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Optimal Monetary Policy, Tariff Shocks and Exporter Dynamics

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Abstract

In this paper, we explore the response of optimal monetary policy to uncoordinated trade policies (foreign tariff shocks). We first provide a simple model of open economy with heterogeneous firms and derive a closed-form solution for the optimal monetary policy response to tariff shocks in presence of nominal rigidities. We show that optimal monetary policy is expansionary following foreign tariff hikes. Under nominal rigidities, uncertainty about foreign tariff hikes induces sluggish adjustments in the labor market reallocation between exporters and domestic firms, leading to an incentive for monetary authority to intervene and mitigate the impact of tariff shocks. In an extended model, we then show the response of our economy to a tariff shock under the Ramsey monetary policy, a Taylor Rule and a fixed exchange rate regime. Finally, we provide empirical evidence for the response of domestic monetary policy to foreign tariff shocks using data on Global Antidumping from the US.

Keywords: Optimal Monetary Policy; Tariff Shocks; Exporter Dynamics
JEL codes: E3, E6, Q54, R1

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1 Introduction

Over the past decade, the escalation of trade conflicts has increased worldwide trade uncertainty. Episodes of tariff wars did not only concern major countries like US and China, but also smaller open economies. For instance, the trade disputes between China and Austria over primary products, or between Japan and South Korea concerning high-tech products underscore the global nature of recent trade conflicts.[1] The use of abrupt measures requires additional analysis of the consequences of sudden shifts in trade policy and the strategies available to mitigate their effects. In fact, even though tariff shocks predominantly affect domestic exporters, they induce adjustments among heterogeneous producers in the domestic economy as well.[2] The uncertainty faced by exporter firms in Foreign markets leads to changes in trade at both intensive and extensive margins, prompting a reallocation of resources towards domestically-oriented firms. In turn, this requires an adjustment in domestic inflation and the output gap. Such dynamics highlight the need for stabilization through monetary policy.

The main objectives of this paper are two-fold: i) study the effects of Foreign tariff shocks on the domestic economy through the resource reallocation between exporter and domestic firms; and ii) explore how monetary policy, including specific exchange rate arrangements, can potentially mitigate the impact of these shocks. We first provide a simple model of open economy with heterogeneous firms and nominal rigidities and derive a closed-form solution for the optimal monetary policy response to tariff shocks in presence of wage rigidity. We then explore the role of the fundamentals of the economy - market size, openness, firm heterogeneity - on the optimal monetary policy in a richer framework.

In our economy, Foreign tariff hikes induce the reallocation of Home workers from exporter firms towards firms operating in the domestic market. This labor reallocation is associated with a reduction in the number of exporter firms and an increase in their average efficiency. Following the reduced labor demand in the trade sector, wages fall under flexible prices and the reduction in production costs mitigates the adjustment of exporter firms. The production in the domestic economy expands thanks to cost reduction, and welfare improves. Instead, in the presence of nominal rigidities, unemployment arising from exporter firms is larger because wages are sticky. The number of Home exporters falls and the selection of exporter firms is amplified. Moreover, the presence of sticky wages prevents the reallocation of Labor towards domestic firms, and the allocation is thus sub-optimal.

In the presence of dampened reallocation of resources between exporter and domestic firms, the monetary policy plays a role in stabilizing the economy facing a Foreign tariff shock. In particular, the closed form-solution of the model shows that monetary policy is expansionary in response to an increase in Foreign import tariffs. The home monetary authority has an incentive to expand its monetary stance as it mitigates the negative external demand shock among domestic

[1]See Makioka and Zhang (2023) on the introduction of Japanese quotas on imports from South Korea of three chemical inputs essential in semiconductor production.

[2]Costinot et al. (2020) and Caliendo et al. (2023) emphasize the role of firm heterogeneity and the selection of exporter firms into Foreign markets for the assessment of the welfare implications of trade shocks.

exporters and enhances the reallocation of workers towards domestic producers. Furthermore, we analytically show that these incentives are stronger when firms are small and homogeneous, when the size of the country is small, and when the openness is high. In short, when a country is more exposed to tariff shocks. Monetary policy therefore counteracts the uncertainty stemming from tariff shocks in the export market and is optimal since it reduces the wage markup.

We then extend the simple model to a more general set up. The purpose of the extended model is to illustrate in a broader framework the main mechanism studied in the analytical solution of the simple model. We use impulse response functions to explore the behavior of our economy following a tariff shock under different monetary policies: the Ramsey optimal monetary policy, a Taylor Rule, and a fixed exchange rate regime. Our results show that the Ramsey optimal policy is expansionary in response to a Foreign tariff hike, leading to a nominal depreciation which compensates the dampened reallocation of resources from exporter to domestic firms due to sticky wages. In the case of a fixed exchange rate arrangement, the monetary policy is contractionary. The increase in Foreign tariffs increases inflation in the Foreign country, leading to an increase in the nominal interest rate following the Taylor rule. As a result, the Home monetary policy also increases the interest rate in order to keep the exchange rate fixed. Moreover, we show that the Ramsey optimal policy limits the welfare losses associated with a rise in Foreign tariffs with respect to the case where both countries adopt a Taylor rule under flexible or fixed exchange rate regime.

Furthermore, we provide empirical evidence for the response of US trade partners to restrictive trade measures originated in the US. We use a large dataset that spans 36 advanced and emerging economies for a period going from the first quarter of 1985 until the last quarter of 2011, and measure trade protectionism by the number of importing products under investigation for which an investigation was initiated in a given period according to the Global Anti-dumping Database (GAD, 2016). We then use local projection methods to study the response of monetary policy to a foreign tariff shock. In line with the findings of our model, we show that monetary policy is expansionary except for the economies under a fixed exchange rate regime.

The paper is related to the literature that analyzes an open economy real business cycle model with heterogeneous firms such as Ghironi and Melitz (2005), Cacciatore and Fiori (2016), and Hamano (2022). Barattieri et al. (2021), and Auray et al. (2022) analyze the impact of tariffs in an open economy. Unlike their research, the focus of our paper is on the impact of tariff hikes by larger open economies on small open economies and the subsequent effects on their domestic economy. Taking a normative standpoint, Jeanne (2021) provides an analysis of the optimal monetary and trade policy in a context of trade wars. In our paper, we do not consider trade wars as we only focus on changes in tariffs, that we consider as exogenous shocks. A number of papers have studied the response of monetary policy with respect to various types of shocks in an open economy – see Corsetti and Pesenti (2005), Devereux and Engel (2003), Devereux (2004), De Paoli (2009), Ottonello (2021) and Hamano and Pappadà (2023) – but they do not explore the response to tariff shocks. Our paper highlights instead the response of monetary policy to tariff shocks and the induced reallocation of resources between domestic and exporter firms. In this respect, this paper is related to Guerrieri et al. (2021), which focus on monetary policy and the sectoral reallocation following the pandemic shock. The main result of our model advocates for an expansionary policy as the optimal response to foreign tariff hikes, mirroring the findings in Bergin and Corsetti (2023). In their paper, Bergin and Corsetti (2023) highlight the unique effects of symmetric tariff shocks, causing both producer price index (PPI) disinflation and consumer price index (CPI) inflation. In our framework with heterogeneous firms, we emphasize instead the impact of asymmetric shocks on small open economies, leading to pronounced PPI disinflation generated by the reallocation between domestic and exporter firms.

The paper is organized as follows. Section 2 introduces a tractable two-country DSGE model with wage rigidities and firm heterogeneity to analyze the impact of foreign import tariff shocks on the domestic economy. In Section 3, we derive the optimal monetary policy and show its response to tariff shocks in our economy under nominal rigidities. In Section 4, we calibrate a more general version of our dynamic two-country New-Keynesian model, and analyze the response to tariff shocks under the Ramsey monetary policy, a Taylor Rule, and a fixed exchange rate regime. Section 5 provides an empirical counterpart of our theoretical results, as we use local projection methods to examine the dynamic responses to exogenous changes in the impositions of international tariffs by the U.S. against its major trading partners. Section 6 concludes.

2 The model

In this section, we introduce a simple two-country DSGE model with heterogeneous firms in order to analyze the impact of foreign import tariff shocks on the domestic economy, and the reaction of monetary policy to these shocks. Our economy consists of two countries, Home and Foreign. Foreign variables are denoted with an asterisk. We normalize the total population in the world economy to one and denote the population share in Home country by n. Firms operate under monopolistic competition and are heterogeneous in their productivity. Fixed costs of operating in export markets determine the selection of exporter firms. Furthermore, we assume that labor services are differentiated and nominal wages adjust only in a sluggish manner. Each country has its own currency. However, money exist as a unit of account only.

We make a number of simplifying assumptions to derive a closed form solution of the model: i) Cobb-Douglas preferences over domestic and imported goods, ii) no differences in product quality, iii) no investment in the form of firm creation, iv) wage setting one period in advance, v) balanced trade and vi) monetary policy controlling directly nominal spending. These assumptions allow us to provide the intuition behind the optimal monetary policy following foreign tariff hikes. In the following section, we relax these assumptions in order to conduct a quantitative analysis.

2.1 Household Preferences and Intra-temporal Choices

The utility of the household j at time t in the Home country depends on her consumption $C_t(j)$ and labor supply $L_t(j)$ as follows

$$U_t(j) = \ln C_t(i) - \eta \frac{L_t(j)^{1+\varphi}}{1+\varphi}, \tag{1}$$

where $\gamma\,(\geq 1)$ denotes risk aversion, $\eta\,(> 0)$ represents the disutility from supplying labor and $\varphi \geq 0$ denotes the inverse of the Frisch elasticity of labor supply.

The consumption $C_t(j)$ is composed of domestic-produced goods $C_{H,t}(j)$ and imported goods produced in the Foreign country $C_{F,t}(j)$:

$$C_t(j) = \left(\frac{C_{H,t}(j)}{\nu}\right)^{\nu} \left(\frac{C_{F,t}(j)}{1-\nu}\right)^{1-\nu},$$

where ν denotes the spending weight on the domestically produced goods. Following De Paoli (2009), we assume that $1-\nu = (1-n)\,\alpha$ where $1-n$ is the relative size of the foreign economy and α is the openness. There exists home bias in consumption when $1/2 < \alpha < 1$.[3]

Furthermore, these baskets are defined over a continuum of goods as follows

$$C_{H,t}(j) = V_{H,t}\left(\left(\frac{1}{n}\right)^{\frac{1}{\sigma}} \int_{\zeta\in\Omega} \left(c_{D,t}(\zeta, j)\right)^{1-\frac{1}{\sigma}} d\zeta\right)^{\frac{1}{1-\frac{1}{\sigma}}}, \; C_{F,t}(j) = V^*_{F,t}\left(\left(\frac{1}{1-n}\right)^{\frac{1}{\sigma}} \int_{\vartheta\in\Omega} \left(c_{X,t}(\vartheta, j)\right)^{1-\frac{1}{\sigma}} d\vartheta\right)^{\frac{1}{1-\frac{1}{\sigma}}},$$

In the above expressions, $c_{D,t}(\zeta, j)$ and $c_{X,t}(\vartheta, j)$ represent the demand addressed for individual product variety ζ produced domestically and that for imported product variety ϑ, respectively. At any given time t, only a subset of goods Ω is available: we define that subset $V_{H,t} \equiv N_{D,t}^{\psi-\frac{1}{\sigma-1}}$, $V^*_{F,t} \equiv N_{X,t}^{*\psi-\frac{1}{\sigma-1}}$, where $N_{D,t}$ and $N^*_{X,t}$ stand for the number of domestic and imported product varieties, respectively. $\sigma$is the elasticity of substitution across these differentiated product varieties and $\psi \geq 0$ determines the marginal utility that stems from one additional increase in the number of varieties in each basket (Benassy, 1996). Note that the preference becomes the one discussed in Dixit and Stiglitz (1977) when $\psi = 1/(\sigma-1)$.

The optimal demand for domestic and imported consumption baskets, and individual product varieties are found as

$$C_{H,t}(j) = \left(\frac{P_{H,t}}{P_t}\right)^{-1} \nu C_t(j), \quad C_{F,t}(j) = \left(\frac{P_{F,t}}{P_t}\right)^{-1} (1-\nu)\, C_t(j),$$

[3] A similar consumption basket is defined for the household j in the foreign country: $C^*_t(j) = \left(\frac{C^*_{F,t}(j)}{1-\nu^*}\right)^{1-\nu^*} \left(\frac{C^*_{H,t}(j)}{\nu^*}\right)^{\nu^*}$, where $\nu^* = n\alpha$.

$$c_{D,t}(\zeta, j) = V_{H,t}^{\sigma-1}\left(\frac{p_{D,t}(\zeta)}{P_{H,t}}\right)^{-\sigma}\frac{1}{n}C_{H,t}(j), \quad c_{X,t}(\vartheta, j) = V_{F,t}^{*\;\sigma-1}\left(\frac{\tau_{M,t}p_{X,t}^{*}(\vartheta)}{P_{F,t}}\right)^{-\sigma}\frac{1}{1-n}C_{F,t}(j),$$

where $p_{D,t}(\zeta)$ and $p_{X,t}^{*}(\vartheta)$ stand for the price of domestic product variety ζ and imported product variety ϑ, respectively. Both prices are denominated in the home currency. $\tau_{M,t}\,(\geq 0)$ is an ad-valorem tariff charged on the dock price $p_{X,t}^{*}(\vartheta)$. Specifically, when $\tau_{M,t} > 1$ import tariffs are positive while when $0 \leq \tau_{M,t} < 1$, they are negative and imported goods are subsidized. P_t, $P_{H,t}$ and $P_{F,t}$ stand for the price indexes that minimize expenditures of respective consumption baskets. These are defined as

$$P_t = P_{H,t}^{\nu}P_{F,t}^{1-\nu},$$

$$P_{H,t} = \frac{1}{V_{H,t}}\left(\frac{1}{n}\int_{\zeta\in\Omega_t} p_{D,t}(\zeta)^{1-\sigma}\,d\zeta\right)^{\frac{1}{1-\sigma}}, \quad P_{F.t} = \frac{1}{V_{F.t}^{*}}\left(\frac{1}{1-n}\int_{\vartheta\in\Omega_t}\tau_{M,t}p_{X,t}^{*}(\vartheta)^{1-\sigma}\,d\vartheta\right)^{\frac{1}{1-\sigma}}.$$

Similar expressions hold for the foreign economy. Crucially, the subset of product varieties which is available to the households in the foreign country during period t, $\Omega_t^{*} \in \Omega$, can be different from those available to the households in the home country.

2.2 Production, Pricing and the Export Decision

Firms produce differentiated product varieties under monopolistic competition. Upon entry, each firm draws its productivity level z from a distribution $G(z)$ over $[z_{\min}, \infty)$, where $z_{\min}$ denotes the minimum productivity level.

A firm with productivity z faces a residual demand schedule with constant elasticity σ. The profit maximization yields the following pricing:

$$p_{D,t}(z) = \frac{\sigma}{\sigma-1}\frac{W_t}{z},$$

where $p_{D,t}(z)$ stands for the nominal price of the product variety produced by the firm. It is assumed that exporting requires fixed costs f_X paid in terms of composite labor units. Consequently, only a subset of firms whose productivity level z is above the cutoff level $z_{X,t}$ exports by charging sufficiently lower prices. If the firm exports, its export price (denominated in the foreign currency) is $p_{X,t}(z) = \tau p_{D,t}(z)\,\varepsilon_t^{-1}$ where τ is iceberg trade costs and ε_t is the nominal exchange rate defined as the price of foreign currency in terms of home currency units.

Using the optimal demand functions found previously, we can express profits from domestic sales $D_{D,t}(z)$ and those from exporting sales $D_{X,t}(z)$ as

$$D_{D,t}(z) = \frac{1}{\sigma} N_D^{\psi(\sigma-1)-1} \left(\frac{p_{D,t}(z)}{P_{H,t}} \right)^{1-\sigma} \nu P_t C_t,$$

and

$$D_{X,t}(z) = \frac{\varepsilon_t}{\sigma} N_{X,t}^{\psi(\sigma-1)-1} \tau_{M,t}^{*-\sigma} \left(\frac{p_{X,t}(z)}{P_{H,t}^*} \right)^{1-\sigma} \frac{\nu^*(1-n)}{n} P_t^* C_t^* - W_t f_{X,t}, \text{ if firm } z \text{ exports, otherwise } D_{X,t}(z) = 0.$$

Similar expressions hold for the Foreign country.[4] Finally, note that in the setup of a small open economy, i.e., $n \to 0$, we have[5]

$$D_{D,t}(z) = \frac{1}{\sigma} N_D^{\psi(\sigma-1)-1} \left(\frac{p_{D,t}(z)}{P_{H,t}} \right)^{1-\sigma} (1-\alpha) P_t C_t,$$

$$D_{X,t}(z) = \frac{\varepsilon_t}{\sigma} N_{X,t}^{\psi(\sigma-1)-1} \tau_{M,t}^{*-\sigma} \left(\frac{p_{X,t}(z)}{P_{H,t}^*} \right)^{1-\sigma} \alpha P_t^* C_t^* - W_t f_{X,t}, \text{ if firm } z \text{ exports, otherwise } D_{X,t}(z) = 0.$$

2.2.1 Firm Averages

The distribution of productivity levels among $N_{D,t}$ domestic firms is defined over $[z_{\min}, \infty)$ for the distribution $G(z)$. Among these firms, there are $N_{X,t} = \left[1 - G\left(z_{X,t}\right)\right] N_{D,t}$ exporters in the Home country. Following Melitz (2003), we define two average productivity levels, $\tilde{z}_D$ for Home firms producing for the domestic market and $\tilde{z}_{X,t}$ for Home exporters as follows

$$\tilde{z}_D \equiv \left[\int_{z_{\min}}^{\infty} z^{\sigma-1} dG(z) \right]^{\frac{1}{\sigma-1}}, \quad \tilde{z}_{X,t} \equiv \left[\frac{1}{1-G(z_{X,t})} \int_{z_{X,t}}^{\infty} z^{\sigma-1} dG(z) \right]^{\frac{1}{\sigma-1}}$$

These average productivity levels summarize all the information about the distribution of productivity. Given these averages, we define the average domestic and exporting price as $\tilde{p}_{D,t} \equiv p_{D,t}(\widetilde{z}_D)$

[4] These are

$$D_{D,t}^*(z) = \frac{1}{\sigma} N_D^{*\psi(\sigma-1)-1} \left(\frac{p_{D,t}^*(z)}{P_{F,t}^*} \right)^{1-\sigma} (1-\nu^*) P_t^* C_t^*,$$

$$D_{X,t}^*(z) = \frac{\varepsilon_t^{-1}}{\sigma} N_{X,t}^{*\psi(\sigma-1)-1} \tau_{M,t}^{-\sigma} \left(\frac{p_{X,t}^*(z)}{P_{F,t}} \right)^{1-\sigma} \frac{(1-\nu)n}{1-n} P_t C_t - W_t^* f_X^*, \text{ if firm } z \text{ exports.}$$

[5] When $n \to 0$, the size of Foreign economy is the largest as possible and these profits become

$$D_{D,t}^*(z) = \frac{1}{\sigma} N_D^{*\psi(\sigma-1)-1} \left(\frac{p_{D,t}^*(z)}{P_{F,t}^*} \right)^{1-\sigma} P_t^* C_t^* \quad \text{and} \quad D_{X,t}^*(z) = 0$$

since all Foreign firms get negative profits by exporting.

and $\tilde{p}_{X,t} \equiv p_{X,t}\left(\tilde{z}_{X,t}\right)$, respectively. Also using these notations and the definitions of price indexes, we have $P_{H,t} = n^{\frac{1}{\sigma-1}} N_{D,t}^{-\psi} \widetilde{p}_{D,t}$, and $P_{F,t} = (1-n)^{\frac{1}{\sigma-1}} N_{X,t}^{*-\psi} \tau_{M,t} \widetilde{p}_{X,t}^{*}$. We also define average profits from domestic and exporting sales as $\tilde{D}_{D,t} \equiv D_{D,t}\left(\tilde{z}_{D}\right)$ and $\tilde{D}_{X,t} \equiv D_{X,t}\left(\tilde{z}_{X,t}\right)$. Finally, average profits of all firms in the home country is given by $\tilde{D}_{t} = \tilde{D}_{D,t} + \left(N_{X,t}/N_{D,t}\right)\tilde{D}_{X,t}$. Similar expressions hold for the foreign economy.

