The Effects of Monetary Policy under Dominant Currency Pricing and Dominant Currency Financing

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Abstract

This paper investigates the effect of domestic and foreign monetary policy under dominant currency pricing and dominant currency financing. Due to the need for working capital, dominant currency pricing and dominant currency financing are complementary. Internationally traded outputs are invoiced in dominant currency while they need to be financed in dominant currency due to the working capital constraint. A small open economy New Keynesian model with dominant currency pricing and working capital constraint is constructed. Under working capital constraint, monetary policy shock affects marginal cost, which is reflected to the inflation rate and export and import prices. Both the expansionary domestic monetary policy and contractionary foreign monetary policy lead to depreciation of domestic currency, but output and trade volume decreases in the latter case while it stays almost the same in the former case. The existence of non-tradables amplifies the response of imports and trade volume to monetary policy shock. The main reason for this is that profits of non-tradables are not insulated from the depreciation. This creates heterogeneous effect of monetary policy on tradable and non-tradable sector. The benchmark model is extended to include tradable and non-tradable sectors. According to this extended model, imports and trade volume are reduced due to the depreciation caused by expansionary domestic monetary policy or tightening of foreign monetary policy.

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1 Introduction

Nominal exchange rate has been considered as one of the tools to affect exports, imports, and trade balance because it governs relative prices in international product markets. For this reason, it has been at the center of policy discussion as well as conflicts among countries, especially during recession. However, the response of these variables to nominal exchange rate varies across different pricing paradigms. Here, pricing paradigms are about which currency global transactions are invoiced in. For example, transactions can be priced in terms of the currency of producer country, whereas the local currency (or destination currency) can also be used for invoicing trades. The former is called producer currency pricing while the latter is called local currency pricing. These paradigms have been widely used in economic research on open economy previously.

Recently, dominant currency pricing (DCP), which assumes that export and import prices are invoiced in dominant currency such as US dollar, is found to explain data better. Gopinath et al. (2020) show that terms-of-trade is stable along exchange rate and the pass-through to prices mainly comes from dollar exchange rate rather than bilateral exchange rate, which are consistent with dominant currency pricing. Accordingly, import prices are sensitive to dollar exchange rate depreciation, which results in variation in trades mostly coming from the variation in imports.

On the other hand, trade invoicing in dominant currency is closely associated with financing in dominant currency. One of such association comes from the need for working capital. According to the literature on the form of payment terms for global transactions, post-shipment term was the main term, implying the time lag between production and sales and the need for the working capital in international trade (Ahn (2014), Antras and Foley (2015), Bruno et al. (2018), and Niepmann and Schmidt-Eisenlohr (2017)). Since imported intermediate inputs are priced in dominant currency, the working capital for these inputs are also needed to be financed in the dominant currency. This creates interdependency between dominant currency pricing and dominant currency financing.

The working capital constraint and dominant currency financing creates another channel of the domestic and foreign monetary policy that affect the home economy in addition to the conventional intertemporal substitution channel. Domestic and foreign interest rate directly affects the marginal cost, which is reflected to the output and inflation. The analysis of the effect of monetary policy is timely in the post-Covid era since large and advanced economies including the US are expected to raise policy rates in the near future. Moreover, this effect may depend on the production structure of the economy, mainly the composition of tradable and non-tradable sectors. Non-tradables are sold only at domestic market while they still need foreign intermediate inputs in their production process. This makes non-tradables more susceptible to depreciation, which is pointed out by Casas et al. (2020). Therefore, this paper investigates the effect of domestic and foreign monetary policy under dominant currency pricing and dominant currency financing with tradable/non-tradable structure.

Based on the above discussion, a small open economy New Keynesian model with dominant currency pricing and working capital constraint is constructed as a benchmark model. The key difference with Gopinath et al. (2020) is the existence of the working capital constraint. Specifically, domestic and foreign monetary policy affects the cost of financing working capital, which is reflected to the marginal cost. This weakens the responses of price variables to expansionary domestic monetary policy shock while the responses to foreign monetary policy tightening are strengthened although both lead to depreciation of domestic currency. Accordingly, the change in trade quantities are also opposite. This argument shows the risk of only looking at the nominal exchange rate. The same depreciation brings about totally different results, implying the importance of the source of the depreciation.

Marginal cost and prices respond more weakly to the expansionary monetary policy shock since lower domestic interest rate decreases the effective cost of labor and domestic intermediate inputs. The exports increase more due to less marginal cost while the decrease in imports are less affected since imported inputs are financed in dominant currency rather than domestic currency. However, the total trade quantities stay almost the same under working capital constraint since the improvement in exports is negligible under DCP. Household consumption increases more while aggregate output decreases.

Meanwhile, the tightening of the foreign monetary policy strengthens the response of price variables by increasing marginal cost. On the other hand, the modest increase in exports is weakened due to the higher export price while the imports decrease more under working capital constraint. In total, the trade quantities decrease more slightly, which is in contrast to the effect of expansionary domestic monetary policy shock. This tells us that we should not look only at depreciation. Depending on the source of the depreciation, trade quantity can move differently. Household consumption and current account-to-GDP ratio decrease more and the increase in output are also weakened due to the increased marginal cost.

Next, the benchmark model is extended such that the aggregate economy is separated into two sectors: tradable and non-tradable sectors. Even though the production technology of both sectors are assumed to be identical, the two sectors are heterogeneous in the sense that non-tradables can be sold only in domestic market. This prevents non-tradables from hedging the depreciation of domestic currency since there is no foreign component in revenue. In response to depreciation caused by either expansionary domestic monetary policy or contractionary foreign monetary policy, profits of non-tradable sectors are diminished. When there is 25bp contractionary US monetary policy shock, profits of non-tradables decline about 0.2%p decrease, leading to a decrease in the share of non-tradables in total output. Accordingly, non-tradable sectors' demand for intermediate inputs decrease, reducing imports and trade quantities. Comparing with the benchmark model where imports decline 1.9%p, the existence of non-tradable sectors expands the decrease in imports to 3.2%p. This amplified responses of imports and trade quantities are in line with the empirical research by Casas et al. (2020). Due to this reduced demand, marginal cost and inflation become lower while domestic currency is more depreciated.

The paper is organized as follows. Section 2 introduces a small open economy New Keynesian model with dominant currency pricing and working capital constraint. Detailed derivations of steady-states and log-linearized system of equations are provided in section C and section B. In section 3, we calibrated the model and present the impulse responses to domestic monetary policy shock and foreign interest rate shock. Then, section 4 extends the benchmark model by splitting the economy into tradable and non-tradable sectors. Section 5 concludes.

Literature Review

This paper is related to literature on the paradigm of invoicing currency. Previously, New Keynesian open economy models were based on the assumption of PCP. For example, Galí and Monacelli (2005) assume producer currency pricing (PCP), which produces much stronger response of exports to depreciation than DCP. In contrast, prices are set and rigid in local currency in Devereux and Engel (2002), making the response of exports to depreciation muted. Gopinath et al. (2020) lay out a small open economy New Keynesian model with several invoicing paradigm such as PCP, LCP, and DCP. They show that terms-of-trade is stable along exchange rate and pass-through to prices mainly come from dollar exchange rate rather than bilateral exchange rate, which are consistent with dominant currency pricing. Accordingly, import prices are sensitive to dollar exchange rate under DCP, which results in variation in trades mostly coming from the variation in imports. This paper also assumes DCP rather than PCP following Gopinath et al. (2020), but contributes to the literature by incorporating working capital constraint in order to analyze dominant currency financing in the same framework.

There has been papers on the need for working capital in the international trade. According to Ahn (2014), about 80-90 percent of the import transactions in Colombia and Chile are paid by the post-shipment term (open account term). This implies that there is a time lag between production and payment or sales, and thus firms need to finance working capital. Also, Antras and Foley (2015) use data on a single US exporting firm and show that about 84% of transactions are mostly paid in terms of cash in advance and open account. Niepmann and Schmidt-Eisenlohr (2017) analyze the data from Society for World-wide Interbank Financial Telecommunications (SWIFT) and show that only 11% of transactions are intermediated by banks, while their importance rose during the global financial crisis. Since banks are not incorporated in our model, this composition effect is not important in our argument. These papers imply that the timing of sales and input expenditure do not coincide. Intermediate input expenditures are needed to be financed prior to production, so trade and financing condition are tightly related.

Some papers focused on the exclusive role of US dollar in trade financing. Bruno et al. (2018)

test whether global value chains are sustained by working capital which are mostly financed in US dollar. They show that stronger US dollar index is correlated with weaker GVC activity. Casas et al. (2020) analyze Colombian firm-level data to show that home currency depreciation against US dollar depresses imports while exporting firms are not affected. Firms which hedge currency risks are not shown to decrease imports in response to devaluation. Adler et al. (2020) also use COMTRADE data and provide evidence on both dominant currency pricing and dominant currency financing. These papers present the relationship between trade activity and dollar exchange rate from the perspective of financing condition. Our work also looks at this relationship based on the open economy New Keynesian model rather than empirical data. This helps us to analyze the effect of US monetary policy tightening on small open economies in the post-Covid era.

On the other hand, Gopinath and Stein (2020) approaches dominant currency financing from a different point of view. They focus on the role of currency as a store of value and theoretically show that the complementarity between unit of account and store of value leads to the emergence of dominant currency in trade invoicing and global financing. This approach differs from out paper in that this paper focuses only on the unit of account rather than store of value. The need for financing in dominant currency comes from the time lag between production and sales.

2 The Model

2.1 Household

The representative household in country j obtains utility from consuming a bundle of goods $C_{j,t}$ and gets wage $W_{j,t}$ by supplying labor $N_{j,t}$. We assume that the per-period utility function of the household is given by the following separable power utility function:

$$U(C_{j,t}, N_{j,t}) = \frac{1}{1-\sigma_c} C_{j,t}^{1-\sigma_c} - \frac{\kappa}{1+\varphi} N_{j,t}^{1+\varphi} \tag{2.1}$$

where σ_c is the inverse of intertemporal substitution, φ is the inverse of the Frisch elasticity, and κ is the parameter for the disutility of labor supply.

The household can trade domestic and international risk-free bonds, implying that they can borrow (lend) from both domestic and international financial market[1]. We assume that the international risk-free bonds are denominated in US dollar, reflecting the predominant role of dollar in financing. Households are paid nominal interest rate $i_{j,t}$ and $i^{\$}_{j,t}$ from holding bonds between time t and $t+1$[2]. Also, since the household owns domestic firms, they can get profits $\Pi_{j,t}$ as dividends.

[1] Unlike Gopinath et al. (2020), both the domestic and the international financial market are assumed to be incomplete. According to Schmitt-Grohe and Uribe (2003), incomplete market model produces similar dynamics as complete market model.

[2] $i^{\$}_{j,t}$ can be country-specific in order to induce stationarity as argued in Schmitt-Grohe and Uribe (2003).

Hence, the household maximizes life-time utility,

$$\max_{\{C_{j,t},N_{j,t},D_{j,t+1},D^{\$}_{j,t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t U(C_{j,t}, N_{j,t}) \tag{2.2}$$

subject to the following per-period budget constraint (denominated in home currency),

$$P_{j,t}C_{j,t} + \mathcal{E}^{\$}_{j,t}(1+i^{\$}_{j,t-1})D^{\$}_{j,t} + (1+i_{j,t-1})D_{j,t} = W_{j,t}N_{j,t} + \Pi_{j,t} + \mathcal{E}^{\$}_{j,t}D^{\$}_{j,t+1} + D_{j,t+1} \tag{2.3}$$

Here, $P_{j,t}$ is the composite price index for the aggregate consumption $C_{j,t}$. $D_{j,t}$ represent domestic debt holdings at time t while $D^{\$}_{j,t}$ is foreign debt holdings denominated in US dollar at time t. Note that the household cannot hold foreign debt denominated in other currencies than home currency and US dollar, reflecting the segmented international financial market. This assumption can be justified as Maggiori et al. (2020) find that investors' debt holdings are biased toward home currency and US dollar. $\mathcal{E}^{\$}_{j,t}$ is the price of a US dollar in currency j, an increase in the exchange rate $\mathcal{E}^{\$}_{j,t}$ corresponding to depreciation of currency j.

