Lastly, we discuss how the choice of trade elasticity leads to different estimated elasticities of trade costs on inflation.

Next, we describe our proposed model and our calibration strategy in detail in Section 4. We propose an open economy multi-country New-Keynesian model with trade in final and intermediate goods. Each country produces two types of goods. A unit continuum of firms produces nontradable differentiated varieties using labor and intermediate inputs. A representative firm, the final good producer, buys these varieties and aggregates them into a single tradable good that is differentiated across countries. These goods are traded across borders and can be used for final consumption or as an intermediate input in production. Similar to Comin and Johnson (2020), we model static trade across countries in an Armington fashion. That is, we assume that consumers and firms aggregate differentiated tradable goods across countries according to constant elasticity of substitution (CES) aggregators. Trade is subject to iceberg-type trade costs that are use-specific and vary in a stochastic fashion over time. These features of our model imply that, at any given point in time, trade across countries is described by gravity-type equations consistent with our empirical strategy to identify trade costs in the data. We assume that firms adjust prices infrequently, as in standard New Keynesian models, implying sluggish price movements. Moreover, we consider nominal wage rigidities in labor markets. Households earn labor income and exchange one-period bonds issued by each country in their own currency. Hence, households face incomplete financial markets.

In Section 6, we calibrate our model to mimic trade linkages in final and intermediate goods across three economies: the U.S., China, and the rest of the world (ROW). We use the model to explain the transmission mechanism of changes in trade costs under three scenarios. First, we consider a generalized increase in intermediate trade costs, which allows us to think about events that could lead to a global surge in inflation. Second, we consider the case of a bilateral increase in trade costs between the U.S. and China and use this experiment to understand the role of third-country effects. Third, we explore the transmission of trade costs under alternative calibrations of the model where we vary the elasticity of substitution between factors of production and the degree of openness to trade.

Lastly, in Section 7, we use a simplified version of our model to analyze the recent surge in inflation in the U.S. We use Bayesian estimation methods to recover key structural shocks using standard macroeconomic time series and data on import flows of intermediate and final consumption goods. Our estimated model allows us to construct a counterfactual in which absent trade costs during 2022Q1:2022Q4, inflation in the U.S. would have been about 1 percentage point lower.

Related Literature This paper relates to multiple strands of the international macroeconomics and trade literature. First, this paper is closely related to the papers that explore the macroeconomic consequences of international trade costs. The seminal work of Obstfeld and Rogoff (2000) posited how costs to trade in goods could help explain several international macroeconomic puzzles. More recent work has taken a more quantitative perspective to explore the role of trade costs not only in these puzzles (Eaton et al., 2016a), but also in other macroeconomic phenomena like risk sharing (Fitzgerald, 2012), trade imbalances (Reyes-Heroles, 2017; Alessandria and Choi, 2021), and the Global Recession (Eaton et al., 2016b), among others.[5] Our work is most closely related to Comin and Johnson (2020), who explore the role of increasing trade in driving the long-run trend in U.S. inflation. We contribute to this literature in two dimensions. First, we exploit panel data to document how cost shocks for trade in final and intermediate goods affect inflation and provide novel evidence that these shocks are inflationary. Second, we develop and estimate a multi-country general equilibrium New-Keynesian model to explore the mechanisms behind our estimated effects in an increasingly interconnected world.

This paper is also related to the recent literature studying the role of trade openness in shaping business cycles through the lens of open economy New-Keynesian models. For instance, Caldara et al. (2020) explore the economic effects of trade policy uncertainty, Ho et al. (2022) analyze multilateral comovement, and Erceg et al. (2023) explore the interactions between trade policies and fiscal devaluations.[6] Our work is most closely related to Barattieri et al. (2021) who identify changes in protectionist measures in the data and study the consequences of changes in these measures on business cycles. We contribute to this literature by focusing on the effects of inflation of shocks to broadly defined trade barriers consistent with the structure of gravity models of international trade. Moreover, in line with our empirical approach, our framework considers more than two countries, which allows us to consider the effects of trade diversion as a result of trade cost shocks.

Lastly, this paper is also related to the literature on international trade that has exploited static gravity models of trade to estimate trade costs. Head and Mayer (2014) review various approaches to estimate trade costs. Fitzgerald (2012); Eaton et al. (2016b,a); Reyes-Heroles (2017) are some papers that exploit the fact that dynamic models can deliver static gravity conditional on aggregate data to identify trade costs given an estimate of the trade elasticity. We contribute to this literature by exploring the correlation between measured trade costs with inflation and other macroeconomic variables and documenting causal relationships.

[5] Alessandria and Choi (2014), Alessandria and Mix (2021), and Alessandria et al. (2023) are additional works focusing on how shocks to trade costs, trade policy, and supply chains can have aggregate effects.

[6] Other work like Hottman and Reyes-Heroles (2023) exploit regional U.S. data and follow a less model-dependent approach to estimate the effects of more openness on inflation dynamics and the slope of the Phillips curve in the U.S.

2 Empirical Patterns

2.1 Trade costs and inflation in the data

Trade costs are the centerpiece of our analysis. Although we cannot observe trade costs directly, we estimate trade costs using a gravity-like framework (Head and Mayer, 2014). We collect input-output data to quantify final goods and intermediate input demands across countries. Towards this end, we employ the World Input-Output Database (WIOD) that provides yearly input-output tables between 1995 and 2014 for a group of 41 countries.[7]. The WIOD tables record transactions across 35 sectors for 2000-2011 and 56 sectors for 2012-2014 of each economy within itself and with the same sectors in other countries. To measure trade costs, we focus only on 16 non-service sectors and then aggregate the sectoral demands for intermediate inputs (M) and final consumption goods (C) to obtain country-by-country bilateral trade flows in these two categories.

After aggregating intermediate and final consumption demands across non-service sectors, we can compute the import demand of country i of goods of type, $j = \{C, M\}$, sourced from country h in period t, which we denote as $\lambda^j_{ih,t}$. Consistent with our gravity framework, we can approximate bilateral trade costs in the destination country-i as follows:

$$HR^j_{ih,t} = \left(\frac{\lambda^j_{ih,t}}{\lambda^j_{hh,t}} \frac{\lambda^j_{hi,t}}{\lambda^j_{ii,t}} \right)^{-\frac{1}{2(\eta-1)}} \propto \tau^j_{ih,t}, \tag{1}$$

where $\eta - 1$ is the long-run trade elasticity.[8] Equation 1 is known as the Head-Ries index (Head and Ries, 2001; Head and Mayer, 2014), and is commonly used in the gravity-trade literature. The Head-Ries index is proportional to the iceberg-trade cost ($\tau^j_{ih,t}$) in a wide class of structural trade models featuring a gravity relationship between trade flows and relative prices— for example, Eaton and Kortum (2002); Arkolakis et al. (2012). Note that the HR indices are symmetric and imply that $HR^j_{ii,t} = 1$, consistent with the notion that trade with one-self is costless. Moreover, given an estimate of the trade elasticity, the HR indices can be computed solely from bilateral trade shares that we observe in the data. In our baseline exercise, we set $\eta = 3$, consistent with estimates from Simonovska and Waugh (2014). However, given the evidence of lower estimates for the long-run trade elasticity documented in Boehm et al. (2023), in Section , we explore the robustness of our main results to different values of the trade elasticity.

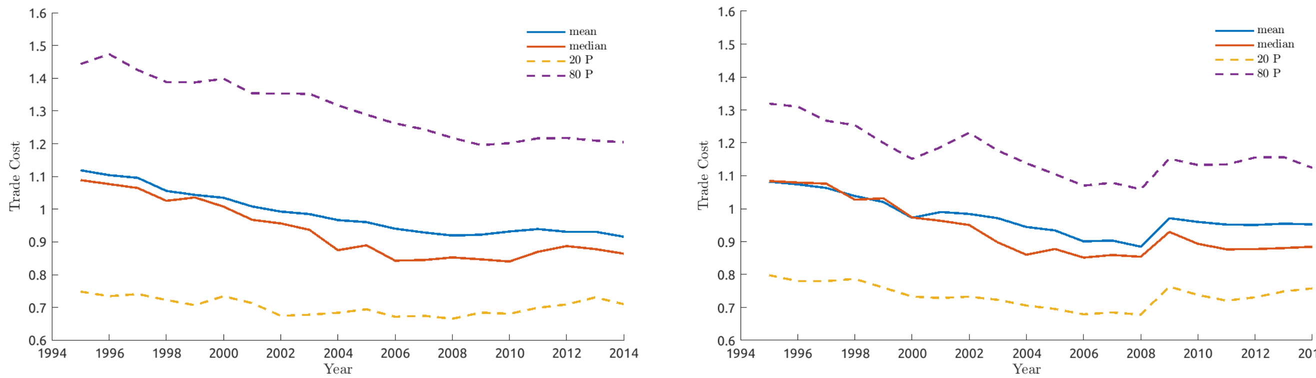
Figure 1 shows our baseline estimates of the HR indices between 1995 and 2014. The left panel corresponds to the HR index for final consumption goods, and the right panel depicts the HR index for intermediate inputs. The solid lines show the cross-country median and the dashed and dashed-dotted

[7] Timmer et al. (2015)

[8] Appendix A shows how HR indices can be derived from a simply microfounded static gravity framework.

Figure 1: **Evolution of global trade costs**

(a) Final trade cost (C) (b) Intermediate trade cost (M)



Note: data comes from WIOD database. The 2011-2014 numbers have been taken from the WIOD 2016 database and stitched to the WIOD 2013 numbers.

lines correspond to the 20th and 80th percentiles, respectively. Based on our calculated HR indices, trade costs significantly declined during this period. For instance, at the beginning of our sample, the median value of the final consumption HR index is 1.1, which implies that trade costs are roughly 100 percent of the final sale price. Toward the end of our sample, the median trade cost declined to around 90 percent. Also, there is substantial variation in trade costs across countries. The trade costs in the 80th percentile were around 130 percent of the final sale price in 2014, whereas for the countries in the bottom 20th percentile, trade costs were around 70 percent of the final sale price in the same year.

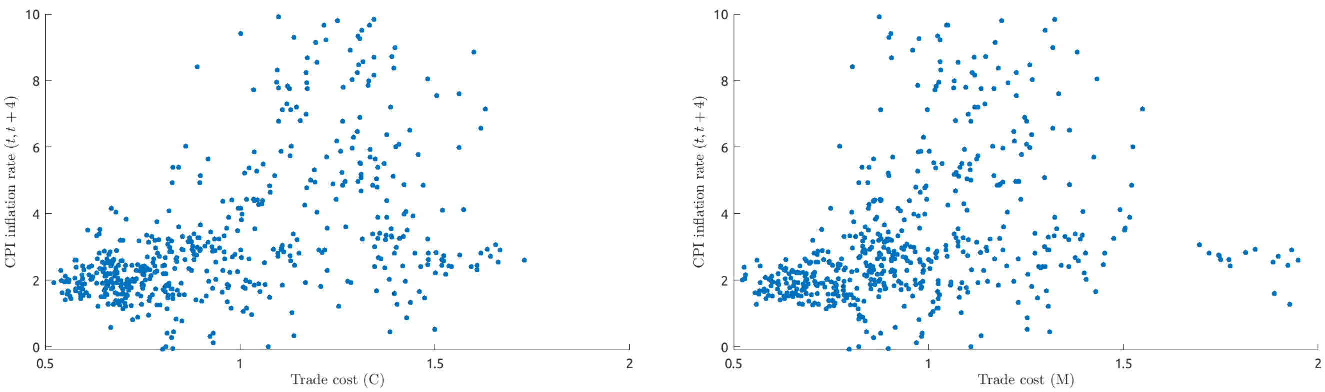
To relate inflation with trade costs, we collect yearly data on inflation for the 41 countries included in the World Development Indicators (WDI) database. We measure inflation as the year-on-year change in the Consumer Price Index (CPI). Because our period of analysis includes some high inflation episodes due to other factors unrelated to trade costs, such as currency crises or macroeconomic turmoil due to pro-market reforms in Eastern Europe, we restrict attention to country-year observation where the inflation is below 10 percent.

Figure 2 shows a scatter plot between trade costs and CPI inflation. The left panel shows the relation between trade costs in final consumption goods and inflation. The right panel shows trade costs in intermediate inputs and inflation. Each dot corresponds to a country-year observation where we relate trade costs in year t with the average CPI inflation observed in the subsequent four years, up to $t + 4$. The relation between contemporaneous inflation and trade costs is similar, but it is instructive to show future average inflation to abstract from variation in inflation that may be unrelated to current trade costs. Visual inspection suggests a positive correlation between higher trade costs, as measured by our HR index, and future CPI inflation. The scatter plot also reveals substantial dispersion in the inflation rate, particularly for country-year observations where trade costs are above 100 percent. Uncovering the causal effect and the magnitude of higher trade costs on inflation requires controlling for unobserved factors driving the positive correlation in this simple scatter plot. We turn to this analysis in the next section.

Figure 2: Trade Costs and Inflation in the Data

(a) Trade costs in consumption and inflation

(b) Trade costs in intermediates and inflation



Note: trade cost data comes from WIOD database, inflation data comes from the WDI database.

