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Abstract

In this paper, we develop an open economy model that incorporates gradual relocation of firms and nominal wage rigidities to explore the effects of a temporary corporate tax reduction by each country on relative consumption levels and the exchange rates. We show that when the degree of firm mobility is large, a temporary corporate tax reduction in one of the three countries raises the relative consumption of that country. In addition, we show that the tax reduction can be detrimental to other countries in terms of relative consumption levels. The opposite mechanism is also valid when the mobility is small.

JEL classification codes: E20; F20; F31; F40; H20

Key words: Exchange rate; consumption; firm mobility; corporate tax reduction

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1. Introduction

In standard 'new open economy macroeconomics' (NOEM) models, a domestic monetary expansion raises output and welfare of both home and foreign countries through the first-order effect of increasing world consumption when there is a fixed spatial distribution of firms (see, for example, Obstfeld and Rogoff, 1995).[1] In particular, an important contribution of their model to the international macroeconomics literature is to show that a monetary expansion, regardless of its source, raises the welfare of all agents across countries even in an open economy with monopolistic competition.[2]

In contrast to this result from the benchmark model of Obstfeld and Rogoff (1995), much effort has been devoted to showing that expansionary monetary policy can be a 'beggar-thy-neighbor' policy by incorporating economic characteristics of the real world into the benchmark model. For example, Betts and Devereux (2000a) allow for pricing-to-market (PTM) behavior that is consistent with empirical evidence 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,

[1] This effect is attributed to the distortion of monopolistic competition in product markets. In closed-economy monopolistic competition models, Svensson (1986) and Blanchard and Kiyotaki (1987) also highlight this first-order effect of a marginal monetary expansion on output.

[2] In the NOEM literature, the relationship between policy shocks and aggregate economic activity 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 (2010, 2013a, 2013b).

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. 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 agents to work harder, resulting in a deterioration in the foreign country's terms of trade. This negative welfare effect dominates the standard positive effect of increasing world consumption to make foreign agents worse off.[3] Corsetti et al. (2000) extend the benchmark model 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] 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).[5] 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

[3] For a survey of dynamic open economy models with PTM, see Lane (2001).

[4] They also present other conditions, including a substantial but small difference between periphery goods and the small periphery share of the world population, for a 'beggar-thy-neighbor' policy to exist.

[5] They assume that the elasticity of goods substitution between the periphery countries is higher than that between the periphery and the center.

against the center to outweigh the improvement in country B's terms of trade against country A, which lowers domestic welfare in country B.[6] 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. 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. Warnock (2003) also predicts a 'beggar-thy-neighbor' effect following a monetary expansion by one country by incorporating home-product bias in consumption preferences into the Obstfeld and Rogoff (1995) model. 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 agents worse off. Furthermore, a number of other factors leading to 'beggar-thy-neighbor' policies, other than monetary expansion, have also been examined in the NOEM literature. These include tariffs (Fender and Yip, 2000) and government spending (Chu, 2005).

[6] Corsetti et al. (2000) also examine the case in which all prices are set in the local currency. In this case, they also 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.

However, in the 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.[7] One exception is Johdo (2015), who attempts to present a NOEM model with international relocation of firms. Johdo (2015) contrasts a two-country NOEM model without international relocation with a NOEM model with international relocation, and 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. However, because Johdo (2015) 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 the exchange rate. Recently, multinational firms have very actively invested across national borders: American, Japanese, and China's multinational firms are increasingly making their way not only into each other's markets but also into Singapore, Brazil, India, and Vietnam. It is, therefore, appropriate that a multicountry model be adopted to examine how allowing for international relocation of firms affects the impacts of a corporate tax reduction on consumption and exchange rates.

Given this motivation, this paper investigates the impacts of corporate tax reductions on the international distribution of firms, the exchange rate, and consumption by extending the two-country model of Johdo (2015) to a three-country model. From this

[7] 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).

analysis, we show explicitly the macroeconomic effects of corporate tax reductions, which lead to firm relocation among three countries.

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 gradual.

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 households in countries *A* and *B* inhabit the intervals [0, 1/3] and (1/3, 2/3], respectively, and those in country *C* inhabit the interval (2/3, 1]. Therefore, the shares of households in *A*, *B*, and *C* are 1/3, 1/3, and 1/3, respectively. There is monopolistic competition in the markets for goods and labor, whereas the markets for money and international bonds are

[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.