From the above optimization problem, we can get the following Euler equations for domestic and international risk-free bonds and intratemporal condition:

$$1 = E_t\Big[\beta \frac{C^{-\sigma_c}_{j,t+1}}{C^{-\sigma_c}_{j,t}} \frac{P_{j,t}}{P_{j,t+1}} (1+i_{j,t})\Big] \tag{2.4}$$

$$1 = E_t\Big[\beta \frac{C^{-\sigma_c}_{j,t+1}}{C^{-\sigma_c}_{j,t}} \frac{P_{j,t}}{P_{j,t+1}} \frac{\mathcal{E}^{\$}_{j,t+1}}{\mathcal{E}^{\$}_{j,t}} (1+i_{j,t})\Big] \tag{2.5}$$

$$\frac{W_{j,t}}{P_{j,t}} = \kappa \frac{N^{\varphi}_{j,t}}{C^{-\sigma_c}_{j,t}} \tag{2.6}$$

The aggregate consumption $C_{j,t}$ is defined by the following Kimball aggregator function in order to generate strategic complementarity and variable markups[3]

$$\sum_i \frac{1}{|\Omega_i|} \int_{\omega \in \Omega_i} \gamma_{ij} \Upsilon\Big(\frac{|\Omega_i| C_{ij,t}(\omega)}{\gamma_{ij} C_{j,t}}\Big) d\omega = 1 \tag{2.7}$$

$C_{ij,t}(\omega)$ is country j's consumption for variety $\omega \in \Omega_i$ produced by country i at time t while γ_{ij} is a parameter representing home consumption bias in country j satisfying $\sum_i \gamma_{ij} = 1$. $|\Omega_i|$ denotes the measure of varieties produced in country i, which is needed for normalization.

The optimal consumption for each variety ω can be derived from the cost-minimization problem, minimizing expenditure $\sum_i \int_{\Omega_i} P_{ij,t}(\omega) C_{ij,t}(\omega) d\omega$ subject to (2.7), which gives rise to the following

[3] It is well-known in this literature that strategic complementarity is needed to match the dynamics of exchange rate pass-through observed in the data. See Burstein and Gopinath (2014) and Gopinath et al. (2020) among others.

demand function:

$$C_{ij,t}(\omega) = \gamma_{ij} \upsilon\Big(D_{j,t}\frac{P_{ij,t}(\omega)}{P_{j,t}}\Big)C_{j,t} \tag{2.8}$$

where $\upsilon(\cdot) = (\Upsilon')^{-1}(\cdot)$ and $D_{j,t} = \sum_i \int_{\Omega_i} \Upsilon'(\frac{|\Omega_i|C_{ij,t}(\omega)}{\gamma_{ij}C_{j,t}})\frac{C_{ij,t}(\omega)}{C_{j,t}}d\omega$. The shape of $\upsilon(\cdot)$ determines the variability of markups. The aggregate price $P_{j,t}$ satisfies $P_{j,t}C_{j,t} = \sum_i \int_{\Omega_i} P_{ij,t}(\omega)C_{ij,t}(\omega)d\omega$. In addition, the price elasticity of demand $\sigma_{ij,t}(\omega)$ is defined as $-\partial \log C_{ij,t}(\omega)/\partial \log Z_{ij,t}(\omega)$ where $Z_{ij,t}(\omega) = D_{j,t}P_{ij,t}(\omega)/P_{j,t}$. The flexible markup is given by $\sigma_{ij,t}(\omega)/(\sigma_{ij,t}(\omega)-1)$, and the elasticity of this markup $\Gamma_{ij,t}(\omega)$ is given by $\partial\mu_{ij,t}(\omega)/\partial \log Z_{ij,t}(\omega)$ where $\mu_{ij,t}(\omega) = \log(\sigma_{ij,t}(\omega)/(\sigma_{ij,t}(\omega)-1))$. If $\Gamma_{ij,t}(\omega)$ is non-zero, this implies that the markup is time-varying. Following Klenow and Willis (2016), we assume that the Kimball aggregator $\Upsilon(\cdot)$ is given by,

$$\Upsilon(x) = 1 + (\sigma-1)\exp(\frac{1}{\epsilon})\epsilon^{\frac{\sigma}{\epsilon}-1}\Big(\Gamma(\frac{\sigma}{\epsilon},\frac{1}{\epsilon}) - \Gamma(\frac{\sigma}{\epsilon},\frac{x^{\frac{\epsilon}{\sigma}}}{\epsilon})\Big) \text{ where } \Gamma(s,t) = \int_t^\infty u^{s-1}e^{-u}du \tag{2.9}$$

Then, the demand for consumption becomes,

$$C_{ij,t}(\omega) = \gamma_{ij}\Big(1-\epsilon\Big(\log Z_{ij,t}(\omega) - \log\frac{\sigma-1}{\sigma}\Big)\Big)^{\frac{\sigma}{\epsilon}}C_{j,t}$$

and the elasticity of demand and markup are

$$\sigma_{ij,t}(\omega) = \frac{\sigma}{1-\epsilon\Big(\log Z_{ij,t}(\omega) - \log\frac{\sigma-1}{\sigma}\Big)}$$
$$\Gamma_{ij,t}(\omega) = \frac{\epsilon}{\sigma-1+\epsilon\Big(\log Z_{ij,t}(\omega) - \log\frac{\sigma-1}{\sigma}\Big)}$$

Note that $\sigma^k_{ji,t}(\omega)$ is not constant generally unless $\epsilon = 0$.

2.2 Firm

Each variety ω in country j is produced using labor and intermediate inputs, which is characterized by the following production function[4]:

$$Y_{j,t} = A_{j,t}L^{\alpha}_{j,t}X^{1-\alpha}_{j,t} \tag{2.10}$$

where $A_{j,t}$ is country-specific aggregate productivity, $L_{j,t}$ is employment, and $X_{j,t}$ is intermediate inputs. For notational convenience, variety ω is omitted. α refers to the labor share in production,

[4] I will use firm and variety interchangeably in this paper since each firm produces only one variety.

which is also value-added share in this model. Aggregate productivity follows AR(1) process given by,

$$\log A_{j,t} = \log \bar{A} + \rho_a(\log A_{j,t-1} - \log \bar{A}) + \epsilon^a_{j,t} \tag{2.11}$$

where ρ_a is the persistence of productivity and $\epsilon^a_{j,t}$ is productivity shock.

Intermediate inputs $X_{j,t}$ is assumed to be implicitly defined by the following Kimball aggregator, which is the same form as (2.7):

$$\sum_i \frac{1}{|\Omega_i|} \int_{\omega \in \Omega_i} \gamma_{ij} \Gamma\Big(\frac{|\Omega_i| X_{ij,t}(\omega)}{\gamma_{ij} X_{j,t}}\Big) d\omega = 1 \tag{2.12}$$

where $X_{ij,t}$ is the intermediate input produced by country i and used by country j.

Importantly, labor and intermediate inputs are needed before goods are produced and sold in markets. We assume that the sales are realized at the end of each period while inputs are required at the beginning of each period. Hence, working capital is needed to finance inputs, making effective prices of inputs to be multiplied by gross interest rate. Moreover, imported inputs of which prices are denominated in dollar need to be financed in terms of dollar. Accordingly, the relevant interest rate for imported inputs is the US dollar interest rate. The following variables with tilde are effective wage and prices of intermediate inputs:

$$\tilde{W}_{j,t} = (1 - \psi + \psi i_{j,t}) W_{j,t} \tag{2.13}$$

$$\tilde{P}_{ij,t}(\omega) = \begin{cases} (1 - \psi + \psi i_{j,t}) P_{jj,t}(\omega) \text{ if } i = j \\ (1 - \psi + \psi i^*_{j,t}) P_{ij,t}(\omega) \text{ if } i \neq j \end{cases} \tag{2.14}$$

where $\psi = 1$ indicates working capital constraint while $\psi = 0$ in the case without working capital constraint.

Cost function of the firm ω is given by,

$$TC_{j,t} = \tilde{W}_{j,t} L_{j,t} + \tilde{P}_{j,t} X_{j,t} \tag{2.15}$$

where

$$\tilde{P}_{j,t} X_{j,t} = \sum_i \int_{\Omega_i} \tilde{P}_{ij,t}(\omega) X_{ij,t}(\omega) d\omega \tag{2.16}$$

Each period firm ω minimizes its cost function, which can be split into two step. First, it minimizes (2.16) subject to (2.12), leading to the following demand function for intermediate inputs which has the same form as (2.8):

$$X_{ij,t}(\omega) = \gamma_{ij} \upsilon\Big(D_{j,t} \frac{\tilde{P}_{ij,t}(\omega)}{\tilde{P}_{j,t}}\Big) X_{j,t} = \gamma_{ij} \upsilon(\tilde{Z}_{ij,t}(\omega)) X_{j,t}$$
$$= \gamma_{ij} \Big(1 - \epsilon\Big(\log \tilde{Z}_{ij,t}(\omega) - \log \frac{\sigma - 1}{\sigma}\Big)\Big)^{\frac{\sigma}{\epsilon}} X_{j,t} \tag{2.17}$$

Similarly, the price elasticity of demand for intermediate input is given by

$$\tilde{\sigma}_{ij,t}(\omega) = \frac{\sigma}{1 - \epsilon\Big(\log \tilde{Z}_{ij,t}(\omega) - \log \frac{\sigma-1}{\sigma}\Big)}$$

Next, firm ω minimizes (2.15) subject to (2.10) and (2.12),

$$\alpha \frac{Y_{j,t}}{L_{j,t}} = \frac{\tilde{W}_{j,t}}{MC_{j,t}} \tag{2.18}$$

$$(1-\alpha) \frac{Y_{j,t}}{X_{j,t}} = \frac{\tilde{P}_{j,t}}{MC_{j,t}} \tag{2.19}$$

where

$$MC_{j,t} = \frac{1}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \frac{\tilde{W}_{j,t}^{\alpha} \tilde{P}_{j,t}^{1-\alpha}}{A_{j,t}} \tag{2.20}$$

Based on the cost function derived in the above section, firms choose prices for the goods they produce. We assume that international markets are segmented, enabling firms to choose price for each market i and invoicing currency k separately. Since we assumed that all goods except domestic goods, which are invoiced in producer currency, are denominated in US dollar, $k = \$$ for $i \neq j$ and $k = j$ for $i = j$. Let $Y_{ji,t}^k$, $C_{ji,t}^k$, and $X_{ji,t}^k$ be the output, consumption, and intermediate input ω that is produced in j and sold in i denominated in currency k respectively, satisfying $Y_{ji,t}^k(\omega) = C_{ji,t}^k(\omega) + X_{ji,t}^k(\omega)$. Also, $Y_{j,t}(\omega) = \sum_{i,k} Y_{ji,t}^k(\omega)$, which also holds for consumption and intermediate inputs. Then, the per-period profit function of the firm ω is,

$$\Pi_{j,t} = \sum_{i,k} \mathcal{E}_{j,t}^k P_{ji,t}^k(\omega) Y_{ji,t}^k(\omega) - TC_{ji,t}(\omega)$$

Here, the demand function that each firm ω faces is the following:

$$Y_{ji,t}^k(\omega) = \gamma_{ji} \upsilon\Big(D_{i,t} \frac{P_{ji,t}(\omega)}{P_{i,t}}\Big) C_{i,t} + \gamma_{ji} \upsilon\Big(D_{i,t} \frac{\tilde{P}_{ji,t}(\omega)}{\tilde{P}_{i,t}}\Big) X_{i,t} \tag{2.21}$$

2.3 Price rigidity

Following New Keynesian literature, firms are subject to Calvo friction in the sense that $(1-\lambda)$ fraction of firms are randomly chosen to reset their prices each period. The distinguished feature of DCP literature is that price is sticky in dominant currency, which is US dollar in this model, except prices of domestic outputs which are denominated in producer currency.

