

Tezukayama RIEB Discussion Paper Series No. 14

International relocation and the effects of monetary policy
in a three-country model with nominal rigidities

Wataru Johdo

Faculty of Economics, Tezukayama University

April 2015

Tezukayama University
Research Institute for Economics and Business
7-1-1 Tezukayama, Nara 631-8501, Japan

International relocation and the effects of monetary policy in a three-country model with nominal rigidities

Wataru Johdo*

Tezukayama University

April 2015

Abstract

This paper extends the new open economy macroeconomics model of Corsetti et al. (2000) to include international relocation of firms, and explores the effects of monetary expansion by each country on the exchange rates, international relocation, and relative consumption levels. The paper shows a new international transmission mechanism: the exchange rate depreciation induced by monetary expansion in one of the three countries (regardless of the source of the expansion) causes foreign firms to relocate to that country, and consequently raises the relative consumption level of that country. In contrast, the monetary expansion can be detrimental to other countries.

JEL classification codes: E52; F20; F31; F41

*Wataru Johdo, Department of Economics, Tezukayama University, 7-1-1, Tezukayama, Nara 631-8501, Japan. Tel.: +81-742-48-9380; fax: +81-742-46-4994. E-mail address: johdo@tezukayama-u.ac.jp

1. Introduction

In the new open economy macroeconomics (hereafter, NOEM) literature, a number of studies have focused on how the macroeconomic activity of each country and the exchange rate are influenced by monetary policy shocks under monopolistic distortions and price rigidities (see, e.g., Obstfeld and Rogoff, 1995 and 2002, Lane, 1997, Betts and Devereux, 2000a and 2000b, Hau, 2000, Bergin and Feenstra, 2001, Corsetti and Pesenti, 2001 and 2005, Cavallo and Ghironi, 2002, Devereux and Engel, 2002, Kollmann, 2001 and 2002, and Smets and Wouters, 2002).¹ The benchmark model of Obstfeld and Rogoff (1995) shows that a domestic monetary expansion raises foreign and domestic output and welfare through the first-order effect of increasing world consumption.

However, most NOEM models have assumed that firms are immobile across countries. Although it is feasible to explore the effects of a monetary policy shock in this framework under the assumption of a fixed international distribution of firms, recent empirical evidence suggests that exchange rates affect the production locations of firms and their foreign direct investments (see, e.g., Cushman, 1985 and 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, and Farrell et al., 2004).² For example, Campbell and Lapham (2004) find that exchange rate movements have a significant effect on the relocation of establishments in U.S. retail trade industries located near the U.S.-Canada border. In

¹ Other related references include Benigno (2002), Engel (2002), Warnock (2003), Devereux (2004), Andersen and Beier (2005), Sutherland (2005), Tille (2008), Johdo (2013), and Sousa (2013).

² For a survey of the literature examining determinants of foreign direct investment, see Blonigen (2005).

addition, in recent years, the entry regulations governing multinational firms in developed (e.g., Japan, South Korea, the US, and the European Union) and newly emerging (e.g., China, ASEAN, India, Russia, Mexico and Brazil) countries alike have been substantially liberalized. As a result, multinational firms from the US, Japan, South Korea, and China have very actively invested across national borders.

However, little attention has been paid in the NOEM literature to the relationship between international relocation of firms and macroeconomic variables, including consumption and the exchange rate. The exception is Johdo (2015), who presents a NOEM model with international relocation of firms.³ In this literature, 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 monetary expansion on the exchange rate and consumption of each country, leading to firm relocation to the other country. 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 monetary expansion on international relocation of firms 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 into each other's markets. It is, therefore, appropriate that a multicountry model be adopted to examine how allowing for international

³ Aizenman (1994), Devereux and Engel (2001), Cavallari (2004, 2005) and Chu (2005) all consider (optimal) monetary policy in a representative firm framework with horizontal foreign direct investment, but do not allow for the endogenous relocation of firms.

relocation of firms affects the impacts of a monetary expansion on consumption and exchange rates.

Given this motivation, this paper investigates the impacts of monetary shocks on the international distribution of firms, the exchange rate, and consumption by generalizing the three-country model of Corsetti et al. (2000) to include international relocation of firms. In particular, a novel feature of our model is that the international distribution of firms responds to exchange rate movements as in Johdo (2015).⁴ This implies that our model generates a new international transmission effect that operates through the international relocation of firms, which has been overlooked by the benchmark model of Corsetti et al. (2000).

In this analysis, we show that the exchange rate depreciation induced by a monetary expansion in one of three countries (regardless of the source of the expansion) causes firms whose production sites are abroad to relocate to that country, which raises the relative consumption of that country. This is because the relocation increases labor demand in that country, which in turn raises labor income. In contrast, the monetary expansion can be detrimental to other countries, in terms of relative consumption level. This is because other countries experience the opposite response to the firm relocation and exchange rate adjustment.

