Tariff Pass-through at the Dock and at the Store

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Abstract

This paper explains a high pass-through of US tariffs at the dock and a low pass-through at the store in general equilibrium in the US-China trade war in 2018. Using a model with costly distribution of traded goods and nominal frictions faced by producers and retailers, this paper demonstrates that a two-country model without retail-level nominal frictions cannot explain the low pass-through at the store quantitatively. A model with only producer-level nominal frictions requires unrealistically high distribution costs to match the data. Strategy complementarity exists for vertically related firms: exogenous tariff shocks increase downstream retail prices and create incentives for upstream producers to increase their prices. This strategic interaction boosts the tariff pass-through at the dock and helps the model to match the data.

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1. Introduction

To what extent do tariffs affect the macroeconomy? One crucial determinant is the expenditure switching effect- an action of switching from foreign to domestic goods. Empirical evidence from the US-China trade-policy war (Cavallo et al., 2019) reveals that a 1% tariffs on final goods imposed by the U.S. raised tariff-inclusive prices by 0.95% at the dock and 0.1% at the store in the short run in the US. This evidence implies that the macroeconomic effects of tariffs are unlikely to operate through expenditure switching effects. What are the factors necessary to explain such differences in pass-through at the dock and at the store? How do these factors affect the expenditure switching channel? Unlike unidentified sources of exchange rate changes, recent episodes of US tariffs are well-identified and exogenous, which provides an opportunity to distinguish mechanisms affecting the tariff pass-through.

Different from the existing exchange rate pass-through literature, tariffs are offset by exchange rate depreciation, whose magnitude cannot be determined in a partial equilibrium model. This paper interprets the results in a two-country model with costly distribution of traded goods to consumers and nominal frictions faced by producers and retailers.

This model illustrates that the observed retail-level pass-through cannot be explained by a realistic level of distribution costs, even though they account for 40% to 70% of the final retail price (Anderson and van Wincoop, 2004; Berger et al., 2012; Crucini and Landry, 2012). Quantitative results from the model indicate that nominal frictions at the retail level are essential modeling ingredients, whose role is not emphasized in existing open economy macroeconomic models. Moreover, sticky-price models with foreign exporters invoicing in the US currency fail to match the high pass-through at the dock quantitatively: unless prices are completely sticky for all foreign exporters, exporters who can adjust prices would lower their prices and this would drive down the at-the-dock pass-through at the aggregate level. However, strategic pricing of producers helps the model to explain this empirical finding.

This strategic pricing comes from the direct interaction of producers and retailers selling each variety. A monopoly upstream producer sells a variety to a downstream monopoly retailer. This retailer faces nominal frictions, has no market power in the input market, and takes input prices as given. Unlike the literature showing strategy complementarity in horizontally related firms with competitors, this paper shows that it also exists for two vertically related firms due to nominal frictions faced by downstream retailers: an increase in the downstream retailer's prices incentivizes upstream suppliers to increase prices.

The results here imply that the expenditure switching argument cannot support the usage of temporary trade barriers. Once the market structure responsible for pass-through is accounted for, the response of trade balances to tariffs is very muted and persistent in the short run. A muted and hump-shaped response is also documented in Barattieri et al. (2018) on Canadian trade barriers empirically but not explained in their model. Moreover, the pass-through dynamic also implies a hump-shaped response of output: output falls before increasing due to tariff shocks. These results cannot be replicated in standard models, and they further imply the need for cautionary usage of trade barriers in normal times.

This paper is unique in considering the strategic interactions of vertically related firms in a Stackelberg game with sticky prices [1] . Devereux and Engel (2007) and Devereux et al. (1999) discuss monetary policy trade-offs when retailers face nominal frictions. Monacelli (2005) is a rare example of an open-economy model with nominal frictions at both retail and producer levels. However, the introduction of perfectly competitively bundlers between retailers and producers eliminates their direct interactions [2]. The consequence of double marginalization from vertically related firms is close to Hong and Li (2017). They considered double marginalizations in a static model rather than in a dynamic model.

The approach of introducing distribution costs follows Corsetti and Dedola (2005) and Corsetti et al. (2008). Nontraded goods as a source of distribution costs are perfectly complementary to traded varieties. Unlike an alternative approach where traded and nontraded goods are substitutable

[1] In fact, Corsetti et al. (2010) (page 51.) conjectured that nominal rigidities at the retail level may create the producers' incentives to raise local prices in response to exchange rate shocks.

[2] In a closed economy, Garga and Singh (2018) also have nominal frictions at both retail and producer levels, but they introduce competitive final goods producers to cutoff their interactions.

[3], the assumption of perfect complementarity generates a variable producer's markup. None of the existing literature with distribution costs includes multiple layered sticky prices or discusses the implications of the choice of currency invoicing. Under the dominant currency paradigm, unilateral tariff shocks depress output in the short run.

The emphasis on nominal frictions for international trade contrasts with the vast trade literature which considers nominal frictions as playing a minor or even inconsequential role. This paper shows that nominal frictions from retailers also allow producers to increase the steady-state markup.

Section 2 presents the stylized facts. Section 4 discusses the quantitative results from the model in Section 3. Section 5 concludes.

2. Stylized Fact: Tariff Pass-through to Retail Prices is Low

Fajgelbaum et al. (2020), Amiti et al. (2019), and Cavallo et al. (2019) all documented an almost-complete pass-through of tariffs at the US dock, though they use different data sources and methodologies. Fajgelbaum et al. (2020) cannot reject the hypothesis that tariff-affected Chinese export prices remained unchanged within 2 quarters of imposing tariffs using publicly available data. Using the data underlying the construction of US terms of trade indices, Cavallo et al. (2019) document that the pass-through of tariffs imposed by the U.S. in 2019 at the dock is around 95% in the first year, meaning that is tariff-inclusive import prices increase by 0.95% for an average of 1% tariffs.

Moreover, Cavallo et al. (2019) merged online prices collected from two large US retail chains to tariff data. Using a distributed lag model, they estimated that for an average tariff of 1%, the price of tariffs affected goods relative to unaffected goods from China increases by 0.035% after one year. I re-establish this evidence here using their retail data. I estimate the responses of retail prices over a horizon of a year through the following local projection which includes controls

[3] For example, reduced form formulations in Burstein et al. (2004) and Burstein et al. (2001). Crucini and Landry (2012) uses a two-country RBC model.

identical to Cavallo et al. (2019).

$$p_{i,j,k,t+h} - p_{i,j,k,t-1} = \beta^h \Delta\tau_{i,j,k,t} + \sum_{l=1}^{6} \Gamma_l^h p_{i,j,k,t-l} + \mathbf{\Lambda} + \epsilon_{i,j,t+h} \quad \forall h = 0, 1, 2, ..., 11 \tag{1}$$

where $\mathbf{\Lambda}$ includes fixed effects: $\mathbb{1}\{j = China\}$ indicates that the origin j of imports is China, $\mathbb{1}\{i \in \{\text{Affected HR Codes}\}\}$ indicates that goods i are in the trade policy affected HR codes, and Λ_k denotes sector fixed effects. Tariffs $\tau_{i,j,k,t}$ and prices $p_{i,j,k,t}$ are all in logs. Estimates β^h graphed in Figure 1 are interpreted as the average cumulative effects on prices of tariffs affect products relative to unaffected products.

For an average tariff increase of 1%, the price of tariff-affected goods relative to unaffected goods increases by 0.1% after a quarter. Then, the impact of tariffs shows a gradual decay, and the cumulative effects after 12 months are around 0.046%. Although the length of the US-China trade war limits what we know about the medium-run effects, the low pass-through of 0.1% for an average tariff of 1% indicates the response of retail prices is sluggish and tariffs were not passed to consumer prices in the short run.

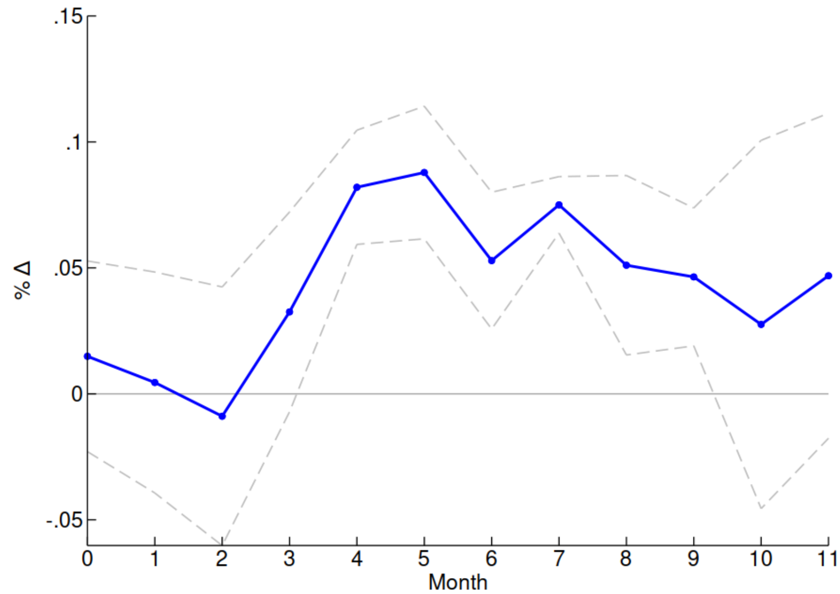
3. A Model of Distribution Costs

Table 1: Model Summary: Market Structures

	Sources of Nominal Frictions		Monopoly Power	
	Producer	Retailer	Producer	Retailer
Model 1	✓		✓	
Model 2		✓		✓
Model 3	✓	✓	✓	✓

The world has equally sized home and foreign countries. Households consume nontraded goods, domestically produced traded goods, and imports. They also trade non-state contingent bonds. Each producer specializes in producing one variety and sells it to individual domestic and foreign retailers. Each retailer also specializes in handling one type of traded goods and distributes

Figure 1: The average changes in retail prices from an average tariff of 1%



Note: This graph plots β^h from estimating a pass-through regression $p_{i,j,k,t+h} - p_{i,j,k,t-1} = \beta^h \Delta\tau_{i,j,k,t} + \sum_{l=1}^{6} \Gamma_l^h p_{i,j,k,t-l} + \mathbf{\Lambda} + \epsilon_{i,j,t+h} \quad \forall h = 0, 1, 2, ..., 11$, where $\mathbf{\Lambda}$ includes fixed effects $\mathbb{1}\{j = China\}$ the origin j of imports is China, $\mathbb{1}\{i \in \{\text{Affected HR Codes}\}\}$ goods i is in the trade policy affected HR codes, Λ_k sector fixed effects. Tariffs $\tau_{i,j,k,t}$ and prices $p_{i,j,k,t}$ are all in logs. The dashed line presents the 90% confidence band from robust standard errors clustered at the sectoral level. Data comes from Cavallo et al. (2019).

it to competitive bundlers, which combine individual goods into a final composite product. Distributing goods requires locally produced nontraded final goods.

The market structure allows monopoly retailers of traded varieties to face nominal frictions and have market power over their buyers. However, retailers cannot exercise market power over their downstream suppliers. To focus on the interaction in the market of traded goods, the model assumes retailers of nontraded goods are perfectly competitive. The description of the model below focuses on the home country, and Appendix B presents all other details.

In the sections below, I also discuss the implications when either producers or retailers face nominal frictions and have market power. I show that these two models cannot explain both high pass-through at the dock and low pass-through at the store simultaneously. Table 1 lists sources of nominal frictions and market power under different market structures.

3.1 Households

A representative household optimally chooses the final consumption bundle C_t, the hours of working L_t, and the holdings of financial assets. $B_{H,t}$ ($B^*_{H,t}$) is an one-period home-currency bond issued by the home country held by home (foreign) agents. It has a gross home currency return I_t. $B^*_{F,t}$ ($B_{F,t}$) is an one-period foreign-currency bond issued by the foreign country held by foreign (home) agents with a gross foreign currency return I^*_t. The corresponding real values are $b_{H,t}$ ($b^*_{H,t}$) in home final consumption bundles and $b^*_{F,t}$ ($b_{F,t}$) in foreign final consumption bundles. A representative household's problem is[4]

$$\max_{\{C_t,L_t\}} E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}-1}{1-\sigma} - \frac{L_t^{1+\varphi}}{1+\varphi}\right) \tag{2}$$

$$s.t. \quad P_tC_t + B_{H,t} + \mathcal{E}_t B_{F,t} = I_{t-1}B_{H,t-1} + \mathcal{E}_t I^*_{t-1} B_{F,t-1} + W_t L_t - \frac{\chi_1}{2}\mathcal{E}_t P^*_t \left(\frac{B_{F,t}}{P^*_t} - \bar{b}_F\right)^2 + TR_t + \Pi_t$$

where β is the discount factor, σ is the inverse of the inter-temporal elasticity of substitution; φ is the inverse of the Frisch elasticity of labor supply. TR_t is the government lump-sum transfer. Each household has an equal share of firms (producers and retailers). Π_t is the total profits earned by all the firms in the home country. P_t (P^*_t) is the home (foreign) country's price level. The nominal exchange rate $\mathcal{E}_t$ measures the price of foreign currency in terms of the home currency. A rise in $\mathcal{E}_t$ represents a nominal depreciation of the home currency.

Adjusting the real balance of portfolios is costly in the financial market (Benigno, 2004). Home households pay the foreign government a cost for adjusting the real balance of their holding of foreign portfolios [5]. A large adjustment cost makes resolving the Backus-Smith puzzle possible. Let Q denote the real exchange rate. Let lower-cased letters c_t, c^*_t, q_t, i_t i^*_t represent the percent

[4] The problem is also subject to the usual non-Ponzi condition and the initial condition of bond holdings.