2.2.2 Firm Entry and Exit

In this simple version of the model, we assume that there is no firm entry, and thus no investments that aim to create new firms. As a result, the total number of firms in each country remains constant over time:

$$N_{D,t} = N_{D}, \qquad N_{D,t}^{*} = N_{D}^{*}.$$

As we will see later, by abstracting from investment, uncertainty in labor demand solely arises from the reallocation of workers between exporters and domestic firms. This assumption, however, is relaxed in the full dynamic model in the next section.

2.2.3 Parametrization of Productivity Draws

We assume the following Pareto distribution for $G(z)$

$$G(z) = 1 - \left(\frac{z_{\min}}{z}\right)^{\kappa},$$

where κ $(> \sigma - 1)$ is a shape parameter. Given this productivity distribution, the average productivity of domestic producers and exporters are expressed as

$$\tilde{z}_{D} = z_{\min}\left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{1}{\sigma-1}}, \quad \tilde{z}_{X,t} = z_{X,t}\left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{1}{\sigma-1}}.$$

The share of exporters in the total number of domestic firms is also given by

$$\frac{N_{X,t}}{N_{D,t}} = z_{\min}^{\kappa}\left(\tilde{z}_{X,t}\right)^{-\kappa}\left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{k}{\sigma-1}}.$$

Finally, there exists a firm with a specific productivity cutoff $z_{X,t}$ that earns zero profits from exporting, as $D_{X,t}\left(z_{X,t}\right) = 0$. With the above Pareto distribution, this implies that

$$\tilde{D}_{X,t} = W_{t} f_{X} \frac{\sigma-1}{\kappa-(\sigma-1)}. \tag{2}$$

Similar expressions hold for the foreign economy.

2.3 Household Budget Constraint and Inter-temporal Choices

The household j in the home country faces the following budget constraint at time t:

$$P_tC_t(j) + B_t(j) = (1+\xi) W_t(j) L_t(j) + (1+i_{t-1})B_{t-1}(j) + N_D\tilde{D}_t(j) + T_t^f \tag{3}$$

where $B_t(j)$ denotes her bond holdings. $\xi W_t(j) L_t(j)$ stands for the appropriately designed labor subsidy which aims to eliminate distortions due to monopolistic power in labor markets. i_t represents nominal interest rate between t and $t+1$ and T_t^f represents lump-sum transfers from domestic government, which includes tax revenues.

We assume that wages are sticky for one time period: the household j sets her wages $W_t(j)$ at $t-1$ by maximizing her expected utility considering the following demand schedule for her labor services:

$$L_t(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\theta} L_t.$$

The first order condition with respect to $W_t(j)$ yields

$$W_t(j) = \frac{\eta\theta}{(\theta-1)(1+\xi)} \frac{\mathrm{E}_{t-1}\left[L_t(j)^{1+\varphi}\right]}{\mathrm{E}_{t-1}\left[\frac{L_t(j)}{P_tC_t(j)}\right]}. \tag{4}$$

The household sets the wage rate so that the expected marginal cost of supplying additional labor services equals the expected marginal revenue.[6] Along with this wage setting, the household also chooses her bond holdings and the first order condition related to this problem yields

$$1 = (1+i_t)E_t\left[M_{t,t+1}(j)\right].$$

where $M_{t,t+1}$ is the stochastic discount factor defined as $M_{t,t+1}(j) \equiv E_t\left[\frac{\beta P_tC_t(j)}{P_{t+1}C_{t+1}(j)}\right]$.

2.4 Balanced Trade and Labor Market Clearings

In equilibrium, there is a symmetry across households so that $C_t(j) = C_t$, $L_t(j) = L_t$, $M_t(j) = M_t$ and $W_t(j) = W_t$. We follow Corsetti et al. (2010) and Bergin and Corsetti (2023) and define monetary stance as

$$\mu_t \equiv P_tC_t.$$

[6]The marginal cost is $\eta\theta W_t(j)^{-1}\,\mathrm{E}_{t-1}\left[L_t(j)^{1+\varphi}\right]$ and the marginal revenue is $(\theta-1)(1+\xi)\,\mathrm{E}_{t-1}\left[\frac{L_t(j)}{P_tC_t(j)}\right]$.

Monetary stance is proportional to nominal expenditures.[7] It is assumed that the government has no power to directly control private lending and borrowing. The balanced budget rule is thus assumed as

$$nT_t^f = -n\xi W_t L_t + n\left(\tau_{M,t} - 1\right) N_{X,t}^* \widetilde{p}_{X,t}^* \widetilde{c}_{X,t}.$$

Trade is assumed to be balanced, thus the value of exports is equal to the value of imports once they are converted to the same unit of currency: $\varepsilon_t P_{H,t}^* C_{H,t}^* = P_{F,t} C_{F,t}$. Combined with the demand of goods found previously, this implies that

$$\varepsilon_t = \frac{\mu_t}{\mu_t^*}. \tag{5}$$

The above is a general expression independent of the monetary policy rule.[8]

We focus now on the labor market clearing condition which determines the equilibrium wage of our economy. Under nominal wage rigidity, the aggregate labor supply L_t adjusts to its demand and the labor market clears as

$$nL_t = N_D \frac{\widetilde{y}_{D,t}}{\widetilde{z}_D} + N_{X,t}\left(\frac{\widetilde{y}_{X,t}}{\widetilde{z}_{X,t}} + f_{X,t}\right), \tag{6}$$

where $\widetilde{y}_{D,t}$ and $\widetilde{y}_{X,t}$ stand for the production scale of each average domestic firms and average exporters. Demand for labor services arise from producers selling their goods in the domestic market (the first term on the right hand side of the equation) and those from exporters (including export fixed costs). A similar expression holds for the foreign country.

We can now determine the equilibrium wage combining the wage setting equation (4) and the above labor market clearing condition (6). The equilibrium wage is given by

$$W_t = \Gamma \left\{ \frac{\mathrm{E}_{t-1}\left[(A_t \mu_t)^{1+\varphi}\right]}{\mathrm{E}_{t-1}\left[A_t\right]} \right\}^{\frac{1}{1+\varphi}}, \tag{7}$$

where $\Gamma \equiv \left[\frac{\eta\theta}{(\theta-1)(1+\xi)}\right]^{\frac{1}{1+\varphi}}$ and

[7]When combining the monetary stance with the Euler equation on bond holdings, one gets

$$\frac{1}{\mu_t} = \mathrm{E}_t \lim_{s\to\infty} \beta^s \frac{1}{\mu_{t+s}} \prod_{\tau=0}^{s-1}(1 + i_{t+\tau}).$$

This shows that monetary stance μ_t may be expressed as a function of future expected path of interest rates or as a rule concerning money supply M_t.

[8]This is different from Hamano and Pappadà (2023) where countries are subject to a stochastic demand shift, and financial markets are complete even under the balanced trade. In this environment with Cobb-Douglas preferences and trade openness, the terms of trade insure consumption risk and realize the allocation under complete asset markets. Put differently, the steady state in our benchmark economy with nominal rigidities is efficient.

$$A_t \equiv \frac{\sigma-1}{\sigma}\left[\nu+\left(1+\frac{1}{\sigma-1}-\frac{1}{\kappa}\right)\frac{\nu^*(1-n)}{n}\frac{1}{\tau^*_{M,t}}\right] \tag{8}$$

The expression (7) shows that the equilibrium wage thus depends on the expected interaction between tariffs and the monetary stance, which is captured in $\mathrm{E}_{t-1}\left[(A_t\mu_t)^{1+\varphi}\right]$.

3 The response of the economy to foreign tariff shocks

Having established the theoretical model, we can now study the allocation and transmission of foreign tariff shock. Since our main focus is the country that faces a stochastic tariff process originating abroad, we discuss the implication for the home country. First, we start by exploring the allocation under the flexible price that serves as a useful benchmark. We then study the implication of foreign tariff shock under nominal rigidities.

3.1 Flexible-wage economy

Under flexible prices, households do not set up wages one period in advance. They are free to adjust their wages in response to current economic shocks. Technically, the equilibrium wage level under flexible price is obtained by just removing the expectation operator from the expression of the equilibrium wage (7). Thus, under flexible prices, the equilibrium wage is

$$W_t^{FL} = \Gamma A_t^{\frac{\varphi}{1+\varphi}}\mu_t$$

where the superscript "FL" stands for the allocation under flexible prices. By plugging the above solution in the solutions presented in Table 1, it is straightforward to see that monetary policy is ineffective and has no real impact on the allocation under flexible prices. For instance, note that we have $L_t^{FL} = A_t\frac{\mu_t}{W_t^{FL}} = \Gamma^{-1}A_t^{\frac{1}{1+\varphi}}$ and thus the labor supply is independent of μ_t. Monetary stances in both country, μ_t and μ_t^* only scale the level of nominal prices including the exchange rate without any real impact.

What would happen to the Home country facing a protectionist measure implemented abroad? The protectionist measure is captured by a rise in $\tau^*_{M,t}$ that directly hits the trade sector, and hence labor demand in the home country. We observe such impact indirectly through a fall in A_t which is a decreasing function with respect to $\tau^*_{M,t}$ as shown in equation (8). As discussed above, since $W_t^{FL} = \Gamma A_t^{\frac{\varphi}{1+\varphi}}\mu_t$ under the flexible price, wage rates adjust to downward following the foreign tariff hikes:

$$\frac{\partial W_t^{FL}}{\partial \tau^*_{M,t}}\Big/\frac{W_t^{FL}}{\tau^*_{M,t}} = -\frac{\varphi}{1+\varphi}\frac{1}{\frac{\tau^*_M}{\left(1+\frac{1}{\sigma-1}-\frac{1}{\kappa}\right)}\left(\frac{1}{(1-n)\alpha}-1\right)+1} < 0,$$

The expressions depends on the initial size of tariff τ^*_M as well as the parameters' value in the

Table 1: The Model's Solution for a given monetary rule under complete markets

Nb of Exporters	$N_{X,t} = \frac{\kappa-(\sigma-1)}{\kappa}\frac{1}{\sigma}\frac{\nu^*(1-n)\varepsilon_t\mu_t^*}{\tau_{M,t}^* W_t f_X}$	$N_{X,t}^* = \frac{\kappa-(\sigma-1)}{\kappa}\frac{1}{\sigma}\frac{(1-\nu)n\varepsilon_t^{-1}\mu_t}{\tau_{M,t} W_t^* f_{X,t}^*}$
Av. Exporters	$\widetilde{z}_{X,t} = \left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{1}{\sigma-1}}\left(\frac{N_{X,t}}{N_D}\right)^{-\frac{1}{\kappa}}$	$\widetilde{z}_{X,t}^* = \left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{1}{\sigma-1}}\left(\frac{N_{X,t}^*}{N_D^*}\right)^{-\frac{1}{\kappa}}$
Production	$\tilde{y}_{D,t} = \frac{\sigma-1}{\sigma}\frac{n\nu\mu_t}{N_D}\frac{\tilde{z}_D}{W_t}, \quad \widetilde{y}_{X,t} = (\frac{1}{\sigma-1}-\frac{1}{\kappa})^{-1}\widetilde{z}_{X,t} f_X$	$\tilde{y}_{D,t}^* = \frac{\sigma-1}{\sigma}\frac{(1-\nu^*)(1-n)\mu_t^*}{N_D^*}\frac{\tilde{z}_D^*}{W_t^*}, \quad \widetilde{y}_{X,t}^* = (\frac{1}{\sigma-1}-\frac{1}{\kappa})^{-1}\widetilde{z}_{X,t}^* f_{X,t}^*$
Average Price	$\widetilde{p}_{D,t} = \frac{\sigma}{\sigma-1}\frac{W_t}{\widetilde{z}_D}, \quad \widetilde{p}_{X,t} = \frac{\sigma}{\sigma-1}\frac{\tau\varepsilon_t^{-1}W_t}{\widetilde{z}_{X,t}}$	$\widetilde{p}_{D,t}^* = \frac{\sigma}{\sigma-1}\frac{W_t^*}{\widetilde{z}_D^*}, \quad \widetilde{p}_{X,t}^* = \frac{\sigma}{\sigma-1}\frac{\tau\varepsilon_t W_t^*}{\widetilde{z}_{X,t}^*}$
Price Indices	$P_{H,t} = \left(\frac{n}{N_D}\right)^{\frac{1}{\sigma-1}}\widetilde{p}_{D,t}, \quad P_{F,t} = \left(\frac{1-n}{N_{X,t}^*}\right)^{\frac{1}{\sigma-1}}\tau_{M,t}\widetilde{p}_{X,t}^*, \quad P_t = P_{H,t}^{\nu}P_{F,t}^{1-\nu}$	$P_{F,t}^* = \left(\frac{1-n}{N_D^*}\right)^{\frac{1}{\sigma-1}}\widetilde{p}_{D,t}^*, \quad P_{H,t}^* = \left(\frac{n}{N_{X,t}}\right)^{\frac{1}{\sigma-1}}\tau_{M,t}^*\widetilde{p}_{X,t}, \quad P_t^* = P_{F,t}^{*1-\nu^*}P_{H,t}^{*\nu^*}$
Consumption	$C_t = \frac{\mu_t}{P_t}$	$C_t^* = \frac{\mu_t^*}{P_t^*}$
Profits	$\widetilde{D}_{D,t} = \frac{1}{\sigma}\frac{n\nu\mu_t}{N_D}, \quad \tilde{D}_{X,t} = \frac{\sigma-1}{\kappa}\frac{1}{\sigma}\frac{\nu^*(1-n)\varepsilon_t\mu_t^*}{\tau_{M,t}^* N_{X,t}}, \quad \widetilde{D}_t = \widetilde{D}_{D,t} + \frac{N_{X,t}}{N_D}\widetilde{D}_{X,t}$	$\widetilde{D}_{D,t}^* = \frac{1}{\sigma}\frac{(1-\nu^*)(1-n)\mu_t^*}{N_D^*}, \quad \tilde{D}_{X,t}^* = \frac{\sigma-1}{\kappa}\frac{1}{\sigma}\frac{(1-\nu)n\varepsilon_t^{-1}\mu_t}{\tau_{M,t}N_{X,t}^*}, \quad \widetilde{D}_t^* = \widetilde{D}_{D,t}^* + \frac{N_{X,t}^*}{N_{D,t}^*}\widetilde{D}_{X,t}^*$
Labor Supply	$nL_t = (\sigma-1)\frac{N_{D,t}\widetilde{D}_t}{W_t} + \sigma N_{X,t} f_{X,t}$	$(1-n)\,L_t^* = (\sigma-1)\frac{N_{D,t}^*\widetilde{D}_t^*}{W_t^*} + \sigma N_{X,t}^* f_{X,t}^*$
Monetary Stance	$\mu_t = P_t C_t$	$\mu_t^* = P_t^* C_t^*$
Wages	$W_t = \Gamma\left\{\frac{\mathrm{E}_{t-1}\left[(A_t\mu_t)^{1+\varphi}\right]}{\mathrm{E}_{t-1}[A_t]}\right\}^{\frac{1}{1+\varphi}}$	$W_t^* = \Gamma\left\{\frac{E_{t-1}\left[\left(A_t^*\mu_t^*\right)^{1+\varphi}\right]}{E_{t-1}[A_t^*]}\right\}^{\frac{1}{1+\varphi}}$
Exchange Rate	$\varepsilon_t = \frac{\mu_t}{\mu_t^*}$	
Definition of A_t	$A_t \equiv \frac{\sigma-1}{\sigma}\left[\nu + \left(1+\frac{1}{\sigma-1}-\frac{1}{\kappa}\right)\frac{\nu^*(1-n)}{n}\frac{1}{\tau_{M,t}^*}\right]$	$A_t^* \equiv \frac{\sigma-1}{\sigma}\left[(1-\nu^*) + \left(1+\frac{1}{\sigma-1}-\frac{1}{\kappa}\right)\frac{(1-\nu)n}{1-n}\frac{1}{\tau_{M,t}}\right]$

economy. In particular, the adjustment in wages is higher i) when the labor supply is less elastic (higher φ), ii) when firms are small and homogeneous (higher κ), iii) when there is tougher competition (higher σ), iv) when the size of initial tariff τ_M^* is lower, v) when the size of country is smaller (lower n), and vi) when openness α is higher. As we will see later, the value of these parameters is crucial in determining the size of optimal monetary policy.

To shed light into the mechanism behind of the wage adjustment, it is useful to focus on the labor market. By plugging the equilibrium values found in Table 1, we rewrite equation (6) as follows:

$$nL_t = \underbrace{\frac{\sigma-1}{\sigma}\frac{n\nu\mu_t}{W_t}}_{L_{D,t}} + \underbrace{\frac{\sigma-1}{\sigma}\left(1+\frac{1}{\sigma-1}-\frac{1}{\kappa}\right)\frac{\nu^*\left(1-n\right)\varepsilon_t\mu_t^*}{W_t\tau_{M,t}^*}}_{L_{X,t}} \tag{9}$$

The labor demand arising from domestic firms $L_{D,t}$ depends positively on monetary stance μ_t and negatively on wage W_t while that of exporters $L_{X,t}$ depends positively on foreign monetary stance μ_t^* and exchange rate ε_t, and negatively on wage W_t and import tariffs $\tau_{M,t}^*$. As discussed, monetary stances are neutral under the flexible prices. A higher level of $\tau_{M,t}^*$ induces a fall in labor demand by exporter firms. However, the negative impact on labor demand for exporters and thus the resulting unemployment is mitigated by the downward adjustments of nominal wages. Furthermore, note that a fall in wages encourages not only exporters to hire more but also domestic firms to do so helping the reallocation of workers from exporter to domestic firms. As a result of the wage adjustments, we have thus the following changes in total employment:

$$\frac{\partial L_t^{FL}}{\partial\tau_{M,t}^*}\Big/\frac{L_t^{FL}}{\tau_{M,t}^*} = -\frac{1}{1+\varphi}\frac{1}{\frac{\tau_M^*}{\left(1+\frac{1}{\sigma-1}-\frac{1}{\kappa}\right)}\left(\frac{1}{(1-n)\alpha}-1\right)+1} < 0$$

Note also that when the labor supply is infinitely elastic ($\varphi\to\infty$), the reallocation of workers is complete and attenuates entirely the negative impact following an increase in $\tau_{M,t}^*$.

What are the consequences of the Foreign tariff shock on consumption and thus welfare? The price index of imported goods for the home country $P_{F,t}$ remains unchanged following an increase in $\tau_{M,t}^*$ since it only impacts the exporters from the home country, not those from the foreign country. As N_D is unchanged, consumption in home expands due to a cheaper domestic goods price, $P_{H,t}$ that materializes through a cheaper production cost. As a result, consumption in the home country even expands in our simple setup, which is consistent with the expansion in domestic production $\widetilde{y}_{D,t}$ discussed above. Put differently, Foreign tariff hikes have the same effect of a positive technology shock as they induce efficiency gains. Note finally, that nominal GDP can be defined as $Y_t\equiv nP_tC_t$ from expenditure side. With a constant monetary stance such that $\mu\equiv P_tC_t$ GDP is therefore constant.[9] The above argument is summarized by the following

[9]The expansionary effect in this simple model is due to the reduction of costs related to wages which is prevailing over the recessionary impact of the fall in wage income. In the extended model, our quantitative results show the recessionary impact of Foreign tariff hikes on GDP and consumption.

proposition.[10]

Proposition 1. ***The impact of Foreign tariff hikes in the flexible-wage economy***

Home country: Foreign tariff hikes induce the reallocation of Home workers reducing the number of exporter firms and increasing their efficiency. Following the reduced labor demand in the trade sector, wages fall under flexible prices and the reduction in production costs mitigates the adjustment of exporter firms. The production in the domestic economy expands thanks to cost reduction, and welfare improves.

Foreign country: The increase in import tariff has a direct cost in terms of welfare because of the higher import prices and the fall in the imported number of varieties.

Note finally that the result remain true without firm heterogeneity ($\kappa \to \infty$). Also, when the labor supply is infinitely elastic as $\varphi = 0$ (a horizontal labor supply schedule), we do not observe any changes in wages and hence in consumption.