Let the time t reset price of firm ω in country j selling its product at country i denominated in currency k be $\bar{P}^k_{ji,t}(\omega)$. $Y^k_{ji,t+s|t}(\omega)$ is the time $(t+s)$ demand faced by the firm ω when the price is fixed at the value of time t reset price. Then, the profit of the firm ω by setting the reset price is given by the following:

$$\sum_{i,k} E_t \sum_{s=t}^{\infty} \lambda^{s-t} \Theta_{j,t,s}[\mathcal{E}^k_{j,s} \bar{P}^k_{ji,t}(\omega) Y^k_{ji,s|t}(\omega) - TC_{j,s}] \tag{2.22}$$

where $\Theta_{j,t,s}$ is the stochastic discount factor of country j between time t and s given by the ratio of marginal utility of consumption. Maximizing (2.22) yields the following FOC:

$$\begin{aligned} &E_t \sum_{s=t}^{\infty} \lambda^{s-t} \Theta_{j,t,s}[(\sigma^k_{ji,s}(\omega)-1)C^k_{ji,s|t}(\omega) + (\tilde{\sigma}^k_{ji,s}(\omega)-1)X^k_{ji,s|t}(\omega)]\mathcal{E}^k_{j,s}\bar{P}^k_{ji,t} \\ &= E_t \sum_{s=t}^{\infty} \lambda^{s-t} \Theta_{j,t,s}[\sigma^k_{ji,s}(\omega) C^k_{ji,s|t}(\omega) + \tilde{\sigma}^k_{ji,s}(\omega) X^k_{ji,s|t}(\omega)] MC_{j,s} \end{aligned} \tag{2.23}$$

for each destination country i and currency k. Intuitively, the above condition (2.23) suggests that firm ω sets optimal reset price as mean of flexible price which is flexible markup over marginal cost. Note that the variable markup, which is determined by $\sigma^k_{ji,s}(\omega)$ and $\tilde{\sigma}^k_{ji,s}(\omega)$, creates the potential difference in the optimal reset price $\bar{P}^k_{ji,t}$ between destination countries i. Due to the strategic complementarity, firm ω can impose higher markup on exported goods to a certain destination country j when the export price to j is high relative to the aggregate price level in j.

In order to investigate price dynamics more conveniently, (2.23) is log-linearized around steady-state, of which derivation is specified in the appendix C.[5]

$$\hat{\bar{p}}^k_{ji,t} = \beta\lambda E_t[\hat{\bar{p}}_{ji,t+1} + \pi^k_{t+1}] + \frac{1-\beta\lambda}{1+\Gamma}\Big[\hat{m}c_{j,t} - \Gamma s^k_{i,t} - s^k_{j,t} - \Gamma\Big(1 - \frac{C_{ji}}{Y_{ji}}\Big)(\log(1+\chi i^k_{i,s}) - \tilde{p}_{i,s})\Big]$$

where marginal cost and aggregate PPI are determined by the following equation:

$$\begin{aligned} \hat{m}c_{j,t} &= \alpha(\psi(i_{j,t} - i^*) + \hat{w}_{j,t}) + (1-\alpha)\hat{\tilde{p}}_{j,t} - \log A_{j,t} \\ \hat{\tilde{p}}_{j,t} &= \gamma_{jj}(\psi(i_{j,t} - i^*) + \hat{p}_{jj,t}) + \sum_{i \neq j} \gamma_{ij}(\psi(i^{\$}_{j,t} - i^*) + \hat{p}_{ij,t}) \end{aligned}$$

[5] The below equation can be found at (C.19).

$\Gamma > 0$ indicates that there is strategic complementarity in price setting, which creates real rigidity. This makes the Phillips curve less steep, reflected in the term $(1-\beta\lambda)/(1+\Gamma)$. On the other hand, ψ is the parameter for the existence of working capital constraint. When $\psi = 1$, marginal cost is affected by the linear combination of domestic and foreign interest rate. However, this effect on marginal cost partially reflected to reset price due to the strategic complementarity captured by $\Gamma > 0$.

2.4 Monetary policy

We assume that the central bank sets the domestic nominal interest rate following Taylor rule with inertia:

$$i_{j,t} - i^* = \rho_m(i_{j,t-1} - i^*) + (1-\rho_m)(\phi_m \pi_{j,t} + \phi_y \tilde{y}_{j,t}) + \epsilon_{j,t} \tag{2.24}$$

Here, ρ_m is the parameter for the intertia, and ϕ_m and ϕ_y are the sensitivity of monetary policy to inflation π_t and output gap $\tilde{y}_{j,t}$. Also, $\epsilon_{j,t}$ follows AR(1) process

$$\epsilon_{j,t} = \rho_\epsilon \epsilon_{j,t-1} + \epsilon^m_{j,t} \tag{2.25}$$

where $\epsilon^m_{j,t}$ is serially uncorrelated monetary policy shock.

2.5 Foreign interest rate

In order to induce stationarity, we assume external debt-elastic interest rate of dominant currency \$ à la Schmitt-Grohe and Uribe (2003),

$$i^{\$}_{j,t} = i^{\$}_t + \psi(\exp(\frac{D^{\$}_{t+1}}{P_{\$,t}} - \bar{d}^{\$}) - 1) \tag{2.26}$$

where $\bar{d}^{\$}$ is the steady-state real foreign debt position and $i^{\$}_t$ is the interest rate in dominant currency country. The country-specific foreign interest rate premium depends on the level of foreign indebtedness, but we assume that the household does not internalize this premium. They take this external premium as exogenously given, and this premium is determined as the outcome of equilibrium. Thus, we can ignore this process when deriving the optimal foreign debt in the household problem.

The foreign interest rate $i^{\$}_t$ evolves as AR(1) process

$$(i^{\$}_t - i^*) = \rho_{\$}(i^{\$}_{t-1} - i^*) + \epsilon^*_t \tag{2.27}$$

2.6 Depreciation rate against RoW

Let $\mathcal{E}^R_{j,t}$ be the nominal exchange rate between domestic currency and the currency of the rest of the world (RoW). Since we assume that households cannot trade nominal bonds denominated in the currency of RoW, there is no Euler equation for the RoW currency, implying the absence of UIP condition between home currency and RoW currency.[6] Thus, we have to assume an exogenous process for the bilateral exchange rate between home currency and RoW currency.

$$\Delta e^R_{j,t} = \zeta \Delta e^{\$}_{j,t} + \epsilon^{eR}_{j,t} \tag{2.28}$$

where $\Delta e^R_{j,t} = \log(\frac{\mathcal{E}^R_{i,t}}{\mathcal{E}^R_{i,t-1}})$. This implies that the depreciation rate against RoW consist of a common component with the depreciation rate against dollar, where strength is parametrized by ζ, and a depreciation rate shock. As it will be stated in the later section, ζ is calibrated as one, implying that depreciation rate against RoW currency is the same as depreciation rate against dollar without shock. This component reflects the symmetry between the US and RoW which is implicitly assumed in this paper.

The depreciation rate shock $\epsilon^{eR}_{j,t}$ follows an AR(1) process:

$$\epsilon^{eR}_{j,t} = \rho_{eR}\epsilon^{eR}_{j,t-1} + \epsilon^R_{j,t} \tag{2.29}$$

2.7 Foreign demand and inflation

For simplicity, we assume that foreign demand for consumption $C_{i,t}$, intermediate input $X_{i,t}$, and inflation $\pi_{i,t}$ follow univariate AR(1) process respectively. Also, these variables are also assumed to be uncorrelated with foreign interest rate $i^{\$}_t$.

$$C_{i,t} = \rho_c C_{i,t-1} + \epsilon^c_t \tag{2.30}$$

$$X_{i,t} = \rho_x X_{i,t-1} + \epsilon^x_t \tag{2.31}$$

$$\pi_{i,t} = \rho_\pi \pi_{i,t-1} + \epsilon^\pi_t \tag{2.32}$$

[6] In effect, we are assuming that the international finance market is incomplete. Since there is no market that households can trade nominal bonds denominated in RoW currency, complete risk-sharing does not hold.

2.8 Equilibrium

Market clearing conditions for goods market, labor market, and domestic bond market are the following equations:

$$Y_{j,t}(\omega) = \sum_i C_{ji,t}(\omega) + X_{ji,t}(\omega) \tag{2.33}$$

$$N_{j,t} = L_{j,t} \tag{2.34}$$

$$B_{j,t} = 0 \tag{2.35}$$

Finally, the real GDP is defined as the sum of consumption and net exports:

$$GDP_{j,t} = C_{j,t} + \sum_i \frac{P_{ji,t}}{P_{j,t}} Y_{ji,t} - \sum_i \frac{P_{ij,t}}{P_{j,t}} C_{ij,t} - \sum_i \frac{\tilde{P}_{ij,t}}{P_{j,t}} X_{ij,t} \tag{2.36}$$

3 Results

3.1 Calibration

Parameters used in this model are listed in Table 1. Some parameters are calibrated in order to match steady-state values and shares of varaibles while others are brought from other literature.

Table 1: Calibration

Parameter	Value	Description	Source
β	0.99	Discount factor	4% annual interest rate
σ_c	2	Relative risk aversion	Gopinath et al. (2020)
κ	1	Disutility of labor	Gopinath et al. (2020)
φ	2	Inverse of Frisch elasticity	Gopinath et al. (2020)
$\bar{d}^{\$}$	0	Steady-state net foreign asset	Gopinath et al. (2020)
$1-\alpha$	2/3	Intermediate input share	Gopinath et al. (2020)
σ	2	Elasticity of substitution between varieties	Gopinath et al. (2020)
ϵ	1	$\Gamma = \epsilon/(\sigma-1) = 1$	Gopinath et al. (2020)
γ_{HH}	0.7	Home bias	Gopinath et al. (2020)
i^*	$1/\beta - 1$	Steady-state interest rate	Direct calcalation
λ	0.75	Price stickiness	Galí (2015)
ψ	0.000001	Interest elasticity of foreign debt	Schmitt-Grohe and Uribe (2003)
$\bar{A}$	1	Steady-state TFP	Gopinath et al. (2020)
ρ_a	0.8	Persistence of TFP	Gopinath et al. (2020)
σ_a	0.01	S.D. of TFP	Gopinath et al. (2020)
ρ_m	0.5	Inertia of Taylor rule	Gopinath et al. (2020)
ϕ_m	1.5	Taylor rule, inflation	Gopinath et al. (2020)
ϕ_y	0.5/4	Taylor rule, output gap	Gopinath et al. (2020)
ρ_ϵ	0.5	Persistence of MP shock	Gopinath et al. (2020)
$\rho_{\$}$	0.9	Persistence of foreign interest rate shock	Gopinath et al. (2020)
ζ	1	Common component in exchange rates	Gopinath et al. (2020)

Following Galí (2015), Calvo price stickiness parameter λ is set as 0.75. Thus, each firm resets its price once a year on average. Unlike Gopinath et al. (2020), we do not assume wage stickiness.

