The role of local currency pricing in international transmission effects of corporate tax reduction in an economy with vertical production linkage and foreign direct investment

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Abstract

By constructing a two-country model with asymmetry in price-setting behavior between home and foreign intermediate goods firms, vertical production and trade, and endogenous entry of three types of final goods firms, we examine the effects of a reduction in the corporate tax rate of the home country. In particular, we focus on the role of asymmetry in price-setting behavior between home and foreign intermediate goods firms. We show that a reduction in home corporate tax rate yields the entry of foreign multinational firms, the exit of home multinational firms, the improvement in home welfare, and the deterioration in foreign welfare. In addition, when the ratio of home and/or foreign intermediate goods firms that set their export prices in the local currency rises, we show that the above effects are weakened.

Keywords: Local currency pricing, Vertical production and trade, Firm entry, Foreign direct investment, Corporate tax reduction

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1 Introduction

The deepening of vertical structures of production and trade, which mean vertical production linkages, and the tremendous growth in foreign direct investment (FDI) that have occurred in the past several decades have changed the structure of macroeconomic interdependence in the global economy. With regard to the deepening of vertical structures of production and trade, Hummels et al. (2001) use data from 10 OECD and four emerging economies and find that such a structure is observed as an important feature of today's global production and trade.[1] Based on such an empirical analysis, recently, some researches have been conducted by incorporating vertical production linkages into the new open economy macroeconomics (NOEM) model pioneered by Obstfeld and Rogoff (1995) (see, e.g., Berger (2006), Huang and Liu (2006, 2007), Shi and Xu (2007) and Dohwa (2014, 2018)). For example, Huang and Liu (2006) examine the effects of home monetary expansion on the welfare of both countries using the stochastic two-country NOEM model with multistage production process. They show that an increase in the stage of production and trade tends to make the home monetary expansion beneficial for the home and foreign countries. However, many researchers including Huang and Liu (2006) examine the effects of various economic shocks on the welfare of both countries in an economy without the new entry of firms.[2]

On the other hand, some researches have also been conducted by incorporating FDI, which involves the new entry of firms,[3] into the NOEM model. For example, by incorporating FDI into the stochastic two-country NOEM model, Russ (2007) examines the relationship between the fluctuation of the nominal exchange rate and the multinational firm's decision to enter a market. He shows that the source of such a fluctuation determines whether or not firms encourage FDI. Using the stochastic two-country NOEM model with endogenous entry by national and multinational firms, Cavallari (2010) examines the roles of these firms' entry in domestic and foreign markets for the

[1] See also Feenstra (1998) and Yi (2003). They also emphasize the same point as Hummels et al. (2001).

[2] Dohwa (2018) examines the effects of monetary and productivity shocks on the welfare of both countries in an economy with the new entry of firms.

[3] A non-exhaustive list of contributions with regard to firm entry includes Corsetti et al. (2004, 2007, 2013), Ghironi and Melitz (2005), Lewis (2006), Bilbiie et al. (2007), Bergin and Corsetti (2008), and Cavallari (2013). The models of these researchers do not include FDI.

international business cycle. He shows that endogenous fluctuations of these firms amplify consumption and employment spillovers in the world economy. Johdo (2015) constructs the standard NOEM model with international relocation of firms, and examines the effects of home monetary expansion on the welfare of both countries.[4] He shows that when this relocation is highly flexible, home monetary expansion can be a beggar-thy-neighbor policy in the sense that it lowers foreign welfare. However, The models of these researchers examine the effects of various economic shocks in an economy without vertical trading chain.

In addition, thus far, many researches based on the NOEM model have been extended by incorporating the factor of firms' price-setting behavior into the models of Obstfeld and Rogoff (1995) and Corsetti and Pesenti (2001).[5] For example, by incorporating firms' behavior of setting their export prices in the local currency into the model of Obstfeld and Rogoff (1995), Betts and Devereux (2000) examine the effects of a country's monetary expansion on the welfare of both countries. However, because they assume that the fraction of exporters who set prices in local currency of sale is symmetric across countries, they cannot consider how the difference in home and foreign firms' price-setting behavior affects the effects of expansionary monetary policy on the welfare of both countries. By incorporating firms' asymmetric price-setting behavior into the model of Corsetti and Pesenti (2001), Michaelis (2006) examines the effects of home monetary expansion on the welfare of both countries. He finds that home monetary expansion improves home and foreign welfare only if the fraction of home exporters who set prices in local currency of sale is somewhat at an intermediate range. By incorporating firms' asymmetric price-setting behavior into the stochastic version of the model of Corsetti and Pesenti (2001), Corsetti and Pesenti (2005) examine the problems of optimal monetary policies. By comparing optimal monetary policies in non-cooperative and cooperative equilibriums, they show that there are gains from cooperation when the fractions of home and foreign exporters who set prices in local currency of sale are properly between

[4] In this paper, we basically regard a simple two-country version of deterministic NOEM models including the model of Obstfeld and Rogoff (1995) as the standard NOEM model.

[5] The reason why this extension has been conducted is because the fact that many firms in major developed countries other than the U.S. set their export prices in the local currency has been discovered by many researchers (see, e.g., Marston (1990), Knetter (1993), Parsley (1993), Athukorala and Menon (1994), ECU Institute (1995) and Gagnon and Knetter (1995)).

zero and unity.

The purpose of this paper is to examine the effects of a reduction in the corporate (or profit) tax rate of the home country on the macroeconomic variables, including the number of final goods firms, and welfare. In particular, we perform such an analysis focusing on the degree of asymmetric price-setting behavior among home and foreign firms engaged in intermediate goods trade. On the basis of above extensions of the NOEM model, we construct the deterministic two-country NOEM model with the three factors of asymmetry in price-setting behavior between home and foreign intermediate goods firms, vertical production and trade, and endogenous entry of three types of home and foreign final goods firms.[6] The main reasons for examining the macroeconomic effects of corporate tax reduction are based on the following backdrops. To begin with, it is commonly believed that such a tax reduction attracts foreign multinational firms, which causes the creation of new jobs, and thereby creates an economic boom. In fact, over the last twenty years, the fact remains that OECD countries have competed with each other to attract FDI by reducing their tax rates on corporate profit (see Devereux et al. (2008)). Next, in recent Japan, the government led by Shinzo Abe proclaimed "Abenomics" as the economic policy for secular stagnation. Abenomics comprises three arrows. Corporate tax reduction is considered one of its growth strategies, which form the "third arrow" of Abenomics. Against these backdrops, we examine the macroeconomic effects of corporate tax reduction.

The remainder of this paper is structured as follows. Section 2 presents the model. In Section 3, we examine the effects of a reduction in the corporate tax rate of the home country on the macroeconomic variables of both

[6] Using the two-country, flexible-price dynamic optimizing model without vertical trading chain, Johdo and Hashimoto (2005) examine the issue of firm entry and exit between the two countries. However, they examine the effects of a rise in the corporate tax rate of the home country on the spatial distribution of firms between the two countries, nominal exchange rate, consumption and welfare. In addition, because they use the two-country model without sticky price, they cannot perform such analyses focusing on the degree of asymmetric price-setting behavior among home and foreign firms. On the other hand, using the three-country, flexible-price dynamic optimizing model without vertical trading chain, Johdo (2013) examines the effects of a reduction in the corporate tax rate in each country on the international location of firms, real wage rate, consumption and welfare. However, because he uses the three-country model without sticky price, like Johdo and Hashimoto (2005), he cannot also perform such analyses focusing on the degree of asymmetric price-setting behavior among home and foreign firms.

countries. In Section 4, we examine the effects of a reduction in home corporate tax rate on the welfare of both countries. The final section summarizes our findings and concludes the paper.

2 The model

2.1 Definitions of various prices

The world consists of two countries, one denoted as the home country and the other as the foreign country. We denote the foreign variables with an asterisk. Both countries have the same population size, which is normalized to unity: Home households are defined over a continuum of unit mass and indexed by $x \in [0,1]$, foreign households by $x^* \in [0,1]$. Households are immobile across countries. They consume a composite of differentiated final goods available in their domestic market. Our assumption about the vertical trade is based on that in Shi and Xu (2007), and Dohwa (2014, 2018). There are two types of firms in each country: final goods firms and intermediate goods firms. Here, firms of the first type operate either in the tradable or in the non-tradable goods sector. Tradable final goods are sold in the domestic markets − they are therefore import-competing goods − or exported. Non-tradable final goods are produced by the multinational firms in the trading partner. These firms produce differentiated final goods using a composite of domestically produced intermediate inputs and a composite of imported intermediate inputs. On the other hand, firms of the second type, which are broken down into either the domestic or the export firms, produce differentiated products using labor. Both final goods firms and intermediate goods firms are monopolistically competitive producers. We assume that the domestic and the export firms in the tradable goods sector of home-located final goods firms continuously exist in the interval $[0, n_{D,t}]$ and the interval $[0, n_{X,t}]$, respectively, and that the foreign multinational firms in the non-tradable goods sector of home-located final goods firms continuously exist in the interval $[0, n^*_{MN,t}]$, where $n_{D,t}$, $n_{X,t}$ and $n^*_{MN,t}$ are endogenous.[7] There

[7] The domestic firms in the tradable goods sector of home-located final goods firms are indexed by $z_{F|D} \in [0, n_{D,t}]$. Similarly, the export firms in the tradable goods sector of home-located final goods firms, and the foreign multinational firms in the non-tradable goods sector of home-located final goods firms are indexed by $z_{F|X} \in [0, n_{X,t}]$ and $z_{F|MN} \in [0, n^*_{MN,t}]$, respectively. A similar interpretation holds for $z^*_{F|D} \in [0, n^*_{D,t}]$, $z^*_{F|X} \in [0, n^*_{X,t}]$

is free entry in the final goods sector, but final goods firms face fixed entry costs to start production of a particular good.[8] The home and foreign intermediate goods are the inputs required for the formulation of entry costs.[9] With regard to the number of intermediate goods firms in both countries, although we assume that the domestic and the export firms continuously exist in the interval $[0, \frac{1}{2}]$ and the interval $[\frac{1}{2}, 1]$, respectively,[10] we assume that a fraction η of the export firms located in the home country and a fraction η^* of the export firms located in the foreign country set their export prices in the local currency, i.e., they employ local-currency-pricing (LCP). The remaining intermediate goods firms in the export sector located in both countries set their export prices in their own currency, i.e., they employ producer-currency-pricing (PCP).[11] This paper adopts a consumption index of the Cobb-Douglas type as the aggregate consumption index (shown below), in which case the consumption-based price indexes (CPIs) are given by:

$$P_t = P_{T,t}^{\delta} P_{N,t}^{1-\delta}, \tag{1}$$

$$P_t^* = P_{T,t}^{*\delta} P_{N,t}^{*1-\delta}, \tag{2}$$

where

$$P_{T,t} = \left(\int_0^{n_{D,t}} p_{h,t}(z_{F|D})^{1-\lambda} dz_{F|D} + \int_0^{n_{X,t}^*} p_{f,t}(z_{F|X}^*)^{1-\lambda} dz_{F|X}^* \right)^{\frac{1}{1-\lambda}}, \tag{3}$$

$$P_{T,t}^* = \left(\int_0^{n_{X,t}} p_{h,t}^*(z_{F|X})^{1-\lambda} dz_{F|X} + \int_0^{n_{D,t}^*} p_{f,t}^*(z_{F|D}^*)^{1-\lambda} dz_{F|D}^* \right)^{\frac{1}{1-\lambda}}, \tag{4}$$

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and $z_{F|MN}^* \in [0, n_{MN,t}]$.

[8]As defined above, although $[0, n_{D,t}]$, $[0, n_{X,t}]$ and $[0, n_{MN,t}^*]$ represent intervals for home-located final goods firms, they can be also interpreted as intervals for the goods produced by home-located final goods firms. A similar interpretation holds for $[0, n_{D,t}^*]$, $[0, n_{X,t}^*]$ and $[0, n_{MN,t}]$.

[9]We assume that both a composite of the inputs produced by home intermediate goods firms and a composite of the inputs produced by foreign intermediate goods firms are required as inventory in setting up a final goods firm.

[10]The home intermediate goods firms sold in the domestic and the export markets are indexed by $z_{I|D} \in [0, \frac{1}{2}]$ and $z_{I|X} \in [\frac{1}{2}, 1]$, respectively. A similar interpretation holds for $z_{I|D}^* \in [0, \frac{1}{2}]$ and $z_{I|X}^* \in [\frac{1}{2}, 1]$.