[5] Although this portfolio adjustment cost is a stationary inducing technique in small open economy models, the model here is stationary even without any portfolio adjustment costs. However, as Yakhin (2020) shows that this specification can be micro-founded from segmented financial markets or financial constraints. The UIP condition is violated with portfolio adjustment costs.

deviations from symmetric steady-state values. The risk-sharing condition is

$$E_t[\Delta c^*_{t+1} - \Delta c_{t+1} + \frac{1}{\sigma}\Delta q_{t+1}] = \frac{\chi_1}{\sigma}(b_{F,t} - \bar{b}_F) \tag{3}$$

The UIP condition is[6]

$$i_t - i^*_t - E_t(\Delta e_{t+1}) = -\chi_1(b_{F,t} - \bar{b}_F), \quad \text{where} \quad \Delta e_{t+1} = log(\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}) \tag{4}$$

The final consumption bundle C_t consists of nontraded $C_{N,t}$ and traded $C_{T,t}$ consumption bundles from a CES aggregator $C_t = \left[(1-\alpha_1)^{\frac{1}{\zeta_1}} C_{T,t}^{\frac{\zeta_1 - 1}{\zeta_1}} + \alpha_1^{\frac{1}{\zeta_1}} C_{N,t}^{\frac{\zeta_1 - 1}{\zeta_1}}\right]^{\frac{\zeta_1}{1-\zeta_1}}$. For any given level C_t, the optimal choices of $C_{N,t}$ and $C_{T,t}$ are given by

$$C_{N,t} = \alpha_1\big(\frac{P_{N,t}}{P_t}\big)^{-\zeta_1} C_t \qquad C_{T,t} = (1-\alpha_1)\big(\frac{P^c_{T,t}}{P_t}\big)^{-\zeta_1} C_t \tag{5}$$

The CPI in the home country is defined as the retail price of one unit of final consumption bundle C_t.

$$P_t = \big((1-\alpha_1) P^{c\,1-\zeta_1}_{T,t} + \alpha_1 P^{1-\zeta_1}_{N,t}\big)^{\frac{1}{1-\zeta_1}} \tag{6}$$

where $P^c_{T,t}$ is the consumer price of one unit of traded consumption bundle. The letter c in the superscript indicates that this is a price faced by consumers and charged by retailers.

3.2 Nontraded Goods Sector

Perfectly competitive firms produce final nontraded goods $Y_{N,t}$ using nontraded varieties $Y_{N,t}(i)$ $\forall i \in [0,1]$ via a CES technology $Y_{N,t} = \left[\int_0^1 (Y_{N,t}(i))^{\frac{\mu-1}{\mu}} di\right]^{\frac{\mu}{\mu-1}}$ with $\mu > 1$. The demand of nontraded variety i is $Y_{N,t}(i) = Y_{N,t}\left(\frac{P_{N,t}(i)}{P_{N,t}}\right)^{-\mu}$. The price index of nontraded good is $P_{N,t} = \left[\int_0^1 P_{N,t}(i)^{1-\mu} di\right]^{\frac{1}{1-\mu}}$.

[6] The (gross) uncovered interest rate differential, U_t is defined as $U_t := E_t \frac{I_t}{I^*_t}\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}$. Let $u_t = log(U_t)$. $u_t = -\chi_1(b_{F,t} - \bar{b}_F)$. This equation says that the home country holds more than the steady-state value of foreign assets when the uncovered interest rate differential is negative. Intuitively, the higher returns of holding foreign currency bonds is used for compensating the transaction cost of holding these bonds.

Monopolistically competitive firms indexed by $i \in [0,1]$ use labor $L_{N,t}(i)$ to produce nontraded variety $Y_{N,t}(i)$ in the home country. The production function is $Y_{N,t}(i) = Z_{N,t}L_{N,t}(i)^{\alpha}$, where $Z_{N,t}$ is the productivity faced by all the firms in the nontraded sector.

The model introduces nominal rigidities via a Rotemberg (1982)-type adjustment cost $AC_{N,t}(i)$ with respect to a zero-inflation steady state for a home country firm i in the nontraded sector. The real stochastic discount factor is $SDF_{t,0} = \frac{\lambda_t}{\lambda_0}\frac{P_0}{P_t}$. The scaling factor is $\Omega_{N,t} = P_{N,t}Y_{N,t}$, which means that the adjustment cost is priced at the value of nontraded final goods in the home country[7]. The problem of the firm producing nontraded variety i is

$$\max_{\{P_{N,t}(i),L_{N,t}(i),Y_{N,t}(i)\}} E_0 \sum_{t=0}^{\infty} \beta^t SDF_{t,0}\Big[P_{N,t}(i)Y_{N,t}(i) - W_t L_{N,t}(i) - AC_{N,t}(i)\Big] \tag{7}$$

$$s.t. \quad AC_{N,t}(i) = \frac{\kappa_n}{2}\left(\frac{P_{N,t}(i)}{P_{N,t-1}(i)} - 1\right)^2 \Omega_{N,t} \quad Y_{N,t}(i) = Y_{N,t}(\frac{P_{N,t}(i)}{P_{N,t}})^{-\mu} \quad Y_{N,t}(i) = Z_{N,t}L_{N,t}(i)^{\alpha}$$

3.3 Firms Producing Final Tradable Goods

Competitive home retailers produce final traded goods for consumption using home and foreign bundles via the following CES technology, where α_2 measures the (inverse) home bias in consumption, and ζ_2 is the elasticity of substitution between home and foreign goods.

$$C_{T,t} = \left[\alpha_2^{\frac{1}{\zeta_2}} Y_{F,t}^{\frac{\zeta_2-1}{\zeta_2}} + (1-\alpha_2)^{\frac{1}{\zeta_2}} Y_{H,t}^{\frac{\zeta_2-1}{\zeta_2}}\right]^{\frac{\zeta_2}{1-\zeta_2}} \tag{8}$$

To produce consumption bundles $Y_{H,t}$ and $Y_{F,t}$, home final traded goods producers source differentiated varieties $Y_{H,t}(i)$ domestically and $Y_{F,t}(i)$ abroad. Their problem is:

$$\max_{Y_{H,t}(i),Y_{F,t}(i)} P^c_{H,t}Y_{H,t} + P^c_{F,t}Y_{F,t} - \left(\int (P^c_{H,t}(i))Y_{H,t}(i)di + \int (P^c_{F,t}(i))Y_{F,t}(i)di\right) \tag{9}$$

[7]The literature explores different ways of specifying the scaling factor. See Schmitt-Grohe and Uribe (2004), Egorov and Mukhin (2020), and Kaplan et al. (2018) for different ways. The model mechanism is invariant to how the cost is scaled.

$$s.t. \quad Y_{H,t} = \Big(\int Y_{H,t}(i)^{\frac{\gamma-1}{\gamma}} di \Big)^{\frac{\gamma}{\gamma-1}} \quad Y_{F,t} = \Big(\int Y_{F,t}(i)^{\frac{\gamma-1}{\gamma}} di \Big)^{\frac{\gamma}{\gamma-1}}$$

The solution to this problem gives the following demand and price indices.

$$P^c_{T,t} = (\alpha_2 P^{c\,1-\zeta_2}_{F,t} + (1-\alpha_2) P^{c\,1-\zeta_2}_{H,t})^{\frac{1}{1-\zeta_2}} \quad Y_{F,t} = \alpha_2 \Big(\frac{P^c_{F,t}}{P^c_{T,t}}\Big)^{-\zeta_2} C_{T,t} \quad Y_{H,t} = (1-\alpha_2)\Big(\frac{P^c_{H,t}}{P^c_{T,t}}\Big)^{-\zeta_2} C_{T,t}$$

3.4 Strategic Interactions between Producers and Retailers of Differentiated Varieties

Both retailers and producers face sticky prices and set prices in a dynamic Stackelberg game. A monopoly retailer purchases one variety from a producer and sells it to competitive bundlers previously described in Section 3.3. Handling each variety costs η units of final nontraded goods. Producers of traded varieties consider this additive cost when setting prices. Modeling traded and nontraded goods to be perfect complements also creates a variable markup channel to explain low retail-level pass-through: tariffs decrease producers' optimal markup and producers would optimally lower their prices. This happens because the impact of producers' price changes on retail prices is larger when a larger fraction of tradable components directly enters into the final retail price due to higher tariffs. Variable markup exists here because of the perfect complementarity between traded and nontraded goods for retailers. However, producers' markup is constant when traded and nontraded goods are substitutes as in Burstein et al. (2001) and Atkeson and Burstein (2008).

In this Stackelberg game, the producer of variety i is the leader, and the retailer of this variety is the follower. Without nominal frictions, this game yields the result of "double marginalization"[8]. The presence of retailers' nominal frictions affects the producer's dynamics decisions. Let the superscript p denote producer prices. An equilibrium involves a leader's strategy $G_{l,i}(P^p; t)$ for

[8]See Church and Ware (2000) Chapter 22 (page 683) for a broad discussion of double marginalization and vertical integration in static settings.

producer i, whose optimal prices $\{P^p_{t,i}\}\forall t$ depends on the followers' response $\{P^c_{t,i}\} = G_{f,i}(P^c; t)$. The dynamic equilibrium can be solved using a backward induction approach for solving Stackelberg games [9].

Below is the problem faced by the home producer of the variety i and home and foreign retailers of this variety. The home retailer takes the sequence of prices $\{P^p_{H,t}\}$ charged by the home producers as given. Its optimization problem is in Eq. 10. The scaling factor of the adjustment cost is $\Omega^c_{H,t} = P^p_{H,t} Y_{H,t}$. Note that it is priced at the producer-level price to exclude the value-added part. Moreover, retailers' exit conditions are excluded here because similar to standard New Keynesian economies (Galí, 2015) with nominal frictions, retailers would still operate under negative profits.

$$\begin{aligned}\big\{P^c_{H,t}\big(P^p_{H,t}(i)\big)\big\}_t \in arg \max_{\{P^c_{H,t}(i)\}} E\sum_{t=0}^{\infty}\beta^t SDF_{t,0}\Bigg(&Y_{H,t}(\frac{P^c_{H,t}(i)}{P^c_{H,t}})^{-\gamma}(P^c_{H,t}(i) - P^p_{H,t}(i) - \eta P_{N,t}) \\ &- \frac{\kappa^r}{2}(\frac{P^c_{H,t}(i)}{P^c_{H,t-1}(i)} - 1)^2\Omega^c_{H,t}\Bigg)\end{aligned} \tag{10}$$

The foreign retailer of the variety i pays its home producer $P^{*p}_{H,t}$ for each unit and pays the foreign government an ad valorem import tariffs τ^{m*}_t. Given the price of home producers, foreign retailers' problem is the following with the adjustment cost scaled by $\Omega^{*c}_{H,t} = P^{*p}_{H,t} Y^*_{H,t}$.

$$\begin{aligned}\big\{P^{*c}_{H,t}\big(P^{*p}_{H,t}(i)\big)\big\}_t \in arg \max_{\{P^{*c}_{H,t}(i)\}} E\sum_{t=0}^{\infty}\beta^t SDF^*_{t,0}\Bigg(&Y^*_{H,t}(\frac{P^{*c}_{H,t}(i)}{P^{*c}_{H,t}})^{-\gamma}(P^{*c}_{H,t}(i) - (1+\tau^{m*}_t)P^{*p}_{H,t}(i) - \eta P^*_{N,t}) \\ &- \frac{\kappa^r}{2}\left(\frac{P^{*c}_{H,t}(i)}{P^{*c}_{H,t-1}(i)} - 1\right)^2\Omega^{*c}_{H,t}\Bigg)\end{aligned} \tag{11}$$

Taking foreign and home retailers' strategies as given, the home producer's problem under the

[9] See Chapter 18 Dynamic Stackelberg Problems without uncertainties in Ljungqvist and Sargent (2018).

local currency pricing (LCP) is the following.

$$\max_{\substack{Y_{H,t}(i),Y^*_{H,t}(i),\\ P^p_{H,t}(i),P^{*p}_{H,t}(i),L_{T,t}(i)}} E_0 \sum_{t=0}^{\infty} \beta^t SDF_{t,0}\Big[P^p_{H,t}(i)Y_{H,t}(i)+\mathcal{E}_t P^{*p}_{H,t}(i)Y^*_{H,t}(i)-W_t L_{T,t}(i)-AC_{H,t}(i)-AC^*_{H,t}(i)\Big] \tag{12}$$

$$\text{s.t.} \begin{cases} AC_{H,t}(i)=\frac{\kappa^p}{2}\left(\frac{P^p_{H,t}(i)}{P^p_{H,t-1}(i)}-1\right)^2\Omega^p_{H,t} \quad AC^*_{H,t}(i)=\frac{\kappa^p}{2}\left(\frac{P^{*p}_{H,t}(i)}{P^{p*}_{H,t-1}(i)}-1\right)^2\Omega^{*p}_{H,t} \\ Y_{H,t}(i)=Y_{H,t}\left(\frac{P^c_{H,t}\left(P^p_{H,t}(i)\right)}{P^c_{H,t}}\right)^{-\gamma} \qquad Y^*_{H,t}(i)=Y^*_{H,t}\left(\frac{P^{*c}_{H,t}\left(P^{*p}_{H,t}(i)\right)}{P^{*c}_{H,t}}\right)^{-\gamma} \qquad Y_{H,t}(i)+Y^*_{H,t}(i)=Z_{T,t}L_{T,t}(i)^{\alpha} \\ \text{eq.10} \quad \text{and} \quad \text{eq.11} \end{cases}$$

where $\Omega^p_{H,t}=\Omega^{*p}_{H,t}=P^p_{H,t}Y_{H,t}$. As it will become apparent in Section 3.6.2, which discusses linearized first-order conditions, the choice of scaling factors $\Omega^p_{H,t}$ and $\Omega^{*p}_{H,t}$ does not matter when the model is solved under the first-order approximation.

3.5 Government

The home government runs a balanced budget each period. It raises revenues from foreign country's portfolio adjustment costs and import tariffs. It spends on lump-sum transfers and export subsidies.

Monetary policy follows the following Taylor rule.

$$\frac{I_t}{\bar{I}}=\left(\frac{I_{t-1}}{\bar{I}}\right)^{\rho}\left[\left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi_\pi}\right]^{1-\rho} \tag{13}$$

The baseline model only stabilizes CPI-inflation by setting $\phi_\pi = 1.5$ (Lubik and Schorfheide, 2007). The home country's government uses import tariffs τ^m_t as a trade policy instrument. The foreign country's import tariff is τ^{m*}_t. Home exporters decide the pre-tariff prices at home dock ($P^{*p}_{H,t}(i)$). Home country's retailers of imports pay import tariffs to the home government.