What is the consequence for the Foreign country that implements the protectionism hike in tariffs? First, wage remains constant in Foreign country following such a shock since there is no change in labor demand (A_t^* remains constant) even under the flexible wage. It implies that domestic price $P_{F,t}^*$ is constant. However, P_H^* changes from several channels, namely through $\tau_{M,t}^*$ directly, and through $N_{X,t}$, and $\widetilde{z}_{X,t}$ indirectly.

3.2 The economy under nominal rigidities

The negative impact of foreign tariff hikes in both Home and Foreign country are mitigated when wages are free to adjust as shown previously. In contrast, this is no longer the case under nominal rigidities. Under nominal rigidities, when $\tau_{M,t}^*$ increases, wage rate remains constant as

$$\frac{\partial W_t}{\partial \tau_{M,t}^*} / \frac{W_t}{\tau_{M,t}^*} = 0$$

As a result, total labor demand decreases sharply as

$$\frac{\partial L_t}{\partial \tau_{M,t}^*} / \frac{L_t}{\tau_{M,t}^*} = \underbrace{\frac{\partial L_{D,t}}{\partial \tau_{M,t}^*} / \frac{L_{D,t}}{\tau_{M,t}^*}}_{=0} + \underbrace{\frac{\partial L_{X,t}}{\partial \tau_{M,t}^*} / \frac{L_{X,t}}{\tau_{M,t}^*}}_{\ll 0} = -\frac{1}{\frac{\sigma-1}{\sigma}\left[\frac{\tau_M^*}{\left(1+\frac{1}{\sigma-1}-\frac{1}{\kappa}\right)}\left(\frac{1}{(1-n)\alpha}-1\right)+1\right]} \ll 0$$

In line with the above fall in employment, as shown in Table 1, it is straightforward to see that the number of exporters $N_{X,t}$ declines one for one with the foreign tariff hikes under nominal rigidities. As a result of the selection of exporters, $\widetilde{z}_{X,t}$ and $\widetilde{y}_{X,t}$ improve sharply. The selection of exporters under the nominal rigidities is thus amplified. Contrary to this stark adjustment for exporters shown by the fall in $L_{X,t}$ due to the constant cost of production under nominal rigidities, the employment in domestic firms $L_{D,t}$ and thus the average production in the home country $\widetilde{y}_{D,t}$ remain instead unchanged following a rise in $\tau_{M,t}^*$. As a result, both $P_{H,t}$ and $P_{F,t}$ remain unchanged

[10] Proof: see section A.2 in the Appendix.

and consumption in the Home country, C_t, remains constant. The increase in Foreign tariff allows the households in the Home country to achieve the same level of consumption with a lower labor supply.

What are the implications of the import tariff hikes for the Foreign country? Besides the contraction in internal demand, the Foreign country incurs a negative effect related to the amplified selection of Home exporters. The imported price in the foreign country P_H^* increases through $\tau_{M,t}^*$ directly, and through the adjustment of home exporters (namely, the changes in $N_{X,t}$, and $\widetilde{z}_{X,t}$) leaving foreign domestic price $P_{F,t}^*$ constant. Without the wage adjustment, the rise in P_H^* is sharper, and hence the consumption in the foreign country falls more strongly under nominal rigidities. The above argument is summarized in the following proposition.[11]

Proposition 2. ***The impact of Foreign tariff hikes in the economy with nominal rigidities*** *Under nominal rigidities, following tariff hikes in the Foreign country, Home exporters are concerned by a stronger selection. Negative repercussions on welfare in the Foreign country are thus amplified.*

It is important to notice that the above allocations under nominal rigidities under-perform those under the flexible price. This is welfare-detrimental per se and gives rise to a rationale for using monetary policy as an active instrument against Foreign tariff shocks.

3.3 Optimal monetary policy

In this section, we derive the optimal monetary policy as a Nash equilibrium where the monetary (and tax) authority in the home country maximizes the welfare of the domestic households. As argued in the previous section, uncertainty about foreign tariff and monetary policy shocks gives the rationale for the policy interventions.

We assume that the monetary authority chooses the optimal monetary policy under full commitment. The policy commitment is to maximize the expected utility of domestic households while taking as given the monetary stance abroad. The monetary authority therefore maximizes the expected utility $\mathrm{E}_{t-1}[\mathcal{U}]$ with respect to both μ_t and $\tau_{M,t}$ for all future periods. The expected utility is defined as

$$\begin{aligned}\mathrm{E}_{t-1}[\mathcal{U}] &= \nu\left[\mathrm{E}_{t-1}[\ln\mu_t] - \frac{1}{1+\varphi}\ln E_{t-1}\left[(A_t\mu_t)^{1+\varphi}\right] + \frac{1}{1+\varphi}\ln\mathrm{E}_{t-1}[A_t]\right]\\ &+(1-\nu)\left(\psi+1-\frac{1}{\kappa}\right)\left\{\mathrm{E}_{t-1}\left[\ln\mu_t^*\right] - \frac{1}{1+\varphi}\ln E_{t-1}\left[\left(A_t^*\mu_t^*\right)^{1+\varphi}\right] + \frac{1}{1+\varphi}\ln\mathrm{E}_{t-1}\left[A_t^*\right] - \mathrm{E}_{t-1}\left[\ln\tau_{M,t}\right]\right\}\\ &\qquad - \eta\frac{\Gamma^{1+\varphi}}{1+\varphi}E_{t-1}[A_t] + \ldots\end{aligned}$$

[11] Proof: see section A.3 in the Appendix.

where we abstract the terms from $t+1$ since they are similar. The following proposition characterizes the optimal monetary policy.[12]

Proposition 3. ***Optimal monetary policy***
Monetary policy works as a powerful tool in stabilizing economy facing a Foreign tariff shock. In particular, monetary policy is expansionary in response to tariff hikes originated abroad. As a result, it mitigates the negative external shock among domestic exporters and enhances the reallocation of workers towards domestic producers.

Given that the term A_t is a function of foreign tariff $\tau^*_{M,t}$, it is optimal for domestic monetary authority to counteract it by raising μ_t. Intuition is straightforward. When the Foreign country raises tariffs, the allocation under nominal rigidities is sub-optimal under sticky wages. Both the number of Home exporters $N_{X,t}$ and Home labor demand are sub-optimally lower under nominal rigidities. The home monetary authority therefore has an incentive to expand her monetary stance by raising μ_t. The above rule counteracts the uncertainty stemming from tariff shocks in the export market and is optimal since it reduces the wage markup.[13]

Corollary. *Under the case of completely inelastic labor supply ($\varphi \to \infty$), the allocation under the above policy rule coincides with the allocation under flexible prices.*

Our analytical solution allows us to clearly assess to what extent the optimal monetary policy reestablishes the allocation under the flexible price. The following proposition describes the role played by each parameter in the economy.

Proposition 4. ***The role of fundamentals***
The monetary policy is further positively correlated to Foreign tariff shocks (e.g. more expansionary in response to tariff hikes) when i) the labor supply is less elastic (higher φ), ii) firms are small and homogeneous (higher κ), iii) competition is stronger (higher σ), iv) the size of initial tariff τ^*_M is low, v) the size n of the country receiving the shock is smaller, and vi) its openness α is higher.

Proof. The derivatives of $\frac{\partial \mu_t}{\partial \tau^*_{M,t}} / \frac{\mu_t}{\tau^*_{M,t}}$ with respect to φ, κ, σ, τ^*_M, n, and α are all positive. □

As labor supply becomes less elastic, following the shift in labor demand, wage adjustments are larger. When firms are small and homogeneous, the trade sector is more vulnerable to external tariff shock requiring a stronger adjustments in the labor markets. The marginal impact of foreign tariff hikes is decreasing with respect to its initial size. Finally, when the country size is small relative to its trade partner or higher openness requires a stronger adjustment in wages following foreign tariff shocks. Note also that the impact of higher σ (competition across variety producing firms) is ambiguous. Proposition 4 is a natural result of the adjustments in labor markets under

[12]Proof: see section A.4 in the Appendix.

[13]Bergin and Corsetti (2023) find a similar expansionary policy under trade uncertainty in a quantitative model. In their environment, following symmetric or asymmetric tariff shock, ex-tariff PPI deflation materializes as firms react to the falling demand, leading monetary authority to conduct an expansionary policy.

nominal rigidities, as $\frac{\partial \mu_t}{\partial \tau^*_{M,t}} / \frac{\mu_t}{\tau^*_{M,t}} = -\frac{1+\varphi}{\varphi} \frac{\partial W^{FL}_t}{\partial \tau^*_{M,t}} / \frac{W^{FL}_t}{\tau^*_{M,t}}$. The scope of the optimal monetary policy is indeed to reestablish the allocation under the flexible price, and the required response to Foreign tariff shocks depends on the "lost" adjustment of wages.

Under the assumption that the Foreign monetary authority faces the same maximization problem (Nash optimal monetary policy), the nominal exchange rate is expressed as

$$\varepsilon_t = \frac{A^*_t}{A_t} = \frac{(1-\nu^*) + \left(1 + \frac{1}{\sigma-1} - \frac{1}{\kappa}\right) \frac{(1-\nu)n}{1-n} \frac{1}{\tau_{M,t}}}{\nu + \left(1 + \frac{1}{\sigma-1} - \frac{1}{\kappa}\right) \frac{\nu^*(1-n)}{n} \frac{1}{\tau^*_{M,t}}}$$

The expression above shows that the nominal exchange rate inherits the volatility of tariff shocks. Higher uncertainty in tariff shocks leads to higher uncertainty in the nominal exchange rate under the above optimal policies. Another implication is that when the stability of the exchange rate is a primary concern, the optimal tariff policies would be inconsistent with that objective.

4 Quantitative Analysis of Unilateral Foreign Tariff Shocks

In this section, we extend the simple model to a more general set up. The purpose of these extensions is to provide an assessment of the impact of Foreign tariff shocks in a broader framework. Our extensions are the following: i) we introduce more general preference as CES, ii) we consider product quality, iii) we allow investment through the creation of new firms (free entry condition), iv) we introduce a more general wage setting process à la Calvo, v) we let monetary policy to follow a standard Taylor rule, vi) we allow International bond holdings and compute the resulting current account dynamics. We refer to Appendix B for the full derivation of the solution of the extended model and summarize it in Table A1 for given monetary stances in both countries.

4.1 Calibration

The calibration is on quarterly basis and is summarized in Table 2. The discount factor, β, is set equal to 0.99. The inverse of the Frisch elasticity of labor supply, φ, is set equal to 2. The coefficient of risk aversion, γ, is set equal to 2. These values are standard in the literature. The elasticity of substitution among varieties, σ, the exogenous exit shock, δ, the Pareto distribution parameter, κ, and the adjustment cost for bond holdings, ϑ, are set equal to 3.8, 0.025, 3.40 and 0.0025 respectively, following Ghironi and Melitz (2005). The preference for variety, ψ, is set as it is the one discussed in Dixit and Stiglitz (1977). The quality ladder ϱ is set to 0.610 based on Feenstra and Romalis (2014a), who estimate the elasticity of firm-specific quality with respect to firm-specific productivity. The entry adjustment costs, ω, is set equal to 2.42 which replicates the standard deviation of firm entry in the US data as argued in Bergin et al. (2018). The parameters that determine nominal wage stickiness, λ, and the elasticity of substitution among differentiated labor services, θ, are set equal to 0.64 and 3.5, respectively, as in Christiano et al. (2005) consistent with the evidence on wage dynamics in the US economy. The coefficients in the Taylor rule

($\phi_i = 0.7$, $\phi_\pi = 1.7$ and $\phi_Y = 0.1$) are consistent with Bergin and Corsetti (2023) and Coenen et al. (2008) which estimate the Taylor rule for open economies.

We assume a non-stochastic steady state with balanced trade. In our benchmark calibration, we set the size of the home country as one percent in the world population ($n = 0.01$) as it proxies a small open economy. Also we set $Z = Z^* = 1$ and $f_E = f_E^* = 1$ without loss of generality. The calibration of f_X is based on the empirical findings of Bernard et al. (2003), according to which the share of exporters is 21 percent. η is set to 0.9278 with which the steady state labor supply is unity: $L = 1$ in both countries. At the steady state, trade costs τ and import tariffs are set to 1.3 and 2 percent, respectively following Barattieri et al. (2021). Lastly, regarding the process of tariff shock, we postulate an AR (1) process featuring a persistence of 0.56. The standard deviation of the tariff shock is predetermined at 0.034, in accordance with the benchmark calibration stipulated by Barattieri et al. (2021).

Table 2: Calibration

β	Discount factor	0.99
φ	Inverse of elasticity of labor supply	2
γ	Risk aversion	2
σ	Elasticity of substitution among varieties	11.5
δ	Exogenous death shock	0.025
κ	Pareto shape	3.40
ψ	love for variety	Dixit-Stiglitz
ϑ	Bond holdings adj costs	0.0025
ϱ	Quality ladder	0.610
ω	Entry adjustment cost	2.42
η	disutility in labor supply	0.3436
n	Home country size	0.01
α	openess	0.3
f_X	Export fixed costs	0.0231
τ	Steady state trade cost	1.3
τ_M	Steady state import tariffs	1.02
λ	Calvo wage parameter	0.64
θ	Elasticity of substitution among workers	3.5
ϕ_i	Interest smoothing on previous rate	0.7
ϕ_π	Inflation target	1.7
ϕ_Y	Output gap stabilization	0.1

In what follows, we study the impulse response functions (IRFs) following foreign tariff shocks in our expanded model. Such shocks occur when the foreign country imposes tariffs on goods and services imported from the home country. This tariff shock can drastically disturb the economic equilibrium in the home country, influencing critical aspects like the trade balance, currency valuation, GDP, and the nation's overall welfare. In particular, we contemplate a one standard deviation increase in tariff shocks $\tau^*_{M,t+1}$.

4.2 Impulse Response Functions

Figure 1 presents the IRFs of primary economic variables in response to a unilateral foreign tariff shock in a benchmark small open economy ($n = 0.01$). Different lines represent IRFs under various monetary policies. Specifically, we highlight the case under the Ramsey optimal policy (solid lines), the benchmark Taylor rule (dashed dotted lines), and the fixed exchange rate arrangement (dotted lines). For all specifications, we assume that the monetary policy in the foreign country aligns with the corresponding Taylor rule, as defined in equation (15).[14]

Taylor Rule

In formulating the Ramsey optimal policy, we presume that a benevolent planner in the home small open economy maximizes the expected utility of domestic households (1), given all other equations. As demonstrated, the optimal policy is found to be expansionary, coinciding with a decline in the nominal rate i following a positive foreign tariff shock, as suggested in Proposition 3. This low nominal rate under the optimal policy stimulates consumption and investment (not shown) in the Home country and it aligns with a depreciation of the nominal exchange rate. As anticipated, under the Ramsey optimal policy, the drop in net exports and real GDP is the least contracted among all other policy specifications. Consequently, the increase in domestic absorption and associated income counteracts the recessionary impact of the foreign tariff shock and mitigates the decline in net exports, which is largely driven by a substantial reduction in the number of home exporters. In the benchmark specification with the Taylor rule (dashed lines), following foreign tariff increases, nominal wages fall sluggishly, inducing disinflation in the economy. Given such price dynamics, under the Taylor rule, monetary policy also becomes expansionary, albeit to a lesser extent than under the optimal policy. Despite being less successful compared to the optimal policy, monetary policy under the Taylor rule effectively mitigates the negative transmission resulting from foreign tariff hikes into the domestic economy.

In the foreign country, import tariff increases inevitably lead to an immediate recession due to the higher prices of imported goods, followed by a monetary contraction in line with the Taylor rule. However, as consumer price inflation abates and transitions into disinflation, an accommodative policy involving a lower nominal rate boosts consumption, investment (not shown), and output in the foreign country. The adjustments of trade through the number of foreign exporters are smaller compared to that in the home country, given the smaller size of the destination country relative to the larger foreign economy.

Figures A1, A2 and A3 in the Appendix compare the Impulse Response Functions (IRFs) of the Ramsey optimal policy in the benchmark small open economy with those of a large open economy ($n = 0.5$), a more open economy ($\alpha = 0.5$), and a less granular economy ($\kappa = 25$). These comparisons align with the analytical results, indicating that in scenarios where firms are small

[14]The impulse response functions under the Ramsey optimal policy and other scenarios are calculated using the first-order perturbation method. The non-stochastic steady states remain consistent across all specifications. The RISE toolbox is employed in the derivation of the first-order dynamics and the optimal policy.

and homogeneous, where the country's size is relatively small, and where economic openness is high, monetary authorities have a stronger incentive to implement more expansionary policies.

Fixed Exchange Rate Arrangement

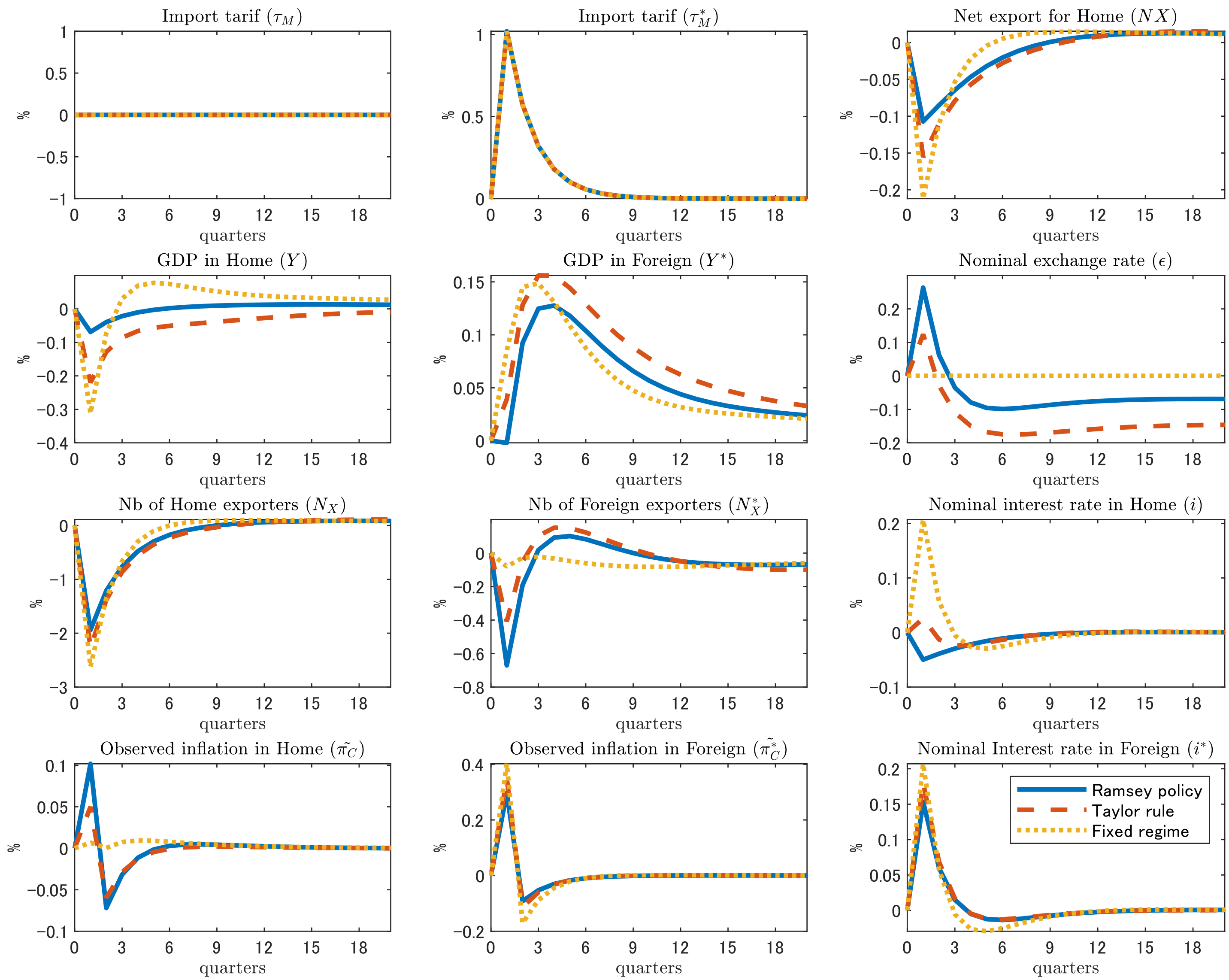
While our focus is predominantly on the Taylor rule and its comparison with the optimal policy, it is insightful to draw a comparison with another type of monetary policy such as the fixed exchange rate arrangement. In outlining the fixed exchange rate, the home country aims to limit fluctuations of the nominal exchange rate, such that $1 + i_t = \left(1 + i_t^*\right) \varepsilon_t^{10}$. This process is akin to that considered by Benigno et al. (2007) for the policy rule that is compatible with the fixed regime. As discussed earlier, foreign tariff hikes invariably exert inflationary pressure in the foreign country. As a result, the nominal interest rate rises in the foreign country following the Taylor rule, inducing an immediate nominal depreciation in the home country. However, to counter the depreciation of the nominal exchange rate, a contractionary policy of a similar nature is required in the home country to stabilize the nominal exchange rate. Importantly, such a contractionary policy prompts a further decrease in real GDP, consumption, and investment during the initial periods following the foreign tariff hikes. In the end, the number of home exporters falls most sharply under the fixed exchange rate regime. This is because, in the absence of depreciation, there is no expenditure switching to alleviate the declining profits of exporters in the home country under producer currency pricing. In contrast, the reduction in the number of foreign country exporters remains relatively modest under the fixed exchange rate regime.