Searching for parameters of Kimball aggregator is the main point of calibration in this model. The elasticity of substitution between varieties σ is set to be 3 following Broda and Weinstein (2006), which takes this value as median of other literature. This implies that the steady-state markup is 1/2. Gopinath and Itskhoki (2011) finds that the elasticity of markup Γ is 1, implying that $\epsilon = 1$ in this model. Since $\epsilon > 0$, there is strategic complementarity in price setting.

3.2 The role of working capital constraint

3.2.1 Domestic monetary policy

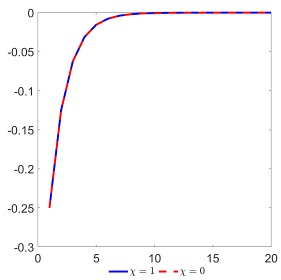
Figure 1 shows impulse responses to an expansionary monetary policy shock, comparing the case with and without working capital constraint. Blue sold line displays the impulse response when there is working capital constraint while red dashed line is the one without the constraint. Normally, the monetary policy transmission channel works through the intertemporal Euler equation. Expansionary monetary policy leads to lower lower rate of return on saving, increasing consumption accordingly.

However, when there is working capital constraint, there is another channel through which monetary policy affects the whole economy. The expansionary monetary policy lowers marginal cost by lowering effective cost of labor and domestic intermediate inputs. As shown in panel (1b), marginal cost increases less when $\psi = 1$.

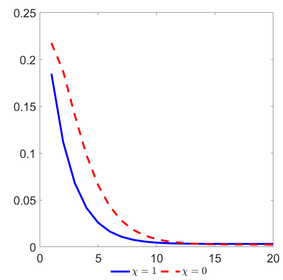
Depreciation rate of dominant currency behaves almost same in both cases since it is determined by uncovered interest rate parity (UIP) up to first order. Depreciation due to expansionary monetary policy is reflected in export and import prices as in (1e) and (1f) since they are sticky in dominant currency by the assumption of DCP. However, the increase in (nominal) export prices are less in the case of $\psi = 1$ since marginal cost increases less as we have seen above.

The increase in (nominal) import prices leads to a decrease in import quantities. Since the effective cost of imported intermediate inputs depend on foreign interest rate rather than domestic interest rate, there is little difference between $\psi = 1$ and $\psi = 0$. Additionally, export quantities do not react much to monetary policy shock compared to import quantities. Import quantities react ten times as much as export quantities. This is due to the assumption of DCP. Since prices of exported goods are rigid in dominant currency, the effect of depreciation does not affect export quantities as much as the case of PCP. However, in the case of working capital constraint, exports increase more due to lower marginal costs. The total response of trade quantity is negative since the decrease in imports outweigh the increase in exports. The difference from working capital constraint is not large, though trade decreases less when there is working capital constraint.

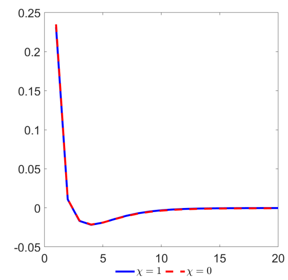
Since this working capital channel is not applied to household consumption, there is little difference in household consumption when we include working capital constraint. Consumption increases in both cases though the increase is slightly larger when there is working capital constraint. Output increases more than household consumption due to the increase in export quantities, and this increase is larger in the case of $psi = 1$ although the difference is not large. Lastly, the current account-to-GDP ratio rises to the expansionary monetary policy shock, which is predicted by the increase in exports and the decrease in imports. Under the working capital constraint, current acount-to-GDP ratio rises more, about 5% point on impact, and more persistently.



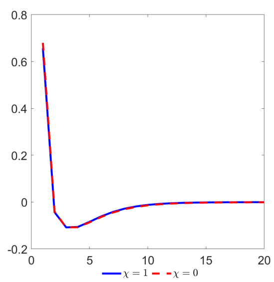
(a) Monetary policy shock



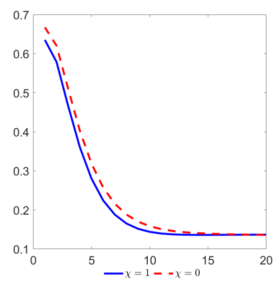
(b) Marginal cost



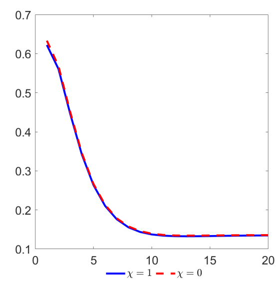
(c) Inflation



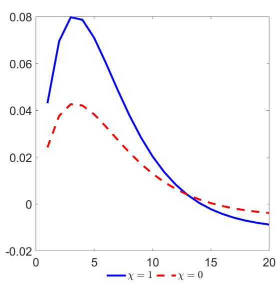
(d) Depreciation rate



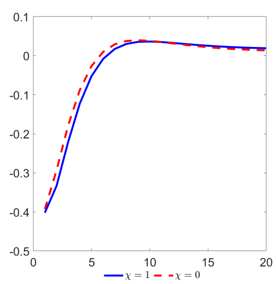
(e) Export price



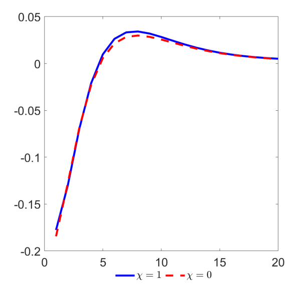
(f) Import price



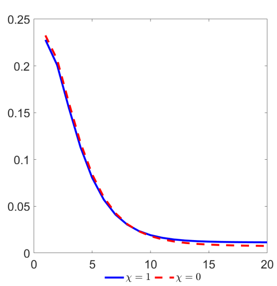
(g) Exports



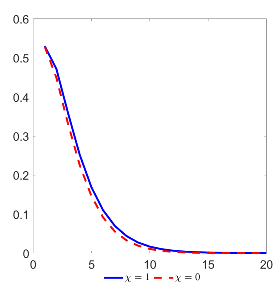
(h) Imports



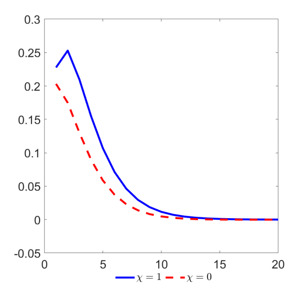
(i) Trade



(j) Consumption



(k) Output



(l) Current Account-to-GDP

Figure 1: Impulse response to monetary policy shock

3.2.2 Monetary policy of dominant currency

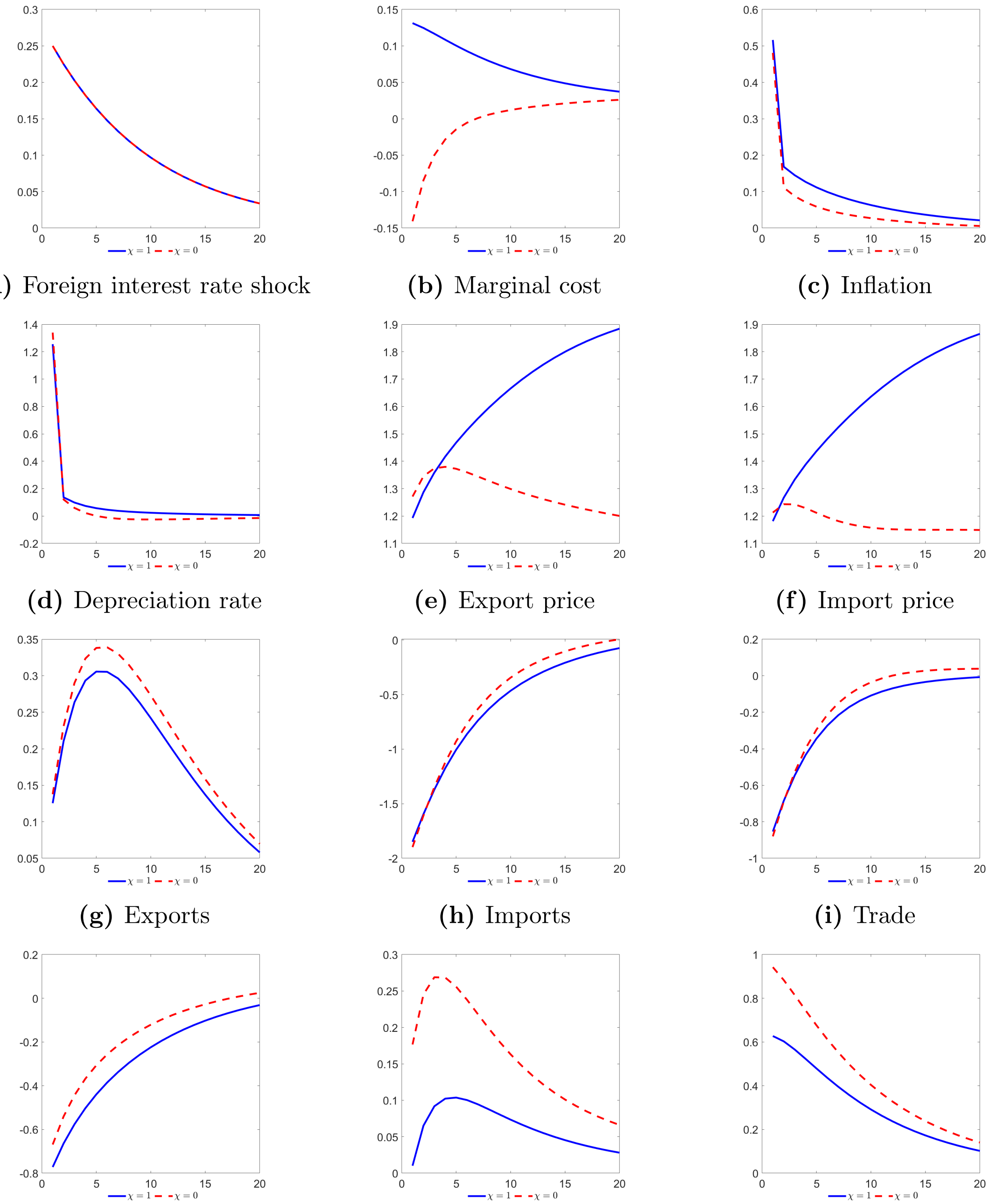
Monetary policy of foreign country affects domestic economy through not only exchange rate channel but also import price channel. Specifically, if the interest rate of dominant currency increases, then the import price of intermediate inputs rises due to working capital constraint. In the case of dominant currency pricing, all firms are required to pay the price of imported intermediate inputs in dominant currency, which is \$. Thus, import prices rises in response to the increase in US nominal interest rate. This leads to the decrease in imported intermediate inputs.

Importantly, marginal cost behaves oppositely when there is working capital constraint. Basically, higher foreign interest rate entails smaller amount of household consumption since it becomes harder to borrow from foreign countries. This leads to lower wage, which comes from intratemporal condition, and marginal costs. However, an increase in foreign interest rate raises effective cost of production. This offsets the decrease in marginal cost when there is no working capital constraint.

The stark increase in marginal cost results in higher and more persistent inflation in response to foreign interest rate shock. Similar to the expansionary monetary policy shock, domestic currency is depreciated against dominant currency and this depreciation is almost same in both cases.