Under the balanced budged assumption, the government budget constraint is

$$TR_t = \frac{\chi_1}{2}(\frac{B^*_{H,t}}{P_t} - \bar{b}^*_H)^2 P_t + P^p_F Y_{F,t} \tau^m_t \tag{14}$$

3.6 Equilibrium and Some Analytics

The model includes import tariff shocks from the home and foreign countries, which follow an AR(1) process. The home country households' budget constraint is used to close the model. Appendix B lists all the equations and defines the equilibrium.

3.6.1 Steady-state Analysis

Under a linear production function ($\alpha = 1$) and a unitary Frisch labor supply elasticity ($\varphi = 1$), the analysis below derives analytical expressions. Since two countries are symmetric, the Law-of-One-Price holds in the steady-state [10]. The literature reports that distribution margins defined as $\frac{P^c_H - P^p_H}{P^c_H}$ are 50% to 70% (Berger et al., 2012). However, a convenient way to define distribution margins in this model is using the value of nontraded goods relative to the retailer's marginal costs. Let $\omega^d := \frac{\eta P_N}{\eta P_N + P_H}$ denote this measure. $\omega^d = 0$ implies the model does not have any distribution costs.

Distribution margins create a wedge in trade elasticity and home bias between consumers and producers. The elasticity of home imports with respect to the relative prices of imports to home tradables[11] is $-\zeta_2(1-\alpha_2)(1-\omega^d)$. Consumer-level home bias [12] $(1-\alpha_2)$ is larger than producer-level home bias $(1-\alpha_2)(1-\omega^d)$, which is the expenditure of home-produced goods relative to the

[10]When two countries are not symmetric in the productivity of nontraded sector in the steady-state, the model has a permanent deviation from the purchasing power parity because 1) unequal values of distribution costs, and 2) the price of the same traded variety is different in two countries due to different demand elasticity for firms which uses a pricing-to-market strategy.

[11]Trade elasticity is defined as $\frac{\partial log Y_F}{\partial log(P^p_F/P^p_H)} = -\zeta_2(1-\alpha_2)(1-\omega^d)$. The model-implied Armington elasticity is $-\zeta_2(1-\omega^d)$.

[12]Consumer-level home bias is defined as $\frac{P^c_H C_H}{P^c_T C_T}$. It is the expenditure of home traded goods relative to the total expenditure of traded goods. Producer-level home bias is defined as $\frac{P^p_H Y_H}{P^c_T C_T}$. It is the expenditure of home-produced traded goods for consumption at home relative to the total expenditure of home traded consumption.

total expenditure of traded goods.

The strategic interaction between producers and retailers affects the markup of producers in the steady state. The steady-state demand elasticity of traded variety faced by producers is $\gamma\Psi$. This elasticity is the demand elasticity faced by retailers (γ) scaled downwards by $\Psi := \frac{dlogP_H^c}{dlogP_H^p} = \frac{\gamma}{\gamma(1+\eta\frac{P_N}{P_H^p})+\kappa^r(1+\beta)}$. Ψ measures the sensitivity of retail prices (P_H^c) to producer prices (P_H^p). As long as $\gamma > 1$, regardless of the value of other parameters, $\gamma\Psi > 1$. Without retail-level nominal frictions (i.e. $\kappa^r = 0$) and distribution margins (i.e. $\eta = 0$), Ψ becomes unity.

Producer's demand elasticity increases in η. Changes in consumer prices will be less sensitive to producer prices when the price of nontraded goods determines a larger fraction of the final prices. With a lower γ, varieties are less substitutable, the markup becomes higher.

Nominal frictions in a model without strategic interactions have no impact on steady-state allocations. With strategic interactions, producer' markup is higher due to downstream retailer's nominal frictions. The markup of tradable producers is $\frac{\gamma+\frac{\eta}{Z_n}\frac{\mu}{\mu-1}}{\gamma-1-\frac{\kappa^r}{\gamma}(1+\beta)}$. An upstream producer with market power can raise its markup further when the price of downstream retailer is costly adjusted. The existence of an equilibrium requires κ^r to satisfy $\gamma^2 - \gamma - \kappa^r(1+\beta) > 0$. If not, nominal frictions from a downstream retailer allow its only upstream supplier to charge an infinite price, and an equilibrium does not exist.

Let q_t be the log CPI-based real exchange rate, s_t be the log terms of trade (defined as export/import prices excluding tariffs), $q_t^N = log(\mathcal{E}_t P_{N,t}^*/P_{N,t})$ be the nontradable-based real exchange rate. Define the difference between the home and foreign country's tariffs $\tilde{\tau}_t^m := \tau_t^m - \tau_t^{*m}$. Under either local currency pricing (LCP) or dominant currency pricing (DCP), the following relationship holds when retailers and producers don't face nominal frictions at the same time. I further assume that the traded and nontraded sectors have the same productivity.

$$q_t = ((1-\omega^T) + \omega^T\omega^d\Xi_1)q_t^N - \omega^T(1-\omega^d)(1-2\alpha_2)(s_t - \tilde{\tau}_t^m) + \omega^T\Xi_2 E_t(\Delta LOOP_{t+1}) \quad (15)$$

$$\Xi_3 q_t^N = -s_t - \Xi_4 E(\Omega_{t+1}) \quad (16)$$

$$\begin{cases} \Xi_1 = 1 + \frac{2(1-\alpha_2)}{\frac{P_H^p}{P}(\gamma\Psi^2 - \Psi + \eta\frac{P_N}{P_H^p})} & \Xi_2 = \kappa^p \times \frac{(1-\omega^d)(1-\alpha_2)\Psi}{\frac{P_H^p}{P}(\gamma\Psi^2 - \Psi + \eta\frac{P_N}{P_H^p})} \quad \Xi_3 = \frac{\varphi - \omega^d}{\varphi + \omega^d} \quad \Xi_4 = \frac{\varphi}{\varphi + \omega^d} \quad \text{Only Sticky Producer Prices} \\ \Xi_1 = 1 & \Xi_2 = \kappa^r \times \frac{1}{(\gamma-1)\frac{P_H^p}{P}} \quad \Xi_3 = 1 \quad \Xi_4 = 1 \quad \text{Only Sticky Retailer Prices} \end{cases}$$

where $\Delta LOOP$ measures the deviation from the Law-of-One-Price due to nominal frictions, and $\varphi = (1-\omega^d)^2(\gamma(1-\omega^d)-1)$. The term $E_t(\Omega_{t+1})$ appears due to nominal frictions in traded and nontraded sectors. It vanishes under flexible prices. Appendix C derives the above relations.

The CPI-based real exchange rate are affected by the relative price of nontradables and the terms of trade. The presence of the term $\omega^T\omega^d\Xi_1$ indicates that nontradables affect the consumer price through changing the cost of distribution margins. The extra term $\frac{2(1-\alpha_2)}{\frac{P_H^p}{P}(\gamma\Psi^2-\Psi+\eta\frac{P_N}{P_H^p})}$ in Ξ_1 under sticky producer prices indicates distribution margins affect producers' optimal prices when they have market power. The term $1-\omega^d$ before s_t indicates distribution margins dampen the direct effect of terms of trade on consumer prices. In the limiting case with no nominal frictions, nontraded goods, and distribution margins (i.e. setting $\omega^T = 1$, $\omega^d = 0$, $\kappa^p = \kappa^n = 0$), the model implies $q_t = -(1-2\alpha_2)(s_t - \tilde{\tau}_t^m)$ and $q_t^N = -s_t$.

Ξ_3 in Eq. 16 is a term with an ambiguous sign under sticky producer prices. As the foreign country's real wage increases, the price of nontraded goods at the foreign country rises and hence q_t^N. This also increases the price of imports in the home country, pushing the value of the terms of trade s_t downward. However, a higher price of nontraded goods ($P_{N,t}^*$) in the foreign country implies a rise in distribution costs, and the home country's exporters have incentives to raise their prices because their demand elasticity is decreasing in $P_{N,t}^*$. This effect tends to increase s_t. When this force dominates, $\varphi - \omega^d < 0$, implying q_t^N and s_t move in the same direction under flexible prices. This model can generate less volatile terms of trade relative to the real exchange rate when the absolute value of $(\Xi_3)^{-1}$ is large.

Assuming that traded and nontraded sectors are equally productive, and that nontradables are only used for distributing traded goods (i.e. $\alpha_1 = 0$), the following partial equilibrium result holds when only producers have market power. This result is obtained by assuming prices are flexible and holding $\tilde{\tau}_t^m$ fixed.

$$\frac{\partial nx_t}{\partial s_t} = \begin{cases} 1 - \check{\zeta}_2 \frac{2(1+\sigma)}{1+\sigma-2\omega^f} + \frac{(1-\omega^d)(1-2\alpha_2)-\Theta_{N,2}}{1+\sigma-2\omega^f} + \zeta_2 \frac{\Theta_{N,1}}{1+\sigma-2\omega^f} & \varphi \neq \omega^d \\ 1 - \check{\zeta}_2 \frac{2(1+\sigma)}{1+\sigma-2\omega^f} + \frac{(1-\omega^d)(1-2\alpha_2)}{1+\sigma-2\omega^f} & \varphi = \omega^d \end{cases} \tag{17}$$

where the model-implied trade elasticity $\check{\zeta}_2 = \zeta_2(1-\alpha_2)(1-\omega^d)$, $\Theta_{N,2} = \Xi_1\omega^d + 1$ and $\Theta_{N,1} = \Xi_3^{-1}(1+\sigma)\omega^d(\Xi_1 - 1) + 2\omega^f(\omega^d + 1))$. Ξ_3 is defined in Eq. 15. $\omega^f := \frac{Y_F}{Y} = \frac{\alpha_2}{1+\eta}$ measures the (inverse) trade openness.

This partial equilibrium relationship between terms of trade and the trade balance can be any value depending on the size of distribution margin ω^d. This happens because of the aforementioned relationship between the relative price of nontraded goods and terms of trade. Figure 3 shows this relation under different distribution margins for trade elasticity $\zeta_2 = 1.5$ and trade openness $\alpha_2 = 0.4$. The response of the trade balance to a terms-of-trade improvement increases in ω^d until reaching a point $\omega^d = \varphi$, depicted by the vertical dashed line.

3.6.2 Intuitions from Linearized First-Order Conditions Under the LCP

This section examines the transmission of the home country's tariffs to retail prices under the LCP. Linearized first-order conditions of the home retailer of foreign imports and foreign exporters are used to illustrate the supply-side transmission of tariff shocks under three cases (also see Table 1): (1) only producers face nominal frictions (eq. 19), (2) only retailers face nominal frictions (eq. 18), and (3) both retailers and producers face nominal frictions and producers set prices strategically (eq. 20). Define $p_{F,t}^p$ and $p_{F,t}^c$ as log prices and $\pi_{F,t}^p$ and $\pi_{F,t}^c$ as their corresponding inflation rates. Let $\psi_{F,t}$ be the percent deviations of the elasticity $\Psi_{F,t}$ from the steady-state value, where $\Psi_{F,t}$ is defined as $\frac{dlogP_{F,t}^c}{dlogP_{F,t}^P}$.

In all three cases, tariffs have a direct effect on retail prices. Exchange rate devaluations due to the home country's tariff shocks would lower the price $p_{F,t}^p$ and offset the effect of tariffs.

In case 1), holding all variables other than the retail price constant, the pass-through elasticity of tariffs to the retail price is $1-\omega^d$. The empirical elasticity being 0.1 potentially requires unrealistically large distribution margins.

Case 1): only producers face nominal frictions.

$$\begin{cases} p^p_{F,t} = e_t + mc^*_{T,t} & \text{Producer} \\ \kappa^r \pi^c_{F,t} = \beta \kappa^r E_t(\pi^c_{F,t+1}) - \gamma(1-\omega^d)^{-1}\left(p^c_{F,t} - (1-\omega^d)p^p_{F,t} - (1-\omega^d)\tau^m_t - \omega^d p_{N,t}\right) & \text{Retailer} \end{cases} \tag{18}$$

In Cases 2) and 3), tariffs also indirectly increase the elasticity $\psi_{F,t}$ and hence lower the price of exports. This channel becomes a source of low retail-level pass-through. The elasticity of retail prices to changes in producer prices always increases with tariffs, and in turn negatively affects producer prices [13]. As discussed in the previous section, a negative force on $\psi_{F,t}$ comes from the price of nontraded goods in case 2).

Case 2): only retailers face nominal frictions.

$$\begin{cases} \kappa^p \pi^p_{F,t} = \beta \kappa^p E_t(\pi^P_{F,t+1}) - (\gamma\psi - 1)\frac{P^p_F}{P}\left(p^p_{F,t} - e_t - mc^*_{T,t} + \frac{1}{\gamma\psi-1}\psi_{F,t}\right) & \text{Producer} \\ \psi_{F,t} = \omega^d \tau^m_t - \omega^d(p_{N,t} - p^p_{F,t}) & \text{Elasticity} \\ p^c_{F,t} = (1-\omega^d)p^p_{F,t} + (1-\omega^d)\tau^m_t + \omega^d p_{N,t} & \text{Retailer} \end{cases} \tag{19}$$

In Case 3), additional downward forces come from current inflation and the expected inflation in the retail sector (i.e. $\pi^c_{F,t}$ and $\pi^c_{F,t+1}$). This results in a lower demand elasticity in case 3) than case 2). In other words, ”strategy complementarity” occurs in this producer-retailer dynamic Stackelberg game: exogenous forces that increase the retail prices incentivize upstream producers to strategically increase prices.