[11]As defined above, although $[0, \frac{1}{2}]$ represents the interval for the home and foreign intermediate goods firms sold in the domestic market, $[0, \frac{1}{2}]$ also represents the interval for the inputs produced by home and foreign intermediate goods firms sold in the domestic market. A similar interpretation holds for $[\frac{1}{2}, 1]$.

$$P_{N,t} = \left(\int_0^{n^*_{MN,t}} p_{h,t}(z_{F|MN})^{1-\lambda} dz_{F|MN} \right)^{\frac{1}{1-\lambda}}, \tag{5}$$

$$P^*_{N,t} = \left(\int_0^{n_{MN,t}} p^*_{f,t}(z^*_{F|MN})^{1-\lambda} dz^*_{F|MN} \right)^{\frac{1}{1-\lambda}}. \tag{6}$$

In Eqs.(1) and (2), P_t (P^*_t) is the CPI of the home (foreign) country, $P_{T,t}$ ($P^*_{T,t}$) is the home (foreign) price index of tradable final goods, $P_{N,t}$ ($P^*_{N,t}$) is the home (foreign) price index of non-tradable final goods, and $\delta \in [0, 1]$ is the share of the tradable composite of differentiated final goods consumed by the households. In Eqs.(3)−(6), $p_{h,t}(z_{F|D})$ ($p^*_{f,t}(z^*_{F|D})$) is the home (foreign)-currency price of the goods produced by home (foreign)-located final goods firm $z_{F|D}$ ($z^*_{F|D}$), $p_{f,t}(z^*_{F|X})$ ($p^*_{h,t}(z_{F|X})$) is the home (foreign)-currency price of the goods produced by foreign (home)-located final goods firm $z^*_{F|X}$ ($z_{F|X}$), $p_{h,t}(z_{F|MN})$ ($p^*_{f,t}(z^*_{F|MN})$) is the home (foreign)-currency price of the goods produced by home (foreign)-located final goods firm $z_{F|MN}$ ($z^*_{F|MN}$) and $\lambda > 1$ is the elasticity of substitution between any two differentiated final goods. This paper assumes that the law of one price holds for final goods in all the periods. Then, the following relationships are derived:

$$p_{h,t}(z_{F|D}) = p_{h,t}(z_{F|MN}) = \varepsilon_t p^*_{h,t}(z_{F|X}), \tag{7}$$

$$p^*_{f,t}(z^*_{F|D}) = p^*_{f,t}(z^*_{F|MN}) = \frac{1}{\varepsilon_t} p_{f,t}(z^*_{F|X}), \tag{8}$$

where ε_t is the nominal exchange rate, defined as the home-currency price of the foreign currency. Here, although Eqs.(7) and (8) holds, $P_{T,t}$ and $\varepsilon_t P^*_{T,t}$ are not necessarily equal in both countries, because the number of domestic firms located in the home (foreign) country is not necessarily equal to that of export firms located in the home (foreign) country. In addition, $P_{N,t}$ and $\varepsilon_t P^*_{N,t}$ are not necessarily equal in both countries because these variables represent the price indexes of different goods. These facts imply that purchasing power parity (PPP) does not necessarily hold.

With regard to the production of final goods, this paper adopts a production function of the Cobb-Douglas type (shown below), in which case the unit costs to produce final goods are given by:

$$\Lambda_t = \tilde{P}^{\frac{1}{2}}_{h,t} \tilde{P}^{\frac{1}{2}}_{f,t}, \tag{9}$$

$$\Lambda^*_t = \tilde{P}^{*\frac{1}{2}}_{h,t} \tilde{P}^{*\frac{1}{2}}_{f,t}, \tag{10}$$

where

$$\tilde{P}_{f,t} = \left(\frac{\eta^*}{2} \left(\tilde{P}_{f,t}^{LCP} \right)^{1-\sigma} + \frac{1-\eta^*}{2} \left(\tilde{P}_{f,t}^{PCP} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \tag{11}$$

$$\tilde{P}_{h,t}^* = \left(\frac{\eta}{2} \left(\tilde{P}_{h,t}^{*LCP} \right)^{1-\sigma} + \frac{1-\eta}{2} \left(\tilde{P}_{h,t}^{*PCP} \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \tag{12}$$

and

$$\tilde{P}_{h,t} = \left(\int_0^{\frac{1}{2}} \tilde{p}_{h,t}(z_{I|D})^{1-\sigma} dz_{I|D} \right)^{\frac{1}{1-\sigma}}, \ \tilde{P}_{f,t}^* = \left(\int_0^{\frac{1}{2}} \tilde{p}_{f,t}^*(z_{I|D}^*)^{1-\sigma} dz_{I|D}^* \right)^{\frac{1}{1-\sigma}}, \tag{13}$$

$$\tilde{P}_{f,t}^{LCP} = \left(\frac{2}{\eta^*} \int_{\frac{1}{2}}^{\frac{1+\eta^*}{2}} \tilde{p}_{f,t}^{LCP}(z_{I|X}^*)^{1-\sigma} dz_{I|X}^* \right)^{\frac{1}{1-\sigma}}, \ \tilde{P}_{h,t}^{*LCP} = \left(\frac{2}{\eta} \int_{\frac{1}{2}}^{\frac{1+\eta}{2}} \tilde{p}_{h,t}^{*LCP}(z_{I|X})^{1-\sigma} dz_{I|X} \right)^{\frac{1}{1-\sigma}}, \tag{14}$$

$$\tilde{P}_{f,t}^{PCP} = \left(\frac{2}{1-\eta^*} \int_{\frac{1+\eta^*}{2}}^{1} \tilde{p}_{f,t}^{PCP}(z_{I|X}^*)^{1-\sigma} dz_{I|X}^* \right)^{\frac{1}{1-\sigma}}, \ \tilde{P}_{h,t}^{*PCP} = \left(\frac{2}{1-\eta} \int_{\frac{1+\eta}{2}}^{1} \tilde{p}_{h,t}^{*PCP}(z_{I|X})^{1-\sigma} dz_{I|X} \right)^{\frac{1}{1-\sigma}}. \tag{15}$$

In Eqs.(9) and (10), $\tilde{P}_{h,t}$ ($\tilde{P}_{h,t}^*$) is the home (foreign) price index that corresponds to a composite of the inputs produced by domestic (export) firms in the home intermediate goods sector, $\tilde{P}_{f,t}$ ($\tilde{P}_{f,t}^*$) is the home (foreign) price index that corresponds to a composite of the inputs produced by export (domestic) firms in the foreign intermediate goods sector. The import price indexes of home- and foreign-located final goods firms are given in Eqs.(11) and (12), where $\tilde{P}_{f,t}^{PCP}$ ($\tilde{P}_{f,t}^{LCP}$) is the home price index that corresponds to a composite of the inputs produced by PCP (LCP) export firms in the foreign intermediate goods sector, and $\tilde{P}_{h,t}^{*PCP}$ ($\tilde{P}_{h,t}^{*LCP}$) is the foreign price index that corresponds to a composite of the inputs produced by PCP (LCP) export firms in the home intermediate goods sector. In Eqs.(13)−(15), $\tilde{p}_{h,t}(z_{I|D})$ ($\tilde{p}_{f,t}^*(z_{I|D}^*)$) is the home (foreign)-currency price of the input produced by domestic firm $z_{I|D}$ ($z_{I|D}^*$) in the home (foreign) intermediate goods sector, $\tilde{p}_{f,t}^{PCP}(z_{I|X}^*)$ ($\tilde{p}_{f,t}^{LCP}(z_{I|X}^*)$) is the home-currency price of the input produced by PCP (LCP) export firm $z_{I|X}^*$ in the foreign intermediate goods sector, $\tilde{p}_{h,t}^{*PCP}(z_{I|X})$ ($\tilde{p}_{h,t}^{*LCP}(z_{I|X})$) is the foreign-currency price of the input produced by PCP (LCP) export firm $z_{I|X}$ in the home intermediate goods sector, and $\sigma > 1$ is the elasticity of substitution between any two differentiated intermediate inputs.

2.2 Firms

2.2.1 Final goods firms

Each of the home-located final goods firms uses home and foreign intermediate goods to produce output according to the following production function:

$$Y_t(z_{F|j}) = 2Y_{h,t}(z_{F|j})^{\frac{1}{2}}Y_{f,t}(z_{F|j})^{\frac{1}{2}}, \quad j = D, X, MN \tag{16}$$

where

$$Y_{h,t}(z_{F|j}) = \left(\int_0^{\frac{1}{2}} Y_{h,t}(z_{F|j}, z_{I|D})^{\frac{\sigma-1}{\sigma}} dz_{I|D}\right)^{\frac{\sigma}{\sigma-1}}, \tag{17}$$

$$Y_{f,t}(z_{F|j}) = \left(\int_{\frac{1}{2}}^{\frac{1+\eta^*}{2}} Y_{f,t}^{LCP}(z_{F|j}, z^*_{I|X})^{\frac{\sigma-1}{\sigma}} dz^*_{I|X} + \int_{\frac{1+\eta^*}{2}}^{1} Y_{f,t}^{PCP}(z_{F|j}, z^*_{I|X})^{\frac{\sigma-1}{\sigma}} dz^*_{I|X}\right)^{\frac{\sigma}{\sigma-1}}. \tag{18}$$

In Eq.(16), $Y_t(z_{F|j})$ is the output produced by home-located final goods firm $z_{F|j}$ and $Y_{h,t}(z_{F|j})$ ($Y_{f,t}(z_{F|j})$) is a composite of the home (foreign) intermediate inputs used by home-located final goods firm $z_{F|j}$. $Y_{h,t}(z_{F|j})$ and $Y_{f,t}(z_{F|j})$ are given in Eqs.(17) and (18), where $Y_{h,t}(z_{F|j}, z_{I|D})$ is the home intermediate input $z_{I|D}$ used by home-located final goods firm $z_{F|j}$, and $Y_{f,t}^{PCP}(z_{F|j}, z^*_{I|X})$ ($Y_{f,t}^{LCP}(z_{F|j}, z^*_{I|X})$) is the foreign PCP (LCP) intermediate input $z^*_{I|X}$ used by home-located final goods firm $z_{F|j}$. Here, the home-located final goods firm $z_{F|j}$'s expenditure for the sum of $Y_{h,t}(z_{F|j})$ and $Y_{f,t}(z_{F|j})$ is represented as follows:

$$\Lambda_t Y_t(z_{F|j}) = \tilde{P}_{h,t}Y_{h,t}(z_{F|j}) + \tilde{P}_{f,t}Y_{f,t}(z_{F|j}). \tag{19}$$

Subject to Eq.(16), the home-located final goods firm $z_{F|j}$ minimizes Eq.(19). Then, the demands of the home-located final goods firm $z_{F|j}$ for $Y_{h,t}(z_{F|j})$ and $Y_{f,t}(z_{F|j})$ are derived as follows:

$$Y_{h,t}(z_{F|j}) = \frac{1}{2}\left(\frac{\tilde{P}_{h,t}}{\Lambda_t}\right)^{-1} Y_t(z_{F|j}), \tag{20}$$

$$Y_{f,t}(z_{F|j}) = \frac{1}{2}\left(\frac{\tilde{P}_{f,t}}{\Lambda_t}\right)^{-1} Y_t(z_{F|j}). \tag{21}$$

Next, we consider the home-located final goods firm $z_{F|j}$'s demand for the input produced by home intermediate goods firm $z_{I|D}$. Here, a composite of the inputs produced by home intermediate goods firms that exist continuously in the interval $[0,\frac{1}{2}]$ is given by Eq.(17), and the home-located final goods firm $z_{F|j}$'s nominal expenditure for the inputs produced by these firms is formulated as $\tilde{P}_{h,t}Y_{h,t}(z_{F|j}) = \int_0^{\frac{1}{2}} \tilde{p}_{h,t}(z_{I|D})Y_{h,t}(z_{F|j}, z_{I|D})dz_{I|D}$. Subject to Eq.(17), the home-located final goods firm $z_{F|j}$ determines $Y_{h,t}(z_{F|j}, z_{I|D})$ in order to minimize this expenditure. Then, the home-located final goods firm $z_{F|j}$'s demand for the input produced by home intermediate goods firm $z_{I|D}$ is derived as follows:

$$Y_{h,t}(z_{F|j}, z_{I|D}) = \left(\frac{\tilde{p}_{h,t}(z_{I|D})}{\tilde{P}_{h,t}}\right)^{-\sigma} Y_{h,t}(z_{F|j}). \tag{22}$$

Similarly, the home-located final goods firm $z_{F|j}$'s demands for the inputs produced by foreign PCP intermediate goods firm $z^*_{I|X}$ and foreign LCP intermediate goods firm $z^*_{I|X}$ can be calculated as follows:

$$Y^{PCP}_{f,t}(z_{F|j}, z^*_{I|X}) = \left(\frac{\tilde{p}^{PCP}_{f,t}(z^*_{I|X})}{\tilde{P}^{PCP}_{f,t}}\right)^{-\sigma} \left(\frac{\tilde{P}^{PCP}_{f,t}}{\tilde{P}_{f,t}}\right)^{-\sigma} Y_{f,t}(z_{F|j}), \tag{23}$$

$$Y^{LCP}_{f,t}(z_{F|j}, z^*_{I|X}) = \left(\frac{\tilde{p}^{LCP}_{f,t}(z^*_{I|X})}{\tilde{P}^{LCP}_{f,t}}\right)^{-\sigma} \left(\frac{\tilde{P}^{LCP}_{f,t}}{\tilde{P}_{f,t}}\right)^{-\sigma} Y_{f,t}(z_{F|j}). \tag{24}$$

Combining Eqs.(20) and (22), the home-located final goods firm $z_{F|j}$'s demand for the input produced by home intermediate goods firm $z_{I|D}$ is derived in the following exact form:

$$Y_{h,t}(z_{F|j}, z_{I|D}) = \frac{1}{2}\left(\frac{\tilde{p}_{h,t}(z_{I|D})}{\tilde{P}_{h,t}}\right)^{-\sigma} \left(\frac{\tilde{P}_{h,t}}{\Lambda_t}\right)^{-1} Y_t(z_{F|j}). \tag{25}$$

Similarly, the home-located final goods firm $z_{F|j}$'s demands for the inputs produced by foreign PCP intermediate goods firm $z^*_{I|X}$ and foreign LCP intermediate goods firm $z^*_{I|X}$ are derived in the exact form as follows:

$$Y^{PCP}_{f,t}(z_{F|j}, z^*_{I|X}) = \frac{1}{2}\left(\frac{\tilde{p}^{PCP}_{f,t}(z^*_{I|X})}{\tilde{P}^{PCP}_{f,t}}\right)^{-\sigma} \left(\frac{\tilde{P}^{PCP}_{f,t}}{\tilde{P}_{f,t}}\right)^{-\sigma} \left(\frac{\tilde{P}_{f,t}}{\Lambda_t}\right)^{-1} Y_t(z_{F|j}), \tag{26}$$

$$Y_{f,t}^{LCP}(z_{F|j}, z_{I|X}^*) = \frac{1}{2}\left(\frac{\tilde{p}_{f,t}^{LCP}(z_{I|X}^*)}{\tilde{P}_{f,t}^{LCP}}\right)^{-\sigma}\left(\frac{\tilde{P}_{f,t}^{LCP}}{\tilde{P}_{f,t}}\right)^{-\sigma}\left(\frac{\tilde{P}_{f,t}}{\Lambda_t}\right)^{-1} Y_t(z_{F|j}). \tag{27}$$

