The International Spillover Effects of a Temporary Corporate Tax Reduction and International Location Shifts of Firms

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Abstract

This paper analyzes the effect of a temporary corporate tax reduction in one of the three countries on relative consumption and the exchange rate based on the theoretical framework developed by Johdo (2021a). In our model, two effects of the model are emphasizing: firm relocation effect and tax redistribution effect. First, the firm relocation effect is that tax reduction in one country attracts foreign firms to relocate to that country, which leads to an international shift in labor demand. The relative income and consumption levels in that country thus increase. In addition, in this case, the currency of that country tends to appreciate since the demand for real money balances increases in proportion to the increase in consumption. Secondly, the tax redistribution effect implies that the corporate tax decrease shifts some tax revenue away from that country toward foreign countries. This is because part of the corporate tax is already borne by some dividend income repatriated to the foreign countries' investors. In this case, because of the decrease in consumption in that country, the currency of that country depreciates. The main results show that: i) when the degree of cross-border firm mobility is large (small), a temporary reduction in one country's corporate tax rate induces an exchange rate appreciation (depreciation) of that country; and ii) when the degree of cross-border firm mobility is large (small), the temporary reduction in one country's corporate tax rate is beneficial (detrimental) to that country in terms of relative consumption but detrimental (beneficial) to the foreign countries. Thus, when the degree of flexibility in relocation of firms between the three countries is sufficiently high, the firm relocation effect exceeds the tax redistribution effect, and a temporary corporate tax reduction can be a beggar-thy-neighbor policy. Otherwise, the tax redistribution effect exceeds the firm relocation effect, and the opposite mechanism

works, that is, decreasing the corporate tax rate can be a prosper-thy-neighbor policy.

1. Introduction

The COVID-19 pandemic and subsequent global recession in 2020 have stimulated policymakers' interest in the role of temporary corporate tax reduction in terms of reducing firms bankruptcy associated with contagion. On the other hand, increased globalization, with the liberalization of foreign exchange and capital transactions and the relaxation of regulations on foreign firms' entry, has led to the strong growth of international business activity through international partnerships between firms and cross-border relocation of firms over the last four decades.

In such age of globalization, countries can gain various macroeconomic benefits, such as increased employment and enhanced economic growth, by encouraging foreign firm entry. In fact, in recent years, several countries have attempted to attract foreign firms using various economic incentives, including corporate tax reduction. For example, over past decades, OECD countries have continuously reduced their corporate tax rates, which have fallen from an average of close to 50 percent among OECD countries in the early 1980s to about 23 percent by 2019 (see, OECD, 2021).

In addition, the liberalization of foreign exchange or capital transactions and the relaxation of regulations on foreign firm entry that occurred during the mid and late 1980s generated a close relationship between exchange rates and international relocations of firms.

However, because existing macroeconomic studies have a focus on the effects of corporate tax changes on macroeconomic variables (e. g., R&D investment, economic growth) within a closed economy, they have neglected the effects on open economy-specific variables (e.g., the exchange rate) despite the growing economic interdependence between countries.

The question that now arises is, first, is the policy of decreasing the corporate tax rate really beneficial for the domestic economy in a globalized economic environment with increased international relocations of firms and a floating exchange rate system? A further question is how does the degree of cross-border mobility of firms affect the effects of a decrease in the corporation tax in one country on consumption and the exchange rate of that country? To answer these queries, it is important to conduct a policy analysis within the framework of open economy macroeconomics, including endogenous determinants of the exchange rate.

Although there are many studies on the effects of fiscal and monetary policies in the field of macroeconomics, there are few theoretical works that analyze the macroeconomic effects of a decrease in the corporation tax rate within the open economy dynamic model. In fact, in the new open economy macroeconomics (NOEM) literature, no one has considered how a corporate tax reduction by one country affects exchange rates, output, and consumption through the international relocation of firms.[1)] One exception is Johdo (2021a), who succeeds in showing explicitly the effects of one country's permanent corporate tax cut on the consumption of the two countries and the exchange rate with the NOEM model. However, because Johdo (2021a) begins with the assumption of a two-country economy, he cannot consider how allowing for a third country affects the impacts of a corporate tax reduction on international relocation and other macroeconomic variables, including consumption and exchange rate.

This paper considers the impacts of temporal corporate tax reductions on the international distribution of firms, exchange rate, and consumption by extending the two-country model of Johdo (2021a) to a three-country model. From this analysis, we show explicitly the impacts of corporate tax reductions, which lead to firm relocation among three countries and the exchange rate changes simultaneously. In addition, from this approach, we can analyze the short- and long-run consequences of temporal corporate tax reductions simultaneously. This implies that this approach enables us to gain more detailed insights into the influences of temporal corporate tax reductions in one country on the world economy.

We conclude that when the degree of flexibility in relocation between the two countries is sufficiently high, a temporary corporate tax reduction can be a 'beggar-thy-neighbor' policy in terms of relative consumption levels. The opposite mechanism is also valid when the relocation of firms is sufficiently rigid. Thus, our results suggest that decreasing the corporate tax rate can be either a beggar-thy-neighbor or a prosper-thy-neighbor policy, depending on conditions. The ambiguity of the policy effects on the domestic and foreign consumption is caused by the competing pressures between the "firm relocation effect" and the "tax redistribution effect." Thus, from this paper, we find that a corporate tax reduction policy does not always lead to economic expansion. This analytical result can provide a theoretical rationale for reviewing the current trend of corporate tax reductions in the world.

Finally, it is worth mentioning that, for the 'beggar-thy-neighbor' policy, some studies in the NOEM literature have shown whether expansionary monetary policy can be a 'beggar-thy-neighbor' policy by incorporating various economic characteristics of the real world into the NOEM model, though they assume the fixed production location of firms.[2] For example, Betts and Devereux (2000a) allow for pricing-to-market (PTM) behavior that is consistent with empirical evidences against the law of one price, in which some firms not only segment the domestic and foreign markets for their goods, but also price their goods in terms of the local currency in each segmented market. By considering the scale of the exogenous PTM fraction parameter, which is between zero and unity, they show that a domestic monetary expansion is a 'beggar-thy-neighbor' policy if there is a high degree of PTM behavior (that is, the PTM parameter is large) in both countries.[3] Corsetti et al. (2000) extend the model of Obstfeld and Rogoff (1995) to a three-country framework that comprises two similar 'periphery' countries (denoted by A and B) and a third 'center' country, and explore the transmission effects of a monetary expansion by either of the periphery countries on its trading partners. In their analysis, they show that under complete pass-through of exchange rates to prices, when there is little substitutability between periphery and center goods, a monetary expansion in country A is a 'beggar-thy-neighbor' policy against country B.[4),5] Tille (2001) extends the model of Obstfeld and Rogoff (1995) by allowing for different elasticities of substitution between and within countries, and shows that if the elasticity of substitution between countries is sufficiently high, a monetary expansion by one country is a 'beggar-thy-neighbor' policy.[6] Warnock (2003) also shows a 'beggar-thy-neighbor' effect following a monetary expansion by incorporating home-product bias in consumption preferences into the Obstfeld and Rogoff (1995) model.[7] Furthermore, a number of other policies leading to 'beggar-thy-neighbor', other than monetary expansion policies, have also been examined in the NOEM literature. These include tariffs (Fender and Yip 2000; Johdo 2019a), deregulation (Johdo 2019b, 2020a) and government spending (Chu 2005; Johdo 2019c, 2020b).

The remainder of this paper is structured as follows. Section 2 outlines the features of the model. Section 3 describes the equilibrium. In Sections 4 and 5, we examine the impacts of temporary corporate tax reductions on the international distribution of firms across the three countries, the real exchange rate, and relative consumptions. The final section summarizes the findings and concludes.

2. The model

In this section, we construct a perfect-foresight, three-country model with international relocation of firms.[8] The three countries are denoted by A, B, and C, respectively. The size of the world population is normalized to unity, and the shares of households in A, B, and C are 1/3, 1/3, and 1/3, respectively. The markets for goods and labor have a monopolistic competition, whereas the markets for money and international bonds are perfectly competitive. On the production side, monopolistically competitive producers exist continuously in the range $[0, 1]$, each of which produces a single differentiated product that is freely tradable. This implies that productive activity cannot be carried out in more than one location. In this model, country A consists of those producers in the interval $[0, m_t]$, country B consists of those producers in the interval $[m_t, n_t]$, and the remaining $[n_t, 1]$ producers are in country C, where m_t and n_t are endogenous variables. Finally, we assume that firms are mobile internationally but their owners are not. Therefore, all profit flows from firms are distributed to their immobile owners according to their share of holdings.

2. 1.　Households

The intertemporal objective function of representative household x in country h at time t, with $h=A, B, C$, is:

$$U^h{}_t(x) = E_t \textstyle\sum_{\tau=t}^{\infty} \beta^{\tau-t} (\log C^h{}_\tau(x) + \chi \log (M^h{}_\tau(x)/P^h{}_\tau) - (\kappa/2)(l^{sh}{}_\tau(x))^2) \tag{1}$$

where E_t represents the mathematical expectation conditional on the information set made available to household i at time t; β is a constant subjective discount factor $(0<\beta<1)$; $C^h{}_t(x)$ is the consumption index that is defined later; $M^h{}_t(x)/P^h{}_t$ represents real money holdings, where $M^h{}_t(x)$ denotes nominal money balances held at the beginning of period $t+1$, and $P^h{}_t$ is the consumption price index of country h; and $l^{sh}{}_t(x)$ is the amount of labor supplied by household x. At each point in time, households receive returns on risk-free nominal bonds, earn wage income by supplying labor, and receive profits from all firms equally. Therefore, a typical domestic household faces the following budget constraint:

$$\begin{aligned}\varepsilon^h{}_t B^h{}_{t+1}(x) + M^h{}_t(x) = {} & (1+i_t)\varepsilon^h{}_t B^h{}_t(x) + M^h{}_{t-1}(x) + W^h{}_t(x) l^{sh}{}_t(x) + P^h{}_t T^h{}_t \\ & - P^h{}_t C^h{}_t(x) + ((1-\tau^A{}_t)(\varepsilon^h{}_t/\varepsilon^A{}_t)\int_0^{m_t} \Pi_t^A(z)dz \\ & + (1-\tau^B{}_t)(\varepsilon^h{}_t/\varepsilon^B{}_t)\int_{m_t}^{n_t} \Pi_t^B(z)dz + (1-\tau^C{}_t)\varepsilon^h{}_t \int_{n_t}^{1} \Pi_t^C(z)dz)\end{aligned} \tag{2}$$