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 monetary policy shocks on the international distribution of firms across the

⁴ Recently empirical evidence shows that the number of firms is reacting to monetary policy shocks (see e.g., Bergin and Corsetti, 2006).

three countries, the exchange rate, and relative consumption levels. The final section summarizes the findings and concludes the paper.

2. The model

In this section, we construct a perfect-foresight, three-country model with international relocation of firms. This model is similar to the one presented by Johdo (2014), in which there are two countries in the world economy: home country and foreign country. In our model, the economy consists of three countries and they 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 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. In this model, country A consists of those producers in the interval $[0, n_t]$, country B consists of those producers in the interval $[n_t, m_t]$, and the remaining $[m_t, 1]$ producers are in country C , where n_t and m_t are endogenous variables. Finally, we assume that firms are mobile internationally but their owners are not.

2.1. Households

The intertemporal objective function of representative household x in country h at time 0, with $h = A, B, C$, is:

$$U^h_0(x) = \sum_{t=0}^{\infty} \beta^t (\log C^h_t(x) + \chi \log(M^h_t(x)/P^h_t) - (\kappa/2)(\ell^{sh}_t(x))^2), \quad (1)$$

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 real bonds, earn wage income by supplying labor, and receive profits from all firms equally.⁵ Therefore, a typical household in country h faces the following budget constraint:

$$\begin{aligned} E^h_t B^h_{t+1}(x) + M^h_t(x) &= (1+i_t)E^h_t B^h_t(x) + M^h_{t-1}(x) + W^h_t(x)\ell^{sh}_t(x) - P^h_t C^h_t(x) - P^h_t z^h_t \\ &+ ((E^h_t/E^A_t) \int_0^{m_t} \Pi_t^A(z) dz + (E^h_t/E^B_t) \int_n^{m_t} \Pi_t^B(z) dz + E^h_t \int_{m_t}^1 \Pi_t^C(z) dz), \end{aligned} \quad (2)$$

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

⁵ In a related two-country monopolistic trade model, Corsetti et al (2005) posit that each home and foreign household receives an equal share of profits of all firms. In contrast, Devereux and Engel (2001), Cavallari (2004), Ghironi and Melitz (2005), Lubik and Russ (2006), and Russ (2007) posit that each household only owns domestic firms in all these models.

household x in period t ; $\int_0^{n_t} \Pi_t^A(z) dz$, $\int_{n_t}^{m_t} \Pi_t^B(z) dz$, and $\int_{m_t}^1 \Pi_t^C(z) dz$ represent the total nominal profit flows of firms located in countries A , B , and C , respectively; $P_t^h C_t^h(x)$ represents nominal consumption expenditure; and τ_t^h denotes real lump-sum transfers from the government in period t . 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 seignorage revenues derived from printing the national currency are rebated to the public in the form of lump-sum transfers. Hence, the government budget constraint in country h is $0 = s^h \tau_t^h + [(M_t^h - M_{t-1}^h)/P_t^h]$, where M_t^h is aggregate money supply and $s^h = 1/3$ denotes the population share of country h in the world population.

Here, we assume that any monopolistically competitive firm that operates in every country employs the same production technology. In country A , firm $z \in [0, n_t]$ 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:

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

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:

$$C_t^h(x) = \left[\int_0^{n_t} c_{At}^h(z, x)^{(\theta-1)/\theta} dz + \int_{n_t}^{m_t} c_{Bt}^h(z, x)^{(\theta-1)/\theta} dz + \int_{m_t}^1 c_{Ct}^h(z, x)^{(\theta-1)/\theta} dz \right]^{0/(\theta-1)}, \quad (5)$$

where $\theta > 1$ is the elasticity of substitution among varieties produced within each country; and $c_{jt}^h(z, x)$ 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 index is defined as:

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

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

$$C^h_j(z, x) = (P^h_j(z)/P^h)^{-\theta} C^h(x), \quad j = A, B, C. \quad (6)$$

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 :

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

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:

$$y_{jt}(z) = (P^j_{jt}(z)/P^j_t)^{-\theta} C^w_t, \quad j = A, B, C, \quad (8)$$

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:

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

$$M^h_t(x)/P_t = \chi C^h_t(x)[(1 + i^h_{t+1})E^h_{t+1}/((1 + i^h_{t+1})E^h_{t+1} - E^h_t)], \quad (10)$$

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 $\ell_t^{sA}(x) = \int_0^{n_t} \ell_{At}(z, x) dz$, $x \in [0, 1/3]$, 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_t^A , P_t^A , and n_t as given, substituting $\ell_t^{sA}(x) = \int_0^{n_t} \ell_{At}(z, x) dz$ and equation (4) into the budget constraint given by (2), and maximizing the lifetime utility given by (1) with respect to the nominal wage rate $W_t^A(x)$, we obtain the following first-order condition for the optimal nominal wage rate, $W_t^A(x)$:

$$\kappa \ell_t^{sA}(x)^2 \phi (W_t^A(x)/P_t^A)^{-1} = (\phi - 1)(\ell_t^{sA}(x)/C_t^A). \quad (11)$$