Here, the resource constraint for goods produced by the home-located final goods firm $z_{F|j}$ is represented as follows:

$$Y_t(z_{F|j}) \geq \int_0^1 C_{h,t}(z_{F|j}, x)dx, \tag{28}$$

where $C_{h,t}(z_{F|j}, x)$ is the home household x's consumption of goods produced by the home-located final goods firm $z_{F|j}$. Using Eq.(28), the home-located final goods firm $z_{F|j}$'s profit is represented as follows:

$$\Pi_{F,t}(z_{F|j}) = (p_{h,t}(z_{F|j}) - \Lambda_t)Y_t(z_{F|j}). \tag{29}$$

To start production, each of the final goods firms must pay a fixed cost. We assume that the entry cost for each class of final goods firms is represented in the following form:

$$q_t(z_{F|j}) = \left(\tilde{P}_{h,t} + \tilde{P}_{f,t}\right) n_{j,t}^{\gamma}, \tag{30}$$

$$q_t(z_{F|MN}) = \left(\tilde{P}_{h,t} + \tilde{P}_{f,t}\right) n_{MN,t}^{*\gamma}, \tag{31}$$

$$q_t^*(z_{F|j}^*) = \left(\tilde{P}_{h,t}^* + \tilde{P}_{f,t}^*\right) n_{j,t}^{*\gamma}, \tag{32}$$

$$q_t^*(z_{F|MN}^*) = \left(\tilde{P}_{h,t}^* + \tilde{P}_{f,t}^*\right) n_{MN,t}^{\gamma}, \tag{33}$$

where $j = (D, X)$ and $\gamma > 0$ is a measure of the concavity of the cost function. For example, Eq.(30) shows that each of the firms that belongs to the tradable goods sector of home-located final goods firms requires both $n_{j,t}^{\gamma}$ units of the composite of home intermediate inputs and $n_{j,t}^{\gamma}$ units of that of foreign intermediate inputs to create a new final good. Given Eqs.(30)$-$(33), the resource constraints in home and foreign intermediate inputs used by home and foreign final goods firms are represented as follows:

$$Y_{h,t} \geq \frac{1}{2}\left(\frac{\tilde{P}_{h,t}}{\Lambda_t}\right)^{-1}\left(\sum_{j=D,X}\int_0^{n_{j,t}} Y_t(z_{F|j})dz_{F|j} + \int_0^{n_{MN,t}^*} Y_t(z_{F|MN})dz_{F|MN}\right)$$

$$+\left(\sum_{j=D,X} n_{j,t}^{1+\gamma} + n_{MN,t}^{*1+\gamma}\right), \tag{34}$$

$$Y_{f,t} \geq \frac{1}{2}\left(\frac{\tilde{P}_{f,t}}{\Lambda_t}\right)^{-1}\left(\sum_{j=D,X}\int_0^{n_{j,t}} Y_t(z_{F|j})dz_{F|j} + \int_0^{n^*_{MN,t}} Y_t(z_{F|MN})dz_{F|MN}\right)$$

$$+\left(\sum_{j=D,X} n_{j,t}^{1+\gamma} + n_{MN,t}^{*1+\gamma}\right), \tag{35}$$

$$Y^*_{h,t} \geq \frac{1}{2}\left(\frac{\tilde{P}^*_{h,t}}{\Lambda^*_t}\right)^{-1}\left(\sum_{j=D,X}\int_0^{n^*_{j,t}} Y^*_t(z^*_{F|j})dz^*_{F|j} + \int_0^{n_{MN,t}} Y^*_t(z^*_{F|MN})dz^*_{F|MN}\right)$$

$$+\left(\sum_{j=D,X} n_{j,t}^{*1+\gamma} + n_{MN,t}^{1+\gamma}\right), \tag{36}$$

$$Y^*_{f,t} \geq \frac{1}{2}\left(\frac{\tilde{P}^*_{f,t}}{\Lambda^*_t}\right)^{-1}\left(\sum_{j=D,X}\int_0^{n^*_{j,t}} Y^*_t(z^*_{F|j})dz^*_{F|j} + \int_0^{n_{MN,t}} Y^*_t(z^*_{F|MN})dz^*_{F|MN}\right)$$

$$+\left(\sum_{j=D,X} n_{j,t}^{*1+\gamma} + n_{MN,t}^{1+\gamma}\right). \tag{37}$$

2.2.2 Intermediate goods firms

As shown in more detail below, the three types of home intermediate goods firms produce a differentiated good using a continuum of labor inputs provided by the home households:

$$Y_{h,t}(z_{I|D}) = \left(\int_0^1 \ell_t(z_{I|D}, x)^{\frac{\xi-1}{\xi}} dx\right)^{\frac{\xi}{\xi-1}}, \tag{38}$$

$$Y_{h,t}^{*PCP}(z_{I|X}) = \left(\int_0^1 \ell_t(z_{I|X}, x)^{\frac{\xi-1}{\xi}} dx\right)^{\frac{\xi}{\xi-1}}, \tag{39}$$

$$Y_{h,t}^{*LCP}(z_{I|X}) = \left(\int_0^1 \ell_t(z_{I|X}, x)^{\frac{\xi-1}{\xi}} dx\right)^{\frac{\xi}{\xi-1}}, \tag{40}$$

where $Y_{h,t}(z_{I|D})$ is the output of goods produced by home intermediate goods firm $z_{I|D}$ toward three types of home-located final goods firms, $Y^{*PCP}_{h,t}(z_{I|X})$ ($Y^{*LCP}_{h,t}(z_{I|X})$) is the output of goods produced by home PCP (LCP) intermediate goods firm $z_{I|X}$ toward three types of foreign-located final goods firms, $\ell_t(z_{I|D}, x)$ ($\ell_t(z_{I|X}, x)$) is the labor of home household x employed by home intermediate goods firm $z_{I|D}$ ($z_{I|X}$), and $\xi > 1$ is the elasticity of substitution among labor varieties. First, the profit of a home intermediate goods firm $z_{I|D}$ is represented as follows:

$$\Pi_{I,t}(z_{I|D}) = (\tilde{p}_{h,t}(z_{I|D}) - W_t)Y_{h,t}(z_{I|D}), \tag{41}$$

where W_t is the aggregate wage index (shown below). Assuming that nominal wages are flexible, given the demand function expressed in Eq.(22), the optimal price is determined as follows:

$$\tilde{p}_{h,t}(z_{I|D}) = \frac{\sigma}{\sigma - 1} W_t \equiv \tilde{p}_{h,t}. \tag{42}$$

Eq.(42) shows that the home intermediate goods firm $z_{I|D}$ sets its good's price at the marginal cost (W_t) multiplied by the mark-up ratio ($\sigma/(\sigma - 1)$).

Next, the profits of a home PCP intermediate goods firm $z_{I|X}$ and a home LCP intermediate goods firm $z_{I|X}$ are represented as follows:

$$\Pi^{PCP}_{I,t}(z_{I|X}) = (\tilde{p}^{PCP}_{h,t}(z_{I|X}) - W_t)Y^{*PCP}_{h,t}(z_{I|X}), \tag{43}$$

$$\Pi^{LCP}_{I,t}(z_{I|X}) = (\varepsilon_t \tilde{p}^{*LCP}_{h,t}(z_{I|X}) - W_t)Y^{*LCP}_{h,t}(z_{I|X}). \tag{44}$$

As per the process of analysis adopted for the profit-maximization problem of a home intermediate goods firm $z_{I|D}$, the sales prices of these firms can be expressed in the following equation, when nominal wages are flexible:

$$\tilde{p}^{PCP}_{h,t}(z_{I|X}) = \varepsilon_t \tilde{p}^{*LCP}_{h,t}(z_{I|X}) = \frac{\sigma}{\sigma - 1} W_t \equiv \tilde{p}_{h,t}. \tag{45}$$

Eq.(45) shows that the sales price of the PCP intermediate goods firm $z_{I|X}$ is equal to that of the LCP intermediate goods firm $z_{I|X}$. Therefore, even if intermediate goods firms set their export prices in different currencies, the law of one price holds for every intermediate good under flexible wages.

On the other hand, as we mention in Section 3, our model takes into account nominal wage rigidity in the short run. Under sticky wages, the law of one price does not hold for the inputs produced by LCP intermediate goods firms. This is because LCP intermediate goods firms do not pass on the exchange rate changes to export prices denominated in the local currency. Focusing on a symmetric equilibrium, as shown in Corsetti and Pesenti (2005), the prices of the intermediate inputs sold in the export market, taking into account the incomplete pass through of the nominal exchange rate, are as follows:

$$\tilde{P}^{*}_{h,t} = \frac{\hat{\tilde{P}}_{h,t}}{\varepsilon_t^{1-\eta}}, \tag{46}$$

$$\tilde{P}_{f,t} = \varepsilon_t^{1-\eta^*} \hat{\tilde{P}}^{*}_{f,t}, \tag{47}$$

where $\hat{\tilde{P}}_{h,t}$ $\left(\hat{\tilde{P}}^{*}_{f,t}\right)$ is the predetermined component of the foreign (home)-currency price that corresponds to a composite of the inputs produced by home (foreign) export firms in the intermediate goods sector.

2.3 Households and government

We define the utility function for the home household x as follows:

$$U_t(x) = \sum_{s=t}^{\infty} \beta^{s-t} \left(lnC_s(x) + \chi ln \frac{M_s(x)}{P_s} - \kappa \ell_s(x) \right), \tag{48}$$

where $\beta \in (0,1)$ is the subjective discount factor, $C(x)$ is the aggregate consumption index of the home household x, $M(x)$ is the home household x's holdings of the home country's currency, $\ell(x)$ is the home household x's labor service, and the other Greek letters are positive parameters. This utility function implies that the home household x gains utility by consuming final goods and holding real money, and suffers disutility by supplying labor. As we mentioned before, the aggregate consumption index of home household x is given by:

$$C_t(x) = \frac{C^{\delta}_{T,t}(x) C^{1-\delta}_{N,t}(x)}{\delta^{\delta}(1-\delta)^{1-\delta}}, \tag{49}$$

where $C_{T,t}(x)$ and $C_{N,t}(x)$ are tradable and non-tradable composites of differentiated final goods consumed by the home household x, respectively. These variables are given by:[12]

$$C_{T,t}(x) = \left(\int_0^{n_{D,t}} C_{h,t}(z_{F|D}, x)^{\frac{\lambda-1}{\lambda}} dz_{F|D} + \int_0^{n^*_{X,t}} C_{f,t}(z^*_{F|X}, x)^{\frac{\lambda-1}{\lambda}} dz^*_{F|X} \right)^{\frac{\lambda}{\lambda-1}}, \tag{50}$$

$$C_{N,t}(x) = \left(\int_0^{n^*_{MN,t}} C_{h,t}(z_{F|MN}, x)^{\frac{\lambda-1}{\lambda}} dz_{F|MN} \right)^{\frac{\lambda}{\lambda-1}}, \tag{51}$$

where $C_{h,t}(z_{F|D}, x)$ is the consumption of the home final good $z_{F|D}$ by home household x, $C_{h,t}(z^*_{F|X}, x)$ is the consumption of the foreign final good $z^*_{F|X}$ by home household x, and $C_{h,t}(z_{F|MN}, x)$ is the consumption of the home final good $z_{F|MN}$ by home household x.

The home household x maximizes utility subject to the following budget constraint:

$$\frac{\varepsilon_t B_{t+1}(x)}{P_t} + \frac{M_t(x)}{P_t} + C_t(x) + \frac{I_t(x)}{P_t} = \frac{\varepsilon_t(1+i^*_t)B_t(x)}{P_t}$$
$$+\frac{M_{t-1}(x)}{P_t} + \frac{w_t(x)\ell_t(x)}{P_t} + \frac{T_t(x)}{P_t} + \frac{\Pi_{F,t}(x)}{P_t} + \frac{\Pi_{I,t}(x)}{P_t}, \tag{52}$$

where $B_t(x)$ is the stock of foreign currency denominated bonds that the home household x holds at the beginning of period t, $I_t(x)$ is the home household x's 'investment' in final goods firms (financing entry costs), i^*_t is the nominal interest rate between periods $t-1$ and t evaluated in foreign currency terms, $w_t(x)$ is the nominal wage, which corresponds to $\ell_t(x)$, $T_t(x)$ are lump-sum transfers from the home government, and $\Pi_{F,t}(x)$ and $\Pi_{I,t}(x)$ are dividend revenues from the final and intermediate goods firms that the home household x owns, respectively.

As mentioned in Corsetti et al. (2004, 2013), we assume that households are endowed with a well-diversified international portfolio of claims on final goods firms' after-tax profits, so that they finance the same fraction of the cost of creating new final goods in each country. Then, the investment of the home household x in a diversified portfolio of final goods firms is defined as follows:

$$I_t(x) = \frac{1}{2}\left(\sum_{j=D,X} \int_0^{n_{j,t}} q_t(z_{F|j}) dz_{F|j} + \int_0^{n^*_{MN,t}} q_t(z_{F|MN}) dz_{F|MN} \right.$$

[12] $C_{T,t}(x)$ and $C_{N,t}(x)$ are consumption indexes of the Dixit and Stigliz (1977) type.

$$+\varepsilon_t\left(\sum_{j=D,X}\int_0^{n^*_{j,t}} q^*_t(z^*_{F|j})dz^*_{F|j}+\int_0^{n_{MN,t}} q^*_t(z^*_{F|MN})dz^*_{F|MN}\right)\Bigg). \tag{53}$$

We assume that, in return, each of the home households receives an equal share of the after-tax profits of all final goods firms located in the home and foreign countries:

$$\Pi_{F,t}(x)=\frac{1}{2}\Bigg((1-\tau_t)\left(\sum_{j=D,X}\int_0^{n_{j,t}}\Pi_{F,t}(z_{F|j})dz_{F|j}+\int_0^{n^*_{MN,t}}\Pi_{F,t}(z_{F|MN})dz_{F|MN}\right)$$

$$+\varepsilon_t\left(\sum_{j=D,X}\int_0^{n^*_{j,t}}\Pi^*_{F,t}(z^*_{F|j})dz^*_{F|j}+\int_0^{n_{MN,t}}\Pi^*_{F,t}(z^*_{F|MN})dz^*_{F|MN}\right)\Bigg), \tag{54}$$

where τ_t is the corporate (or profit) tax rate of the home country.