where $\varepsilon^h{}_t$ denotes the nominal exchange rate, defined as country h's currency per unit of country C's currency (so that $\varepsilon^C{}_t=1$); $B^h{}_{t+1}(x)$ denotes the nominal bond denominated in the country C's currency held by country h's agent x in period $t+1$; i_t denotes the nominal yield on the bond in terms of the country C's currency; $W^h{}_t(x)l^{sh}{}_t(x)$ is nominal labor income, where $W^h{}_t(x)$ denotes the nominal wage rate of labor supplied by household x in period t; $T^h{}_t$ denotes real lump-sum transfers from the government in period t; $(1-\tau^A{}_t)\int_0^{m_t}\Pi_t^A(z)dz$, $(1-\tau^B{}_t)\int_{m_t}^{n_t}\Pi_t^B(z)dz$, and $(1-\tau^C{}_t)\int_{n_t}^{1}\Pi_t^C(z)dz$ represent the after-tax total nominal profit flows of firms located in countries A, B, and C, respectively; $P^h{}_tC^h{}_t(x)$ represents nominal consumption expenditure; and $\tau^h{}_t$ denotes the corporate tax rate of country h. All variables in (2) are measured in per capita terms. In the government sector, we assume that government spending is zero and that all seigniorage revenues derived from printing the national currency and all corporate tax revenues are rebated to the public in the form of lump-sum transfers. Hence, the government budget constraint in country A is $s^AT^A{}_t=\tau^A{}_t\int_0^{m_t}\Pi_t^A(z)dz+[(M^A{}_{t+1}-M_t^A)/P^A{}_t]$, where $M^A{}_t$ is aggregate money supply and s^h $(=1/3)$ denotes the population share of country h in the world population. Countries B and C have an analogous government budget constraint.

Here, we assume that any monopolistically competitive firm that operates in every country employs the same production technology. In what follows, we mainly focus on the description of country A, because other countries are described analogously. In country A, firm $z\in[0, m_t]$ hires a continuum of differentiated labor inputs domestically and produces a unique product in a single location according to the following CES production function:

$$y_{At}(z) = \left((1/3)^{-1/\phi}\int_0^{1/3} l_{At}(z,x)^{(\phi-1)/\phi}dx\right)^{\phi/(\phi-1)} \tag{3}$$

where $y_{At}(z)$ denotes the production of firm z in period t; $l_{At}(z,x)$ is firm z's input of labor from household x in period t; and $\phi>1$ is the elasticity of input substitution. Given the firm's cost minimization problem, firm z's optimal demand function for labor x is as follows:

$$l_{At}(z,x) = (1/3)^{-1}(W_t^A(z)/W_t^A)^{-\phi}y_{At}(z) \tag{4}$$

where $W_t^A\equiv\left((1/3)^{-1}\int_0^{1/3} W_t^A(x)^{(1-\phi)}dx\right)^{1/(1-\phi)}$ is a price index for labor input. Similarly, the other countries' firms have an optimal demand function for labor x that is analogous to equation (4).

2.1.1. Definition of consumption basket

The consumption basket of household x living in country h at period t is:

$$C_t^h(x) = \left[\int_0^{m_t} c_{At}^h(z,x)^{(\theta-1)/\theta}dz+\int_{m_t}^{n_t} c_{Bt}^h(z,x)^{(\theta-1)/\theta}dz+\int_{n_t}^{1} c_{Ct}^h(z,x)^{(\theta-1)/\theta}dz\right]^{\theta/(\theta-1)} \tag{5}$$

where $\theta>1$ is the elasticity of substitution among varieties produced within each country;

and $c^h{}_{jt}(z,x)$ denotes consumption by household x located in country h of the good produced by firm z located in country j. From (5), the consumption-based price indexeis defined as:

$$P^h{}_t=\left(\int_0^{m_t}(P^h_{At}(z))^{1-\theta}dz+\int_{m_t}^{n_t}(P^h_{Bt}(z))^{1-\theta}dz+\int_{n_t}^{1}(P^h_{Ct}(z))^{1-\theta}dz\right)^{1/(1-\theta)}$$

where $P^h{}_{jt}(z)$ is the price in country h of the good produced by firm z in country j, $j=A,B,C$.

2. 1. 2. Household decisions

Households maximize the consumption index $C^h{}_t(x)$ subject to a given level of expenditure by optimally allocating differentiated goods produced in the three countries $c^h{}_{jt}(z,x)$, $j=A,B,C$. From this problem, we obtain the following private demand functions:

$$c^h{}_{jt}(z,x)=(P^h{}_{jt}(z)/P^h{}_t)^{-\theta}C^h{}_t(x),\quad j=A,B,C \tag{6}$$

Summing the above demand functions and equating the resulting equation to the product of firm z located in country j yields the following market-clearing condition for any product z produced in country j:

$$y_{jt}(z)=(P^A{}_{jt}(z)/P^A{}_t)^{-\theta}C^A{}_t+(P^B{}_{jt}(z)/P^B{}_t)^{-\theta}C^B{}_t+(P^C{}_{jt}(z)/P^C{}_t)^{-\theta}C^C{}_t,$$
$$j=A,B,C \tag{7}$$

where $C^A{}_t=\int_0^{1/3}C^A_t(x)dx$, $C^B{}_t=\int_{1/3}^{2/3}C^B_t(x)dx$, and $C^C{}_t=\int_{2/3}^{1}C^C_t(x)dx$. From the law of one price and the purchasing power parity arising from symmetric preferences, (7) is rewritten as:

$$y_{jt}(z)=(P^j{}_{jt}(z)/P^j{}_t)^{-\theta}C^w{}_t,\quad j=A,B,C \tag{8}$$

where $C^w{}_t\equiv C^A{}_t+C^B{}_t+C^C{}_t$. In the second stage, households maximize (1) subject to (2). The first-order conditions for this problem with respect to $B^h{}_{t+1}(x)$ and $M^h{}_t(x)$ can be written as:

$$1/C^h{}_t(x)=\beta(1+i_{t+1})E_t[(P^h{}_t/\varepsilon^h{}_t)/(P^h{}_{t+1}/\varepsilon^h{}_{t+1})C^h{}_{t+1}(x)] \tag{9}$$

$$M^h{}_t(x)/P_t=\chi C^h{}_t(x)[(1+i_{t+1})E_t\varepsilon^h{}_{t+1}/((1+i_{t+1})E_t\varepsilon^h{}_{t+1}-\varepsilon^h{}_t)] \tag{10}$$

where i_{t+1} is the nominal interest rate for country C's currency loans between periods t and $t+1$, defined as usual by $1+i_{t+1}=(1+r_{t+1})E_t[(P^C{}_{t+1}/P^C{}_t)]$, and where r_{t+1} denotes the real interest rate. Equation (9) is the Euler equation for consumption, and (10) is the money-demand schedule. The terminal condition is $\lim_{T=\infty}[1/\Pi_{\nu=1}^{t+T}(1+r_\nu)][B_{t+T+1}^h+(M_{t+T}^h/P_{t+T}^h)]=0$.

Following the work of Corsetti and Pesenti (2001), we introduce nominal rigidities into the model in the form of one-period wage contracts. The nominal wages in period t are predetermined at the end of period $t-1$. In monopolistic labor markets, each household provides a single variety of labor input to a continuum of domestic firms. Hence, in country A, the equilibrium labor-market conditions can be expressed as $l_t^{sA}(x)=\int_0^{m_t} l_{At}(z,x)dz$, $x\in[0, 1/3]$, where the left-hand side represents the amount of labor supplied by household x, and the right-hand side represents firms' total demand for labor x. Taking W_t^A, P_t^A, and m_t as given, by substituting $l_t^{sA}(x)=\int_0^{m_t} l_{At}(z,x)dz$ and equation (4) into the budget constraint, given by (2), and maximizing the lifetime utility, given by (1), with respect to the nominal wage $W_t^A(x)$, we obtain the following first-order condition for the optimal nominal wage, $W_t^A(x)$:

$$\kappa l_t^{sA}(x)^2\phi(W_t^A(x)/P_t^A)^{-1} = (\phi-1)(l_t^{sA}(x)/C^A{}_t) \tag{11}$$

The labor suppliers of countries B and C have analogous optimal wage conditions.

2. 2. Firm's decision

Since the country A-located firm z hires labor domestically, given $W^A{}_t$, $P^A{}_{At}$, and $P^A{}_t$, m_t, (4), and subject to (8), the country A-located firm z faces the following profit-maximization problem:

$$\max_{P_{At}^A(z)} \Pi_{At}(z) = P^A{}_{At}(z)y_{At}(z)-\int_0^{1/3} W_t^A(z)l_{At}(z,x)\,dx = (P^A{}_{At}(z)-W^A{}_t)y_{At}(z)$$

subject to $y_{At}(z)=(P^A{}_{At}(z)/P^A{}_t)^{-\theta}C^w{}_t$

Given the above, the price mark-up is chosen according to:

$$P^A{}_{At}(z) = (\theta/(\theta-1))W^A{}_t \tag{12}$$

Since W^A is a given, (12) yields $P^A{}_{At}(z)=P^A{}_{At}$, $z\in[0, m_t]$. Similarly, other firms located in different country have the price mark-up that is analogous to equation (12). By denoting the maximized real profit flows of country j-located firms by $\Pi_{jt}(z)/P^j{}_t$, and by substituting (8) and (12) into $\Pi_{jt}(z)$, we obtain

$$\Pi_{jt}(z)/P^j{}_t = (1/\theta)(P^j{}_{jt}(z)/P^j{}_t)^{1-\theta}C^w{}_t, \quad j = A, B, C \tag{13}$$

2. 3.　Relocation behavior

The driving force for relocation to other countries is the difference in current real profits between two bounded countries. Following the formulation of Johdo (2015), we assume that all firms are not allowed to relocate instantaneously even if there is the profit gap. At each point in time, this adjustment mechanism of relocation between countries A and B is formulated as follows:

$$\begin{aligned} m_t - m_{t-1} &= \gamma[(1-\tau^{A}{}_t)\Pi_{At}(z)/P_t^A - (1-\tau^{B}{}_t)\Pi_{Bt}(z)/P_t^B] \\ &= \gamma[(1-\tau^{A}{}_t)\Pi_{At}(z)/P_t^A - (1-\tau^{B}{}_t)(\varepsilon^{A}{}_t/\varepsilon^{B}{}_t)\Pi_{Bt}(z)/P_t^A] \end{aligned} \tag{14}$$

Analogously, the adjustment mechanism of relocation between countries B and C is formulated as follows:

$$\begin{aligned} n_t - n_{t-1} &= \gamma[(1-\tau^{B}{}_t)\Pi_{Bt}(z)/P_t^B - (1-\tau^{C}{}_t)\Pi_{Ct}(z)/P_t^C] \\ &= \gamma[(1-\tau^{B}{}_t)\Pi_{Bt}(z)/P_t^B - (1-\tau^{C}{}_t)\varepsilon^{B}{}_t\Pi_{Ct}(z)/P_t^B] \end{aligned} \tag{15}$$

where γ ($0 \leq \gamma < \infty$) is a constant positive parameter used to determine the degree of firm mobility between two bounded countries: a larger value of γ implies higher firm mobility between countries.

