Tariffs across the supply chain*

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Abstract

What are the macroeconomic impacts of tariffs on final goods versus intermediate inputs? We set up a two-region, multi-sector model with global production networks, sticky prices and wages, and trade in consumption, investment, and intermediate goods. We show, analytically and quantitatively, that import tariffs on final goods have a smaller negative impact on GDP compared to tariffs on intermediate inputs, as final goods can be more readily substituted domestically. By contrast, tariffs on intermediate inputs lead to larger GDP losses, given the limited substitutability of foreign inputs. Moreover, inflation persistence is lower under tariffs on final goods, whereas tariffs on intermediate goods give rise to persistent cost pressures through production linkages. The results imply that revenue-equivalent import tariffs targeting only final goods can cushion the adverse effects of trade fragmentation.

Keywords: Tariffs, Global Value Chains, Inflation, Armington Elasticity

JEL: E31, E32, F12, F13, F41

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1. Introduction

How does the structure of tariffs influence their aggregate macroeconomic impact? Amid rising geopolitical fragmentation, countries and blocs increasingly employ — or threaten — tariffs and retaliation as tools of geopolitical pressure. These measures disrupt trade flows, distort prices, and shift production costs in both the imposing and retaliating economies. As trade tensions escalate, their ultimate macroeconomic consequences will depend crucially on the design of these restrictions and the types of goods targeted. This paper explores these consequences by focusing on two pivotal questions: Does the impact differ when tariffs are imposed on intermediate versus final goods? Furthermore, how does the degree of substitutability between domestic and imported goods shape the macroeconomic outcome?

Tariffs on final goods can directly raise consumer prices, reducing demand for imports and potentially shifting consumption toward domestic alternatives. In contrast, tariffs on intermediate inputs affect production costs for firms that rely on these goods, influencing their pricing decisions, competitiveness, and overall economic activity. When tariffs target intermediate goods that are essential for production, they can disrupt supply chains and lead to persistent inflation, affecting output and employment more broadly. This is especially the case for economies that are highly open and deeply integrated in global value chains, such as the European Union, where more than 50% of trade involves intermediate goods (Figure 1).[1]

The extent to which tariffs alter trade patterns also depends on the substitutability of the affected goods. If tariffed products have close alternatives — either from domestic producers or third-country suppliers — their impact may be mitigated as buyers shift away from the taxed varieties. Conversely, low substitutability and strong production interdependencies can substantially amplify the effects of tariff shocks along global value chains. These chains typically involve durable relationships: input customization and the costs of identifying suitable alternative suppliers of parts and components naturally impart stickiness among participants (Antràs, 2020). As a result, foreign intermediate inputs are often difficult to replace with domestic alternatives in the short run, particularly when production relies on

[1] Importantly, this pattern is stable over time and across different data sources: Figure A.1 in the Appendix shows that very similar trade compositions as those displayed in Figure 1 (using 2014 data from the latest WIOD vintage) are confirmed by Eurostat data for 2019 and 2024.

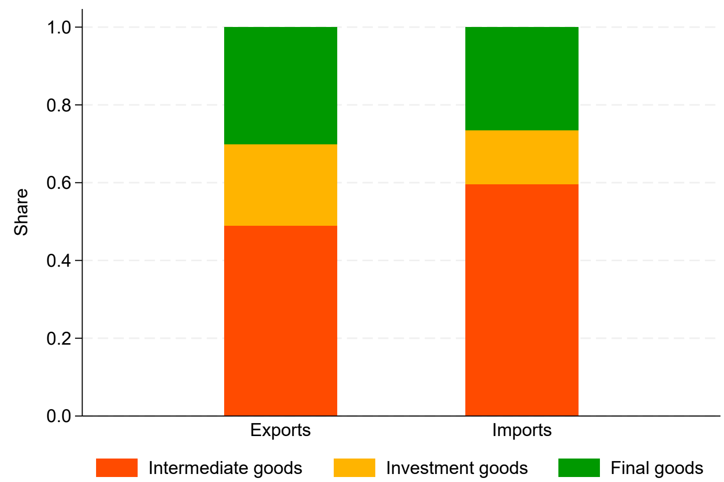

Figure 1: Extra-EU trade in goods by end use. *Note*: The shares are calculated using 2014 data from the latest vintage of WIOD and pertain to goods produced in sectors A (agriculture) and C (manufacturing) according to the NACE Rev. 2 classification.

highly specific technologies or co-specialized inputs. By contrast, consumers can generally adjust their purchases more quickly, reallocating expenditure between domestic and foreign varieties in response to changes in relative prices.

To investigate these issues, we develop a two-region, multi-sector model with a full input-output structure and international production networks, and examine the transmission channels of a differentiated tariff shock on final or intermediate goods. The model builds on Bouakez et al. (2023) and Hinterlang et al. (2023), incorporates sticky wages and prices, investment adjustment costs, and cross-border tariff shocks, and is calibrated to the European Union and the rest of the world.

To build intuition, we first show analytically, in a simplified setting, how import tariffs levied either on final goods or intermediate inputs have radically different economic implications. Households can more easily substitute foreign goods with domestic counterparts, limiting the impact on GDP of tariffs imposed on final goods, only at the cost of a temporary surge in inflation, which is entirely due to the direct impact of the tariff change. This spike in prices, indeed, does not influence the price-setting behavior of domestic producers. By contrast, import tariffs on foreign inputs increase production costs, giving rise to persistent pressures on the price of domestically-produced goods. Given that foreign inputs are more difficult to substitute domestically compared to final goods, the drop in GDP is more severe.

In the full quantitative model, these results are further compounded by the presence of a richer input-output structure, as tariff shocks to inputs ripple through the production network. Indeed, when tariffs are imposed on intermediate goods, there is a direct effect on production costs and prices. Due to the interaction with price stickiness, this effect is further compounded through input-output linkages.[2]

In our full quantitative application, we investigate the potential impact of alternative retaliatory strategies in response to foreign tariffs faced by the EU. We find that a broad retaliation scenario, targeting both final and intermediate goods, results in a more pronounced contraction in EU GDP and more persistent inflation, compared to a revenue-equivalent retaliation scenario targeting only final goods. Indeed, the latter approach mitigates the economic fallout by avoiding persistent cost pressures on domestic production, amplified through production linkages.

Related Literature. This paper is related to three main strands of the literature. First, it contributes to a rapidly growing literature studying the role of production networks in propagating the effects of shocks in multi-sector models with nominal rigidities. From this perspective, we relate to studies highlighting the role of sectoral heterogeneity and production linkages in amplifying the effects of monetary policy shocks (Pasten et al., 2020; Ghassibe, 2021; Rubbo, 2023), government spending (Bouakez et al., 2023), and the transmission of sectoral shocks to aggregate variables (Afrouzi and Bhattarai, 2023). Our paper applies these frameworks to an open-economy setting to shed light on the implications of production linkages in propagating the effect of tariff shocks.

Our paper also relates to open-economy multi-sector New Keynesian models with international production networks (Devereux et al., 2023; Hinterlang et al., 2023). Particularly, close to our approach, Kalemli-Özcan et al. (2025) also investigate the impact of tariffs in a multi-country multi-sector model with sticky prices and international production networks, showing how the inflationary effects of tariffs are amplified. In contrast, we focus on the specific question of how tariffs exert a different impact depending on the stage at which they

[2]See, e.g., Afrouzi and Bhattarai (2023), who show analytically how production linkages amplify the persistence of inflation and GDP responses to sectoral shocks.

are levied on the supply chain, emphasizing the role played by the distinct elasticities of substitution characterizing intermediate as opposed to final goods.

Third, and prominently, we contribute to the emerging interest in investigating the short-run macroeconomic impact of trade fragmentation in the context of rising global trade tensions (Moro and Nispi Landi, 2024; Ambrosino et al., 2026). In particular, Bergin and Corsetti (2023), using a New Keynesian model with global value chains find that the optimal monetary policy response to foreign tariff shocks on exports is expansionary but becomes contractionary in the case of import tariffs. Bianchi and Coulibaly (2025), instead, show that the optimal monetary policy response is expansionary, regardless of whether tariffs apply to consumption goods or intermediate inputs. Other contributions typically consider tariffs affecting only either an imported final good (see, for instance, Monacelli, 2025) or an imported input (Auclert et al., 2025). While Auray et al. (2025) consider tariffs affecting both, they do not investigate their potential different impacts as we do.

Other studies, such as Grossman et al. (2024), have investigated the welfare implications of tariff-induced supply chain disruptions, focusing on the long run and hence abstracting from nominal rigidities and monetary policy. To our knowledge, our paper is among the first to investigate — both in a simple analytical framework as well as in a rich quantitative setting — the short-run implications of tariffs levied at different stages of the supply chain, distinguishing between the impact of tariffs levied on final goods as opposed to intermediate inputs and highlighting the role of the elasticity of substitution between domestic and foreign products. In a similar vein, also Cuba-Borda et al. (2025) find that higher trade costs for final goods cause large but short-lived inflation spikes, while increased costs for intermediate inputs trigger more persistent inflation; Antonova et al. (2025) show that upstream import tariffs lower domestic output downstream, raising inflation modestly but persistently, whereas downstream tariffs raise upstream production and lead to larger but less persistent inflationary effects. These patterns are broadly consistent with available empirical evidence (Cuba-Borda et al., 2025; Khalil et al., 2025).

Roadmap. The remainder of this paper is structured as follows. Section 2 describes the model, while Section 3 provides some intuition on the basis of a simplified version. Section 4 deals with quantitative analysis, and Section 5 concludes.

2. The Model

The basic structure of the model is akin to Bouakez et al. (2023) and Hinterlang et al. (2023). We focus on a two-region specification — capturing a domestic economy and the rest of the world — enriched by including wage and price stickiness in domestic currency, investment adjustment costs, and cross-border tariff shocks. Each economy comprises S sectors, interconnected through input-output linkages both within and between regions. The two regions, $i \in \{h, f\}$, have relative size ω_h and $\omega_f = 1 - \omega_h$, and engage in international trade in intermediate, investment and final goods. We also allow the representative household in each region to invest in an internationally-traded asset. The model will be used to analyze the effects of tariff shocks, modeled as cross-border taxes on imports in each region.

2.1. Households

A representative household in each region i chooses aggregate consumption, $C_{i,t}$, labor supply, $N_{i,t}$, a basket of investment goods, $I_{i,t}$, and holdings of domestic bonds, $B_{i,t}$, as well as internationally-traded assets, $A_{ij,t}$, which are potentially denominated in the other region's currency. Expected lifetime utility is

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_{i,t} - \gamma\, C_{i,t-1})^{1-\sigma}}{1-\sigma} - \chi_i \, \frac{N_{i,t}^{1+\varphi}}{1+\varphi} \right], \tag{1}$$

where $\beta \in (0,1)$ is the discount factor, σ is the inverse elasticity of intertemporal substitution, $\gamma \geq 0$ captures habit persistence in consumption, φ is the inverse Frisch elasticity of labor supply, and χ_i captures the region-specific relative disutility of labor and consumption. The household budget constraint, with nominal prices and quantities denominated in domestic currency, is

$$\begin{aligned} &P^C_{i,t}\, C_{i,t} + P^I_{i,t}\, I_{i,t} + B_{i,t} + A_{ij,t}\, \mathcal{E}_{i,t} + \frac{\zeta}{2} \left(\frac{A_{ij,t}\, \mathcal{E}_{i,t}}{P^C_{i,t}} - \frac{A_{ij}\, \mathcal{E}_i}{P^C_i} \right)^2 P^C_{i,t} \\ &\quad \leq\; W^c_{i,t}\, N_{i,t} + R^K_{i,t}\, K_{i,t-1} + R_{i,t-1}\, B_{i,t-1} + R^a_{t-1}\, A_{ij,t-1}\, \mathcal{E}_{i,t} + TR_{i,t} + D_{i,t} \end{aligned} \tag{2}$$

where $P^C_{i,t}$ denotes the consumer price index (CPI), $P^I_{i,t}$ is the price of the investment goods basket, $W^c_{i,t}$ is the wage earned by the household, $R^K_{i,t}$ denotes the nominal rental rate of capital, and $R_{i,t-1}$ is the gross nominal return on domestic bonds. The accumulation of physical capital, $K_{i,t}$, is subject to convex adjustment costs

$$K_{i,t} = (1-\delta)\,K_{i,t-1} + I_{i,t}\left[1 - \frac{\xi}{2}\left(\frac{I_{i,t}}{I_{i,t-1}} - 1\right)^2\right], \tag{3}$$

where $\delta \in (0,1)$ is the depreciation rate and $\xi \geq 0$ governs the magnitude of the adjustment costs. Internationally-traded assets pay a return $R^a_{i,t-1}$ between $t-1$ and t, and are subject to quadratic portfolio adjustment costs, whose magnitude is governed by $\zeta > 0$.[3] $\mathcal{E}_{i,t}$ denotes the bilateral exchange rate between i and j, with $\mathcal{E}_{i,t} = 1/\mathcal{E}_{j,t}$ and a higher value of $\mathcal{E}_{i,t}$ corresponding to a depreciation of i's currency. We assume, without loss of generality, that the internationally-traded asset is denominated in f's currency.[4] Finally, $TR_{i,t}$ and $D_{i,t}$ denote, respectively, lump-sum transfers from the government and dividends collected from producers.