In addition, the household is a monopoly supplier of a differentiated labor service and faces the following labor-demand curve:

$$\ell_t(x)=\left(\frac{w_t(x)}{W_t}\right)^{-\xi}\left(\int_0^{\frac{1}{2}}Y_{h,t}(z_{I|D})dz_{I|D}+\int_{\frac{1}{2}}^{\frac{1+\eta}{2}}Y^{*LCP}_{h,t}(z_{I|X})dz_{I|X}+\int_{\frac{1+\eta}{2}}^{1}Y^{*PCP}_{h,t}(z_{I|X})dz_{I|X}\right), \tag{55}$$

where $W_t=\left(\int_0^1 w_t(x)^{1-\xi}dx\right)^{\frac{1}{1-\xi}}$ is the constant-elasticity-of-substitution (CES) wage index.

Before turning to the intertemporal maximization problem, we consider the optimal consumption demands for $C_{h,t}(z_{F|D},x)$, $C_{f,t}(z_{F|X},x)$ and $C_{h,t}(z_{F|MN},x)$. To begin with, the home household x's expenditure for the sum of $C_{T,t}(x)$ and $C_{N,t}(x)$ is represented as follows:

$$P_tC_t(x)=P_{T,t}C_{T,t}(x)+P_{N,t}C_{N,t}(x). \tag{56}$$

Subject to Eq.(56), the home household x maximizes Eq.(49). Then, the demands of the home household x for $C_{T,t}(x)$ and $C_{N,t}(x)$ are derived as follows:

$$C_{T,t}(x)=\delta\left(\frac{P_{T,t}}{P_t}\right)^{-1}C_t(x), \tag{57}$$

$$C_{N,t}(x)=(1-\delta)\left(\frac{P_{N,t}}{P_t}\right)^{-1}C_t(x). \tag{58}$$

Next, we consider the home household x's demands for the goods produced by domestic firm $z_{F|D}$ that belongs to the tradable goods sector of home-located final goods firms and export firm $z^*_{F|X}$ that belongs to the tradable goods sector of foreign-located final goods firms. Here, $C_{T,t}(x)$ is given by Eq.(50), and the nominal consumption expenditure, which corresponds to $C_{T,t}(x)$, is defined as $P_{T,t}C_{T,t}(x) \equiv \int_0^{n_{D,t}} p_{h,t}(z_{F|D})C_{h,t}(z_{F|D}, x)dz_{F|D} + \int_0^{n^*_{X,t}} p_{f,t}(z^*_{F|X})C_{f,t}(z^*_{F|X}, x)dz^*_{F|X}$. Subject to this definition, the agent determines $C_{h,t}(z_{F|D}, x)$ and $C_{f,t}(z^*_{F|X}, x)$ in order to maximize Eq.(50). Then, the optimal consumption demands for $C_{h,t}(z_{F|D}, x)$ and $C_{f,t}(z^*_{F|X}, x)$ are derived as follows:

$$C_{h,t}(z_{F|D}, x) = \left(\frac{p_{h,t}(z_{F|D})}{P_{T,t}}\right)^{-\lambda} C_{T,t}(x), \tag{59}$$

$$C_{f,t}(z^*_{F|X}, x) = \left(\frac{p_{f,t}(z^*_{F|X})}{P_{T,t}}\right)^{-\lambda} C_{T,t}(x). \tag{60}$$

Similarly, the optimal consumption demand for $C_{h,t}(z_{F|MN}, x)$ can be calculated as follows:

$$C_{h,t}(z_{F|MN}, x) = \left(\frac{p_{h,t}(z_{F|MN})}{P_{N,t}}\right)^{-\lambda} C_{N,t}(x). \tag{61}$$

From Eqs.(57), (59) and (60), the optimal consumption demands for $C_{h,t}(z_{F|D}, x)$ and $C_{f,t}(z^*_{F|X}, x)$ are derived in the following exact form:

$$C_{h,t}(z_{F|D}, x) = \delta \left(\frac{p_{h,t}(z_{F|D})}{P_{T,t}}\right)^{-\lambda} \left(\frac{P_{T,t}}{P_t}\right)^{-1} C_t(x), \tag{62}$$

$$C_{f,t}(z^*_{F|X}, x) = \delta \left(\frac{p_{f,t}(z^*_{F|X})}{P_{T,t}}\right)^{-\lambda} \left(\frac{P_{T,t}}{P_t}\right)^{-1} C_t(x). \tag{63}$$

Similarly, the optimal consumption demand for $C_{h,t}(z_{F|MN}, x)$ is derived in the exact form as follows:

$$C_{h,t}(z_{F|MN}, x) = (1-\delta) \left(\frac{p_{h,t}(z_{F|MN})}{P_{N,t}}\right)^{-\lambda} \left(\frac{P_{N,t}}{P_t}\right)^{-1} C_t(x). \tag{64}$$

We now turn to the intertemporal maximization problem. Subject to Eq.(52), the home household x maximizes Eq.(48). Then, the first-order necessary conditions for $C_t(x)$, $M_t(x)$ and $\ell_t(x)$ are derived as follows:

$$\frac{C_{t+1}(x)}{C_t(x)} = \beta(1+i^*_{t+1})\frac{P_t/\varepsilon_t}{P_{t+1}/\varepsilon_{t+1}}, \tag{65}$$

$$\frac{M_t(x)}{P_t} = \chi\frac{(1+i^*_{t+1})\varepsilon_{t+1}}{(1+i^*_{t+1})\varepsilon_{t+1}-\varepsilon_t}C_t(x), \tag{66}$$

$$\frac{w_t(x)}{P_t} = \frac{\xi\kappa}{\xi-1}C_t(x). \tag{67}$$

Eq.(65) is the Euler equation, Eq.(66) is the real money demand function, and Eq.(67) shows that the real wage rate is equal to a constant markup over the marginal rate of substitution between consumption and leisure.

From now, we denote the first-order necessary conditions for the home households as a whole. For example, we define the average consumption of home households in period t as the integral of $C_t(x)$ over all x. We denote such a variable as C_t. We also define M_t and B_t in analogous ways for money holdings and bond holdings, respectively. Then, by focusing on symmetric equilibrium, where all home households are identical within the home country, we can derive the following relationships for all t:

$$C_t = C_t(x), \quad M_t = M_t(x), \quad B_t = B_t(x). \tag{68}$$

Considering Eqs.(65)−(68) and assuming a symmetric equilibrium, the first-order necessary conditions for $C_t(x)$, $M_t(x)$ and $\ell_t(x)$ are corrected as follows, respectively:

$$\frac{C_{t+1}}{C_t} = \beta(1+i^*_{t+1})\frac{P_t/\varepsilon_t}{P_{t+1}/\varepsilon_{t+1}}, \tag{69}$$

$$\frac{M_t}{P_t} = \chi\frac{(1+i^*_{t+1})\varepsilon_{t+1}}{(1+i^*_{t+1})\varepsilon_{t+1}-\varepsilon_t}C_t, \tag{70}$$

$$\frac{W_t}{P_t} = \frac{\xi\kappa}{\xi-1}C_t. \tag{71}$$

Under the assumption that all revenues from both corporate taxes and money creation are distributed across households in a lump-sum fashion, the budget constraint for the home government can be represented as follows:

$$M_t - M_{t-1} + \tau_t\Bigg(\sum_{j=D,X}\int_0^{n_{j,t}}\Pi_{F,t}(z_{F|j})dz_{F|j} + \int_0^{n^*_{MN,t}}\Pi_{F,t}(z_{F|MN})dz_{F|MN}$$

$$+\int_0^{\frac{1}{2}} \Pi_{I,t}(z_{I|D})dz_{I|D} + \int_{\frac{1}{2}}^1 \Pi_{I,t}(z_{I|X})dz_{I|X}\Bigg) = T_t. \tag{72}$$

Although our analytical purpose is to examine the effects of an unanticipated permanent reduction in the corporate tax rate of the home country, in our model, it is analytically convenient to introduce a measure of monetary stance $\mu_t \equiv P_t C_t$.[13] Using this measure, we can rewrite Eqs.(69) and (70) as follows:

$$\frac{1}{\mu_t} = \beta(1 + i^*_{t+1})\frac{\varepsilon_{t+1}}{\varepsilon_t}\frac{1}{\mu_{t+1}}, \tag{73}$$

$$M_t = \chi\frac{(1 + i^*_{t+1})\varepsilon_{t+1}}{(1 + i^*_{t+1})\varepsilon_{t+1} - \varepsilon_t}\mu_t. \tag{74}$$

Foreign households have the same preferences as home households. Thus, the foreign household x^*'s lifetime utility function and its budget constraint are shown as follows:

$$U^*_t(x^*) = \sum_{s=t}^{\infty}\beta^{s-t}\left(lnC^*_s(x^*) + \chi ln\frac{M^*_s(x^*)}{P^*_s} - \kappa\ell^*_s(x^*)\right), \tag{75}$$

$$\frac{B^*_{t+1}(x^*)}{P^*_t} + \frac{M^*_t(x^*)}{P^*_t} + C^*_t(x^*) + \frac{I^*_t(x^*)}{P^*_t} = \frac{(1 + i^*_t)B^*_t(x^*)}{P^*_t}$$
$$+\frac{M^*_{t-1}(x^*)}{P^*_t} + \frac{w^*_t(x^*)\ell^*_t(x^*)}{P^*_t} + \frac{T^*_t(x^*)}{P^*_t} + \frac{\Pi^*_{F,t}(x^*)}{P^*_t} + \frac{\Pi^*_{I,t}(x^*)}{P^*_t}, \tag{76}$$

where β, χ and κ are the same as in the home country.

Now, we represent the equilibrium condition for the asset market. The worldwide net supply of bonds has to be equal to zero. Therefore, the equilibrium condition for the asset market is represented as follows:[14]

$$B_t + B^*_t = 0. \tag{77}$$

[13] Our definition of the variables of monetary policy is based on that in Corsetti and Pesenti (2005), and Corsetti and Dedola (2005). This definition implies that the government controls nominal consumption. In addition, as mentioned in footnotes 15 and 16, we use the relationship of $B_{t+1} = B_t = 0$. Therefore, a temporary home monetary easing at period t, associated with a higher μ_t, leads to a lower i_{t+1} (see Eq.(A) in footnote 14).

[14] We define i_t as the nominal interest rate between periods $t-1$ and t evaluated in home currency terms. Although we do not describe i_t in the text, uncovered interest rate parity (UIP), i.e., $1 + i_t = (1 + i^*_t)(\varepsilon_t/\varepsilon_{t-1})$, holds between i_t and i^*_t, since there is free trade between the countries in nominal bonds. From here onwards Eqs.(73) and (74) can be rewritten as follows, respectively:

2.4 Final goods prices, price indexes of final goods and CPIs

From Eqs.(62)−(64), the aggregate home consumption demands for goods produced by the domestic firm $z_{F|D}$, which belongs to the tradable goods sector of home-located final goods firms, the export firm $z^*_{F|X}$, which belongs to the tradable goods sector of foreign-located final goods firms and the foreign multinational firm $z_{F|MN}$, which belongs to the non-tradable goods sector of home-located final goods firms are represented as follows:

$$\int_0^1 C_{h,t}(z_{F|D}, x)dx \equiv C_{h,t}(z_{F|D}) = \delta \left(\frac{p_{h,t}(z_{F|D})}{P_{T,t}} \right)^{-\lambda} \left(\frac{P_{T,t}}{P_t} \right)^{-1} C_t, \tag{78}$$

$$\int_0^1 C_{f,t}(z^*_{F|X}, x)dx \equiv C_{f,t}(z^*_{F|X}) = \delta \left(\frac{p_{f,t}(z^*_{F|X})}{P_{T,t}} \right)^{-\lambda} \left(\frac{P_{T,t}}{P_t} \right)^{-1} C_t, \tag{79}$$

$$\int_0^1 C_{h,t}(z_{F|MN}, x)dx \equiv C_{h,t}(z_{F|MN}) = (1-\delta) \left(\frac{p_{h,t}(z_{F|MN})}{P_{N,t}} \right)^{-\lambda} \left(\frac{P_{N,t}}{P_t} \right)^{-1} C_t. \tag{80}$$

Using Eqs.(28), (29) and (78), we can easily derive the optimal price charged by domestic firm $z_{F|D}$, which belongs to the tradable goods sector of home-located final goods firms as follows:

$$p_{h,t}(z_{F|D}) = \frac{\lambda}{\lambda - 1} \Lambda_t \equiv p_{h,t}. \tag{81}$$

Similarly, we can also derive the optimal prices charged by export firm $z^*_{F|X}$, which belongs to the tradable goods sector of foreign-located final goods firms, and foreign multinational firm $z_{F|MN}$, which belongs to the non-tradable goods sector of home-located final goods firms as follows:

$$\frac{p_{f,t}(z^*_{F|X})}{\varepsilon_t} = \frac{\lambda}{\lambda - 1} \Lambda^*_t \equiv p^*_{f,t}, \tag{82}$$

$$\frac{1}{\mu_t} = \beta(1 + i_{t+1}) \frac{1}{\mu_{t+1}}, \tag{A}$$

$$M_t = \chi \frac{1 + i_{t+1}}{i_{t+1}} \mu_t. \tag{B}$$

$$p_{h,t}(z_{F|MN}) = \frac{\lambda}{\lambda-1}\Lambda_t \equiv p_{h,t}. \tag{83}$$