Case 3): both retailers and producers face nominal frictions and producers set prices strategi-

[13]As long as $\gamma > 1$, the multiplier $(\gamma+1)\psi - 1 > 0$ for τ^m_t in Eq. 20.

cally.

$$
\begin{cases}
\kappa^p \pi^p_{F,t} = \beta \kappa^p E_t(\pi^P_{F,t+1}) - (\gamma\psi - 1)\frac{P^p_F}{P}\left(p^p_{F,t} - e_t - mc^*_{T,t} + \frac{1}{\gamma\psi - 1}\psi_{F,t}\right) & \text{Producer} \\
\psi_{F,t} = \big(\overbrace{(\gamma+1)\psi - 1}^{¿0}\big)\tau^m_t + \dfrac{\psi\omega^d}{1-\omega^d}(p^p_{F,t} - p_{N,t}) & \\
\quad - \psi\left(2\dfrac{\kappa^r}{\gamma}\pi^c_{F,t} + 4\beta\dfrac{\kappa^r}{\gamma}E_t(\pi^c_{F,t+1}) + \beta\dfrac{\kappa^r}{\gamma}E(\Theta_{t+1})\right) & \text{Elasticity} \\
\kappa^r \pi^c_{F,t} = \beta\kappa^r E_t(\pi^c_{F,t+1}) - \gamma(1-\omega^d)^{-1}\left(p^c_{F,t} - (1-\omega^d)p^p_{F,t} - (1-\omega^d)\tau^m_t - \omega^d p_{N,t}\right) & \text{Retailer}
\end{cases}
\tag{20}
$$

where $E_t(\Theta_{t+1}) = E_t(\Delta y_{F,t+1}) + E_t(\Delta\pi^p_{F,t+1}) - E_t(\Delta\pi_{t+1}) - \sigma E_t(\Delta c_{t+1})$. This term comes from linearizing $E_t[SDF_{t+1,t}\frac{\Omega^c_{F,t+1}}{\Omega^c_{F,t}}]$, where SDF is the real stochastic discount factor for the home country, and Ω^c_F is the scaling factor in the Rotemberg adjustment cost for home retailers of foreign goods. The Rotemberg scaling factor does not affect linearized first order conditions in cases 1 and 2, and its presence here is the result of upstream producers strategically internalizing the scaling factor. It is possible to demonstrate the choice of $\Omega^c_{F,t}$ does not affect the quantitative results in the model.

4. Quantitative Results

4.1 Parameter Values

The simulation in this section uses a trade elasticity $\zeta_2 = 1.5$, and (inverse of) trade openness $\alpha_2 = 0.4$. The distribution share $\omega^d := \frac{\eta P_N}{\eta P_N + P^p_H}$ is a key value in the model because it determines the model-implied trade elasticity and openness. To facilitate isolating the main transmission mechanism in the model, I calibrate η (the units of nontraded final goods required for tradable consumption) so that $\frac{P^c_H}{\text{RetailerMarkup} \times P^p_H} = \frac{\eta P_N + P^p_H}{P^p_H} = 1.68$ in the steady state. This implies $\omega^d = 0.40$. This is also equivalent to an empirical-relevant distribution margin (defined as $\frac{P^c_H - P^p_H}{P^c_H}$) of 44%, that is 44% of the retail price comes from nontradable value-added components. This value is at the lower end of estimates in the literature. Later, Table 3 also reports results using an empirical-relevant distribution margin of 63%.

To choose the persistence of tariff shocks on final goods in the model, I use the coefficient ρ from the following regression using the retail data in Cavallo et al. (2019). Here, the model includes sectoral fixed effects α_k. Table 2 summarizes other parameters, and Appendix A.1 summarizes how I calibrate Rotemberg adjustment costs.

$$\Delta log(\tau_{i,k,t}) = \rho \Delta log(\tau_{i,k,t-1}) + \alpha_k + \epsilon_{i,k,t}$$

4.2 Pass-through On Impact Under the LCP

Table 3 shows the pass-through of the home country's tariffs on impact at the dock and at the store for three cases mentioned in the previous section, that is only sticky producer prices, only sticky retail prices, and both. When only producers face nominal frictions, low pass-through at the store occurs through variable markup and distribution cost channels. Tariffs increase producers' demand elasticity, and producers would lower their prices at the dock to offset tariffs. Due to distribution costs, a fraction of ω^d of the retailers' marginal cost comes from locally produced nontraded goods. Therefore, the retail-level pass-through is roughly the pass-through at the dock (0.844) scaled downwards by $1-\omega^d = 0.6$. The fact that the pass-through value of 0.451 at the store is lower than $0.844 * 0.6 = 0.5064$ indicates that lower nontradable prices decrease the retailer's marginal cost in general equilibrium. When both retailers and producers face nominal frictions, "strategy complementarity" contributes to increasing the pass-through from 0.844 to 0.940: retail-level inflation lowers producer-level demand elasticity, and producers would be less willing to decrease their prices to offset tariffs.

A model with only producer-level nominal frictions is unable to replicate the degree of low pass-through even with a large distribution margin. On the other hand, once retail-level nominal frictions are added, the model fits the data better. With lower nominal frictions, all models are unable to match the data. In summary, empirical pass-through estimates from tariffs on differentiated

Table 2: Quarterly Calibration and Parameter Values

Parameters	Description	Value	Source
σ	(Inverse) IES	1.5	
β	Subjective discount factor	0.99	4% annual return
φ	(Inverse) Frisch labor supply elasticity	2	
χ_1	Portfolio adjustment cost	0.01	[a]
$\bar{b}_F$ $\bar{b}_H^*$	S.S. bond holdings	0	Balanced trade in s.s.
α_1	Shares of nontradables	0.6	
ζ_1	Elasticity of substitution between tradables and nontradables	0.5	Uribe and Schmitt-Grohé (2017)
α_2	(inverse) of trade openness	0.4	Galí (2015) [b]
ζ_2	Elasticity of substitution between home and foreign traded goods	1.5	Galí (2015) [b]
α	Labor share in nontraded and traded sectors	1	
μ	Elasticity of substitution across nontradable varieties	9	
γ	Elasticity of substitution across tradable varieties	15	
κ^r κ^p κ^n	Parameter in Rotemberg adjustment cost for retailers and producers of traded and non-traded goods	$\rightarrow$	Half-life of price adjustment 3 quarters
η	Parameter for distribution costs	$\rightarrow$	Distri. Margin 1.8 [c]
ρ	Parameter in Taylor rule	0.85	
ϕ_π	Parameter in Taylor rule	1.5	
ρ	Persistence in tariff shock	$\rightarrow$	Matching AR(1) coeff of tariffs in Cavallo et al. (2019)
σ_m	Standard deviation of shock	0.01	
$\bar{Z}_N$ $\bar{Z}_N^*$	S.S. productivity in nontradable sector	0.8	[d]
$\bar{Z}_T$ $\bar{Z}_T^*$	S.S. productivity in tradable sector	1	Normalized to 1

Note: a : Its value has a wide range from 1 in Schmitt-Grohé and Uribe (2018) to 0.001 in Itskhoki and Mukhin (2021). It their paper, this parameter is used to match the persistent of the net foreign asset position. I choose a value in between. b : See page 242 in Galí (2015). c : From Berger et al. (2012). ^{d} : Mano and Castillo (2015) estimated tradable and nontradable sector productivity in a large panel of developed countries. They show the nontradable sector productivity is much lower than that in the tradable sector.

goods point to a model with retail-market frictions. Standard models with a perfectly competitive retail market without any retail-market nominal frictions (or market power) cannot replicate empirical findings. On the other hand, ”strategy complementarity” from vertically-related producers and retailers further boosts the pass-through at the dock and helps the model to explain the data better.

Table 3: Impact Effects of Tariff Shocks at the Dock and at the Store Under LCP

Sources of Nominal Frictions			Pass-through on Impact	
Producer	Retailer		at the Dock	at the Store
		Data	0.95	0.10
Baseline				
✓			0.844	0.451
	✓		0.891	0.097
✓	✓		0.940	0.166
High Distribution Margins				
✓			0.871	0.290
	✓		0.578	0.031
✓	✓		0.943	0.130
Low Nominal Frictions				
✓			0.823	0.440
	✓		0.837	0.176
✓	✓		0.910	0.274

Notes: The pass-through at the dock is defined as $\frac{dlog(P^p_{F,t}(1+\tau^m_t))}{dlog(1+\tau^m_t)}$. The pass-through at the store is defined as $\frac{dlog(p^c_{F,t})}{dlog(1+\tau^m_t)}$. Models with a high distribution margin set $\frac{P^c_H}{\text{RetailerMarkup}\times P^p_H} = 2.7$. Under the case of low nominal frictions, Rotemberg adjustment cost parameters $\kappa^r, \kappa^p, \kappa^n$ are one-third of their baseline values. Moreover, to keep ω^d constant when κ^r changes, η is calibrated so that the distribution margin $\frac{P^c_H}{\text{RetailerMarkup}\times P^p_H} = 1.8$.

4.3 Dynamic Responses to Tariff Shocks

Figure 4 and Figure 5 show the home country’s dynamic response to a 1% increase in the home country’s tariffs under the LCP and the DCP respectively. Exchange rates only partially offset tariffs. This is consistent with the conclusion by Jeanne and Son (2020).

The retail-level pass-through is smaller and more persistent under models with retail-level nominal frictions than in a model with only producer-level nominal frictions. The pass-through elasticity increases in the second period in a model with only retail-level nominal frictions. The trade balance is less volatile due to retail-level nominal frictions. With only producer-level nominal frictions, a large pass-through to retail-level prices implies a large expenditure switching effect and hence a large trade balance improvement on impact. This result implies that policymakers need to consider the degree of tariff pass-through when evaluating the expenditure switching and overall macroeconomic impacts of tariffs. A muted response of trade balances from the model indicates that positive expenditure switching effects are unlikely to support the usage of tariffs.

The choice of currency invoicing paradigm doesn't affect results as expected except for the terms of trade because the foreign country's exports are denominated in the home currency under the LCP and the DCP. When producer prices are sticky and under the DCP, the adjustment of the exchange rate only affects the import price. Exchange rate depreciations further lower the value of the home country's exports denominated in the foreign currency, whereas under the DCP exchange rates do not affect the home country's export prices. Therefore, the impact effect of tariffs on the terms of trade is larger under the DCP.

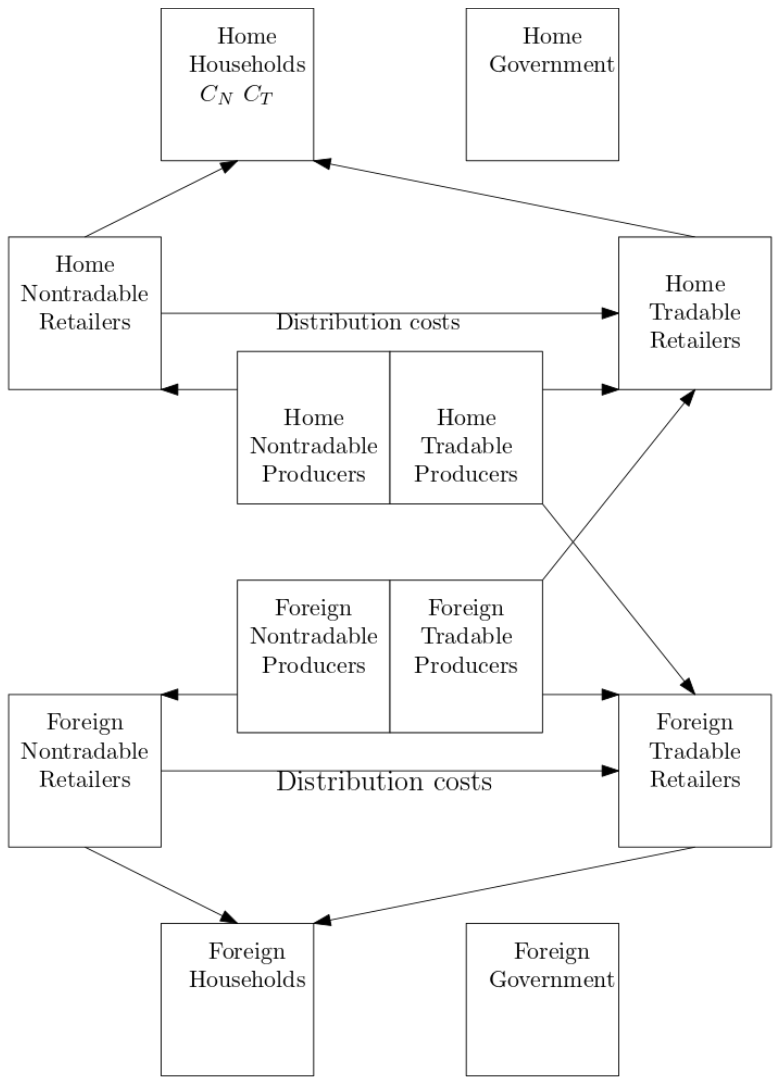
Tariffs are inflationary and lower the real wage in the home country. Meanwhile, reduced home country's imports are recessionary for the foreign country. The price level in the foreign country is lowered. The decrease in real wage lowers export prices. However, the home country's export prices relative to the foreign country's consumer prices still rise, and as a result home country's export quantities decrease.

The response of output happens because a higher pass-through generates expenditure switching to domestic goods, and this is a dominant force of raising the output. However, this expenditure switching channel is dampened by a decrease in export quantity. Under the DCP and nominal frictions faced by producers and retailers, the expenditure switching channel is not powerful, and the output decreases on impact. This result complies with the empirical finding that negative GDP growth happens due to tariffs in the short run (Barattieri et al., 2018). In general, this negative impact effect on output indicates that the expenditure switching effect takes time to occur due to nominal frictions in the domestic retail market. This result itself does not support the usage of tariffs on final goods.