We now compute the welfare consequences of an unilateral foreign tariff shock when the domestic monetary authority follows a Taylor rule or adopts a fixed exchange rate regime.[15] In Table 3, we report the ratio of the standard deviations of each variable under Taylor rule (or fixed regime) over the standard deviation under the Ramsey optimal policy. GDP (Y and Y^*), consumption (C and C^*), investments (inv and inv^*), inflation ($\tilde{\pi}_C$ and $\tilde{\pi}_C^*$), and the real exchange rate (Q) are defined in terms of welfare, i.e. including the fluctuations in the number of available product varieties. The results in Table 3 show that Home variables are less volatile under the Taylor rule than under the fixed exchange rate regime. As expected, both the standard deviations of inflation in the Home country and the real exchange rate are lower under the fixed exchange rate regime than under the Taylor rule. These patterns are in line with our findings in the impulse response analysis. Regarding the welfare losses associated with foreign tariff shocks, the values are small in absolute terms, but relatively larger under the fixed regime. In the Foreign country, the welfare loss is slightly lower under the fixed exchange rate regime: while Foreign terms of trade deteriorate when the Home monetary authority follows a Taylor rule, there is no such detrimental movements in the terms of trade under a fixed regime.[16]

[15] In computing the second moments and unconditional welfare, we use the RISE toolbox (Maih, 2015). We rely on the first-order perturbation for the theoretical moments, and for welfare, we utilize the second-order approximation for perturbation.

[16] For comparative purposes, we also detail the standard deviations and welfare loss in the context of a large open economy, that is setting $n = 0.5$. These results are documented in Table A2 in the Appendix, which delivers similar insights compared to the benchmark case of a small economy.

Figure 1: Unilateral foreign tariff shock for a small open economy (n=0.01)



Note: Figure shows the impulse response functions of major economic variables under different specifications with respect to unilateral foreign tariff shock for the benchmark small open economy. Vertical axes measure the percent changes of the variable from its steady state value. Horizontal axes represent quarters.

Table 3: Welfare analysis

	Taylor rule	Fixed regime
Standard deviations		
Y	3.69	3.93
Y^*	5.14	4.41
C	2.09	1.39
C^*	4.02	3.52
L	6.33	6.83
L^*	4.99	4.32
Inv	0.91	2.13
Inv^*	7.98	6.71
π_C	0.75	0.24
π_C^*	2.43	1.96
Q	0.78	0.46
N_X	1.42	1.46
N_X^*	1.02	0.47
Welfare Loss		
Home	0.0471	0.0562
Foreign	0.0291	0.0212

Note: In the top panel, we report for each variable the ratio of the standard deviation relative to the one under the Ramsey optimal policy. The welfare loss is expressed in terms of percentage points with respect to the welfare under the Ramsey policy.

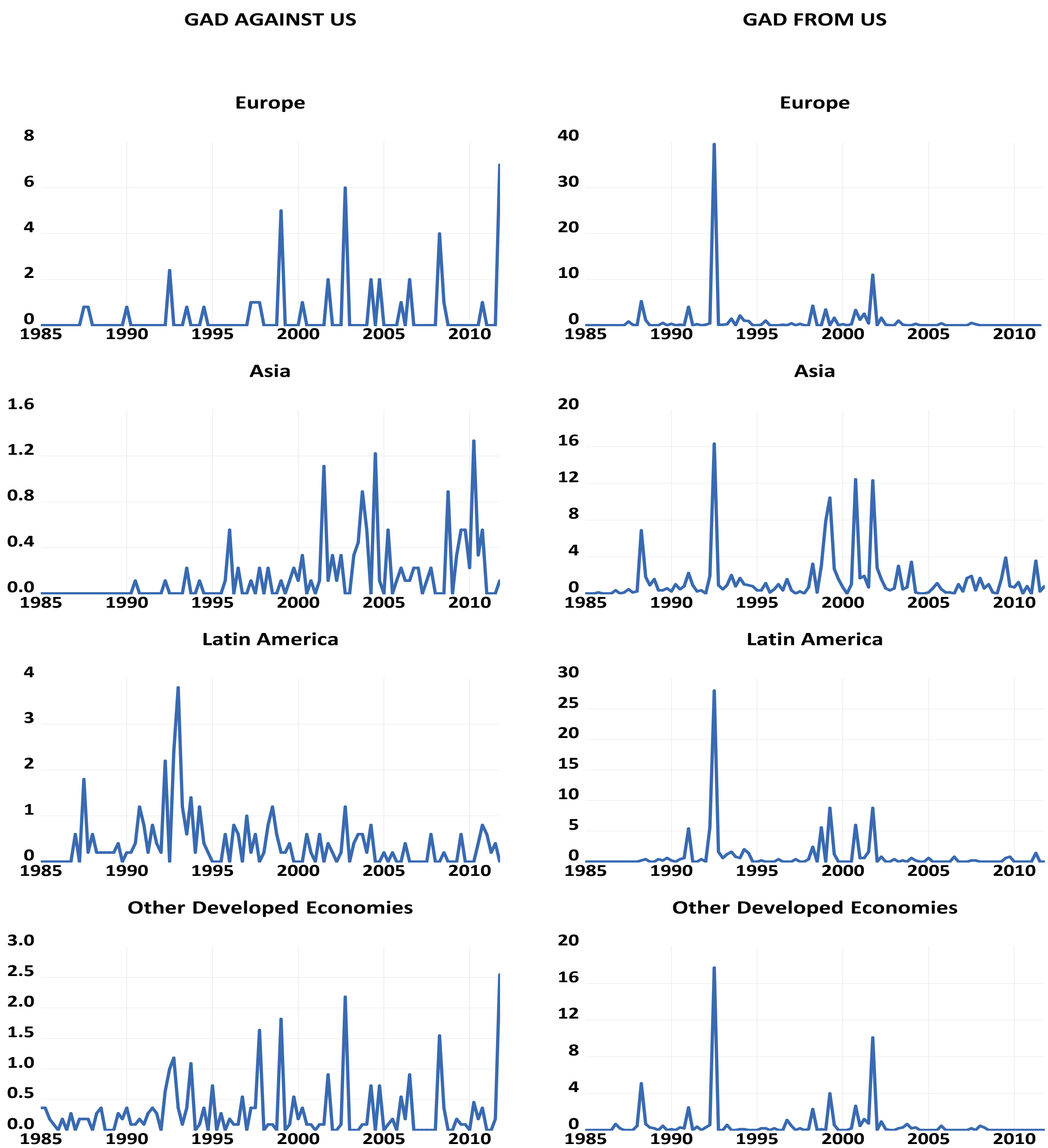
5 Empirical Evidence

In this Section, we study the effects of trade protection on macroeconomic and trade dynamics using data on tariffs from the Global Anti-dumping Database (GAD, 2016). This database collects the details of anti-dumping initiatives imposed by national government users from the original government documentation. We use data for 35 trading partners of the U.S. over the sample period that goes from 1985 till 2011.[17]

Figure 2 reports the average number of anti-dumping policy initiatives at quarterly frequency imposed by the U.S. and against the U.S. The anti-dumping measures are reported by 4 groups of countries: Europe, Asia, Latin America, and other developed economies. In order to be comparable, we restrict the range of the anti-dumping measures between 0 and 8. Related to the U.S. bilateral trade, the tariffs imposed on imports of goods to trading partners have been more intense and frequent. While the GAD against the U.S. peaks the average value of 6 in 2002 and 7 in 2011, the GAD imposed against trading partners shows various peaks over time, in particular during the period between 1990-1995, and the period 2000-2005. Further, the U.S. have been more aggressive in terms of protectionism against Asian and Latin American countries since 2010.

[17] Appendix C.1 provides additional details on data.

Figure 2: Anti-dumping Policy Actions from and against the U.S. (1985-2011)



Source: Global Antidumping Database. *Note*: Europe includes: Austria, Belgium, Germany, Spain, Finland, France, Greece, Italy, Netherlands and Portugal. Asia includes: Japan, China, Indonesia, India, South Korea, Malaysia, Philippines, Singapore and Thailand. Latin America includes: Argentina, Brazil, Chile, Mexico and Peru. Other Advanced Economies includes: Australia, Canada, Switzerland, Norway, New Zealand, Sweden, United Kingdom, United States, Saudi Arabia, South Africa, Turkey and Denmark.

We now examine the dynamic responses to changes in the anti-dumping initiatives by the U.S. against its major trading partners. In order to do that, we rely on local projection method (henceforth LP) developed by Jordà (2005) to estimate the reaction of a number of key variables of interest to an exogenous change in U.S. tariffs on imports.[18] The variables included in our empirical model are: *GDP* ($\tilde{Y}$), inflation ($\tilde{\pi}_C$), net exports (NX), numbers of exporters and importers (N_X and N_X^*), the average quality of exporters and importers ($\tilde{q}_X$ and $\tilde{q}_X^*$), the nominal exchange rate (ε), and tariff on U.S. imports (τ_M^*).[19] We follow Auray et al. (2020) in calculating the tariff index, which is expressed as follows:

$$\tau_M^* = log(1 + GAD_{US}),$$

where GAD_{US} indicates the number of anti-dumping initiatives imposed by the U.S. against its trading partners. We estimate the following regression for the varying prediction horizon $h = 0, 1, ..., H$:

$$\Delta_h y_{i,t} = \alpha_i^h + \gamma_y^h + \beta^h \Delta\tau_{M,i,t}^* + \Sigma_{k=0}^2 \phi_k^h \Delta X_{i,t-k} + \epsilon_{i,t+k}$$

where $\Delta_h y_{i,t} = y_{i,t+h} - y_{i,t}$ is the key variable of interest (macroeconomic or trade variable) for country i between quarter t and quarter $t+h$; $\Delta\tau_{M,i,t}^*$ denotes changes in tariffs on imports implemented by the U.S. against country i at time t; α_i^h is a dummy variable to control for country fixed effects in order to take account of unobserved cross-country heterogeneity; γ_y^h are time-fixed effects to control for global trends; $X_{i,t}$ is a vector of controlling variables;[20] and $\epsilon_{i,t}$ represents unexplained residuals. In our experiment, we choose the maximum prediction horizon, H, to be equal to 12. The additional set of control variables includes 2 lags of changes of exogenous variables, namely: the U.S. short-term interest rate, the U.S. inflation rate, the U.S. growth rate, the trade policy uncertainty (TPU Index), the volatility of the TPU index, the trade share of imports and exports for each country. The key coefficient of interest, β^h, summarizes the impulse response functions of variables of interest to tariff shocks.

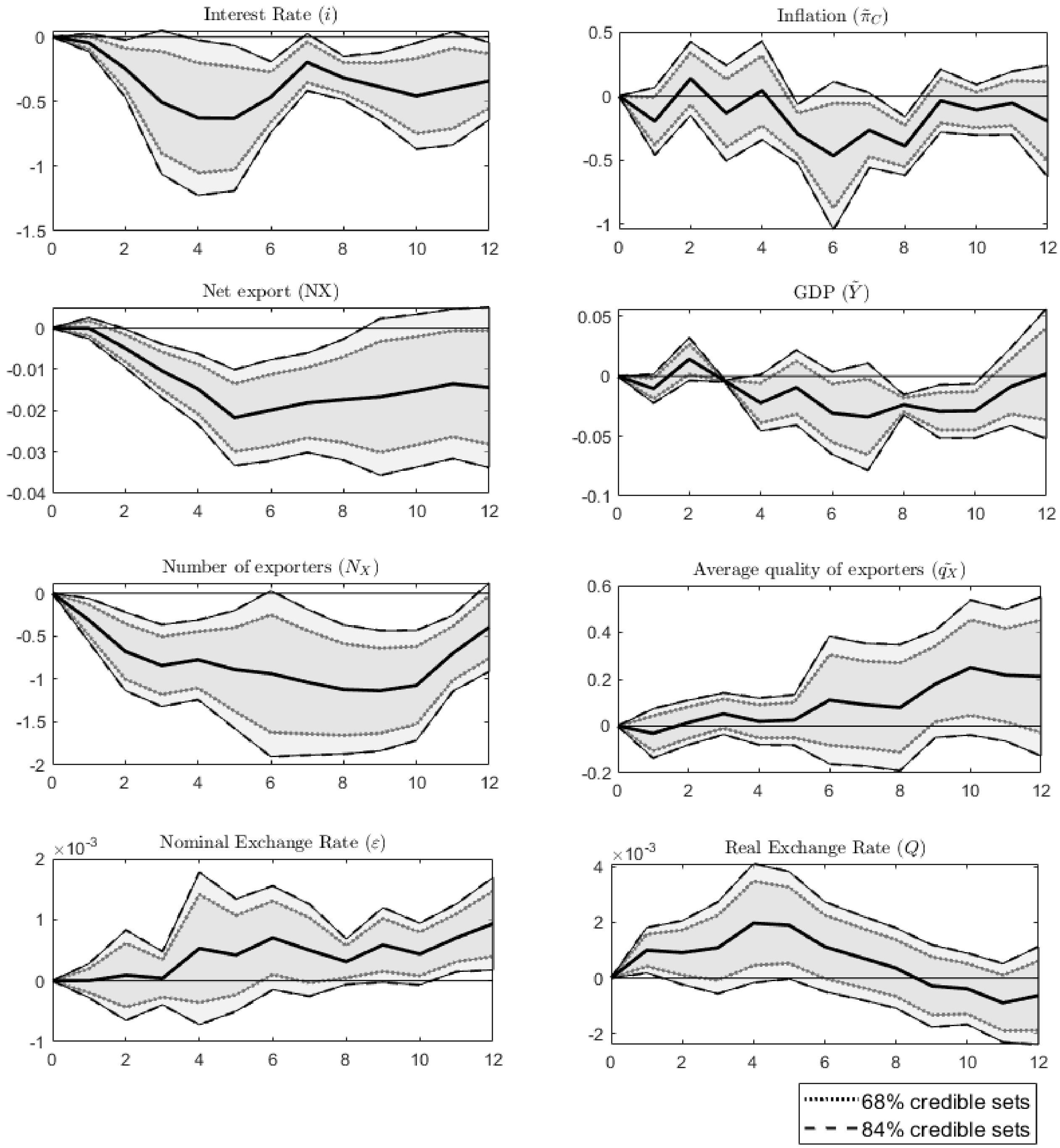
Figure 3 displays the cumulative responses of variable of interest to a one-standard deviation rise in the U.S. tariff rate on imports over the following 12 quarters for countries under a flexible exchange rate regime according to Ilzetzki et al. (2019). The dotted lines (dashed lines) around the dark gray area (light gray area) indicate 68% (84%) confidence level of the error bands, corresponding to 1 (1.41) standard deviations. The estimated impulse responses reveal a dynamic pattern similar to the impulse response functions from the theoretical model. In Figure 4, we

[18] Jordà (2005) introduces local projections as a flexible way to compute impulse responses that are more robust to misspecification and allow for the inclusion of control variables. Indeed, LP frameworks allows both joint or pointwise analytic inference on the estimated impulse responses, allowing to account for highly nonlinear and flexible specifications. Plagborg-Møller and Wolf (2021) shows that LP and VAR estimate very similar impulse responses, and linear VAR models are as robust to non-linearities as linear LP approaches. While a standard VAR model extrapolates into increasingly distant horizons in computing the impulse responses, LP method measures the relationship between exogenous and endogenous variables at different time points. In Appendix C.3, we report the impulse responses estimated by using a Panel Structural VAR model as robustness check.

[19] All variables are expressed in real terms and in their *log*, with the exception of the tariff index. We interchangeably refer to the variety of exported goods as the number of exporters. $\tilde{Y}$ and $\tilde{\pi}_C$ are the data-consistent measures of output and inflation, see Appendix B.6 for the definition of the theoretical counterpart of these variables.

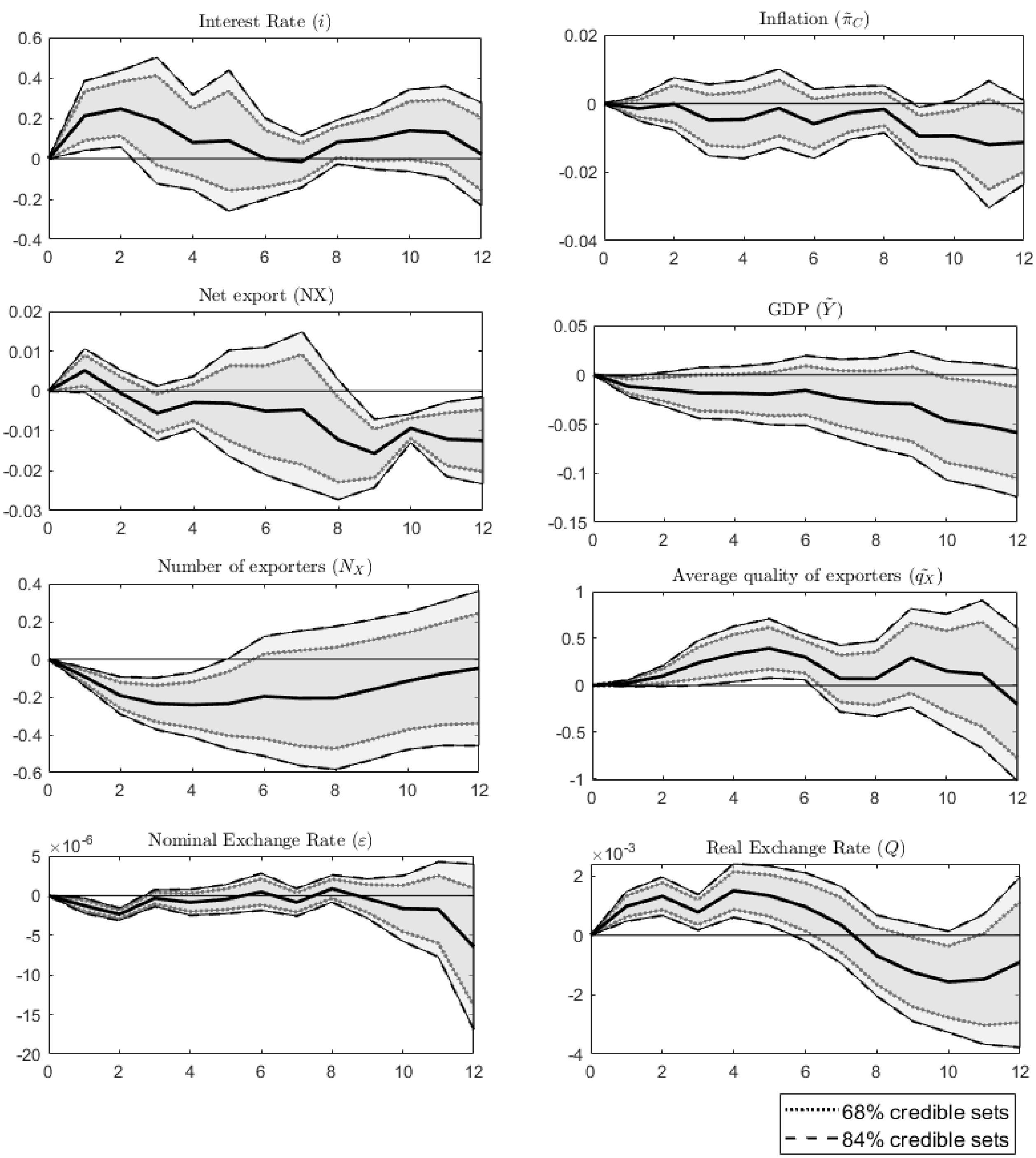
[20] For more details, see Jordà et al. (2013) who implement local projection methods by conditioning to a broad set of macroeconomic controls.