2. 4.　Market conditions

The equilibrium condition for the integrated international bond market is given by:

$$\int_0^{1/3} B_t^A(x)dx + \int_{1/3}^{2/3} B_t^B(x)dx + \int_{2/3}^{1} B_t^C(x)dx = 0 \tag{16}$$

In addition, the money markets are always assumed to be clear in all countries. Hence, the equilibrium conditions are given by $M^{A}{}_t = \int_0^{1/3} M_t^A(x)dx$, $M^{B}{}_t = \int_{1/3}^{2/3} M_t^B(x)dx$, and $M^{C}{}_t = \int_{2/3}^{1} M_t^C(x)dx$.

3.　Steady state values

In this section, we derive the solution for a symmetric steady state in which all variables are constant, the initial net foreign assets are zero ($B^{h}{}_0 = 0$) and $\tau^{h}{}_0 = 0$, $h = A, B, C$. In the symmetric steady state, we drop the index value "x" from all variables in order to simplify notation. Then, we denote the steady-state values by using the subscript *ss*. In the symmetric steady state, given the Euler equation for consumption (equation (9)), the constant real interest rate is given by:

$$r_{ss} = (1-\beta)/\beta \equiv \delta \tag{17}$$

where δ is the rate of time preference. Because symmetry, which implies $C^h{}_{ss}=C^w{}_{ss}$, holds, the steady-state international allocations of firms are:

$$m_{ss} = 1/3 \tag{18}$$

$$n_{ss} = 2/3 \tag{19}$$

The steady state output levels are:

$$y_{jss} = l^{sh}{}_{ss} = C^h{}_{ss} = C^w{}_{ss} = ((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}, \quad j, h = A, B, C \tag{20}$$

Substituting $C^w{}_{ss}$ from equation (20) into equation (13) yields the steady-state levels of real profit flows of country j-located firms, which have equal values.

$$\Pi_{jss}/P^j{}_{ss} = (1/\theta)((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}, \quad j = A, B, C \tag{21}$$

4. A log-linearized analysis

The macroeconomic effects of unanticipated temporary corporate tax reductions need to be examined. Thus, we solve a log-linear approximation of the system around the initial, zero-shock steady state with $B^h{}_{ss,0}=0, h=A, B, C$, as derived in the previous section. Following the formulation of Obstfeld and Rogoff (1995), for any variable X, we use $\widehat{X}$ to denote short-run percentage deviations from the initial steady-state value, and we use $\overline{X}$ to denote long-run percentage deviations from the initial steady-state value (see Appendix for the derivation of short-run and long-run tax reduction effects).

By log-linearizing equations (14) and (15) around the symmetric steady state and by setting $\widehat{P}^j_j(z)=0, j=A, B, C$, we obtain the following log-linearized expression for the international distribution of firms:

$$\widehat{m} = (3\gamma/\theta)((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}[(\theta-1)(\widehat{\varepsilon}^A-\widehat{\varepsilon}^B)-d\tau^A+d\tau^B] \tag{22}$$

$$\widehat{n} = (3\gamma/2\theta)((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}[(\theta-1)\widehat{\varepsilon}^B-d\tau^B+d\tau^C] \tag{23}$$

Equation (22) shows that a reduction in τ^A ($d\tau^A<0$) leads to the relocation of some firms from country B to country A ($\widehat{m}>0$), and a reduction in τ^B ($d\tau^B<0$) leads to the relocation of some firms from country A to country B ($\widehat{m}<0$). In addition, equation (22) shows that under given ε^B and $\Pi_{Ct}(z)/P^C_t$, exchange rate depreciation of country A's currency

$(\tilde{\varepsilon}^A - \tilde{\varepsilon}^B > 0)$ induces relocation of firms located in country B towards the country A. Intuitively, with fixed nominal wages, which cause nominal product prices to be sticky because of the mark-up pricing by monopolistic product suppliers, depreciation in country A's currency increases relative production of country A's goods through the 'expenditure-switching effect'; i.e., $\hat{y}^A - \hat{y}^B = \theta(\tilde{\varepsilon}^A - \tilde{\varepsilon}^B)$. This increases the relative profits of country A-located firms, and consequently, firms located in country B relocate to the country A. Equation (22) also shows that nominal exchange rate changes have greater effects the greater is the flexibility of relocation (the larger is γ). By contrast, when relocation costs are high ($\gamma = 0$), nominal exchange rate changes have a negligible effect on the relocation of firms. The intuition behind the impacts of τ^B, τ^C and ε^B in equation (23) on $\hat{n}$ can be explained analogously.

5. The effects of corporate tax reduction

We consider the effects of temporary corporate tax reductions.

5.1. The case of $d\tau^A < 0$, $d\tau^B = d\tau^C = 0$

In this subsection, we focus on the impacts of a temporary corporate tax reduction in country A ($d\tau^A < 0$). In this case, the closed-form solutions for the four key variables are as follows:

$$\tilde{\varepsilon}^A - \tilde{\varepsilon}^B = \left[\frac{\alpha_2 T_2 - \alpha_1 T_1}{(\alpha_2)^2 - (\alpha_1)^2}\right] < (>)\ 0, \text{ when } \gamma \text{ is large (small)} \tag{24}$$

$$\tilde{\varepsilon}^B = \left[\frac{\alpha_2 T_1 - \alpha_1 T_2}{(\alpha_2)^2 - (\alpha_1)^2}\right] > (<)\ 0, \text{ when } \gamma \text{ is large (small)} \tag{25}$$

$$\hat{C}^A - \hat{C}^B = -(\tilde{\varepsilon}^A - \tilde{\varepsilon}^B) > (<)\ 0, \text{ when } \gamma \text{ is large (small)} \tag{26}$$

$$\hat{C}^A - \hat{C}^C = -\tilde{\varepsilon}^A > (<)\ 0, \text{ when } \gamma \text{ is large (small)} \tag{27}$$

where

$$\alpha_1 = \left\{\delta^{-1}\left\{1 + 2\tilde{\theta}\left[\frac{(6\gamma\theta_1 + \theta)(1 + 6\gamma\theta_1 + \theta) - 9\gamma^2\theta_1^2}{(1 + 6\gamma\theta_1 + \theta)^2 - 9\gamma^2\theta_1^2}\right] - \tilde{\theta}\right\} + 1 + 6\gamma\theta_1\tilde{\theta} + \tilde{\theta}(\theta - 1)\right\} > 0 \tag{28}$$

$$\alpha_2 = -\left\{\delta^{-1}\left[\frac{6\gamma\theta_1\tilde{\theta}}{(1 + 6\gamma\theta_1 + \theta)^2 - 9\gamma^2\theta_1^2}\right] + 3\gamma\theta_1\tilde{\theta}\right\} < 0 \tag{29}$$

$$T_1 = 6\gamma\theta_1\tilde{\theta}(\theta-1)^{-1}d\tau^A - \theta^{-1}d\tau^A \tag{30}$$

$$T_2 = -3\gamma\theta_1\tilde{\theta}(\theta-1)^{-1}d\tau^A \tag{31}$$

$$\theta_1 = ((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{3/2}(1/\kappa)^{1/2} > 0 \tag{32}$$

$$\tilde{\theta} = (\theta-1)/\theta \tag{33}$$

The results in (24), (25), (26), and (27) show that the effects of a reduction in country A's corporate tax depend on the degree of firm mobility (γ). Equation (24) indicates that a reduction in country A's profit tax leads to exchange rate appreciation (depreciation) in $\varepsilon^A - \varepsilon^B$ when γ is large (small). Equation (25) indicates that a reduction in country A's corporate tax leads to exchange rate depreciation (appreciation) in ε^B when γ is large (small). Equation (26) shows that the relative consumption level between countries A and B rises (decreases) when γ is large (small). Finally, equation (27) shows that the relative consumption level between countries A and C rises (decreases) when γ is large (small).

The above results can be explained intuitively as follows. First, as shown in (26), the corporate tax reduction has two effects on $\widehat{C}^A - \widehat{C}^B$, with opposing implications. On one hand, a decrease in the corporate tax in country A results in fewer differentiated products being produced in country B because of the relocation of some firms to country A (see equation (22)). This then leads to a shift in labor demand from country B to country A, thereby increasing country A's labor income and decreasing country B's labor income. Hereafter, we call this phenomenon the 'AB relocation effect'. This then increases the consumption of country A and decreases the consumption of country B. Therefore, the AB relocation effect is positive for country A's consumption and negative for country B's consumption. On the other hand, the corporate tax decrease shifts part of tax revenue away from country A toward countries B and C. Because part of the burden of country A's corporate tax have already extended to investors in countries B and C under cross-border ownership of firms.[9) Hereafter, we call this phenomenon the 'tax redistribution effect'. Therefore, the tax redistribution effect is negative for country A and positive for countries B and C. Thus, the net outcome in (26) depends on the relative strengths of these competing pressures. However, if γ (the degree of firm mobility) is large (small), the corporate tax reduction results in a proportionate increase (decrease) in the relative consumption level of country A, $\widehat{C}^A - \widehat{C}^B >$ ($<$) 0. Intuitively, as the relocation of firms becomes more flexible (γ increases), there is a greater relative increase in labor income in country A, because more firms relocate, and therefore the increase in the relative consumption in country A (B) is greater (smaller).[10] Therefore, a reduction in the corporate tax in economies with a large γ causes the AB relocation effect to dominate the tax redistribution effect, and hence the net effect on $\hat{C}^A - \hat{C}^B$ is positive. The opposite mechanism is also valid when γ is small.