5. Conclusion

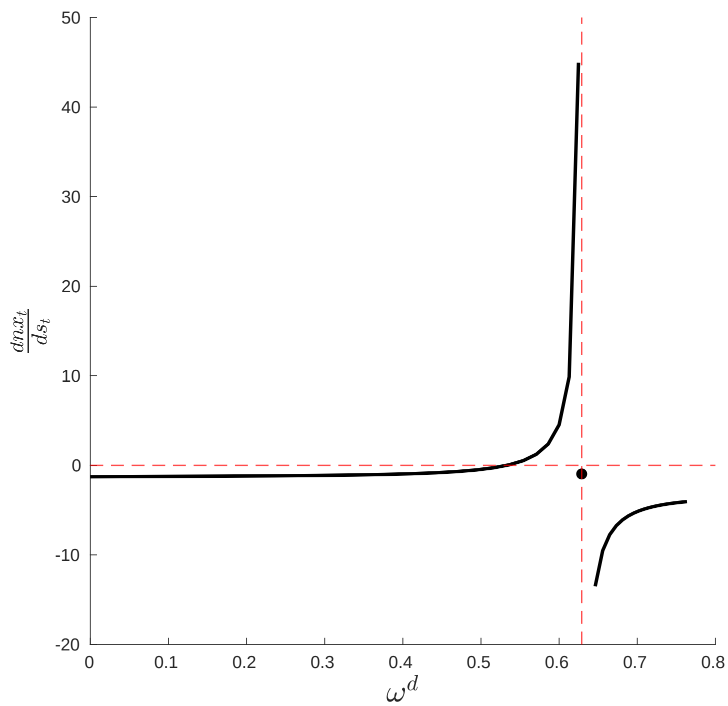
The paper asks what explains a high pass-through of tariff shocks at the dock and a low pass-through at the store in general equilibrium. Using a model with costly distribution of traded goods and nominal frictions from producers and retailers, the paper demonstrates that a two-country model without retail-level nominal frictions cannot explain a low pass-through at the store quantitatively. A model with only producer-level nominal frictions requires unrealistically high distribution margins to match the data. Moreover, the paper demonstrates that strategy complementarity exists for vertically related firms: exogenous tariff shocks increase downstream retailers' prices and create incentives for upstream producers to increase their prices. This strategic interaction boosts the pass-through elasticity at the dock and helps the model to match the data.

Figure 2: Model Summary: Flow of Goods



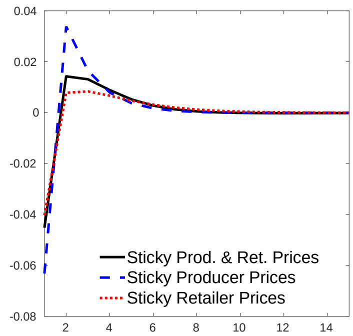
Notes: This illustration shows the flow of goods in this model. For example, home producers of tradable goods charge $P^p_{H,t}$ for home country's retailers and $P^{*p}_{H,t}$ for foreign country's retailers. Retail prices of these goods sold by retailers to consumers are $P^c_{H,t}$ and $P^{*c}_{H,t}$ respectively. Arrows indicate the directions of goods flow from one player to another player in this model.

Figure 3: Trade Balance and Terms of Trade Under Flexible Prices and Producer Market Powers

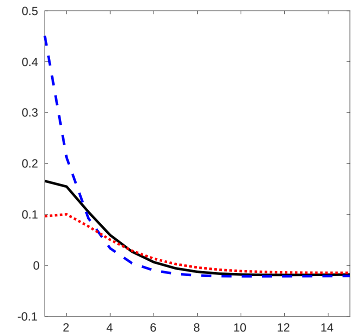


Notes: This graph shows the numerical value in eq. 17 for different ω^d when trade elasticity $\zeta_2 = 1.5$, trade openness $\alpha_2 = 0.4$, and the elasticity of substitution of tradable varieties $\gamma = 15$. It includes a horizontal dashed line at 0 and a vertical dashed-lined at $\omega^d = \varphi$. ω^d measures the fraction of distribution costs in the retailer's marginal costs. $\varphi = (1 - \omega^d)^2(\gamma(1 - \omega^d) - 1)$.

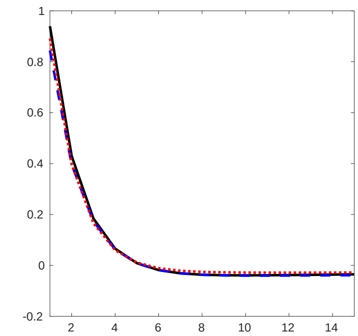
Figure 4: Home Country's Impulse Responses to a 1% Home Country Tariff Shock Under the LCP



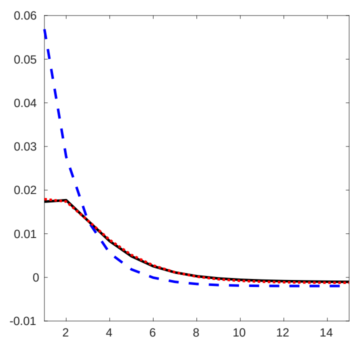
(a) Exchange Rate Depreciation (in %)



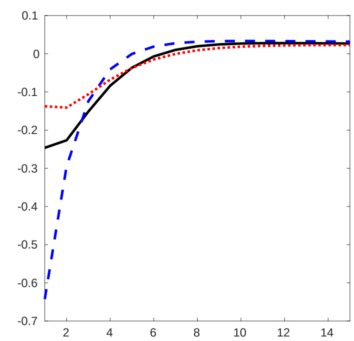
(b) CPI (incl. tariffs) of foreign goods at the store



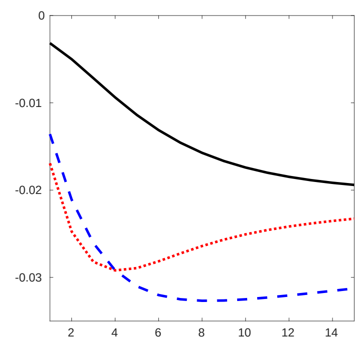
(c) Price index (incl. tariffs) of foreign goods at the home dock



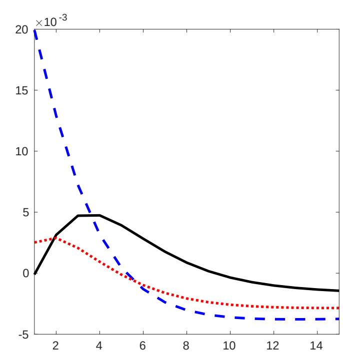
(d) Trade Balance



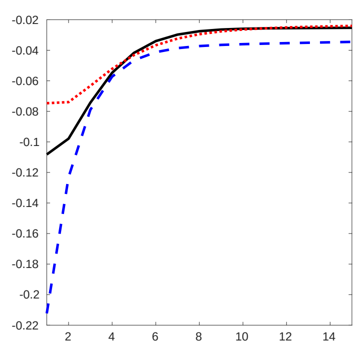
(e) Import Quantity



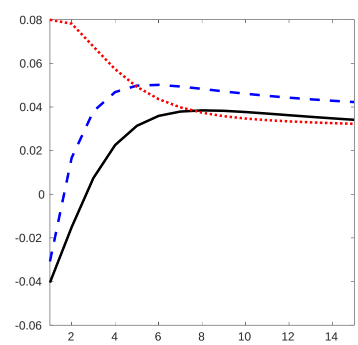
(f) Export Quantity



(g) Output



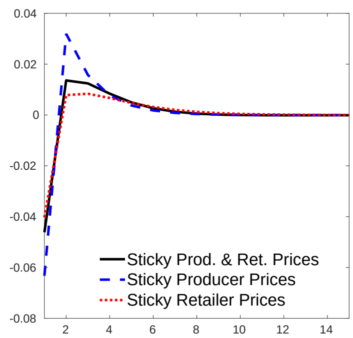
(h) Real exchange rate



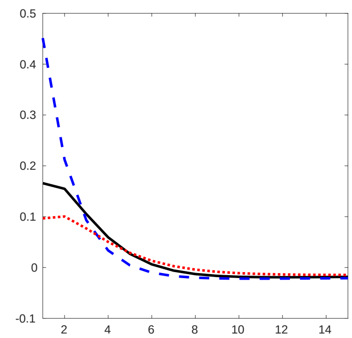
(i) Terms of Trade

Notes: There are no tariffs in the steady state. All values are percent deviations from the steady state.

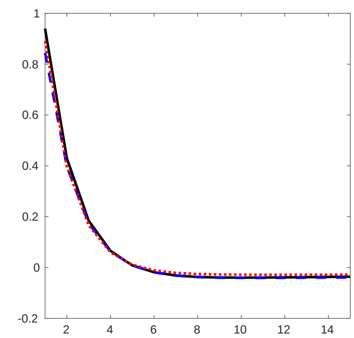
Figure 5: Home Country's Impulse Responses to a 1% Home Country Tariff Shock Under the DCP



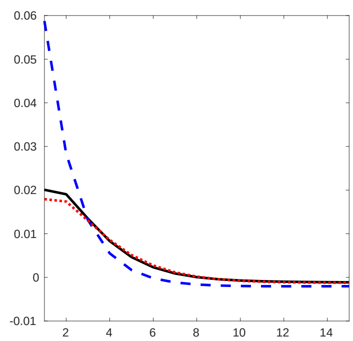
(a) Exchange Rate Depreciation (in %)



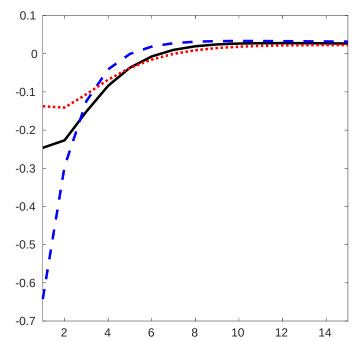
(b) CPI (incl. tariffs) of foreign goods at the store



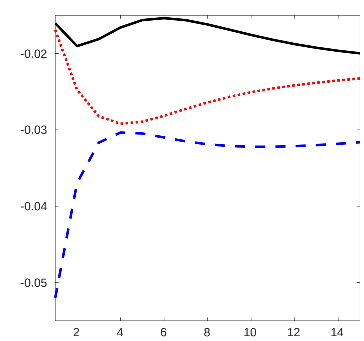
(c) Price index (incl. tariffs) of foreign goods at the home dock



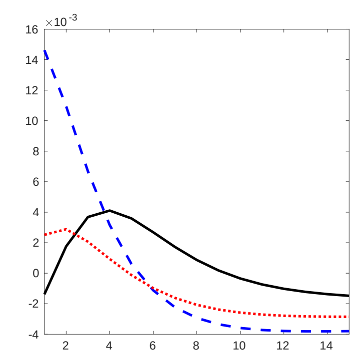
(d) Trade Balance



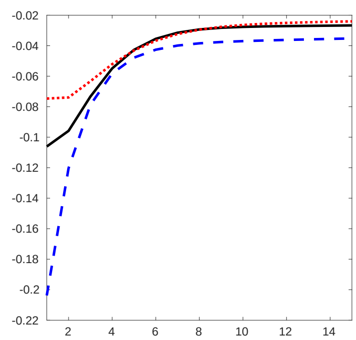
(e) Import Quantity



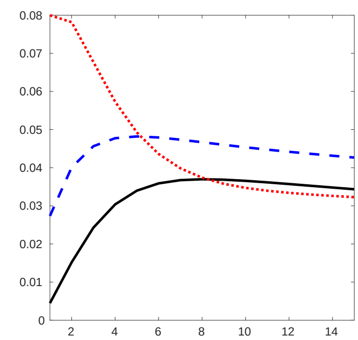
(f) Export Quantity



(g) Output



(h) Real exchange rate



(i) Terms of Trade

Notes: There are no tariffs in the steady state. All values are percent deviations from the steady state.

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A. Additional Details

A.1 Calibrating Rotemberg Parameter

I use the simulated IRF to a near-permanent monetary policy shock to calibrate the size of adjustment costs across different models. I match the half-life of price adjustment to a near-permanent monetary policy shock. Since the degree of nominal friction is important, here I use conservative values assuming that the probability of price adjustment each quarter is 0.25, implying a half-life of prices of $log(0.5)/log(1-0.25) = 2.41$ quarters. I round this value to 3, and this paper uses a half-life of 3 quarters. This value is smaller than the 5 quarters implied by the probability of price adjustment being 0.13 in Del Negro et al. (2015).

To calibrate nominal frictions, I replace the Taylor-rule with a money supply growth rule and add the real balance of money. I choose parameters $\kappa^r, \kappa^p, \kappa^n$ across different models such that the half life of the price level responses to a one time monetary supply shock is around 3 quarters. For the home country, I add the term for real balance $log(\frac{M_t}{P_t})$ in the utility function. Let $\frac{M_t}{P_t}$ be the real balance, and M_t be the money supply. The additional first order condition is $(\frac{M_t}{P_t})^{-1} - C_t^{-\sigma} + \beta E_t(\frac{C^{-\sigma}}{\pi_{t+1}})$. The shock process is $log(\frac{M_t}{M_{t-1}}) = \epsilon_t$, where ϵ_t is a one time one standard deviation shock.