3 Estimating the Effect of Trade Costs on Inflation

3.1 Estimation Strategy

We turn to analyzing the response of inflation and the domestic sourcing share to higher trade costs. For our empirical strategy, we use local projections as in Jordà (2005) and estimate the following panel specification:

$$y_{i,t+h} = \alpha_i + \beta_h^y \tau_{i,t}^j + A_h Z_{i,t} + \varepsilon_{i,t+h} \qquad \text{for } h \geq 0, \tag{2}$$

where $y_{i,t+h}$ is the dependent variable of interest for country i in period $t+h$: for instance, we begin our analysis considering the domestic sourcing share ($s_{i,t}$) and the CPI inflation rate ($\pi_{i,t}$); thus we have $y_{i,t} = \{s_{i,t}, \pi_{i,t}\}$. To isolate the effect of trade costs, $\tau_{i,t}$ on the variables of interest, we control for unobserved sources of variation that are time-invariant but specific to each country. We capture these factors through the country-fixed effect term α_i. The coefficient β_h^y in Equation 2 captures the average effect of trade costs on the variable of interest h periods ahead. We use the vector, $Z_{i,t}$, to control for other observable characteristics in country i for period t. In our baseline specification the vector $Z_{i,t}$ includes the first lag of the dependent variable, the first lag of the unemployment rate, and the first lag of GDP growth. Finally, to account for outliers related to macroeconomic events, which are unlikely to be related to changes in trade costs, we include country-year dummy observations related to a banking crisis, currency crisis, and systemic crisis. We tabulate these dummy variables from the Global Crises Data database and include these dummies in the vector $Z_{i,t}$.[9]

Given our interpretation of the HR indices as trade costs relative to the final sale price, the raw coefficient β_h^y corresponds to the effect of a 100 percent increase in trade costs. In computing the response of $y_{i,t+h}$, however, we re-scale the response coefficient to offer a more natural comparison. First, we run the contemporaneous regression of domestic sourcing share on trade costs:

$$s_{i,t} = \alpha_i + \beta_0^s \tau_{i,t}^j + A_0 Z_{i,t} + \varepsilon_{i,t}, \tag{3}$$

after obtaining the estimate of β_0^s, we report the coefficient $\tilde{\beta}_h^y = \beta_h^y / \beta_0^s$, to scale all the responses relative to the impact effect on the domestic sourcing share. This allows us to interpret the coefficient $\tilde{\beta}_h^\pi$ as the $t+h$ response of inflation to a 1 percentage point, exogenous, increase in the domestic sourcing share due to higher trade costs.

3.2 Results

Contemporaneous response ($h = 0$)

We start by investigating the short-term response of CPI inflation to an increase in trade costs. Table 1 shows the estimated coefficient $\tilde{\beta}_0^\pi$ for different specifications of the vector of controls $Z_{i,t}$. We estimate our panel specification using the approach suggested in Correia (2016), and report heteroskedasticity-robust standard errors. The top panel corresponds to the response of inflation to an increase in the trade cost of final consumption goods. The bottom panel shows the estimated response of inflation to an increase in intermediate trade costs. In each table, column (1) is our baseline specification. Subsequent columns include country-specific macro dummies to our baseline specification. Specifically, column (2) includes a systemic crisis dummy, which combines episodes of currency and banking crises. Column (3) includes a banking crisis dummy. Column (4) includes a currency crisis dummy.

Overall, we find trade cost shocks that increase domestic sourcing of final goods by 1 percentage point, leading to an increase in CPI inflation ranging from 0.8 to about 1.2 percentage points on impact. All our regression specifications yield statistically significant results. The response of inflation to trade costs in intermediate inputs is slightly more moderate. We find that higher trade costs that increase the domestic sourcing share of intermediates by 1 percentage point also increase CPI inflation between 0.2 and 0.8 percentage points. In this case, not all our estimates of the impact response of inflation are statistically

[9]See https://www.hbs.edu/behavioral-finance-and-financial-stability/data/Pages/global.aspx

Table 1: Trade Costs and Inflation

(a) Contemporaneous Response to Final Trade Costs ($\tilde{\beta}_0^{\pi}$)

	YoY Inflation Rate			
	(1)	(2)	(3)	(4)
τ_C	1.2651**	0.9785*	1.2605**	0.8182***
	(0.4426)	(0.4765)	(0.4635)	(0.2402)
Systemic Crisis		✓		
Banking Crisis			✓	
Currency Crisis				✓
R-squared	0.4872	0.4863	0.6183	0.6744
Number of individuals	37	37	26	27
Number of observations	681	681	472	495

(b) Contemporaneous Response to Intermediate Trade Costs ($\tilde{\beta}_0^{\pi}$)

	YoY Inflation Rate			
	(1)	(2)	(3)	(4)
τ_M	0.8352**	0.5732	0.3562*	0.2150
	(0.3589)	(0.3721)	(0.2006)	(0.2039)
Systemic Crisis		✓		
Banking Crisis			✓	
Currency Crisis				✓
R-squared	0.4682	0.4721	0.6108	0.6646
Number of individuals	37	37	26	27
Number of observations	681	681	472	495

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Note: country fixed effects and year error clustering are included. The coefficient estimates are scaled to reflect an increase in trade costs that corresponds to a 1 p.p. increase in the corresponding sourcing share. For the trade cost computations, $\eta - 1 = 2$. Controls not shown include one lag of the inflation rate, lag of GDP growth, and lag of unemployment.

different from zero but still suggest a positive link between inflation and trade costs in intermediate inputs.

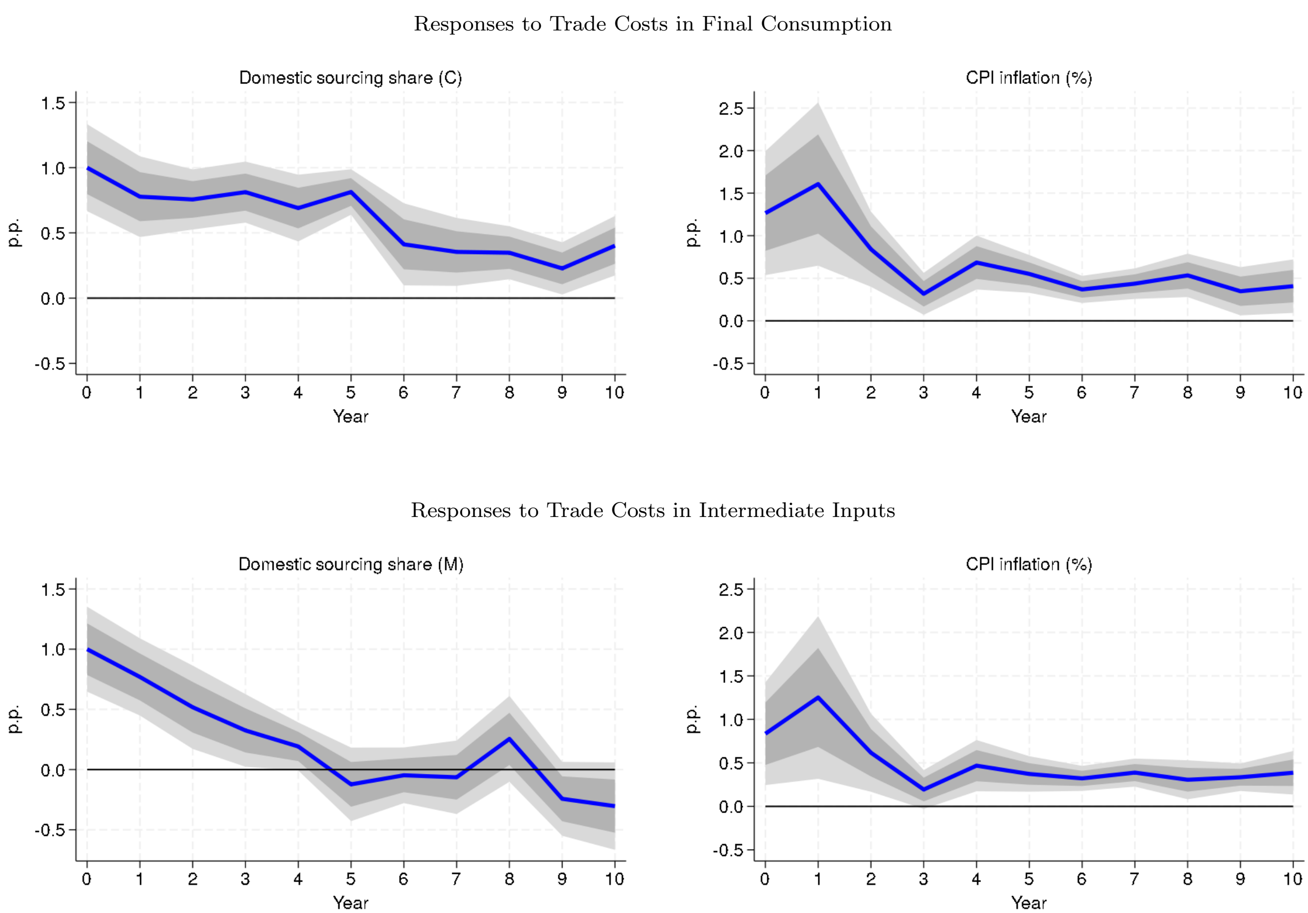
Dynamic responses ($h \geq 0$)

Now we turn to analyze the dynamic response of domestic sourcing shares and inflation to trade costs using our local projection estimates of Equation 2. We compute $\tilde{\beta}_h^y$ for horizons $h = 1, \ldots, 10$ to capture the long-term effects up to 10 years ahead. Figure 3 shows our main results. The top panels show the response in the final consumption sourcing share and inflation to higher trade costs in final goods. The bottom panels show the response in intermediate sourcing shares and inflation to higher trade costs in intermediate inputs. The impact effect of the sourcing shares is normalized as previously described, thus, by construction $\tilde{\beta}_0^s = 1$, which implies that on impact final and intermediate sourcing shares increase by 1 percentage point. The dark-shaded areas correspond to the 70% confidence interval, and the light-shaded area is the 90% confidence interval.

Two results emerge from the local projection estimates in Figure 3. First, higher trade costs have persistent effects on domestic sourcing shares. Moreover, the effect of higher trade costs in final goods on the domestic sourcing share persists for over 10 years. Similarly, higher trade costs in intermediate inputs lead to a persistent increase in the domestic sourcing of such inputs. These results are consistent with the standard gravity framework: higher iceberg trade costs hamper bilateral trade flows and result in higher domestic sourcing shares.

The second result is the positive and significant increase in inflation in response to higher trade costs. A 1 percentage point increase in domestic sourcing due to higher trade costs is associated with a peak increase of CPI inflation of 1-1.5 percentage points after two years. The inflation response moderates from the third year onward, but inflation remains persistently higher–at about 0.20 percentage points relative to a baseline without trade shocks–for several years.

Figure 3: Response of Domestic Sourcing and Inflation to Trade Costs



Note: country fixed effects and year error clustering are included. Controls are one lag of CPI inflation, Unemployment and GDP growth. The size of the trade cost shock is scaled so that we experience a 1% increase in the sourcing share.

3.3 Trade Costs and the Macroeconomy

Having estimated the impact of trade costs on inflation and the domestic sourcing share, we now turn to the transmission of trade costs to other macroeconomic variables. We amend our regression specification such that, given $y_{i,t}$, we estimate:

$$\log y_{i,t+h} - \log y_{i,t-1} = \alpha_i + \beta_h^j \tau_{i,t} + A_h Z_{i,t} + \varepsilon_{i,t+h} \qquad \text{for } h \geq 0 \tag{4}$$

where $y_{i,t}$ is our chosen real macroeconomic quantity, and $C_{i,t}$ is a vector of controls including lagged unemployment, GDP year-on-year growth, CPI inflation rate, and $y_{i,t-1}$, or a lag of the macroeconomic variable of interest.

Figure 4 plots the response of four macroeconomic aggregates: real GDP, real exports, real imports, and the real exchange rate. The top panels trace out the responses of these four variables to an increase in final trade costs. The bottom panels trace out the responses to intermediate trade costs. We scale the response of all the macroeconomic aggregates to a 1 p.p. increase in the corresponding sourcing share.

[FIGURE 4 AROUND HERE]

Our main result is that higher trade costs that increase the domestic sourcing share by 1 percentage point generate a persistent contraction in economic activity, a decline in real exports, a decline in real imports, and an appreciation of the real exchange rate. The real GDP response is weak on impact, but it progressively increases over time, bottoming out at around -1% after five years. The economic recovery is slow, with the level of real GDP recovering its losses only after 10 years. The response of GDP with respect to final and intermediate trade costs is broadly similar.

Turning to the response of trade variables, an increase in trade costs leads to a contraction in real exports and real imports. The muted short-run response of trade variables is consistent with a low-trade elasticity due to fixed costs in exporting and importing decisions (Alessandria and Choi, 2021). However, real exports decline by about -3% to -4%, while real imports decline slightly less, implying a deterioration of the real trade balance Once again, the effects of higher trade costs on trade flows are persistent, with imports and exports taking nearly a decade to recover. The reduction in trade flows and the increase in the domestic sourcing shares translates into an appreciation of the real exchange rate of about -1.5% to -2.5% by year five. The appreciation induced by higher trade costs reverts slowly.

3.4 Robustness

The Trade Elasticity

To compute our measure of trade costs we made an assumption about the value of the trade elasticity. Despite its central importance, there is a wide range of estimates for the value of η in the literature, with long-run estimates ranging from $\eta \approx 3$ to $\eta \approx 9$, see Boehm et al. (2023). We explore how the trade elasticity affects our main result. We first recompute the Head-Ries indices in Equation 1 using four different values of the trade elasticity $\eta - 1 = \{2, 4, 6, 8\}$. We then re-estimate our local projection in Equation 2 to obtain the impact response of inflation ($h = 0$).

Table 2b shows the results. The top panel presents estimation results of the impact response of inflation to final trade costs. The bottom panels shows the impact responses of inflation to higher trade costs of intermediate inputs. Across all specifications we normalize the estimated response coefficient to obtain a 1 percentage point increase in the domestic sourcing shares.

Our results are consistent across different specifications of the trade elasticity, with inflation increasing between 0.6 and 1.2 percentage points in response to higher trade costs. Note, however, that the trade elasticity matters to determine the size of the shock. In each panel, the memo line shows the associated increase in the Head-Ries index necessary to achieve a 1 percentage point increase in the domestic sourcing shares. We note that the required change in trade costs to induce a 1 percentage point increase in the sourcing share is decreasing in the value of the trade elasticity.