The corporate tax reduction also leads to exchange rate appreciation in $\varepsilon^A - \varepsilon^B$ when γ is large ($\hat{\varepsilon}^A - \hat{\varepsilon}^B < 0$, see equation (24)). This scenario can be attributed to the demand for real money balances, which increases with consumption (as implied by the money demand function), and country A's currency must appreciate and raise the supply of real money balances in country A to restore money market equilibrium. The opposite mechanism is also valid when γ is small: the corporate tax reduction leads to exchange rate depreciation, $\hat{\varepsilon}^A - \hat{\varepsilon}^B > 0$.

From the decrease in the consumption of country B through the AB relocation effect, country B's currency must depreciate and decrease the supply of real money balances in country B to restore money market equilibrium when γ is large ($\hat{\varepsilon}^B > 0$, see equation (25)). This in turn causes country C's firms to relocate to country B because of the increase in the relative profits of firms located in country B (see equation (23)). This relocation then increases labor demand in country B and decreases labor demand in country C, which in turn raises labor income in country B and decreases labor income in country C. Hereafter, we call this phenomenon the 'BC relocation effect'. Furthermore, recall that a decrease in the corporate tax redistributes firms' profits partially from country A to country C, i.e., the tax redistribution effect. This leads to a rise in income in country C, thereby raising the consumption in country C. Therefore, C^C is determined by the two conflicting mechanisms of the BC relocation effect and the tax redistribution effect. However, from (23), a reduction in the corporate tax rate in economies with a large γ causes the BC relocation effect to dominate the tax redistribution effect, and hence the net effect on income in country C is negative. As a result, country C households decrease consumption. In addition, recall that if γ is large, the corporate tax reduction results in a proportionate increase in C^A (see equation (26)). Therefore, the relative consumption level between countries A and C increases when γ is large ($\hat{C}^A - \hat{C}^C > 0$, see equation (27)). Country A's currency must appreciate and increase the supply of real money balances in country A to restore money market equilibrium accordingly. ($\hat{\varepsilon}^A < 0$, see equation (27)) when γ (the degree of firm mobility) is large. The opposite mechanism is also valid when γ is small: the corporate tax reduction decreases the relative consumption level between countries A and C, $\hat{C}^A - \hat{C}^C < 0$ and leads to exchange rate depreciation, $\hat{\varepsilon}^A>0$.

In sum, when the degree of firm mobility is large, a corporate tax reduction in country A always benefits country A in terms of the relative consumption revel, while it can be detrimental not only to country B but also to country C in terms of relative consumption level. The opposite mechanism is also valid when γ is small.

Incidentally, we can see the impacts that the absence of relocation of firms $(\gamma=0)$ has on exchange rate and relative consumption. Substituting $\gamma=0$ into equations (25) to (31), we obtain:

$$\hat{\varepsilon}^A-\hat{\varepsilon}^B=\frac{T_1}{\alpha_1}<0,\quad \hat{\varepsilon}^B=0,\quad \hat{m}=0,\quad \hat{n}=0,\quad \hat{C}^A-\hat{C}^B=-\frac{T_t}{\alpha_1}<0,$$

$$\hat{C}^A-\hat{C}^C=-\frac{T_1}{\alpha_1}<0$$

where

$$\alpha_1=\left\{\delta^{-1}\left\{2\left(\frac{\theta-1}{1+\theta}\right)+\frac{1}{\theta}\right\}+\theta-1+\frac{1}{\theta}\right\}>0,\quad \alpha_2=0,\quad T_1=-\theta^{-1}d\tau^A<0,\quad T_2=0$$

5.2. The case of $d\tau^B<0, d\tau^A=d\tau^C=0$

In this subsection, we focus on the impacts of a temporary corporate tax reduction in country B $(d\tau^B<0)$. In this case, the closed-form solutions for the four key variables are as follows:

$$\hat{\varepsilon}^A-\hat{\varepsilon}^B=\left[\frac{\alpha_1+\alpha_2}{(\alpha_2)^2-(\alpha_1)^2}\right]T_2>(<)\ 0,\text{ when }\gamma\text{ is large (small)}\tag{34}$$

$$\hat{\varepsilon}^B=-\left[\frac{\alpha_1+\alpha_2}{(\alpha_2)^2-(\alpha_1)^2}\right]T_2<(>)\ 0,\text{ when }\gamma\text{ is large (small)}\tag{35}$$

$$\hat{C}^A-\hat{C}^B=-(\hat{\varepsilon}^A-\hat{\varepsilon}^B)<(>)\ 0,\text{ when }\gamma\text{ is large (small)}\tag{36}$$

$$\hat{C}^B-\hat{C}^C=-\hat{\varepsilon}^B>(<)\ 0,\text{ when }\gamma\text{ is large (small)}\tag{37}$$

where

$$T_1=-9\gamma\theta_1\tilde{\theta}(\theta-1)^{-1}d\tau^B+\theta^{-1}d\tau^B\tag{38}$$

$$T_2=9\gamma\theta_1\tilde{\theta}(\theta-1)^{-1}d\tau^B-\theta^{-1}d\tau^B\tag{39}$$

The results in (34), (35), (36), and (37) show that the effects of a reduction in country

B's corporate tax depend on the degree of firm mobility (γ). The above results can be explained intuitively as follows. First, as shown in (36) and (37), the corporate tax reduction has two effects on $\widehat{C}^A-\widehat{C}^B$ and $\widehat{C}^B-\widehat{C}^C$, respectively, with opposing implications. On one hand, a decrease in the corporate tax rate in country B results in fewer differentiated products being produced in both countries A and C because of the relocation of some firms to country B (see equations (22) and (23)). This then leads to a shift in labor demand from countries A and C to country B, thereby increasing country B's labor income and decreasing labor income of countries A and C (the AB and BC relocation effects). As a result, the consumption in country B increases while the consumptions in countries A and C decrease. Therefore, the AB and BC relocation effects are positive for country B and negative for countries A and C. On the other hand, the tax decrease in country B shifts part of tax revenue away from country B toward countries A and C. Because the burden of country B's corporate tax have already extended to investors in countries A and C under cross-border ownership of firms. Therefore, the tax redistribution effect is negative for country B and positive for countries A and C. Thus, the net outcomes in (36) and (37) depend on the relative strengths of these competing pressures. However, if γ (the degree of firm mobility) is large (small), the corporate tax reduction results in a proportionate decrease (increase) in the relative consumption level between countries A and B, $\widehat{C}^A-\widehat{C}^B<(>)\ 0$ (see equation (36)) and a proportionate increase (decrease) in the relative consumption level between countries B and C, $\widehat{C}^B-\widehat{C}^C>(<)\ 0$ (see equation (37)). Intuitively, as the relocation of firms becomes more flexible (as γ increases), there is a greater increase in relative labor income in country B, because more firms relocate, and therefore the increase in relative consumption in country B is greater (see equation (37)). Therefore, a reduction in the corporate tax in economies with a large γ causes the AB and BC relocation effects to dominate the tax redistribution effect, and hence the net effect on $\widehat{C}^A-\widehat{C}^B$ ($\widehat{C}^B-\widehat{C}^C$) is negative (positive). The opposite mechanism is also valid when γ is small.

Under a given ε^A, the relative increase in consumption in country B leads not only to exchange rate depreciation in $\varepsilon^A-\varepsilon^B$ but also to exchange rate appreciation in ε^B when γ is large (see equations (34) and (35)). This scenario can be attributed to the demand for real money balances, which increases with consumption, and country B's currency must appreciate ($\hat{\varepsilon}^B<0$) and raise the supply of real money balances in country B to restore money market equilibrium. The opposite mechanism is also valid when γ is small: the corporate tax reduction leads to $\hat{\varepsilon}^A-\hat{\varepsilon}^B<0$ and $\hat{\varepsilon}^B>0$.

In sum, when the degree of firm mobility is large, a corporate tax reduction in country B

always benefits country B, while it is detrimental to countries A and C. The opposite mechanism is also valid when γ is small.

5.3. The case of $d\tau^C<0$, $d\tau^A=d\tau^B=0$

In this subsection, we focus on the impacts of a temporary corporate tax reduction in country C ($d\tau^C<0$). In this case, the closed-form solutions for the four key variables are as follows:

$$\hat{\varepsilon}^A-\hat{\varepsilon}^B=\left[\frac{\alpha_2 T_2-\alpha_1 T_1}{(\alpha_2)^2-(\alpha_1)^2}\right]>(<)\ 0,\ \text{when } \gamma \text{ is large (small)} \tag{40}$$

$$\hat{\varepsilon}^B=\left[\frac{\alpha_2 T_1-\alpha_1 T_2}{(\alpha_2)^2-(\alpha_1)^2}\right]>(<)\ 0,\ \text{when } \gamma \text{ is large (small)} \tag{41}$$

$$\widehat{C}^B-\widehat{C}^C=-\hat{\varepsilon}^B<(>)\ 0,\ \text{when } \gamma \text{ is large (small)} \tag{42}$$

$$\widehat{C}^A-\widehat{C}^C=-\hat{\varepsilon}^A<(>)\ 0,\ \text{when } \gamma \text{ is large (small)} \tag{43}$$

where

$$T_1=3\gamma\theta_1\tilde{\theta}(\theta-1)^{-1}d\tau^C \tag{44}$$

$$T_2=-6\gamma\theta_1\tilde{\theta}(\theta-1)^{-1}d\tau^C+\theta^{-1}d\tau^C \tag{45}$$

The results in (40), (41), (42), and (43) show that the effects of a reduction in country C's corporate tax depend on the degree of firm mobility (γ). The above results can be explained intuitively as follows. First, as shown in (42), the corporate tax reduction has two effects on $\widehat{C}^B-\widehat{C}^C$, with opposing implications. On one hand, a decrease in the corporate tax rate in country C results in fewer differentiated products being produced in country B because of relocation of some firms to country C (see equation (23)). This then leads to a shift in labor demand from country B to country C, thereby increasing country C's labor income and decreasing country B's labor income (the BC relocation effect). As a result, country C households increase consumption, while country B households decrease consumption. Therefore, the BC relocation effect is positive for country C and negative for country B. On the other hand, the tax decrease shifts part of tax revenue away from country C toward countries A and B. Because part of the burden of country C's corporate tax have already extended to investors in countries A and B under cross-border firm ownership. Therefore, the tax redistribution effect is negative for country C and positive for countries A

and B. Thus, the net outcome in (42) depends on the relative strengths of these competing pressures. However, if γ (the degree of firm mobility) is large (small), the corporate tax reduction results in a proportionate decrease (increase) in $\widehat{C}^B - \widehat{C}^C$ (see equation (42)). Intuitively, as the relocation of firms becomes more flexible (γ increases), there is a greater increase in country C's labor income, because more firms relocate, and therefore the relative increase in consumption in country C is greater. Therefore, a reduction in the corporate tax in economies with a large γ causes the BC relocation effect to dominate the tax redistribution effect, and hence the net effect on $\widehat{C}^B - \widehat{C}^C$ is negative. The opposite mechanism is also valid when γ is small.