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 0, with $h = A, B, C$, is:

$$U^h{}_0(x) = \sum_{t=0}^{\infty} \beta^t \left(\log C^h{}_t(x) + \chi \log(M^h{}_t(x)/P^h{}_t) - (\kappa/2)(\ell^{sh}{}_t(x))^2\right) \tag{1}$$

where $0 < \beta < 1$ is a constant subjective discount factor; $C^h{}_t(x)$ is the consumption index that is defined later; $M^h{}_t(x)/P^h{}_t$ is 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 $\ell^{sh}{}_t(x)$ 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:

$$E^h{}_t B^h{}_{t+1}(x) + M^h{}_t(x) = (1 + i_t) E^h{}_t B^h{}_t(x) + M^h{}_{t-1}(x) + W^h{}_t(x) \ell^{sh}{}_t(x) + P^h{}_t T^h{}_t - P^h{}_t C^h{}_t(x)$$

$$+ ((1-\tau^{A}{}_{t})(E^{h}{}_{t}/E^{A}{}_{t})\int_{0}^{m_t}\Pi_{t}^{A}(z)dz + (1-\tau^{B}{}_{t})(E^{h}{}_{t}/E^{B}{}_{t})\int_{m_t}^{n_t}\Pi_{t}^{B}(z)dz + (1-\tau^{C}{}_{t})E^{h}{}_{t}\int_{n_t}^{1}\Pi_{t}^{C}(z)dz) \quad (2)$$

where $E^{h}{}_{t}$ denotes the nominal exchange rate, defined as country h's currency per unit of country C's currency (so that $E^{C}{}_{t} = 1$); $B^{h}{}_{t+1}(x)$ 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; $W^{h}{}_{t}(x)\ell^{sh}{}_{t}(x)$ 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; $P^{h}{}_{t}C^{h}{}_{t}(x)$ represents nominal consumption expenditure; and $\tau^{h}{}_{t}$ denotes the corporate tax rate of country h. Note that 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 $s^{A}T^{A}{}_{t} = \tau^{A}{}_{t}\int_{0}^{m_t}\Pi_{t}^{A}(z)dz + [(M^{A}{}_{t+1} - M^{A}{}_{t})/P^{A}{}_{t}]$, where $M^{A}{}_{t}$ is aggregate money supply and s^{h} 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 CES production function:

$$y_{At}(z) = ((1/3)^{-1/\phi} \int_0^{1/3} \ell_{At}(z, x)^{(\phi-1)/\phi} dx)^{\phi/(\phi-1)} \quad (3)$$

where $y_{At}(z)$ denotes the production of firm z in period t; $\ell_{At}(z, x)$ is the 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:

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

where $W_t^A \equiv ((1/3)^{-1} \int_0^{1/3} W_t^A(x)^{(1-\phi)} dx)^{1/(1-\phi)}$ 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:

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

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:

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

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*:

$$y_{jt}(z) = (P^A_{jt}(z)/P^A_t)^{-\theta} C^A_t + (P^B_{jt}(z)/P^B_t)^{-\theta} C^B_t + (P^C_{jt}(z)/P^C_t)^{-\theta} C^C_t, \quad j = A, B, C \tag{7}$$

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:

$$C^h_{t+1}(x) = \beta C^h_t(x)(1 + i_{t+1})[(P^h_t/E^h_t)/(P^h_{t+1}/E^h_{t+1})] \tag{9}$$

$$M^h_t(x)/P^h_t = \chi C^h_t(x)[(1 + i_{t+1})E^h_{t+1}/((1 + i_{t+1})E^h_{t+1} - E^h_t)] \tag{10}$$

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 $1 + i_{t+1} = (P^C_{t+1}/P^C_t)(1 + r_{t+1})$, and where r_{t+1} denotes the real interest rate. Equation (9) is the Euler equation for consumption, and (10) is the one for money demand.

Following Corsetti and Pesenti (2001), we introduce nominal rigidities into the model in the form of one-period wage contracts under which nominal wages in period t are predetermined at the end of period $t - 1$. In the monopolistic labor market, each household provides a single variety of labor input to a continuum of domestic firms. Hence, in country A, the equilibrium labor-market conditions imply that $\ell^{sA}_t(x) = \int_0^{m_t} \ell_{At}(z, x)dz$, $x \in [0, 1/3]$, 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. By taking W^A_t, P^A_t, and m_t as given, substituting $\ell^{sA}_t(x) = \int_0^{m_t} \ell_{At}(z, x)dz$ and equation (4) into the budget constraint given by (2), and maximizing the lifetime utility given by (1) with respect to the nominal wage $W^A_t(x)$, we obtain the following first-order condition for the optimal nominal wage, $W^A_t(x)$:

$$\kappa \ell^{sA}_t(x)^2 \phi (W^A_t(x)/P^A_t)^{-1} = (\phi - 1)(\ell^{sA}_t(x)/C^A_t) \tag{11}$$