B. Appendix: Model

B.1 Foreign Household Block

Foreign households pay the home government when they adjust the real balances of the home portfolios that they are holding. The problem of the foreign households is the following.

$$\max_{\{C_t^*, L_t^*\}} E_0 \sum_{t=0}^{\infty} \beta^t \Big(\frac{C_t^{*1-\sigma} - 1}{1-\sigma} - \frac{L_t^{*1+\varphi}}{1+\varphi}\Big) \tag{21}$$

$$\begin{cases} P_t^* C_t^* + B_{F,t}^* + \mathcal{E}_t^{-1} B_{H,t}^* = \mathcal{E}_t^{-1} I_{t-1} B_{H,t-1}^* + I_{t-1}^* B_{F,t-1}^* + W_t^* L_t^* - \frac{\chi_1}{2} \mathcal{E}_t^{-1} P_t (\frac{B_{H,t}^*}{P_t} - \bar{b}_H^*)^2 + TR_t^* + \Pi_t^* \\ \text{no-ponzi condition} \\ B_{H,0}^*, B_{F,0}^* \quad \text{are given} \end{cases}$$

B.2 Foreign Firm Block

When producers and retailers both face nominal frictions, the optimization problems of producers and retailers that involve foreign produced goods are the following:

$$\begin{aligned} \left\{P_{F,t}^c\left(P_{F,t}^p(i)\right)\right\}_t \in arg \max_{\{P_{F,t}^c(i)\}} E \sum_{t=0}^{\infty} \beta^t SDF_{t,0} \Bigg(& Y_{F,t}(\frac{P_{F,t}^c(i)}{P_{F,t}^c})^{-\gamma}(P_{F,t}^c(i) - (1+\tau_t^m)P_{F,t}^p(i) - \eta P_{N,t}) \\ & - \frac{\kappa^r}{2}(\frac{P_{F,t}^c(i)}{P_{F,t-1}^c(i)} - 1)^2 \Omega_{F,t}^c \Bigg) \end{aligned} \tag{22}$$

where $\Omega_{F,t}^c = P_{F,t}^p Y_{F,t}$. τ_t^m is the home country's import tariff.

$$\begin{aligned} \left\{P_{F,t}^{*c}\left(P_{F,t}^{*p}(i)\right)\right\}_t \in arg \max_{\{P_{F,t}^{*c}(i)\}} E \sum_{t=0}^{\infty} \beta^t SDF_{t,0}^* \Bigg(& Y_{F,t}^*(\frac{P_{F,t}^{*c}(i)}{P_{F,t}^{*c}})^{-\gamma}(P_{F,t}^{*c}(i) - P_{F,t}^{*p}(i) - \eta P_{N,t}^*) \\ & - \frac{\kappa^r}{2}\left(\frac{P_{F,t}^{*c}(i)}{P_{F,t-1}^{*c}(i)} - 1\right)^2 \Omega_{F,t}^{*c} \Bigg) \end{aligned} \tag{23}$$

where $\Omega_{F,t}^{*c} = P_{F,t}^{*p} Y_{F,t}^*$.

$$\max_{\substack{Y_{F,t}(i), Y_{F,t}^*(i), \\ P_{F,t}^p(i), P_{F,t}^{*p}(i), L_{T,t}^*(i)}} E_0 \sum_{t=0}^{\infty} \beta^t SDF_{t,0}^* \Big[\mathcal{E}_t^{-1} P_{F,t}^p(i) Y_{F,t}(i) + P_{F,t}^{*p}(i) Y_{F,t}^*(i) - W_t^* L_{T,t}^*(i) - AC_{F,t}(i) - AC_{F,t}^*(i) \Big] \tag{24}$$

$$
\text{s.t.} \begin{cases} AC_{F,t}(i) = \frac{\kappa^p}{2}\left(\frac{P^p_{F,t}(i)}{P^p_{F,t-1}(i)} - 1\right)^2 \Omega^p_{F,t} \quad AC^*_{F,t}(i) = \frac{\kappa^p}{2}\left(\frac{P^{*p}_{F,t}(i)}{P^{p*}_{F,t-1}(i)} - 1\right)^2 \Omega^{*p}_{F,t} \\ Y_{F,t}(i) = Y_{F,t}\left(\frac{P^c_{F,t}\left(P^p_{F,t}(i)\right)}{P^c_{F,t}}\right)^{-\gamma} \qquad Y^*_{F,t}(i) = Y^*_{F,t}\left(\frac{P^{*c}_{F,t}\left(P^{*p}_{F,t}(i)\right)}{P^{*c}_{F,t}}\right)^{-\gamma} \qquad Y_{F,t}(i) + Y^*_{F,t}(i) = Z^*_{T,t} L^*_{T,t}(i)^\alpha \\ \text{Eq.22} \quad \text{and} \quad \text{Eq.23} \end{cases}
$$

where $\Omega^p_{F,t} = \Omega^{*p}_{F,t} = P^{*p}_{F,t} Y^*_{F,t}$.

B.3 Appendix: Equilibrium Condition

The following expresses the equilibrium conditions in stationary variables by deflating all nominal variables by the CPI.

Home household block

- Consumption

$$
C_t^{-\sigma} = \lambda_t \tag{25}
$$

- Labor supply

$$
\lambda_t W_t / P_t = L_t^\varphi \tag{26}
$$

- Demand for home issued bonds:

$$
\beta E_t[\frac{\lambda_{t+1}}{\lambda_t} \frac{I_t}{\pi_{t+1}}] = 1 \tag{27}
$$

- Demand for foreign issued bonds:

$$
1 + \chi_1(b_{F,t} - \bar{b}_F) = \beta E_t[\frac{\lambda_{t+1}}{\lambda_t} \frac{I^*_t}{\pi^*_{t+1}} \frac{S_{t+1}}{S_t}] \tag{28}
$$

Foreign household block

- consumption:

$$
C_t^{*-\sigma} = \lambda^*_t \tag{29}
$$

- labor supply:

$$\lambda_t^* W_t^*/P_t^* = L_t^{*\varphi} \tag{30}$$

- demand for foreign issued bonds

$$\beta E_t \Bigg(\frac{\lambda_{t+1}^*}{\lambda_t^*} \frac{I_t^*}{\pi_{t+1}^*}] = 1 \tag{31}$$

- demand for home issued bonds:

$$1 + \chi_1(b_{H,t}^* - \bar{b}_H^*) = \beta E_t [\frac{\lambda_{t+1}^*}{\lambda_t^*} \frac{I_t}{\pi_{t+1}} \frac{S_t}{S_{t+1}}] \tag{32}$$

Home firms producing nontraded varieties

- labor demand:

$$\alpha MC_{N,t} Z_{N,t} L_{N,t}^{\alpha-1} = W_t/P_t \tag{33}$$

- optimal price:

$$\pi_{N,t}(\pi_{N,t} - \bar{\pi}) = \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \pi_{N,t+1}(\pi_{N,t+1} - \bar{\pi}) \frac{P_t P_{N.t+1} Y_{N,t+1}}{P_{t+1} P_{N,t} Y_{N,t}} \right) + \frac{\mu}{\kappa} (\frac{MC_{N,t} P_t}{P_{N,t}} - \frac{\mu - 1}{\mu}) \tag{34}$$

Foreign firms producing nontraded varieties

- labor demand:

$$\alpha MC_{N,t}^* Z_{N,t}^* L_{N,t}^{*\alpha-1} = W_t^*/P_t^* \tag{35}$$

- optimal price:

$$\pi_{N,t}^*(\pi_{N,t}^* - \bar{\pi}^*) = \beta E_t \left(\frac{\lambda_{t+1}^*}{\lambda_t^*} \pi_{N,t+1}^*(\pi_{N,t+1}^* - \bar{\pi}^*) \frac{P_t^* P_{N,t+1}^* Y_{N,t+1}^*}{P_{t+1}^* P_{N,t}^* Y_{N,t}^*} \right) + \frac{\mu}{\kappa} (\frac{MC_t^* P_t^*}{P_{N,t}^*} - \frac{\mu - 1}{\mu}) \tag{36}$$

Exogenous shocks

- Tariff shocks follow the following processes:

$$\begin{bmatrix} \tau_t^m \\ \\ \tau_t^{*m} \end{bmatrix} = \rho \begin{bmatrix} \tau_{t-1}^m \\ \\ \tau_{t-1}^{*m} \end{bmatrix} + (1-\rho) \begin{bmatrix} \bar{\tau}^m \\ \\ \bar{\tau}^{*m} \end{bmatrix} + \boldsymbol{\rho_\nu} \nu_t^m \quad \text{where} \quad \nu \sim N(0, \sigma_m)$$

where $\boldsymbol{\rho_\nu} = [1 \quad 1]'$ under foreign's retaliation and $\boldsymbol{\rho_\nu} = [1 \quad 0]'$ when the foreign government does not retaliate with home country's import tariffs.

Monetary policy

- Home country's monetary policy

$$\frac{I_t}{I} = (\frac{I_{t-1}}{I})^\rho \Big[(\frac{\pi_t}{\bar{\pi}})^{\phi_\pi} \Big]^{1-\rho} \tag{37}$$

- Foreign country's monetary policy

$$\frac{I_t^*}{I} = (\frac{I_{t-1}^*}{I})^\rho \Big[(\frac{\pi_t^*}{\bar{\pi}})^{\phi_\pi} \Big]^{1-\rho} \tag{38}$$

Production functions

$$Y_{H,t} + Y_{H,t}^* = Z_t L_{T,t}^\alpha \tag{39}$$

$$Y_{N,t} = Z_{N,t} L_{N,t}^\alpha \tag{40}$$

$$Y_{F,t}^* + Y_{F,t} = Z_{T,t}^{*\alpha} \tag{41}$$

$$Y_{N,t}^* = Z_{N,t}^* L_{N,t}^{*\alpha} \tag{42}$$

Defining relative prices

$$\pi_{H,t}^p = \pi_t \frac{P_{H,t}}{P_t} / \frac{P_{H,t-1}}{P_{t-1}} \tag{43}$$

$$\pi^p_{N,t} = \pi_t \frac{P_{N,t}}{P_t} / \frac{P_{N,t-1}}{P_{t-1}} \tag{44}$$

$$\pi^*_{N,t} = \pi^*_t \frac{P^*_{N,t}}{P^*_t} / \frac{P^*_{N,t-1}}{P^*_{t-1}} \tag{45}$$

$$\pi_{F,t} = \pi_t \frac{P_{F,t}}{P_t} / \frac{P_{F,t-1}}{P_{t-1}} \tag{46}$$

$$\pi^{*p}_{F,t} = \pi^*_t \frac{P^{*p}_{F,t}}{P_t} / \frac{P^{*p}_{F,t-1}}{P_{t-1}} \tag{47}$$

$$\pi^c_{H,t} = \pi^*_t \frac{P^c_{F,t}}{P_t} / \frac{P^c_{F,t-1}}{P_{t-1}} \tag{48}$$

$$\pi^c_{F,t} = \pi_t \frac{P^c_{F,t}}{P_t} / \frac{P^c_{F,t-1}}{P_{t-1}} \tag{49}$$

$$\pi^{*c}_{F,t} = \pi^*_t \frac{P^{*c}_{F,t}}{P_t} / \frac{P^{*c}_{F,t-1}}{P_{t-1}} \tag{50}$$

$$\pi^{*c}_{H,t} = \pi^*_t \frac{P^{*c}_{H,t}}{P_t} / \frac{P^{*c}_{H,t-1}}{P_{t-1}} \tag{51}$$

$$\text{Under the LCP} \quad \pi^*_{H,t} = \pi^*_t \frac{P^{*p}_{H,t}}{P^*_t} / \frac{P^{*p}_{H,t-1}}{P^*_{t-1}} \quad \text{Under the DCP} \quad \pi^*_{H,t} = \pi_t \frac{P^{*p}_{H,t}}{P_t} / \frac{P^{*p}_{H,t-1}}{P_{t-1}} \tag{52}$$

Price indices

$$1 = (1-\alpha_1)(\frac{P^c_{T,t}}{P_t})^{1-\zeta_1} + \alpha_1(\frac{P_{N,t}}{P_t})^{1-\zeta_1} \tag{53}$$

$$(\frac{P^c_{T,t}}{P_t})^{1-\zeta_2} = (1-\alpha_2)(\frac{P^c_{H,t}}{P_t})^{1-\zeta_2} + \alpha_2(\frac{P^c_{F,t}}{P_t})^{1-\zeta_2} \tag{54}$$

$$1 = (1-\alpha_1)(\frac{P^{*c}_{T,t}}{P^*_t})^{1-\zeta_1} + \alpha_1(\frac{P^*_{N,t}}{P^*_t})^{1-\zeta_1} \tag{55}$$

$$(\frac{P^{*c}_{T,t}}{P^*_t})^{1-\zeta_2} = (1-\alpha_2)(\frac{P^{*c}_{H,t}}{P^*_t})^{1-\zeta_2} + \alpha_2(\frac{P^{*c}_{F,t}}{P^*_t})^{1-\zeta_2} \tag{56}$$

Other equations and market clearing conditions

- Exchange rate ($\Delta\mathcal{E}_t := \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}}$)

$$\frac{Q_t}{Q_{t-1}} = \frac{\Delta\mathcal{E}_t \pi^*_t}{\pi_t} \tag{57}$$

- Bond market clearing

$$b_{H,t} + b^*_{H,t} = 0 \tag{58}$$

$$b_{F,t} + b^*_{F,t} = 0 \tag{59}$$

- Labor market clearing

$$L_{T,t} + L_{N,t} = 0 \tag{60}$$

$$L^*_{T,t} + L^*_{N,t} = 0 \tag{61}$$

- Goods market clearing

$$Y_{H,t} = (1-\alpha_2)(1-\alpha_1)(\frac{P^c_{H,t}}{P_t})^{-\zeta_2}(\frac{P_{T,t}}{P_t})^{\zeta_2-\zeta_1}C_t + Y_{H,t}\frac{\kappa^p}{2}(\pi^p_{H,t}-1)^2 + Y_{H,t}\frac{\kappa^r}{2}(\pi^c_{H,t}-1)^2 + Y_{H,t}\frac{\kappa^p}{2}(\pi^{*p}_{H,t}-1)^2 \tag{62}$$

$$Y^*_{H,t} = (1-\alpha_1)\alpha_2(\frac{P^{*c}_{H,t}}{P^*_t})^{-\zeta_2}(\frac{P^*_{T,t}}{P^*_t})^{\zeta_2-\zeta_1}C^*_t + Y^*_{H,t}\frac{\kappa^r}{2}(\pi^{*c}_{H,t}-1)^2 \tag{63}$$

$$Y_{F,t} = (1-\alpha_1)\alpha_2(\frac{P^c_{F,t}}{P_t})^{-\zeta_2}(\frac{P_{T,t}}{P_t})^{\zeta_2-\zeta_1}C_t + Y_{F,t}\frac{\kappa}{2}(\pi^c_{F,t}-1)^2 \tag{64}$$

$$Y^*_{F,t} = (1-\alpha_1)(1-\alpha_2)(\frac{P^c_{F,t}}{P^*_t})^{-\zeta_2}(\frac{P_{T,t}}{P^*_t})^{-\zeta_2-\zeta_1}C^*_t + Y^*_{F,t}\frac{\kappa^p}{2}(\pi^{*p}_{F,t}-1)^2 + Y^*_{F,t}\frac{\kappa^r}{2}(\pi^{*c}_{F,t}-1)^2 + Y^*_{F,t}\frac{\kappa^p}{2}(\pi^p_{F,t}-1)^2 \tag{65}$$

$$Y_{N,t} = \alpha_1(\frac{P_{N,t}}{P_t})^{-\zeta_1}C_t + Y_{N,t}\frac{\kappa^n}{2}(\pi_{N,t}-1)^2 + \eta(Y_{F,t} + Y_{H,t}) \tag{66}$$

$$Y^*_{N,t} = \alpha_1(\frac{p^*_{N,t}}{P^*_t})^{-\zeta_1}C^*_t + Y^*_{N,t}\frac{\kappa^n}{2}(\pi^*_{N,t}-1)^2 + \eta(Y^*_{F,t} + Y^*_{H,t}) \tag{67}$$

- Other variables

  Home country's terms of trade is $Q_t\frac{P^{*p}_{F,t}}{P^*_t}/\frac{P^p_{F,t}}{P_t}$ under the LCP and $\frac{P^{*p}_{F,t}}{P_t}/(Q_t\frac{P^p_{F,t}}{P_t})$ under the DCP. The price of foreign exports at the home dock is $\frac{P_{F,t}}{P_t}(1+\tau^m_t)$. The price of foreign exports at the home retail store is $\frac{P^c_{F,t}}{P_t}$. Home country's trade balance is $NX_t = Q_t\frac{P^*_{H,t}}{P^*_t}Y^*_{H,t} - \frac{P^p_{F,t}}{P_t}Y_{F,t}$ under the LCP and $\frac{P^*_{H,t}}{P^*_t}Y^*_{H,t} - \frac{P^p_{F,t}}{P_t}Y_{F,t}$ under the DCP.