Household optimal decisions give the following first-order conditions regarding labor supply,

$$\chi_i\, N^{\varphi}_{i,t} = \mu_{i,t}\,\frac{W_{i,t}}{P^C_{i,t}}\,, \tag{4}$$

investment and capital accumulation choices

$$\frac{P^I_{i,t}}{P^C_{i,t}} = q_{i,t}\left[1 - \frac{\xi}{2}\left(\frac{I_{i,t}}{I_{i,t-1}} - 1\right)\left(3\,\frac{I_{i,t}}{I_{i,t-1}} - 1\right)\right] + \xi\,\beta\,\mathbb{E}\left[\frac{\mu_{i,t+1}}{\mu_{i,t}}\,q_{i,t+1}\left(\frac{I_{i,t}}{I_{i,t-1}} - 1\right)\left(\frac{I_{i,t}}{I_{i,t-1}}\right)^2\right], \tag{5}$$

$$q_{i,t} = \beta\,\mathbb{E}_t\left\{\frac{\mu_{i,t+1}}{\mu_{i,t}}\left[\frac{R^K_{i,t+1}}{P^C_{i,t+1}} + (1-\delta)\,q_{i,t+1}\right]\right\}, \tag{6}$$

and domestic bond and foreign asset holdings

$$1 = \beta\,\mathbb{E}_t\left[\frac{\mu_{i,t+1}}{\mu_{i,t}}\,\frac{R_{i,t}}{\Pi^{CPI}_{i,t+1}}\right], \tag{7}$$

[3] These adjustment costs are typically calibrated to a small amount and are introduced to pin down the international asset position following transitory shocks (see Schmitt-Grohé and Uribe, 2003).

[4] In other words, in the budget constraint in (2), when $i = h$ and $j = f$, $A_{ij,t}\,\mathcal{E}_{i,t} = A_{hf,t}\,\mathcal{E}_{h,t}$, while $A_{ij,t}\,\mathcal{E}_{i,t}$ is replaced by $A_{fh,t}$ when $i = f$ and $j = h$.

$$1 = \beta\,\mathbb{E}_t \left\{ \frac{\mu_{i,t+1}}{\mu_{i,t}} \, \frac{\mathcal{E}_{i,t+1}}{\mathcal{E}_{i,t}} \, \frac{R_t^a}{\Pi_{i,t+1}^{CPI} \left[1 + \zeta \left(a_{ij,t} - a_{ij}\right)\right]} \right\} , \tag{8}$$

where $\mu_{i,t} = (C_{i,t} - \gamma\, C_{i,t-1})^{-\sigma} - \gamma\,\beta\,\mathbb{E}_t[(C_{i,t+1} - \gamma\, C_{i,t})^{-\sigma}]$ is the marginal utility of current consumption, $q_{i,t}$ is the marginal value of capital, and $\Pi_{i,t}^{CPI} = P_{i,t}^C / P_{i,t-1}^C$ denotes the gross CPI inflation rate in region i. Given the presence of portfolio adjustment costs, the return on internationally-traded assets includes a risk premium, $[1 + \zeta\,(a_{ij,t} - a_{ij})]^{-1}$, where $a_{ij,t} := A_{ij,t}\, \mathcal{E}_{i,t} / P_{i,t}^C$.

The total amount of labor supplied by the household in each region i is a constant-elasticity-of-substitution (CES) aggregator of the labor supplied to each sector, $N_{i,s,t}$:

$$N_{i,t} = \left(\sum_{s=1}^{S} {\omega_{i,s}^n}^{-1/\nu_n} \, {N_{i,s,t}}^{1+1/\nu_n} \right)^{\frac{\nu_n}{1+\nu_n}} , \tag{9}$$

where $\omega_{i,s}^n$ is the weight attached to sector s in region i, and $\nu_n > 0$ denotes the elasticity of substitution of labor supply across domestic sectors. In other words, labor is assumed to be (imperfectly) mobile domestically across sectors, but not across regions. Given the CES structure, sectoral labor supply is given by

$$N_{i,s,t} = \omega_{i,s}^n \, \left(\frac{W_{i,s,t}^c}{W_{i,t}^c} \right)^{\nu_n} N_{i,t} \tag{10}$$

where

$$W_{i,t}^c = \left[\sum_{s=1}^{S} \omega_{i,s}^n \, {W_{i,s,t}^c}^{(1+\nu_n)} \right]^{\frac{1}{1+\nu_n}} \tag{11}$$

and $W_{i,s,t}^c$ is the wage earned in sector s.

Similarly, aggregate capital supplied by the household bundles sectoral capital services, $K_{i,s,t}$, by means of the following CES aggregator

$$K_{i,t} = \left(\sum_{s=1}^{S} {\omega_{i,s}^k}^{-1/\nu_k} \, {K_{i,s,t}}^{1+1/\nu_k} \right)^{\frac{\nu_k}{1+\nu_k}} , \tag{12}$$

where $\omega_{i,s}^k$ denotes the weight attached to capital supplied to sector s in region i, and $\nu_k > 0$ is the elasticity of substitution of capital supply across domestic sectors. Sectoral capital supply is given by

$$K_{i,s,t} = \omega^k_{i,s} \left(\frac{R^K_{i,s,t}}{R^K_{i,t}} \right)^{\nu_k} K_{i,t} \tag{13}$$

where

$$R^K_{i,t} = \left[\sum_{s=1}^{S} \omega^k_{i,s} \, {R^K_{i,s,t}}^{(1+\nu_k)} \right]^{\frac{1}{1+\nu_k}} \tag{14}$$

and $R^K_{i,s,t}$ is the rental rate of capital in sector s.

2.2. Labor Unions

We introduce nominal wage rigidity following Devereux et al. (2023). We posit that there are monopolistically competitive labor unions operating in each different sector and region. These unions transform homogeneous labor services from the household into different varieties $L_{i,s,t}(l)$, which are then converted into a final labor composite $L_{i,s,t}$ that is sold to sectoral producers. The labor aggregators have the following CES structure

$$L_{i,s,t} = \left(\int_0^1 L_{i,s,t}(l)^{1-1/\varepsilon^w_{i,s}} \, dl \right)^{\frac{\varepsilon^w_{i,s}}{\varepsilon^w_{i,s}-1}} , \tag{15}$$

where $\varepsilon^w_{i,s}$ is the elasticity of substitution among different labor services within each region and sector. Cost minimisation yields the following demand curves for each variety

$$L_{i,s,t}\,(l) = \left(\frac{W_{i,s,t}(l)}{W_{i,s,t}} \right)^{-\varepsilon^w_{i,s}} L_{i,s,t} \tag{16}$$

where the nominal wage paid by producers in each sector is given by

$$W_{i,s,t} = \left(\int_0^1 W_{i,s,t}(l)^{1-\varepsilon^w_{i,s}} \, dl \right)^{\frac{1}{1-\varepsilon^w_{i,s}}} . \tag{17}$$

The unions set the wages for the varieties of labor services, $W_{i,s,t}\,(l)$, subject to (16) and facing quadratic adjustment costs à la Rotemberg. Unions' period profits are

$$D^w_{i,t}(l) = [W_{i,s,t}(l) - W^c_{i,s,t}] \, L_{i,s,t}\,(l) - \frac{\psi^w_{i,s}}{2} \left(\frac{W_{i,s,t}(l)}{W_{i,s,t-1}(l)} - 1 \right)^2 W_{i,s,t} \tag{18}$$

where $\psi^w_{i,s}$ governs the size of wage adjustment costs. Union l operating in sector s of region

i solves

$$\max_{\{W_{i,s,t}(l),\, L_{i,s,t}(l)\}} \mathbb{E}_t \sum_{v=t}^{\infty} \beta^v \frac{P^C_{i,t}}{P^C_{i,v}} D^w_{i,v}(l) \tag{19}$$

subject to (16). Given symmetry, the optimality condition for the union problem gives

$$\Pi^w_{i,s,t}\left(\Pi^w_{i,s,t}-1\right) = \frac{\varepsilon^w_{i,s}}{\psi^w_{i,s}} \left(\frac{W^c_{i,s,t}}{W_{i,s,t}} - \mathcal{M}^w_{i,s}\right) L_{i,s,t} + \beta\, \mathbb{E}_t \left[\Pi^w_{i,s,t+1}\left(\Pi^w_{i,s,t+1}-1\right) \frac{\Pi^w_{i,s,t+1}}{\Pi^{CPI}_{i,t+1}}\right] \tag{20}$$

where $\mathcal{M}^w_{i,s} = 1-1/\varepsilon^w_{i,s}$ is the steady-state wage markdown, and $\Pi^w_{i,s,t} = W_{i,s,t}/W_{i,s,t-1}$ denotes gross sectoral wage inflation.

2.3. Firms

2.3.1. Domestic Retailers

In each region i, a perfectly competitive representative retailer purchases sectoral consumption goods $C_{i,s,t}$ from sectoral retailers, which are then bundled into final consumption, $C_{i,t}$, using the following CES technology

$$C_{i,t} = \left[\sum_{s=1}^{S} {\omega^c_{i,s}}^{1/\sigma_c} C^{1-1/\sigma_c}_{i,s,t}\right]^{\frac{\sigma_c}{\sigma_c-1}} \tag{21}$$

where $\omega^c_{i,s}$ is the weight of sector s in the consumption bundle in region i, and σ_c denotes the elasticity of substitution of consumption across sectors. Given the CES structure, the demand schedules for sectoral consumption goods are

$$C_{i,s,t} = \omega^c_{i,s} \left(\frac{P^C_{i,s,t}}{P^C_{i,t}}\right)^{-\sigma_c} C_{i,t} \tag{22}$$

where

$$P^C_{i,t} = \left[\sum_{s=1}^{S} \omega^c_{i,s} {P^C_{i,s,t}}^{(1-\sigma_c)}\right]^{\frac{1}{1-\sigma_c}} \tag{23}$$

and $P^C_{i,s,t}$ is the sectoral price of consumption goods.

Similarly, a perfectly competitive representative retailer assembles the final investment good according to the following CES technology

$$I_{i,t} = \left[\sum_{s=1}^{S} \omega_{i,s}^{I}{}^{1/\sigma_I} \, I_{i,s,t}^{1-1/\sigma_I} \right]^{\frac{\sigma_I}{\sigma_I - 1}} \tag{24}$$

where $I_{i,s,t}$ denotes sectoral demand for investment goods, $\omega_{i,s}^{I}$ is the weight attached to each sector s in the investment bundle in region i, and σ_I denotes the elasticity of substitution of investment across domestic sectors. The demand schedules for sectoral investment goods are

$$I_{i,s,t} = \omega_{i,s}^{I} \left(\frac{P_{i,s,t}^{I}}{P_{i,t}^{I}} \right)^{-\sigma_I} I_{i,t} \tag{25}$$

where

$$P_{i,t}^{I} = \left[\sum_{s=1}^{S} \omega_{i,s}^{I} \, P_{i,s,t}^{I}{}^{(1-\sigma_I)} \right]^{\frac{1}{(1-\sigma_I)}} \tag{26}$$

and $P_{i,s,t}^{I}$ is the price of sectoral investment goods.

Finally, in each sector s of region i, a perfectly competitive retailer aggregates sectoral intermediate inputs $M_{i,sx,t}$ into an intermediate-input bundle $M_{i,s,t}$ using the following CES technology

$$M_{i,s,t} = \left[\sum_{x=1}^{S} \omega_{i,sx}^{m}{}^{1/\sigma_m} \, M_{i,sx,t}^{1-1/\sigma_m} \right]^{\frac{\sigma_m}{\sigma_m - 1}}$$

where $M_{i,sx,t}$ denotes the amount of intermediate goods purchased from sector x, whose weight in the overall bundle is governed by $\omega_{i,sx}^{m}$; σ_m is the elasticity of substitution of intermediate inputs across sectors within each region. The demand schedules for sectoral intermediate goods are

$$M_{i,sx,t} = \omega_{i,sx}^{m} \left(\frac{P_{i,sx,t}^{M}}{P_{i,s,t}^{M}} \right)^{-\sigma_m} M_{i,s,t} \, , \tag{27}$$

where

$$P_{i,s,t}^{M} = \left[\sum_{x=1}^{S} \omega_{i,sx}^{m} \, P_{i,sx,t}^{M}{}^{(1-\sigma_m)} \right]^{\frac{1}{(1-\sigma_m)}} \tag{28}$$

and $P_{i,sx,t}^{M}$ is the price paid by producers in sector s to purchase intermediate goods from producers in sector x.

Importantly, sectoral consumption, investment and intermediate good prices and quantities will be influenced by domestic as well as by foreign dynamics. These mechanisms, which play a pivotal role in our framework, are now discussed in detail.

2.3.2. International Retailers

The two regions are interconnected also through trade in goods. Specifically, in each sector s and region i, competitive international retailers bundle consumption, investment and intermediate goods combining domestic and foreign goods. We introduce tariffs as exogenous cross-border taxes on imports, assumed to be rebated to households in a lump-sum manner through transfers T_t. Moreover, we differentiate between tariffs on consumption and intermediate goods.

The CES bundle for a perfectly competitive international consumption goods retailer operating in sector s of region i is

$$C_{i,s,t} = \left[{\eta^c_{i,s}}^{1/\lambda^c_{i,s}} \, C_{ii,s,t}^{1-1/\lambda^c_{i,s}} + \left(1 - \eta^c_{i,s}\right)^{1/\lambda^c_{i,s}} \, C_{ij,s,t}^{1-1/\lambda^c_{i,s}} \right]^{\frac{\lambda^c_{i,s}}{\lambda^c_{i,s}-1}} , \tag{29}$$

where $C_{ii,s,t}$ denotes consumption goods produced domestically; $C_{ij,s,t}$ denotes consumption goods produced abroad — in region $j \neq i$ — and consumed domestically in region i; $\eta^c_{i,s}$ is the sectoral preference bias of region i towards goods produced domestically, which pins down the share of imports of consumption goods, and $\lambda^c_{i,s}$ is the elasticity of substitution between domestic and foreign consumption goods. The demand schedules for domestic and foreign consumption goods in region i are

$$C_{ii,s,t} = \eta^c_{i,s} \left(\frac{P_{i,s,t}}{P^C_{i,s,t}} \right)^{-\lambda^c_{i,s}} C_{i,s,t} \, , \tag{30}$$

$$C_{ij,s,t} = (1 - \eta^c_{i,s}) \left[\frac{(1 + \tau^c_{i,s,t}) \, P_{j,s,t} \, \mathcal{E}_{i,t}}{P^C_{i,s,t}} \right]^{-\lambda^c_{i,s}} C_{i,s,t} \, , \tag{31}$$

where

$$P^C_{i,s,t} = \left\{ \eta^c_{i,s} \, P_{i,s,t}^{1-\lambda^c_{i,s}} + \left(1 - \eta^c_{i,s}\right) \, \left[(1 + \tau^c_{i,s,t}) \, P_{j,s,t} \, \mathcal{E}_{i,t}\right]^{1-\lambda^c_{i,s}} \right\}^{\frac{1}{1-\lambda^c_{i,s}}} , \tag{32}$$

$P_{i,s,t}$ is the producer price of region i, $P_{j,s,t}$ is the producer price of region j, converted in domestic currency through the nominal exchange rate $\mathcal{E}_{i,t}$, and $\tau^c_{i,s,t}$ is a tariff on consumption goods of sector s imported from region j. These tariffs are assumed to follow an exogenous AR(1) process.