The right-hand side of (11) represents the marginal consumption utility of additional labor income resulting from a decrease in the nominal wage rate. This term is positive because $\phi > 1$. The left-hand side represents the marginal disutility of an associated increase in labor effort. Hence, each monopolistically competitive household uses (11) to set its wage rate. 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:

$$\max_{P^A_{At}(z)} \Pi_{At}(z) = P^A_{At}(z) y_{At}(z) - \int_0^{1/3} W_t^A(z) \ell_{At}(z, x)\, dx = (P^A_{At}(z) - W^A_t) y_{At}(z)$$

$$\text{subject to } y_{At}(z) = (P^A_{At}(z)/P^A_t)^{-\theta} C^w_t$$

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 given, (12) yields $P^A_{At}(z) = P^A_{At}$, $z \in [0, m_t]$. These relationships imply that each firm located in country *A* supplies the same quantity of goods. Similarly, other firms located in different country have the price mark-up that is analogous to equation (12). Denoting the maximized real profit flows of country *j*-located firms by $\Pi_{jt}(z)/P^j_t$, and substituting (8) and (12) into $\Pi_{jt}(z)$ yields:

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

2.3. Relocation behavior

The driving force for relocation to other countries is differences in current real profits between two bounded countries.[9] Following the formulation in 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 for relocation between countries *A* and *B* is formulated as follows:

$$m_t - m_{t-1} = \gamma[(1-\tau^{A}_{t})\Pi_{At}(z)/P_t^{A} - (1-\tau^{B}_{t})\Pi_{Bt}(z)/P_t^{B}] = \gamma[(1-\tau^{A}_{t})\Pi_{At}(z)/P_t^{A} - (1-\tau^{B}_{t})(E^{A}_{t}/E^{B}_{t})\Pi_{Bt}(z)/P_t^{A}] \tag{14}$$

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

$$n_t - n_{t-1} = \gamma[(1-\tau^{B}_{t})\Pi_{Bt}(z)/P_t^{B} - (1-\tau^{C}_{t})\Pi_{Ct}(z)/P_t^{C}] = \gamma[(1-\tau^{B}_{t})\Pi_{Bt}(z)/P_t^{B} - (1-\tau^{C}_{t})E^{B}_{t}\,\Pi_{Ct}(z)/P_t^{B}] \tag{15}$$

where γ ($0 \leq \gamma < \infty$) is a constant positive parameter that determine the degree of firm mobility between two bounded countries: a larger value of γ implies higher firm mobility between countries. Intuitively, the parameter γ reflects the costs falling on mobile firms in their new locations. Examples include the costs of finding appropriate

[9] In the literature on multinational firms, Helpman et al. (2004) and Eckel and Egger (2009) derive the share of multinational firms endogenously by using this type of profit differential between exporting and multinational activity.

plants, training the local workforce, and adapting to the local legal system. Because of these costs, firms cannot move instantaneously to a better location even if a profit gap between two countries provides the motivation.

2.4. Market conditions

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

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

This means that the net supply of bonds worldwide is zero. In addition, the money markets are assumed always to clear in all countries, so that 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 $M^C{}_t = \int_{2/3}^{1} M_t^C(x)dx$, respectively.

3. Steady state values

In this section, we derive the solution for a symmetric steady state in which all variables are constant, initial net foreign assets are zero ($B^h{}_0 = 0$) and $\tau^h{}_0 = 0$, $h = A, B, C$.[10] Henceforth, 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:

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

[10] In the symmetric steady state, we drop the index value "*x*" from all variables in order to simplify notation.

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:

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

Equation (20) shows that not only do all firms worldwide produce the same amount of output, it also shows that all households worldwide consume this output and supply the labor required to produce this output. Substituting C^w_{ss} from equation (20) into equation (13) yields the following steady-state levels of real profit flows of country *j*-located firms, which are equal:

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

4. A log-linearized analysis

To examine the macroeconomic effects of an unanticipated temporary corporate tax reduction, 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. For any variable *X*, we use $\hat{X}$ to denote short-run percentage deviations from the initial steady-state value, i.e., $\hat{X} = dX_1/X_{ss,0}$, where $X_{ss,0}$ is the initial, zero-shock steady-state value, and subscript 1 denotes the period in which the shock takes place.