3.5 Sectoral Trade Costs

In our baseline results we investigated the effect of aggregate trade costs on inflation. We now briefly investigate if the inflation response is more sensitive to particular sectors in the economy. We use the granularity of the Input-Output tables to construct sector specific trade costs. In particular we map 16 non-service WIOD sectors for the 2000-2011 period and 23 non-service WIOD sectors for the 2012-2014 period, into four broad categories: (a) agricultural and mining, (b) low-tech manufacturing, (c) mid-tech manufacturing, and (d) high-tech manufacturing. We then run a local projection of the following form:

$$y_{i,t+h} = \alpha_i + \beta^y_{h,s} \tau^j_{i,s,t} + A_{h,s} Z_{i,t} + \varepsilon_{i,s,t+h} \qquad \text{for } h \geq 0,, \tag{5}$$

where the coefficient $\beta^y_{h,s}$ now traces the response of inflation to an increase in trade costs in sector $s = \{a, b, c, d\}$ for goods of type $j = \{C, M\}$, after h years following the shock. For comparison, we scale the aggregate inflation response such that the sectoral trade costs lead to an increase in sectoral domestic sourcing shares of 1 percentage point.

Table 2: Inflation regressions on different elasticities ($\eta - 1$) of trade cost

(a) Final trade cost, scaled to 1% increase in final sourcing share

	YoY Inflation Rate			
	(1)	(2)	(3)	(4)
	$\eta - 1 = 2$	$\eta - 1 = 4$	$\eta - 1 = 6$	$\eta - 1 = 8$
τ_C	1.2651**	0.9439**	0.8487**	0.8038**
	(0.4426)	(0.3384)	(0.3044)	(0.2883)
Memo				
Implied $\Delta\tau_C$ *(p.p.)*	92.97	9.98	4.31	2.64
R-squared	0.4872	0.4808	0.4769	0.4749
Number of individuals	37	37	37	37
Number of observations	681	681	681	681

(b) Intermediate trade cost, scaled to 1% increase in intermediate sourcing share

	YoY Inflation Rate			
	(1)	(2)	(3)	(4)
	$\eta - 1 = 2$	$\eta - 1 = 4$	$\eta - 1 = 6$	$\eta - 1 = 8$
τ_M	0.8352**	0.7028**	0.6546**	0.6302**
	(0.3589)	(0.3019)	(0.2820)	(0.2720)
Memo				
Implied $\Delta\tau_M$ *(p.p.)*	73.84	9.11	4.07	2.52
R-squared	0.4682	0.4655	0.4636	0.4627
Number of individuals	37	37	37	37
Number of observations	681	681	681	681

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Note: country fixed effects and year error clustering are included. The magnitudes reflect the increase in Tau that correspond to a 1 p.p. increase in the corresponding domestic sourcing share. Controls not shown includes one lag of the inflation rate, lag of GDP growth, and lag of unemployment.

Figure 5 shows the inflation responses to sectoral trade costs. For illustration, we focus on final trade costs in each sector. The peak inflation response, typically observed one year after the shock, ranges from 0.5 to 3 percentage points. The magnitudes are consistent with the average effects of higher trade costs in the aggregate. Heterogeneity in inflation responses is consistent with the different importance and substitutability of domestic and foreign goods across different sectors. For example, inflation increase modestly in response to higher trade costs in low-tech manufacturing sectors. In contrast, inflation is more sensitive to increases in trade costs in the high-tech manufacturing sector.

[FIGURE 5 AROUND HERE]

4 Model

We now explore the quantitative importance of trade cost shocks for U.S. inflation dynamics using a structural model. We build a multi-country New Keynesian model with trade in final consumption and intermediate inputs and with nominal price and wage rigidities. Our New Keynesian block is similar to canonical open economy models—see Corsetti et al. (2010) for a review. For our trade block, the central piece is the gravity equation. Because several models of trade are consistent with gravity, we follow the framework of Anderson and van Wincoop (2003) and assume Armington specialization in final consumption and intermediate inputs.

There are N countries, each with population ξ_j, for $j = 1, ..., N$. We normalize world population to unity. We take country 1 to be the United States. International financial markets are incomplete: countries can only trade in a risk-free international bond, denominated in (real) dollars (country 1's currency). Aside from the fact that country 1's currency is the one used in international financial markets, countries are otherwise symmetric, and so we describe below the structure of a generic country j.

4.1 Households

The objective function of household h in country j is

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{{C_t^j}^{1-\sigma} - 1}{1-\sigma} - \frac{{L_{h,t}^j}^{1+\varphi}}{1+\varphi} \right], \tag{6}$$

where

$$C_t^j = \left(\sum_{i=1}^{N} {\omega_i^j}^{\frac{1}{\eta}} {C_{i,t}^j}^{1-\frac{1}{\eta}} \right)^{\frac{\eta}{\eta-1}}, \tag{7}$$

with $\sum_{i=1}^{N} \omega_i^j = 1$. $C_{i,t}^j$ denote country j's households' consumption of the good produced in country i. $L_{h,t}^j$ denotes labor hours by household h in country j, where heterogeneity in labor and wages across households is introduced to motivate nominal wage rigidity as in Erceg et al. (2000) (EHL). Maximization is subject to

$$\sum_{i=1}^{j} \tau_{i,t}^j P_{i,t}^j C_{i,t}^j + B_{j,t}^j + B_{1,t}^j \frac{1}{\mathcal{E}_{j,t}^1} \leq W_{h,t}^j L_{h,t}^j + R_{t-1}^j B_{j,t-1}^j + R_{t-1}^1 \Psi_{t-1}^j B_{1,t-1}^j \frac{1}{\mathcal{E}_{j,t}^1} + T_t^j, \tag{8}$$

where $B_{j,t}^j$ denotes holdings of country j's bond, $B_{1,t}^j$ denotes holdings of country 1's bond, and $\mathcal{E}_{j,t}^1$ denotes country j's nominal exchange rate against country 1 (expressed as units of country 1 currency per unit of country j's currency), with $\mathcal{E}_{1,t}^1 = 1$. The variables $\tau_{i,t}^j$ are exogenous iceberg trade costs, following exogenous autoregressive processes, with $\tau_{j,t}^j = 1$. We allow for a *risk premium* Ψ_{t-1}^j, with $\Psi_t^1 = 1$ but different from unity for any other j:

$$\Psi_t^j = (1 - \psi \frac{b_{1,t}^j}{\mathcal{Q}_{j,t}^1 Y_t^j}) \varepsilon_{\psi,t}^j \tag{9}$$

for $j = 2, ..., N$, where $b_{1,t}^j \equiv \frac{B_{1,t}^j}{P_t^1}$ and $\varepsilon_{\psi,t}^j$ is an exogenous shock following a first-order autoregressive process.

The first-order conditions determining consumption goods' demand are

$$C_{i,t}^j = \omega_i^j \left(\tau_{i,t}^j p_{i,t}^j\right)^{-\eta} C_t^j \tag{10}$$

for $i = 1, ...N$, where $p_{i,t}^j \equiv \frac{P_{i,t}^j}{P_t^j}$ denotes the real price of good i in terms of the price of country j's consumption basket, with P_t^j denoting the standard CES price index. Re-writing the latter, these real prices must satisfy

$$1 = \left[\sum_{i=1}^{N} \omega_i^j (\tau_{i,t}^j p_{i,t}^j)^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{11}$$

The consumption Euler equation is

$$U_{c,t}^j = R_t^j \mathbb{E}_t \beta \left(\frac{U_{c,t+1}^j}{\pi_{t+1}^j}\right), \tag{12}$$

where

$$U_{c,t}^j = (C_t^j)^{-\sigma} \tag{13}$$

and

$$\pi_t^j \equiv \frac{P_t^j}{P_{t-1}^j}. \tag{14}$$

For countries other than $j = 1$, the household's first-order conditions also include an "uncovered interest parity" condition:

$$R_t^j \mathbb{E}_t \left[\frac{1}{\pi_{t+1}^j} \Big(\frac{(C_{t+1}^j / C_t^j)^{-\sigma}}{\pi_{t+1}^j} \Big) \right] = R_t^1 \Psi_t^j \mathbb{E}_t \left[\frac{1}{\pi_{t+1}^1} \Big(\frac{(C_{t+1}^j / C_t^j)^{-\sigma}}{\pi_{t+1}^j} \Big) \frac{\mathcal{Q}_{j,t}^1}{\mathcal{Q}_{j,t+1}^1} \right] \tag{15}$$

for $j = 2, ..., N$, expressed here in real terms, with the $\mathcal{Q}_{j,t}^1$ denoting the real bilateral exchange rate between country j and country 1:

$$\mathcal{Q}_{j,t}^1 \equiv \frac{\mathcal{E}_{j,t}^1 P_t^j}{P_t^1}. \tag{16}$$

4.2 Wage setting

We model wage rigidity as in EHL. A labor union in each country aggregates individual labor varieties:

$$L_t^j = \left(\int_0^1 L_{ht}^j{}^{\frac{\epsilon_w - 1}{\epsilon_w}} di \right)^{\frac{\epsilon_w}{\epsilon_w - 1}}, \tag{17}$$

leading to demand for labor variety h

$$L_{h,t}^j = \left(\frac{W_{h,t}^j}{W_t^j} \right)^{-\epsilon_w} L_t^j, \tag{18}$$

where

$$W_t^j = \left(\int_0^1 W_{h,t}^j{}^{1-\epsilon_w} di \right)^{\frac{1}{1-\epsilon_w}} \tag{19}$$

Household h can reset the nominal wage $W_{h,t}$ only with probability $1 - \theta_w$, and with probability θ_w must set the previous-period nominal wage W_{it-1}. The optimal reset nominal wage $\overline{W}_t^j$ is chosen to maximize

$$\mathbb{E}_t \sum_{k=0}^{\infty} \beta^k \theta_w^k \left(U_{c,t+k}^j \frac{\overline{W}_t^j}{P_{t+k}^j} L_{t+k|t}^j - \frac{L_{t+k|t}^j{}^{1+\eta}}{1+\eta} \right) \tag{20}$$

where

$$L_{t+k|t}^j = \left(\frac{\overline{W}_t^j}{W_{t+k}^j} \right)^{-\epsilon_w} L_{t+k}^j \tag{21}$$

denotes labor demand in period $t+k$ for a wage-setter that last rest its wage in period t.

The resulting optimality condition is

$$\mathbb{E}_t \sum_{k=0}^{\infty} \beta^k \theta_w^k L^j_{t+k|t} U^j_{c,t+k} \left(\frac{\overline{W}^j_t}{P^j_{t+k}} - \frac{\epsilon_w}{\epsilon_w - 1} \frac{L^{j\ \eta}_{t+k|t}}{U^j_{c,t+k}} \right) = 0. \tag{22}$$

Since measure θ_w of firms keep their price unchanged and $1-\theta$ reset it optimally, W^j_t satisfies

$$W^{j1-\epsilon_w}_t = \theta_w (W^j_{t-1})^{1-\epsilon_w} + (1-\theta_w)(\overline{W}^j_t)^{1-\epsilon_w} \tag{23}$$

4.3 Firms

There is a continuum of measure 1 of differentiated firms in each country. $Y^j_{v,t}$ is the quantity produced of variety v. These varieties are aggregated by competitive "final good producers" which produce homogeneous output Y^j_t by means of the production function

$$Y^j_t = \left(\int_0^1 Y^{j\ \frac{\epsilon-1}{\epsilon}}_{v,t} dv \right)^{\frac{\epsilon}{\epsilon-1}} \tag{24}$$

This homogeneous output is then either consumed domestically (as either consumption good or input) or exported. The first-order condition for final good producers (associated with maximizing profit subject to (24)) is

$$Y^j_t(i) = \left(\frac{P^j_t(i)}{P^j_{j,t}} \right)^{-\epsilon} Y^j_t \tag{25}$$

where

$$P^j_{j,t} = \left[\int_0^1 P^{j\ 1-\epsilon}_{v,t} \right]^{\frac{1}{1-\epsilon}}, \tag{26}$$

with $P^j_{v,t}$ denoting the country-j-currency nominal price charged by firm v in country j, and $P^j_{j,t}$ the country-j-currency price of the country-j homogeneous output.

4.3.1 Price setting

We assume PCP: home firms sets prices in dollars and let their prices in the foreign currencies adjust with the exchange rate. Let nominal marginal cost be MC^j_t and let $\overline{P}^j_{j,t}$ be country j firms' reset price, in country j currency. This price is set to maximize

$$\mathbb{E}_t \sum_{k=0}^{\infty} \frac{U_{c,t}^j}{P_{t+k}^j} \beta^k \theta^k \left(\overline{P}_{j,t}^j - MC_{t+k}^j \right) \left(\frac{\overline{P}_{j,t}^j}{P_{j,t+k}^j} \right)^{-\epsilon} Y_{t+k}^j \tag{27}$$

FOC:

$$\mathbb{E}_t \sum_{k=0}^{\infty} \frac{U_{c,t}^j}{P_{t+j}^j} \beta^k \theta^k P_{j,t+k}^{j\epsilon} Y_{t+k}^j \left[\overline{P}_{j,t}^j - \frac{\epsilon}{\epsilon - 1} MC_{t+k}^j \right] = 0. \tag{28}$$

Since measure θ of firms keep their price unchanged and $1 - \theta$ reset it optimally, $P_{j,t}^j$ satisfies

$$P_{j,t}^j{}^{1-\epsilon} = \theta P_{j,t-1}^j{}^{1-\epsilon} + (1 - \theta) \overline{P}_{j,t}^j{}^{1-\epsilon} \tag{29}$$

4.3.2 Cost minimization

The production function is[10]

$$Y_t^j = A_t^j \left[(1 - \nu)^{\frac{1}{\varepsilon_y}} L_t^j{}^{\frac{\varepsilon_y - 1}{\varepsilon_y}} + \nu^{\frac{1}{\varepsilon_y}} M_t^j{}^{\frac{\varepsilon_y - 1}{\varepsilon_y}} \right]^{\frac{\varepsilon_y}{\varepsilon_y - 1}}, \tag{30}$$

where A_t^j is exogenous productivity, L_t^j is labor input, and M_t^j is intermediates input. The latter is itself a CES aggregate of intermediates sourced domestically and from abroad:

$$M_t^j = \left[\sum_{i=1}^{N} \omega_{m,i}^j{}^{\frac{1}{\eta_m}} M_{i,t}^j{}^{1 - \frac{1}{\eta_m}} \right]^{\frac{\eta_m}{\eta_m - 1}} \tag{31}$$

where $\sum_{i=1}^{N} \omega_{m,i}^j = 1$.