Similarly, the CES bundle for investment goods of sector s in region i is

$$I_{i,s,t} = \left[{\eta^I_{i,s}}^{1/\lambda^I_{i,s}} \, I_{ii,s,t}^{1-1/\lambda^I_{i,s}} + \left(1-\eta^I_{i,s}\right)^{1/\lambda^I_{i,s}} \; I_{ij,s,t}^{1-1/\lambda^I_{i,s}} \right]^{\frac{\lambda^I_{i,s}}{\lambda^I_{i,s}-1}} , \tag{33}$$

where $I_{ii,s,t}$ denotes investment goods produced domestically; $I_{ij,s,t}$ denotes investment goods produced abroad and consumed domestically; $\eta^I_{i,s}$ is the home bias of region i for investment goods of sector s, and $\lambda^I_{i,s}$ is the elasticity of substitution between domestic and foreign investment goods. The demand schedules for domestic and foreign investment goods in region i are

$$I_{ii,s,t} = \eta^I_{i,s} \left(\frac{P_{i,s,t}}{P^I_{i,s,t}} \right)^{-\lambda^I_{i,s}} I_{i,s,t} \, , \tag{34}$$

$$I_{ij,s,t} = (1-\eta^I_{i,s}) \left(\frac{P_{j,s,t}\,\mathcal{E}_{i,t}}{P^I_{i,s,t}} \right)^{-\lambda^I_{i,s}} I_{i,s,t} \, , \tag{35}$$

where

$$P^I_{i,s,t} = \left\{ \eta^I_{i,s} \, P_{i,s,t}^{1-\lambda^I_{i,s}} + \left(1-\eta^I_{i,s}\right) \, \left(P_{j,s,t}\,\mathcal{E}_{i,t}\right)^{1-\lambda^I_{i,s}} \right\}^{\frac{1}{1-\lambda^I_{i,s}}} . \tag{36}$$

Lastly, the CES aggregator that bundles domestic and foreign intermediate goods used by sector s and sourced from sector x is

$$M_{i,sx,t} = \left[{\eta^m_{i,sx}}^{1/\lambda^m_{i,sx}} \, M_{ii,sx,t}^{1-1/\lambda^m_{i,sx}} + \left(1-\eta^m_{i,sx}\right)^{1/\lambda^m_{i,sx}} \; M_{ij,sx,t}^{1-1/\lambda^m_{i,sx}} \right]^{\frac{\lambda^m_{i,sx}}{\lambda^m_{i,sx}-1}} \tag{37}$$

where $M_{ii,sx,t}$ denotes intermediate goods used in sector s of region i and produced in sector x of region i; $M_{ij,sx,t}$ denotes intermediate goods used in sector s of region i and produced in sector x of region $j \neq i$; $\eta^m_{i,sx}$ is the home bias of region i for intermediate inputs, and $\lambda^m_{i,sx}$ is the elasticity of substitution between domestic and foreign intermediate goods. The demand schedules for domestic and foreign intermediate goods in region i are

$$M_{ii,sx,t} = \eta^m_{i,sx} \left(\frac{P_{i,x,t}}{P^M_{i,sx,t}} \right)^{-\lambda^m_{i,sx}} M_{i,sx,t} \, , \tag{38}$$

$$M_{ij,sx,t} = (1 - \eta^m_{i,sx}) \left[\frac{\left(1 + \tau^m_{i,x,t}\right) \, P_{j,x,t} \, \mathcal{E}_{i,t}}{P^M_{i,sx,t}} \right]^{-\lambda^m_{i,sx}} M_{i,sx,t} \, , \tag{39}$$

where

$$P^M_{i,sx,t} = \left\{ \eta^m_{i,sx} \, P^{1-\lambda^m_{i,sx}}_{i,x,t} + \left(1 - \eta^m_{i,sx}\right) \left[\left(1 + \tau^m_{i,x,t}\right) \, P_{j,x,t} \, \mathcal{E}_{i,t}\right]^{1-\lambda^m_{i,sx}} \right\}^{\frac{1}{1-\lambda^m_{i,sx}}} \tag{40}$$

and imports of intermediate goods of region i are subject to sector-specific, exogenous AR(1) tariff shocks $\tau^m_{i,x,t}$.

2.3.3. Producers

In each sector s in region i, there is a continuum of monopolistically competitive firms producing differentiated varieties indexed by $z \in [0, 1]$. These varieties are aggregated into a single sectoral good with the following CES technology:

$$y_{i,s,t} = \left[\int_0^1 y_{i,s,t} \left(z\right)^{1-1/\varepsilon^P_{i,s}} \right]^{\frac{\varepsilon^P_{i,s}}{\varepsilon^P_{i,s}-1}} \tag{41}$$

where $\varepsilon^P_{i,s} > 1$ represents the elasticity of substitution across varieties within each sector in region i. The implied demand curve for each variety is

$$y_{i,s,t} \left(z\right) = \left(\frac{P_{i,s,t} \left(z\right)}{P_{i,s,t}} \right)^{-\varepsilon^P_{i,s}} y_{i,s,t} \tag{42}$$

where $P_{i,s,t} = \left[P_{i,s,t}(z)^{1-\varepsilon^P_{i,s}} dz\right]^{\frac{1}{1-\varepsilon^P_{i,s}}}$ and $P_{i,s,t}\left(z\right)$ denotes the price of variety z.

Each variety z is supplied by a single monopolistic producer using the following technology

$$y_{i,s,t} \left(z\right) = A_{i,s} \, M_{i,s,t} \left(z\right)^{\alpha^m_{i,s}} \left[K_{i,s,t-1} \left(z\right)^{\alpha^k_{i,s}} \; L_{i,s,t} \left(z\right)^{1-\alpha^k_{i,s}} \right]^{1-\alpha^m_{i,s}} \tag{43}$$

where $A_{i,s}$ is a Hicks-neutral, country- and sector-specific productivity term.

Cost minimization gives the following input demands

$$M_{i,s,t}(z) = \alpha^m_{i,s} \, \frac{MC_{i,s,t}}{P^M_{i,s,t}} \, y_{i,s,t} \left(z\right) \, , \tag{44}$$

$$K_{i,s,t-1}(z) = \left(1 - \alpha^m_{i,s}\right) \alpha^k_{i,s} \, \frac{MC_{i,s,t}}{R^K_{i,s,t}} \, y_{i,s,t} \left(z\right) \, , \tag{45}$$

$$L_{i,s,t}(z) = (1-\alpha^m_{i,s})\,(1-\alpha^k_{i,s})\,\frac{MC_{i,s,t}}{W_{i,s,t}}\,y_{i,s,t}\,(z)\ , \tag{46}$$

where

$$MC_{i,s,t} = \frac{1}{A_{i,s}}\left(\frac{P^M_{i,s,t}}{\alpha^m_{i,s}}\right)^{\alpha^m_{i,s}}\left[\left(\frac{1}{1-\alpha^m_{i,s}}\right)\left(\frac{R^K_{i,s,t}}{\alpha^k_{i,s}}\right)^{\alpha^k_{i,s}}\left(\frac{W_{i,s,t}}{1-\alpha^k_{i,s}}\right)^{1-\alpha^k_{i,s}}\right]^{1-\alpha^m_{i,s}} \tag{47}$$

is the nominal marginal cost.

Producers set nominal prices $P_{i,s,t}\,(z)$ in domestic currency, subject to quadratic adjustment costs à la Rotemberg. Period-t profits are

$$D_{i,t}(z) = P_{i,s,t}(z)\,y_{i,s,t}(z) - MC_{i,s,t}\,y_{i,s,t}(z) - \frac{\psi^P_{i,s}}{2}\left(\frac{P_{i,s,t}\,(z)}{P_{i,s,t-1}\,(z)} - 1\right)^2 P_{i,s,t}\,y_{i,s,t}, \tag{48}$$

where $\psi^P_{i,s}$ is the sector- and region-specific parameter governing the size of price adjustment costs. Producers choose $P_{i,s,t}\,(z)$ and $y_{i,s,t}\,(z)$ to maximise their expected discounted stream of profits,

$$\max_{\{P_{i,s,t}(z),\,y_{i,s,t}(z)\}} \mathbb{E}_t \sum_{v=t}^{\infty} \beta^v\,\frac{\mu_{i,v}}{\mu_{i,t}}\,\frac{P^C_{i,t}}{P^C_{i,v}}\,D_{i,v}(z) \tag{49}$$

subject to (42). Given symmetry, the solution to the price-setting problem gives the following region- and sector-specific New Keynesian Phillips curve:

$$\left(\Pi^{PPI}_{i,s,t} - 1\right)\,\Pi^{PPI}_{i,s,t} = \frac{\varepsilon^P_{i,s}}{\psi^P_{i,s}}\left(\frac{MC_{i,s,t}}{P_{i,s,t}} - \frac{1}{\mathcal{M}^P_{i,s}}\right) + \beta\,\mathbb{E}_t\left[\frac{\mu_{i,t+1}}{\mu_{i,t}}\left(\Pi^{PPI}_{i,s,t+1} - 1\right)\frac{\left(\Pi^{PPI}_{i,s,t+1}\right)^2}{\Pi^{CPI}_{i,t+1}}\,\frac{y_{i,s,t+1}}{y_{i,s,t}}\right] \tag{50}$$

where $\mathcal{M}^P_{i,s} = \varepsilon^P_{i,s}/(\varepsilon^P_{i,s} - 1)$ is the steady-state price markup, and $\Pi^{PPI}_{i,s,t} = P_{i,s,t}/P_{i,s,t-1}$ denotes the gross PPI inflation rate in sector s of region i.

2.3.4. Government

Tariff revenues are rebated to households in each region in lump-sum form

$$TR_{i,t} = \mathcal{E}_{i,t}\sum_{s=1}^{S} P_{j,s,t}\left(\tau^c_{i,s,t}\,C_{ij,s,t} + \tau^m_{i,s,t}\sum_{x=1}^{S} M_{ij,xs,t}\right)\ . \tag{51}$$

2.4. Monetary Policy

Monetary policy is assumed to follow a Taylor rule of the form

$$\frac{R_{i,t}}{R_i} = \left(\frac{R_{i,t-1}}{R_i}\right)^{\rho_R} \left[\left(\frac{\Pi_{i,t}}{\Pi_i}\right)^{\phi_\pi} \left(\frac{Y_{i,t}^{VA}}{Y_i^{VA}}\right)^{\phi_y}\right]^{1-\rho_R} \tag{52}$$

where $\rho_R \in [0, 1)$ is a smoothing parameter, Π_i is the target inflation rate in region i, and the parameters ϕ_π and ϕ_y capture the responsiveness of the nominal interest rate to deviations of inflation and GDP from their steady-state values.

2.5. Market clearing

Market clearing in the labor market requires, for each sector and region,

$$N_{i,s,t} = L_{i,s,t} \, . \tag{53}$$

Goods' market clearing entails

$$y_{i,s,t} = \underbrace{C_{ii,s,t} + I_{ii,s,t} + \sum\nolimits_x M_{ii,xs,t}}_{\text{domestic demand}} + \underbrace{\frac{\omega_j}{\omega_i}\left(C_{ji,s,t} + I_{ji,s,t} + \sum\nolimits_x M_{ji,xs,t}\right)}_{\text{foreign demand}} + \frac{\psi_{i,s}^P}{2} \pi_{i,s,t}^{PPI\,2}\, y_{i,s,t} \, . \tag{54}$$

The aggregate trade balance of region i is given by $TB_{i,t} = \sum_{s=1}^{S} TB_{i,s,t}$, where sectoral trade balances are defined as

$$\begin{aligned} TB_{i,s,t} \; &= P_{i,s,t}\,\frac{\omega_j}{\omega_i}\left(C_{ji,s,t} + I_{ji,s,t} + \sum_{x=1}^{S} M_{ji,xs,t}\right) \\ &\quad - P_{j,s,t}\,\mathcal{E}_{i,t}\left((1+\tau_{i,s,t}^{c})\,C_{ij,s,t} + I_{ij,s,t} + (1+\tau_{i,s,t}^{m})\sum_{x=1}^{S} M_{ij,xs,t}\right) . \end{aligned} \tag{55}$$

At the aggregate level,[5]

$$GDP_{i,t} = C_{i,t} + \frac{P_{i,t}^{I}}{P_{i,t}^{C}}\, I_{i,t} + \frac{TB_{i,t}}{P_{i,t}^{C}} \, . \tag{56}$$

[5] Equivalently, $GDP_{i,t} = \sum_s \left(\frac{P_{i,s,t}}{P_{i,t}^C} Y_{i,s,t} - \sum_x \frac{P_{i,sx,t}^M}{P_{i,t}^C}\, M_{i,sx,t}\right)$.