Both the export and import prices rise due to the depreciation of domestic currency, which is the main point of dominant currency paradigm. In addition, the increase in US interest rate raises the effective price of traded intermediate inputs. Owing to the assumption of dominant currency financing, US monetary policy affects prices of exported and imported inputs.

This increase in import prices leads to a decrease in imports of which amount is larger when $\psi = 1$. Depreciation of domestic currency leads to the increase in exports, but the extent of this response is only modest since prices are rigid in dominant currency rather than producer currency. Also, this increase in export shrinks in face of working capital constraint due to the higher export price. In total, trade quantity decreases more than 1% in response to the rise of US interest rate. Also, this decrease is larger under the working capital constraint. This is in contrast to the case of expansionary domestic monetary policy shock even though both shocks lead to depreciation of domestic currency against dominant currency. The main difference comes from the difference in the behavior of exports. The working capital constraint lowers the response of marginal cost to the expansionary domestic monetary policy while it increases the response of marginal cost to the foreign interest rate hike. Finally, the improvement in current account-to-GDP ratio becomes diminished as is implied by the change in exports.



(a) Foreign interest rate shock
(b) Marginal cost
(c) Inflation
(d) Depreciation rate
(e) Export price
(f) Import price
(g) Exports
(h) Imports
(i) Trade
(j) Consumption
(k) Output
(l) Current Account-to-GDP

Figure 2: Impulse response to foreign interest rate shock

4 Extension: tradable and non-tradable sectors

Previously, all varieties in each country can be traded internationally. However, not all products can be traded; in reality, non-tradables occupy a large amount in each economy. Non-tradable sectors are less insulated from the depreciation of domestic currency since products of these sectors can only be sold at domestic market though they still need foreign intermediate inputs in the production process. In order to investigate the effect of the non-tradable sector, it is assumed that the whole economy is split into tradable and non-tradable sector in this section.

4.1 Extended model

A variety ω belongs to either Ω_T or Ω_{NT} where Ω_T is the set of tradables while Ω_{NT} is the set of non-tradables. Then, country j's aggregate consumption $C_{j,t}$ can be implicitly defined by the following Kimball aggregator

$$\frac{1}{|\Omega_T|}\int_{\omega\in\Omega_T}\gamma_T\Upsilon\Big(\frac{|\Omega_T|C^T_{j,t}(\omega)}{\gamma_T C_{j,t}}\Big)d\omega+\frac{1}{|\Omega_{NT}|}\int_{\omega\in\Omega_{NT}}(1-\gamma_T)\Upsilon\Big(\frac{|\Omega_{NT}|C^{NT}_{j,t}(\omega)}{(1-\gamma_T)C_{j,t}}\Big)d\omega=1 \tag{4.1}$$

where $C^T_{j,t}$ and $C^{NT}_{j,t}$ are tradable and non-tradable consumption respectively. Here, the form of the Kimball aggregator is the same as (2.9). Then, the household consumption for tradables are the following:

$$C^T_{j,t}(\omega)=\gamma_T\Big(1-\epsilon\Big(\log Z^T_{j,t}(\omega)-\log\frac{\sigma-1}{\sigma}\Big)\Big)^{\frac{\sigma}{\epsilon}}C_{j,t} \tag{4.2}$$

where $Z^T_{j,t}=D_{j,t}P^T_{j,t}/P_{j,t}$ and $P^T_{j,t}$ is the tradable price index. The household consumption for non-tradables can be derived similarly. Tradable consumption can be aggregated from domestic and imported consumption as the previous section. Note that the relative prices of domestic and imported consumption for tradable goods are measured relative to tradable price index $P^T_{j,t}$.

The production function for tradable and non-tradable sector are defined respectively as[7],

$$Y^T_{j,t}=A_{j,t}(L^T_{j,t})^{\alpha}(X^T_{j,t})^{1-\alpha} \tag{4.3}$$

$$Y^{NT}_{j,t}=A_{j,t}(L^{NT}_{j,t})^{\alpha}(X^{NT}_{j,t})^{1-\alpha} \tag{4.4}$$

Production functions of tradables and non-tradables are assumed to be identical, leading to the same marginal cost between two sectors. This assumption is without loss of generality since our main interest is the role of dollar-denominated revenue in hedging dollar exchange rate shock which comes from demand-side rather than cost-side.

[7]We assume that the total factor productivity is common for both tradables and non-tradables. Since we mainly focus on the effect of monetary policy, this assumption is without loss of generality.

For tradable sector, tradable and non-tradable intermediate inputs are aggregated using the same Kimball function:

$$\frac{1}{|\Omega_T|}\int_{\omega\in\Omega_T}\gamma_T\Upsilon\Big(\frac{|\Omega_T|X^{T,T}_{j,t}(\omega)}{\gamma_T X^T_{j,t}}\Big)d\omega+\frac{1}{|\Omega_{NT}|}\int_{\omega\in\Omega_{NT}}(1-\gamma_T)\Upsilon\Big(\frac{|\Omega_{NT}|X^{NT,T}_{X,t}(\omega)}{(1-\gamma_T)X^T_{j,t}}\Big)d\omega=1 \tag{4.5}$$

$X_{T,T}$ is the tradable intermediate input of the tradable sector while $X_{NT,T}$ is the non-tradable intermediate input of the tradable sector. Intermediate input aggregator of the non-tradable sector can also be defined by the same way. From the above Kimball aggregator, tradable sector's demand functions for intermediate input are the following:

$$X^{T,T}_{j,t}(\omega)=\gamma_T\Big(1-\epsilon\Big(\log\tilde{Z}^T_{j,t}(\omega)-\log\frac{\sigma-1}{\sigma}\Big)\Big)^{\frac{\sigma}{\epsilon}}X^T_{j,t} \tag{4.6}$$

$$X^{NT,T}_{j,t}(\omega)=(1-\gamma_T)\Big(1-\epsilon\Big(\log\tilde{Z}^{NT}_{j,t}(\omega)-\log\frac{\sigma-1}{\sigma}\Big)\Big)^{\frac{\sigma}{\epsilon}}X^T_{j,t} \tag{4.7}$$

where $\tilde{Z}^T_{j,t}=D_{j,t}\tilde{P}^T_{j,t}/\tilde{P}_{j,t}$ and $\tilde{Z}^{NT}_{j,t}=D_{j,t}\tilde{P}^{NT}_{j,t}/\tilde{P}_{j,t}$. Non-tradable sector's demand functions can be derived by the same way. Also, tradable intermediate inputs are aggregated from domestic and imported intermediate inputs as the previous section. Here, the relative prices of domestic and imported intermediate inputs are measured relative to tradable intermediate input price $\tilde{P}^T_{j,t}$.

Lastly, the aggregate output is defined as the total real value of tradable and non-tradable output.

$$Y_{j,t}=\frac{P^T_{j,t}}{P_{j,t}}Y^T_{j,t}+\frac{P^{NT}_{j,t}}{P_{j,t}}Y^{NT}_{j,t} \tag{4.8}$$

All other parts constituting the equilibrium of this model are assumed to be the same as the previous section.

4.2 Results

The steady-state share of tradable sector, γ_T, is calibrated to be 0.26 following Uribe and Schmitt-Grohé (2017). The following impulse response functions of the extended model are then displayed and compared with the benchmark case where all varieties are tradables. Blue sold line indicates the benchmark case while green dotted line is the one with $\gamma_T=0.26$ case.

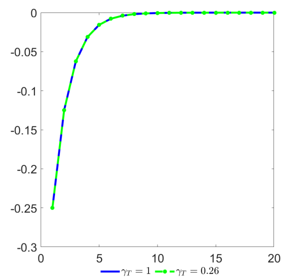
4.2.1 Domestic monetary policy

Figure 3 shows the impulse responses to 25bp expansionary domestic monetary policy shock. In response to the shock, domestic currency is depreciated about 0.7%p, which is slightly larger than the benchmark case. The depreciation hampers the profit of non-tradable sectors more than tradable sectors since non-tradables are only sold at the domestic market while they still need foreign inputs of which costs rise due to the depreciation. This lack of insulation from the depreciation shifts down marginal cost since non-tradable sector's demand for labor and intermediate inputs contracts. From the panel (3b), we can see that the response of marginal cost decreased from 0.18%p to 0.12%p. The weakened response of marginal cost is reflected to the behavior of inflation. As in panel (3c), the increase in inflation when there are non-tradables is less than half of that in the benchmark case.

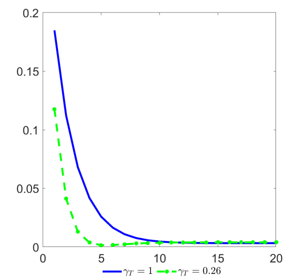
Since there is less inflation, Taylor rule suggests lower domestic interest rate, which leads to higher depreciation rate of domestic currency though the change is not large. The higher depreciation rate is reflected in the responses of export and import price. When there are non-tradable sectors in the economy, the increase in export and import prices become 0.1%p larger immediately, but return to the steady-state more quickly due to the following lower inflation.

The stark difference with the benchmark model comes from import quantities and total trades. Since the profit of the non-tradable sectors is largely affected by depreciation, their demand for intermediate inputs decline, which results in a decrease in imports. The decrease in imports is 0.8%p whereas it is 0.4%p in the benchmark model, implying that the decrease in imports become twice larger when there are non-tradables. On the contrary, the increase in export quantities becomes larger from 0.04%p to 0.07%p due to the reallocation of resources from non-tradables to tradables. This reallocation channel will be investigated in more detail in the next section. However, this change in exports is negligible relative to that in imports. Thus, in total, trade quantities decrease about 0.35%p, which is twice larger than the benchmark model.

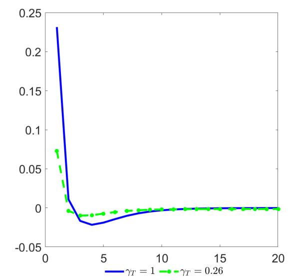
On the other hand, household consumption increases about 0.35% point, which is higher than 0.23%p increase in benchmark model, since domestic interest rate decreases more due to the lower inflation rate. Aggregate output rises about 0.5% point which is slightly larger than the benchmark case. Lastly, current account-to-GDP ratio becomes lower due to the increase in consumption.