Imported inputs choice. The choice of usage of intermediate inputs $M_{i,t}^j$ consists of minimizing

$$\sum_{i=1}^{N} \tau_{m,i,t}^j P_{M,i,t}^j M_{i,t}^j \tag{32}$$

subject to a (31) for a given M_t^j. The variables $\tau_{m,i,t}^j$ are exogenous iceberg trade costs affecting trade in intermediates, which follow first-order autoregressive processes, with $\tau_j^j = 1$.

[10] We will restrict attention to a first-order approximation of the model, so we ignore second-order price dispersion terms and in this section treat the aggregate production function as being analogous to the individual-producer production function (the difference between the two arises from price dispersion and is therefore of second order).

The corresponding first-order conditions are

$$M_{i,t}^j = \omega_{m,i}^j \left(\frac{\tau_{m,i,t}^j P_{M,i,t}^j}{P_{M,t}^j} \right)^{-\eta_m} M_t^j, \tag{33}$$

with

$$P_{M,t}^j = \left[\sum_{i=1}^N \omega_{m,i}^j (\tau_{i,t}^j P_{M,i,t}^j)^{1-\eta_m} \right]^{\frac{1}{1-\eta_m}}. \tag{34}$$

Labor and intermediates choice. The choice of L_t^j and M_t^j consists of minimizing

$$W_t^j L_t^j + P_{M,t}^j M_t^j \tag{35}$$

subject to (30). The first-order conditions give one expression for nominal marginal cost MC_t^j and another linking the ratio of inputs to the ratio of input prices. Marginal cost:

$$MC_t^j = \frac{1}{A_t^j} \left[(1-\nu) {W_t^j}^{1-\varepsilon_y} + \nu {P_{M,t}^j}^{1-\varepsilon_y} \right]^{\frac{1}{1-\varepsilon_y}}. \tag{36}$$

Inputs ratio:

$$\frac{W_t^j}{P_{M,t}^j} = \left(\frac{1-\nu}{\nu} \right)^{\frac{1}{\varepsilon_y}} \left(\frac{L_t^j}{M_t^j} \right)^{-\varepsilon_y}. \tag{37}$$

4.4 Monetary policy

The central bank follows in each country follows a conventional inertial Taylor rule:

$$R_t^j = \left(R_{t-1}^j \right)^{\phi_r} \left(\frac{1}{\beta} \left(\pi_t^j \right)^{\phi_\pi} \left(\frac{Y_t^j}{Y_0^j} \right)^{\phi_y} \varepsilon_{r,t}^1 \right)^{1-\phi_r}. \tag{38}$$

4.5 Market clearing and balance of payments

Goods with origin in country i are either consumed domestically, used as inputs for domestic firms, or exported, leading to the market clearing conditions

$$\xi^i Y_t^i = \sum_{j=1}^N \xi^j (C_{i,t}^j + M_{i,t}^j) \tag{39}$$

for $i = 1, ...N$, where the population terms ξ^i reflect the fact that all variables are expressed in per-capita terms.

For countries other than $j = 1$, by aggregating domestic budget constraints a balance of payments equation can be derived determining the evolution of these countries' holdings of the dollar-denominated international bond:

$$C_t^j + \frac{1}{\mathcal{Q}_{j,t}^1} b_{1,t}^j = \frac{1}{\mathcal{Q}_{j,t}^1} \frac{R_{t-1}^1 \Psi_{t-1}^j}{\pi_t^1} b_{1,t-1}^j + p_{j,t}^j Y_t^j - p_{m,t}^j M_t^j \tag{40}$$

for $j = 2, .., N$.

5 Calibration

For the numerical experiments in the following section, we set $N = 3$ and calibrate countries 1, 2, and 3 to correspond to the United States, China, and the Rest of the World (ROW) respectively. Table 3 lists the corresponding parameter values. The preference and technology parameters are standard, and similar to those in Comin and Johnson (2020). The one exception is the trade elasticity, which in our baseline calibration we set to a lower value based on evidence that this elasticity is much lower in the short run than in the medium run. The population parameters ξ^j are set to replicate the weights of U.S. and China in world GDP. Because we assume trade is balanced in steady state, we can only calibrate three out of the six openness parameters for final consumption goods (ω_i^j) and for intermediate inputs ($\omega_{m,i}^j$), with the rest determined by the balanced-trade restriction. We set these parameters based on world input-output tables.

6 Analysis

We next perform a series of experiments aimed at illustrating the model's predictions on the effects of disruptions in intermediate goods trade. We first examine the effects on the U.S. and global economies of a generalized increase in trade costs in the model, mimicking the empirical results illustrated above. We next focus on the role of two key model parameters: the degree of input substitutability, and the degree of openness. Finally, we consider the effects of an increase in trade costs between the U.S. and China bilaterally.

Table 3: Calibrated Parameters

Parameter	Description	Value
β	Discount factor	0.99
σ	Inverse IES	2
η	Trade substitution elasticity consumption	1.5
φ	Inverse labor supply elasticity	2
ϵ	Home varieties' substitution elasticity	6
ϵ_w	Labor varieties' substitution elasticity	6
θ	Price rigidity	0.75
θ_w	Wage rigidity	0.75
ν	Intermediates weight in production	0.43
ε_y	Intermediates-labor substitution elasticity	1
η_m	Trade substitution elasticity intermediates	1.5
ϕ_π	Taylor rule inflation coefficient	1.5
ϕ_y	Taylor rule output coefficient	0.10
ϕ_r	Taylor rule inertia	0.85
ψ	Risk premium elasticity to NFA	0.005
ρ_τ	Persistence trade shock (consumption)	0.90
ρ_{τ_m}	Persistence trade shock (intermediates)	0.90
ρ_a	Persistence TFP shock	0.9
ρ_r	Persistence monetary shock	0.5
ρ_ψ	Persistence risk premium shock	0.9
ξ_1	U.S. Global GDP share (PPP), 2023	20.2/100
ξ_2	China Global GDP share (PPP), 2023	19.4/100
ω_1^1	Share of U.S. final consumption sourced domestically	0.946
ω_1^2	Share of U.S. final consumption sourced from China	0.011
ω_2^3	Share of China final consumption sourced from Rest of World (ROW)	0.046
$\omega_{m,1}^1$	Share of U.S. intermediate inputs sourced domestically	0.897
$\omega_{m,1}^2$	Share of U.S. intermediate inputs sourced from China	0.010
$\omega_{m,2}^3$	Share of China intermediate inputs sourced from ROW	0.061

6.1 Generalized increase in intermediates trade costs

In Figure 6, we assume that costs of intermediates trade $\tau_{m,i,t}^{j}$ increase for all country pairs, simultaneously and by the same amount. We size the magnitude of the shock so that it increases the U.S. sourcing share of U.S.-produced intermediates by 1 percentage point (first panel). The remaining panels show the effects on the U.S. economy of this trade shock.

The key observation is that inflation rises, by close to 1 percentage point, and that GDP declines nearly 1 percent. These magnitudes resemble those obtained from the empirical analysis discussed earlier. The mechanics are as follows. The shock increases the costs of U.S. firms sourcing intermediates from abroad. As a result, the real price of the intermediate input bundle in the U.S. (first panel, second row), rises sharply, feeding into domestic marginal costs. The impetus from this force explains the rise in U.S. inflation. At the same time, U.S. firms lower the quantity of intermediates sourced from abroad, and despite the increase of intermediates sourced from the U.S. itself ($M^1_{1,t}$ rises), the total quantity of the intermediate input basket used, M^1_t, falls considerably. U.S. firms also partly substitute by using more labor, but total output nevertheless falls considerably.

[FIGURE 6 AROUND HERE]

Turning to external variables, the model predicts a sharp fall in imports and exports, along with a deterioration of the U.S. trade balance, and an appreciation of the dollar. The latter occurs because foreign countries increase their dollar borrowing, which raises the risk premium on their currencies.

Figure 7 plots the global effects of the shock. The key takeaway is that inflation rises globally. Thus, a shock of this type can potentially explain part of the inflation surge observed globally between 2021 and 2023, which we explore further in the next section. Observe, also, that GDP declines in all regions as well. Thus, the shock has the features of a negative global supply shock—which generates adverse trade-offs for monetary authorities globally.

[FIGURE 7 AROUND HERE]

6.2 Role of key parameters

Returning to Figure 6, we explore the role of a higher trade elasticity, which we assume to be 3 in the simulation shown by the red dash-dotted line. In this experiment we re-size the shock so that it continues to induce an increase of 1 percent in the domestic sourcing share. We highlight that the effects go in the same direction qualitatively as our baseline case, but are quantitatively smaller. Thus, a higher elasticity is consistent by the smaller effects in the medium run we find in our empirical analysis.

[FIGURE 8 AROUND HERE]

Next, we examine the role subtitutability between labor and intermediates, captured by the parameter ε_y, in shaping the effects of the trade shock. Figure 8 shows the implications of the shock in our baseline calibration in blue, which assumes $\varepsilon_y = 1$ (the Cobb-Douglas case), and the implications assuming $\varepsilon_y = 0.5$. shown in red. With a lower elasticity, a larger increase in labor is required, for a given reduction in intermediate input, to maintain production at a given level. In our simulation with $\varepsilon_y = 0.5$, aggregate labor input increases much more than in our baseline calibration. The increase in labor usage is associated with much stronger wage pressures: wage inflation rises nearly four times as much, feeding into higher price inflation. Observe, also, that output follows roughly the same path as our baseline experiment. Thus, this lower-elasticity setting implies a worsened tradeoff for monetary policy.

The next experiment assesses the implications of a trade shock of a given size occurring in a world that's relatively closed, compared to its implications if it occurs in a world that is much more open in terms of intermediates' trade. Specifically, we compare our baseline calibration (in which the home bias in intermediates is fairly high) against an alternative in which this home bias is much lower, roughly matching the increase in openness seen in the last two decades (measured in terms of goods trade).

[FIGURE 9 and 10 AROUND HERE]

Figure 10 shows the effects of a shock to $\tau^{j}_{m,i,t}$ of the same size, in the "low openness" world (in blue) compared with the "high openness" world (in red dashed). The key observation is that the same shock has much larger effects in the high-openness calibration. Thus, in a context in which firms are highly reliant to foreign inputs, an increase in intermediates trade costs—driven by, say, a supply chain disruption, or an increase in tariffs— has more adverse effects.

6.3 A China-specific trade shock

Our model can also be used to examine the effects of an increase in trade costs between specific country pairs. In particular, in this subsection we show the effects in our model of an increase in intermediates' trade costs between the U.S. and China (countries 1 and 2 in our calibration). Specifically, we assume a commensurate rise in $\tau^{1}_{m,2,t}$ and $\tau^{2}_{m,1,t}$, and set the size of the shock so that the U.S. intermediate input sourcing share from China falls by 1 percentage point. Compared to the more-generalized increase in trade costs examined previously, the effects on the U.S. economy are more muted, but still non-negligible, with inflation rising a third of a percentage point and GDP falling 0.25 percent. Interestingly, part of this more-muted effect occurs because the U.S. sources more from the rest of the world, which sees its exports of intermediates to the U.S. ($M^{1}_{3,t}$) rise by 0.35 percent, as shown in the last panel.

7 Post-Pandemic Trade Costs

In this section we use a variant of the model presented in Section 4 to explore the contribution of trade cost shocks during the most recent surge in inflation in the U.S. during 2021-2022, in the aftermath of the COVID-19 pandemic. This period lends itself as a natural laboratory to explore the role of disruptions to trade flows resulting from several factors, but most prominently those related to supply chain disruptions, bottlenecks and higher shipping costs. We capture all these factors using the iceberg trade costs in our model and run a comparison with other supply and demand forces that were also at play during this period.

7.1 Departures from baseline model

For simplicity we focus solely on the dynamics of the U.S. economy and model the U.S. as a small-open economy. This entails considering a two-country variant of the model in Section 4 where we additionally treat all foreign variables as being driven by exogenous process. In particular, we assume that the price of the foreign good $P_F = P_1$

7.2 Data

U.S. Variables. We link six U.S. macroeconomic time series to model counterparts. Our data includes four traditional macroeconomic aggregates: real GDP, real consumption, CPI inflation, and the Federal Funds Rate. We also use time series data to discipline the trade block of the model. We obtain data on the GDP share of expenditure on imported consumption goods, $(M_{F,t}/Y_t)$, and the GDP share of expenditure of imported industrial inputs, $C_{F,t}/Y_t$. To be consistent with our measurement of foreign inflation, we exclude expenditure in automobiles and petroleum from the respective series, and express the expenditure shares in logs.