In addition, because of the decrease in consumption in country B, the corporate tax reduction leads to exchange rate depreciation in ε^B when γ is large ($\widehat{\varepsilon}^B > 0$, see equation (41)). This happens because given that the demand for real money balances is increasing with consumption, country B's currency must depreciate and decrease the supply of real money balances in country B to restore money market equilibrium. Furthermore, this leads to reduction of the real prices of country B's goods relative to country A's goods, which causes world demand to switch from country A's goods to country B's goods. These demand shifts increase the relative profits of firms located in country B, which cause firms located in country A to relocate to country B (see equation (22)). This relocation increases labor demand in country B and decreases labor demand in country A, which in turn increases labor income in country B and decreases labor income in country A (the AB relocation effect). As a result, the relocation decreases the consumption in country A. Furthermore, recall that a decrease in the corporate tax rate redistributes firms' profits partially from country C to country A, i.e., the tax redistribution effect. This leads to a rise in income in country A, thereby raising consumption in country A. Therefore C^A is determined by the two conflicting mechanisms of the AB relocation effect and the tax redistribution effect. However, from (23), if γ (the degree of firm mobility) is large, the increase in C^A through the tax redistribution effect is dominated by the country A's consumption reduction through the AB relocation effect, and therefore the consumption in country A decreases. Intuitively, as the relocation of firms becomes more flexible (as γ increases), there is a greater decrease in relative labor income in country A, because more firms relocate, and therefore the decrease in consumption in country A is greater. In addition, recall that if γ is large, the corporate tax reduction results in a proportionate increase in C^C (see equation (42)). Therefore, the relative consumption level between countries C and A decreases when γ (the degree of firm mobility) is large ($\widehat{C}^A - \widehat{C}^C < 0$, see equation (43)). Accordingly, country A's currency must depreciate and decrease the supply of real money balances in country A to restore money market equilibrium. ($\tilde{\varepsilon}^A - \tilde{\varepsilon}^B > 0$, see equation (40)) when γ (the degree of firm mobility) is large. The opposite mechanism is also valid when γ is small: the corporate tax reduction increases the relative consumption level between countries C and A, $\widehat{C}^A - \widehat{C}^C > 0$ and leads to exchange rate appreciation, $\tilde{\varepsilon}^A - \tilde{\varepsilon}^B < 0$.

In sum, when γ (the degree of firm mobility) is large, a corporate tax reduction in country C benefits country C in terms of the relative consumption revel, while it can be detrimental not only to country B but also to country A in terms of relative consumption level. The opposite mechanism is also valid when γ is small.

6. Conclusion

Understanding the macroeconomic implications of corporate tax reduction is of great importance to policymakers, especially following the global economic crisis caused by the COVID-19 pandemic. In particular, understanding the effects of temporal corporate tax reduction shocks using a three country model will help us to understand the underlying relationships between macroeconomic variables under the global economic crisis.

This paper employed a three-country model with international firm mobility to examine the impact on consumption and exchange rates of a temporal reduction in one country's corporate tax rate. In such a model, we showed that both the tax redistribution and firm relocation offer the key to understanding the impact of the temporal corporate tax reduction. From this model, when the degree of firm mobility is large (small), a temporal corporate tax reduction in one of the three countries benefits (is detrimental to) that country, while it is detrimental to (benefits) other countries in terms of the relative consumption.

Appendix

Long-run equilibrium conditions

The long-run equilibrium conditions of this model are derived. By log-linearizing the model around the initial, zero-shock symmetric steady state with $B_{ss,0}=0$, we obtain the following equations to characterize the long-run equilibrium of the system:

$$\overline{P}^A = \overline{M}^A - \overline{C}^A, \quad \overline{P}^B = \overline{M}^B - \overline{C}^B, \quad \overline{P}^C = \overline{M}^C - \overline{C}^C \tag{A.1}$$

$$\overline{C}^A = \delta\overline{B}^A + ((\theta-1)/\theta)(\overline{W}^A - \overline{P}^A + \overline{l}^{As}) + (1/3\theta)[\overline{\Pi}^A + \overline{\Pi}^B + \overline{\Pi}^C + 2\overline{\varepsilon}^A - \overline{\varepsilon}^B] - (1/\theta)\overline{P}^A \tag{A.2}$$

$$\overline{C}^B = \delta\overline{B}^B + ((\theta-1)/\theta)(\overline{W}^B - \overline{P}^B + \overline{l}^{Bs}) + (1/3\theta)[\overline{\Pi}^A + \overline{\Pi}^B + \overline{\Pi}^C - \overline{\varepsilon}^A + 2\overline{\varepsilon}^B] - (1/\theta)\overline{P}^B \quad (A.3)$$

$$\overline{C}^C = \delta\overline{B}^C + ((\theta-1)/\theta)(\overline{W}^C - \overline{P}^C + \overline{l}^{Cs}) + (1/3\theta)[\overline{\Pi}^A + \overline{\Pi}^B + \overline{\Pi}^C - \overline{\varepsilon}^A - \overline{\varepsilon}^B] - (1/\theta)\overline{P}^C \quad (A.4)$$

$$\overline{y}^A = \theta(\overline{P}^A - \overline{P}^A_A) + \overline{C}^W, \quad \overline{y}^B = \theta(\overline{P}^B - \overline{P}^B_B) + \overline{C}^W, \quad \overline{y}^C = \theta(\overline{P}^C - \overline{P}^C_C) + \overline{C}^W \quad (A.5)$$

$$\overline{C}^W \equiv (1/3)\overline{C}^A + (1/3)\overline{C}^B + (1/3)\overline{C}^C = (1/3)\overline{y}^A + (1/3)\overline{y}^B + (1/3)\overline{y}^C \equiv \overline{y}^W \quad (A.6)$$

$$\overline{m} = (3\gamma/\theta)((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}[\overline{\Pi}^A - \overline{\Pi}^B - \overline{\varepsilon}^A + \overline{\varepsilon}^B] \quad (A.7)$$

$$\overline{n} = (3\gamma/2\theta)((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}[\overline{\Pi}^B - \overline{\Pi}^C - \overline{\varepsilon}^B] \quad (A.8)$$

$$\overline{\Pi}^A = (1-\theta)\hat{P}^A_A + \theta\hat{P}^A + \hat{C}^W \quad (A.9)$$

$$\overline{\Pi}^B = (1-\theta)\hat{P}^B_B + \theta\hat{P}^B + \hat{C}^W \quad (A.10)$$

$$\overline{\Pi}^C = (1-\theta)\hat{P}^C_C + \theta\hat{P}^C + \hat{C}^W \quad (A.11)$$

$$\overline{y}^A = \overline{l}^{Ad}, \quad \overline{y}^B = \overline{l}^{Bd}, \quad \overline{y}^C = \overline{l}^{Cd} \quad (A.12)$$

$$\overline{l}^{As} = \overline{m} + \overline{l}^{Ad}, \quad \overline{l}^{Bs} = 2\overline{n} - \overline{m} + \overline{l}^{Bd}, \quad \overline{l}^{Cs} = -2\overline{n} + \overline{l}^{cd} \quad (A.13)$$

$$\overline{P}^A_A = \overline{W}^A, \quad \overline{P}^B_B = \overline{W}^B, \quad \overline{P}^C_C = \overline{W}^C \quad (A.14)$$

$$\overline{P}^A - \overline{P}^B = \overline{\varepsilon}^A - \overline{\varepsilon}^B, \quad \overline{P}^B - \overline{P}^C = \overline{\varepsilon}^B, \quad \overline{P}^A - \overline{P}^C = \overline{\varepsilon}^A \quad (A.15)$$

$$\overline{l}^{As} = \overline{W}^A - \overline{P}^A - \overline{C}^A, \quad \overline{l}^{Bs} = \overline{W}^B - \overline{P}^B - \overline{C}^B, \quad \overline{l}^{Cs} = \overline{W}^C - \overline{P}^C - \overline{C}^C, \quad (A.16)$$

where $\overline{B} \equiv dB_{t+1}/C^W_{ss,0}$, in which $C^W{}_{ss,0}$ is the initial value of world consumption. The equations in (A. 1) correspond to the money-demand equations. Equations (A. 2), (A. 3) and (A. 4) represent the long-run change in incomes (returns on real bonds, real labor incomes, and real profit incomes), which equal the long-run changes in consumption in each country. The equations in (A. 5) represent the world demand schedules for each country's products. Equation (A. 6) is the world goods-market equilibrium condition. Equation (A. 7) and (A. 8) are the cross-border relocation of firms. The equations in (A. 9), (A. 10), and (A. 11) are the nominal profit equations for firms. The equations in (A. 12) represent the production technology, and those in (A. 13) represent the long-run labor-market clearing conditions for each country. The equations in (A. 14) represent the optimal pricing equations for firms in each country. Equation (A. 15) is the purchasing power parity equation. The equations in (A. 16) represent the first-order conditions for optimal wage setting.