Figure 3: Responses to a U.S. Tariff shock on Imports - Flexible exchange rate regime countries.



Note: Cumulative impulse responses to a one-standard deviation increase in U.S. tariff on imports. The dotted line (over the dark gray area) and the dashed (over the light gray area) report a 1 standard deviation and 1.41 standard deviations, respectively.

Figure 4: Responses to a U.S. Tariff shock on Imports - Fixed exchange rate regime countries.



Note: Cumulative impulse responses to a one-standard deviation increase in U.S. tariff on imports. The dotted line (over the dark gray area) and the dashed (over the light gray area) report a 1 standard deviation and 1.41 standard deviations, respectively.

replicate the same exercise for countries under fixed exchange rate regime.

Figure 3 displays a significant negative correlation between changes in tariffs on imports and the net exports. Indeed net export declines during both short- and medium-run horizon, reaching an approximate level of -0.02% after 5 quarters. Such decline is driven by a large drop in exports as the higher price of foreign goods lead U.S. consumers to lower demand of foreign goods. After 2 years, the decline is no longer statistically significant at the 84% credible sets.[21] Figure 3 also shows that an increase in import tariffs leads to a persistent decrease in output in the medium-term. The falling GDP response appears to be short-lived, as the GDP eventually increases 2 years later, after reaching its lowest level of about 0.05%. Inflation declines as well around 0.05% five quarters later, however the decline is persistent but statistically significant only at the 68% confidence interval. Relative to trade dynamics, the LP approach estimates that a tariff change leads to a negative correlation with the numbers of U.S. exporters (N_X^*) and the U.S. trade partners (N_X). Figure 3 shows that both varieties initially fall after the U.S. trade policy has been implemented. While for the U.S. variety, the coefficient is negative and large, reaching -1% after 10 quarters, the coefficient for the U.S. trade partners variety of exports decreases to -0.2% and -0.4% after 5 and 10 quarters, respectively. However, the coefficient further declines the longer the horizon. In contrast, the negative coefficients of cumulative responses of variety of exports for the U.S. trading partners remain stable for longer time horizons but starts increasing after 10 years. The coefficient of average quality of exporters, $\tilde{q}_X$ and $\tilde{q}_X^*$, are both positively correlated with the tariff shock, but they are statistically significant only at the 68% credible sets, with the exception of $\tilde{q}_X^*$ which appears to be statistically significant at both 68% and 84% percentile only during the first five quarters with a coefficient level of 0.25%. From Figure 3, we can notice that exporters first adjust the variety of their goods sold abroad instantaneously and persistently, while they adjust the average quality after few quarters, trying to increase the quality of products sold abroad as the variety declines even more. Finally, Figure 3 indicates that monetary policy becomes expansionary for countries under a flexible exchange rate regime, with a depreciation of the currency over medium-run horizon. In contrast, countries committed to a fixed exchange rate regime react to a tariff shock with a contractionary response of the short-term interest rate. As shown in Figure 4, under a fixed exchange rate regime, the response of the rest of the variables to the tariff shocks is similar to the one under a flexible exchange rate but with lower quantitative impact. For instance, the recessionary effect is more contained under a fixed exchange rate in the short-run horizon, as the tightening of the monetary policy tends to protect more domestic exporters and limits the fall in net exports.

The empirical evidence in Figures 3 and 4 indirectly validates the impulse response functions followed by foreign tariff hikes presented in the previous section: small open economies mitigate the recessionary impact bought by US anti-dumping shock with adequate monetary reaction. Further, results corroborate predictions established in Section 4: an expansionary response of the monetary policy under flexible exchange rate regime, against a contractionary response under

[21] A general disadvantage of local projection method is that it typically obtains a wiggly impulse response function and has wide confidence/credible intervals. See Ramey (2016).

fixed regime. Relative to macroeconomic variables, we find that protectionism through higher tariffs on imports produce similar effects as a negative demand shock on tariff-targeted countries, with a recessionary impact on GDP and lower inflation. Similar results are found in Barattieri et al. (2021), Furceri et al. (2020), and Auray et al. (2020)). However, different from our model, Barattieri et al. (2021) focus on the impact of the domestic economy which is increasing tariffs on its imports, and find that protectionism is inflationary and recessionary, thus acting as a negative supply shock. In contrast to them, our paper focus on the domestic impact following a tariff shock generated by a foreign country, a shock that directly affects domestic exports. Such shock hits the domestic economy by generating deflation and depressing output, thus acting as a negative demand shock.[22]

6 Conclusion

In this paper, we explore the response of optimal monetary policy to uncoordinated trade policies (foreign tariff shocks). We first provide a simple model of open economy with heterogeneous firms and derive a closed-form solution for the optimal monetary policy response to tariff shocks in presence of nominal rigidities. We show that optimal monetary policy is expansionary following foreign tariff hikes. Under nominal rigidities, uncertainty about foreign tariff hikes induces sluggish adjustments in the labor market reallocation between exporters and domestic firms, leading to an incentive for monetary authority to intervene and mitigate the impact of tariff shocks.

In an extended model, we then show the response of our economy to a tariff shock under the Ramsey monetary policy, a Taylor Rule and a fixed exchange rate regime. Our results show that the Ramsey monetary policy is expansionary in response to a Foreign tariff hike, leading to a nominal depreciation which compensates the dampened reallocation of resources from exporter to domestic firms due to sticky wages. The Ramsey monetary policy limits the welfare losses associated with a rise in Foreign tariffs with respect to a Taylor rule under a flexible or a fixed exchange rate regime. Finally, we provide empirical evidence for the response of domestic monetary policy to foreign tariff shocks using data on Global Antidumping from the US. In line with our model results, we find that monetary policy tend to be expansionary following a US anti-dumping procedure in countries under a flexible exchange rate regime.

Among the possible extensions of our study, two are worth mentioning. First, we have only considered optimal monetary policy under full commitment. Second, we did not explore a richer set of instruments for the monetary and tax authorities, including the potential interaction of tariff policy and monetary policy facing a Foreign tariff shock. We leave these avenues for future research.

[22] In terms of trade dynamics, we find a negative correlation between variety and quality for both imports and exports. Specifically, when the U.S. increase tariffs on imported goods, the U.S. trading partner countries tend to decrease the variety of both imported and exported goods, but increase the quality of such traded goods. In terms of quantity, the U.S. trading partner countries run a deficit in their net export on impact, which reverts in the medium-term.

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APPENDIX

A Complements to the theory

In this section, we provide the following complements to Sections 2 and 3: (i) we describe the equilibrium wage in the simple model; and (ii) we provide the detailed derivation the extended model of Section 3.

A.1 Equilibrium wage in the simple model

With $P^*_{H,t} = n^{\frac{1}{\sigma-1}} N^{-\psi}_{X,t} \tau^*_{M,t} \widetilde{\rho}_{X,t}$, $V^*_{H,t} \equiv N^{\psi-\frac{1}{\sigma-1}}_{X,t}$ and using the optimal demand, the average dividens from exporting is expressed as

$$\tilde{D}_{X,t} = \frac{\varepsilon_t}{\sigma} \frac{\nu^* (1-n) P^*_t C^*_t}{\tau^*_{M,t} N_{X,t}} - W_t f_{X,t} \quad (10)$$

With the cutoff condition, $\tilde{D}_{X,t} = W_t f_X \frac{\sigma-1}{\kappa-(\sigma-1)}$, we get

$$\tilde{D}_{X,t} = \frac{\sigma-1}{\kappa} \frac{\varepsilon_t}{\sigma} \frac{\nu^* (1-n) P^*_t C^*_t}{\tau^*_{M,t} N_{X,t}}$$

This gives the solutin for $\tilde{D}_{X,t}$ given $N_{X,t}$, ε_t and $P^*_t C^*_t$. is solved using (10) and (2) as

$$N_{X,t} = \frac{\sigma-1}{\sigma} \left(\frac{1}{\sigma-1} - \frac{1}{\kappa} \right) \frac{\nu^* (1-n) \varepsilon_t P^*_t C^*_t}{\tau^*_{M,t} W_t f_{X,t}}$$

which gives the solution of $N_{X,t}$ given W_t, ε_t and $P^*_t C^*_t$.

Finally, noting that $\widetilde{y}_{X,t} = \frac{\sigma\left(\tilde{D}_{X,t} + W_t f_{X,t}\right)}{\varepsilon_t p_{D,t}\left(\tilde{z}_{X,t}\right)} = \frac{\sigma-1}{\sigma} \frac{\tilde{z}_{X,t} \nu^* (1-n) \varepsilon_t P^*_t C^*_t}{W_t N_{X,t} \tau^*_{M,t}}$ and $\widetilde{y}_{D,t} = \frac{\sigma-1}{\sigma} \frac{n \nu \mu_t}{N_{D,t}} \frac{\tilde{z}_D}{W_t}$. By plugging these expression in the labor market clearing condition (6), we get equation (9).

A.2 Proof of Proposition 1

Proof. With $\frac{\partial W^{FL}_t}{\partial \tau^*_{M,t}} / \frac{W^{FL}_t}{\tau^*_{M,t}} < 0$ and $\frac{\partial N^{FL}_{X,t}}{\partial \tau^*_{M,t}} / \frac{N^{FL}_{X,t}}{\tau^*_{M,t}} < 0$, we have $\frac{\partial \widetilde{z}^{FL}_{X,t}}{\partial \tau^*_{M,t}} / \frac{\widetilde{z}^{FL}_{X,t}}{\tau^*_{M,t}} = \frac{\partial \widetilde{y}^{FL}_{X,t}}{\partial \tau^*_{M,t}} / \frac{\widetilde{y}^{FL}_{X,t}}{\tau^*_{M,t}} = -\frac{1}{\kappa} \frac{\partial N^{FL}_{X,t}}{\partial \tau^*_{M,t}} / \frac{N^{FL}_{X,t}}{\tau^*_{M,t}} > 0$ and $\frac{\partial \widetilde{y}^{FL}_{D,t}}{\partial \tau^*_{M,t}} / \frac{\widetilde{y}^{FL}_{D,t}}{\tau^*_{M,t}} = -\frac{\partial W^{FL}_t}{\partial \tau^*_{M,t}} / \frac{W^{FL}_t}{\tau^*_{M,t}} > 0$. Further, since $\frac{\partial P^{FL}_{H,t}}{\partial \tau^*_{M,t}} / \frac{P^{FL}_{H,t}}{\tau^*_{M,t}} = \frac{\partial W^{FL}_t}{\partial \tau^*_{M,t}} / \frac{W^{FL}_t}{\tau^*_{M,t}} < 0$, we have $\frac{\partial C^{FL}_t}{\partial \tau^*_{M,t}} / \frac{C^{FL}_t}{\tau^*_{M,t}} = -\nu \frac{\partial P^{FL}_{H,t}}{\partial \tau^*_{M,t}} / \frac{P^{FL}_{H,t}}{\tau^*_{M,t}} > 0$.

Following a rise in $\tau^*_{M,t}$, we have $\frac{\partial W^*_t}{\partial \tau^*_{M,t}} / \frac{W^*_t}{\tau^*_{M,t}} = 0$. The price index of imported goods in the foreign country changes as $\frac{\partial P^{*FL}_H}{\partial \tau^*_{M,t}} / \frac{P^{*FL}_H}{\tau^*_{M,t}} = -\frac{1}{\sigma-1} \frac{\partial N^{FL}_{X,t}}{\partial \tau^*_{M,t}} / \frac{N^{FL}_{X,t}}{\tau^*_{M,t}} + \frac{\partial \tau^*_{M,t}}{\partial \tau^*_{M,t}} / \frac{\tau^*_{M,t}}{\tau^*_{M,t}} - \frac{\partial \widetilde{z}^{FL}_{X,t}}{\partial \tau^*_{M,t}} / \frac{\widetilde{z}^{FL}_{X,t}}{\tau^*_{M,t}} = 1 - \left(\frac{1}{\sigma-1} - \frac{1}{\kappa}\right) \frac{\partial N^{FL}_{X,t}}{\partial \tau^*_{M,t}} / \frac{N^{FL}_{X,t}}{\tau^*_{M,t}} > 0$. As a result, we have $\frac{\partial C^{*FL}_t}{\partial \tau^*_{M,t}} / \frac{C^{*FL}_t}{\tau^*_{M,t}} = -\nu^* \frac{\partial P^{*FL}_H}{\partial \tau^*_{M,t}} / \frac{P^{*FL}_H}{\tau^*_{M,t}} < 0$, $\quad \frac{\partial L^{*FL}_t}{\partial \tau^*_{M,t}} / \frac{L^{*FL}_t}{\tau^*_{M,t}} = 0$ $\square$

A.3 Proof of Proposition 2

Proof. Under nominal rigidities, we have $\frac{\partial N_{X,t}}{\partial \tau^*_{M,t}} / \frac{N_{X,t}}{\tau^*_{M,t}} = -1 < \frac{\partial N^{FL}_{X,t}}{\partial \tau^*_{M,t}} / \frac{N^{FL}_{X,t}}{\tau^*_{M,t}} < 0$, $0 < \frac{\partial \widetilde{z}^{FL}_{X,t}}{\partial \tau^*_{M,t}} / \frac{\widetilde{z}^{FL}_{X,t}}{\tau^*_{M,t}} = \frac{\partial \widetilde{y}^{FL}_{X,t}}{\partial \tau^*_{M,t}} / \frac{\widetilde{y}^{FL}_{X,t}}{\tau^*_{M,t}} < \frac{\partial \widetilde{z}_{X,t}}{\partial \tau^*_{M,t}} / \frac{\widetilde{z}_{X,t}}{\tau^*_{M,t}} = \frac{\partial \widetilde{y}_{X,t}}{\partial \tau^*_{M,t}} / \frac{\widetilde{y}_{X,t}}{\tau^*_{M,t}}$, and therefore $\frac{\partial P^{FL}_{H,t}}{\partial \tau^*_{M,t}} / \frac{P^{FL}_{H,t}}{\tau^*_{M,t}} < \frac{\partial P_{H,t}}{\partial \tau^*_{M,t}} / \frac{P_{H,t}}{\tau^*_{M,t}} = 0$, $\frac{\partial P_{F,t}}{\partial \tau^*_{M,t}} / \frac{P_{F,t}}{\tau^*_{M,t}} = 0$ in the home country. In the foreign country, we have $\frac{\partial P^*_{H,t}}{\partial \tau^*_{M,t}} / \frac{P^*_{H,t}}{\tau^*_{M,t}} > \frac{\partial P^{*FL}_{H,t}}{\partial \tau^*_{M,t}} / \frac{P^{*FL}_{H,t}}{\tau^*_{M,t}} > 0$, and $\frac{\partial P^*_{F,t}}{\partial \tau^*_{M,t}} / \frac{P^*_{F,t}}{\tau^*_{M,t}} = 0$. Given these changes in the price indices, we have $\frac{\partial C^{FL}_t}{\partial \tau^*_{M,t}} / \frac{C^{FL}_t}{\tau^*_{M,t}} > \frac{\partial C_t}{\partial \tau^*_{M,t}} / \frac{C_t}{\tau^*_{M,t}} = 0$ and $\frac{\partial C^*_t}{\partial \tau^*_{M,t}} / \frac{C^*_t}{\tau^*_{M,t}} < \frac{\partial C^{*FL}_t}{\partial \tau^*_{M,t}} / \frac{C^{*FL}_t}{\tau^*_{M,t}} < 0$. □

A.4 Proof of Proposition 3

Proof. By deriving the expected utility $\mathrm{E}_{t-1}[\mathcal{U}]$ with respect to μ_t , we get the following optimal monetary policy rule against stochastic foreign tariffs.

$$\mu_t = \frac{\left\{ E_{t-1}\left[(A_t \mu_t)^{1+\varphi} \right] \right\}^{\frac{1}{1+\varphi}}}{A_t} \tag{11}$$

which is an increasing function with respect to $\tau^*_{M,t}$ such that

$$\frac{\partial \mu_t}{\partial \tau^*_{M,t}} / \frac{\mu_t}{\tau^*_{M,t}} = \frac{1}{\frac{\tau^*_M}{\left(1+\frac{1}{\sigma-1}-\frac{1}{\kappa}\right)} \left(\frac{1}{(1-n)\alpha} - 1 \right) + 1} > 0$$

□

B The extended model

In this section, we extend the simple model presented previously to a more general set up. The purpose of this extensions is to show the mechanism demonstrated analytically in a quantitative model. Our extensions are as follows. 1) Use a more general preference as a CES, 2)inclusion of product quality, 3)Introduce investment as firm creations, 4) A more general wage setting process a la Calvo, 5) Monetary policies as a standard Taylor rule 6) International bond holdings and the resulting current account dynamics. In the presentation, we focus on these points.

B.1 Household Preferences and Intratemporal Choices

In stead of the Cobb-Douglas aggregator, we assume a more general CES preference. The consumption $C_t(j)$ is composed from goods produced in the home economy $C_{H,t}(j)$ and those imported from the foreign economy $C_{F,t}(j)$:

$$C_t(j) = \left[\nu^{\frac{1}{\sigma}} C_{H,t}(j)^{1-\frac{1}{\sigma}} + (1-\nu)^{\frac{1}{\sigma}} C_{F,t}(j)^{1-\frac{1}{\sigma}} \right]^{\frac{1}{1-\frac{1}{\sigma}}},$$

where $\sigma\,(>0)$ denotes the elasticity of substitution across product varieties. Following De Paoli (2009), we assume that $1-\nu=(1-n)\,\alpha$ with $1-n$ is the relative size of Foreign economy and α is the openness.

$$C_t^*(j)=\left[(1-\nu^*)^{\frac{1}{\sigma}}\,C_{F,t}^*(j)^{1-\frac{1}{\sigma}}+\nu^{*\frac{1}{\sigma}}C_{H,t}^*(j)^{1-\frac{1}{\sigma}}\right]^{\frac{1}{1-\frac{1}{\sigma}}},$$

where $\nu^*=n\alpha$.

Furthermore, these baskets are defined over a continuum of goods Ω as

$$C_{H,t}(j)=V_{H,t}\left(\left(\frac{1}{n}\right)^{\frac{1}{\sigma}}\int_{\zeta\in\Omega}\left(q_D(\zeta)c_{D,t}(\zeta,j)\right)^{1-\frac{1}{\sigma}}d\zeta\right)^{\frac{1}{1-\frac{1}{\sigma}}},\quad C_{F,t}(j)=V_{F,t}^*\left(\left(\frac{1}{1-n}\right)^{\frac{1}{\sigma}}\int_{\vartheta\in\Omega}\left(q_X^*(\vartheta)c_{X,t}(\vartheta,j)\right)^{1-\frac{1}{\sigma}}d\vartheta\right)$$

where $\psi\,(\geq 0)$ determines the marginal utility that stems from one additional increase in the number of varieties in each basket (Benassy, 1996). Specifically, the preference becomes the one discussed in Dixit and Stiglitz (1977) when $\psi=\frac{1}{\sigma-1}$. At any given time t, only a subset of goods Ω_t is available from total universe of goods Ω. $c_{D,t}(\zeta,j)$ and $c_{X,t}(\vartheta,j)$ represent the demand addressed for individual product variety ζ produced domestically and that for imported product variety ϑ, respectively. $q_{D,t}(\zeta)$ and $q_{X,t}^*(\vartheta)$ indicate the quality of these product varieties.