Both domestic and internationally-traded assets are in zero net supply. Therefore,

$$B_{i,t} = 0 \tag{57}$$

and, since the internationally-traded asset is denominated in f's currency,

$$\omega_h \, A_{hf,t} + \omega_f \, A_{fh,t} = 0\,. \tag{58}$$

Furthermore, the equilibrium and market clearing conditions imply that the evolution of internationally-traded assets obeys

$$A_{fh,t} = R^a_{t-1} \, A_{fh,t-1} + TB_{f,t} + TR_{f,t}. \tag{59}$$

3. A Simplified Example

In this section, we rely on a simplified version of the full model presented in Section 2, and provide some intuition on the mechanisms underlying the different impact of tariffs on final as opposed to intermediate goods. Specifically, we assume that the domestic country is so small compared to the rest of the world that the latter behaves as a closed economy and is unaffected by tariff shocks in the domestic economy — a restriction that we will relax later in the full quantitative application.

We furthermore assume that the domestic economy consists of a single sector, whose production is exported, consumed, and used itself as an input, along with the labor services supplied by the representative household.

3.1. The Simplified Model

In what follows, we summarize the key equations of the simplified model, focusing on the domestic economy and omitting the subscript i for notational clarity.

3.1.1. Households

Under the assumption that $\sigma \to 1$, $\gamma = 0$, $\chi = 1$, and $\varphi = 0$, optimal household choices give the labor supply condition

$$C_t^{-1} \, \frac{W_t}{P_t} = 1\,, \tag{60}$$

demand schedules for domestic and foreign consumption,

$$C_{h,t} = \eta \left(\frac{P_{h,t}}{P_t} \right)^{-\lambda^c} C_t \,, \tag{61}$$

$$C_{f,t} = (1-\eta) \left[\frac{(1+\tau_t^c)\, \mathcal{E}_t}{P_t} \right]^{-\lambda^c} C_t \,, \tag{62}$$

and Euler equations associated with domestic and foreign bonds,

$$1 = \beta\, \mathbb{E}_t \left[\frac{C_t}{C_{t+1}} \left(\frac{R_t}{1+\pi_{t+1}} \right) \right] , \tag{63}$$

$$1 = \beta\, \mathbb{E}_t \left[\frac{C_t}{C_{t+1}} \left(\frac{R^a}{1+\pi_{t+1}} \right) \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \right] , \tag{64}$$

where $P_t = \left[\eta\, P_{h,t}^{1-\lambda^c} + (1-\eta)\, P_{f,t}^{1-\lambda^c} \right]^{\frac{1}{1-\lambda^c}}$, $\pi_t = P_t/P_{t-1} - 1$ denotes (net) CPI inflation, and portfolio adjustment costs are assumed to be absent (i.e., $\zeta \to 0$).[6]

3.1.2. Firms

Cost minimization gives the following demand schedules for hours and the composite intermediate input

$$N_t(z) = (1-\alpha^m) \left(\frac{W_t}{MC_t} \right)^{-1} Y_t(z) \,, \tag{65}$$

$$M_t(z) = \alpha^m \left(\frac{P_t^M}{MC_t} \right)^{-1} Y_t(z) \,, \tag{66}$$

where $MC_t = W_t^{(1-\alpha^m)} P_t^{M\alpha^m}$ is the nominal marginal cost and P_t^M is the price of the composite intermediate input. The demand schedules for domestic and foreign intermediate inputs are

$$M_{h,t}(z) = \eta \left(\frac{P_{h,t}}{P_t^M} \right)^{-1} M_t(z) \,, \tag{67}$$

[6]Notice that the model is non-stationary under this assumption. However, as shown in detail by Schmitt-Grohé and Uribe (2003), the current specification yields —in first-order approximation— identical dynamics to the (stationary) complete asset markets case, which implies the perfect international risk-sharing condition $C_t = \mathcal{E}_t/P_t$, as rest-of-the-world aggregates are taken to be constant.

$$M_{f,t}(z) = (1-\eta)\left(\frac{P^M_{f,t}}{P^M_t}\right)^{-1} M_t(z)\,, \tag{68}$$

where

$$P^M_t = \left[\eta\, P_{h,t}^{(1-\lambda^m)} + (1-\eta)\, P_{f,t}^{M\,(1-\lambda^m)}\right]^{\frac{1}{1-\lambda^m}} \tag{69}$$

and $P^M_{f,t} = (1+\tau^m_t)\,\mathcal{E}_t$.

Optimality conditions and symmetry yield the NK Phillips curve

$$\pi^{PPI}_{h,t}\,(1+\pi^{PPI}_{h,t}) = \frac{\varepsilon}{\psi}\left(\frac{MC_t}{P_{h,t}} - 1\right) + \mathbb{E}_t\left[\Lambda_{t,t+1}\,\pi^{PPI}_{h,t+1}\,(1+\pi^{PPI}_{h,t+1})\,\frac{Y_{t+1}}{Y_t}\right] \tag{70}$$

where $\pi^{PPI}_{h,t} = P_{h,t}/P_{h,t-1} - 1$ is the (net) inflation rate of domestically produced goods, and the steady-state markup is offset by a production subsidy.

3.1.3. Monetary Policy

In small open economy New Keynesian models —where the prices of domestically produced goods are typically sticky in terms of the domestic currency— monetary policy is generally prescribed to target PPI inflation, while looking through fluctuations in the foreign component of CPI inflation (see, e.g., Clarida et al., 2002). Accordingly, we assume the following PPI-targeting rule for monetary policy

$$R_t = \frac{1}{\beta}\,\left(1+\pi^{PPI}_{h,t}\right)^{\phi}\,. \tag{71}$$

3.1.4. Equilibrium

The equilibrium of the simplified model is characterized by the household optimality conditions in (60) to (64), firm optimal input demands in (65) and (66), the optimal pricing condition posed by the NKPC in (70), the monetary policy rule in (71) and, finally, by market clearing in the bond and goods market. In this latter respect, the domestic bond is in zero net supply ($B_t = 0$ at every t), while market clearing for goods implies

$$Y_t = C_{h,t} + M_{h,t} + X_t + \frac{\psi}{2}\,{\pi^{PPI}_{h,t}}^2\,Y_t \tag{72}$$

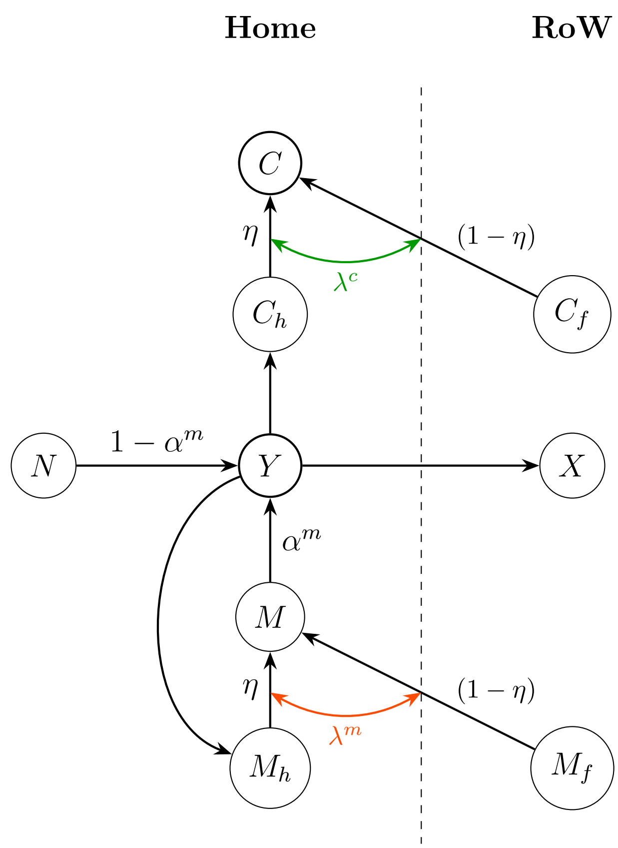

Figure 2: Supply chain in the simplified model.

where we postulate the following demand for exports

$$X_t = \left(\frac{1-\eta}{1-\alpha^m}\right)\left(\frac{P_{h,t}}{\mathcal{E}_t}\right)^{-\delta}. \tag{73}$$

with $\delta = (1-\alpha^m)\,\lambda^c + \alpha^m\,\lambda^m$ representing the price elasticity of export demand.

Real GDP (in units of final consumption) is given by the real value of production net of the real value of intermediate inputs[7]

$$GDP_t = \frac{P_{h,t}}{P_t}\,Y_t - \frac{P^M_t}{P_t}\,M_t\,. \tag{74}$$

The structure of the simple model is summarized in Figure 2.

[7]At equilibrium, it also holds that $GDP_t = \frac{P_{h,t}}{P_t}\,Y_t - \frac{P^M_t}{P_t}\,M_t = \frac{W_t}{P_t}\,N_t + \left(\frac{P_{h,t}}{P_t} - \frac{MC_t}{P_t}\right)Y_t = C_t + \frac{TB_t}{P_t}$, where $TB_t = P_{h,t}\,X_t - P_{f,t}\,C_{f,t} - P^M_{f,t}\,M_{f,t}$ is the trade balance.

3.2. The Impact of Tariffs

Letting hats denote proportional (or percentage-point) deviations from the zero-inflation steady state, the first-order approximate dynamics of the simplified model are described by the following set of equations

$$\widehat{c}_{h,t} = -\lambda^c \, \widehat{p}_{h,t} + \widehat{c}_t \tag{75}$$

$$\widehat{c}_{f,t} = -\lambda^c \, (\widehat{\tau}^c_t + \widehat{\mathcal{R}}_t) + \widehat{c}_t \tag{76}$$

$$\widehat{c}_t = \widehat{w}_t \tag{77}$$

$$r_t - \mathbb{E}_t(\pi_{t+1}) = \mathbb{E}_t(\widehat{c}_{t+1} - \widehat{c}_t) \tag{78}$$

$$0 = \eta \, \widehat{p}_{h,t} + (1-\eta) \, (\widehat{\tau}^c_t + \widehat{\mathcal{R}}_t) \tag{79}$$

$$\pi_t = \pi^{PPI}_{h,t} + \frac{1-\eta}{\eta} \, (\Delta \widehat{\tau}^c_t + \Delta \widehat{\mathcal{R}}_t) \tag{80}$$

$$\widehat{c}_t = \widehat{\mathcal{R}}_t \tag{81}$$

$$\pi^{PPI}_{h,t} = \beta \, \mathbb{E}_t \left(\pi^{PPI}_{h,t+1} \right) + \kappa \, (\widehat{mc}_t - \widehat{p}_{h,t}) \tag{82}$$

$$\widehat{mc}_t = (1-\alpha^m) \, \widehat{w}_t + \alpha^m \, \widehat{p}^M_t \tag{83}$$

$$\widehat{p}^M_t = \eta \, \widehat{p}_{h,t} + (1-\eta) \, (\widehat{\tau}^m_t + \widehat{\mathcal{R}}_t) \tag{84}$$

$$\widehat{n}_t = -\widehat{w}_t + \widehat{mc}_t + \widehat{y}_t \tag{85}$$

$$\widehat{m}_t = -\widehat{p}^M_t + \widehat{mc}_t + \widehat{y}_t \tag{86}$$

$$\widehat{m}_{h,t} = -\lambda^m \, (\widehat{p}_{h,t} - \widehat{p}^M_t) + \widehat{m}_t \tag{87}$$

$$\widehat{m}_{f,t} = -\lambda^m \, (\widehat{\tau}^m_t + \widehat{\mathcal{R}}_t - \widehat{p}^M_t) + \widehat{m}_t \tag{88}$$

$$\widehat{x}_t = -\delta \, (\widehat{p}_{h,t} - \widehat{\mathcal{R}}_t) \tag{89}$$

$$\widehat{y}_t = \eta \, (1-\alpha^m) \, \widehat{c}_{h,t} + \eta \, \alpha^m \, \widehat{m}_{h,t} + (1-\eta) \, \widehat{x}_t \tag{90}$$

$$\widehat{gdp}_t = \widehat{p}_{h,t} + \widehat{y}_t - \left(\frac{\alpha_m}{1-\alpha_m} \right) (\widehat{mc}_t - \widehat{p}_{h,t}) \tag{91}$$

$$\widehat{R}_t = \phi \, \pi^{PPI}_{h,t} \tag{92}$$

where prices, wages and costs are expressed, in real terms, in units of the final good, $\mathcal{R}_t$ denotes the real exchange rate, and $\kappa = \varepsilon / \psi$.

We are now interested in analyzing how the model behaves in response to AR(1) tariff shocks to imports of final as opposed to intermediate goods,

$$\widehat{\tau}_t^g = \rho\,\widehat{\tau}_{t-1}^g + \sigma_t^g \tag{93}$$

with $g \in \{c, m\}$ and $\rho \in [0, 1)$.

Aggregate demand and output. Combining the linearized Euler equation in (78) with (80), (81), and (92) —and given (75), (77), (79), (89), and (90)— allows to derive the following (downward sloping) dynamic IS relationship between domestic output and PPI inflation

$$\begin{aligned} \pi_{h,t}^{PPI} \;=\; & -\left(\frac{1-\rho}{\phi-\rho}\right)\frac{(1-\eta\,\alpha^m)}{\Gamma}\,\widehat{y}_t \\ & + \left(\frac{1-\rho}{\phi-\rho}\right)\frac{(1-\alpha^m)\,\eta\,(1-\eta)}{\Gamma}\,(\lambda^c-1)\,\widehat{\tau}_t^c \\ & - \left(\frac{1-\rho}{\phi-\rho}\right)\frac{\alpha^m\,\eta\,(1-\eta)}{\Gamma}\,(1-\alpha^m-\lambda^m)\,\widehat{\tau}_t^m \end{aligned} \tag{94}$$

where $\Gamma = (1-\alpha^m)\,[\eta^2 + (1-\eta^2)\,\lambda^c] + \alpha^m\,[\eta^2\,(1-\alpha^m) + (1-\eta^2)\,\lambda^m]$. Therefore, import tariffs on final goods shift the curve outward when $\lambda^c > 1$, i.e. when domestic and foreign final goods are substitutes and, hence, demand reallocation towards domestic goods (governed by the elasticity λ^c) is sufficiently strong to overcome the negative income effect. Conversely, import tariffs on intermediate goods shift the curve inward when $\lambda^m < 1-\alpha^m$, i.e. when the substitutability of foreign intermediate inputs with domestic production is low and, hence, demand for domestic production as an input is also depressed.