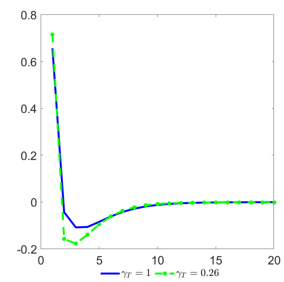
(a) Monetary policy shock



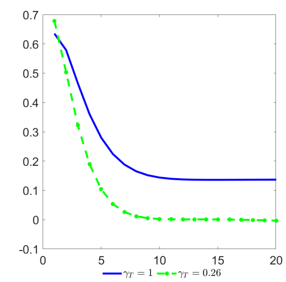
(b) Marginal cost



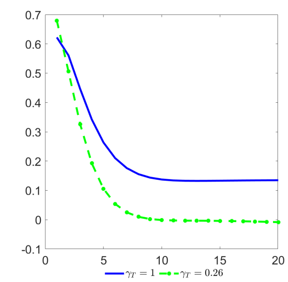
(c) Inflation



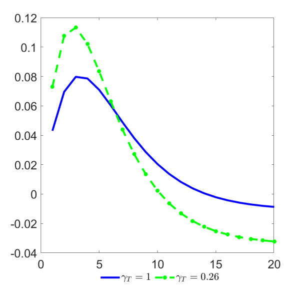
(d) Depreciation rate



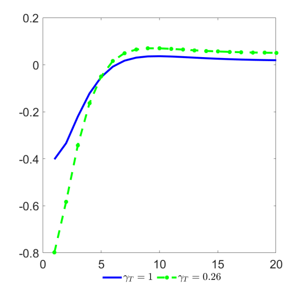
(e) Export price



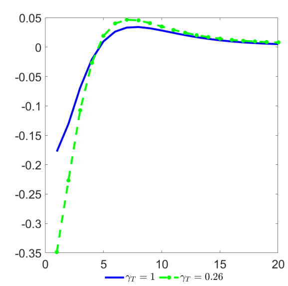
(f) Import price



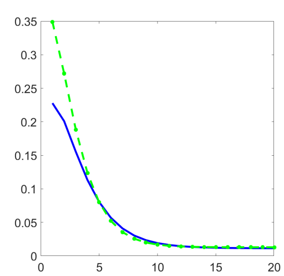
(g) Exports



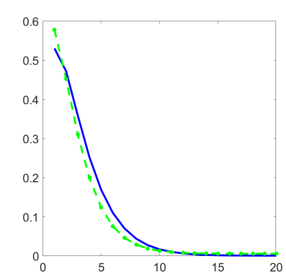
(h) Imports



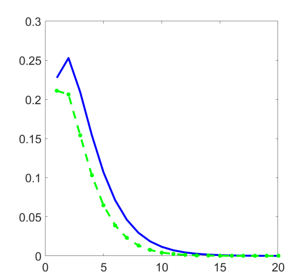
(i) Trade



(j) Consumption



(k) Output

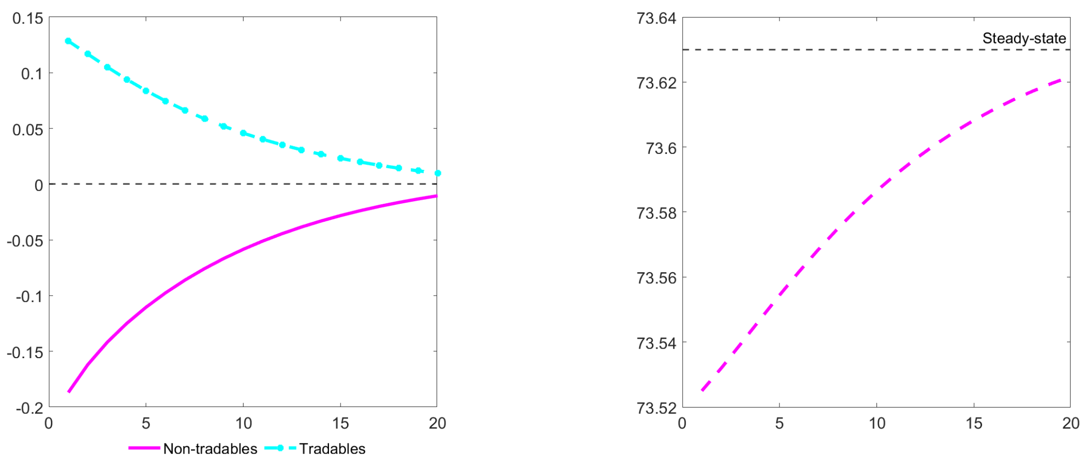


(l) Current Account-to-GDP

Figure 3: Impulse response to monetary policy shock ($\gamma_T = 0.26$)

4.2.2 Monetary policy of dominant currency

The rise of US dollar interest rate increases effective cost of intermediate inputs and results in depreciation of dominant currency as the previous section. The important difference from the benchmark case comes from the existence of non-tradables which are not insulated from the depreciation due to the absence of dollar-denominated revenue. Hence, depreciation diminishes profits of non-tradables. Meanwhile, tradables are less vulnerable to depreciation of home currency since part of their revenues are denominated in dominant currency of which value increases in response to depreciation of home currency. This heterogeneity between tradables and non-tradables is reflected in the responses of profit of both sectors. In Figure 4a, profits of non-tradables decrease about 0.2% point while those of tradables rise up to 0.13% point. Accordingly, as in panel 4b, the share of non-tradables in total output decreases more than 0.1% point, reflecting the point that resources are reallocated from non-tradables to tradables.



(a) Profits of non-tradables and tradables

(b) Share of non-tradables in total output

Figure 4: Heterogeneous responses of tradables and non-tradables

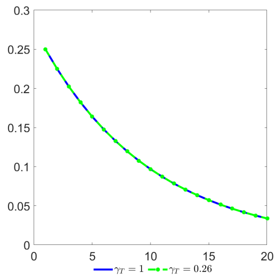
In Figure 5, impulse responses to 25bp foreign interest rate increase are displayed. As discussed above, depreciation following the contractionary foreign monetary policy leads to lower profits of non-tradables, resulting in the decrease in the demand for inputs and marginal cost. We can see that the increase in marginal cost becomes around two-thirds of the case where all sectors are tradables. The lower response of marginal cost is reflected in the impulse response of inflation; the increase in inflation rate is also the half of that when all sectors are tradables.

The change in the responses of depreciation rate, export price, and import price are similar to the case of domestic monetary policy shock. Lower inflation induces lower domestic interest rate as implied by Taylor rule, leading to higher depreciation rate of home currency. Home currency is depreciated about 1.8%p compared to 1.3%p in the benchmark case. Accordingly, in panel (5e) and

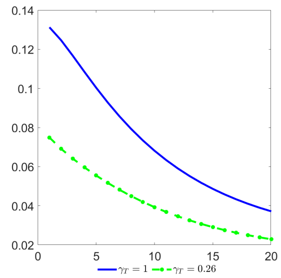
(5f), export and import prices rise more than the benchmark case just after the shock. Both prices rise about 1.7%p on impact while those changes are 1.2%p for the benchmark case. However, since the inflation rate is about the half of the benchmark case, nominal export and import prices decline faster. This stark difference suggests imperfect pass-through of exchange rate to export and import prices.

From the panel (5g) and (5h), we can see that the changes in both export and import quantities are expanded. Exports rises up to 0.64%p after 5 quarters, which is more than two times larger than the increase when there are only tradables. The further increase in exports is due to the reallocation of labor and intermediate inputs from non-tradables to tradables. However, this change is negligible compared to that in imports which decline 3.2%p where as the size of the decrease is 1.9%p in only-tradable case. The main point of this result is that the profit of the non-tradable sector is largely affected by the change in depreciation rate. Due to the diminished profit of the non-tradable sector following depreciation, its demand for intermediate inputs contracts, resulting in the large decrease in imported intermediate inputs. In total, the decrease in imports outweigh the increase in exports, so trade volume decreases about twice more when there are non-tradables.

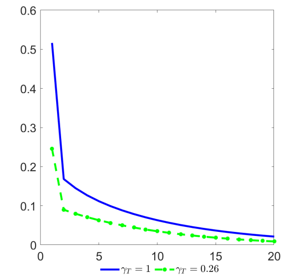
Household consumption drops less by the same reason as the previous section. Importantly, gross output decreases in contrast to the benchmark case though the size of the decrease is negligible. In the benchmark case, output increases due to the depreciation of home currency followed by expenditure switching. However, this expenditure switching mechanism does not work for non-tradables. Production of non-tradables decrease due to higher cost of imported intermediate inputs, and the decrease in non-tradables can outweigh the increase in tradables depending on the parameter γ_T. Although domestic currency is depreciated due to the tightening of US monetary policy, gross domestic output can decrease when the share of non-tradables is large enough. Lastly, current account-to-GDP ratio becomes lower compared to the benchmark case due to the increase in consumption.



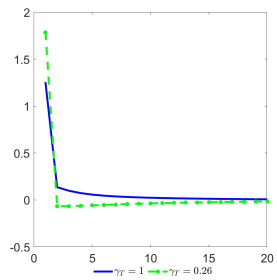
(a) Foreign interest rate shock



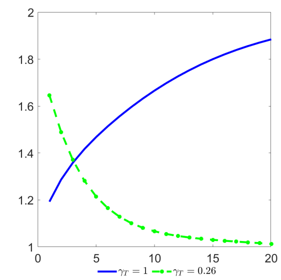
(b) Marginal cost



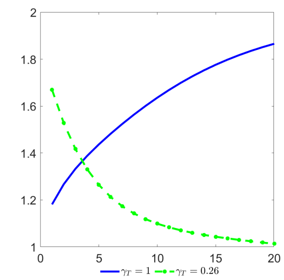
(c) Inflation



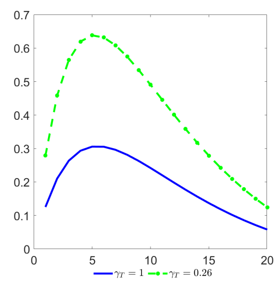
(d) Depreciation rate



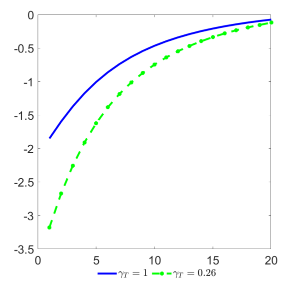
(e) Export price



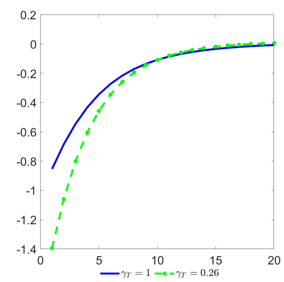
(f) Import price



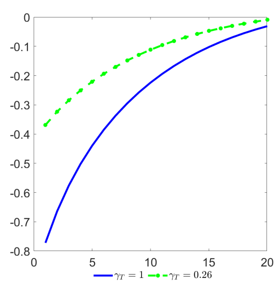
(g) Exports



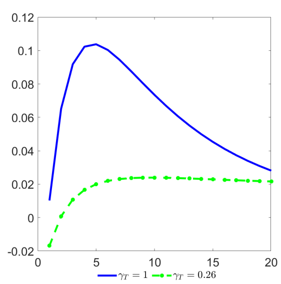
(h) Imports



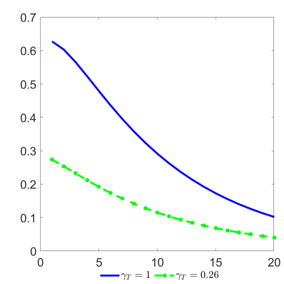
(i) Trade



(j) Consumption



(k) Output



(l) Current Account-to-GDP

Figure 5: Impulse response to foreign interest rate shock ($\gamma_T = 0.26$)

4.2.3 Pass-through of exchange rate

In this section, I examine the effect of working capital constraint and non-tradable sectors on the pass-through of exchange rate into import and export prices. Since non-tradable sectors are not insulated from the depreciation of home currency, intermediate input costs are reflected to dominant currency value of export prices more than tradable sectors. For the case of tradable sectors, dominant currency value of export prices responds less since their revenue in home currency rises due to the depreciation. Hence, the existence of non-tradables in the model strengthens the exchange rate pass-through (ERPT).

In order for analyzing ERPT in this model, I obtain artificial data by running Monte Carlo simulations from the calibrated models in previous sections, and then use bootstrap method to estimate the ERPT coefficients. Specifically, 200 quarters of series are replicated for totally 10,000 number of simulations.