The optimal demand for domestic basket, imported basket and individual home product variety and foreign product variety are found as

$$C_{H,t}(j)=\left(\frac{P_{H,t}}{P_t}\right)^{-\sigma}\nu C_t(j),\quad C_{F,t}(j)=\left(\frac{P_{F,t}}{P_t}\right)^{-\sigma}(1-\nu)\,C_t(j),$$

$$c_{D,t}(\zeta,j)=\left(V_{H,t}q_{D,t}(\zeta)\right)^{\sigma-1}\left(\frac{p_{D,t}(\zeta)}{P_{H,t}}\right)^{-\sigma}\frac{1}{n}C_{H,t}(j),\quad c_{X,t}(\vartheta,j)=\left(V_{F,t}^*q_{X,t}^*(\vartheta)\right)^{\sigma-1}\frac{1}{1-n}\left(\frac{\tau_{M,t}p_{X,t}^*(\vartheta)}{P_{F,t}}\right)^{-\sigma}C_{F,t}(j).$$

where $p_{D,t}(\zeta)$ and $p_{X,t}^*(\vartheta)$ stand for the price of home product variety ζ and imported product variety ϑ. Both prices are denominated in home currency. $\tau_{M,t}\,(\geq 1)$ is an ad-varolem import tariffs charged on the dock price $p_{X,t}^*(\vartheta)$. P_t, $P_{H,t}$ and $P_{F,t}$ stand for the price indices that minimize expenditures. These are defined as

$$P_t=\left[\nu P_{H,t}^{1-\sigma}+(1-\nu)\,P_{F,t}^{1-\sigma}\right]^{\frac{1}{1-\sigma}},$$

$$P_{H,t}=\frac{1}{V_{H,t}}\left(\frac{1}{n}\int_{\zeta\in\Omega_t}\left(\frac{p_{D,t}(\zeta)}{q_{D,t}(\zeta)}\right)^{1-\sigma}d\zeta\right)^{\frac{1}{1-\sigma}},\quad P_{F,t}=\frac{1}{V_{F,t}^*}\left(\frac{1}{1-n}\int_{\vartheta\in\Omega_t}\left(\frac{\tau_{M,t}p_{X,t}^*(\vartheta)}{q_{X,t}^*(\vartheta)}\right)^{1-\sigma}d\vartheta\right)^{\frac{1}{1-\sigma}}.$$

Observe that the price indices defined on a welfare basis depending on both the number of product varieties and their product qualities. Finally, we choose the consumer price index, P_t, as numéraire for the home economy and define the real prices as $\rho_{H,t} \equiv \frac{p_{H,t}}{P_t}$, $\rho_{F,t} \equiv \frac{p_{F,t}}{P_t}$, $\rho_{D,t}(\zeta) \equiv \frac{p_{D,t}(\zeta)}{P_t}$ and $\rho^*_{X,t}(\vartheta) \equiv \frac{p^*_{X,t}(\vartheta)}{P_t}$.

Similar expressions hold for the foreign economy. Crucially, the subset of product varieties and their qualities available to the foreign households during period t, $\Omega^*_t \in \Omega$, can be different from those available to the home households.

B.2 Production, Pricing and the Export Decision

Firms are heterogeneous in terms of their specific productivities and produce differentiated product varieties in monopolistically competitive markets. Upon entry, firms draw their productivity level z from a distribution $G(z)$ over $[z_{\min}, \infty)$ where $z_{\min}$ denotes the minimum productivity level. We assume that the production of product variety with higher quality requires higher marginal costs. The real marginal cost of the firm with productivity level z is specified as

$$mc_t(z) = \left(1 + \frac{q(z)^{\frac{1}{\varrho}}}{z}\right)\frac{w_t}{Z_t z},$$

where $\varrho\,(0 \leq \varrho < 1)$ determines "quality ladder" in the economy and w_t denotes the real wage. Given a firm-specific productivity level z, the firm endogenously chooses its specific quality level $q(z)$ by minimizing the quality-adjusted marginal cost $mc_t(z)/q(z)$. The optimal quality chosen by the firm with productivity level z is given by

$$q(z) = \left(\frac{\varrho}{1-\varrho}z\right)^{\varrho}.$$

Firms with high productivities therefore produce product varieties with high qualities. Note that when there is no quality ladder ($\varrho = 0$), firms produce differentiated product varieties with identical quality such that $q(z) = q = 1$.

The firm with productivity level z faces a residual demand curve with constant elasticity σ. The profit maximization by the firm yields

$$\rho_{D,t}(z) = \frac{\sigma}{\sigma - 1} mc_t(z),$$

where $\rho_{D,t}(z)$ stands for the real price of the product variety produced by the firm with productivity level z. Exporting requires fixed costs f_X paid in terms of composite labor units. Consequently, only a subset of firms whose productivity level z is above the cutoff level $z_{X,t}$ exports by charging sufficiently lower quality-adjusted prices and thus earning positive profits despite the existence of fixed costs for exporting f_X. If the firm exports, its real export price is $\rho_{X,t}(z) = \tau\rho_{D,t}(z)Q_t^{-1}$ where τ is iceberg trade costs. Q_t is the real exchange rate defined as the price of foreign consumption goods in terms of home consumption goods, i.e., $Q_t \equiv \varepsilon_t P^*_t/P_t$ where ε_t is the nominal exchange rate defined as the price of one unit foreign currency in terms of home currency units.

The total profits of the firm with productivity level z is those from domestic sales $d_{D,t}(z)$ and those from exporting sales $d_{X,t}(z)$ such that $d_t(z) = d_{D,t}(z) + d_{X,t}(z)$. Using the optimal demand functions found previously, we can write the real profits from domestic markets and exporting as

$$d_{D,t}(z) = \frac{1}{\sigma} N_{D,t}^{\psi(\sigma-1)-1} \left(\frac{\rho_{D,t}(z)}{q(z)} \right)^{1-\sigma} \nu C_t,$$

$$d_{X,t}(z) = \frac{Q_t}{\sigma} N_{X,t}^{\psi(\sigma-1)-1} \tau_{M,t}^{*-\sigma} \left(\frac{\rho_{X,t}(z)}{q(z)} \right)^{1-\sigma} \frac{\nu^*(1-n)}{n} C_t^* - \frac{w_t f_X}{Z_t}, \text{ if firm } z \text{ exports, otherwise } d_{X,t}(z) = 0.$$

Similar expressions hold for the foreign country.[23][24] Note that in the setup of a small open economy, i.e., $n \to 0$, we have

$$d_{D,t}(z) = \frac{1}{\sigma} N_{D,t}^{\psi(\sigma-1)-1} \left(\frac{\rho_{D,t}(z)}{q(z)} \right)^{1-\sigma} (1-\alpha) C_t,$$

$$d_{X,t}(z) = \frac{Q_t}{\sigma} N_{X,t}^{\psi(\sigma-1)-1} \tau_{M,t}^{*-\sigma} \left(\frac{\rho_{X,t}(z)}{q(z)} \right)^{1-\sigma} \alpha C_t^* - \frac{w_t f_X}{Z_t}, \text{ if firm } z \text{ exports, otherwise } d_{X,t}(z) = 0$$

[25]

Given the average productivity level $\tilde{z}_D$ for domestically producing firms and $\tilde{z}_{X,t}$ for exporters, we define the average real domestic and exporting price as $\tilde{\rho}_{D,t} \equiv \rho_{D,t}(\widetilde{z}_D)$ and $\tilde{\rho}_{X,t} \equiv \rho_{X,t}\left(\tilde{z}_{X,t}\right)$, respectively. Similarly, the average domestic and average exporting quality are defined as $\tilde{q}_D \equiv q_D(\tilde{z}_D)$ and $\tilde{q}_{X,t} \equiv q_{X,t}\left(\tilde{z}_{X,t}\right)$, respectively. We also define the average real profit from domestic sales and exporting sales as $\tilde{d}_{D,t} \equiv d_{D,t}(\tilde{z}_D)$ and $\tilde{d}_{X,t} \equiv d_{X,t}\left(\tilde{z}_{X,t}\right)$. Finally, the average real profit among all home producers is given by $\tilde{d}_t = \tilde{d}_{D,t} + \left(N_{X,t}/N_{D,t}\right)\tilde{d}_{X,t}$.

Similar expressions hold for the foreign country.

[23] Note that intensive margins of trade are defined as $d_{X,t}(z) = \frac{Q_t}{\sigma}\rho_{X,t}(z)\, y_{X,t}(z) - \frac{w_t f_X}{Z_t}$

[24] For Foreign firms,

$$d_{D,t}^*(z) = \frac{1}{\sigma} N_{D,t}^{*\psi(\sigma-1)-1} \left(\frac{\rho_{D,t}^*(z)}{q^*(z)} \right)^{1-\sigma} (1-\nu^*) C_t^*,$$

$$d_{X,t}^*(z) = \frac{Q_t^{-1}}{\sigma} N_{X,t}^{*\psi(\sigma-1)-1} \tau_{M,t}^{-\sigma} \left(\frac{\rho_{X,t}^*(z)}{q^*(z)} \right)^{1-\sigma} \frac{(1-\nu)n}{1-n} C_t - \frac{w_t^* f_X^*}{Z_t^*}, \text{ if firm } z \text{ exports.}$$

[25] For Foreign firms,

$$d_{D,t}^*(z) = \frac{1}{\sigma} N_{D,t}^{*\psi(\sigma-1)-1} \left(\frac{\rho_{D,t}^*(z)}{q^*(z)} \right)^{1-\sigma} C_t^*,$$

$d_{X,t}^*(z) = 0$, since all firms get negative profits.

B.3 Firm Entry and Exit

Prior to entry, firms are identical and face sunk entry costs f_E which are defined as

$$f_E = Z_t l_{E,t},$$

where $l_{E,t}$ is the demand for composite labor units for entry.

Firms produce unless they are hit by an exogenous depreciation shock, which takes place with probability $\delta \in (0, 1)$ in every period. This exit-inducing shock is independent of firm-specific productivity and assumed to take place at the very end of the period. We assume that entrants at time t only start producing at time $t + 1$. These entrants discount the stream of their expected profits $\left\{ \tilde{d}_s \right\}_{s=t+1}^{\infty}$

Firm entry occurs until this expected post-entry firm value $\tilde{v}_t$ is equalized with the entry cost, leading to the following free entry condition:

$$\tilde{v}_t = \frac{w_t}{Z_{E,t}} f_E \left(\frac{N_{E,t}}{N_{E,t-1}} \right)^{\omega}.$$

where $\omega\,(> 0)$ captures the congestion and hence the adjustment costs for firm entry dynamics as in Bergin et al. (2018). Finally, the timing of entry and production implies that the number of domestically producing firms evolves according to $N_{D,t} = (1 - \delta) \left(N_{D,t-1} + N_{E,t-1}\right)$.

Similar conditions hold for the foreign economy.

B.4 Household Budget Constraint and Intertemporal Choices

The home household j maximizes her expected intertemporal utility, $E_t \sum_{s=t}^{\infty} \beta^{s-t} U_t(j)$, where $\beta\,(0 < \beta < 1)$ is an exogenous discount factor. The home household j finances entry costs for new entrants $N_{E,t}$ and all producing firms $N_{D,t}$ in the home country at time t by purchasing a share of home equities $s_{h,t+1}(j)$ through a mutual fund. In addition to domestically issued equities, the household holds bonds $b_{h,t+1}(j)$ and $b_{f,t+1}(j)$ issued in the home and foreign country at time t, respectively. The budget constraint of the home household j expressed in home consumption units is thus given by

$$\begin{aligned} C_t(j) + \widetilde{v}_t \left(N_{D,t} + N_{E,t}\right) s_{h,t+1}(j) + b_{h,t+1}(j) + Q_t b_{f,t+1}(j) + \frac{\vartheta}{2} b_{h,t+1}^2(j) + \frac{\vartheta}{2} Q_t b_{f,t+1}^2(j) = \\ (1 + \nu)\, w_t(j) L_t(j) + N_{D,t} \left(\widetilde{v}_t + \widetilde{d}_t\right) s_{h,t}(j) + (1 + r_t)\, b_{h,t}(j) + \left(1 + r_t^*\right) Q_t b_{f,t}(j) + T_t^f + T_t. \quad (12) \end{aligned}$$

where ϑ stands for quadratic adjusting costs for bond holdings ϑ and T_t^f is the free rebate of these adjusting costs. ν is the subsidy for labor income. T_t is the lamp-sum transfer for all tax revenues of the government. r_t and $r_t^*$are the real returns between t and $t - 1$ of home and foreign bonds expressed in home consumption units such that

$$1+r_t \equiv \frac{1+i_t}{1+E_t\left[\pi_{C,t+1}\right]}, \quad 1+r_t^* \equiv \frac{1+i_t^*}{1+E_t\left[\pi_{C,t+1}^*\right]},$$

where i_{t-1} and i_{t-1}^* are the nominal interest rate at time $t-1$ in the home and foreign country. $\pi_{C,t}$ and $\pi_{C,t}^*$ are the inflation rate between time t and $t-1$ in the home and foreign country, respectively.

The household maximizes the expected intertemporal utility with respect to $s_{h,t+1}(j)$, $b_{h,t+1}(j)$, $b_{f,t+1}(j)$ and $C_t(j)$ subject to (12) for all time periods. The first order condition with respect to equity holdings gives[26]

$$\tilde{v}_t = \beta E_t\left[\left(\frac{C_{t+1}(j)}{C_t(j)}\right)^{-\gamma}\left(\tilde{v}_{t+1}+\tilde{d}_{t+1}\right)\right].$$

The first order conditions with respect to home and foreign bond holdings are

$$1+\vartheta b_{h,t+1}(j) = \beta E_t\left[\left(\frac{C_{t+1}(j)}{C_t(j)}\right)^{-\gamma}(1+r_{t+1})\right],\ 1+\vartheta b_{f,t+1}(j) = \beta E_t\left[\left(\frac{C_{t+1}(j)}{C_t(j)}\right)^{-\gamma}\left(1+r_{t+1}^*\right)\left(\frac{Q_t}{Q_{t+1}}\right)^{-1}\right].$$

Wages are assumed to be sticky a la Calvo (1991) and only a fraction of $1-\lambda$ households re-optimize their wage rates knowing the labor demand addressed to them. The cost minimization problem of firms yields the following labor demand for type j labor service:

$$L_t(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\theta} L_t, \tag{13}$$

where W_t denotes the corresponding nominal wage index defined as

$$W_t = \left(\int_0^1 W_t(j)^{1-\theta} dj\right)^{\frac{1}{}}.$$

The household maximizes her expected intertemporal utility by setting her pre set wage $W_t'(i)$. This yields the following first order condition:

$$\left(\frac{W_t'(j)}{W_t}\right)^{1+\varphi\theta} = \frac{\frac{\eta\theta}{(\theta-1)(1+\nu)}\sum_{s=0}^{\infty}(\beta\lambda)^s E_t\left[\left(\frac{W_{t+s}}{W_t}\right)^{\theta(1+\varphi)} L_{t+s}^{1+\varphi}\right]}{\sum_{s=0}^{\infty}(\beta\lambda)^s E_t\left[\frac{1}{C_{t+k}}\frac{W_{t+s}}{P_{t+s}}\left(\frac{W_{t+s}}{W_t}\right)^{\theta-1} L_{t+s}\right]}. \tag{14}$$

[26]Using these equilibrium conditions, the post-entry value of firm is expressed as

$$\tilde{v}_t = E_t\sum_{s=t+1}^{\infty}\beta^{s-t}\left(\frac{C_s(j)}{C_t(j)}\right)^{-\gamma}(1-\delta)^{s-t}\tilde{d}_s$$

Also since $W_t = \left(\int_0^1 W_t(j)^{1-\theta} dj \right)^{\frac{1}{1-\theta}}$, by the low of large number, wage is determined as

$$W_t^{1-\theta} = \lambda W_{t-1}^{1-\theta} + (1-\lambda) W_t^{'1-\theta}$$

Expressed with wage inflation, it becomes

$$\lambda \left(1 + \pi_{w,t}\right)^{\theta-1} + (1-\lambda) \left(\frac{W_t'}{W_t} \right)^{1-\theta} = 1.$$

Similar conditions hold for the foreign country.

B.5 General Equilibrium and Net Foreign Asset Dynamics

In equilibrium, there is a symmetry across households such that $C_t(j) = C_t$, $L_t(j) = L_t$ and $W_t(j) = W_t$.

The wage markup μ_t^w is determined by the following equation:

$$w_t = \mu_{w,t} \eta L_t^{\varphi} C_t^{\gamma}.$$

Furthermore, there exists a link between wage inflation and welfare-consistent inflation as

$$\frac{w_t}{w_{t-1}} = \frac{1 + \pi_{w,t}}{1 + \pi_{C,t}}.$$

Supplied labor units nL_t are demanded for fixed costs of exporting, production of goods and firm creation. This implies the following labor market clearing condition:

$$nL_t = \frac{N_{E,t}\tilde{v}_t}{w_t} + (\sigma - 1) \frac{N_{D,t}\tilde{d}_t}{w_t} + \sigma N_{X,t} \frac{f_X}{Z_t}$$

Finally, we discuss the implication of the international bonds. Net foreign assets (in Home consumption units) at the end of period t is defined as

$$NFA_{t+1} \equiv b_{f,t+1} Q_t - b_{h,t+1}^*.$$

where $b_{h,t+1}^*$ stands for the home bonds held by foreign households. Since there are no cross-border equity holdings by assumption, only cross-border bond holdings appear in the above expression. With the above expression of net foreign assets, the budget constraint (\ref{peb}) can be rewritten and provides the following net foreign asset dynamics:[27]

$$NFA_{t+1} - NFA_t = NX_t + r_t b_{h,t} + r_t^* Q_t b_{f,t},$$

where NX_t denotes net exports which are given by

[27] Note that changes in the net foreign assets are defined with current accounts as $CA_t \equiv NX_t + r_t b_{h,t} + r_t^* Q_t b_{f,t}$

$$NX_t \equiv \frac{1}{2}\left[w_t n L_t + N_{D,t}\widetilde{d}_t - Q_t\left(w_t^*\left(1-n\right)L_t^* + N_{D,t}^*\widetilde{d}_t^*\right)\right] - \frac{1}{2}\left[\left(nC_t + N_{E,t}\widetilde{v}_t\right) - Q_t\left(\left(1-n\right)C_t^* + N_{E,t}^*\widetilde{v}_t^*\right)\right]$$

Note that excess returns are zero in the first-order dynamics because of zero bond holdings due to adjustment costs in the steady state. Finally, asset markets clear in all periods as

$$b_{h,t+1} + b_{h,t+1}^* = b_{f,t+1} + b_{f,t+1}^* = 0,$$

where $b_{f,t+1}^*$ represents the holdings of bonds issued in Foreign and held by Foreign households.

B.6 Monetary Policy

GDP is defined as $Y_t \equiv w_t L_t + N_{D,t}\tilde{d}_t$ and Y_t^f is GDP under flexible prices. We specify the following Taylor rule:

$$1 + i_t = \left(1 + i_{t-1}\right)^{\phi_i}\left[\left(1 + i\right)\left(\frac{\tilde{P}_t}{\tilde{P}_{t-1}}\right)^{\phi_\pi}\left(\frac{\tilde{Y}_t}{\tilde{Y}_t^f}\right)^{\phi_Y}\right]^{1-\phi_i}, \tag{15}$$

where $\tilde{P}_t \equiv \left(N_{D,t} + N_{X,t}^*\right)^{\psi}\widetilde{q}_{X,t}^* P_t$ is the average nominal price between domestically produced goods and imported goods in the home country.[28] i stands for the nominal interest rate in the non-stochastic steady state. The nominal interest rate is thus set according to the past nominal rate, the average inflation and the output gap where $\tilde{Y}_t$ and $\tilde{Y}_t^f$ stand for the data-consistent measure of GDP defined as $\tilde{Y}_t \equiv \frac{P_t Y_t}{\tilde{P}_t}$ and $\tilde{Y}_t^f \equiv \frac{P_t Y_t^f}{\tilde{P}_t}$, respectively. Finally, investment is defined as $Inv_t \equiv N_{D,t}\widetilde{v}_t$.

Similar expressions hold for the foreign country. The whole system is summarized in Table A1. Furthermore, similar to Barattieri et al. (2021), the home country is considered as a small open economy by assuming that foreign aggregate variables are determined as a closed economy except trade variables.