Marginal cost and inflation dynamics. Combining the expression for real marginal cost (in terms of units of the domestic good) in (83) with (77), (79), and (81) —and given (75), (89), and (90)— allows to express the NKPC in (82) as the following (upward sloping) relationship between domestic output and PPI inflation

$$\begin{aligned} \pi_{h,t}^{PPI} \;=\; & \kappa\,\frac{(1-\eta\,\alpha^m)^2}{(1-\beta\,\rho)\,\Gamma}\,\widehat{y}_t \\ & - \kappa\,\frac{(1-\eta\,\alpha^m)\,(1-\alpha^m)\,\eta\,(1-\eta)}{(1-\beta\,\rho)\,\Gamma}\,(\lambda^c-1)\,\widehat{\tau}_t^c \\ & + \kappa\,\alpha^m\,(1-\eta)\,\frac{(1-\alpha^m)\,[\eta^2 + (1-\eta^2)\,\lambda^c] + \alpha^m\,\lambda^m + \eta\,(1-\alpha^m-\lambda^m)}{(1-\beta\,\rho)\,\Gamma}\,\widehat{\tau}_t^m\,. \end{aligned} \tag{95}$$

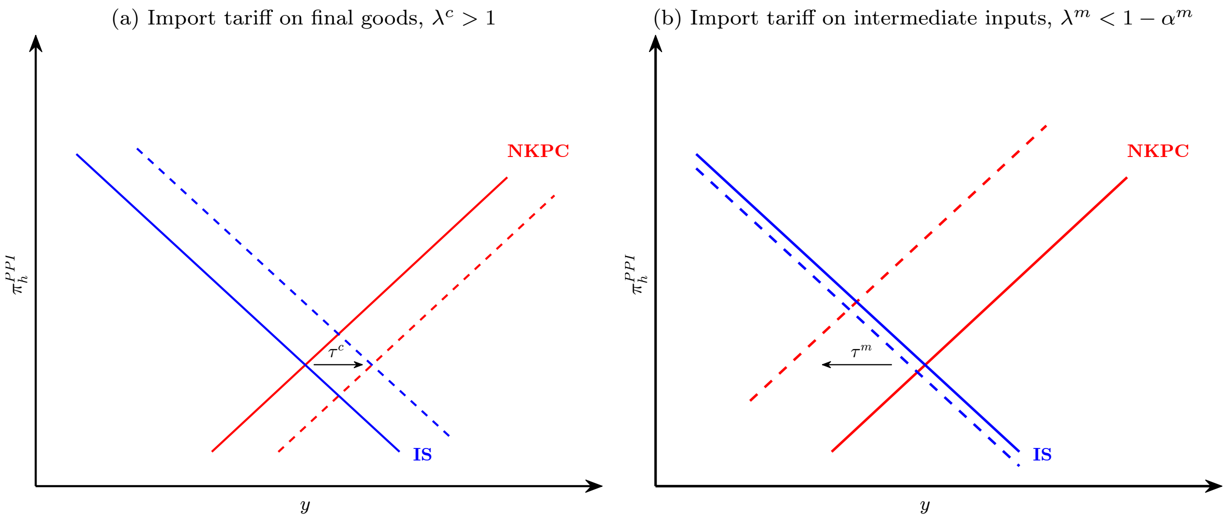

Figure 3: NKPC and IS Shifts. *Note*: See equations (94) and (95) for details.

Import tariffs on final goods can shift the curve downward when $\lambda^c > 1$. Intuitively, for given output, import tariffs on final goods imply real appreciation and lower wages, making production cheaper and domestic PPI inflation lower. Conversely, import tariffs on intermediate goods make production unambiguously costlier for given output when $\lambda^m < 1 - \alpha^m$, implying an upward shift of the NKPC.

3.2.1. Equilibrium dynamics

Figure 3 illustrates the shifts in the Dynamic IS and NKPC occurring in response to import tariffs on final goods as opposed to intermediate inputs, as highlighted in equations (94) and (95).

Import tariffs on final goods. Given the relative shifts in the Dynamic IS and NKPC, the response of domestic output to tariff shocks on imported consumption goods is

$$\widehat{y}_t = \frac{\eta\,(1-\eta)\,(1-\alpha^m)}{(1-\eta\,\alpha^m)}\,(\lambda^c - 1)\,\widehat{\tau}_t^c\,. \tag{96}$$

As in Monacelli (2025), output increases in response to rising import tariffs on final goods when the substitution towards domestic goods (governed by the elasticity λ^c) is sufficiently strong to overcome the negative income effect, that can be gauged from the fact that $\widehat{c}_t = -(1-\eta)\,\widehat{\tau}_t^c$. In practice, this occurs when imported final goods are substitutes in consumption (i.e.,

$\lambda^c > 1$). However, in this economy there are also imported intermediate goods that are used in production. Therefore, the definitions of output and GDP do not coincide, and an increase in output might not also imply an increase in GDP, given how the latter will be influenced by fluctuations in the real value of production net of those in the real value of intermediate inputs, as can be seen from (91). At equilibrium,

$$\widehat{gdp}_t = (1-\eta)\left[\eta\left(\frac{1-\alpha^m}{1-\eta\,\alpha^m}\right)(\lambda^c-1)-1\right]\widehat{\tau}_t^c\,. \tag{97}$$

Intuitively, following a rise in import tariffs on final goods, the real exchange rate appreciates by $\widehat{\mathcal{R}}_t = -(1-\eta)\,\widehat{\tau}_t^c$, making imported production inputs cheaper. However, the real value of output also decreases, by $\widehat{p}_{h,t} = -(1-\eta)\,\widehat{\tau}_t^c$. As a consequence, while output increases when $\lambda^c > 1$, this condition might not be sufficient to have an increase also in GDP, which, instead, requires that

$$\lambda^c > 2 + \left(\frac{1-\eta}{\eta}\right)\left(\frac{1}{1-\alpha^m}\right)\,. \tag{98}$$

When $\lambda^c > 1$, import tariffs on final goods imply both increased demand for domestic production (shifting the Dynamic IS curve rightward) and reduced production costs (shifting the NKPC downward). In this simplified setting, these relative shifts end up implying a null effect on domestic PPI inflation

$$\pi_{h,t}^{PPI} = 0\,. \tag{99}$$

However, due to the direct effect of exchange rate appreciation on the domestic CPI, as can be gauged from (80) the increase in import tariffs on consumption goods is transitorily inflationary as far as overall CPI inflation is concerned

$$\pi_t = (1-\eta)\,\Delta\widehat{\tau}_t^c\,. \tag{100}$$

Import tariffs on intermediate goods. Coming to tariff shocks on imported production inputs, the response of domestic output resulting from the relative supply-side and demand-side shifts is

$$\widehat{y}_t = \underbrace{- \frac{\kappa}{(1-\beta\,\rho)} \left[\frac{\alpha^m\,(1-\eta)}{1-\eta\,\alpha^m}\right] \left\{\frac{(1-\alpha^m)\,[\eta^2 + (1-\eta^2)\,\lambda^c] + \alpha^m\,\lambda^m + \eta\,(1-\alpha^m-\lambda^m)}{(1-\eta\,\alpha^m)\,\kappa/(1-\beta\,\rho) + (1-\rho)/(\phi-\rho)}\right\} \widehat{\tau}_t^m}_{\text{supply-side shift}}$$
$$\underbrace{- \left(\frac{1-\rho}{\phi-\rho}\right) \left[\frac{\alpha^m\,(1-\eta)}{1-\eta\,\alpha^m}\right] \left[\frac{\eta\,(1-\alpha^m-\lambda^m)}{(1-\eta\,\alpha^m)\,\kappa/(1-\beta\,\rho) + (1-\rho)/(\phi-\rho)}\right] \widehat{\tau}_t^m}_{\text{demand-side shift}} \tag{101}$$

which is surely negative when $\lambda^m < 1 - \alpha^m$, as there is little scope for substituting foreign inputs with domestic ones, and the shock increases costs to producers. Moreover,

$$\begin{aligned}\widehat{gdp}_t = &- \frac{\alpha^m\,(1-\eta)\,\kappa\,\left[(1-\alpha^m)\,(1-\eta^2)\,(\lambda^c-1) + (\eta-\alpha^m)\,(1-\lambda^m) + \eta\,(1-\eta\,\alpha^m)\right]}{(1-\eta\,\alpha^m)\,(1-\beta\,\rho)\,\left[(1-\eta\,\alpha^m)\,\kappa/(1-\beta\,\rho) + (1-\rho)/(\phi-\rho)\right]} \widehat{\tau}_t^m \\ &- \frac{\alpha^m\,(1-\eta)\,(1-\rho)}{(1-\eta\,\alpha^m)\,(1-\alpha^m)\,(\phi-\rho)} \left[\frac{\eta\,(1-\alpha^m)\,(1-\lambda^m) + (1-\eta)\,\alpha^m}{(1-\eta\,\alpha^m)\,\kappa/(1-\beta\,\rho) + (1-\rho)/(\phi-\rho)}\right] \widehat{\tau}_t^m\end{aligned} \tag{102}$$

and we can see, in particular, that GDP decreases if

$$\begin{aligned}\lambda^m < 1 &+ \frac{\kappa}{(1-\beta\,\rho)} \left[\frac{(1-\alpha^m)\,(1-\eta^2)\,(\lambda^c-1) + \eta\,(1-\eta\,\alpha^m)}{(\eta-\alpha^m)\,\kappa/(1-\beta\,\rho) + \eta\,(1-\rho)/(\phi-\rho)}\right] \\ &+ \left(\frac{1-\rho}{\phi-\rho}\right) \left[\frac{\alpha^m\,(1-\eta)/(1-\alpha^m)}{(\eta-\alpha^m)\,\kappa/(1-\beta\,\rho) + \eta\,(1-\rho)/(\phi-\rho)}\right]\end{aligned} \tag{103}$$

which is surely satisfied when imported inputs are complements in production (i.e., $\lambda^m < 1$), imported final goods are substitutes in consumption (i.e., $\lambda^c > 1$), and $\eta > \alpha^m$.

Given the relative shifts in the Dynamic IS and NKPC, domestic PPI inflation unambiguously rises

$$\pi_{h,t}^{PPI} = \frac{\kappa\,(1-\rho)\,(1-\eta)\,\alpha^m}{\kappa\,(\phi-\rho)\,(1-\eta\,\alpha^m) + (1-\rho)\,(1-\beta\,\rho)} \widehat{\tau}_t^m\,. \tag{104}$$

By contrast, the pressure on CPI inflation is partially dampened, on impact, by currency appreciation

$$\pi_t = \frac{\kappa\,(1-\eta)\,\alpha^m}{\kappa\,(\phi-\rho)\,(1-\eta\,\alpha^m) + (1-\rho)\,(1-\beta\,\rho)} \left[(1-\rho)\,\widehat{\tau}_t^m - (1-\eta)\,(\phi-\rho)\,\Delta\widehat{\tau}_t^m\right]. \tag{105}$$

However, when the shock is persistent, so is the pressure on domestic PPI and, eventually, CPI inflation, while the downward pressure from currency appreciation is only transitory.

3.2.2. Illustrative quantification

The full set of analytical responses is summarised in Figure 4 under an illustrative parametrisation. Consistent with the calibration of the full quantitative model —discussed later, in detail, in Section 4— as a baseline we set $\lambda^c = 3$ (the median value reported by Bajzik et al., 2020) and $\lambda^c = 1.8$ as a counterfactual (the lower bound reported in the same study). As for intermediate inputs, we set $\lambda^m = 0.1$ as a baseline (as suggested by Boehm et al., 2019) and $\lambda^m = 0.6$ as a counterfactual (the value chosen by Kalemli-Özcan et al., 2025).

Corroborating the intuition from the analytical results, when import tariffs are imposed on final goods, GDP declines as $\lambda^m < 1$, but the impact is milder when $\lambda^m = 0.6$ compared to when $\lambda^m = 0.1$, due to a smaller decline in labor demand. When $\lambda^c = 3$, both output and GDP increase in response to import tariffs on final goods. By contrast, when $\lambda^c = 1.8$, even if output increases, this is not sufficient to support GDP, given the fall in the real price of the domestic good, p_h.

As for the impact on inflation, import tariffs on consumption goods are transitorily inflationary, and due only to their direct effect on the domestic CPI. By contrast, the rise in inflation induced by import tariffs on intermediate inputs is smaller on impact, but persistent. Importantly, only tariffs on intermediate inputs affect the price-setting behavior of firms and the associated output losses arising from quadratic price-adjustment costs. Therefore, while monetary policy reacts to the (persistent) rise in PPI inflation induced by intermediate input tariffs, it can instead look through the temporary fluctuations in CPI inflation induced by final good tariffs, that leave PPI inflation unaffected. This simple insight will be further corroborated in the quantitative application of the full model in Section 4.