Foreign Variables. Because we have not specified the foreign block, we need to make some assumptions about the evolution of the vector of foreign variables, $x_t^* = [\hat{\pi}_{F_t}, \hat{C}_t^*]'$, evolves according to a bi-variate reduced form VAR $x_t^* = A(L)x_t^* + \epsilon_t^*$. Where $\hat{\pi}_{F,t} = \Delta\hat{p}_{F_t} + \hat{\pi}_{C,t}$ is the model implied inflation of foreign goods, $A(L)$ is a polynomial in the lag operator determining the number of lags in the model. The vector of reduced from disturbances is normally distributed with a non-diagonal variance covariance matrix that we recover from the data, $\epsilon_t^* \sim N(0, \Sigma)$. In the data, we can approximate $\hat{\pi}_{C,t}$ with the log-change in the U.S. CPI index. We collect data on inflation for final imported goods $(\pi_{F,t}^C)$, and intermediate imported imports $(\pi_{F,t}^M)$. Our measure for foreign inflation, is the weighted average of these inflation series $\hat{\pi}_{F_t} = \sum_s \left(\frac{P_{s_0}C_{s_0}}{P_0C_0}\right)\pi_{F_t}^s$ for $s \in \{C, M\}$, where the weights are obtained from the corresponding expenditure shares observed in 1990. We measure $\pi_{F,t}^C$ with imported consumer goods, excluding automobiles, price inflation. For $\pi_{F,t}^M$ we use the imported industrial materials excluding petroleum price inflation. Both series are obtained from the BEA.[11]

[11] For 1967-1998 we use Table 4.2.5A. "Exports and Imports of Goods and Services by Type of Product". For 1999-2022 we use Table 4.2.5B. "Exports and Imports of Goods and Services by Type of Product"

7.3 Model Solution and Inference

After calibrating the model, we estimate the remaining parameters using Bayesian methods. We estimate the parameters governing the evolution of six exogenous processes for: technology Z_t, domestic demand Z_t^D, domestic goods markups, Z_t^P, trade costs of imported final consumption, τ_{C_t}, trade costs of intermediate inputs, τ_{M_t}, and monetary policy shocks, Z_t^R. The exogenous variables follow an auto regressive process $x_t = \rho_x x_{t-1} + \sigma_x \epsilon_{x,t}$ for $x = Z, Z^D, Z^P, \tau^C, \tau^M Z^R$ and where $\varepsilon_{x,t} \sim N(0,1)$. We make the additional assumption that $\rho_{Z^R} = 0$. The Appendix provides details on prior distributions, observation equations and estimation results.

7.4 Counterfactual Analysis

Using the model we recover a time path for structural shocks, $\varepsilon^x_{1980Q1:2022Q4}$ where $x = Z, Z^D, Z^P, \tau^C, \tau^M Z^R$, that replicate the evolution of the series used in estimation. We focus on the evolution of inflation under a counterfactual path in which we set $\varepsilon^{\tau^M}_{2022Q1:2022Q4} = \varepsilon^{\tau^C}_{2022Q1:2022Q4} = 0$. Figure 11 shows the evolution of CPI inflation in the data, shown as the solid green line, and a counterfactual path of inflation constructed using the model without the realized trade cost shocks in 2022.

[FIGURE 11 AROUND HERE]

We find that absent trade cost shocks, inflation in the U.S. would have been about 2 percentage points lower by the end of 2022. Our trade cost shocks likely capture the cumulative effect of a series of factors such as bottlenecks and supply chain disruptions that unwound since late 2021 and drove the inflation surge in 2022.

8 Conclusions

TBW

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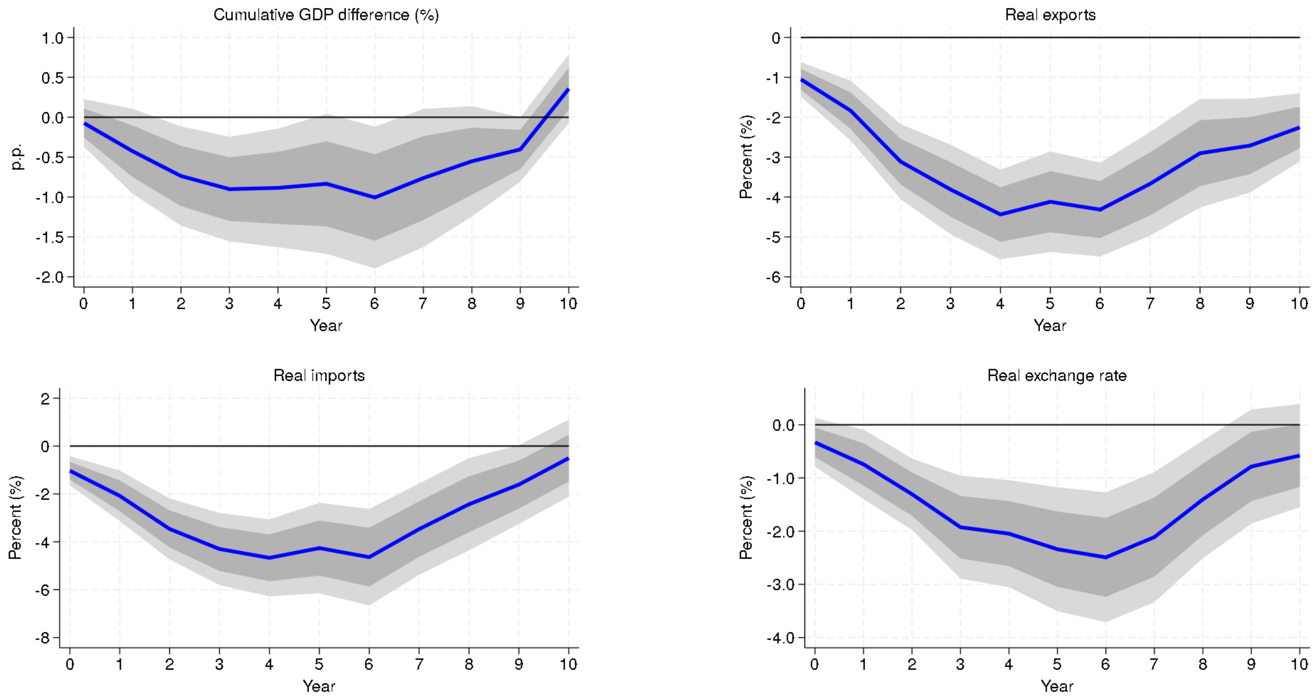
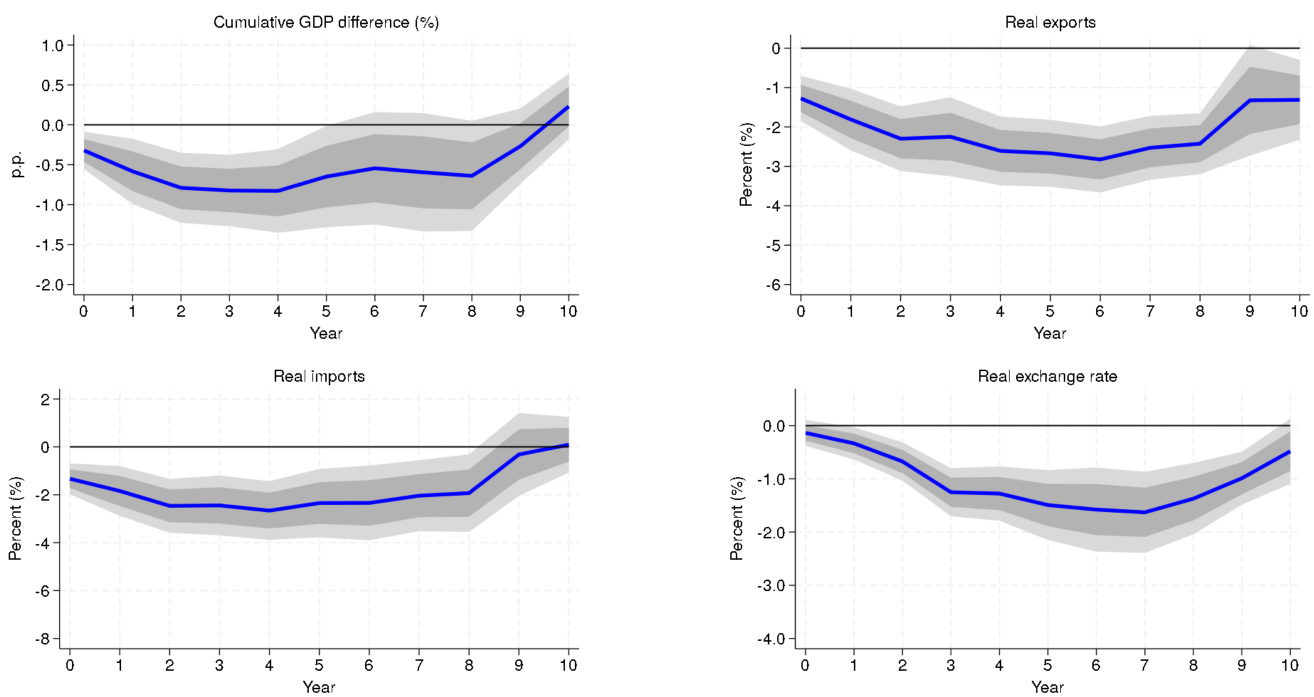
Figure 4: Macroeconomic Response to Higher Trade Costs

Response to Final Trade Costs



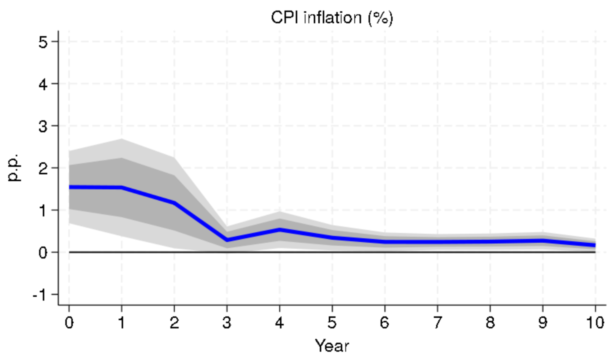
Response to Intermediate Trade Costs



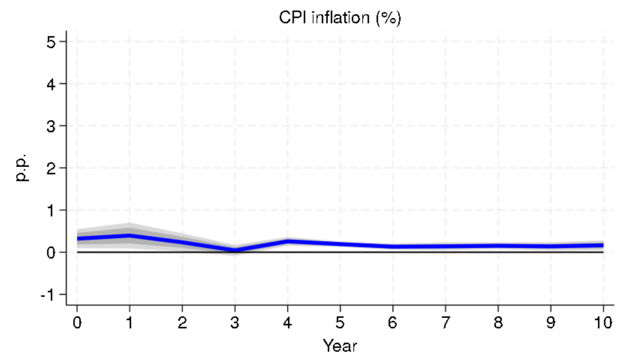
Note: country fixed effects and year error clustering are included. We multiply the trade cost by the same coefficient as in Figure 3 so as to correspond to a 1% increase in the sourcing share. This gives us the same numbers in Year 0 as we computed, namely 4.3% and 4% for final and intermediate trade costs, respectively.

Figure 5: Inflation Response to Sectoral Trade Costs (Final Goods)

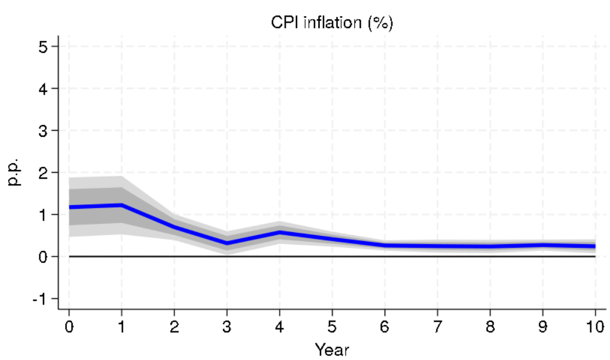
(a) Agriculture and mining



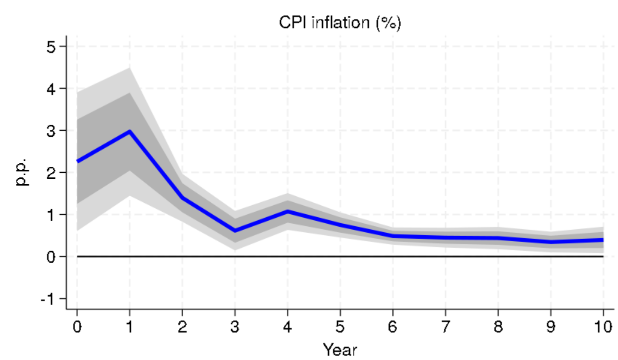
(b) Low-tech manufacturing



(c) Mid-tech manufacturing



(d) High-tech manufacturing



Note: country fixed effects and year error clustering are included. Controls are one lag of CPI inflation, Unemployment and GDP growth. The size of the trade cost shock is scaled to 1% for all, and the sourcing share is the corresponding sub-sector sourcing share.