Balance of payments The following equation comes from manipulating the budget constraint of home households. This holds regardless of the source of nominal frictions in the model.

$$
\begin{aligned}
C_t + \frac{TB_t}{P_t} =& \frac{P_{N,t}}{P_t} Y_{N,t} (1 - \frac{\kappa^n}{2}(\pi_{N,t} - 1)^2) - \frac{P^p_{H,t}}{P_t} Y_{H,t} (\frac{\kappa^p}{2}(\pi^{*p}_{H,t} - 1)^2 + \frac{\kappa^p}{2}(\pi^p_{H,t} - 1)^2) \\
&+ \frac{P^c_{H,t}}{P_t} Y_{H,t} - \frac{P^p_{H,t}}{P_t} Y_{H,t} \frac{\kappa^r}{2} (\frac{P^c_{H,t}}{P_t} - 1)^2 - \eta \frac{P_{N,t}}{P_t} Y_{H,t} \\
&+ \frac{P^c_{F,t}}{P_t} Y_{F,t} - \frac{P^p_{F,t}}{P_t} Y_{F,t} \frac{\kappa^r}{2} (\frac{P^c_{F,t}}{P_t} - 1)^2 - \eta \frac{P_{N,t}}{P_t} Y_{F,t} - \frac{P^p_{F,t}}{P_t} Y_{F,t} + \text{ExportRevenues}_t
\end{aligned}
\tag{68}
$$

where ExportRevenues_t is $Q_t \frac{P^{*p}_{H,t}}{P^*_t} Y^*_{H,t}$ under the LCP and $Q_t \frac{P^{*p}_{H,t}}{P^*_t} Y^*_{H,t} = \frac{P^{*p}_{H,t}}{P_t} Y^*_{H,t}$ under the DCP.

$$
\frac{TB_t}{P_t} = b_{H,t} + Q_t b_{F,t} - \frac{I_{t-1} b_{H,t-1}}{\pi_t} - \frac{b_{F,t-1} I^*_{t-1} Q_t}{\pi^*_t} - \frac{\chi_1}{2}(b^*_{H,t} - \bar{b}^*_H)^2 + \frac{\chi_1 Q_t}{2}(b_{F,t} - \bar{b}_F)^2 \tag{69}
$$

Labor demand of tradable producers

- Home country

$$
W_t/P_t = \alpha MC_{T,t} Z_{T,t} L^{\alpha-1}_{T,t} \tag{70}
$$

- Foreign country

$$
W^*_t/P^*_t = \alpha MC^*_{T,t} Z^*_{T,t} L^{*\alpha-1}_{T,t} \tag{71}
$$

Both retailers and producers face nominal frictions

This section focuses on the first-order conditions when both retailers and producers face nominal frictions. The first-order conditions are obtained by setting $\kappa^p = 0$ and the producer' markup to 1 (i.e. setting $mk_{H,t} = mk_{F,t} = mk^*_{F,t} = mk^*_{H,t} = 1$). The first-order conditions when only produces face nominal frictions are obtained by setting $\kappa^r = 0$ and $mk^r_t = 1$.

Define the following scaling factors in the Rotemberg adjustment costs: $\Omega^c_{H,t} := \frac{P^p_{H,t}}{P_t} Y_{H,t}$, $\Omega^c_{F,t} := \frac{P^p_{F,t}}{P_t} * Y_{F,t}$, $\Omega^{*c}_{F,t} := \frac{P^{*p}_{F,t}}{P^*_t} Y^*_{F,t}$, $\Omega^{*c}_{H,t} := \frac{P^{*p}_{H,t}}{P^*_t} Y^*_{H,t}$. Let the markup of retailers be $mk^r_t = \frac{\gamma}{\gamma-1}$

- Home produced goods consumed in the home country
  - Producer problem

$$\kappa^p(\pi^p_{H,t}-1)\pi^p_{H,t}\frac{P_{H,t}}{P_t}Y_{H,t} = \beta\kappa^p E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\pi^p_{H,t+1}(\pi^p_{H,t+1}-1)\frac{P_{H,t+1}}{P_{t+1}}Y_{H,t+1}\right) - (\gamma\Psi_{H,t}-1)Y_{H,t}(\frac{P_{H,t}}{P_t} - mk_{H,t}mc_{T,t}) \tag{72}$$

$$\text{where the markup is } mk_{H,t} = \gamma\Psi_{H,t}/(\gamma\Psi_{H,t}-1) \tag{73}$$

  - Elasticity

$$1 = \Psi_{H,t}((1+\eta\frac{P_{N,t}}{P_t}/\frac{P_{H,t}}{P_t})(\gamma+1) - \frac{P^c_{H,t}}{P_t}(\gamma-1)/\frac{P_{H,t}}{P_t} + \frac{\kappa^r}{\gamma}(\pi^c_{H,t})^2 + \beta\frac{\kappa^r}{\gamma}E_t\left(\frac{\lambda_{t+1}}{\lambda_t}(3(\pi^c_{H,t+1})^2 - 2\pi^c_{H,t+1})\frac{P_{H,t+1}}{P_{t+1}}Y_{H,t+1}/\left(\frac{P_{H,t}}{P_t}Y_{H,t}\right)\right)) \tag{74}$$

  - Retailer problem

$$\kappa^r(\pi^c_{H,t}-1)\pi^c_{H,t}\Omega^c_{H,t} = \beta\kappa^r E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\pi^c_{H,t+1}(\pi^c_{H,t+1}-1)\Omega^c_{F,t+1}\right) - (\gamma-1)Y_{H,t}(\frac{P^c_{H,t}}{P_t} - mk^r_t(\frac{P_{H,t}}{P_t}+\eta\frac{P_{N,t}}{P_t})) \tag{75}$$

- Home produced goods exported to the foreign country
  - Producer problem
    - Under the LCP

$$\kappa^p(\pi^{*p}_{H,t}-1)\pi^{*p}_{H,t}\frac{P_{H,t}}{P_t}Y_{H,t} = \beta\kappa^p E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\pi^{*p}_{H,t+1}(\pi^{*p}_{H,t+1}-1)\frac{P_{H,t+1}}{P_{t+1}}Y_{H,t+1}\right) - (\gamma\Psi^*_{H,t}-1)Y^*_{H,t}(\frac{P^{*p}_{H,t}}{P^*_t}Q_t(1+\tau^x_t) - mk^*_{H,t}mc_{T,t}) \tag{76}$$

$$mk^*_{H,t} = \gamma\Psi^*_{H,t}/(\gamma\Psi^*_{H,t}-1); \tag{77}$$

* Under the DCP

$$\kappa^p(\pi^{*p}_{H,t}-1)\pi^{*p}_{H,t}\frac{P_{H,t}}{P_t}Y_{H,t} = \beta\kappa^p E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\pi^{*p}_{H,t+1}(\pi^{*}_{H,t+1}-1)\frac{P_{H,t+1}}{P_{t+1}}Y_{H,t+1}\right) - (\gamma\Psi^*_{H,t}-1)Y^*_{H,t}(\frac{P^{*p}_{H,t}}{P_t}(1+\tau^x_t) - mk^*_{H,t}mc_{T,t}) \tag{78}$$

$$mk^*_{H,t} = \gamma\Psi^*_{H,t}/(\gamma\Psi^*_{H,t}-1) \tag{79}$$

- Elasticity

  * Under the LCP

$$1+\tau^{*m}_t = \Psi^*_{H,t}\Bigg[(1+\tau^{*m}_t+\eta\frac{P^*_{N,t}}{P^*_t}/\frac{P^{*p}_{H,t}}{P^*_t})(\gamma+1) - \frac{P^{*c}_{H,t}}{P^*_t}(\gamma-1)/\frac{P^{*p}_{H,t}}{P^*_t} + \frac{\kappa^r}{\gamma}(\pi^{*c}_{H,t})^2 + \beta\frac{\kappa^r}{\gamma}E_t\left(\frac{\lambda^*_{t+1}}{\lambda^*_t}(3(\pi^{*c}_{H,t})^2 - 2\pi^{*c}_{H,t+1})\frac{P^{*p}_{H,t+1}}{P^*_{t+1}}Y^*_{H,t+1}/(\frac{P^{*p}_{H,t}}{P^*_t}Y^*_{H,t})\right)\Bigg] \tag{80}$$

  * Under the DCP

$$1+\tau^{*m}_t = \Psi^*_{H,t}\Bigg[(1+\tau^{*m}_t+Q_t\eta\frac{P^*_{N,t}}{P_t}/\frac{P^{*p}_{H,t}}{P_t})(\gamma+1) - Q_t\frac{P^{*c}_{H,t}}{P^*_t}(\gamma-1)/\frac{P^{*p}_{H,t}}{P_t} + \frac{\kappa^r}{\gamma}(\pi^{*c}_{H,t})^2) + \beta\frac{\kappa^r}{\gamma}E_t\left(\frac{\lambda^*_{t+1}}{\lambda^*_t}(3(\pi^{*c}_{H,t+1})^2 - 2\pi^{*c}_{H,t+1})\frac{P^{*p}_{H,t+1}}{P_{t+1}}Y^*_{H,t+1}Q_t/(Q_{t+1}\frac{P^{*p}_{H,t}}{P_t}Y^*_{H,t})\right)\Bigg] \tag{81}$$

- Retailer problem

  * Under the LCP

$$\kappa^r(\pi^{*c}_{H,t}-1)\pi^{*c}_{H,t}\Omega^{*c}_{H,t} = \beta\kappa^r E_t\left(\frac{\lambda^*_{t+1}}{\lambda^*_t}\pi^{*c}_{H,t+1}(\pi^{*c}_{H,t+1}-1)\Omega^{*c}_{H,t+1}\right) - (\gamma-1)Y^*_{H,t}(\frac{P^{*c}_{H,t}}{P^*_t} - mk^r_t((1+\tau^{*m}_t)\frac{P^p_{H,t}}{P^*_t} + \eta\frac{P^*_{N,t}}{P^*_t})) \tag{82}$$

* Under the DCP

$$\kappa^r(\pi^{*c}_{H,t}-1)\pi^{*c}_{H,t}\frac{P^{*p}_{H,t}}{P_t}Y^*_{H,t}\frac{1}{Q_t}=\beta\kappa^r E_t\left(\frac{\lambda^*_{t+1}}{\lambda^*_t}\pi^{*c}_{H,t+1}(\pi^{*c}_{H,t+1}-1)\frac{P^{*p}_{H,t+1}}{P_{t+1}}Y^*_{H,t+1}\frac{1}{Q_{t+1}}\right)$$
$$-(\gamma-1)Y^*_{H,t}(\frac{P^{*c}_{H,t}}{P^*_t}-mk^r_t*((1+\tau^{*m}_t)\frac{P^{*p}_{H,t}}{P_t}/Q_t+\eta\frac{P^*_{N,t}}{P^*_t})) \tag{83}$$

- Foreign produced goods consumed at the foreign country

  - Producer problem

$$\kappa^p(\pi^{*p}_{F,t}-1)\pi^{*p}_{F,t}\frac{P^{*p}_{F,t}}{P^*_t}Y^*_{F,t}=\beta\kappa^p E_t\left(\frac{\lambda^*_{t+1}}{\lambda^*_t}\pi^{*p}_{F,t+1}(\pi^{*p}_{F,t+1}-1)\frac{P^{*p}_{F,t+1}}{P^*_{t+1}}Y^*_{F,t+1}\right)$$
$$-(\gamma\Psi^*_{F,t}-1)Y^*_{F,t}(\frac{P^{*p}_{F,t}}{P^*_t}-mk^*_{F,t}mc^*_{T,t}) \tag{84}$$

$$mk^*_{F,t}=\gamma\Psi^*_{F,t}/(\gamma\Psi^*_{F,t}-1); \tag{85}$$

  - Elasticity

$$1=\Psi^*_{F,t}\Bigg[(1+\eta\frac{P^*_{N,t}}{P^*_t}/\frac{P^{*p}_{F,t}}{P^*_t})(\gamma+1)-\frac{P^{*c}_{F,t}}{P^*_t}(\gamma-1)/\frac{P^{*p}_{F,t}}{P^*_t}+\frac{\kappa^r}{\gamma}(\pi^{*c}_{F,t})^2)$$
$$+\beta\frac{\kappa^r}{\gamma}E_t\left(\frac{\lambda^*_{t+1}}{\lambda^*_t}(3(\pi^{*c}_{F,t})^2-2\pi^{*c}_{F,t})\frac{P^{*p}_{F,t+1}}{P^*_{t+1}}Y^*_{F,t+1}/(\frac{P^{*p}_{F,t}}{P^*_t}Y^*_{F,t})\right)\Bigg] \tag{86}$$