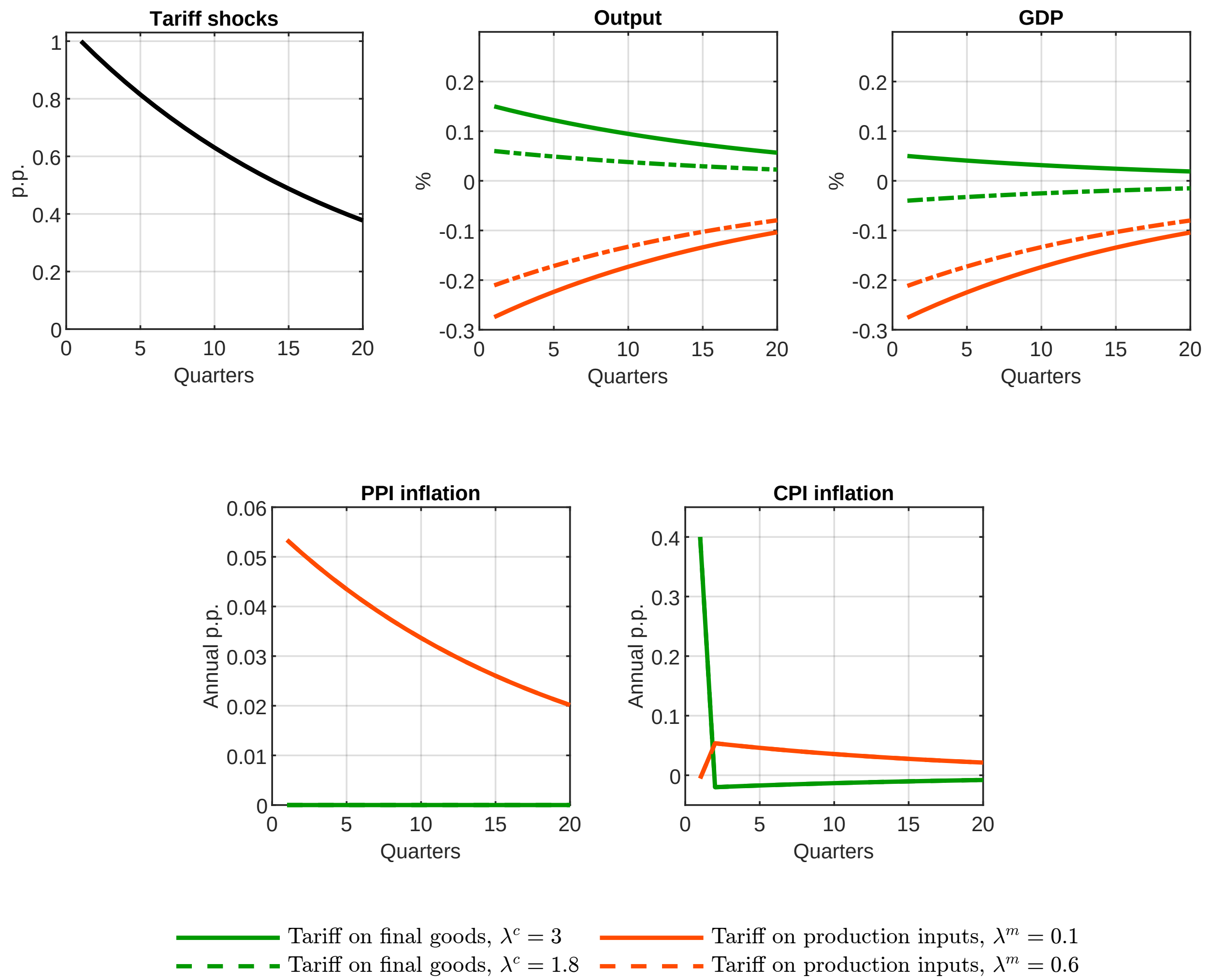

Figure 4: Impact of import tariffs in the simplified model. *Note*: $\alpha^m = 0.66$, $\eta = 0.9$, $\rho = 0.95$, $\beta = 0.99$, $\phi = 1.5$, $\kappa = 0.1$, $\delta = 1$. $\lambda^c = 3$ and $\lambda^m = 0.1$, unless otherwise noted.

4. Quantitative Analysis

4.1. Calibration

We calibrate the model at quarterly frequency and to two regions — the EU and the rest of the world. The relative size of the two regions is set according to the share of the EU in global GDP at purchasing power parity, i.e. $\omega_{EU} = 0.15$ and $\omega_{RoW} = 1 - \omega_{EU}$.

We first discuss aggregate parameters, that are common across the two regions, to then turn to choices regarding sector-specific parametrizations. The calibration is summarized in Table 1.

Table 1: Calibration.

Parameter	Description	Value	Target/Source
A. Aggregate economy			
$\omega_{EU}, \omega_{RoW}$	Relative size	0.15, 0.85	Share of global GDP at PPP
β	Discount factor	0.998	1% annual interest rate
σ	Inverse EIS	1	Coenen et al. (2013)
φ	Inverse Frisch elasticity	2	Coenen et al. (2013)
δ	Depreciation rate of capital	0.025	10% per year
ξ	Investment adjustment costs	5	Coenen et al. (2013)
γ	Habit persistence	0.6	Coenen et al. (2013)
ζ	Portfolio adjustment costs	0.001	Schmitt-Grohé and Uribe (2003)
B. Sector-specific parameters			
$\mathcal{M}^P_{i,s}$	Price markups	$1.18 - 1.86$	Christopoulou and Vermeulen (2012)
$\mathcal{M}^w$	Wage markdown	0.77	Coenen et al. (2013)
$\psi^P_{i,s}$	Price adjustment costs	$0.05 - 136$	Dhyne et al. (2006); Gautier et al. (2024)
ψ^w	Wage adjustment costs	75	Born and Pfeifer (2020)
$\alpha^m_{i,s}; \alpha^k_{i,s}$	Factor intensities		WIOD socio-economic accounts
$\omega^n_{i,s}; \omega^k_{i,s}$	Sectoral labour and capital weights		WIOD socio-economic accounts
$\omega^c_{i,s}; \omega^I_{i,s}$	Sectoral consumption and investment weights		WIOD national accounts
$\eta^c_{i,s}; \eta^I_{i,s}$	Home biases in consumption and investment		WIOD national accounts
C. Elasticites of substitution			
σ_c	Across sectoral consumption	2	Bouakez et al. (2023)
σ_I	Across sectoral investment	2	Bouakez et al. (2023)
σ_m	Across sectoral inputs	0.1	Bouakez et al. (2023)
ν_n	Across sectoral labour supply	1	Bouakez et al. (2023)
ν_k	Across sectoral capital supply	1	Bouakez et al. (2023)
λ^c	Between foreign and domestic consumption	3	Bajzik et al. (2020)
λ^m	Between foreign and domestic inputs	0.1	Boehm et al. (2019)
D. Input-output linkages			
$\omega^m_{i,sx}$	Sectoral intermediate input weights		WIOD input-output tables
$\eta^m_{i,sx}$	Home biases in intermediate-input use		WIOD input-output tables
E. Monetary Policy			
ρ_R	Inertia in the Taylor rule	0.85	Coenen et al. (2013)
ϕ_π	Inflation weight in the Taylor rule	1.9	Coenen et al. (2013)
ϕ_y	GDP weight in the Taylor rule	0.1	Christiano et al. (2005)

Note: See Appendix B for additional details.

Aggregate Economy. The discount factor β is set to 0.998, reflecting a 1% annual interest rate, while the inverse intertemporal elasticity of substitution is set to $\sigma = 1$, in line with Coenen et al. (2013). Also in line with the latter study, habit persistence is set to $\gamma = 0.6$, and the Frisch elasticity of labor supply to 0.5 (hence, $\varphi = 2$). The capital depreciation rate is targeted to be 10% per year (i.e., $\delta = 0.025$), and the investment adjustment cost parameter is set to $\xi = 5$.

Sector-Specific Parameters. We consider 10 sectors, following the NACE Rev. 2 classification: agriculture (A); mining and quarrying (B); manufacturing (C); electricity and gas (D); water supply and waste management (E); construction (F); wholesale and retail trade, transportation, accommodation and food services (G-I); information and communication (J); professional, scientific, technical, administration and support services (M-N); other services (R-S).

A first dimension across which we allow for sectoral heterogeneity entails the elasticity of substitution across varieties, $\varepsilon^P_{i,s}$, which is calibrated to target the implied steady-state sectoral price markups. In line with evidence from Christopoulou and Vermeulen (2012) for the euro area, markups range between 18% in manufacturing and 86% in information and communication services. The elasticity of substitution among differentiated labor services, ε^w, is taken to be common across sectors and reflecting an implied steady-state wage markdown of 23% (Coenen et al., 2013). As for price stickiness, we calibrate $\psi^P_{i,s}$ to reflect the frequency of price adjustment that would be implied in a Calvo model, matching the evidence reported in Dhyne et al. (2006) and Gautier et al. (2024).[8] The resulting $\psi^P_{i,s}$'s range between 0.05 for energy (sector D) and 136 for sector E in the EU. As for wage stickiness, we set ψ^w to 75, in line with Born and Pfeifer (2020).

A second set of parameters pertains to input-output linkages. We rely on the calibration toolkit provided by Hinterlang et al. (2023) and compute intermediate use coefficients, factor intensities, sectoral contributions to final demand and home biases from WIOD data. Sectoral weights for consumption ($\omega^c_{i,s}$) and investment ($\omega^I_{i,s}$) are computed from national accounts,

[8] This amounts to setting $\psi^P_{i,s} = (\varepsilon^P_{i,s} - 1)\, \frac{\theta^P_{i,s}}{(1-\theta^P_{i,s})\,(1-\beta\, \theta^P_{i,s})}$, where $\theta^P_{i,s}$ is the fraction of unadjusted prices in a quarter.

while sectoral weights for the capital stock ($\omega^k_{i,s}$) and employment ($\omega^n_{i,s}$) are based on WIOD socioeconomic accounts. The same data allows to impute factor intensities, $\alpha^m_{i,s}$ and $\alpha^k_{i,s}$, and the weight of each sector in the input-output network (reflected in the $\omega^m_{i,sx}$ weights). Factor intensities of intermediate inputs are computed by dividing the values of intermediate inputs by gross output per industry. Similarly, the factor intensities of labor are computed using the share of labor compensation in gross output per industry. The home biases for consumption and investment ($\eta^c_{i,s}$, $\eta^I_{i,s}$) are also imputed in a similar way from national accounts, while those for intermediate inputs ($\eta^m_{i,sx}$) are imputed from input-output tables.[9]

Following Bouakez et al. (2023), we set the elasticities of substitution across sectoral consumption and investment (σ_c and σ_I) to 2, and the elasticity of substitution across sectoral inputs to $\sigma_m = 0.1$. The latter choice implies strong complementarity of intermediate inputs across industries, as is standard in the literature and consistent with the estimates of Atalay (2017) and Miranda-Pinto (2021). As in Bouakez et al. (2023), the elasticities of substitution of labor and capital supply, ν_n and ν_k, are both set to 1.

Armington Elasticities. Crucial parameter choices regard the elasticities of substitution between domestic and foreign goods, also known as Armington elasticities.[10] We set the elasticity of substitution between domestic and foreign final goods to 3, consistent with the median value reported in the meta-analysis by Bajzik et al. (2020) based on the approach of Feenstra et al. (2018).[11] In counterfactual simulations, we instead use the lower bound of the 95% confidence intervals reported in the same study, and set the Armington elasticity for final goods to 1.8.

As for the investment basket, empirical evidence on the Armington elasticity is limited. Therefore, we set it to 0.75, as the cross-sector elasticity of substitution of investment within each region.

In contrast, we assume a very low elasticity of substitution between domestic and foreign

[9]As shown in Appendix B, manufacturing is characterized by both high intermediate-input intensity and strong import dependence, whereas service sectors exhibit substantially lower levels of each.

[10]The elasticity of substitution between domestic and foreign goods is commonly called the Armington elasticity in honor of Armington (1969), who first formulated a theoretical model featuring goods distinguished by their place of origin.

[11]Structural models that focus on the long run, such Caliendo and Parro (2015), typically assume higher values (around 5).

intermediate inputs, equal to 0.1, consistent with the short-run focus of the model. This parameter choice is in line with estimates of Boehm et al. (2019), who provide evidence of strong complementarities, with an estimated Armington elasticity near zero.[12] In counterfactual simulations, we set the Armington elasticity for intermediate inputs to 0.6, which aligns with the value chosen by Kalemli-Özcan et al. (2025).

Monetary Policy. Given the open-economy setting, the target rate of inflation in the Taylor rule is taken to correspond to the domestic component of the CPI.[13] As for the Taylor rule coefficients, we set $\phi_y = 0.1$ as in Christiano et al. (2005) and, given our focus on the euro area, $\phi_\pi = 1.9$ and $\rho_R = 0.85$, in line with Coenen et al. (2013).

4.2. Results

4.2.1. Impact of Import Tariffs

We begin by showing that the mechanisms identified in the simplified model carry over to the full quantitative model. Specifically, we consider an increase in tariffs on imports of agriculture and manufacturing products — sectors characterized by strong participation in global value chains and frequently subject to trade restrictions — distinguishing between tariffs that target exclusively final goods versus intermediate inputs. Since final and intermediate goods account for different shares of total imports, tariffs on only one type could, in principle, affect a smaller or larger subset, depending on which type has a larger share. For better comparison, we therefore adjust the tariff rates on each type of good according to their steady-state import shares, i.e. such that steady-state tariff revenue remains the same. Nevertheless, under the calibration, the two shares — and hence the corresponding tariff rates — are roughly equal.

Corroborating the insights from the simplified model, the level of substitutability between domestic and foreign goods plays a crucial role also in the full quantitative model. When

[12] In a companion paper, Boehm et al. (2014) show that this choice also helps to bring international co-movement of the variables in the model closer to what is observed in the data, corroborating the insight of Heathcote and Perri (2002), who first proposed values below 1 for this parameter (notwithstanding difficulties in its empirical estimation at the time, which traditionally led to considerable uncertainty in calibration procedures for this parameter).