Figure 6: U.S. effects of generalized increase in intermediates' trade costs

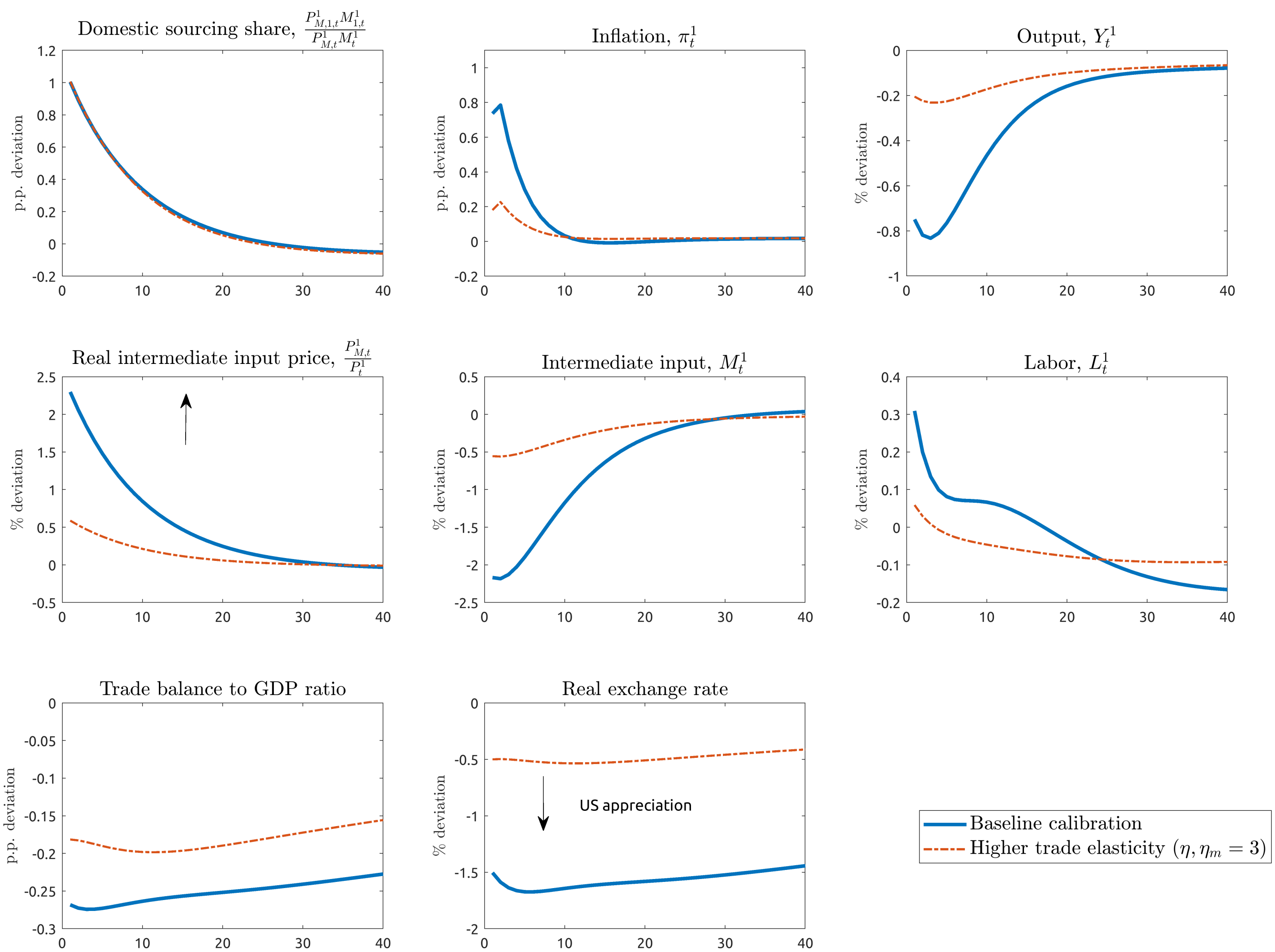


Figure 7: Global effects of generalized increase in intermediates' trade costs

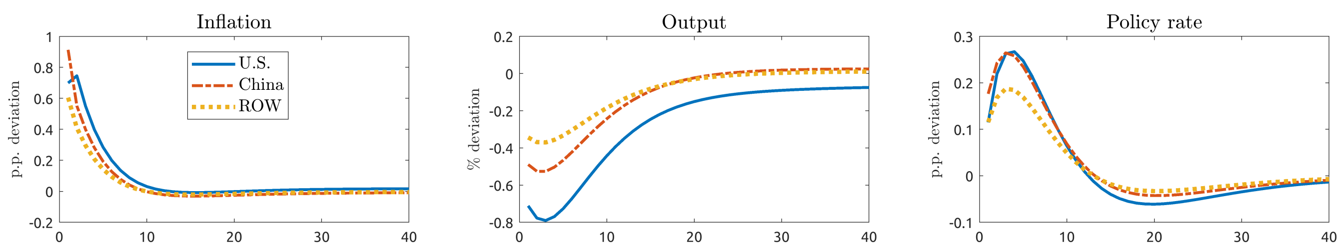


Figure 8: U.S. effects of generalized increase in intermediates' trade costs, role of intermediates-labor substitution elasticity

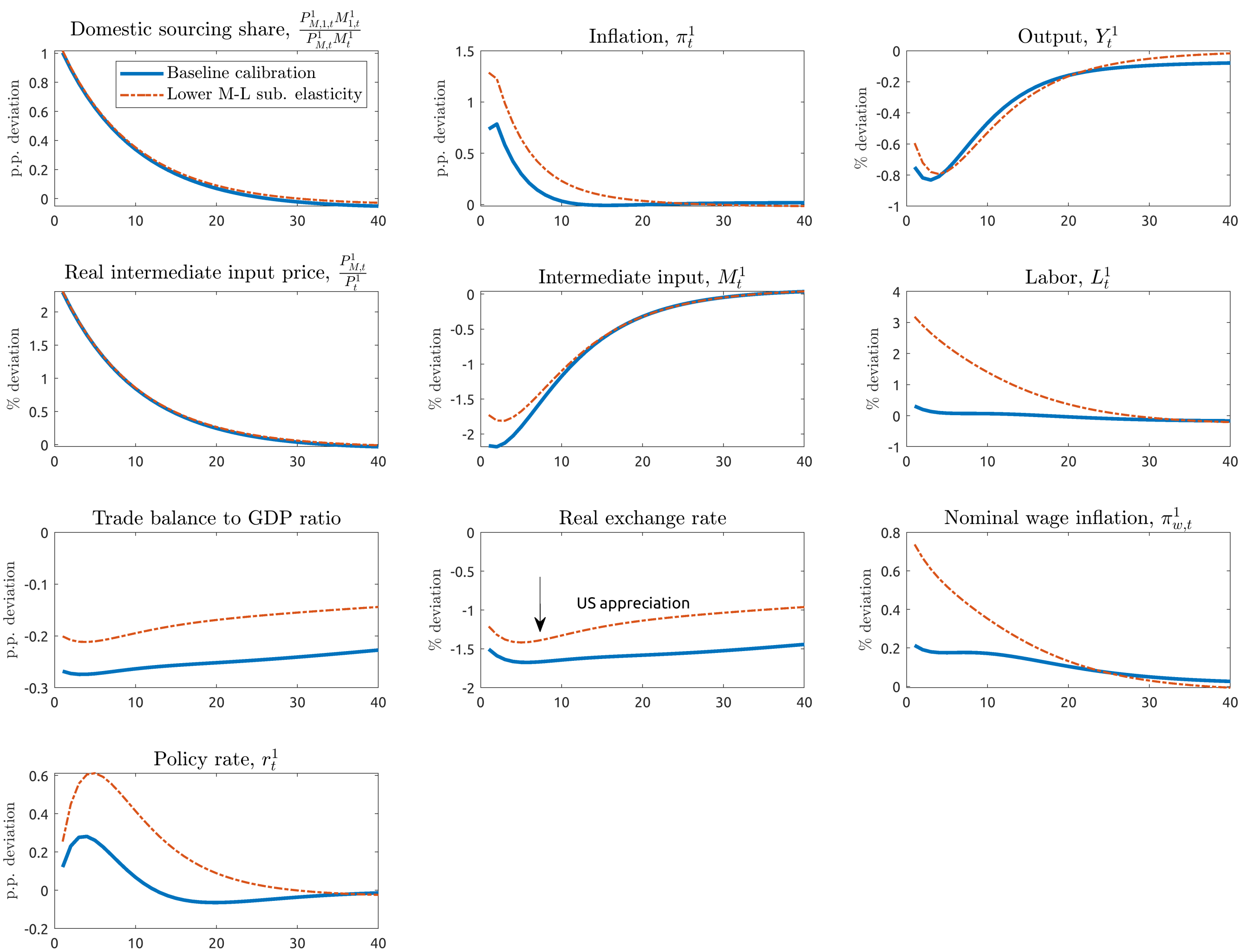


Figure 9: U.S. effects of generalized increase in intermediates' trade costs, role of openness

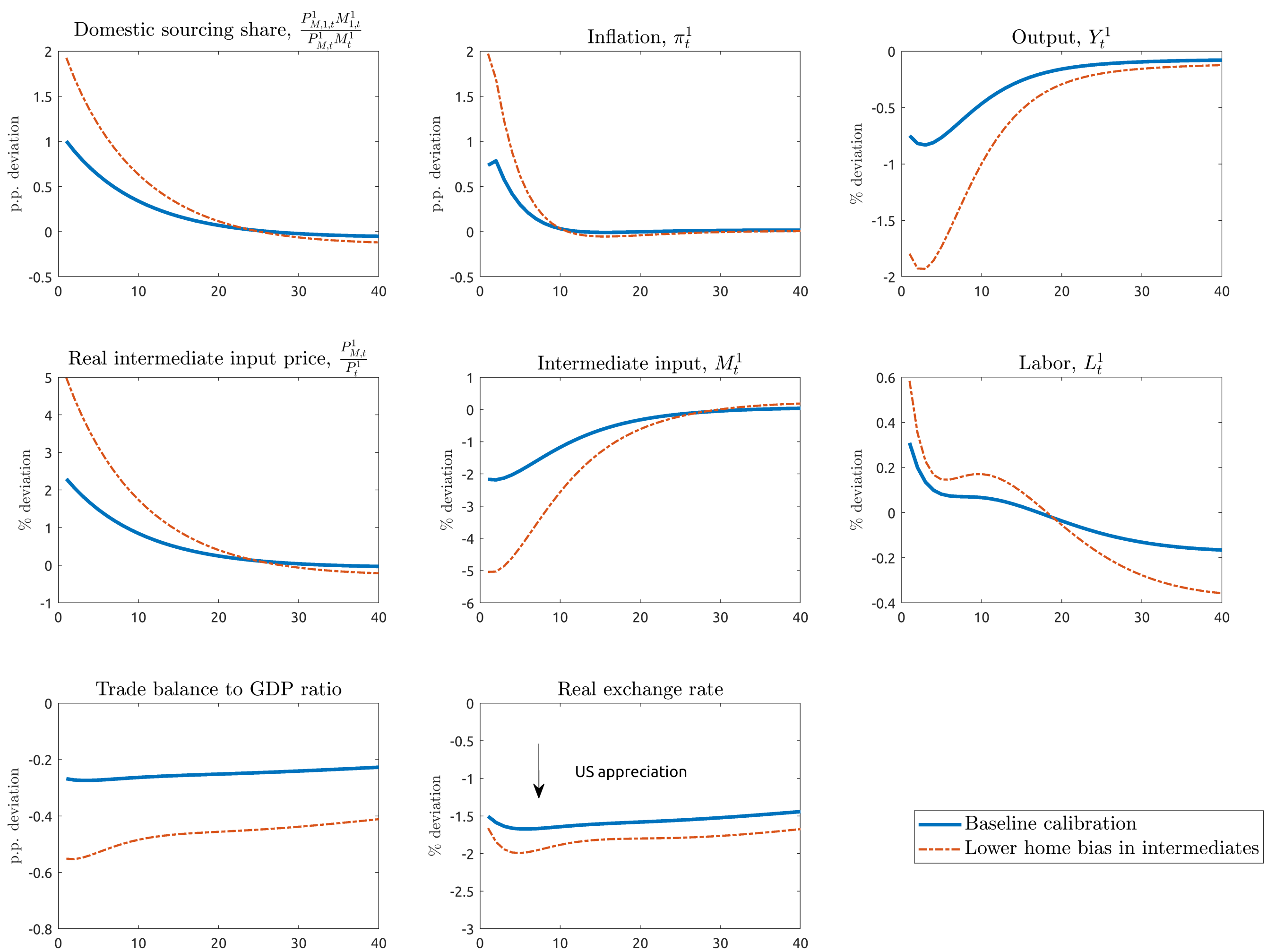


Figure 10: Effects of increase in intermediates' trade costs between U.S. and China