With regard to the final goods firms sold in the foreign market, we can derive the optimal prices of these firms as follows:

$$p^*_{f,t}(z^*_{F|D}) = \frac{\lambda}{\lambda-1}\Lambda^*_t \equiv p^*_{f,t}, \tag{84}$$

$$\varepsilon_t p^*_{h,t}(z_{F|X}) = \frac{\lambda}{\lambda-1}\Lambda_t \equiv p_{h,t}, \tag{85}$$

$$p^*_{f,t}(z^*_{F|MN}) = \frac{\lambda}{\lambda-1}\Lambda^*_t \equiv p^*_{f,t}. \tag{86}$$

Here, using Eqs.(13), (42) and (45)−(47), the unit costs to produce home and foreign final goods, which are given in Eqs.(9) and (10), can be represented as follows:

$$\Lambda_t = 2^{\frac{1}{\sigma-1}}\frac{\sigma}{\sigma-1}\varepsilon_t^{\frac{1-\eta^*}{2}}W_t, \tag{87}$$

$$\Lambda^*_t = 2^{\frac{1}{\sigma-1}}\frac{\sigma}{\sigma-1}\varepsilon_t^{\frac{\eta-1}{2}}W^*_t. \tag{88}$$

Therefore, from Eqs.(81)−(88), $p_{h,t}$ and $p^*_{f,t}$ can be rewritten as follows:

$$p_{h,t} = 2^{\frac{1}{\sigma-1}}\frac{\lambda}{\lambda-1}\frac{\sigma}{\sigma-1}\varepsilon_t^{\frac{1-\eta^*}{2}}W_t, \tag{89}$$

$$p^*_{f,t} = 2^{\frac{1}{\sigma-1}}\frac{\lambda}{\lambda-1}\frac{\sigma}{\sigma-1}\varepsilon_t^{\frac{\eta-1}{2}}W^*_t. \tag{90}$$

With regard to the price indexes for tradable and non-tradable composites of differentiated final goods consumed by the households of both countries, from Eqs.(81)−(86), they are equal to:

$$P_{T,t} = p_{h,t}A_t^{\frac{1}{1-\lambda}}, \tag{91}$$

$$P^*_{T,t} = p^*_{f,t}A_t^{*\frac{1}{1-\lambda}}, \tag{92}$$

$$P_{N,t} = p_{h,t}n_{MN,t}^{*\frac{1}{1-\lambda}}, \tag{93}$$

$$P^*_{N,t} = p^*_{f,t}n_{MN,t}^{\frac{1}{1-\lambda}}, \tag{94}$$

where

$$A_t \equiv n_{D,t} + n^*_{X,t}\left(\varepsilon_t p^*_{f,t}/p_{h,t}\right)^{1-\lambda}, \tag{95}$$

$$A^*_t \equiv n^*_{D,t} + n_{X,t}\left(\varepsilon_t p^*_{f,t}/p_{h,t}\right)^{\lambda-1}. \tag{96}$$

From Eqs.(91)−(94), the CPIs of both countries are equal to:

$$P_t = p_{h,t} n^{*\frac{1-\delta}{1-\lambda}}_{MN,t} A_t^{\frac{\delta}{1-\lambda}}, \tag{97}$$

$$P^*_t = p^*_{f,t} n^{\frac{1-\delta}{1-\lambda}}_{MN,t} A_t^{*\frac{\delta}{1-\lambda}}. \tag{98}$$

2.5 Free entry and the balance of payments

In this subsection, we mainly represent the conditions that hold under a situation of free entry and the balance of payments of the home country. To begin with, using Eqs.(28), (29), (81), (83) and (85), we can represent the after-tax profits earned by the home-located final goods firms as follows:

$$(1-\tau_t)\Pi_{F,t}(z_{F|D}) = \delta\frac{(1-\tau_t)\mu_t}{\lambda\left(n_{D,t} + n^*_{X,t}\varepsilon_t^{\frac{(\eta+\eta^*)(1-\lambda)}{2}}\right)}, \tag{99}$$

$$(1-\tau_t)\Pi_{F,t}(z_{F|X}) = \delta\frac{(1-\tau_t)\mu^*_t\varepsilon_t^{\frac{(\eta+\eta^*)(\lambda-1)+2}{2}}}{\lambda\left(n^*_{D,t} + n_{X,t}\varepsilon_t^{\frac{(\eta+\eta^*)(\lambda-1)}{2}}\right)}, \tag{100}$$

$$(1-\tau_t)\Pi_{F,t}(z_{F|MN}) = (1-\delta)\frac{(1-\tau_t)\mu_t}{\lambda n^*_{MN,t}}. \tag{101}$$

Similarly, we can represent the profits earned by the foreign-located final goods firms as follows:

$$\Pi^*_{F,t}(z^*_{F|D}) = \delta\frac{\mu^*_t}{\lambda\left(n^*_{D,t} + n_{X,t}\varepsilon_t^{\frac{(\eta+\eta^*)(\lambda-1)}{2}}\right)}, \tag{102}$$

$$\Pi^*_{F,t}(z^*_{F|X}) = \delta\frac{\left(\mu_t\varepsilon_t^{\frac{(\eta+\eta^*)(1-\lambda)-2}{2}}\right)}{\lambda\left(n_{D,t} + n^*_{X,t}\varepsilon_t^{\frac{(\eta+\eta^*)(1-\lambda)}{2}}\right)}, \tag{103}$$

$$\Pi^*_{F,t}(z^*_{F|MN}) = (1-\delta)\frac{\mu^*_t}{\lambda n_{MN,t}}. \tag{104}$$

Other things being equal, Eqs.(99)−(104) show that a higher number of final goods firms in a sector reduces the after-tax profits of each final goods firm in that sector.

With free entry, optimal investment in new final goods of the home country implies that the value of a home-located final goods firm is equal to the cost of creating a home final good, and in equilibrium this must be equal to the value of the after-tax profits of a home-located final goods firm. Therefore, the following relationships are derived:

$$q_t(z_{F|D}) = (\tilde{P}_{h,t} + \tilde{P}_{f,t})n^{\gamma}_{D,t} = (1-\tau_t)\Pi_{F,t}(z_{F|D}), \tag{105}$$

$$q_t(z_{F|X}) = (\tilde{P}_{h,t} + \tilde{P}_{f,t})n^{\gamma}_{X,t} = (1-\tau_t)\Pi_{F,t}(z_{F|X}), \tag{106}$$

$$q^*_t(z^*_{F|MN}) = (\tilde{P}_{h,t} + \tilde{P}_{f,t})n^{*\gamma}_{MN,t} = (1-\tau_t)\Pi_{F,t}(z_{F|MN}). \tag{107}$$

We define these relationships as the free entry conditions of the home country. Similarly, we can represent the free entry conditions of the foreign country as follows:

$$q^*_t(z^*_{F|D}) = (\tilde{P}^*_{h,t} + \tilde{P}^*_{f,t})n^{*\gamma}_{D,t} = \Pi^*_{F,t}(z^*_{F|D}), \tag{108}$$

$$q^*_t(z^*_{F|X}) = (\tilde{P}^*_{h,t} + \tilde{P}^*_{f,t})n^{*\gamma}_{X,t} = \Pi^*_{F,t}(z^*_{F|X}), \tag{109}$$

$$q_t(z_{F|MN}) = (\tilde{P}^*_{h,t} + \tilde{P}^*_{f,t})n^{\gamma}_{MN,t} = \Pi^*_{F,t}(z^*_{F|MN}). \tag{110}$$

Next, aggregating the households' budget constraints in the home country, and using the government budget constraint and the relationship of $B_{t+1} = B_t = 0$, we can represent the balance of payments of the home country as follows:[15]

$$\delta\left(\frac{n_{X,t}(\varepsilon_t\mu^*_t)\left(\frac{\varepsilon_t p^*_{f,t}}{p_{h,t}}\right)^{\lambda-1}}{A^*_t} - \frac{n^*_{X,t}\mu_t\left(\frac{\varepsilon_t p^*_{f,t}}{p_{h,t}}\right)^{1-\lambda}}{A_t}\right)$$

$$-\frac{(1-\tau_t)}{2}\left(\sum_{j=D,X} n_{j,t}\Pi_{F,t}(z_{F|j}) + n^*_{MN,t}\Pi_{F,t}(z_{F|MN})\right)$$

[15] With regard to the relationship of $B_{t+1} = B_t = 0$, refer to the content in footnote 16.

$$+\frac{1}{2}\left(\varepsilon_t\left(\sum_{j=D,X} n^*_{j,t}\Pi^*_{F,t}(z^*_{F|j})\right)+\varepsilon_t n_{MN,t}\Pi^*_{F,t}(z^*_{F|MN})\right)$$

$$+\frac{1}{2}\left(\sum_{j=D,X} n_{j,t}q_t(z_{F|j})+n^*_{MN,t}q_t(z_{F|MN})\right)$$

$$-\frac{1}{2}\left(\varepsilon_t\left(\sum_{j=D,X} n^*_{j,t}q^*_t(z^*_{F|j})\right)+\varepsilon_t n_{MN,t}q^*_t(z^*_{F|MN})\right)=0. \qquad (111)$$

On the left-hand side of Eq.(111), the first term of the first line represents home exports, while the second term of this line represents home imports. Therefore, their difference is the trade balance. The second line represents net after-tax profits paid by home-located final goods firms to foreign households, and the third line represents net profits paid by foreign-located final goods firms to home households. Therefore, their difference is the net factor payments. The sum of the trade balance and the net factor payments constitutes the current account. The sum of the last two lines represents the financial account, i.e., the financing of home-located final goods firms by foreign households minus the financing of foreign-located final goods firms by home households.

3 The transmission mechanism in an economy without trade in international bonds

In this section, we examine the effects of an unanticipated temporary reduction in the corporate tax rate of the home country.[16] We distinguish between three periods. In the initial period, the economy is in a symmetric steady state where no country has any net claims on the other. In period t, a negative home corporate tax shock occurs and we observe a short-run equilibrium, which assumes that nominal wages are fixed, before this shock can be observed. In the long run (from period $t+1$ onward), nominal wages are adjusted, and all variables reach their new steady-state values. To represent variables in the initial steady-state, we hereafter represent these variables

[16] In this paper, we focus on the analytical investigation as much as possible. Therefore, we examine the effects of a reduction in the corporate tax rate of the home country by ruling out trade in international bonds.

without a time subscript. Although we distinguish between three periods, all real variables in the long run return to their pre-shock levels, since we assume the absence of current account imbalances. Therefore, we examine only the short-run effects of this shock.

3.1 The initial steady state

In this subsection, we illustrate closed form solutions derived in the initial steady state with $\tau = 0$, $B = B^* = 0$ and $\mu = \mu^* = 1$.[17]

To begin with, from Eq.(71) and its foreign analog, we derive:

$$W = W^* = \frac{\xi\kappa}{\xi - 1}. \tag{112}$$

Next, from the two conditions of $PC = P^*C^*$ and $P_T C_T = \varepsilon P_T^* C_T^*$, we derive:

$$\varepsilon = 1. \tag{113}$$

Further, from Eqs.(112) and (113), and the relationships of $\tilde{p}_h^*(z_{I|X}) = \hat{\tilde{p}}_h(z_{I|X})/\varepsilon$, $\tilde{p}_f(z_{I|X}^*) = \varepsilon\hat{\tilde{p}}_f^*(z_{I|X}^*)$, $\tilde{p}_h(z_{I|D}) = \frac{\sigma}{\sigma-1}W$, $\tilde{p}_f^*(z_{I|D}^*) = \frac{\sigma}{\sigma-1}W^*$, $\hat{\tilde{p}}_h(z_{I|X}) = \tilde{p}_h(z_{I|D})$ and $\hat{\tilde{p}}_f^*(z_{I|X}^*) = \tilde{p}_f^*(z_{I|D}^*)$, we derive:[18]

$$\tilde{p}_h(z_{I|D}) = \tilde{p}_h^*(z_{I|X}) = \tilde{p}_f^*(z_{I|D}^*) = \tilde{p}_f(z_{I|X}^*) = \frac{\sigma}{\sigma - 1}\frac{\xi\kappa}{\xi - 1}. \tag{114}$$

Moreover, from Eqs.(9), (10), (13), (46), (47), and (114), we derive:

$$\Lambda = \Lambda^* = 2^{\frac{1}{\sigma-1}}\frac{\sigma}{\sigma - 1}\frac{\xi\kappa}{\xi - 1}. \tag{115}$$

Therefore, from Eqs.(81)−(86), (113) and (115), we derive:

$$\begin{aligned} p_h(z_{F|D}) &= p_h^*(z_{F|X}) = p_h(z_{F|MN}) = p_f^*(z_{F|D}^*) = p_f(z_{F|X}^*) \\ &= p_f^*(z_{F|MN}^*) = 2^{\frac{1}{\sigma-1}}\frac{\lambda}{\lambda - 1}\frac{\sigma}{\sigma - 1}\frac{\xi\kappa}{\xi - 1}. \end{aligned} \tag{116}$$

[17] We assume that the initial steady-state levels of home and foreign money supply are: $M = M^* = \chi(1-\beta)^{-1}$.

[18] $\hat{\tilde{p}}_h(z_{I|X})$ $\left(\hat{\tilde{p}}_f^*(z_{I|X}^*)\right)$ is the predetermined component of the foreign (home)-currency price of input produced by each of home (foreign) export firms in the intermediate goods sector.