Subtracting (A. 3) from (A. 2) yields the long-run response of relative per capita consumption levels,

$$\overline{C}^A - \overline{C}^B = (\delta/P^C)(\overline{B}^A - \overline{B}^B) + ((\theta-1)/\theta)(\overline{l}^A - \overline{l}^B) + ((\theta-1)/\theta)(\overline{W}^A - \overline{W}^B - (\overline{P}^A - \overline{P}^B)) \quad (A.17)$$

Subtracting (A. 4) from (A. 3) yields the long-run response of relative per capita consumption levels,

$$\begin{aligned}\overline{C}^B-\overline{C}^C &= (\delta/P^C)(\overline{B}^B-\overline{B}^C)+((\theta-1)/\theta)(\overline{l}^B-\overline{l}^C)\\ &\quad +((\theta-1)/\theta)(\overline{W}^B-\overline{W}^C-(\overline{P}^B-\overline{P}^C))\end{aligned} \tag{A. 18}$$

Substituting (A. 9), (A. 10), (A. 11), (A. 14), and (A. 15) into equations (A. 7) and (A. 8), respectively, yields

$$\overline{m} = 3\gamma\theta_1[\overline{\varepsilon}^A-\overline{\varepsilon}^B-(\overline{W}^A-\overline{W}^B)] \tag{A. 19}$$

$$\overline{n} = (3\gamma/2)\theta_1[\overline{\varepsilon}^B-(\overline{W}^B-\overline{W}^C)] \tag{A. 20}$$

From equations (A. 5), (A. 12), (A. 13), (A. 14), and (A. 15), we obtain

$$\overline{l}^{As}-\overline{l}^{Bs} = 2(\overline{m}-\overline{n})+\theta[\overline{\varepsilon}^A-\overline{\varepsilon}^B-(\overline{W}^A-\overline{W}^B)] \tag{A. 21}$$

$$\overline{l}^{Bs}-\overline{l}^{Cs} = 4\overline{n}-\overline{m}+\theta[\overline{\varepsilon}^B-(\overline{W}^B-\overline{W}^C)] \tag{A. 22}$$

From equations (A. 15) and (A. 16), we obtain

$$\overline{l}^{As}-\overline{l}^{Bs}+\overline{C}^A-\overline{C}^B = \overline{W}^A-\overline{W}^B-(\overline{\varepsilon}^A-\overline{\varepsilon}^B) \tag{A. 23}$$

$$\overline{l}^{Bs}-\overline{l}^{Cs}+\overline{C}^B-\overline{C}^C = \overline{W}^B-\overline{W}^C-\overline{\varepsilon}^B \tag{A. 24}$$

From (A. 15), (A. 17) and (A. 18),

$$\begin{aligned}\overline{C}^A-\overline{C}^B &= (\delta/P^C)(\overline{B}^A-\overline{B}^B)+((\theta-1)/\theta)(\overline{l}^A-\overline{l}^B)\\ &\quad +((\theta-1)/\theta)(\overline{W}^A-\overline{W}^B-(\overline{\varepsilon}^A-\overline{\varepsilon}^B))\end{aligned} \tag{A. 25}$$

$$\begin{aligned}\overline{C}^B-\overline{C}^C &= (\delta/P^C)(\overline{B}^B-\overline{B}^C)+((\theta-1)/\theta)(\overline{l}^B-\overline{l}^C)\\ &\quad +((\theta-1)/\theta)(\overline{W}^B-\overline{W}^C-\overline{\varepsilon}^B)\end{aligned} \tag{A. 26}$$

Substituting (A. 23) into (A. 25) yields

$$\overline{C}^A-\overline{C}^B = (\delta/P^C)(\overline{B}^A-\overline{B}^B)+2((\theta-1)/\theta)(\overline{l}^A-\overline{l}^B)+((\theta-1)/\theta)(\overline{C}^A-\overline{C}^B) \tag{A. 27}$$

Substituting (A. 24) into (A. 26) yields

$$\overline{C}^B-\overline{C}^C = (\delta/P^C)(\overline{B}^B-\overline{B}^C)+2((\theta-1)/\theta)(\overline{l}^B-\overline{l}^C)+((\theta-1)/\theta)(\overline{C}^B-\overline{C}^C) \tag{A. 28}$$

Substituting (A. 23) into (A. 19) yields

$$\overline{m} = -3\gamma\theta_1[\overline{l}^A-\overline{l}^B+\overline{C}^A-\overline{C}^B] \tag{A. 29}$$

where $\theta_1=((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{3/2}(1/\kappa)^{1/2}>0$. Substituting (A. 24) into (A. 20) yields

$$\bar{n} = -(3/2)\gamma\theta_1[\bar{l}^B - \bar{l}^C + \bar{C}^B - \bar{C}^C] \qquad \text{(A. 30)}$$

Substituting (A. 23), (A. 29), and (A. 30) into (A. 21) yield

$$(1+6\gamma\theta_1+\theta)(\bar{l}^{As}-\bar{l}^{Bs}) = -(6\gamma\theta_1+\theta)(\bar{C}^A-\bar{C}^B)+3\gamma\theta_1[\bar{l}^B-\bar{l}^C+\bar{C}^B-\bar{C}^C] \qquad \text{(A. 31)}$$

Substituting (A. 24), (A. 29), and (A. 30) into (A. 22) yields

$$\bar{l}^B-\bar{l}^C = -\left(\frac{6\gamma\theta_1+\theta}{1+6\gamma\theta_1+\theta}\right)(\bar{C}^B-\bar{C}^C)+\left(\frac{3\gamma\theta_1}{1+6\gamma\theta_1+\theta}\right)(\bar{l}^A-\bar{l}^B+\bar{C}^A-\bar{C}^B) \qquad \text{(A. 32)}$$

Substituting (A. 32) into (A. 31) yields

$$\bar{l}^A-\bar{l}^B = -\left[\frac{(6\gamma\theta_1+\theta)(1+6\gamma\theta_1+\theta)-9\gamma^2\theta_1^2}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right](\bar{C}^A-\bar{C}^B)$$

$$+\left[\frac{3\gamma\theta_1}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right](\bar{C}^B-\bar{C}^C) \qquad \text{(A. 33)}$$

Substituting (A. 33) into (A. 27) yields

$$\left\{1+2\tilde{\theta}\left[\frac{(6\gamma\theta_1+\theta)(1+6\gamma\theta_1+\theta)-9\gamma^2\theta_1^2}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right]-\tilde{\theta}\right\}(\bar{C}^A-\bar{C}^B)$$

$$= (\delta/P^C)(\bar{B}^A-\bar{B}^B)+\left[\frac{6\gamma\theta_1\tilde{\theta}}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right](\bar{C}^B-\bar{C}^C) \qquad \text{(A. 34)}$$

where $\tilde{\theta}=(\theta-1)/\theta$. Substituting (A. 32) and (A. 33) into (A. 28) yields

$$\left\{1+2\tilde{\theta}\left[\frac{(6\gamma\theta_1+\theta)(1+6\gamma\theta_1+\theta)-9\gamma^2\theta_1^2}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right]-\tilde{\theta}\right\}(\bar{C}^B-\bar{C}^C)$$

$$=(\delta/P^C)(\bar{B}^B-\bar{B}^C)+\left[\frac{6\gamma\theta_1\tilde{\theta}}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right](\bar{C}^A-\bar{C}^B) \qquad \text{(A. 35)}$$

Short-run equilibrium conditions

The short-run equilibrium conditions of this model are derived. By log-linearizing the model around the initial, zero-shock symmetric steady state with $B_{ss,0}=0$, we obtain the following equations to characterize the short-run equilibrium of the system:

$$\bar{C}^A = \hat{C}^A+(\delta/(1+\delta))\bar{r}+\bar{\varepsilon}^A-\hat{\varepsilon}^A \qquad \text{(A. 36)}$$

$$\bar{C}^B = \hat{C}^B+(\delta/(1+\delta))\bar{r}+\bar{\varepsilon}^B-\hat{\varepsilon}^B \qquad \text{(A. 37)}$$

$$\bar{C}^C = \hat{C}^C+(\delta/(1+\delta))\bar{r} \qquad \text{(A. 38)}$$

$$\hat{M}^A-\hat{P}^A = \hat{C}^A-\bar{r}/(1+\delta)-(\bar{P}^A-\hat{P}^A)/\delta-\bar{\varepsilon}^A/\delta+\hat{\varepsilon}^A/\delta \qquad \text{(A. 39)}$$

$$\hat{M}^B-\hat{P}^B = \hat{C}^B-\bar{r}/(1+\delta)-(\bar{P}^B-\hat{P}^B)/\delta-\bar{\varepsilon}^B/\delta+\hat{\varepsilon}^B/\delta \qquad \text{(A. 40)}$$

$$\hat{M}^C-\hat{P}^C = \hat{C}^C-\bar{r}/(1+\delta)-(\bar{P}^C-\hat{P}^C)/\delta \qquad \text{(A. 41)}$$

$$\bar{B}^A/P^C = -((\theta-1)/\theta)\hat{P}^A+((\theta-1)/\theta)(\hat{m}+\hat{l}^{Ad})$$

$$+(1/3\theta)[\hat{\Pi}^A+\hat{\Pi}^B+\hat{\Pi}^C+2\hat{\varepsilon}^A-\hat{\varepsilon}^B-3\hat{P}^A-d\tau^A-d\tau^B-d\tau^C]$$
$$-\hat{C}^A+(1/\theta)d\tau^A \qquad (A.42)$$

$$\bar{B}^B/P^C = -((\theta-1)/\theta)\hat{P}^B+((\theta-1)/\theta)(2\hat{n}-\hat{m}+\hat{l}^{Bd})$$
$$+(1/3\theta)[\hat{\Pi}^A+\hat{\Pi}^B+\hat{\Pi}^C-\hat{\varepsilon}^A+2\hat{\varepsilon}^B-3\hat{P}^B-d\tau^A-d^B-d\tau^C]$$
$$-\hat{C}^B+(1/\theta)d\tau^B \qquad (A.43)$$

$$\bar{B}^C/P^C = -((\theta-1)/\theta)\hat{P}^C+((\theta-1)/\theta)(-2\hat{n}+\hat{l}^{Cd})$$
$$+(1/3\theta)[\hat{\Pi}^A+\hat{\Pi}^B+\hat{\Pi}^C-\hat{\varepsilon}^A-\hat{\varepsilon}^B-3\hat{P}^C-d\tau^A-d\tau^B-d\tau^C]$$
$$-\hat{C}^C+(1/\theta)d\tau^C \qquad (A.44)$$

$$\hat{y}^A = \theta\hat{P}^A+\hat{C}^W, \quad \hat{y}^B = \theta\hat{P}^B+\hat{C}^W, \quad \hat{y}^C = \theta\hat{P}^C+\hat{C}^W \qquad (A.45)$$

$$\hat{y}^A = \hat{l}^{Ad}, \quad \hat{y}^B = \hat{l}^{Bd}, \quad \hat{y}^C = \hat{l}^{Cd} \qquad (A.46)$$

$$\hat{\Pi}^A = \theta\hat{P}^A+\hat{C}^W, \quad \hat{\Pi}^B = \theta\hat{P}^B+\hat{C}^W, \quad \hat{\Pi}^C = \theta\hat{P}^C+\hat{C}^W \qquad (A.47)$$

$$\hat{m} = (3\gamma/\theta)((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}[\hat{\Pi}^A-\hat{\Pi}^B-\hat{\varepsilon}^A+\hat{\varepsilon}^B-d\tau^A+d\tau^B] \qquad (A.48)$$