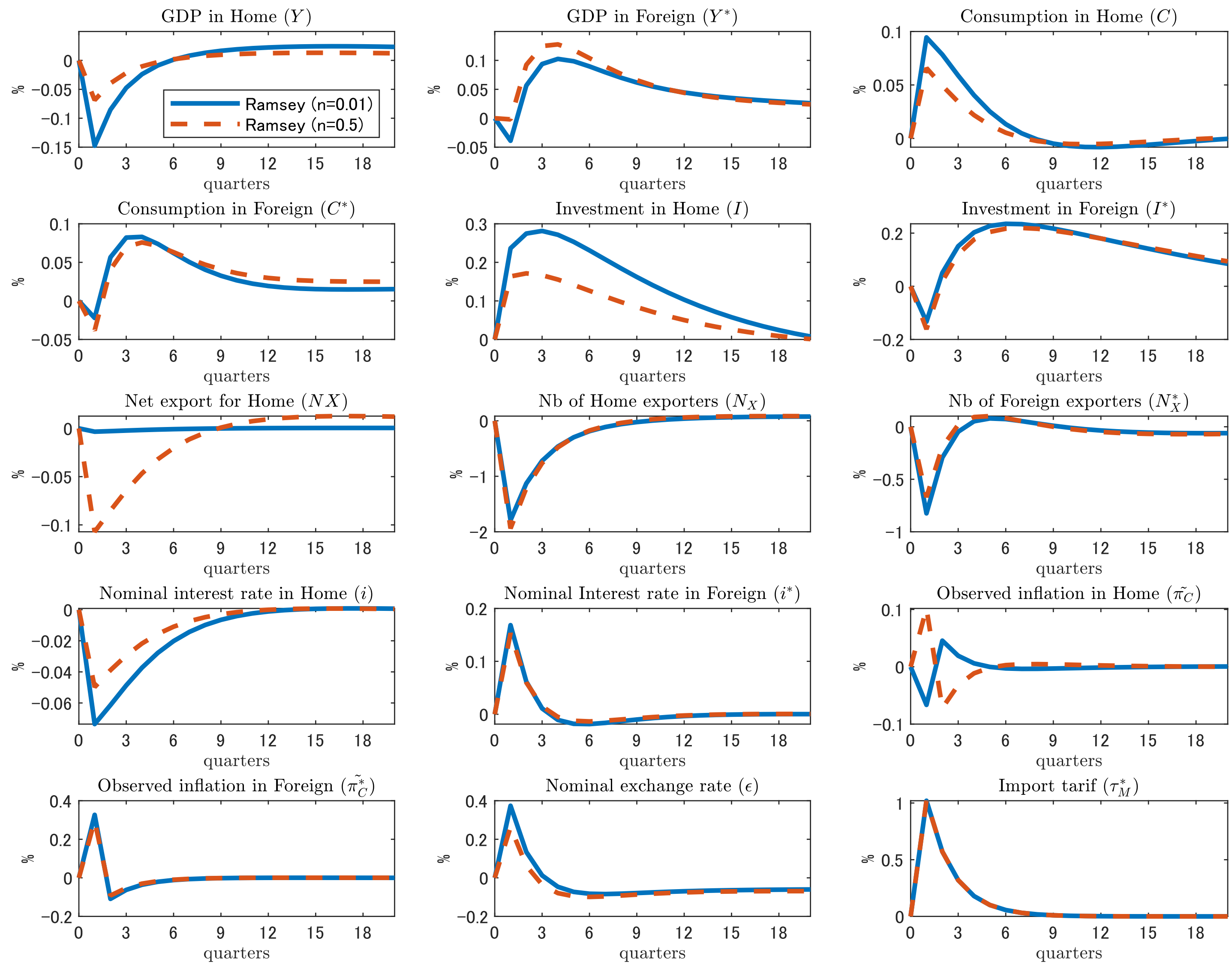
[28] We assume that statistical agencies capture imperfectly fluctuations in the number of product varieties and their qualities as Hamano and Vermeulen (2019):

$$\tilde{\pi}_{C,t} = \pi_{C,t} + \psi\left(\mathsf{N}_{D,t} - \mathsf{N}_{D,t-1}\right) + \psi\left(\mathsf{N}_{X,t}^* - \mathsf{N}_{X,t-1}^*\right) + \left(\tilde{\mathsf{q}}_{X,t}^* - \tilde{\mathsf{q}}_{X,t-1}^*\right).$$

Table A1: System of Equations

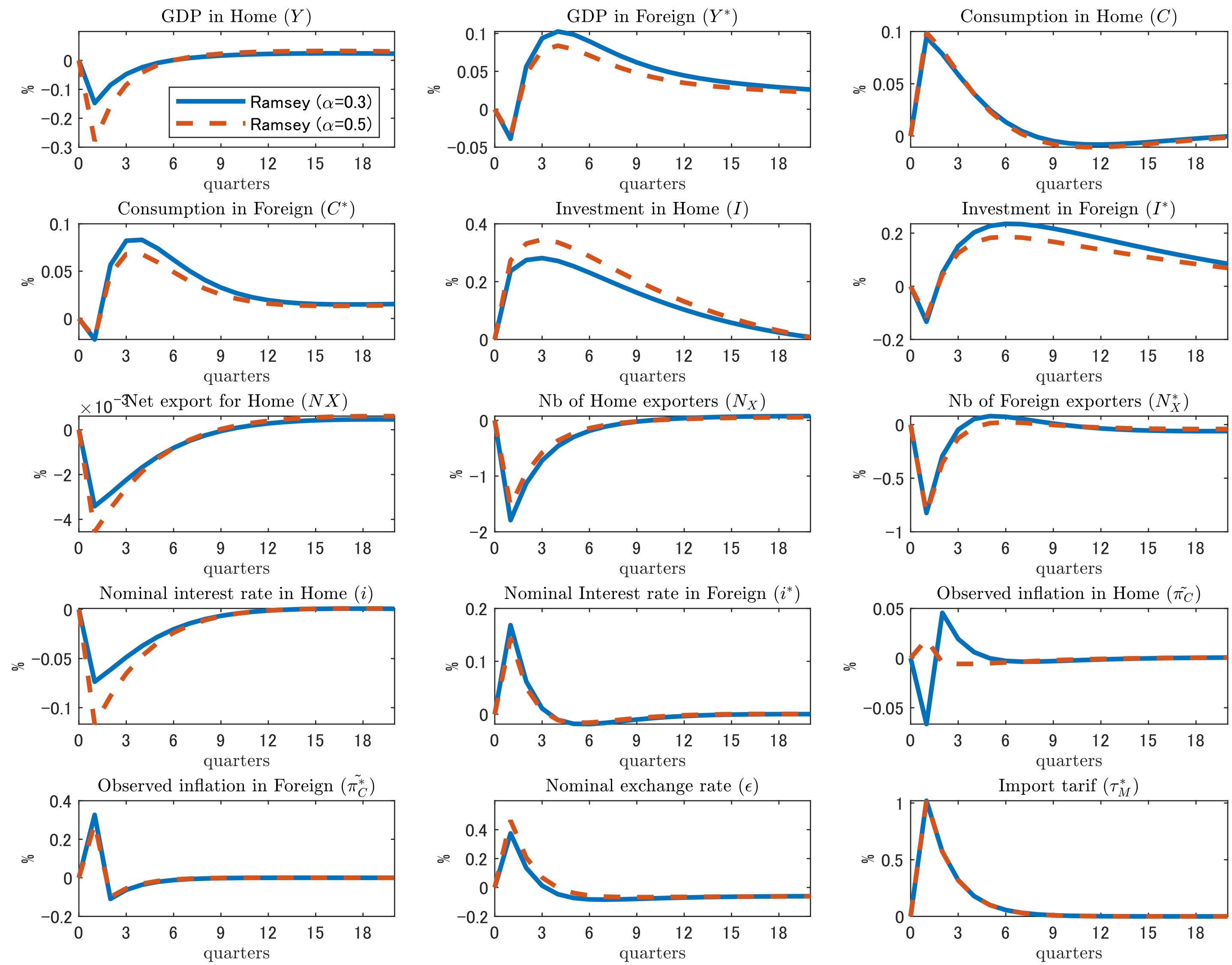
Price indices	$\nu\rho_{H,t}^{1-\sigma}+(1-\nu)\,\rho_{F,t}^{1-\sigma}=1,\ \rho_{H,t}=n^{\frac{1}{\sigma-1}}N_{D,t}^{-\psi}\frac{\widetilde{\rho}_{D,t}}{\widetilde{q}_D},\ \rho_{F,t}=(1-n)^{\frac{1}{\sigma-1}}\,N_{X,t}^{*-\psi}\frac{\tau_{M,t}\widetilde{\rho}^*_{X,t}}{\widetilde{q}^*_{X,t}}$
	$(1-\nu^*)\,\rho_{F,t}^{*1-\sigma}+\nu^*\rho_{H,t}^{*1-\sigma}=1,\ \rho^*_{F,t}=(1-n)^{\frac{1}{\sigma-1}}\,N_{D,t}^{*-\psi}\frac{\widetilde{\rho}^*_{D,t}}{\widetilde{q}^*_D},\ \rho^*_{H,t}=n^{\frac{1}{\sigma-1}}N_{X,t}^{-\psi}\frac{\tau^*_{M,t}\widetilde{\rho}_{X,t}}{\widetilde{q}_{X,t}}$
Pricing	$\widetilde{\rho}_{D,t}=\frac{\sigma}{\sigma-1}\frac{1}{1-\varrho}\frac{w_t}{Z_t\widetilde{z}_D},\ \widetilde{\rho}_{X,t}=\frac{\sigma}{\sigma-1}\frac{1}{1-\varrho}\frac{w_t}{Z_t\widetilde{z}_{X,t}}Q_t^{-1}\tau_t$
	$\widetilde{\rho}^*_{D,t}=\frac{\sigma}{\sigma-1}\frac{1}{1-\varrho}\frac{w_t}{Z^*_t\widetilde{z}^*_D},\ \widetilde{\rho}^*_{X,t}=\frac{\sigma}{\sigma-1}\frac{1}{1-\varrho}\frac{w^*_t}{Z^*_t\widetilde{z}^*_{X,t}}Q_t\tau_t$
Profits	$\widetilde{d}_t=\widetilde{d}_{D,t}+\frac{N_{X,t}}{N_{D,t}}\widetilde{d}_{X,t},\quad \widetilde{d}_{D,t}=\frac{1}{\sigma}N_{D,t}^{\psi(\sigma-1)-1}\left(\frac{\widetilde{\rho}_{D,t}}{\widetilde{q}_D}\right)^{1-\sigma}\nu C_t$
	$\widetilde{d}_{X,t}=\frac{Q_t}{\sigma}N_{X,t}^{\psi(\sigma-1)-1}\tau_{M,t}^{*-\sigma}\left(\frac{\widetilde{\rho}_{X,t}}{\widetilde{q}_{X,t}}\right)^{1-\sigma}\frac{\nu^*(1-n)}{n}C^*_t-\frac{w_tf_X}{Z_t}$
	$\widetilde{d}^*_t=\widetilde{d}^*_{D,t}+\frac{N^*_{X,t}}{N^*_{D,t}}\widetilde{d}^*_{X,t},\quad \widetilde{d}^*_{D,t}=\frac{1}{\sigma}N_{D,t}^{*\psi(\sigma-1)-1}\left(\frac{\widetilde{\rho}^*_{D,t}}{\widetilde{q}^*_D}\right)^{1-\sigma}(1-\nu^*)\,C^*_t$
	$\widetilde{d}^*_{X,t}=\frac{Q_t^{-1}}{\sigma}N_{X,t}^{*\psi(\sigma-1)-1}\tau_{M,t}^{-\sigma}\left(\frac{\widetilde{\rho}^*_{X,t}}{\widetilde{q}^*_{X,t}}\right)^{1-\sigma}\frac{(1-\nu)n}{1-n}C_t-\frac{w^*_tf^*_X}{Z^*_t}$
Free entry	$\tilde{v}_t=\frac{w_t}{Z_t}f_E\left(\frac{N_{E,t}}{N_{E,t-1}}\right)^{\omega},\qquad \tilde{v}^*_t=\frac{w^*_t}{Z^*_t}f^*_E\left(\frac{N^*_{E,t}}{N^*_{E,t-1}}\right)^{\omega}$
LMC	$w_tnL_t=N_{E,t}\tilde{v}_t+(\sigma-1)\,N_{D,t}\tilde{d}_t+\sigma N_{X,t}\frac{w_tf_X}{Z_t}$
	$w^*_t\,(1-n)\,L^*_t=N^*_{E,t}\tilde{v}^*{}_t+(\sigma-1)\,N^*_{D,t}\tilde{d}^*_t+\sigma N^*_{X,t}\frac{w^*_tf^*_X}{Z^*_t}$
Export share	$\frac{N_{X,t}}{N_{D.t}}=z_{\min}^{\kappa}\left(\widetilde{z}_{X,t}\right)^{-\kappa}\left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{\kappa}{\sigma-1}},\quad \frac{N^*_{X,t}}{N^*_{D,t}}=z_{\min}^{\kappa}\left(\widetilde{z}^*_{X,t}\right)^{-\kappa}\left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{\kappa}{\sigma-1}}$
ZCP	$\widetilde{d}_{X,t}=\frac{w_tf_X}{Z_t}\frac{\sigma-1}{\kappa-(\sigma-1)},\quad \widetilde{d}^*_{X,t}=\frac{w^*_tf^*_X}{Z^*_t}\frac{\sigma-1}{\kappa-(\sigma-1)}$
AEQ	$\widetilde{q}_{X,t}=\left(\frac{\varrho}{1-\varrho}\widetilde{z}_{X,t}\right)^{\varrho},\ \widetilde{q}^*_{X,t}=\left(\frac{\varrho}{1-\varrho}\widetilde{z}^*_{X,t}\right)^{\varrho},\ \widetilde{q}_D=\left(\frac{\varrho}{1-\varrho}\widetilde{z}_D\right)^{\varrho},\ \widetilde{q}^*_D=\left(\frac{\varrho}{1-\varrho}\widetilde{z}^*_D\right)^{\varrho}$
Nb of firms	$N_{D,t+1}=(1-\delta)\left(N_{D,t}+N_{E,t}\right),\ \ N^*_{D,t+1}=(1-\delta)\left(N^*_{D,t}+N^*_{E,t}\right)$
Euler shares	$\widetilde{v}_t=\beta E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\left(\widetilde{v}_{t+1}+\widetilde{d}_{t+1}\right)\right],\ \widetilde{v}^*_t=\beta E_t\left[\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\gamma}\left(\widetilde{v}^*_{t+1}+\widetilde{d}^*_{t+1}\right)\right]$
Euler bonds	$1+\vartheta b_{h,t+1}=\beta E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}(1+r_{t+1})\right],\ 1+\vartheta b^*_{f,t+1}=\beta E_t\left[\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\gamma}\left(1+r^*_{t+1}\right)\right]$
	$1+\vartheta b_{f,t+1}=\beta E_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\left(1+r^*_{t+1}\right)\left(\frac{Q_t}{Q_{t+1}}\right)^{-1}\right]$
	$1+\vartheta b^*_{h,t+1}=\beta E_t\left[\left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\gamma}(1+r_{t+1})\frac{Q_t}{Q_{t+1}}\right]$
Real rates	$1+r_t\equiv\frac{1+i_t}{1+E_t\left[\pi_{C,t+1}\right]},\quad 1+r^*_t\equiv\frac{1+i^*_t}{1+E_t\left[\pi^*_{C,t+1}\right]}$
BMC	$nb_{h,t+1}+(1-n)\,b^*_{h,t+1}=0,\ \ nb_{f,t+1}+(1-n)\,b^*_{f,t+1}=0.$
NFA	$NFA_{t+1}=nb_{f,t+1}Q_t+nb_{h,t+1}$
NFA dynamics	$NFA_{t+1}-NFA_t=NX_t+r_tnb_{h,t}+r^*_tQ_tnb_{f,t}$
Net exports	$NX_t=\frac{1}{2}\left[w_tnL_t+N_{D,t}\widetilde{d}_t-Q_t\left(w^*_t\,(1-n)\,L^*_t+N^*_{D,t}\widetilde{d}^*_t\right)\right]-\frac{1}{2}\left[\left(nC_t+N_{E,t}\widetilde{v}_t\right)-Q_t\left((1-n)\,C^*_t+N^*_{E,t}\widetilde{v}^*_t\right)\right]$
Def. Exchange Rate	$\frac{Q_t}{Q_{t-1}}=\frac{\varepsilon_t}{\varepsilon_{t-1}}\frac{1+\pi^*_{C,t}}{1+\pi_{C,t}}$
Wage markup definition	$w_t=\mu_{w,t}\eta L_t^{\varphi}C_t^{\gamma},\ w^*_t=\mu^*_{w,t}\eta L_t^{*\varphi}C_t^{*\gamma}$
Wage setting	$\left(\frac{W'_t}{W_t}\right)^{1+\varphi\theta}=\frac{\frac{\eta\theta}{(\theta-1)(1+\xi)}\sum_{s=0}^{\infty}(\beta\lambda)^sE_t\left[\left(\frac{W_{t+s}}{W_t}\right)^{\theta(1+\varphi)}L_{t+s}^{1+\varphi}\right]}{\sum_{s=0}^{\infty}(\beta\lambda)^sE_t\left[\frac{1}{C_{t+k}}\frac{W_{t+s}}{P_{t+s}}\left(\frac{W_{t+s}}{W_t}\right)^{\theta-1}L_{t+s}\right]},\quad \left(\frac{W^{*\prime}_t}{W^*_t}\right)^{1+\varphi\theta}=\frac{\frac{\eta\theta}{(\theta-1)(1+\xi)}\sum_{s=0}^{\infty}(\beta\lambda)^sE_t\left[\left(\frac{W^*_{t+s}}{W_t}\right)^{\theta(1+\varphi)}L_{t+s}^{*1+\varphi}\right]}{\sum_{s=0}^{\infty}(\beta\lambda)^sE_t\left[\frac{1}{C^*_{t+k}}\frac{W^*_{t+s}}{P^*_{t+s}}\left(\frac{W^*_{t+s}}{W^*_t}\right)^{\theta-1}L^*_{t+s}\right]}$
Wage dynamics	$\lambda\left(1+\pi_{w,t}\right)^{\theta-1}+(1-\lambda)\left(\frac{W'_t}{W_t}\right)^{1-\theta}=1,\quad \lambda\left(1+\pi^*_{w,t}\right)^{\theta-1}+(1-\lambda)\left(\frac{W^{*\prime}_t}{W^*_t}\right)^{1-\theta}=1$
CPI inflation	$\frac{w_t}{w_{t-1}}=\frac{1+\pi^w_t}{1+\pi_{C,t}},\quad \frac{w^*_t}{w^*_{t-1}}=\frac{1+\pi^{w*}_t}{1+\pi^*_{C,t}}$
Def. of Emp Price	$1+\tilde{\pi}_{C,t}=\left(\frac{N_{D,t}+N^*_{X,t}}{N_{D,t-1}+N^*_{X,t-1}}\right)^{\psi}\left(\frac{\widetilde{q}^*_{X,t}}{\widetilde{q}^*_{X,t-1}}\right)\left(1+\pi_{C,t}\right),\quad 1+\tilde{\pi}^*_{C,t}=\left(\frac{N^*_{D,t}+N_{X,t}}{N^*_{D,t-1}+N_{X,t-1}}\right)^{\psi}\left(\frac{\widetilde{q}_{X,t}}{\widetilde{q}_{X,t-1}}\right)\left(1+\pi^*_{C,t}\right)$
GDP	$Y_t=w_tnL_t+N_{D,t}\widetilde{d}_t,\ Y^*_t=w^*_t\,(1-n)\,L^*_t+N^*_{D,t}\widetilde{d}^*_t$
Policy	$1+i_t=(1+i_{t-1})^{\phi_i}\left[(1+i)\left(\frac{\tilde{P}_t}{\tilde{P}_{t-1}}\right)^{\phi_\pi}\left(\frac{Y_t}{Y_t^f}\right)^{\phi_Y}\right]^{1-\phi_i},\quad 1+i^*_t=\left(1+i^*_{t-1}\right)^{\phi_i}\left[(1+i)\left(\frac{\tilde{P}^*_t}{\tilde{P}^*_{t-1}}\right)^{\phi_\pi}\left(\frac{Y^*_t}{Y_t^{*f}}\right)^{\phi_Y}\right]^{1-\phi_i}$

Figure A1: Unilateral foreign tariff shock for a different size open economies ($n = 0.01; 0.5$)