These short-run percentage deviations are consistent with the length of nominal wage contracts. Thus, nominal wages and goods prices can be determined as $\hat{W}^j = \hat{P}_j^j(z) = 0$, $j = A, B, C$, in the short-run log-linearized equations. In addition, we use $\overline{X}$ to denote long-run percentage deviations from the initial steady-state value, i.e., $\overline{X} = dX_2 / X_{ss,0} = dX_{ss} / X_{ss,0}$, which is consistent with flexible nominal wages. Note that $X_2 = X_{ss}$ because the new steady state is reached at period 2 (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 setting $\hat{P}_j^j(z) = 0$, $j = A, B, C$, we obtain the following log-linearized expression for the international distribution of firms:

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

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

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* ($\hat{m} > 0$), and a reduction in τ^B ($d\tau^B < 0$) leads to the relocation of some firms from country *A* to country *B* ($\hat{m} < 0$). In addition, equation (22) shows that under a given E^B, an exchange rate depreciation of country *A*'s currency ($\hat{E}^A - \hat{E}^B > 0$) induces relocation of firms located in country *B* towards the country *A*.[11]

[11] This result is consistent with the evidence found in the empirical literature on the relationship between exchange rates and FDI (e.g., Cushman, 1988, Caves, 1989, Froot and Stein, 1991, Campa, 1993, Klein and Rosengren, 1994, Blonigen, 1997, Goldberg and Klein, 1998, Bénassy-quéré et al, 2001, Chakrabarti and Scholnick, 2002, Kiyota and Urata, 2004, and Bolling et al, 2007).

Intuitively, with fixed nominal wages, which cause nominal product prices to be sticky because of mark-up pricing by monopolistic product suppliers, the depreciation in country *A*'s currency increases relative production of country *A*'s goods through the 'expenditure-switching effect'; i.e., $\hat{y}^A - \hat{y}^B = \theta\left(\hat{E}^A - \hat{E}^B\right)$. [12] 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 E^B in equation (23) on *n* can be explained analogously.

5. The effects of corporate tax reduction

Now, we consider the effects of a temporary corporate tax reduction in each country.

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:

[12] The expenditure-switching effect arises intuitively because exchange rate depreciation causes a decrease in the relative real price of country *A*'s goods for households in all countries so that world consumption demand switches toward country *A*'s goods. Corsetti et al (2005) also define this as 'competitive effect'.

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

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

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

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

where

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

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

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

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

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

$$\tilde{\theta} \equiv (\theta - 1)/\theta$$

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 $E^A - E^B$ when γ is large (small). Equation (25) indicates that a reduction in country *A*'s corporate tax leads to exchange rate depreciation (appreciation) in E^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 $\hat{C}^A - \hat{C}^B$, 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 shall call this 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 tax decrease shifts tax revenue away from country *A* toward countries *B* and *C*, because the burden of country *A*'s corporate tax is partly borne by rent income repatriation to households in countries *B* and *C*. Hereafter, we shall call this 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*, $\hat{C}^A - \hat{C}^B > (<) 0$. 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). 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 $E^A - E^B$ when γ is large ($\hat{E}^A - \hat{E}^B < 0$, see equation (24)). This happens because, given that the demand for real money balances is increasing with consumption (as implied by the money demand function), 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, $\hat{E}^A - \hat{E}^B > 0$.

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 ($\hat{E}^B > 0$, 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 shall call this the '*BC* relocation effect'. Furthermore, recall that a decrease in the corporate tax redistributes rent incomes 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, $\hat{C}^C$ 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)). Accordingly, country *A*'s currency must appreciate and increase the supply of real money balances in country *A* to restore money market equilibrium. ($\hat{E}^A < 0$, 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, $\hat{E}^A > 0$.

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.