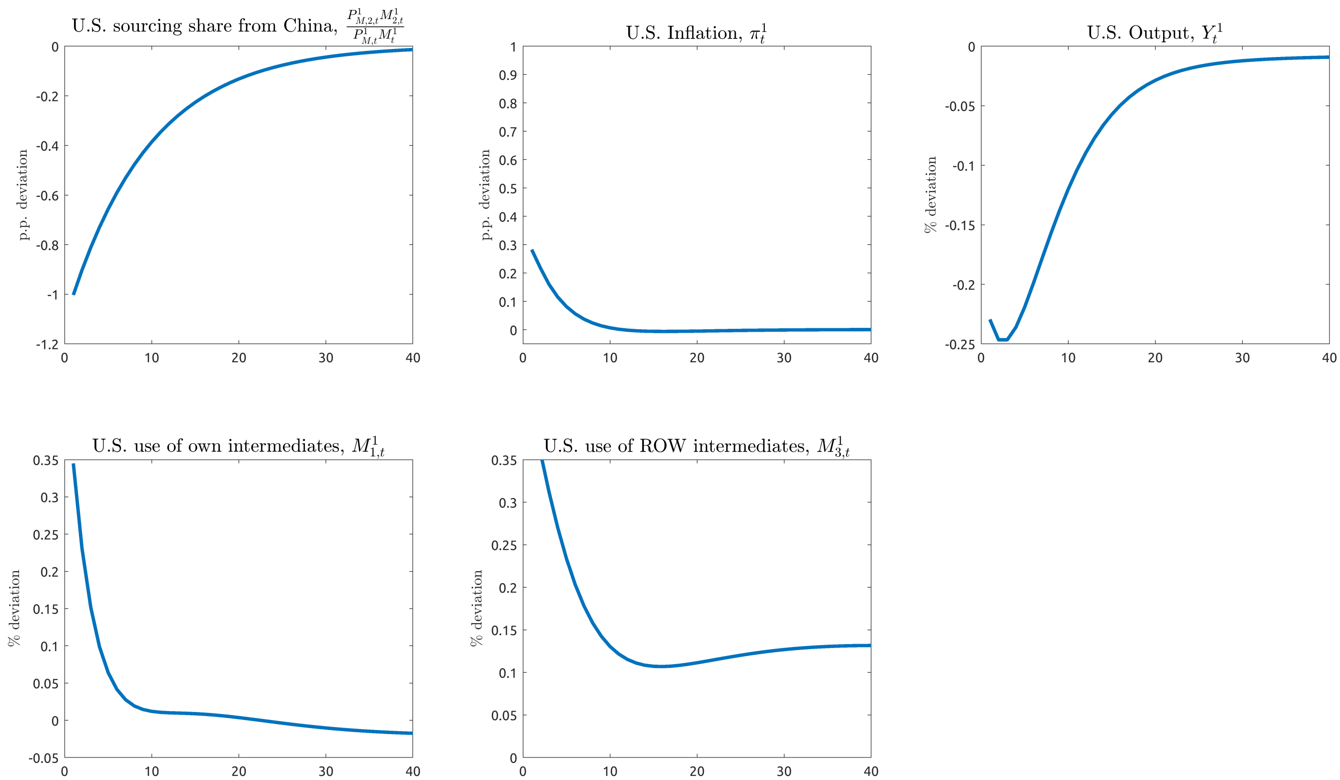
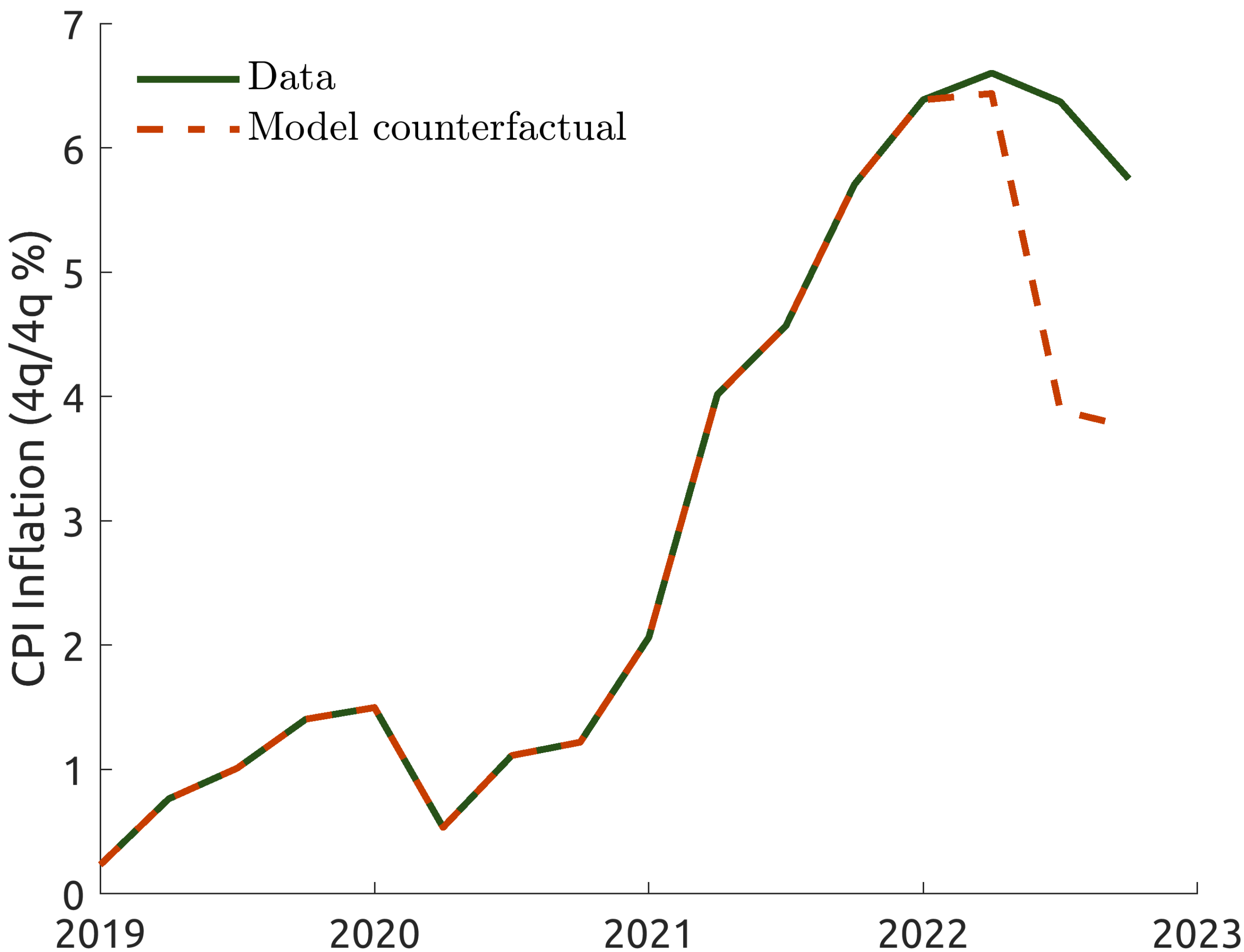


Figure 11: U.S. Inflation Counterfactual - No Trade Costs (2022Q1:2022Q4)



A Measuring Trade Costs: The Head-Ries Index

Consider a static environment with multiple countries indexed by i, h. In period t, country i is endowed with $L_{i,t}$ units of labor that can be used to produce a unique good sourced to all other countries, that is, there is National Product Differentiation. The technology available to country i to produce this good is linear and given by

$$Y_{i,t} = Z_{i,t} L_{i,t}, \tag{41}$$

where $Z_{i,t}$ denotes labor productivity. The labor market in each country is perfectly competitive.

Let $q_{ih,t}$ denote the use by country i of goods produced in h at time t. These goods can be either used for final consumption or as intermediate goods in production. We focus on the case in which these goods have a single use. Each country i aggregates goods across sources into a single composite good according to constant elasticity of substitution (CES) aggregator given by

$$Q_{i,t} = \left(\sum_h (q_{ih,t})^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{42}$$

with $\eta > 1$.

Trade across countries is subject to iceberg-type trade costs given by $\tau_{ih,t} \geq 1$, implying that for one unit of good produced in h to be delivered to i, $\tau_{ih,t}$ units have to be shipped at time t. That is, $\tau_{ih,t} - 1$ units of the good disappear when this is shipped internationally from country h to country i. We normalize domestic trade costs such that $\tau_{ii,t} = 1$ from every i.

Let $p_{ih,t}$ denote the price paid by country i for goods bought from country h. Perfectly competitive good and labor markets imply that

$$p_{ih,t} = \tau_{ih,t} \frac{w_{h,t}}{Z_{h,t}}, \tag{43}$$

where $w_{h,t}$ is the wage in country h. Agents in country i seek to minimize expenditure when choosing $\{q_{ih,t}\}_h$, leading to the following conditional demand functions:

$$q_{ih,t} = \left(\frac{\tau_{ih,t} Z_{h,t}^{-1} w_{h,t}}{P_{i,t}} \right)^{-\eta} Q_{i,t}, \tag{44}$$

where

$$P_{i,t} \equiv \left(\sum_h \left(\tau_{ih,t} \frac{w_{h,t}}{Z_{h,t}} \right)^{1-\eta} \right)^{\frac{1}{1-\eta}} \tag{45}$$

denotes the ideal price index for composite good $Q_{i,t}$.

Let $\lambda_{ih,t}$ denote the share of expenditure by country i on goods produced in country h, $\lambda_{ih,t} \equiv \frac{p_{ih,t} q_{ih,t}}{P_{i,t} Q_{i,t}}$. Equation 44 implies that

$$\lambda_{ih,t} = \left(\frac{\tau_{ih,t} Z_{h,t}^{-1} w_{h,t}}{P_{i,t}} \right)^{-(\eta-1)}, \tag{46}$$

implying that the trade elasticity in this model is given by $\eta - 1$. Note then that

$$\frac{\lambda_{ih,t}}{\lambda_{hh,t}} = \left(\tau_{ih,t} \frac{P_{h,t}}{P_{i,t}} \right)^{-(\eta-1)} \tag{47}$$

and

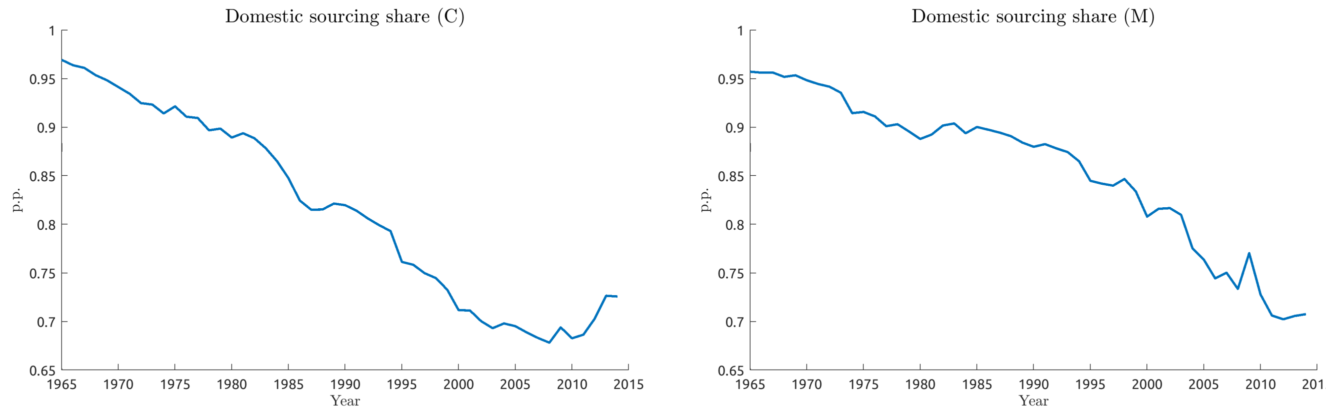
$$\frac{\lambda_{ih,t}}{\lambda_{hh,t}} \frac{\lambda_{hi,t}}{\lambda_{ii,t}} = \left(\tau_{ih,t} \tau_{hi,t} \right)^{-(\eta-1)}. \tag{48}$$

Hence, if we have data on expenditure shares, we can recover the product of bilateral trade costs for a particular country pair as

$$\tau_{ih,t} \tau_{hi,t} = \left(\frac{\lambda_{ih,t}}{\lambda_{hh,t}} \frac{\lambda_{hi,t}}{\lambda_{ii,t}} \right)^{\eta-1}. \tag{49}$$

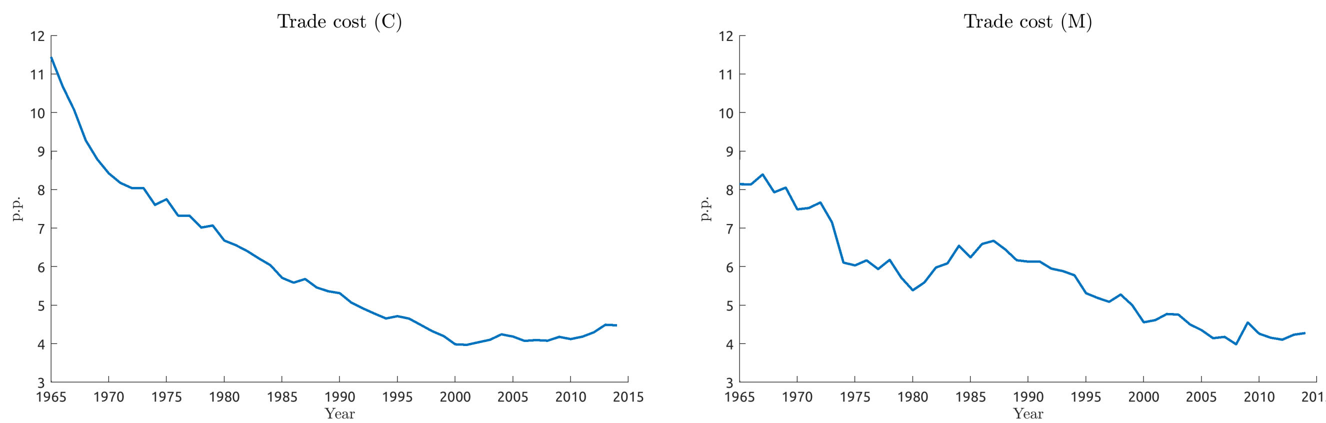
B Evolution of Trade Costs Around the World

Figure 12: **Evolution of United States domestic sourcing share**



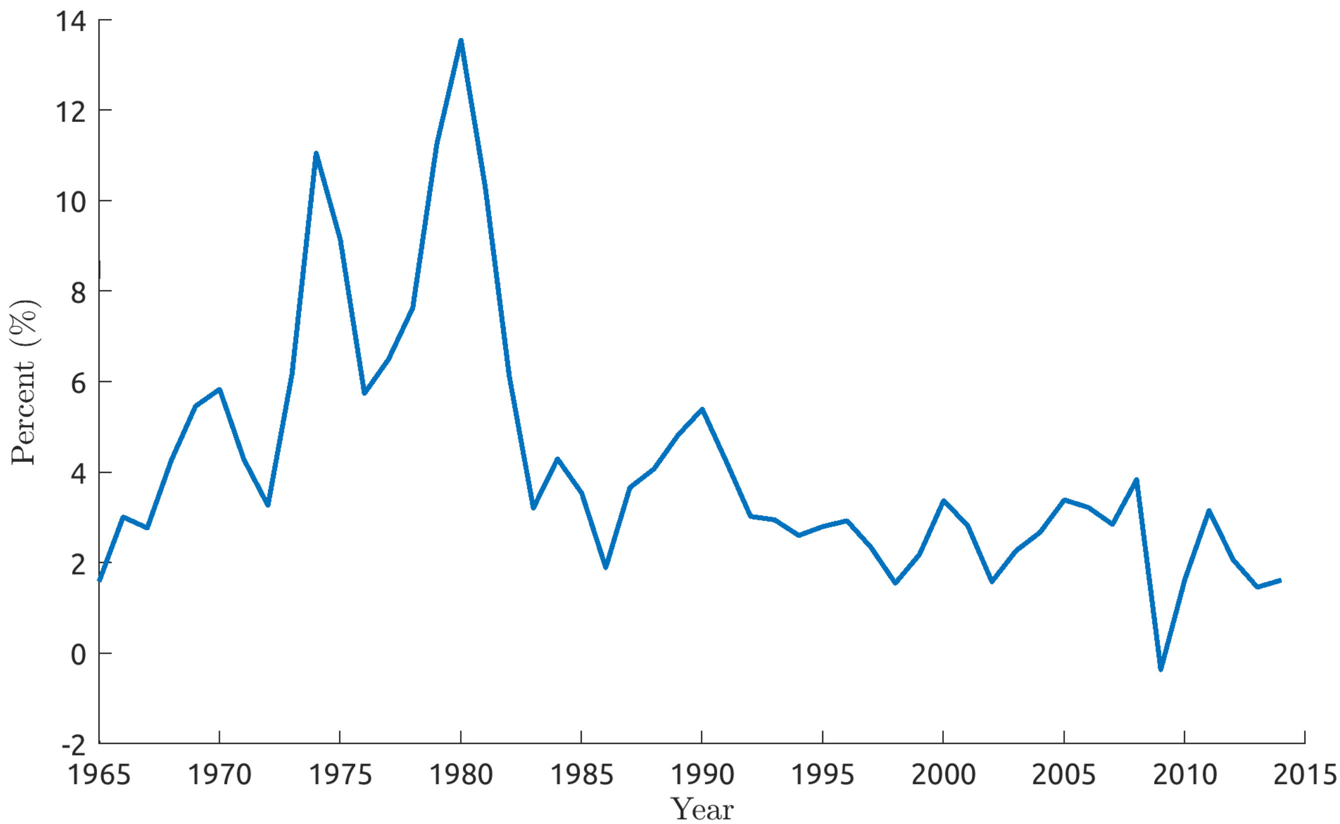
Note: data comes from WIOD database. The 2011-2014 numbers have been taken from the WIOD 2016 database and stitched to the WIOD 2013 numbers. The 1965-1999 come from the historical WIOD database