Following Burstein and Gopinath (2014) and Gopinath et al. (2020), I estimate the following ERPT regression:

$$\Delta p_{ij,t} = \alpha_{ij} + \delta_t + \sum_{k=0}^{T} \beta_k \Delta e_{ij,t-k} + \sum_{k=0}^{T} \beta_k^{\$} \Delta e_{\$j,t-k} + \gamma' X_{i,t} + \epsilon_{ij,t} \tag{4.9}$$

where α_{ij} and δ_t are dyadic and time fixed effects respectively. $p_{ij,t}$ refers to the (log) price of output flowing from country i to j denominated in the currency of j while $e_{ij,t}$ and $e_{\$,j}$ denote bilateral and dollar exchange rate. Thus, β_k and $\beta_k^{\$}$ are coefficients for bilateral ERPT and dollar ERPT respectively. The regression equation contains lag k up to $T = 8$ reflecting the usual convention in this literature that includes lags up to 2 years. $X_{i,t}$ denotes covariates controlling for observables in exporting country i. Following the literature, inflation rate of the tradable sector's producer price index (PPI) and its lags (up to 8) are included as covariates.

Table 2 reports bootstrap estimates of ERPT coefficients from the fixed effect regression (4.9). Columns show the regression coefficients for each model that is used to replicate the artificial data and estimate ERPT; column 1 and column 2 refer to the model without and with working capital constraint respectively while column 3 reports estimates from the model with non-tradable sectors. As the assumption of dominant currency pricing suggests, exchange rate pass-through is stronger for the case of dollar exchange rate than bilateral exchange rate. This dominance of dollar exchange rate becomes stronger when there is working capital constraint and non-tradable sectors. Especially, we can find that the dollar exchange rate pass-through strengthens in the model with non-tradables.

Table 2: Exchange rate pass-through implied by calibrated models

	No working capital	With working capital	With non-tradables
	$\Delta p_{ij,t}$	$\Delta p_{ij,t}$	$\Delta p_{ij,t}$
	(1)	(2)	(3)
$\Delta e_{ij,t}$	0.351***	0.184***	0.166***
	(0.105)	(0.005)	(0.006)
$\Delta e_{\$j,t}$	0.375*	0.647***	0.702***
	(0.219)	(0.011)	(0.014)
R^2	0.929	0.997	0.995
Observations	768	768	768

Note. All the regressions include covariates (with lags up to 8) and lagged $\Delta e_{ij,t}$ and $\Delta e_{\$j,t}$ of which coefficients are not displayed. Numbers in parentheses are bootstrap standard errors. $*$, $**$, and $***$ refer to significance level of 10%, 5%, and 1% respectively.

5 Conclusion

This paper investigates the effect of domestic and foreign monetary policy under dominant currency pricing and dominant currency financing. For this purpose, a small open economy New Keynesian model with dominant currency pricing and working capital constraint is constructed. Similar to Gopinath et al. (2020), all consumption goods and intermediate inputs are assumed to be priced and rigid in dominant currency, except domestic consumption and intermediate inputs which are invoiced and sticky in domestic currency.

Importantly, the expenditure on labor and intermediate inputs are required to be financed prior to sales, which creates the need for working capital naturally. Since imported intermediate inputs are invoiced in dominant currency, working capital for these inputs are assumed to be financed in dominant currency. This indicates interdependency between dominant currency pricing and dominant currency financing. Based on the calibrated model, the effect of domestic and foreign (US) interest rate policy are investigated.

First, the effect of the expansionary monetary policy shock on marginal cost and prices are weakened. This is due to the existence of working capital constraint since lower domestic interest rate diminishes the effective cost of labor and domestic intermediate inputs. The decrease in imports are less affected since imported inputs are financed in dominant currency rather than domestic currency, but exports increase more due to less marginal cost. However, since the improvement in exports is negligible under DCP, the total trade quantities change slightly under working capital constraint. Accordingly, the current account-to-GDP ratio rises more.

Next, unlike the expansionary domestic monetary policy shock, the tightening of foreign interest rate strengthen the response of price variables. In addition to the effect of depreciation of domestic currency on inflation, the increase in marginal cost rises inflation, export, and import prices more. The modest increase in exports is weakened due to the higher export price, and the imports decrease more under working capital constraint. The total trade quantities decrease more, which is in contrast to the effect of expansionary domestic monetary policy shock. This tells us that we should not look only at depreciation. Depending on the source of the depreciation, trade quantity can move differently. The increase in output are weakened due to higher financial cost of foreign borrowing and lower exports.

Then, the benchmark model is extended such that the whole economy is split into tradable and non-tradable sectors. As suggested by empirical literature, there is heterogeneity between tradables and non-tradables in the response to depreciation. This is mainly because non-tradables are not hedged against depreciation. They are sold only at domestic market while they still need foreign intermediate inputs in their production process. In order to investigate this heterogeneity, this paper investigates the effect of domestic and foreign monetary policy under dominant currency pricing and dominant currency financing with tradable/non-tradable structure.

Calibrated model shows that profits of non-tradable sectors are diminished in response to depreciation caused by either expansionary domestic monetary policy or contractionary foreign monetary policy. Imports and trade quantities are then reduced since non-tradable sectors' demand for intermediate inputs decrease. This amplifies the responses of imports and trade quantities, which is in line with the empirical research by Casas et al. (2020). Also, marginal cost and inflation become lower due to this reduced demand while domestic currency is more depreciated.

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Appendix A Complete set of equilibrium conditions

First, nominal variables are transformed into real variables using relevant denominators.

$$w_{j,t} = \frac{W_{j,t}}{P_{j,t}} \qquad \text{(real wage)}$$

$$profit_{j,t} = \frac{Profit_{j,t}}{P_{j,t}} \qquad \text{(real profit)}$$

$$\Pi_{j,t} = \frac{P_{j,t}}{P_{j,t-1}} \qquad \text{(gross inflation rate)}$$

$$\Pi^j_{t,s} = \frac{P_{j,s}}{P_{j,t}} \qquad \text{(gross inflation rate from } t \text{ to } s\text{)}$$

$$E^k_{j,t} = \frac{\mathcal{E}^k_{j,t}}{\mathcal{E}^k_{j,t-1}} \qquad \text{(gross depreciation rate)}$$

$$s^k_{j,t} = \frac{\mathcal{E}^k_{j,t} P_{k,t}}{P_{j,t}} \qquad \text{(real exchange rate)}$$

$$d^k_{j,t+1} = \frac{D^k_{j,t+1}}{P_{k,t}} \qquad \text{(real foreign debt)}$$

$$mc_{j,s} = \frac{MC_{j,s}}{P_{j,s}} \qquad \text{(real marginal cost)}$$

$$p_{ij,t} = \frac{P_{ij,t}}{P_{j,t}} \qquad \text{(relative import price)}$$

$$\tilde{p}_{j,t} = \frac{\tilde{P}_{j,t}}{P_{j,t}} \qquad \text{(relative producer price)}$$

$$\tilde{p}_{ij,t} = \frac{\tilde{P}_{ij,t}}{P_{j,t}} \qquad \text{(relative import producer price)}$$

$$p^k_{ji,t} = \frac{P^k_{ji,t}}{P_{k,t}} \qquad \text{(relative invoicing price)}$$

$$\bar{p}^k_{ji,t} = \frac{\bar{P}^k_{ji,t}}{P_{k,t}} \qquad \text{(relative reset price)}$$

Then, all equilibrium conditions which are functions of above real variables are collected.

$$1 = E_t\Big[\beta \frac{C_{j,t+1}^{-\sigma_c}}{C_{j,t}^{-\sigma_c}} \frac{1}{\Pi_{j,t+1}}(1+i_{j,t})\Big] \tag{A.1}$$

$$1 = E_t\Big[\beta \frac{C_{j,t+1}^{-\sigma_c}}{C_{j,t}^{-\sigma_c}} \frac{E_{j,t+1}^{\$}}{\Pi_{j,t+1}}(1+i_{j,t}^{\$})\Big] \tag{A.2}$$

$$w_{j,t} = \kappa \frac{N_{j,t}^{\varphi}}{C_{j,t}^{-\sigma_c}} \tag{A.3}$$

$$C_{j,t} + s_{j,t}^{\$} \frac{1+i_{j,t-1}^{\$}}{\Pi_t^{\$}} d_{j,t}^{\$} = w_{j,t}N_{j,t} + profit_{j,t} + s_{j,t}^{\$} d_{j,t+1}^{\$} \tag{A.4}$$

$$profit_{j,t} = \sum_{i,k} \theta_{ji}^k s_{j,t}^k p_{ji,t}^k Y_{ji,t}^k - mc_{j,t}Y_{j,t} \tag{A.5}$$

$$\frac{s_{j,t}^k}{s_{j,t-1}^k} = E_{j,t}^k \frac{\Pi_{k,t}}{\Pi_{j,t}} \tag{A.6}$$

$$\alpha \frac{Y_{j,t}}{L_{j,t}} = (1+i_{j,t}) \frac{w_{j,t}}{mc_{j,t}} \tag{A.7}$$

$$(1-\alpha)\frac{Y_{j,t}}{X_{j,t}} = \frac{\tilde{p}_{j,t}}{mc_{j,t}} \tag{A.8}$$

$$mc_{j,t} = \frac{1}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} \frac{(1+i_{j,t})^{\alpha} w_{j,t}^{\alpha} \tilde{p}_{j,t}^{1-\alpha}}{A_{j,t}} \tag{A.9}$$

$$Y_{j,t} = \sum_i Y_{ji,t} \tag{A.10}$$

$$Y_{ij,t} = \sum_k \theta_{ij}^k (C_{ij,t}^k + X_{ij,t}^k) \tag{A.11}$$

$$C_{ij,t}^k = \gamma_{ij}\Big(1 - \epsilon\Big(\log s_{j,t}^k p_{ij,t}^k + \log D_{j,t} - \log \frac{\sigma-1}{\sigma}\Big)\Big)^{\frac{\sigma}{\epsilon}} C_{j,t} \tag{A.12}$$

$$X_{ij,t}^k = \gamma_{ij}\Big(1 - \epsilon\Big(\log s_{j,t}^k \frac{\tilde{p}_{ij,t}^k}{\tilde{p}_{j,t}} + \log D_{j,t} - \log \frac{\sigma-1}{\sigma}\Big)\Big)^{\frac{\sigma}{\epsilon}} X_{j,t} \tag{A.13}$$

$$C_{j,t} = \sum_i p_{ij,t} C_{ij,t} \tag{A.14}$$

$$p_{ij,t}C_{ij,t} = \sum_k s_{j,t}^k p_{ij,t}^k C_{ij,t}^k \tag{A.15}$$

$$\tilde{p}_{j,t}X_{j,t} = \tilde{p}_{jj,t}X_{jj,t} + \sum_{i\neq j} \tilde{p}_{ij,t}X_{ij,t} \tag{A.16}$$

$$\tilde{p}_{ij,t} = \begin{cases} (1+i_{j,t})p_{jj,t} & \text{if } i = j \\ (1+i_{j,t}^{\$})p_{ij,t} & \text{if } i \neq j \end{cases} \tag{A.17}$$

$$\begin{aligned} &E_t \sum_{s=t}^{\infty} \lambda^{s-t} \Theta_{j,t,s} [(\sigma_{ji,s}^k(\omega) - 1)C_{ji,s|t}^k(\omega) + (\tilde{\sigma}_{ji,s}^k(\omega) - 1)X_{ji,s|t}^k(\omega)] s_{j,s}^k \frac{\Pi_{t,s}^j}{\Pi_{t,s}^k} \bar{p}_{ji,t}^k \\ &= E_t \sum_{s=t}^{\infty} \lambda^{s-t} \Theta_{j,t,s} [\sigma_{ji,s}^k(\omega) C_{ji,s|t}^k(\omega) + \tilde{\sigma}_{ji,s}^k(\omega) X_{ji,s|t}^k(\omega)] \Pi_{t,s}^j mc_{j,s} \end{aligned} \tag{A.18}$$