$$\hat{n} = (3\gamma/2\theta)((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}[\hat{\Pi}^B-\hat{\Pi}^C-\hat{\varepsilon}^B-d\tau^B+d\tau^C] \qquad (A.49)$$

$$\hat{C}^W \equiv (1/3)\hat{C}^A+(1/3)\hat{C}^B+(1/3)\hat{C}^C = (1/3)\hat{y}^A+(1/3)\hat{y}^B+(1/3)\hat{y}^C \equiv \hat{y}^W \qquad (A.50)$$

$$\hat{P}^A = (2/3)\hat{\varepsilon}^A-(1/3)\hat{\varepsilon}^B, \quad \hat{P}^B = -(1/3)\hat{\varepsilon}^A+(2/3)\hat{\varepsilon}^B,$$
$$\hat{P}^C = -(1/3)\hat{\varepsilon}^A-(1/3)\hat{\varepsilon}^B \qquad (A.51)$$

$$\hat{l}^{As} = \hat{m}+\hat{l}^{Ad}, \quad \hat{l}^{Bs} = 2\hat{n}-\hat{m}+\hat{l}^{Bd}, \quad \hat{l}^{Cs} = -2\hat{n}+\hat{l}^{Cd} \qquad (A.52)$$

where we set nominal wages and prices of goods as $\hat{W}^h=\hat{P}^j_j(z)=0$, $h, j=A, B, C$, for the above short-run log-linearized equations. The equations in (A. 36), (A. 37), and (A. 38) are the Euler equations. The equations in (A. 39), (A. 40) and (A. 41) describe equilibrium in the money markets in the short run. The equations in (A. 42), (A. 43) and (A. 44) are linearized short-run current account equations. The equations in (A. 45) represent the world demand schedules for representative country j products ($j=A, B, C$). Equation (A. 46) is the production function. The equations in (A. 47) are the nominal profit equations for representative country j firms ($j=A, B, C$). Equation (A. 48) and (A. 49) are the dynamic relocation equation. Equation (A. 50) is the world goods-market equilibrium condition. Equation (A. 51) is the price index equation in the short run. The equations in (A. 52) represent the short-run labor-market clearing conditions for each country. Subtracting (A. 43) from (A. 42) yields

$$(\bar{B}^A-\bar{B}^B)/P^C = -((\theta-1)/\theta)(\hat{P}^A-\hat{P}^B)+2((\theta-1)/\theta)(\hat{m}-\hat{n})+((\theta-1)/\theta)(\hat{l}^{Ad}-\hat{l}^{Bd})$$
$$+(1/\theta)(\hat{\varepsilon}^A-\hat{\varepsilon}^B-\hat{P}^A+\hat{P}^B)-(\hat{C}^A-\hat{C}^B)+(1/\theta)(d\tau^A-d\tau^B) \qquad (A.53)$$

Substituting (A. 47) and (A. 51) into (A. 48) and (A. 49), respectively, yields

$$\hat{m} = (3\gamma/\theta)((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}[(\theta-1)(\hat{\varepsilon}^A-\hat{\varepsilon}^B)-d\tau^A+d\tau^B] \qquad (A.54)$$

$$\hat{n} = (3\gamma/2\theta)((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}[(\theta-1)\hat{\varepsilon}^B - d\tau^B + d\tau^C] \quad (A.55)$$

Given equations (A. 45), (A. 46), and (A. 51) and subtracting, relative labor demand is

$$\hat{l}^{Ad} - \hat{l}^{Bd} = \theta(\hat{P}^A - \hat{P}^B) = \theta(\hat{\varepsilon}^A - \hat{\varepsilon}^B) \quad (A.56)$$

Subtracting (A. 55) from (A. 54) yields

$$\begin{aligned}\hat{m} - \hat{n} &= 3\gamma\theta_1(\hat{E}^A - \hat{E}^B) - 3\gamma\theta_1(\theta-1)^{-1}(d\tau^A - d\tau^B) - (3/2)\gamma\theta_1\hat{\varepsilon}^B \\ &\quad + (3/2)\gamma\theta_1(\theta-1)^{-1}(d\tau^B - d\tau^C) \quad (A.57)\end{aligned}$$

Substituting (A. 51), (A. 56), and (A. 57) into (A. 53) yields

$$\begin{aligned}(\overline{B}^A - \overline{B}^B)/P^C &= 2\tilde{\theta}[3\gamma\theta_1(\hat{\varepsilon}^A - \hat{\varepsilon}^B) - 3\gamma\theta_1(\theta-1)^{-1}(d\tau^A - d\tau^B) - (3/2)\gamma\theta_1\hat{\varepsilon}^B \\ &\quad + (3/2)\gamma\theta_1(\theta-1)^{-1}(d\tau^B - d\tau^C)] \\ &\quad + \tilde{\theta}(\theta-1)(\hat{\varepsilon}^A - \hat{\varepsilon}^B) - (\hat{C}^A - \hat{C}^B) + (1/\theta)(d\tau^A - d\tau^B) \quad (A.58)\end{aligned}$$

From (A. 36), (A. 37), and (A. 38)

$$\overline{C}^A - \overline{C}^B = \hat{C}^A - \hat{C}^B \quad (A.59)$$

$$\overline{C}^B - \overline{C}^C = \hat{C}^B - \hat{C}^C \quad (A.60)$$

Substituting (A. 59) and (A. 60) into (A. 34) yields

$$\begin{aligned}(1/P^C)(\overline{B}^A - \overline{B}^B) &= \delta^{-1}\left\{1 + 2\tilde{\theta}\left[\frac{(6\gamma\theta_1+\theta)(1+6\gamma\theta_1+\theta) - 9\gamma^2\theta_1^2}{(1+6\gamma\theta_1+\theta)^2 - 9\gamma^2\theta_1^2}\right] - \tilde{\theta}\right\}(\hat{C}^A - \hat{C}^B) \\ &\quad - \delta^{-1}\left[\frac{6\gamma\theta_1\tilde{\theta}}{(1+6\gamma\theta_1+\theta)^2 - 9\gamma^2\theta_1^2}\right](\hat{C}^B - \hat{C}^C) \quad (A.61)\end{aligned}$$

Substituting (A. 61) into (A. 58) yields

$$\begin{aligned}&\left\{\delta^{-1}\left\{1 + 2\tilde{\theta}\left[\frac{(6\gamma\theta_1+\theta)(1+6\gamma\theta_1+\theta) - 9\gamma^2\theta_1^2}{(1+6\gamma\theta_1+\theta)^2 - 9\gamma^2\theta_1^2}\right] - \tilde{\theta}\right\} + 1\right\}(\hat{C}^A - \hat{C}^B) \\ &- \delta^{-1}\left[\frac{6\gamma\theta_1\tilde{\theta}}{(1+6\gamma\theta_1+\theta)^2 - 9\gamma^2\theta_1^2}\right](\hat{C}^B - \hat{C}^C) \\ &\quad = \tilde{\theta}\theta_1[6\gamma(\hat{\varepsilon}^A - \hat{\varepsilon}^B) - 3\gamma\hat{\varepsilon}^B] - 2\tilde{\theta}[3\gamma\theta_1(\theta-1)^{-1}(d\tau^A - d\tau^B) \\ &\quad\quad - (3/2)\gamma\theta_1(\theta-1)^{-1}(d\tau^B - d\tau^C)] + \tilde{\theta}(\theta-1)(\hat{\varepsilon}^A - \hat{\varepsilon}^B) + (1/\theta)(d\tau^A - d\tau^B) \quad (A.62)\end{aligned}$$

From (A. 39), (A. 40), (A. 41), (A. 51), (A. 59) and (A. 60),

$$(\hat{C}^A - \hat{C}^B) = -(\hat{\varepsilon}^A - \hat{\varepsilon}^B) \quad (A.63)$$

$$(\hat{C}^B - \hat{C}^C) = -\hat{\varepsilon}^B \quad (A.64)$$

From (A. 62), (A. 63) and (A. 64), we obtain

$$2\tilde{\theta}[3\gamma\theta_1(\theta-1)^{-1}(d\tau^A-d\tau^B)-(3/2)\gamma\theta_1(\theta-1)^{-1}(d\tau^B-d\tau^C)]-(1/\theta)(d\tau^A-d\tau^B)$$
$$=\left\{\delta^{-1}\left\{1+2\tilde{\theta}\left[\frac{(6\gamma\theta_1+\theta)(1+6\gamma\theta_1+\theta)-9\gamma^2\theta_1^2}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right]-\tilde{\theta}\right\}+1+6\gamma\theta_1\tilde{\theta}+\tilde{\theta}(\theta-1)\right\}(\hat{\varepsilon}^A-\hat{\varepsilon}^B)$$
$$-\left\{\delta^{-1}\left[\frac{6\gamma\theta_1\tilde{\theta}}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right]+3\gamma\theta_1\tilde{\theta}\right\}\hat{\varepsilon}^B \quad \text{(A. 65)}$$

(A. 65) can be rewritten as

$$T_1=\alpha_1(\hat{\varepsilon}^A-\hat{\varepsilon}^B)+\beta_1\hat{\varepsilon}^B \quad \text{(A. 66)}$$

where

$$T_1\equiv 2\tilde{\theta}[3\gamma\theta_1(\theta-1)^{-1}(d\tau^A-d\tau^B)-(3/2)\gamma\theta_1(\theta-1)^{-1}(d\tau^B-d\tau^C)]$$
$$-(1/\theta)(d\tau^A-d\tau^B) \quad \text{(A. 67)}$$

$$\alpha_1\equiv\left\{\delta^{-1}\left\{1+2\tilde{\theta}\left[\frac{(6\gamma\theta_1+\theta)(1+6\gamma\theta_1+\theta)-9\gamma^2\theta_1^2}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right]-\tilde{\theta}\right\}+1+6\gamma\theta_1\tilde{\theta}+\tilde{\theta}(\theta-1)\right\}>0$$
$$\text{(A. 68)}$$

$$\beta_1\equiv-\left\{\delta^{-1}\left[\frac{6\gamma\theta_1\tilde{\theta}}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right]+3\gamma\theta_1\tilde{\theta}\right\}<0 \quad \text{(A. 69)}$$