Figure 13: **Evolution of United States trade costs**



Note: data comes from WIOD database. The 2011-2014 numbers have been taken from the WIOD 2016 database and stitched to the WIOD 2013 numbers. The 1965-1999 come from the historical WIOD database

Figure 14: **Evolution of United States inflation, 1965-2014**



Note: core PCE inflation from WDI database - World Development Indicators. Washington D.C. : The World Bank. We end our inflation data in 2014 to coincide with the end of the WIOD database in 2014.

C Additional Regression Results

Table 4: Inflation and sourcing share regressions on different elasticities (θ) of trade cost

(a) Final sourcing share and trade cost

	YoY Inflation Rate				Sourcing share			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$\eta-1=2$	$\eta-1=4$	$\eta-1=6$	$\eta-1=8$	$\eta-1=2$	$\eta-1=4$	$\eta-1=6$	$\eta-1=8$
Tau	0.0138**	0.0946**	0.1967**	0.3050**	0.0109***	0.1002***	0.2318***	0.3795***
	(0.0048)	(0.0339)	(0.0706)	(0.1094)	(0.0022)	(0.0194)	(0.0454)	(0.0748)
CPI rate % (-1)	0.2561***	0.2673***	0.2735***	0.2767***				
	(0.0515)	(0.0545)	(0.0561)	(0.0570)				
Sourcing share (-1)					0.6462***	0.6009***	0.5920***	0.5886***
					(0.0559)	(0.0613)	(0.0628)	(0.0634)
GDP growth % (-1)	0.0118	0.0256	0.0319	0.0352	-0.0366	-0.0235	-0.0218	-0.0215
	(0.0896)	(0.0887)	(0.0883)	(0.0881)	(0.0385)	(0.0380)	(0.0376)	(0.0373)
Unemployment % (-1)	-0.1026	-0.0981	-0.0946	-0.0926	-0.0495	-0.0467	-0.0471	-0.0475
	(0.1027)	(0.0981)	(0.0970)	(0.0965)	(0.0668)	(0.0629)	(0.0615)	(0.0608)
R-squared	0.4872	0.4808	0.4769	0.4749	0.9835	0.9849	0.9853	0.9855
Num. ind.	37	37	37	37	37	37	37	37
Num. obs.	681	681	681	681	681	681	681	681

(b) Intermediate sourcing share and trade cost

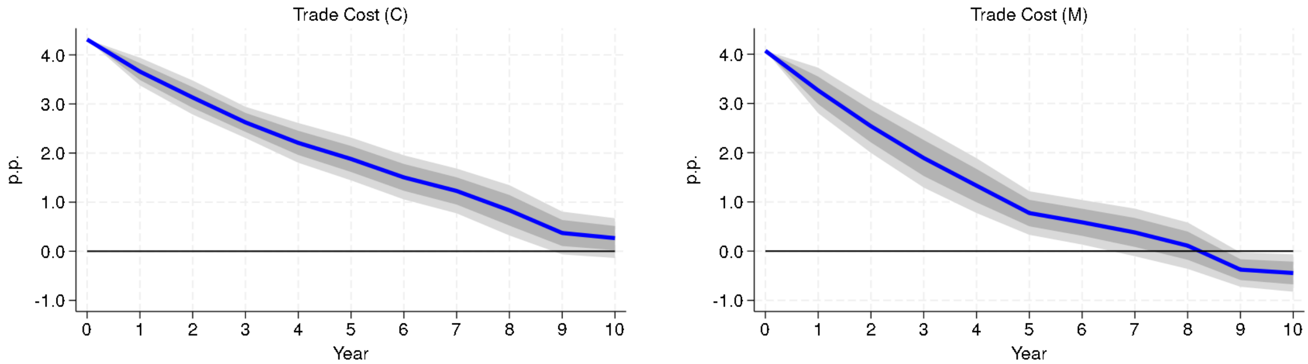
	YoY Inflation Rate				Sourcing share			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$\eta-1=2$	$\eta-1=4$	$\eta-1=6$	$\eta-1=8$	$\eta-1=2$	$\eta-1=4$	$\eta-1=6$	$\eta-1=8$
Tau	0.0113**	0.0771**	0.1608**	0.2503**	0.0135***	0.1097***	0.2457***	0.3973***
	(0.0049)	(0.0331)	(0.0693)	(0.1081)	(0.0029)	(0.0216)	(0.0470)	(0.0750)
CPI rate % (-1)	0.2868***	0.2906***	0.2934***	0.2948***				
	(0.0595)	(0.0605)	(0.0613)	(0.0618)				
Sourcing share (-1)					0.6314***	0.6059***	0.6007***	0.5981***
					(0.0695)	(0.0699)	(0.0695)	(0.0693)
GDP growth % (-1)	0.1108	0.1172	0.1176	0.1176	0.0064	0.0203	0.0220	0.0226
	(0.0912)	(0.0920)	(0.0920)	(0.0920)	(0.0613)	(0.0575)	(0.0568)	(0.0564)
Unemployment % (-1)	-0.0998	-0.1040	-0.1015	-0.0999	-0.0899	-0.1001	-0.1015	-0.1020
	(0.1060)	(0.1054)	(0.1049)	(0.1046)	(0.1014)	(0.0974)	(0.0963)	(0.0958)
R-squared	0.4682	0.4655	0.4636	0.4627	0.9810	0.9819	0.9821	0.9821
Num. ind.	37	37	37	37	37	37	37	37
Num. obs.	681	681	681	681	681	681	681	681

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Note: country fixed effects and year error clustering are included. Both sourcing share and CPI inflation tables respond to a 1% increase in trade costs. We compare different theta values for the Head-Ries index, which is $\eta - 1 = 6$ for our analysis.

D Additional Local Projection Responses

Figure 15: **Local projection of trade cost on itself**

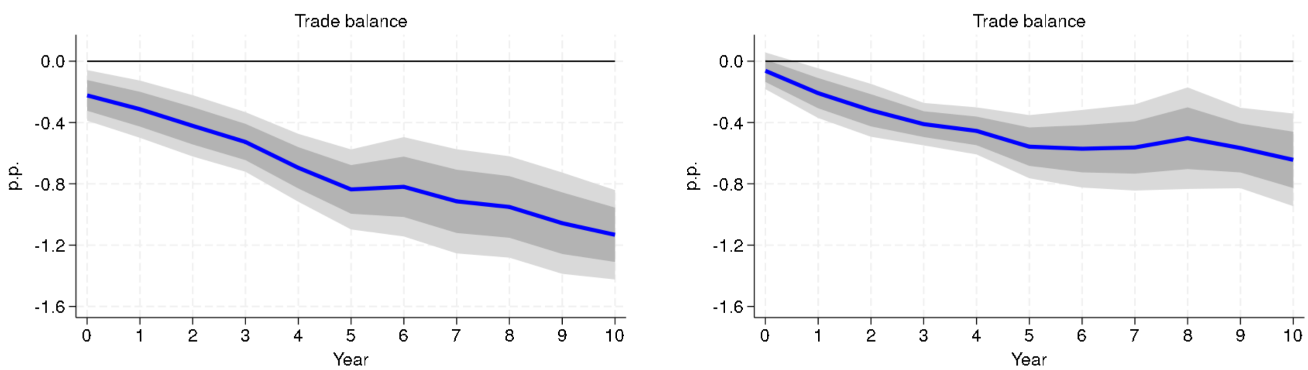


(a) Final trade cost

(b) Intermediate trade cost

Note: country fixed effects and year error clustering are included. We multiply the trade cost by the same coefficient as in Figure 3 so as to correspond to a 1 p.p. increase in the sourcing share.

Figure 16: **Local projection of trade cost on Trade Balance (% GDP)**



(a) Final trade cost

(b) Intermediate trade cost

Note: country fixed effects and year error clustering are included. We multiply the trade cost by the same coefficient as in Figure 3 so as to correspond to a 1 p.p. increase in the sourcing share.

E Post-Pandemic Inflation: Bayesian Estimation

E.1 Data Summary

- Gross Domestic Product (Y): we collect quarterly real GDP from the Bureau of Economic Analysis (BEA). We take the quarter-on-quarter log difference as our final measure.
- Personal consumption Expenditure (C): we collect real consumption from the BEA, taking the quarter-on-quarter log difference.
- PCE Inflation (π^C): we take the personal consumption expenditure price inflation index, which we then transform by taking the quarter-on-quarter log difference.
- Foreign GDP (C^*): we obtain the measure of foreign real GDP from the Dallas FED Globalization and Monetary Policy Institute. We take the quarter-on-quarter log difference.
- Imported foreign final consumption price inflation (π^F): we take the price of imported consumer goods ex auto price inflation to proxy the price index of imported final goods. We take the quarter-on-quarter log difference. Taken from the BEA.
- Real imported foreign intermediate consumption growth (M_F): we collect industrial supplies and materials, as well as petroleum and products, from the BEA in nominal terms. To back out industrial supplies and materials ex-petroleum and products in real terms, we first subtract the nominal series to obtain nominal industrial supplies and materials ex-Petroleum/products, then divide by the deflator of the price series of industrial supplies and materials ex-Petroleum/products. This then gives us the real series, and finally we take the quarter-on-quarter log difference.
- Real imported foreign final consumption growth (C_F): we obtain imported consumer goods ex auto in real terms from the BEA, which we then use to proxy for imported final goods quantity. We then transform to quarter-on-quarter log difference.
- Interest rate (r): we take the Wu-Xia shadow federal funds rate to measure the interest rate, to prevent from being stuck at the ZLB. The data is assembled by the Federal Reserve Bank of Atlanta.

E.2 Observation Equations

$\log(MFY_t)^o = \log(\frac{\bar{M_F}}{\bar{Y}}) + \hat{M}_{F,t} - \hat{Y}_t$

$\log(CFY_t)^o = \log(\frac{\bar{C_F}}{\bar{Y}}) + \hat{C}_{F,t} - \hat{Y}_t$

$\pi_t^o = \bar{\pi}_C + \hat{\pi}_{C,t}$

$\hat{y}_t^o = \hat{y}_t$

$\hat{c}_t^o = \hat{c}_t$

$R_t^o = \log(\bar{r}\bar{\pi}_C) + \hat{R}_t$

E.3 Estimated Parameters

Table 5: Estimated Parameters

	High Sourcing Share		**Low Sourcing Share**	
Shock Persistence	**Mean**	**[5 95]**	**Mean**	**[5 95]**
ρ_{p_F}	0.99	[0.98, 1]	0.98	[0.97, 0.99]
ρ_{C^*}	0.96	[0.93, 1]	0.98	[0.95, 1]
ρ_z	0.77	[0.73, 0.81]	0.83	[0.8, 0.87]
ρ_z^d	0.94	[0.91, 0.97]	0.91	[0.87, 0.95]
ρ_{p_H}	0.89	[0.86, 0.93]	0.95	[0.93, 0.96]
ρ_{τ_c}	0.97	[0.96, 0.99]	0.97	[0.96, 0.98]
ρ_{τ_m}	0.98	[0.96, 1]	0.99	[0.98, 1]
Standard Deviation	**Mean**	**[5 95]**	**Mean**	**[5 95]**
$100 \times \sigma_{p_F}$	1.52	[1.36, 1.68]	1.57	[1.4, 1.72]
$100 \times \sigma_{C^*}$	0.63	[0.56, 0.69]	0.63	[0.56, 0.7]
$100 \times \sigma_z$	1.91	[1.65, 2.14]	4.59	[3.9, 5.26]
$100 \times \sigma_z^d$	2.78	[1.87, 3.62]	2.38	[1.78, 2.95]
$100 \times \sigma_{p_H}$	3.94	[3.19, 4.69]	6.69	[5.43, 7.95]
$100 \times \sigma_{\tau_c}$	1.97	[1.76, 2.18]	1.97	[1.75, 2.17]
$100 \times \sigma_{\tau_m}$	2.92	[2.6, 3.23]	3.02	[2.69, 3.35]
$100 \times \sigma_r$	0.11	[0.1, 0.12]	0.11	[0.1, 0.12]