Here, from Eqs.(95), (96), (105)−(111), (113), (116) and the condition of $P_T = \varepsilon P_T^*$, we derive:

$$n_D = n_X = n_D^* = n_X^*. \tag{117}$$

Therefore, from Eqs.(13), (47), (99), (105), (113), (114) and (117), we derive:

$$n_D (= n_X = n_D^* = n_X^*) = \left(\frac{\delta}{2^{\frac{2\sigma-1}{\sigma-1}} \lambda} \frac{\sigma-1}{\sigma} \frac{\xi-1}{\xi\kappa} \right). \tag{118}$$

Similarly, from Eqs.(13), (46), (47), (107), (110), (113) and (114), we derive the number of foreign (home) multinational firms in the non-tradable goods sector of home (foreign)-located final goods firms as follows:

$$n_{MN}^* (= n_{MN}) = \left(\frac{1-\delta}{2^{\frac{\sigma}{\sigma-1}} \lambda} \frac{\sigma-1}{\sigma} \frac{\xi-1}{\xi\kappa} \right)^{\frac{1}{1+\gamma}}. \tag{119}$$

Finally, from Eqs.(13), (20), (21), (46), (47), (55), (105)−(110), (115)−(117), (119), $\Pi_F(z_{F|j}) = \frac{p_h Y(z_{F|j})}{\lambda}$ and their foreign analogs, the home and foreign labor services are derived as follows:

$$\ell = \ell^* = \frac{\sigma-1}{\sigma} \frac{\xi-1}{\xi\kappa}. \tag{120}$$

3.2 The short-run equilibrium

In the next subsection, we will examine the effects of a negative home corporate tax shock ($d\tau_t < 0$) on the macroeconomic variables. In particular, we will examine the effects of this shock by focusing on the degree of LCP.

Before turning to the analysis mentioned above, in this subsection, we first take a first-order approximation for each of Eqs.(105)−(111) in the neighborhood of the initial steady state and consider the relationships between various macroeconomic variables. Now, from Eqs.(105) and (106), we obtain the following equations:

$$\frac{1}{2} \frac{dn_{D,t}}{n_D} = -d\tau_t - \frac{1}{2} \frac{dn_{X,t}^*}{n_X^*} + \frac{(\eta+\eta^*)(\lambda-1)}{4} d\varepsilon_t - \frac{dq_t(z_{F|D})}{\Pi_F(z_{F|D})}, \tag{121}$$

$$\frac{1}{2} \frac{dn_{X,t}}{n_X} = -d\tau_t - \frac{1}{2} \frac{dn_{D,t}^*}{n_D^*} + \frac{(\eta+\eta^*)(\lambda-1)+4}{4} d\varepsilon_t - \frac{dq_t(z_{F|X})}{\Pi_F(z_{F|X})}. \tag{122}$$

Eqs.(121) and (122) have the following characteristics. To begin with, a decrease of τ_t ($d\tau_t < 0$) increases after-tax profits for domestic and export firms in the tradable goods sector of home-located final goods firms. Consequently, it encourages new entry into the home market. Next, when the number of export (domestic) firms in the tradable goods sector of foreign-located final goods firms, i.e., $\frac{dn^*_{X,t}}{n^*_X}\left(\frac{dn^*_{D,t}}{n^*_D}\right)$, increases, the home (foreign) household's consumption of final goods produced in the home country decreases, which causes a decrease in the sales revenues of domestic (export) firms in the tradable goods sector of home-located final goods firms, and thereby decreases after-tax profits for these domestic (export) firms. Consequently, it leads to exit from the home market. Finally, the effects of a depreciation ($d\varepsilon_t > 0$) on the number of domestic and export firms in the tradable goods sector of home-located final goods firms are positive. We can explain these results as follows. The depreciation, since it increases the sales revenues of domestic and export firms in the tradable goods sector of home-located final goods firms, increases after-tax profits for these two types of firms, and hence, the number of these two types of firms increases. In addition, from the perspective of LCP in both countries, we can show that these results have the following properties. When the value of η and/or η^* rises, the increase in the number of domestic and export firms in the tradable goods sector of home-located final goods firms gets steeper. This is because a rise in η and/or η^* intensifies the increase in after-tax profits for these two types of firms through a deterioration in the terms of trade under the trade in final goods.[19]

From a first-order approximation of Eqs.(108) and (109), we obtain the following equations:

$$\frac{1}{2}\frac{dn^*_{D,t}}{n^*_D} = -\frac{1}{2}\frac{dn_{X,t}}{n_X} - \frac{(\eta+\eta^*)(\lambda-1)}{4}d\varepsilon_t - \frac{dq^*_t(z^*_{F|D})}{\Pi^*_F(z^*_{F|D})}, \tag{123}$$

$$\frac{1}{2}\frac{dn^*_{X,t}}{n^*_X} = -\frac{1}{2}\frac{dn_{D,t}}{n_D} - \frac{(\eta+\eta^*)(\lambda-1)+4}{4}d\varepsilon_t - \frac{dq^*_t(z^*_{F|X})}{\Pi^*_F(z^*_{F|X})}. \tag{124}$$

Eqs.(123) and (124) have the following characteristics. To begin with, the increase in the number of export (domestic) firms in the tradable goods sector of home-located final goods firms, i.e., $\frac{dn_{X,t}}{n_X}\left(\frac{dn_{D,t}}{n_D}\right)$, leads to an exit

[19] We define the terms of trade under the trade in final goods as $TOT_t = \frac{\varepsilon_t p^*_{f,t}}{p_{h,t}}$. Then, we can represent a first-order approximation for TOT_t as $\frac{dTOT_t}{TOT} = \frac{\eta+\eta^*}{2}d\varepsilon_t$.

from the foreign market, since the increase in $\frac{dn_{X,t}}{n_X}$ $\left(\frac{dn_{D,t}}{n_D}\right)$ decreases the foreign (home) household's consumption of final goods produced in the foreign country, which causes a decrease in the sales revenues of domestic (export) firms in the tradable goods sector of foreign-located final goods firms, and thereby decreases profits for these domestic (export) firms. Next, the effects of a depreciation ($d\varepsilon_t > 0$) on the number of domestic and export firms in the tradable goods sector of foreign-located final goods firms are negative. We can explain these results as follows. The depreciation, since it decreases the sales revenues of domestic and export firms in the tradable goods sector of foreign-located final goods firms, decreases profits for these two types of firms, and hence, the number of these two types of firms decreases. In addition, from the perspective of LCP in both countries, we can show that these results have the following properties. When the value of η and/or η^* rises, the decrease in the number of domestic and export firms in the tradable goods sector of foreign-located final goods firms gets steeper. This is because a rise in η and/or η^* intensifies the decrease in profits for these two types of firms through an improvement in the terms of trade under the trade in final goods.

From a first-order approximation of Eqs.(107) and (110), we obtain the following equations:

$$\frac{dn^*_{MN,t}}{n^*_{MN}} = -\frac{dq_t(z_{F|MN})}{\Pi_F(z_{F|MN})} - d\tau_t, \tag{125}$$

$$\frac{dn_{MN,t}}{n_{MN}} = -\frac{dq^*_t(z^*_{F|MN})}{\Pi^*_F(z^*_{F|MN})}. \tag{126}$$

Eq.(125) has the following characteristics. A decrease of τ_t ($d\tau_t < 0$) increases after-tax profits for foreign multinational firms in the non-tradable goods sector of home-located final goods firms. Consequently, it encourages new entry into the home market.

From a first-order approximation of Eq.(111), we obtain the following equation:

$$\left(1 + \frac{(\eta + \eta^*)(\lambda - 1)}{2}\right) d\varepsilon_t = -\frac{1}{2}\left(\frac{dn_{D,t}}{n_D} - \frac{dn^*_{X,t}}{n^*_X}\right) + \frac{1}{2}\left(\frac{dn^*_{D,t}}{n^*_D} - \frac{dn_{X,t}}{n_X}\right). \tag{127}$$

Eq.(127) has the following characteristics. To begin with, an increase in the relative number of tradable final goods firms sold in the home country

$\left(\frac{dn_{D,t}}{n_D} - \frac{dn^*_{X,t}}{n^*_X}\right)$ leads to an appreciation of the nominal exchange rate. The balance of payments is restored via the appreciation, since such an increase leads to an increase in the net export of tradable final goods. Next, an increase in the relative number of tradable final goods firms sold in the foreign country $\left(\frac{dn^*_{D,t}}{n^*_D} - \frac{dn_{X,t}}{n_X}\right)$ leads to a depreciation of the nominal exchange rate. Unlike previous case, the balance of payments is restored via the depreciation, since such an increase leads to a decrease in the net export of tradable final goods. Here, from Eq.(127), we get $\frac{d\left(\partial d\varepsilon_t/\partial\left(\frac{dn_{D,t}}{n_D} - \frac{dn^*_{X,t}}{n^*_X}\right)\right)}{d\eta} > 0$, $\frac{d\left(\partial d\varepsilon_t/\partial\left(\frac{dn_{D,t}}{n_D} - \frac{dn^*_{X,t}}{n^*_X}\right)\right)}{d\eta^*} > 0$, $\frac{d\left(\partial d\varepsilon_t/\partial\left(\frac{dn^*_{D,t}}{n^*_D} - \frac{dn_{X,t}}{n_X}\right)\right)}{d\eta} < 0$, and $\frac{d\left(\partial d\varepsilon_t/\partial\left(\frac{dn^*_{D,t}}{n^*_D} - \frac{dn_{X,t}}{n_X}\right)\right)}{d\eta^*} < 0$. This shows that the degrees of appreciation and depreciation, which are based on the increase in these variables, gets milder.

3.3 The effects of corporate tax reduction on macroeconomic variables

We now turn to the analysis of the effects of corporate tax reduction.

3.3.1 Effect on the nominal exchange rate

In this subsubsection, we examine the effect of a negative home corporate tax shock ($d\tau_t < 0$) on the nominal exchange rate. To begin with, from Eqs.(121) and (124), we derive:

$$\frac{dn_{D,t}}{d\tau_t}\frac{1}{n_D} - \frac{dn^*_{X,t}}{d\tau_t}\frac{1}{n^*_X} = -\frac{1}{\gamma} + \frac{\lambda(\eta+\eta^*)}{2\gamma}\frac{d\varepsilon_t}{d\tau_t}. \tag{128}$$

Next, from Eqs.(122) and (123), we derive:

$$\frac{dn^*_{D,t}}{d\tau_t}\frac{1}{n^*_D} - \frac{dn_{X,t}}{d\tau_t}\frac{1}{n_X} = \frac{1}{\gamma} - \frac{\lambda(\eta+\eta^*)}{2\gamma}\frac{d\varepsilon_t}{d\tau_t}. \tag{129}$$

Therefore, from Eqs.(127)−(129), we derive:

$$\frac{d\varepsilon_t}{d\tau_t} = \frac{2}{\Delta} > 0, \tag{130}$$

where $\Delta \equiv \gamma\{(\eta+\eta^*)(\lambda-1)+2\} + \lambda(\eta+\eta^*) > 0$. Eq.(130) shows that this shock unambiguously leads to an appreciation of the nominal exchange rate.

Eq.(130) also shows that the degree of appreciation decreases in response to the rise in η and/or η^*. This can be explained as follows. To begin with, from Eqs.(128) and (129), when the value of η and/or η^* rises, the relative number of tradable final goods firms sold in the home country decreases, and the relative number of tradable final goods firms sold in the foreign country increases. These things reduce the degree of trade surplus. In addition, when the value of η and/or η^*, which is the component of coefficient of $d\varepsilon_t$ in Eq.(127), rises, the degree of trade surplus also decreases. Consequently, from these two perspectives, the degree of appreciation, which is required to correct the resulting trade surplus, decreases.

3.3.2 Effects on the number of final goods firms

In this subsubsection, we examine the effects of a negative home corporate tax shock ($d\tau_t < 0$) on the number of various final goods firms. To begin with, from Eqs.(121)−(124) and (130), the number of domestic and export firms in the tradable goods sector of home-located final goods firms are as follows:

$$\frac{dn_{D,t}}{d\tau_t}\frac{1}{n_D} = -\frac{1}{2\gamma(1+\gamma)}\left((1+2\gamma) + \frac{\gamma(2+\eta-\eta^*) - \lambda(\eta+\eta^*)(1+\gamma)}{\Delta}\right) < 0, \tag{131}$$

$$\frac{dn_{X,t}}{d\tau_t}\frac{1}{n_X} = -\frac{1}{2\gamma(1+\gamma)}\left((1+2\gamma) - \frac{\gamma(2+\eta^*-\eta) + \lambda(\eta+\eta^*)(1+\gamma)}{\Delta}\right) < 0. \tag{132}$$

Eqs.(131) and (132) show that the effects of this shock on the number of domestic and export firms in the tradable goods sector of home-located final goods firms are positive. These results can be explained intuitively as follows. When this shock occurs, the after-tax profits for these two types of firms increase. At the same time, it causes a decrease in entry costs for these two types of firms. Consequently, the number of these two types of firms increases, since it causes an increase in difference between after-tax profits and entry costs for each of these firms (see Eqs.(121), (122) and (130)). Here, differentiating Eq.(131) with respect to η and η^*, we can show that the rise in η and/or η^* weakens the increase in the number of domestic firms in the tradable goods sector of home-located final goods firms. This can be explained as follows. The larger the value of η and/or η^*, the lower the degree of the increase in difference between after-tax profits and entry costs for domestic firms in the tradable goods sector of home-located final goods firms (see the right hand side of Eq.(121)). This weakens the degree of entry for these domestic firms. Consequently, the degree of the increase in the number of these domestic firms weakens. On the other hand, differentiating Eq.(132) with respect to η and η^*, we can show that the rise in η basically intensifies the increase in the number of export firms in the tradable goods sector of home-located final goods firms, while the rise in η^* weakens the increase in the number of these export firms. In particular, the former result can be explained based on the fact that the increase in difference between after-tax profits and entry costs for these export firms basically intensifies (see the right hand side of Eq.(122)).