[13] This assumption rules out transitory foreign disturbances and exchange-rate movements from directly influencing the conduct of domestic monetary policy, while still allowing their effects to be captured insofar as they pass through to domestic prices.

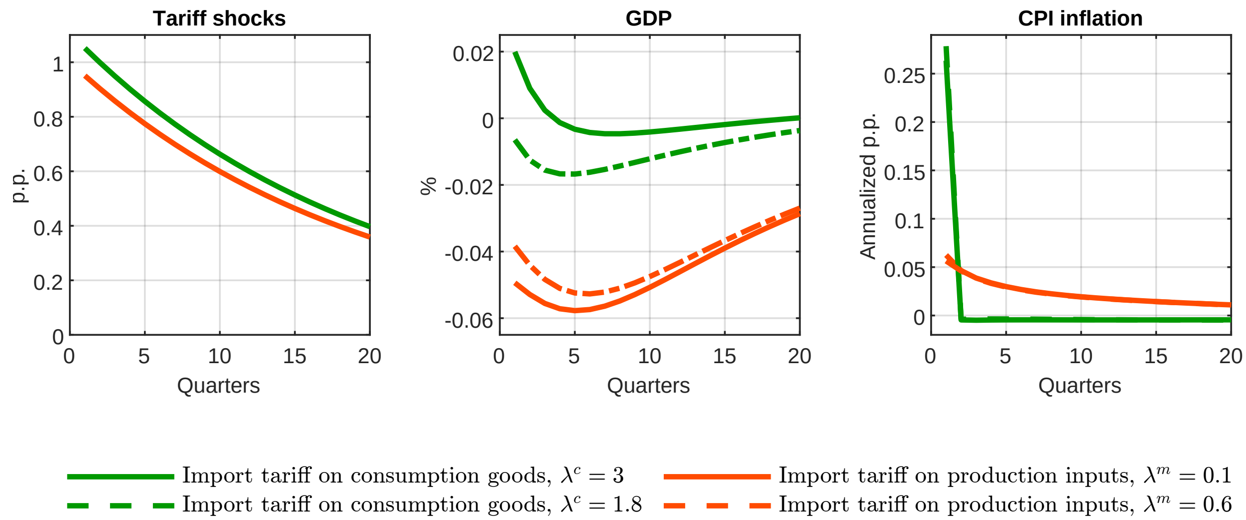

Figure 5: Impact of import tariffs in the full model. *Note:* $\lambda^c = 3$ and $\lambda^m = 0.1$, unless otherwise noted.

final goods are less substitutable, the effect on economic activity of import tariffs on final goods is reversed: as can be seen in Figure 5, the impact on GDP is positive for $\lambda^c = 3$ but becomes negative for $\lambda^c = 1.8$. Conversely, higher substitutability of intermediate goods can mitigate the GDP decline when import tariffs affect these inputs. In both cases, habit in consumption gives rise to a hump-shaped behavior in the full model.

Figure 6 decomposes the impact of import tariffs on CPI inflation. Given (23) and (32), to a first order

$$\begin{aligned}\pi^{CPI}_{h,t} \approx\ & \underbrace{\sum_s \omega^c_{h,s}\, \eta^c_{h,s}\, \pi^{PPI}_{h,s,t}}_{\text{Domestic PPI}} + \underbrace{\sum_s \omega^c_{h,s}\, (1-\eta^c_{h,s})\, \pi^{PPI}_{f,s,t}}_{\text{Foreign PPI}} \\ & + \underbrace{\sum_s \omega^c_{h,s}\, (1-\eta^c_{h,s})\, \Delta\tau^c_{h,s,t}}_{\text{Tariff change (direct)}} + \underbrace{\sum_s \omega^c_{h,s}\, (1-\eta^c_{h,s})\, \Delta\mathcal{E}_{hf,t}}_{\text{Exchange rate adjustment}} .\end{aligned} \tag{106}$$

The basic insights from the simplified setting are again confirmed: while tariffs levied at the final stage of the supply chain have only a temporary effect on inflation, tariffs levied more upstream, at the intermediate-input stage, have persistent effects on production costs and inflation. Moreover, these effects are now further compounded by the presence of a rich input-output structure, as tariff shocks to inputs are propagated through the production network.

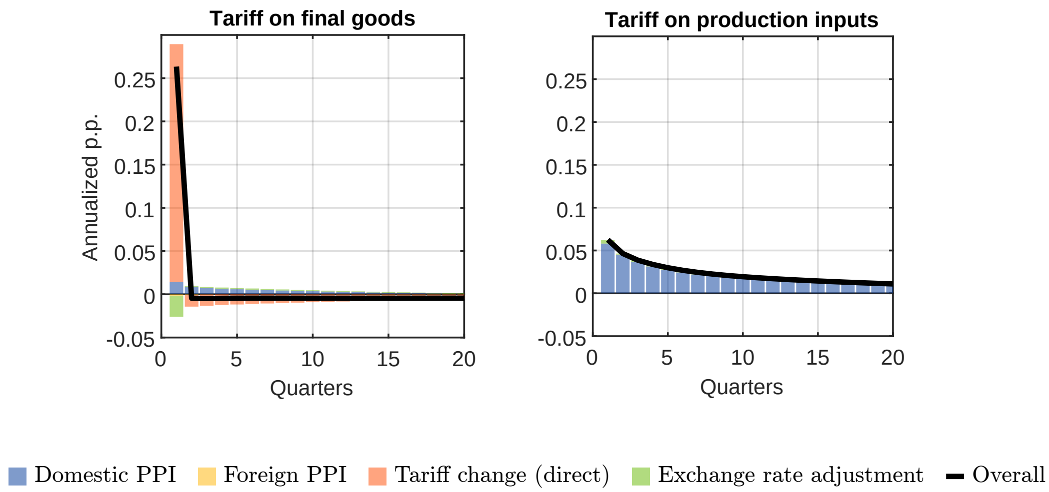

Figure 6: Decomposition of the effect of import tariffs on domestic CPI inflation. *Note*: See Equation (106) for details.

4.2.2. Foreign Tariffs and Retaliation

We now perform a quantitative assessment of the impact of potential retaliatory measures by the EU against rising foreign tariffs affecting its exports. We consider four scenarios: (i) tariffs levied by the rest of the world (RoW) on both final and intermediate goods imports from the EU, with no retaliation from the EU; (ii) uniform retaliation by the EU, taxing both final and intermediate goods imports; (iii) EU retaliation only on imports of final goods; and (iv) EU retaliation only on imports of intermediate goods. The baseline scenario in (i) considers a 1 percentage-point increase in tariffs on RoW imports from the EU, affecting agriculture and manufacturing. Since the third and fourth scenarios would involve retaliation on a smaller subset of imports compared to (ii), they are calibrated in such a way that the ex-ante (steady-state) revenue from the tariff is equivalent to that under the second scenario. These revenue-equivalent tariffs on final or intermediate goods are around twice as large as the across-the-board tariff on both final and intermediate goods considered in the second scenario.

As shown in Figure 7, a persistent increase in tariffs faced by EU exporters in the baseline scenario cools down overall economic activity while nudging up consumer prices right away. GDP dips modestly and inflation jumps a little on impact before returning to target. The temporary increase in consumer prices comes mainly from the fact that the real exchange rate depreciates to offset the loss in export competitiveness, while making imports (including

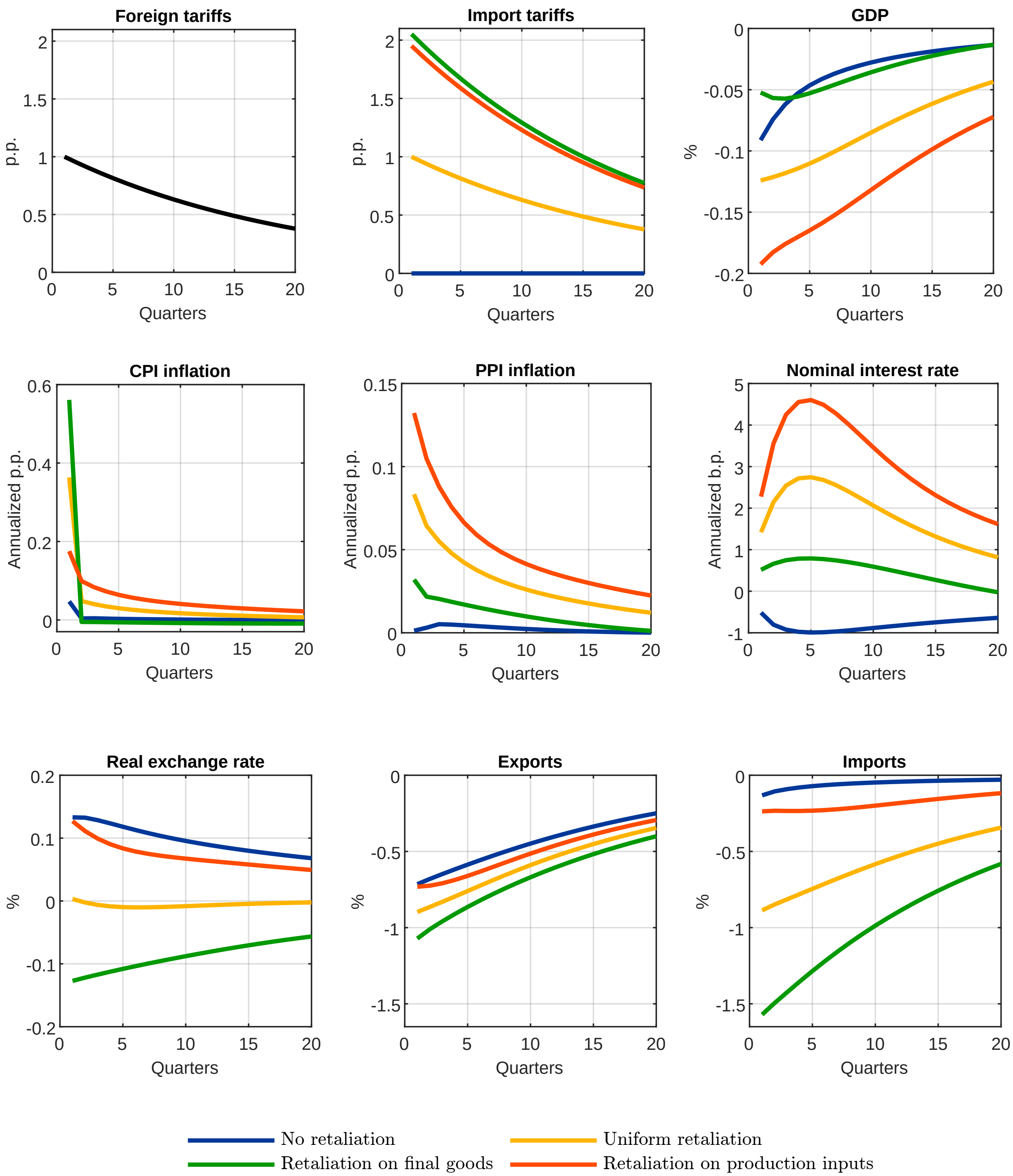

Figure 7: Impact of foreign tariffs and alternative retaliatory measures. *Note*: An increase in the real exchange rate corresponds to a real depreciation of the domestic currency.

those of intermediate inputs) more expensive.

If the EU strikes back by uniformly matching tariffs on both final and intermediate imports, the hit is larger: GDP falls by around twice as much than under no retaliation. Inflation climbs on impact due to the direct impact of the change in tariffs, but also stays persistently positive thereafter, due to the way higher input costs ripple through production linkages.

In the third scenario, where the EU instead targets only final goods with its counter-tariffs, the fallout is milder. Consumers can more easily swap foreign finished products for domestic alternatives (which is, instead, more challenging for intermediate inputs used in production), and the network effects are milder, so GDP shrinks less than under uniform retaliation. Although inflation initially ticks up, it soon falls back to target. Imports of final goods plunge more than in the full-retaliation case, pushing the real exchange rate up further. Producers dodge the worst of input-cost shocks, and the stronger currency helps offset the price of imported materials.

Clearly, the most adverse outcome arises if retaliatory measures focus solely on intermediate inputs, leading to the largest increase in PPI inflation and the most pronounced contraction in GDP.

5. Conclusions

This paper investigates how the macroeconomic impact of tariffs depends on where along the supply chain they are levied. Using both analytical and quantitative results from a multi-sector model featuring international production linkages, we show that tariffs on final goods and tariffs on intermediate inputs have markedly different consequences for GDP and inflation.

The key asymmetry stems from differences in substitutability. Households can more readily reallocate expenditure toward domestic alternatives when tariffs target final goods, limiting GDP losses and generating only transitory inflation with little impact on domestic producers' costs. Tariffs on intermediate inputs, by contrast, directly raise marginal costs, generating persistent inflationary pressures that are further amplified through input-output linkages and — given the limited scope for substituting foreign inputs domestically — entail larger output losses.

These mechanisms translate into a clear policy implication for the design of trade restrictions. Revenue-equivalent tariffs concentrated on final goods substantially mitigate the costs of trade fragmentation relative to a uniform approach, while targeting intermediate inputs produces the worst outcome across all dimensions. For economies deeply integrated in global value chains, the composition of tariffs matters no less than their level.