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:

$$\hat{E}^A - \hat{E}^B = \left[\frac{\alpha_1 + \alpha_2}{(\alpha_2)^2 - (\alpha_1)^2}\right] T_2 \ > (<)\ 0, \text{ when } \gamma \text{ is large (small)} \tag{33}$$

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

$$\hat{C}^A - \hat{C}^B = -\left(\hat{E}^A - \hat{E}^B\right) \ < (>)\ 0, \text{ when } \gamma \text{ is large (small)} \tag{35}$$

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

where

$$T_1 = -9\gamma\theta_1\tilde{\theta}(\theta - 1)^{-1} d\tau^B + \theta^{-1} d\tau^B \tag{37}$$

$$T_2 = 9\gamma\theta_1\tilde{\theta}(\theta - 1)^{-1} d\tau^B - \theta^{-1} d\tau^B \tag{38}$$

The results in (33), (34), (35), and (36) 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 (35) and (36), the corporate tax reduction has two effects on $\hat{C}^A - \hat{C}^B$ and $\hat{C}^B - \hat{C}^C$, 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 shifts tax revenue away from country *B* toward countries *A* and *C*, because the burden of country *B*'s corporate tax is partly borne by rent income repatriation to households in countries *A* and *C*. Therefore, the tax redistribution effect is negative for country *B* and positive for countries *A* and *C*. Thus, the net outcomes in (35) and (36) 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*, $\hat{C}^A - \hat{C}^B < (>) 0$ (see equation (35)) and a proportionate increase (decrease) in the relative consumption level between countries *B* and *C*, $\hat{C}^B - \hat{C}^C > (<) 0$ (see equation (36)). 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 (36)). 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 $\hat{C}^A - \hat{C}^B$ ($\hat{C}^B - \hat{C}^C$) is negative (positive). The opposite mechanism is also valid when γ is small.

Under a given E^A, the relative increase in consumption in country *B* leads not only to exchange rate depreciation in $E^A - E^B$ but also to exchange rate appreciation in E^B when γ is large (see equations (33) and (34)). This happens because, given that the demand for

real money balances is increasing with consumption, country *B*'s currency must appreciate ($\hat{E}^B < 0$) 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 $\hat{E}^A - \hat{E}^B < 0$ and $\hat{E}^B > 0$.

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:

$$\hat{E}^A - \hat{E}^B = \left[\frac{\alpha_2 T_2 - \alpha_1 T_1}{(\alpha_2)^2 - (\alpha_1)^2}\right] > (<)\ 0, \text{ when } \gamma \text{ is large (small)} \tag{39}$$

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

$$\hat{C}^B - \hat{C}^C = -\hat{E}^B < (>)\ 0, \text{ when } \gamma \text{ is large (small)} \tag{41}$$

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

where

$$T_1 = 3\gamma\theta_1\tilde{\theta}(\theta - 1)^{-1} d\tau^C \tag{43}$$

$$T_2 = -6\gamma\theta_1\tilde{\theta}(\theta-1)^{-1}d\tau^C + \theta^{-1}d\tau^C \tag{44}$$

The results in (39), (40), (41), and (42) 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 (41), the corporate tax reduction has two effects on $\hat{C}^B - \hat{C}^C$, 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 tax revenue away from country *C* toward countries *A* and *B* because the burden of country *C*'s corporate tax is partly borne by rent income repatriation to households in countries *A* and *B*. Therefore, the tax redistribution effect is negative for country *C* and positive for countries *A* and *B*. Thus, the net outcome in (41) 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 $\hat{C}^B - \hat{C}^C$ (see equation (41)). 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 $\hat{C}^B - \hat{C}^C$ 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 E^B when γ is large ($\hat{E}^B > 0$, see equation (40)). 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 rent incomes 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 $\hat{C}^A$ 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 $\hat{C}^A$ 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 (41)). Therefore, the relative consumption level between countries *C* and *A* decreases when γ (the degree of firm mobility) is large ($\hat{C}^A - \hat{C}^C < 0$, see equation (42)). Accordingly, country *A*'s currency must depreciate and decrease the supply of real money balances in country *A* to restore money market equilibrium. ($\hat{E}^A - \hat{E}^B > 0$, see equation (39)) 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*, $\hat{C}^A - \hat{C}^C > 0$ and leads to exchange rate appreciation, $\hat{E}^A - \hat{E}^B < 0$.

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

This paper employed a three-country model with international firm mobility to examine the impact on consumption and the exchange rates of a 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 corporate tax reduction. From this model, it was found that when the degree of firm mobility is large (small), a 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.

However, the model developed here is rather simple in a number of respects. This suggests many directions for future research. First, this paper may yield results that are more interesting if the current model is modified to include sunk costs, as in Russ (2007).[13] Further, the consideration of the effects of corporate tax reduction under a fixed exchange rate system in our model is noteworthy. These issues remain for future research.

[13] Campa (1993) finds the negative effect of sunk costs (e.g., investment in advertising and media promotion) on industry entry into the US during the 1980s. Brainard (1997) also finds that overseas production by multinationals decreases with the fixed costs of production.

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