Next, from Eqs.(121)−(124) and (130), the number of domestic and export firms in the tradable goods sector of foreign-located final goods firms are as follows:

$$\frac{dn^*_{D,t}}{d\tau_t}\frac{1}{n^*_D} = \frac{1}{2\gamma(1+\gamma)}\left(1 + \frac{\gamma(2+\eta^*-\eta) - \lambda(\eta+\eta^*)(1+\gamma)}{\Delta}\right) > 0, \quad (133)$$

$$\frac{dn^*_{X,t}}{d\tau_t}\frac{1}{n^*_X} = \frac{1}{2\gamma(1+\gamma)}\left(1 - \frac{\gamma(2+\eta-\eta^*) + \lambda(\eta+\eta^*)(1+\gamma)}{\Delta}\right) < 0. \quad (134)$$

Eq.(133) shows that the effect of this shock on the number of domestic firms in the tradable goods sector of foreign-located final goods firms is negative, while Eq.(134) shows that the effect of this shock on the number of export firms in the tradable goods sector of foreign-located final goods firms is positive. These results can be explained intuitively as follows. When this shock occurs, it brings more entry costs than profits for the former firms, but it brings more profits than entry costs for the latter firms. Consequently, the number of the former firms decreases and that of the latter firms increases. Here, differentiating Eq.(133) with respect to η and η^*, we can show that the rise in η and/or η^* weakens the decrease in the number of domestic firms in the tradable goods sector of foreign-located final goods firms. On the other hand, differentiating Eq.(134) with respect to η and η^*, we can show that the rise in η intensifies the increase in the number of export firms in the tradable goods sector of foreign-located final goods firms, while the rise in η^* basically weakens the increase in the number of these export firms. The logic of these mechanisms can also be explained by using that adopted for the result obtained from Eq.(132).

Finally, from Eqs.(125), (126) and (130), the number of foreign multinational firms in the non-tradable goods sector of home-located final goods firms, and that of home multinational firms in the non-tradable goods sector of foreign-located final goods firms are as follows:

$$\frac{dn^*_{MN,t}}{d\tau_t}\frac{1}{n^*_{MN}} = -\frac{1}{1+\gamma}\left(\frac{1-\eta^*}{\Delta}+1\right) < 0, \tag{135}$$

$$\frac{dn_{MN,t}}{d\tau_t}\frac{1}{n_{MN}} = \frac{1}{1+\gamma}\frac{1-\eta}{\Delta} \geq 0. \tag{136}$$

Eq.(135) shows that the effect of this shock on the number of foreign multinational firms in the non-tradable goods sector of home-located final goods firms is positive, while Eq.(136) shows that the effect of this shock on the number of home multinational firms in the non-tradable goods sector of foreign-located final goods firms is non-positive. The reason why these results are obtained is that while this shock causes both an increase in after-tax profits and a decrease in entry costs for the former firms, in the foreign country it prevents the entry costs for the latter firms from decreasing (see Eqs.(125), (126) and (130)). Here, differentiating both Eqs.(135) and (136) with respect to η and η^*, we can show that the rise in η and/or η^* basically weakens both the increase in the number of foreign multinational firms in the non-tradable goods sector of home-located final goods firms and the decrease in the number of home multinational firms in the non-tradable goods sector of foreign-located final goods firms. In particular, the latter result can be explained as follows. The larger the value of η and/or η^*, the lower the degree of the increase in entry costs for home multinational firms in the non-tradable goods sector of foreign-located final goods firms. This weakens the degree of exit of these multinational firms. Consequently, the degree of the decrease in the number of these multinational firms weakens.

3.3.3 Effects on CPI and overall consumption

In this subsubsection, we examine the effects of a negative home corporate tax shock ($d\tau_t < 0$) on the CPIs of both the countries and overall consumptions in both countries. To begin with, we consider the effects of this shock on the CPIs of both the countries. The effects of this shock on the CPIs of both the countries are as follows:

$$\frac{dP_t}{d\tau_t}\frac{1}{P} = \frac{1}{2(\lambda-1)(1+\gamma)}\left(2-\delta+\frac{\{1+(1+\gamma)(\lambda-1)\}\{2(1-\eta^*)+\delta(\eta+\eta^*)\}}{\Delta}\right) > 0, \tag{137}$$

$$\frac{dP_t^*}{d\tau_t}\frac{1}{P^*} = \frac{1}{2(\lambda-1)(1+\gamma)}\left(\delta - \frac{\{1+(1+\gamma)(\lambda-1)\}\{2(1-\eta)+\delta(\eta+\eta^*)\}}{\Delta}\right). \tag{138}$$

Eq.(137) shows that the effect of this shock on home CPI is negative, while Eq.(138) shows that the effect of this shock on foreign CPI is ambiguous. Using the variables that represent the number of various final goods firms and the nominal exchange rate, Eqs.(137) and (138) can be rewritten as follows:

$$\frac{dP_t}{d\tau_t}\frac{1}{P} = -\frac{1}{\lambda-1}\left(\frac{\delta}{2}\left(\frac{dn_{D,t}}{d\tau_t}\frac{1}{n_D} + \frac{dn_{X,t}^*}{d\tau_t}\frac{1}{n_X^*}\right) + (1-\delta)\frac{dn_{MN,t}^*}{d\tau_t}\frac{1}{n_{MN}^*} - \frac{(\lambda-1)\{2(1-\eta^*)+\delta(\eta+\eta^*)\}}{4}\frac{d\varepsilon_t}{d\tau_t}\right) > 0 \tag{139}$$

$$\frac{dP_t^*}{d\tau_t}\frac{1}{P^*} = -\frac{1}{\lambda-1}\left(\frac{\delta}{2}\left(\frac{dn_{D,t}^*}{d\tau_t}\frac{1}{n_D^*} + \frac{dn_{X,t}}{d\tau_t}\frac{1}{n_X}\right) + (1-\delta)\frac{dn_{MN,t}}{d\tau_t}\frac{1}{n_{MN}} + \frac{(\lambda-1)\{2(1-\eta)+\delta(\eta+\eta^*)\}}{4}\frac{d\varepsilon_t}{d\tau_t}\right) \tag{140}$$

As shown in Eq.(139), the effect of this shock on home CPI can be separated into two channels: the weighted sum of the number of three types of final goods firms that sell in the home market, and the nominal exchange rate. Both of these channels are negative.[20] Therefore, the overall effect of this shock on home CPI is negative. This is determined independently of home and foreign LCP parameters. Similarly, as shown in Eq.(140), the effect of this shock on foreign CPI can be also separated into two channels:

[20]More precisely, we can explain the mechanisms of these two channels as follows. To begin with, the mechanism of the former channel can be explained as follows. When a negative home corporate tax shock occurs ($d\tau_t < 0$), the effect on the weighted sum of the number of three types of final goods firms that sell in the home market is positive, which causes a decline in the weighted sum of the home-currency prices of final goods produced by these firms through the increase in the supply of final goods sold in the home country. Consequently, the effect of this channel on home CPI is negative. Next, the mechanism of the latter channel can be explained as follows. When such a shock occurs, the nominal exchange rate appreciates, which cause a decline in the weighted sum of the home-currency prices of final goods sold in the home country. Consequently, the effect of this channel on home CPI is also negative.

the weighted sum of the number of three types of final goods firms that sell in the foreign market, and the nominal exchange rate. Unlike in the case of the home country, the former channel is ambiguous, but the latter channel is positive. Therefore, the overall effect of this shock on foreign CPI is ambiguous. Here, the rise in η^* weakens the decrease in home CPI, and the rise in η weakens the increase in (or intensifies the decrease in) foreign CPI. In particular, the former result can be explained by the decline in the degree of the decrease in the two channels due to the rise in η^*.

Next, we consider the effects of a negative home corporate tax shock ($d\tau_t < 0$) on overall home consumption $C_t(\equiv 1/P_t)$ and overall foreign consumption $C_t^*(\equiv 1/P_t^*)$. The effect of this shock on C_t is positive, since the effect of this shock on home CPI is always negative. Here, from the definition of C_t, when the decrease in home CPI weakens, the increase in C_t weakens. On the other hand, the effect of this shock on C_t^* is ambiguous, since the effect of this shock on foreign CPI is ambiguous. Here, from the definition of C_t^*, when the increase (or decrease) in foreign CPI weakens (or intensifies), the decrease (or increase) in C_t^* weakens (or intensifies).

3.3.4 Effects on employment

In this subsubsection, we examine the effects of a negative home corporate tax shock ($d\tau_t < 0$) on the employment levels of both countries. Here, the effects of this shock on the employment levels of both countries are as follows:

$$\frac{d\ell_t}{d\tau_t}\frac{1}{\ell} = \frac{1}{2\lambda}\left(\frac{2\lambda(1-\eta)-(2-\eta-\eta^*)}{\Delta} - 1\right), \tag{141}$$

$$\frac{d\ell_t^*}{d\tau_t}\frac{1}{\ell^*} = \frac{1}{2\lambda}\left(\frac{(2-\eta-\eta^*)-2\lambda(1-\eta^*)}{\Delta} - 1\right) < 0. \tag{142}$$

Eq.(141) shows that the effect of this shock on home employment is ambiguous, while Eq.(142) shows that the effect of this shock on foreign employment is positive. Using the variables that represent the number of various final goods firms and the nominal exchange rate, Eqs.(141) and (142) can be rewritten as follows:

$$\frac{d\ell_t}{d\tau_t}\frac{1}{\ell} = \frac{1}{2}\Bigg((1+\gamma)\Bigg\{\frac{\delta}{2}\left(\frac{dn_{D,t}}{d\tau_t}\frac{1}{n_D} + \frac{dn_{X,t}^*}{d\tau_t}\frac{1}{n_X^*} + \frac{dn_{D,t}^*}{d\tau_t}\frac{1}{n_D^*} + \frac{dn_{X,t}}{d\tau_t}\frac{1}{n_X}\right)$$

$$+(1-\delta)\left(\frac{dn_{MN,t}}{d\tau_t}\frac{1}{n_{MN}}+\frac{dn^*_{MN,t}}{d\tau_t}\frac{1}{n^*_{MN}}\right)\Bigg\}+\frac{\lambda-1}{\lambda}\left(1+\frac{2-\eta-\eta^*}{2}\frac{d\varepsilon_t}{d\tau_t}\right)\Bigg), \tag{143}$$

$$\frac{d\ell^*_t}{d\tau_t}\frac{1}{\ell^*}=\frac{1}{2}\Bigg((1+\gamma)\Bigg\{\frac{\delta}{2}\left(\frac{dn_{D,t}}{d\tau_t}\frac{1}{n_D}+\frac{dn^*_{X,t}}{d\tau_t}\frac{1}{n^*_X}+\frac{dn^*_{D,t}}{d\tau_t}\frac{1}{n^*_D}+\frac{dn_{X,t}}{d\tau_t}\frac{1}{n_X}\right)$$

$$+(1-\delta)\left(\frac{dn_{MN,t}}{d\tau_t}\frac{1}{n_{MN}}+\frac{dn^*_{MN,t}}{d\tau_t}\frac{1}{n^*_{MN}}\right)\Bigg\}+\frac{\lambda-1}{\lambda}\left(1-\frac{2-\eta-\eta^*}{2}\frac{d\varepsilon_t}{d\tau_t}\right)\Bigg)<0. \tag{144}$$

As shown in Eqs.(143) and (144), the effects of this shock on the employment levels of both countries can be separated into two channels: the weighted sum of the number of three types of final goods firms located in both countries, and the nominal exchange rate. Although the effect of the first channel on home employment is the same as that on foreign employment, the effect of the second channel on home employment is different from that on foreign employment. The difference between the second channel in Eq.(143) and that in Eq.(144) plays a critical role in the effects of this shock on the employment levels of both countries. Therefore, the overall effect of this shock on foreign employment is positive, since the effect of the second channel in Eq.(144) is positive.[21] This is determined independently of home and foreign LCP parameters. Here, the rise in η weakens the decrease in (or

[21] More precisely, the effect of a negative home corporate tax shock ($d\tau_t < 0$) on foreign employment is shown by the effects through two macroeconomic variables of $Y^*_{f,t}$, which is a composite of the foreign intermediate inputs used by foreign-located final goods firms, and $Y_{f,t}$, which is a composite of the foreign intermediate inputs used by home-located final goods firms. The effect of this shock on $Y^*_{f,t}$ is shown by the following three channels: the weighted sum of the number of three types of foreign-located final goods firms, the weighted sum of the profits earned by the three types of foreign-located final goods firms, and the nominal exchange rate. To begin with, when this shock occurs, the weighted sum of the number of three types of foreign-located final goods firms basically decreases, which basically causes the decrease in the supply of foreign final goods. This basically weakens the foreign-located final goods firms' demand for a composite of the inputs produced by domestic firms in the foreign intermediate goods sector. Consequently, the effect of this channel on $Y^*_{f,t}$ is basically negative. Next, when this shock occurs, the weighted sum of the profits earned by three types of foreign-located final goods firms basically increases, which basically causes an increase in the supply of foreign final goods. This basically intensifies the foreign-located final goods firms' demands for a composite of the inputs produced by domestic firms in the foreign intermediate goods sector. Consequently, the effect of this channel on $Y^*_{f,t}$ is basically positive. Finally, when this shock occurs, the nominal exchange rate appreciates. Under circumstances other than $\eta = 1$, this bumps the foreign-

intensifies the increase in) home employment and the rise in η^* weakens the increase in foreign employment. In particular, the latter result can mainly be explained by the decline in the degree of the increase in the second channel due to the rise in η^*.