$$p^k_{ji,t} = (1-\lambda)\bar{p}^k_{ji,t} + \lambda \frac{p^k_{ji,t-1}}{\Pi_{k,t}} \tag{A.19}$$

$$N_{j,t} = L_{j,t} \tag{A.20}$$

$$i_{j,t} - i^* = \rho_m(i_{j,t-1} - i^*) + (1-\rho_m)(\phi_m \log \Pi_{j,t} + \phi_y(\log Y_{j,t} - \log Y_j)) + \epsilon_{j,t} \tag{A.21}$$

$$\epsilon_{j,t} = \rho_\epsilon \epsilon_{j,t-1} + \epsilon^m_{j,t} \tag{A.22}$$

$$i^\$_{j,t} = i^\$_t + \psi(\exp(d^\$_{t+1} - \bar{d}^\$) - 1) \tag{A.23}$$

$$i^\$_t = i^* + \rho_\$(i^\$_{t-1} - i^*) + \epsilon^*_t \tag{A.24}$$

$$\log A_{j,t} = \rho_a \log A_{j,t-1} + \epsilon^a_{j,t} \tag{A.25}$$

Appendix B Steady-states

We look for symmetric steady-state where $p_{ij} = 1$ for all i and j. Then, steady-states for prices are the following:

$$\tilde{p}_{ij} = 1 + i^* \tag{B.1}$$

$$\tilde{p}_j = 1 + i^* \tag{B.2}$$

$$p^k_{ij} = 1 \tag{B.3}$$

$$\bar{p}^k_{ij} = 1 \tag{B.4}$$

From (A.1) and (A.2),

$$i^* = \frac{1}{\beta} - 1 \tag{B.5}$$

From (A.18),

$$mc_j = \frac{\sigma - 1}{\sigma} \tag{B.6}$$

Plugging this into (A.5),

$$profit_j = \frac{1}{\sigma} Y_j \tag{B.7}$$

(A.9) implies that

$$w_j = \left[\left(\frac{\sigma - 1}{\sigma} \right) \frac{\alpha^\alpha (1-\alpha)^{1-\alpha}}{1 + i^*} \right]^{\frac{1}{\alpha}} \tag{B.8}$$

From (A.7) and (A.8),

$$X_j = \frac{1-\alpha}{1+i^*} \frac{\sigma - 1}{\sigma} Y_j \tag{B.9}$$

$$N_j = \frac{\alpha}{1+i^*} \frac{\sigma - 1}{\sigma} \frac{1}{w_j} Y_j \tag{B.10}$$

The intratemporal condition (A.3) leads to

$$C_j = \left(\frac{w_j}{\kappa N_j^\varphi} \right)^{\frac{1}{\sigma_c}} \tag{B.11}$$

while (A.4) implies

$$C_j = w_j N_j + profit_j - i^* \bar{d}^{\$} = \Big[\frac{\alpha}{1+i^*}\frac{\sigma-1}{\sigma} + \frac{1}{\sigma}\Big] Y_j - i^* \bar{d}^{\$} \tag{B.12}$$

Since both are functions of Y_j, we can obtain steady-state aggregate output Y_j.

Finally, steady-state import quantities are given by the following

$$C_{ij}^k = \gamma_{ij} C_j \tag{B.13}$$

$$X_{ij}^k = \gamma_{ij} X_j \tag{B.14}$$

$$Y_{ij} = \gamma_{ij}(C_j + X_j) \tag{B.15}$$

which are implied by (A.11)- (A.13).

Appendix C Log-linearized equations

For each variable x, let $\hat{x}$ denote the log-deviation from its steady-state.

First, the log-linearized version of Euler equations (A.1) and (A.2) are the following:

$$\hat{c}_{j,t} = E_t\hat{c}_{j,t+1} - \frac{1}{\sigma_c}(i_{j,t} - i^* - E_t\pi_{j,t+1}) \tag{C.1}$$

$$\hat{c}_{j,t} = E_t\hat{c}_{j,t+1} - \frac{1}{\sigma_c}(i^{\$}_{j,t} - i^* - E_t\pi_{j,t+1} + E_t\Delta e^{\$}_{j,t+1}) \tag{C.2}$$

From the intratemporal condition (A.3),

$$\hat{w}_{j,t} = \varphi\hat{n}_{j,t} + \sigma_c\hat{c}_{j,t} \tag{C.3}$$

On the other hand, log-linearizing budget constraint (A.4) yields

$$\hat{c}_{j,t} + \frac{i^*\overline{d}^{\$}}{C_j}\hat{s}^{\$}_{j,t} = \frac{w_j N_j}{C_j}(\hat{w}_{j,t} + \hat{n}_{j,t}) + \frac{1}{C_j}\hat{profit}_{j,t} + \frac{1+i^*}{C_j}\pi^{\$}_t - \frac{1}{C_j}(i^{\$}_{j,t-1} - i^*) - \frac{1+i^*}{C_j}\hat{d}^{\$}_{j,t} \tag{C.4}$$

where log-deviation of (A.5) is the following:

$$\hat{profit}_{j,t} = \sum_{i,k}\theta^k_{ji}Y^k_{ji}(\hat{s}^k_{j,t} + \hat{p}^k_{ji,t} + \hat{y}^k_{ji,t}) - Y_j mc_j(\hat{mc}_{j,t} + \hat{y}_{j,t}) \tag{C.5}$$

From (A.6), we can obtain the following:

$$\hat{s}^{\$}_{j,t} - \hat{s}^{\$}_{j,t-1} = \Delta e^k_{j,t} + \pi_{k,t} - \pi_{j,t} \tag{C.6}$$

Log-linearizing (A.7) and (A.8) yields the following:

$$\hat{y}_{j,t} - \hat{l}_{j,t} = \psi(i_{j,t} - i^*) + \hat{w}_{j,t} - \hat{mc}_{j,t} \tag{C.7}$$

$$\hat{y}_{j,t} - \hat{x}_{j,t} = \hat{\tilde{p}}_{j,t} - \hat{mc}_{j,t} \tag{C.8}$$

while the log-deviation of marginal cost (A.9) becomes

$$\hat{mc}_{j,t} = \alpha(\psi(i_{j,t} - i^*) + \hat{w}_{j,t}) + (1-\alpha)\hat{\tilde{p}}_{j,t} - \log A_{j,t} \tag{C.9}$$

From (A.10) and (A.11), we can obtain

$$\hat{y}_{j,t} = \sum_i \frac{\gamma_{ji} Y_i}{Y_j} \hat{y}_{ji,t} \tag{C.10}$$

$$\hat{y}_{ij,t} = \sum_k \theta_{ij}^k [\alpha \hat{c}_{ij,t}^k + (1-\alpha)\hat{x}_{ij,t}^k] \tag{C.11}$$

On the other hand, Kimball demand functions (A.12) and (A.13) become

$$\hat{c}_{ij,t}^k = -\sigma(\hat{s}_{ij,t}^k + \hat{p}_{ij,t}^k) + \hat{c}_{j,t} \tag{C.12}$$

$$\hat{x}_{ij,t}^k = -\sigma(\hat{s}_{ij,t}^k + \hat{\tilde{p}}_{ij,t}^k - \hat{\tilde{p}}_{j,t}) + \hat{x}_{j,t} \tag{C.13}$$

Log-linearizing aggregate and import price indexes (A.14)-(A.17) lead to the following equations:

$$0 = \sum_i \gamma_{ij} \hat{p}_{ij,t} \tag{C.14}$$

$$\hat{p}_{ij,t} = \sum_k (\hat{s}_{j,t}^k + \hat{p}_{ij,t}^k) \tag{C.15}$$

$$\hat{\tilde{p}}_{j,t} = \gamma_{jj}(\psi(i_{j,t} - i^*) + \hat{p}_{jj,t}) + \sum_{i \neq j} \gamma_{ij}(\psi(i_{j,t}^{\$} - i^*) + \hat{p}_{ij,t}) \tag{C.16}$$

$$\hat{\tilde{p}}_{ij,t} = \begin{cases} \psi(i_{j,t} - i^*) + \hat{p}_{jj,t} & \text{if } i = j \\ \psi(i_{j,t}^{\$} - i^*) + \hat{p}_{ij,t} & \text{if } i \neq j \end{cases} \tag{C.17}$$

From the equation (A.18) for the optimal reset price,

$$\sum_{s=t}^{\infty} (\beta\lambda)^{s-t} E_t[\hat{\bar{p}}_{ji,t}^k + \hat{s}_{j,s}^k - \pi_{t,s}^k] = \sum_{s=t}^{\infty} (\beta\lambda)^{s-t} E_t[\hat{m}c_{j,s} - \frac{1}{\sigma-1}\frac{C_{ji}}{Y_{ji}}\hat{\sigma}_{ji,s}^k - \frac{1}{\sigma-1}\Big(1 - \frac{C_{ji}}{Y_{ji}}\Big)\hat{\tilde{\sigma}}_{ji,s}^k]$$

Since the log-deviation of elasticities are derived as the following,

$$\hat{\sigma}_{ji,s}^k(\omega) = \epsilon \hat{z}_{ji,t}^k(\omega) = \epsilon(\hat{s}_{i,s}^k - \pi_{t,s}^k + \hat{\bar{p}}_{ji,t}^k)$$
$$\hat{\tilde{\sigma}}_{ji,s}^k(\omega) = \epsilon(\hat{s}_{i,s}^k - \pi_{t,s}^k + \hat{\bar{p}}_{ji,t}^k + \log(1 + \chi i_{i,s}^k) - \tilde{p}_{i,s})$$

we can obtain the dynamics for the optimal reset price:

$$\hat{\bar{p}}_{ji,t}^k = \beta\lambda E_t[\hat{\bar{p}}_{ji,t+1} + \pi_{t+1}^k] + \frac{1-\beta\lambda}{1+\Gamma}\Big[\hat{m}c_{j,t} - \Gamma s_{i,t}^k - s_{j,t}^k - \Gamma\Big(1 - \frac{C_{ji}}{Y_{ji}}\Big)(\log(1 + \chi i_{i,s}^k) - \tilde{p}_{i,s})\Big] \tag{C.18}$$

Log-linearizing the equation (A.19) for the evolution of prices,

$$\hat{p}^k_{ji,t} - \hat{p}^k_{ji,t-1} + \pi^k_t = (1-\lambda)(\hat{\bar{p}}^k_{ji,t} - \hat{p}^k_{ji,t-1} + \pi^k_t) \tag{C.19}$$

Market clearing condition for labor market (A.20) yields

$$\hat{n}_{j,t} = \hat{l}_{j,t} \tag{C.20}$$

Log-linearizing Taylor rule (A.21) and foreign interest rate (A.23) yields the following:

$$i_{j,t} - i^* = \rho_m(i_{j,t-1} - i^*) + (1-\rho_m)(\phi_m \pi_{j,t} + \phi_y \hat{y}_{j,t}) + \epsilon_{j,t} \tag{C.21}$$

$$i^\$_{j,t} = i^\$_t + \psi(d^\$_{t+1} - \bar{d}^\$) \tag{C.22}$$

Finally, exogenous shock processes (A.22), (A.24), and (A.25) are described in log-linearized form:

$$\epsilon_{j,t} = \rho_\epsilon \epsilon_{j,t-1} + \epsilon^m_{j,t} \tag{C.23}$$

$$i^\$_t = i^* + \rho_\$(i^\$_{t-1} - i^*) + \epsilon^*_t \tag{C.24}$$

$$\hat{a}_{j,t} = \rho_a \hat{a}_{j,t-1} + \epsilon^a_{j,t} \tag{C.25}$$