Appendix A. Extra-EU trade decomposition by end use

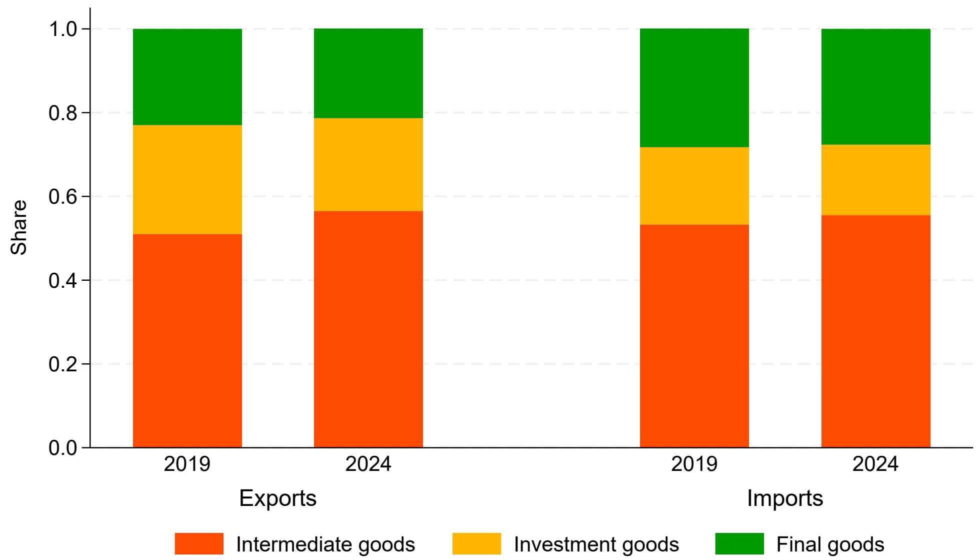

Figure A.1: Extra-EU trade in goods by end use. *Note*: The shares are calculated using Eurostat data for 2019 and 2024 and pertain to goods produced in sectors A (agriculture) and C (manufacturing) according to the NACE Rev. 2 classification.

Appendix B. Additional Details on the Calibration

Table B.1: Sector-specific parameters — markups and price adjusmtent costs.

NACE Rev.2 Sector		Markup $\mathcal{M}^P_s$	Fraction of unadjusted prices $\theta^P_{EU,s}$	$\theta^P_{RoW,s}$	Price adjustment cost $\psi^P_{EU,s}$	$\psi^P_{RoW,s}$
(A)	Agriculture	1.20	0.42	0.13	6.30	0.82
(B)	Mining	1.20	0.02	0.02	0.08	0.08
(C)	Manufacturing	1.18	0.73	0.51	54.85	11.92
(D)	Electricity & Gas	1.31	0.02	0.02	0.05	0.05
(E)	Water Supply	1.21	0.83	0.61	136.46	19.58
(F)	Construction	1.21	0.73	0.51	47.02	10.22
(G-I)	Wholesale & Transport	1.46	0.83	0.61	62.30	8.94
(J)	Information & Comm.	1.86	0.83	0.61	33.32	4.78
(M-N)	Professional Services	1.64	0.83	0.61	44.78	6.42
(R-S)	Other Services	1.58	0.83	0.61	49.41	7.09

Note: $\psi^P_{i,s} = \theta^P_{i,s}/[(\mathcal{M}^P_{i,s} - 1)\,(1 - \theta^P_{i,s})\,(1 - \beta\,\theta^P_{i,s})]$, to reflect the frequency of price adjustment that would be implied in a Calvo model, matching the evidence reported in Dhyne et al. (2006) and Gautier et al. (2024).

Table B.2: Sector-specific parameters — factor intensities and weights.

NACE Rev.2 Sector		$\alpha^m_{EU,s}$	$\alpha^k_{EU,s}$	$\omega^n_{EU,s}$	$\omega^k_{EU,s}$	$\omega^c_{EU,s}$	$\omega^I_{EU,s}$	$\eta^c_{EU,s}$	$\eta^I_{EU,s}$
(A)	Agriculture	0.577	0.344	0.153	0.142	0.029	0.004	0.875	0.957
(B)	Mining	0.425	0.676	0.001	0.004	0.003	0.001	0.775	0.823
(C)	Manufacturing	0.712	0.391	0.156	0.177	0.331	0.309	0.813	0.794
(D)	Electricity & Gas	0.662	0.713	0.004	0.114	0.042	0.006	0.986	0.993
(E)	Water Supply	0.601	0.520	0.008	0.124	0.016	0.001	0.998	0.980
(F)	Construction	0.616	0.290	0.096	0.067	0.015	0.418	0.992	1.000
(G-I)	Wholesale & Transport	0.500	0.342	0.337	0.244	0.409	0.073	0.967	0.963
(J)	Information & Comm.	0.509	0.436	0.034	0.057	0.056	0.081	0.918	0.925
(M-N)	Professional Services	0.454	0.274	0.223	0.131	0.036	0.103	0.884	0.949
(R-S)	Other Services	0.418	0.269	0.075	0.092	0.062	0.005	0.980	0.984

NACE Rev.2 Sector		$\alpha^m_{RoW,s}$	$\alpha^k_{RoW,s}$	$\omega^n_{RoW,s}$	$\omega^k_{RoW,s}$	ω^c_{RoW}	$\omega^I_{RoW,s}$	$\eta^c_{RoW,s}$	$\eta^I_{RoW,s}$
(A)	Agriculture	0.420	0.228	0.844	0.069	0.068	0.006	0.979	0.995
(B)	Mining	0.410	0.725	0.006	0.069	0.002	0.016	0.917	0.988
(C)	Manufacturing	0.752	0.512	0.141	0.259	0.344	0.266	0.935	0.909
(D)	Electricity & Gas	0.676	0.692	0.001	0.161	0.035	0.001	0.992	0.927
(E)	Water Supply	0.508	0.399	0.000	0.048	0.009	0.000	0.998	0.914
(F)	Construction	0.642	0.273	0.100	0.024	0.001	0.552	0.988	1.000
(G-I)	Wholesale & Transport	0.437	0.425	0.199	0.138	0.387	0.057	0.985	0.974
(J)	Information & Comm.	0.435	0.509	0.011	0.163	0.057	0.056	0.975	0.966
(M-N)	Professional Services	0.430	0.306	0.021	0.086	0.029	0.046	0.920	0.978
(R-S)	Other Services	0.437	0.241	0.074	0.220	0.069	0.001	0.992	0.979

Note: The table shows the calibrated values for the sector-specific factor intensities and weights, computed using 2014 data from the latest vintage of WIOD.

Table B.3: Input-output weights.

NACE Rev.2	Sector	$\omega^m_{EU,s(A)}$	$\omega^m_{EU,s(B)}$	$\omega^m_{EU,s(C)}$	$\omega^m_{EU,s(D)}$	$\omega^m_{EU,s(E)}$	$\omega^m_{EU,s(F)}$	$\omega^m_{EU,s(G-I)}$	$\omega^m_{EU,s(J)}$	$\omega^m_{EU,s(M-N)}$	$\omega^m_{EU,s(R-S)}$
(A)	Agriculture	0.266	0.004	0.422	0.029	0.014	0.017	0.160	0.011	0.072	0.004
(B)	Mining	0.004	0.111	0.299	0.112	0.025	0.033	0.227	0.023	0.157	0.008
(C)	Manufacturing	0.058	0.049	0.558	0.030	0.017	0.012	0.164	0.016	0.090	0.005
(D)	Electricity & Gas	0.004	0.140	0.143	0.436	0.016	0.038	0.115	0.022	0.079	0.006
(E)	Water Supply	0.002	0.005	0.199	0.042	0.321	0.042	0.134	0.044	0.200	0.011
(F)	Construction	0.002	0.009	0.398	0.012	0.008	0.279	0.140	0.015	0.131	0.007
(G-I)	Wholesale & Transport	0.012	0.003	0.244	0.032	0.009	0.023	0.430	0.047	0.186	0.014
(J)	Information & Comm.	0.002	0.001	0.163	0.020	0.006	0.017	0.126	0.390	0.246	0.027
(M-N)	Professional Services	0.003	0.001	0.130	0.017	0.009	0.027	0.155	0.108	0.526	0.023
(R-S)	Other Services	0.006	0.002	0.182	0.048	0.023	0.032	0.173	0.088	0.220	0.227

NACE Rev.2	Sector	$\omega^m_{RoW,s(A)}$	$\omega^m_{RoW,s(B)}$	$\omega^m_{RoW,s(C)}$	$\omega^m_{RoW,s(D)}$	$\omega^m_{RoW,s(E)}$	$\omega^m_{RoW,s(F)}$	$\omega^m_{RoW,s(G-I)}$	$\omega^m_{RoW,s(J)}$	$\omega^m_{RoW,s(M-N)}$	$\omega^m_{RoW,s(R-S)}$
(A)	Agriculture	0.348	0.005	0.414	0.035	0.006	0.012	0.153	0.004	0.019	0.003
(B)	Mining	0.001	0.306	0.300	0.132	0.006	0.023	0.130	0.010	0.082	0.011
(C)	Manufacturing	0.074	0.109	0.593	0.035	0.004	0.004	0.129	0.008	0.039	0.005
(D)	Electricity & Gas	0.000	0.286	0.139	0.448	0.008	0.015	0.071	0.008	0.022	0.004
(E)	Water Supply	0.002	0.015	0.275	0.132	0.205	0.068	0.147	0.027	0.096	0.032
(F)	Construction	0.010	0.030	0.582	0.020	0.003	0.114	0.145	0.018	0.071	0.007
(G-I)	Wholesale & Transport	0.030	0.004	0.328	0.039	0.007	0.024	0.316	0.043	0.188	0.020
(J)	Information & Comm.	0.001	0.001	0.210	0.020	0.003	0.019	0.127	0.357	0.227	0.035
(M-N)	Professional Services	0.008	0.003	0.281	0.017	0.007	0.013	0.190	0.110	0.342	0.028
(R-S)	Other Services	0.006	0.006	0.372	0.049	0.020	0.027	0.218	0.055	0.144	0.104

Note: The table reports the calibrated input-output weights. $\omega^m_{i,sx}$ denotes the weight of intermediate goods sourced from sector x by sector s in region i. Rows correspond to using sectors, while columns correspond to supplying sectors. The weights are computed as the share of total material input expenditure in sector s allocated to inputs from supplying sector x, based on 2014 data from the latest vintage of WIOD.

Table B.4: Home biases in intermediate-input use.

NACE Rev.2 Sector		$\eta^m_{EU,s(A)}$	$\eta^m_{EU,s(B)}$	$\eta^m_{EU,s(C)}$	$\eta^m_{EU,s(D)}$	$\eta^m_{EU,s(E)}$	$\eta^m_{EU,s(F)}$	$\eta^m_{EU,s(G-I)}$	$\eta^m_{EU,s(J)}$	$\eta^m_{EU,s(M-N)}$	$\eta^m_{EU,s(R-S)}$
(A)	Agriculture	0.912	0.313	0.876	0.957	0.928	0.993	0.947	0.882	0.885	0.978
(B)	Mining	0.935	0.366	0.874	0.960	0.926	0.987	0.884	0.895	0.859	0.973
(C)	Manufacturing	0.892	0.235	0.828	0.952	0.915	0.981	0.908	0.896	0.884	0.961
(D)	Electricity & Gas	0.963	0.254	0.836	0.977	0.943	0.981	0.831	0.925	0.920	0.936
(E)	Water Supply	0.934	0.389	0.872	0.954	0.909	0.994	0.942	0.908	0.928	0.967
(F)	Construction	0.898	0.375	0.874	0.962	0.935	0.989	0.939	0.903	0.927	0.914
(G-I)	Wholesale & Transport	0.890	0.389	0.861	0.963	0.938	0.990	0.923	0.910	0.892	0.934
(J)	Information & Comm.	0.697	0.343	0.789	0.967	0.941	0.988	0.871	0.918	0.751	0.929
(M-N)	Professional Services	0.898	0.602	0.845	0.960	0.942	0.988	0.911	0.910	0.912	0.920
(R-S)	Other Services	0.891	0.456	0.826	0.964	0.948	0.993	0.927	0.914	0.917	0.970

NACE Rev.2 Sector		$\eta^m_{RoW,s(A)}$	$\eta^m_{RoW,s(B)}$	$\eta^m_{RoW,s(C)}$	$\eta^m_{RoW,s(D)}$	$\eta^m_{RoW,s(E)}$	$\eta^m_{RoW,s(F)}$	$\eta^m_{RoW,s(G-I)}$	$\eta^m_{RoW,s(J)}$	$\eta^m_{RoW,s(M-N)}$	$\eta^m_{RoW,s(R-S)}$
(A)	Agriculture	0.982	0.920	0.972	0.993	0.902	0.995	0.975	0.973	0.961	0.995
(B)	Mining	0.977	0.886	0.956	0.993	0.902	0.992	0.956	0.935	0.944	0.993
(C)	Manufacturing	0.985	0.929	0.972	0.995	0.937	0.990	0.978	0.931	0.959	0.995
(D)	Electricity & Gas	0.886	0.874	0.960	0.991	0.879	0.988	0.972	0.892	0.904	0.996
(E)	Water Supply	0.968	0.903	0.953	0.992	0.895	0.994	0.969	0.920	0.928	0.991
(F)	Construction	0.985	0.894	0.973	0.993	0.962	0.995	0.979	0.980	0.960	0.994
(G-I)	Wholesale & Transport	0.983	0.890	0.962	0.992	0.946	0.995	0.974	0.962	0.949	0.995
(J)	Information & Comm.	0.949	0.871	0.964	0.990	0.947	0.994	0.982	0.966	0.946	0.995
(M-N)	Professional Services	0.982	0.895	0.964	0.987	0.944	0.992	0.976	0.971	0.944	0.993
(R-S)	Other Services	0.982	0.924	0.969	0.993	0.944	0.994	0.976	0.961	0.940	0.995

Note: The table reports the calibrated home-bias parameters in intermediate input sourcing. $\eta^m_{i,sx}$ denotes the degree of home bias in the use of inputs from sector x by sector s in region i. Rows correspond to using sectors, while columns correspond to supplying sectors. The parameters are calibrated to match the observed domestic expenditure share in intermediate inputs from sector x used by sector s, based on 2014 data from the latest vintage of WIOD.

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