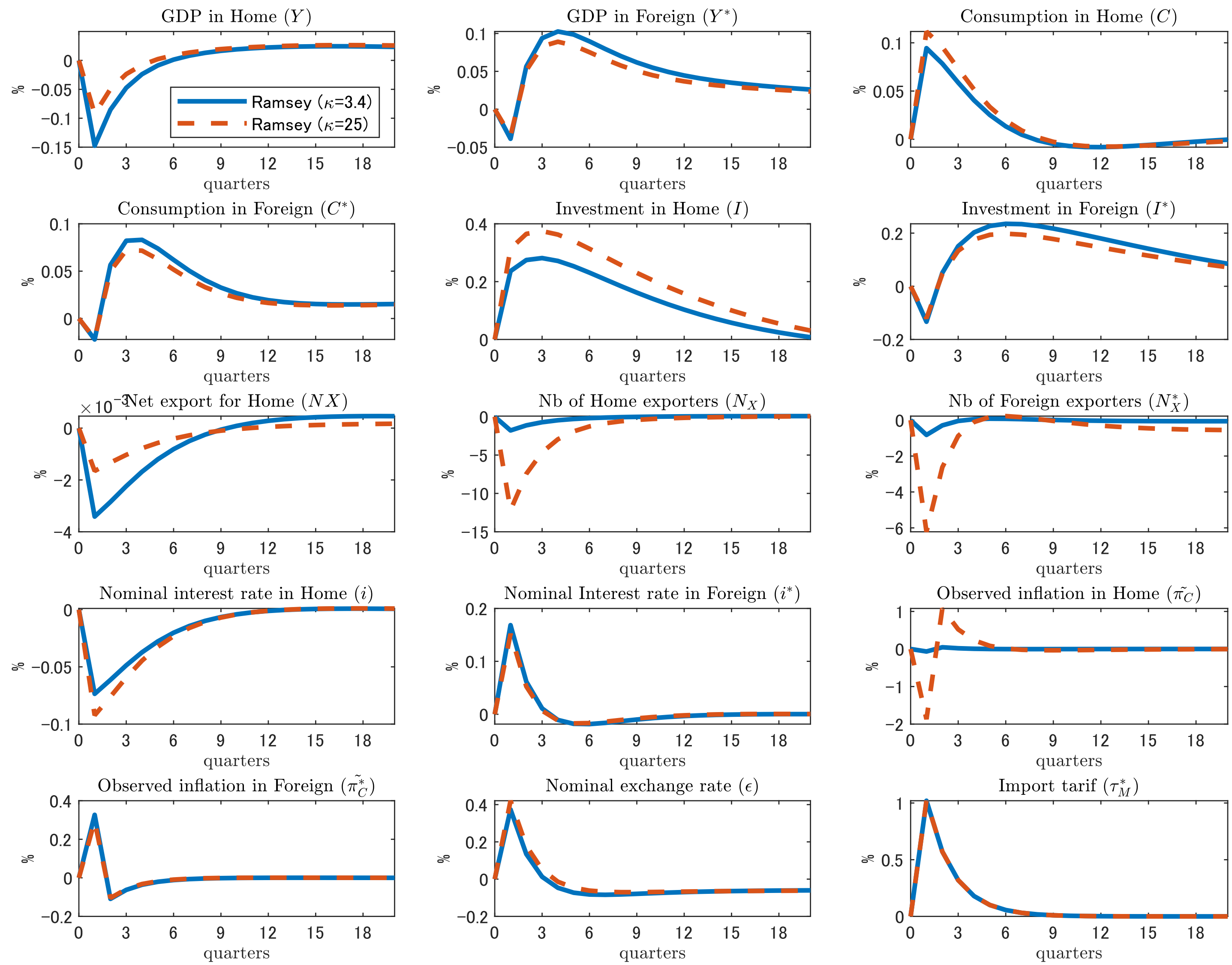
Note: Figure shows the impulse response functions of major economic variables under different specifications with respect to unilateral foreign tariff shock for the benchmark small open economy. Vertical axes measure the percent changes of the variable from its steady state value. Horizontal axes represent quarters.

Figure A2: Unilateral foreign tariff shock for different home bias ($\alpha = 0.3; 0.5$)



Note: Figure shows the impulse response functions of major economic variables under different specifications with respect to unilateral foreign tariff shock for the benchmark small open economy. Vertical axes measure the percent changes of the variable from its steady state value. Horizontal axes represent quarters.

Figure A3: Unilateral foreign tariff shock for different firm heterogeneity (Pareto shape $\kappa = 3.4; 25$)



Note: Figure shows the impulse response functions of major economic variables under different specifications with respect to unilateral foreign tariff shock for the benchmark small open economy. Vertical axes measure the percent changes of the variable from its steady state value. Horizontal axes represent quarters.

Table A2: Welfare analysis - large open economy ($n = 0.5$)

	Taylor rule	Fixed regime
Y	2.99	3.81
Y^*	1.29	1.03
C	2.42	3.10
C^*	2.26	1.88
L	4.98	6.39
L^*	1.29	1.09
Inv	0.68	1.57
Inv^*	1.25	1.08
π_C	0.81	0.56
π_C^*	1.21	1.37
Q	0.77	0.55
N_X	1.17	1.22
N_X^*	0.91	0.47
Welfare Loss		
Home	0.0181	0.0233
Foreign	0.0413	0.0370

Note: In the top panel, we report for each variable the ratio of the standard deviation relative to the one under the Ramsey optimal policy. The welfare loss is expressed in terms of percentage points with respect to the welfare under the Ramsey policy.

C Complements to the empirical evidence

C.1 Data

We analyze a large dataset that spans 36 advanced and emerging economies for a period going from the first quarter of 1985 until the last quarter of 2011.[29] Data are expressed in real terms at quarterly frequency, with the exception of the nominal exchange rate. The nominal GDP, consumer price index (CPI) and nominal exchange rate are obtained from Datastream, while the Global Antidumping Database (GAD) provides data on U.S. bilateral trade.[30] For trade data, we retrieve the custom-level international trade data from the UN Comtrade Database. First, we document the number of varieties (NB), whereas the varieties are recorded at the six-digit level of the Harmonized System (HS) classification. Second, we calculate bilateral trade values (TV) and trade shares (TS) which documents the share of the bilateral trade values to the total values of trade with the rest of the world (TVALL). Third, we follow Hummels and Klenow (2005) to decompose trade shares into empirical margins, which are the extensive margins (EM) and the intensive margins (IM). The EM measures the number of varieties traded, weighted by trade values, whereas the IM captures the average trade values across varieties. Last, we draw the data on the quality of traded products from Feenstra and Romalis (2014b). The paper estimates the quality of imported products at the four-digit level of the Standard International Trade Classification (SITC).[31]

The database covers the historical records since the 1980s on the initiation of the anti-dumping investigation, including the country user's name, the name of the country under investigation, the description of the product subject to investigations, and the initiation date. The database also provides details on the implementation and exit strategies of the anti-dumping policy measures. We measure trade protectionism by the number of importing products under investigation for which an investigation was initiated in a given period. The products are recorded at the six-digit level of HS classification. In some cases, the product description code is more disaggregated than the six-digit level. Following Barattieri et al. (2021), we convert the disaggregated data back to a six-digit level by counting an observation once whenever at least one disaggregated product is investigated.

In assessing the impact of trade tariffs, we also consider 7 exogenous variables: the U.S. short-term interest rate, the U.S. inflation rate, the U.S. growth rate, the trade policy uncertainty (TPU Index), the volatility of the TPU index, the trade share of imports and exports for each country. The inclusion of U.S. variables is important as they have important spillover effects from the U.S. to the rest of the world, and can affect the trade dynamics, while the inclusion of the TPU

[29] More specifically, the countries included in the sample are: Austria (AT), Belgium (BE), Germany (DE), Spain (ES), Finland (FI), France (FR), Greece (GR), Italy (IT), Netherlands (NL), Portugal (PT), Australia (AU), Canada (CA), Switzerland (CH), Japan (JP), Norway (NO), New Zealand (NZ), Sweden (SE), United Kingdom (UK), United States (US), Argentina (AR), Brazil (BR), Chile (CL), China (CN), Indonesia (ID), India (IN), South Korea (KR), Mexico (MX), Malaysia (MY), Peru (PE), Philippines (PH), Saudi Arabia (SA), Singapore (SG), Thailand (TH), South Africa (ZA), Turkey (TR), Denmark (DK).

[30] Original data are expressed at annual frequency. We interpolate them to obtain a quarterly frequency.

[31] Details about the derivations of the bilateral trade data can be found in Appendix C.2.

index and its volatility is fundamental as they represent additional controlling determinants of the U.S. bilateral trade dynamics.[32] The trade share is used to shed light on the importance of trade liberalization of each individual country trading with the U.S.[33]

C.2 Decomposition of trade value share

We first calculate trade value share (TS). Let i accounts for product category index, whereas j, k, and m account for country index. Denotes x_{kmi} as the value of exports of product i from country k to country m. Also, let I_{km} be the indicator variable that takes 1 for every product which m imports from k. Let k be the rest of the world. Trade share for j's exports to m can be computed as

$$TS_{jm} = \frac{\sum_{I_{jm}} x_{jmi}}{\sum_{I_{km}} x_{kmi}}.$$

We decompose trade share (TS) into the extensive margin (EM) and the intensive margin (IM) following Hummels and Klenow (2005). The EM_{jm} is a weighted number of product categories imported by j compare to the weighted number of product imported by k, which in this case represents the rest of the world. The EM_{jm} for j's exports to m can be calculated as

$$EM_{jm} = \frac{\sum_{I_{jm}} x_{kmi}}{\sum_{I_{km}} x_{kmi}}.$$

On the other hand, the IM for j's exports to m compares the value of j's exports with value of the rest of the world k's exports only in the categories in which j exports to m, that is,

$$IM_{jm} = \frac{\sum_{I_{jm}} x_{jmi}}{\sum_{I_{jm}} x_{kmi}}.$$

Practically, IM_{jm} can be calculated by

$$IM_{jm} = \frac{\sum_{I_{jm}} x_{jmi}}{\sum_{I_{jm}} x_{kmi}} = \frac{\frac{\sum_{I_{jm}} x_{jmi}}{\sum_{I_{km}} x_{kmi}}}{\frac{\sum_{I_{jm}} x_{kmi}}{\sum_{I_{km}} x_{kmi}}} = \frac{TS_{jm}}{EM_{jm}}.$$

C.3 Panel VAR

This Section develops a Panel Vector Autoregression (henceforth PVAR) model for the 35 trading partners of the U.S. over the period 1985-2011.

[32] The TPU index and its volatility are constructed by Caldara et al. (2020)).

[33] According to the Akaike information criterion, we include two lags of each variable.

We estimate the following system:

$$Y_{it} = AY_{it-1} + BX_{it-1} + u_i + e_{it} \tag{16}$$

where Y_{it} is a $(k * 1))$ vector of dependent variables, X_{it-1} is a $(1 * 1)$ vector of exogenous controlling variables, A is a $(k * k)-$dimensional matrix of the VAR coefficients on lagged quantities and B is a vector of nuisance coefficients. u_i and e_{it} are $(k * 1)$ vectors of dependent variable-specific panel fixed-effects and idiosyncratic errors, respectively. For all $t > s$, $E(e_{it}) = 0$, $E(e_{it}e_{it}^{'}) = \Sigma$, and $E(e_{it}'e_{is}) = 0$ for $t < s$. The Panel VAR model is estimated using the General Method of Moments (GMM), which allows the use of the lagged values of regressors as instruments. Further, through the Helmert procedure, we apply forward mean differencing, or orthogonal deviations, to remove the fixed effects. Thus, all variables in the model are transformed in deviations from forward means. See Arellano and Bover (1995) and Love and Zicchino (2006).

The variables included in the PVAR model are: GDP (Y), inflation (π_C), net exports (NX), numbers of exporters and importers (N_x and N_x^*), average quality of exporters and importers ($\tilde{q}_x$ and $\tilde{q}_x^*$), and tariff on U.S. imports (τ).[34] We follow Auray et al. (2020) in calculating the tariff index, which is expressed as in the following:

$$\tau = log(1 + GAD_{US}) \tag{17}$$

where GAD_{US} indicates tariff on imports imposed by the U.S. against its trading partners. Equation (17) implies that a positive shock to tariff on imports increases by a unit. The PVAR model includes 7 exogenous variables: the U.S. short-term interest rate, the U.S. inflation rate, the U.S. growth rate, the trade policy uncertainty (TPU Index), the volatility of the TPU index, the trade share of imports and exports for each country. The inclusion of U.S. variables is important as they have important spillover effects from the U.S. to the rest of the world, and can affect the trade dynamics, while the inclusion of the TPU index and its volatility is fundamental as they represent additional controlling determinants of the U.S. bilateral trade dynamics.[35] The trade share is used to shed light on the the importance of trade liberalization of each individual country trading with the U.S.[36] In contrast to the Local Projections (LP) framework, the PVAR model abstract from estimating the response of short-term interest rate and nominal exchange rate, as these two variables behave differently depending on the exchange rate regime adopted by a country. This Section only aims at corroborating the results found in both theoretical model and LP approach of a recessionary effect of tariff shocks, associated to a negative (positive) response of variety (quality) of traded goods.

Identification. We identify the tariff shock by ordering the measure for U.S. trade dispute on imports as the first variables in the system. Similar to Barattieri et al. (2021), we assume that

[34] All variables are expressed in real terms and in their log, with the exception of the tariff index.
[35] The TPU index and its volatility are constructed by Caldara et al. (2020)).
[36] According to the Akaike information criterion, we include two lags of each variable.

the trade policy decision of imposing new tariffs on U.S. imports is not anticipated by economic agents, thus macroeconomic and trade variables react to the trade policy with some lags. Further, Ghironi and Melitz (2007) find that GDP expansion occurs after the expansion in product variety.[37]. Indeed, variety is driven by new market entry of firms with relatively high productivity, which anticipate a future economic growth and produce new variety by borrowing from abroad to finance new production lines. See Ghironi and Melitz (2005). Thus, we order quality and variety of imports and exports after the trade dispute measure, and before the macroeconomic variables. Inflation rate is order after GDP, as changing in production will have implications for the inflation rate. Similar intuition is found in Barattieri et al. (2021) and Auray et al. (2020).

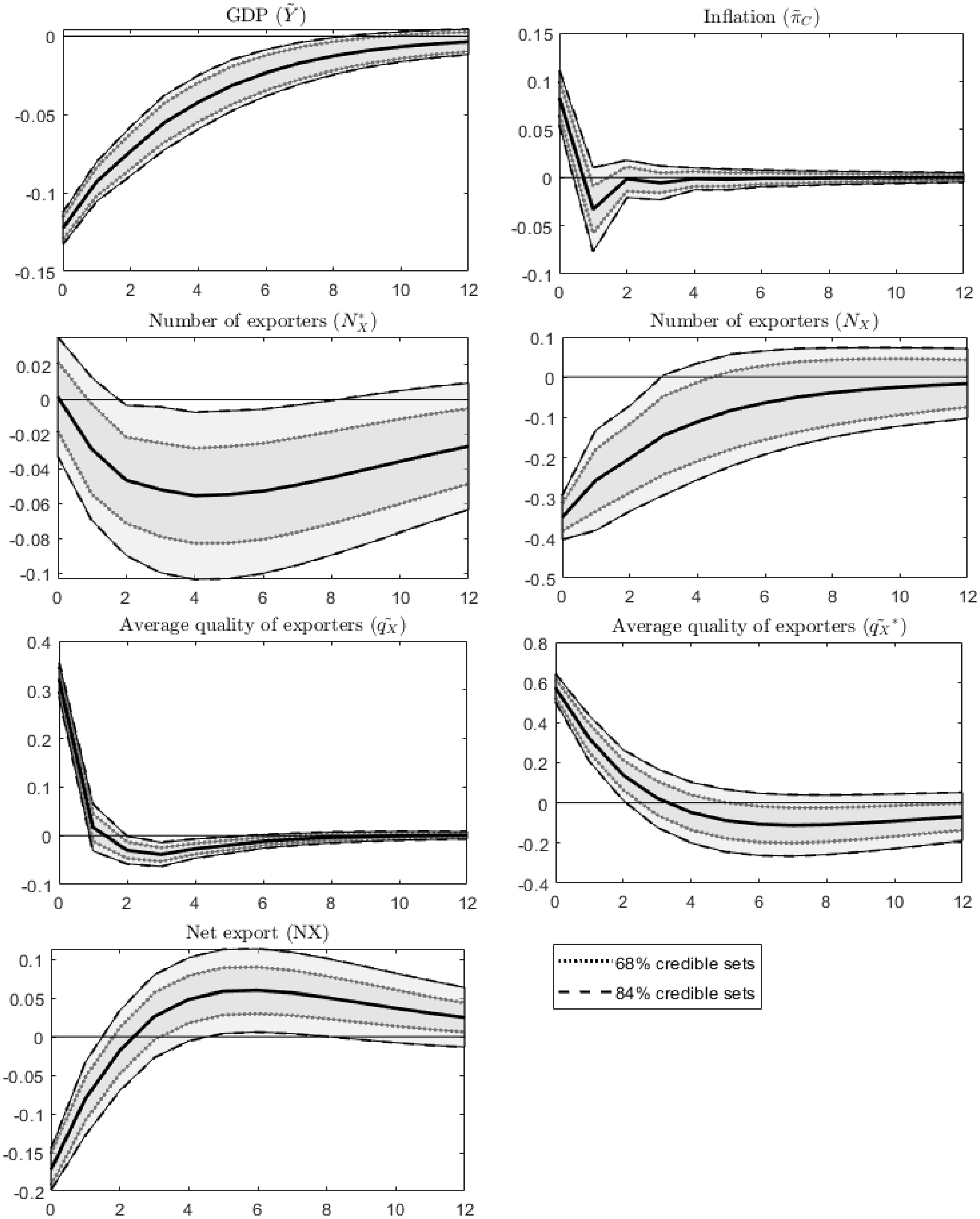
Figure A4 shows the impulses responses to a one-standard deviation increase in U.S. tariffs on imports along with the 68 percent (dark gray area) and 84 percent posterior (light gray area) credible sets over a 20-quarter horizon.[38] A positive shock to trade dispute initiated in the U.S. leads to lower exports, and consequentially to a decline in net exports by approximately 0.15%, driven by lower demand of domestic goods by the foreign economy (i.e. the U.S.) as a consequence of higher prices on imports. This generates a recessionary effect by lowering GDP on impact by approximately 0.12%. However, GDP takes about 3 years before returning to the initial steady-state. Inflation increases on impact but decreases right after 1 period. Both imported and exported goods respond to the increasing tariffs on imports with a decrease in variety and an increase in quality. Obviously, the best strategy for the U.S. trading partners is to export lower quantities at modestly higher prices. Indeed, after the imposition of higher tariffs on imports, low-quality imported goods in the U.S. will become too expensive for low and middle income households, who will reduce the demand for such goods. Therefore, trading partners may target high-quality markets, such as luxury or high-technology goods. As a matter of fact, due to the higher exporting cost, firms with low productivity prefer to sell their product only to their domestic market, reducing the extensive margin of product made available for abroad before the tariff shock. It can be noticed that while the variety of exports returns to the initial steady state, variety on imports peaks around -0.05% at its lowest point after 4 quarters and then rebound during the medium-term. However, the negative impact on the number of exporters affects exports much more than imports with a decrease of about 0.3% deviation from steady-state. As a consequence of lower variety, foreign countries tend to increase the quality of the fewer imported and exported goods. Similar to variety, the quality of traded goods responds with higher impact on exports, relative to imports. Further, quality on exports and imports becomes negative between second and third quarter, respectively.

Overall, we conclude that an increase in protectionism through higher U.S. tariffs on imports acts as a negative demand shock for tariff-targeted countries.

[37]It follows that the product quality is a function of the variety. Thus, quality and variety are ordered before GDP.

[38]We follow Kilian (1998) in setting our confidence bands.

Figure A4: Responses to U.S. Tariff shock on Imports (PVAR Model).



Note: Impulse responses to a one-standard deviation increase in U.S. tariff on imports. The IRF confidence intervals are computed using 200 Monte Carlo draws based on the estimated model. The dotted line (over the dark gray area) and the dashed (over the light gray area) report 68% and 84% credible sets, respectively.