Subtracting (A. 44) from (A. 43) and considering (A. 45), (A. 46), (A. 51), (A. 54) and (A. 55) yields

$$(\overline{B}^B-\overline{B}^C)/P^C=6\gamma\theta_1\tilde{\theta}\hat{\varepsilon}^B-6\gamma\theta_1(\theta-1)^{-1}\tilde{\theta}(d\tau^B-d\tau^C)-3\gamma\theta_1\tilde{\theta}(\hat{\varepsilon}^A-\hat{\varepsilon}^B)$$
$$+3\gamma\theta_1\tilde{\theta}(\theta-1)^{-1}(d\tau^A-d\tau^B)+\tilde{\theta}(\theta-1)\hat{\varepsilon}^B-(\widehat{C}^B-\widehat{C}^C)$$
$$+(1/\theta)(d\tau^B-d\tau^C) \quad \text{(B. 70)}$$

Substituting (A. 59) and (A. 60) into (A. 35) yields

$$\frac{1}{P^C}(\overline{B}^B-\overline{B}^C)=\delta^{-1}\left\{1+2\tilde{\theta}\left[\frac{6\gamma\theta_1+\theta}{1+6\gamma\theta_1+\theta}\right]\right.$$
$$\left.-\tilde{\theta}-2\tilde{\theta}\left[\frac{3\gamma\theta_1}{1+6\gamma\theta_1+\theta}\right]\left[\frac{3\gamma\theta_1}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right]\right\}(\widehat{C}^B-\widehat{C}^C)$$
$$-\delta^{-1}\left[\frac{6\gamma\theta_1\tilde{\theta}}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right](\widehat{C}^A-\widehat{C}^B) \quad \text{(A. 71)}$$

Substituting (A. 71) into (A. 70) yields

$$\left\{\delta^{-1}\left\{1+2\tilde{\theta}\left[\frac{6\gamma\theta_1+\theta}{1+6\gamma\theta_1+\theta}\right]-\tilde{\theta}-2\tilde{\theta}\left[\frac{3\gamma\theta_1}{1+6\gamma\theta_1+\theta}\right]\left[\frac{3\gamma\theta_1}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right]\right\}+1\right\}(\widehat{C}^B-\widehat{C}^C)$$
$$-\delta^{-1}\left[\frac{6\gamma\theta_1\tilde{\theta}}{(1+6\gamma\theta_1+\theta)^2-9\gamma^2\theta_1^2}\right](\widehat{C}^A-\widehat{C}^B)$$

$$= 6\gamma\theta_1\tilde{\theta}\hat{\varepsilon}^B - 3\gamma\theta_1\tilde{\theta}(\hat{\varepsilon}^A - \hat{\varepsilon}^B) + \tilde{\theta}(\theta-1)\hat{\varepsilon}^B - 6\gamma\theta_1(\theta-1)^{-1}\tilde{\theta}(d\tau^B - d\tau^C)$$
$$+3\gamma\theta_1\tilde{\theta}(\theta-1)^{-1}(d\tau^A - d\tau^B) + (1/\theta)(d\tau^B - d\tau^C) \tag{A.72}$$

From (A. 63), (A. 64) and (A. 72), we obtain

$$-6\gamma\theta_1(\theta-1)^{-1}\tilde{\theta}(d\tau^B - d\tau^C) + 3\gamma\theta_1\tilde{\theta}(\theta-1)^{-1}(d\tau^A - d\tau^B) + (1/\theta)(d\tau^B - d\tau^C)$$
$$= -\left\{\delta^{-1}\left[\frac{6\gamma\theta_1\tilde{\theta}}{(1+6\gamma\theta_1+\theta)^2 - 9\gamma^2\theta_1^2}\right] + 3\gamma\theta_1\tilde{\theta}\right\}(\hat{\varepsilon}^A - \hat{\varepsilon}^B)$$
$$+\left\{\delta^{-1}\left\{1+2\tilde{\theta}\left[\frac{6\gamma\theta_1+\theta}{1+6\gamma\theta_1+\theta}\right] - \tilde{\theta} - 2\tilde{\theta}\left[\frac{3\gamma\theta_1}{1+6\gamma\theta_1+\theta}\right]\left[\frac{3\gamma\theta_1}{(1+6\gamma\theta_1+\theta)^2 - 9\gamma^2\theta_1^2}\right]\right\}\right.$$
$$\left. +1+6\gamma\theta_1\tilde{\theta} + \tilde{\theta}(\theta-1)\right\}\hat{\varepsilon}^B \tag{A.73}$$

(A. 73) can be rewritten as

$$T_2 = \alpha_2(\hat{\varepsilon}^A - \hat{\varepsilon}^B) + \beta_2\hat{\varepsilon}^B \tag{A.74}$$

where

$$T_2 \equiv -6\gamma\theta_1(\theta-1)^{-1}\tilde{\theta}(d\tau^B - d\tau^C) + 3\gamma\theta_1\tilde{\theta}(\theta-1)^{-1}(d\tau^A - d\tau^B) + (1/\theta)(d\tau^B - d\tau^C) \tag{A.75}$$

$$\beta_2 = \alpha_1 \equiv \left\{\delta^{-1}\left\{1+2\tilde{\theta}\left[\frac{(6\gamma\theta_1+\theta)(1+6\gamma\theta_1+\theta) - 9\gamma^2\theta_1^2}{(1+6\gamma\theta_1+\theta)^2 - 9\gamma^2\theta_1^2}\right] - \tilde{\theta}\right\} + 1 + 6\gamma\theta_1\tilde{\theta} + \tilde{\theta}(\theta-1)\right\} \tag{A.76}$$

$$\alpha_2 = \beta_1 \equiv -\left\{\delta^{-1}\left[\frac{6\gamma\theta_1\tilde{\theta}}{(1+6\gamma\theta_1+\theta)^2 - 9\gamma^2\theta_1^2}\right] + 3\gamma\theta_1\tilde{\theta}\right\} \tag{A.77}$$

Derivation of the impacts of temporary corporate tax reductions

From (A. 66) and (A. 74), we obtain

$$\hat{\varepsilon}^A - \hat{\varepsilon}^B = \left[\frac{\beta_1 T_2 - \beta_2 T_1}{\alpha_2\beta_1 - \alpha_1\beta_2}\right] \tag{A.78}$$

$$\hat{\varepsilon}^B = \left[\frac{\alpha_2 T_1 - \alpha_1 T_2}{\alpha_2\beta_1 - \alpha_1\beta_2}\right] \tag{A.79}$$

From $\alpha_1 = \beta_2$ and $\alpha_2 = \beta_1$, (A. 77) and (A. 78) can be rewritten as

$$\hat{\varepsilon}^A - \hat{\varepsilon}^B = \left[\frac{\alpha_2 T_2 - \alpha_1 T_1}{(\alpha_2)^2 - (\alpha_1)^2}\right] \tag{A.80}$$

$$\hat{\varepsilon}^B = \left[\frac{\alpha_2 T_1 - \alpha_1 T_2}{(\alpha_2)^2 - (\alpha_1)^2}\right] \tag{A.81}$$

The relative consumption changes are

$$\widehat{C}^A - \widehat{C}^B = -(\hat{\varepsilon}^A - \hat{\varepsilon}^B) \tag{A. 82}$$

$$\widehat{C}^B - \widehat{C}^C = -\hat{\varepsilon}^B \tag{A. 83}$$

$$\widehat{C}^A - \widehat{C}^C = -(\hat{\varepsilon}^A - \hat{\varepsilon}^B) - \hat{\varepsilon}^B \tag{A. 84}$$

Acknowledgement

This work was supported in part by Tezukayama University.

Notes

1) There is a large body of empirical research on the relationship between exchange rates and firms' production location (see, for example, Cushman 1985, 1988; Froot and Stein 1991; Campa 1993; Klein and Rosengren 1994; Goldberg and Kolstad 1995; Blonigen 1997; Goldberg and Klein 1998; Bénassy-quéré et al 2001; Chakrabarti and Scholnick 2002; Farrell et al. 2004).

2) In the NOEM literature, the relationship between policy shocks and macroeconomic variables has been studied extensively; see, for example, Obstfeld and Rogoff (1995, 2002), Lane (1997), Betts and Devereux (2000a, 2000b), Hau (2000), Bergin and Feenstra (2001), Corsetti and Pesenti (2001, 2005), Cavallo and Ghironi (2002), Devereux and Engel (2002), Kollmann (2001, 2002), Smets and Wouters (2002), Sutherland (2005a, 2005b), Senay and Sutherland (2007), and Johdo (2013a, 2013b, 2019d, 2021b).

3) This is because, given a domestic demand increase following an unanticipated domestic monetary expansion, the presence of PTM behavior magnifies the cross-country positive correlations between outputs, which requires foreign households to work harder, resulting in a deterioration in the foreign country's terms of trade. This negative welfare effect dominates the standard positive welfare effect of increasing world consumption, making foreign households worse off. For a survey of the NOEM models with PTM, see Lane (2001).

4) This is because if periphery goods and center goods are poor substitutes in demand, a given depreciation of country A's currency requires that less world demand shifts to country B goods from the center goods (or country C goods). This makes the supply of country B's goods decline relative to other countries, which causes the deterioration in country B's terms of trade against the center to outweigh the improvement in country B's terms of trade against country A, which lowers domestic welfare in country B. They also present other conditions, including the elasticity of goods substitution between the periphery countries is higher than that between the periphery and the center, a small difference between A and B goods for the consumers in the center, and the small periphery share of the world population, for a 'beggar-thy-neighbor' policy to exist.

5) Corsetti et al. (2000) also examine the case in which all prices are set in the local currency.

Even in this case, they show that a monetary expansion in country A is a 'beggar-thy-neighbor' policy against country B. This is because devaluing the currency of country A induces a fall in export revenues and consumption in country B, so that households in country B must supply more labor to restore the initial consumption level.

6) This is because if cross-country substitutability is high, the extent of world demand switching away from foreign goods towards home goods following a deterioration in the home country's terms of trade is magnified, which reduces foreign income and consumption and makes foreign residents worse off.

7) The intuition behind this result is that home-product bias magnifies the response of the nominal exchange rate to shocks, and thereby magnifies the negative effect of world demand switching away from foreign goods so that it dominates the positive effect of the shocks that operates through increasing world consumption, to make foreign households worse off.

8) This model is similar to the one presented by Corsetti et al. (2000), in which there are three types of countries in the world economy: two Periphery countries and one Center country. However, in Corsetti et al. (2000), the international distribution of firms remains fixed.

9) This is also because the lump-sum taxes that finance the corporate tax reduction are borne entirely by the country A's households.

10) This is because the tax redistribution effect is independent of the degree of cross-border firm mobility.

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