3.3.5 Effects on aggregate output

In this subsubsection, we examine the effects of a negative home corporate tax shock ($d\tau_t < 0$) on the aggregate output in both countries. Here, the effects of this shock on the aggregate output in both countries are as follows:

$$\frac{dY_t}{d\tau_t}\frac{1}{Y} = -\frac{1-\eta^*}{\Delta} \leq 0, \tag{145}$$

$$\frac{dY_t^*}{d\tau_t}\frac{1}{Y^*} = \frac{1-\eta}{\Delta} \geq 0. \tag{146}$$

Eq.(145) shows that the effect of this shock on aggregate home output is non-negative, while Eq.(146) shows that the effect of this shock on aggregate foreign output is non-positive. Using the variables that represent the numbers of various final goods firms, Eqs.(145) and (146) can be rewritten as follows:

$$\frac{dY_t}{d\tau_t}\frac{1}{Y} = 1 + (1+\gamma)\left(\frac{\delta}{2}\left(\frac{dn_{D,t}}{d\tau_t}\frac{1}{n_D} + \frac{dn_{X,t}}{d\tau_t}\frac{1}{n_X}\right) + (1-\delta)\frac{dn^*_{MN,t}}{d\tau_t}\frac{1}{n^*_{MN}}\right) \leq 0, \tag{147}$$

currency price that corresponds to a composite of the inputs produced by export firms in the home intermediate goods sector, which causes a decrease in the foreign-located final goods firms' demands for a composite of the inputs produced by export firms in the home intermediate goods sector. The decrease in this demand leads to the decrease in the foreign-located final goods firms' outputs, and hence, the foreign-located final goods firms' demand for a composite of the inputs produced by domestic firms in the foreign intermediate goods sector declines. Consequently, the effect of this channel on $Y^*_{f,t}$ is negative under such circumstances. Except for the direct effect of this shock, the effect of this shock on $Y_{f,t}$ can be also shown by the following three channels: the weighted sum of the number of three types of home-located final goods firms, the weighted sum of the profits earned by three types of home-located final goods firms, and the nominal exchange rate. Unlike in the case of $Y^*_{f,t}$, the effect of an appreciation on $Y_{f,t}$ is positive under circumstances other than $\eta^* = 1$. This can be explained as follows. When the nominal exchange rate appreciates, the home-currency price that corresponds to a composite of the inputs produced by export firms in the foreign intermediate goods sector declines. This causes an increase in the home-located final goods firms' demand for a composite of the inputs produced by export firms in the foreign intermediate goods sector. Consequently, the effect of this channel on $Y_{f,t}$ is positive under such circumstances.

$$\frac{dY_t^*}{d\tau_t}\frac{1}{Y^*} = (1+\gamma)\left(\frac{\delta}{2}\left(\frac{dn_{D,t}^*}{d\tau_t}\frac{1}{n_D^*} + \frac{dn_{X,t}^*}{d\tau_t}\frac{1}{n_X^*}\right) + (1-\delta)\frac{dn_{MN,t}}{d\tau_t}\frac{1}{n_{MN}}\right) \geq 0. \tag{148}$$

As shown in Eq.(147), the effect of this shock on the weighted sum of the number of three types of home-located final goods firms is positive. Therefore, there is a potential for an increase in aggregate home output. On the other hand, as shown in Eq.(148), the effect of this shock on the weighted sum of the number of three types of foreign-located final goods firms is non-positive. Therefore, there is a potential for a decrease in aggregate foreign output (with regard to a part of the mechanisms of these results, refer to the content in footnote 21). Here, the rise in η and/or η^* basically weakens the increase in aggregate home output and the decrease in aggregate foreign output. These results can be explained by the fluctuations of the numbers of various final goods firms due to the rise in η and/or η^*. For example, the rise in η^* weakens the increase in the number of each of the three types of home-located final goods firms. Therefore, the rise in this value basically weakens the increase in aggregate home output.

4 Welfare

In this section, we examine the effects of a reduction in the corporate tax rate of the home country on the welfare of both countries. Following Obstfeld and Rogoff (1995, 1996) and others, we focus on the real parts of a household's utility and assume that the effect of real balances on utility is small enough to be neglected.[22] By taking the first-order approximation of the household's utility under such an assumption, we examine the effects of such a reduction on the welfare of both countries. As with the analysis of the effects of this reduction on the macroeconomic variables, we examine its effects by focusing on the degree of LCP. However, it is difficult to evaluate fully its effects from the perspective of analytical investigation. Therefore, we examine its effects numerically. To perform analyses based on the numerical example, we need to specify the values of five parameters. To begin with, we

[22] By abstracting from the utility of real balances, we follow the formulation of Obstfeld and Rogoff (1995, 1996). Many literatures of NOEM model use this formulation; see, e.g., Betts and Devereux (2000), Corsetti et al. (2000), Obstfeld and Rogoff (2000, 2002), Tille (2001), Sutherland (2004), Corsetti and Pesenti (2005), Berger (2006), Shi and Xu (2007), and Dohwa (2008, 2014, 2018).

set the elasticity of substitution between any two differentiated final goods at $\lambda = 10$, since final goods tend to be highly substitutable, and thus the elasticity among them tends to be high. On the other hand, we set the elasticity of substitution between any two differentiated intermediate inputs at $\sigma = 3$, since intermediate inputs tend to be highly differentiated, and thus the elasticity among them tends to be low. The values of these elasticities are basically based on the idea of Shioji (2006). Next, following Erceg et al. (2000), we set the elasticity of substitution among labor varieties at $\xi = 6$. Finally, we set γ and δ somewhat arbitrarily at 1 and 0.5, respectively. In what follows, we describe the closed form solutions that show the effects of this reduction on the welfare of both countries. After introducing some speculation from the perspective of analytical investigation, we show the numerical example described above.

4.1 Analytical investigation

The effects of a negative home corporate tax shock ($d\tau_t < 0$) on the welfare of both countries are as follows:

$$\frac{dU_t}{d\tau_t} = -\frac{dP_t}{d\tau_t}\frac{1}{P} - \kappa\ell\frac{d\ell_t}{d\tau_t}\frac{1}{\ell}, \tag{149}$$

$$\frac{dU_t^*}{d\tau_t} = -\frac{dP_t^*}{d\tau_t}\frac{1}{P^*} - \kappa\ell^*\frac{d\ell_t^*}{d\tau_t}\frac{1}{\ell^*}. \tag{150}$$

From Eqs.(149) and (150), the effects of this shock on the welfare of both countries are basically ambiguous. Therefore, we consider under what circumstances this shock raises or does not raise the levels of home and foreign welfare. To begin with, it follows from Eqs.(137), (141) and (149) that this shock raises home welfare as long as η and η^* meet the following condition:

$$\left[(2\lambda-1)\Phi + (\Phi - 2\lambda\sigma\xi)\,\Omega\right]\eta < (1-\Omega)\Phi\eta^* + \left[\lambda\sigma\xi\left\{\Omega + \gamma(2-\delta)\right\} - (1+\gamma-\lambda)\Phi\right], \tag{151}$$

where $\Omega \equiv \gamma(\lambda - 1) + \lambda > 0$ and $\Phi \equiv (\sigma-1)(\xi-1)(\lambda-1)(1+\gamma) > 0$.

On the other hand, when η and η^* satisfy the following condition, this shock lowers home welfare:

$$\left[(2\lambda-1)\Phi + (\Phi - 2\lambda\sigma\xi)\,\Omega\right]\eta > (1-\Omega)\Phi\eta^* + \left[\lambda\sigma\xi\left\{\Omega + \gamma(2-\delta)\right\} - (1+\gamma-\lambda)\Phi\right]. \tag{152}$$

The condition (151) shows that this shock causes the positive effect on welfare from the consumption of final goods to dominate the negative effect on welfare from employment. On the other hand, the condition (152) shows that this shock causes the negative effect on welfare from employment to dominate the positive effect on welfare from the consumption of final goods.

Next, from Eqs.(138), (142) and (150), this shock raises foreign welfare when η and η^* satisfy the following condition:

$$[(1+\Omega)\Phi - 2\lambda\sigma\xi\Omega]\,\eta < (2\lambda - 1 - \Omega)\Phi\eta^* + 2\left[\lambda\sigma\xi(\gamma\delta - \Omega) + (1-\gamma-\lambda)\Phi\right]. \tag{153}$$

On the other hand, when η and η^* satisfy the following condition, this shock lowers foreign welfare:

$$[(1+\Omega)\Phi - 2\lambda\sigma\xi\Omega]\,\eta > (2\lambda - 1 - \Omega)\Phi\eta^* + 2\left[\lambda\sigma\xi(\gamma\delta - \Omega) + (1-\gamma-\lambda)\Phi\right]. \tag{154}$$

The condition (153) shows that this shock causes the positive effect on welfare from the consumption of final goods to dominate the negative effect on welfare from employment. On the other hand, the condition (154) shows that this shock causes the negative effect on welfare from employment to dominate the positive effect on welfare from the consumption of final goods. Under the condition (154), this shock can be regarded as a beggar-thy-neighbor policy in the sense that it lowers foreign welfare.

4.2 Numerical example

[Insert Table 1]

In this subsection, we examine the effects of a negative home corporate tax shock ($d\tau_t < 0$) from the perspective of a numerical example. Before examining the effects of this shock on the welfare of both countries, we examine the effects of this shock on the overall consumptions of both countries (C_t and C_t^*) and the employment levels of both countries (ℓ_t and ℓ_t^*). These analyses adopt scenario (a) in Table 1 as the benchmark scenario. To begin with, the first and second lines of Table 1 show the effect of this shock on C_t and C_t^*, respectively. In all scenarios in Table 1, the effect of this shock on C_t is positive. On the other hand, in scenarios other than scenarios (b) and (d) in Table 1, the effect of this shock on C_t^* is negative. In scenario (a) in Table 1, the positive effect on C_t is largest. One of the reasons why this result is obtained is that all of the intermediate goods firms employ PCP.

When the degree of LCP rises, this effect is significantly weakened compared with the benchmark scenario. Next, the third and fourth lines of Table 1 show the effect of this shock on ℓ_t and ℓ_t^*, respectively. In scenarios other than scenario (a) in Table 1, the effect of this shock on ℓ_t is positive. On the other hand, in all scenarios in Table 1, the effect of this shock on ℓ_t^* is positive. In scenario (a) in Table 1, the effect of this shock on ℓ_t^* is largest. One of the reasons why this result is obtained is that all of the intermediate goods firms employ PCP. When the degree of LCP rises, the positive effect on ℓ_t^* is significantly weakened compared with the benchmark scenario.

We now examine the effects of a negative home corporate tax shock on the welfare of both countries. The fifth and sixth lines of Table 1 show the effect of this shock on the home country's utility and that on the foreign country's utility, respectively. In all scenarios in Table 1, the effect of this shock on the home country's utility is positive, but that on the foreign country's utility is negative. Therefore, all scenarios in Table 1 show that this shock has a prosper-thyself and beggar-thy-neighbor effect. This can be explained based on the results that η and η^* satisfy the conditions (151) and (154). In addition, compared with the benchmark scenario, the effect of this shock on the home country's utility weakens in scenarios $(b)-(d)$ in Table 1, but that on the foreign country's utility strengthens in the same scenarios.

5 Conclusions

By incorporating the three factors of LCP, vertical production and trade, and endogenous entry by final goods firms into the standard NOEM model with nominal wage and price rigidities, this paper has examined how a negative home corporate tax shock affects the macroeconomic variables and welfare. The main findings of this paper can be summarized as follows. First, we show that a rise in the degree of LCP weakens the appreciation of the nominal exchange rate caused by this shock. Second, we show that a rise in the degree of LCP magnifies the effect of this shock on the number of final goods firms located in the home and foreign countries. In particular, we show that a rise in the degree of LCP basically weakens both the increase in the number of foreign multinational firms in the non-tradable goods sector of home-located final goods firms, and the decrease in the number of home multinational firms in the non-tradable goods sector of foreign-located final goods firms. Third, the effect of this shock on aggregate home output is basically positive, while that on aggregate foreign output is basically negative. When the degree of LCP rises, these effects are basically weakened compared with the scenario of full PCP. Finally, the effect of this shock on home welfare is positive, while that on foreign welfare is negative. When the degree of LCP rises, these effects are also weakened compared with the scenario of full PCP.

The above four findings illustrate that a change in the degree of firms' price-setting behavior affects the effects of a reduction in home corporate tax rate. Hence, the government should take into account this factor when making decisions. If the aim of a reduction in home corporate tax rate is to strengthen the exit of home multinational firms, the entry of foreign multinational firms, the increase in aggregate home output, and the improvement in home welfare, the home government should aggressively conduct such a tax reduction when the degree of this factor is small.

In this paper, we obtained the above findings by making some strong assumptions. It would be more desirable to find the various results by relaxing these assumptions. First, this paper may yield results that are more interesting if the current model is modified to include "third country currency" as in Shioji (2006), Dohwa (2008), and Goldberg and Tille (2009). Second, this paper may also yield results that are more interesting if we extend the current model to a model allowing households to borrow and lend on international markets. These issues remain for future research.

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Table 1: The effects of a negative home corporate tax shock.

	$(a)\ \eta = \eta^* = 0$	$(b)\ \eta = 1,\ \eta^* = 0$	$(c)\ \eta = 0,\ \eta^* = 1$	$(d)\ \eta = \eta^* = 1$
$\frac{dC_t}{d\tau_t}\frac{1}{C}$	0.569	0.104	0.054	0.055
$\frac{dC_t^*}{d\tau_t}\frac{1}{C^*}$	-0.514	0.001	-0.049	0.001
$\frac{d\ell_t}{d\tau_t}\frac{1}{\ell}$	-0.4	0.052	0.005	0.05
$\frac{d\ell_t^*}{d\tau_t}\frac{1}{\ell^*}$	0.5	0.095	0.048	0.05
$\frac{dU_t}{d\tau_t}$	0.792	0.075	0.052	0.027
$\frac{dU_t^*}{d\tau_t}$	-0.792	-0.052	-0.075	-0.027

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