  - Retailer problem

$$\kappa^r(\pi^{*c}_{F,t}-1)\pi^{*c}_{F,t}\Omega^{*c}_{F,t}=\beta\kappa^r E_t\left(\frac{\lambda^*_{t+1}}{\lambda^*_t}\pi^{*c}_{F,t+1}(\pi^{*c}_{F,t+1}-1)\Omega^{*c}_{F,t+1}\right)-(\gamma-1)Y^*_{F,t}(\frac{P^{*c}_{F,t}}{P^*_t}-mk^r_t(\frac{P^{*p}_{F,t}}{P^*_t}+\eta\frac{P^*_{N,t}}{P^*_t})) \tag{87}$$

- Foreign produced goods exported to the home country

– Producer problem

$$\kappa^p(\pi^p_{F,t}-1)\pi^p_{F,t}\frac{P^{*p}_{F,t}}{P^*_t}Y^*_{F,t} = \beta\kappa^p E_t\left(\frac{\lambda^*_{t+1}}{\lambda^*_t}\pi^p_{F,t+1}(\pi^p_{F,t+1}-1)\frac{P^{*p}_{F,t}}{P^*_{t+1}}Y^*_{F,t+1}\right) - (\gamma\Psi_{F,t}-1)Y_{F,t}(\frac{P^p_{F,t}}{P_t}/Q_t - mk_{F,t}mc^*_{T,t}) \tag{88}$$

$$mk_{F,t} = \gamma\Psi_{F,t}/(\gamma\Psi_{F,t}-1) \tag{89}$$

– Elasticity

$$1+\tau^m_t = \Psi_{F,t}\Bigg[1+\tau^m_t+\eta\frac{P_{N,t}}{P_t}/\frac{P^p_{F,t}}{P_t})(\gamma+1) - \frac{P^c_{F,t}}{P_t}(\gamma-1)/\frac{P^p_{F,t}}{P_t} + \frac{\kappa^r}{\gamma}(\pi^c_{F,t})^2 + \beta\frac{\kappa^r}{\gamma}E_t\left(\frac{\lambda_{t+1}}{\lambda_t}(3(\pi^c_{F,t+1})^2 - 2\pi^c_{F,t+1})\frac{P^p_{F,t+1}}{P_{t+1}}Y_{F,t+1}/(\frac{P^p_{F,t}}{P_t}Y_{F,t})\right)\Bigg] \tag{90}$$

– Retailer problem

$$\kappa^r(\pi^c_{F,t}-1)\pi^c_{F,t}\Omega^c_{F,t} = \beta\kappa^r E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\pi^c_{F,t+1}(\pi^c_{F,t+1}-1)\Omega^c_{F,t+1}\right) - (\gamma-1)Y_{F,t}(\frac{P^c_{F,t}}{P_t} - mk^r_t(\frac{P^p_{F,t}}{P_t}(1+\tau^m_t)+\eta\frac{P_{N,t}}{P_t})) \tag{91}$$

B.4 Definition of Equilibrium

This section defines the equilibrium when both retailers and producers face nominal frictions in a Stackelberg game. A monopolisticcally competitive equilibrium of home and foreign economies consists of

- Households in the home and foreign countries who maximize utility over consumption, labor supply, and portfolio choice.
- Nontradable producers in the home and foreign countries and retailers who maximize profits over labor demand in the nontraded sector.

- Retailers maximize profits by taking the price charged by producers as given. Producers take retailers' strategies as given and maximize profits over labor demand in the traded sector.
- The government has a balanced budget and implements monetary policy according to a Taylor rule.
- Market clearing conditions for the labor, the bond, and the goods market
- Exogenous shocks to tariffs follow AR(1) processes.

B.5 Appendix: Solving for non-stochastic steady-state prices

This section first solves steady-state prices when both retailers and producers face nominal frictions. It is possible to obtain analytical solutions to steady-state variables for two symmetric countries under a linear production function (i.e. setting $\alpha = 1$). This symmetry implies the exchange rate $\mathcal{E}$ and relative prices $\frac{P^*}{P} = 1$, and the real exchange rate $Q = 1$.

Combining the consumption Euler equation, $\frac{W}{C^\sigma} = (L_T + L_N)^\varphi$, the optimal price of nontradable producers $P_N Z_N = \frac{\mu}{\mu-1} W$, and the production functions $Y_H + Y_H^* = L_T$, $Y_N = Z_N L_N$ yield:

$$P_N Z_N = \frac{\mu}{\mu - 1} (Y_H + Y_H^* + Y_N / Z_N)^\varphi C^\sigma \tag{92}$$

The optimal price of tradable producers is $P_H = \frac{\gamma\Psi}{\gamma\Psi - 1} W$, and this implies

$$P_H = \frac{\gamma\Psi}{\gamma\Psi - 1} (Y_H + Y_H^* + Y_N / Z_N)^\varphi C^\sigma \tag{93}$$

This implies $P_H = \frac{\gamma\Psi}{\gamma\Psi - 1} P_N Z_N \frac{\mu - 1}{\mu}$. Moreover, the Law of One Price holds in the steady state. Since the exchange rate is unity, $P_H^* = P_F^* = P_F = P_H$. There is only one demand elasticity in the steady state, which has the relative price of nontraded to traded goods.

$$\Psi = \frac{\gamma}{\gamma(1+\eta\frac{P_N}{P_H}) + \kappa^r(1+\beta)}; P_H = \frac{\gamma\Psi}{\gamma\Psi - 1} P_N Z_N \frac{\mu-1}{\mu} \to \frac{P_N}{P_H} = \frac{\gamma^2 - \gamma - \kappa^r(1+\beta)}{\gamma^2\frac{\mu-1}{\mu} Z_N + \gamma\eta} \quad (94)$$

Above expressions imply the markup of tradable producers is $\frac{\gamma + \frac{\eta}{Z_N}\frac{\mu}{\mu-1}}{\gamma - 1 - \frac{\kappa^r}{\gamma}(1+\beta)}$. Next, I use the optimal price of retailers and the definition of the price indices to solve P_H^c and P_N:

$$P_H^c = \frac{\gamma}{\gamma-1}(P_H^p + \eta P_N); 1 = (P_H^c)^{1-\zeta_1}(1-\alpha_1) + \alpha_1(P_N)^{1-\zeta_1} \quad (95)$$

Let the consumption share of nontraded goods ($\frac{C_N}{C}$) be ω^N, the value added of nontraded goods in tradables be ω^d, and the relative price of traded to nontraded goods be $\frac{P_N}{P_H^p}$. Steady state prices under different market structures are summarized below.

$$\omega^N := \alpha_1(\tfrac{P_N}{P})^{1-\zeta_1} = \tfrac{\alpha_1}{\Omega^{1-\zeta_1}(1-\alpha_1)+\alpha_1}; \quad \omega^d := \tfrac{\eta P_N}{\eta P_N + P_H}; \quad \tfrac{P_N}{P_H^p} = \Lambda$$
$$\begin{cases} \Omega = \frac{\gamma}{\gamma-1}\left(\Lambda^{-1}+\eta\right); \Lambda = \frac{\gamma^2-\gamma-\kappa^r(1+\beta)}{\gamma^2\frac{\mu-1}{\mu}Z_N+\gamma\eta}, & \text{Sticky producer \& retailer prices} \\ \Omega = \frac{\gamma}{\gamma-1}\left(\Lambda^{-1}+\eta\right); \Lambda = \frac{1}{\frac{\mu-1}{\mu}Z_N}, & \text{Sticky retailer prices} \\ \Omega = \left(\Lambda^{-1}+\eta\right); \quad \Lambda = \frac{\gamma-1}{\gamma\frac{\mu-1}{\mu}Z_N+\eta}, & \text{Sticky Producer prices} \end{cases} \quad (96)$$

C. Appendix: Deriving Analytical Results in Section 3.6.1

The derivation below assumes $\alpha = 1$, $\varphi = 1$, and $Z_{N,t} = Z_{T,t} = 1$. All the derivations below are performed with the log-linearized model.

C.1 Deriving the decomposition of the price indices

Eq. 16 can be obtained from performing the following manipulations.

Under the LCP:

$$(Eq.36 - Eq.88) - (Eq.34 - Eq.76) \quad (97)$$

Under the LCP:

$$(Eq.36 - Eq.88) - (Eq.34 - Eq.78) \tag{98}$$

When only producers face nominal frictions, $\Psi = \frac{1}{1+\eta\frac{P_N}{P_H}}$, and define $\omega^d = \frac{\eta P_N}{\eta P_N + P_H}$. $\Psi = 1 - \omega^d$. The results above becomes Eq.16, and the expression of $E_t(\Omega_{t+1})$ is

$$E_t(\Omega_{t+1}) = \kappa^n \frac{\pi^*_{N,t} - \beta E(\pi^*_{N,t+1}) - \pi_{N,t} + E(\pi_{N,t+1})}{\mu - 1} - \kappa^p \frac{\pi_{F,t} - \beta E(\pi_{F,t+1}) - \pi^*_{H,t} + E(\pi^*_{H,t+1})}{\frac{P^p_H}{P}(\gamma(1-\omega^d) - 1)} \tag{99}$$

When only retailers have sticky prices, $\Psi = 1$ and the expression of $E_t(\Omega_{t+1})$ is

$$E_t(\kappa^n \frac{\pi^*_{N,t} - \beta E(\pi^*_{N,t+1}) - \pi_{N,t} + E(\pi_{N,t+1})}{\mu - 1}) \tag{100}$$

Eq. 15 uses the definition of relative prices. Let the relative price of tradables q^T_t be $e_t + p^{*c}_t - p^c_t$ and the real exchange rate $q = e_t + p^*_t - p_t$. The expressions below are derived from linearizing the definition of all the prices indices and manipulating them to get desired terms.

$$q^T_t = (1-\alpha_2)(1-\omega^d)q^p_t + \alpha_2(1-\omega^d)s_t - \alpha_2(1-\omega^d)\tilde{\tau}^m_t - \omega^d q^N_t \tag{101}$$

$$q_t = (1-\alpha_1)\omega^T q^T_t + \alpha_1(1-\omega^T)q^N_t \tag{102}$$

where $\omega^T := \frac{P_T}{P}$ and $q^p_t := e_t + p^*_{F,t} - p_{H,t}$. Note that above relationships hold under both the LCP and the DCP.

An expression of $-s_t - q^p_t$ is obtained by combining $(Eq.72 - Eq.76) + (Eq.88 - Eq.84)$ under the LCP and $(Eq.72 - Eq.78) + (Eq.88 - Eq.84)$ under the DCP. This expression of $-s_t - q^p_t$ is used to eliminate q^p_t in $Eq.101$. Combining $Eq.101$ and $Eq.102$ yields the Eq. 15 in the text.

A similar approach is used to derive the decomposition of price indices when only retailers face nominal frictions.

C.2 Deriving the decomposition of trade balances

In this section, variables with ˜ means the difference between home and foreign countries. Let $nx_t := \frac{NX_t}{P_H^* Y_H^*/P}$, then home country's trade balance $nx_t = y^*_{H,t} - y_{F,t} + s_t$. We can replace $y^*_{H,t}$ and $y_{F,t}$ with linreazied goods market clearing conditions $Eq.63$ and $Eq.64$.

$$nx_t = -\zeta_2(p^{*c}_{H,t} - p^c_{F,t} + e_t) + \zeta_2 q_t - \tilde{c}_t + s_t \tag{103}$$

We can get the expression of $p^{*c}_{H,t} - p^c_{F,t}$ using $Eq.82 - Eq.91$ under the LCP and $Eq.83 - Eq.91$ under the DCP. This gives me

$$nx_t = (1 - \zeta_2(1-\omega^d))s_t + \zeta_2 q_t - \zeta_2 \omega q^N_t - \tilde{c}_t + \zeta_2(1-\omega^d)\tilde{\tau}^m_t - \text{Term 1} \tag{104}$$

where Term $1 = 0$ when only producers face nominal frictions. It is $\zeta_2 \frac{\kappa^r}{(\gamma-1)P^c_H/P}(\beta E(\pi^{*c}_{H,t+1} - \pi^c_{F,t+1}) - (\pi^{*c}_{H,t} - \pi^c_{F,t})$.

To derive an expression of $\tilde{c}_t$, I focus on the case where only producers face nominal frictions. When the production function is linear and $Z_{N,t} = Z_{T,t}$, the linrearized Euler equations give $\tilde{w}_t = \sigma\tilde{c}_t + \varphi\tilde{y}_t$. Moreover, the relative real wage between home and foreign countries can be expressed using q^N_t and q_t as in $Eq.34 - Eq.36$:

$$\frac{\kappa^n}{\mu - 1}(\tilde{\pi}_{N,t} - \beta E_t(\tilde{\pi}_{N,t+1})) + \tilde{p}_{N,t} - \tilde{p}_t = \sigma\tilde{c}_t + \varphi\tilde{y}_t \tag{105}$$

Manipulating the linearized goods market clearing conditions gives an expressing involving $\tilde{c}_t$, $\tilde{y}_t$. This expression is used to eliminate $\tilde{y}_t$ in $Eq.105$. For simplicity, assume $\varphi = 1$ and the result is

$$(1+\sigma-2\omega^f)\widetilde{c}_t = (1-2\zeta_2\omega^f)q_t - (1-2\zeta_2\omega^f)q^N_t + 2\zeta_2\omega^f(1-\omega^d)(s_t - \widetilde{\tau}^m_t) + E_t(\Xi_{t+1}) \tag{106}$$

where Ξ_{t+1} is a term depending on how rigid prices are and the currency invoicing choice, $\omega^f := \frac{\alpha_2}{1+\eta}$. Combining Eq. 16, Eq. 15, Eq. 105, and Eq. 106 yields an expression involving nx_t and s_t

and terms due to nominal frictions. The expression in the text comes from a case without nominal frictions.