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_t^A , P_{At}^A , and P_t^A , n_t , (3), and subject to (8), the country A -located firm z faces the following profit-maximization problem:

$$\max_{P_{At}^A(z)} \Pi_{At}(z) = P_{At}^A(z)y_{At}(z) - \int_0^{1/3} W_{it}^A(z)\ell_{At}(z, x)dx = (P_{At}^A(z) - W_{it}^A) y_{At}(z),$$

$$\text{subject to } y_{At}(z) = (P_{At}^A(z)/P_t^A)^{-\theta} C_t^w.$$

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

$$P_{At}^A(z) = (\theta/(\theta - 1))W_{it}^A. \quad (12)$$

Since W^A is given, (12) yields $P_{At}^A(z) = P_{At}^A$, $z \in [0, n_t]$. 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 $\Pi_{jt}(x)/P_t^j$, and substituting (8) and (12) into Π_j yields:

$$\Pi_{jt}(z)/P_t^j = (1/\theta)(P_{jt}^j(z)/P_t^j)^{1-\theta} C_t^w, \quad j = A, B, C. \quad (13)$$

2.3. Relocation behavior

We assume that the driving force for relocation to other countries is differences in current real profits between two countries.⁶ In addition, 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:

⁶ 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.

$$n_t - n_{t-1} = \gamma[\Pi_{A_t}(z)/P_t^A - \Pi_{B_t}(z)/P_t^B] = \gamma[\Pi_{A_t}(z)/P_t^A - (E_t^A/E_t^B)\Pi_{B_t}(z)/P_t^A]. \quad (14)$$

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

$$m_t - m_{t-1} = \gamma[\Pi_{B_t}(z)/P_t^B - \Pi_{C_t}(z)/P_t^C] = \gamma[\Pi_{B_t}(z)/P_t^B - E_t^B\Pi_{C_t}(z)/P_t^B], \quad (15)$$

where γ ($0 \leq \gamma < \infty$) is a constant positive parameter that determine the degree of firm mobility between two 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 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. As we explain in Section 4, this relocation adjustment makes our international transmission mechanism differ crucially from those in models in which the international allocation of firms is fixed.⁷

2.4. Market conditions

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

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

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

⁷ By using a closed economy model with firm entry, Bergin and Corsetti (2006) show numerically that there is some persistence in the effect of monetary expansion on entry of firms.

are given by $M_t^A = \int_0^{1/3} M_t^A(x)dx$, $M_t^B = \int_{1/3}^{2/3} M_t^B(x)dx$, and $M_t^C = \int_{2/3}^1 M_t^C(x)dx$, 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 ($B_0^h = 0$), $h = A, B, C$. 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:

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

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

$$n_{ss} = 1/3, \quad (18)$$

$$m_{ss} = 2/3. \quad (19)$$

The steady state output levels are:

$$y_{hss} = \ell_{ss}^{sh} = C_{ss}^h = C_{ss}^w = ((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}, \quad h = A, B, C. \quad (20)$$

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_{ss}^w from equation (20) into equation

(13) yields the following steady-state levels of real profit flows of country j -located firms, which are equal:

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

From equations (10), (17), and (20), the real balances of country h agents are identical in the steady state:

$$M_{ss}^h/P_{ss}^h = \chi((1+\delta)/\delta)((\phi-1)/\phi)^{1/2}((\theta-1)/\theta)^{1/2}(1/\kappa)^{1/2}, \quad h = A, B, C. \quad (22)$$

From these money demand equations, and given PPP, the steady-state nominal exchange rates are determined by the ratio of M_{ss}^h to M_{ss}^C ; i.e., $E_{ss}^h = M_{ss}^h/M_{ss}^C$, $h = A, B, C$.

4. A log-linearized analysis

To examine the macroeconomic effects of an unanticipated permanent monetary policy shock, we solve a log-linear approximation of the system around the initial, zero-shock steady state with $B_{ss,0}^h = 0$, $h = A, B, C$, 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 $\hat{W}^h = \hat{P}_j^j(z) = 0$, $h, j = A, B, C$, in the short-run log-linearized equations. In addition, we use \bar{X} to denote long-run percentage deviations from the initial steady-state value, i.e.,

$\bar{X} = dX_2/X_{ss,0} = dX_{ss}/X_{ss,0}$, which is consistent with flexible nominal wages. Note that $X_2 = X_{ss}$ because the new steady state is reached at period 2.

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 expressions for the international distribution of firms:

$$\hat{n} = 3\gamma((\phi - 1)/\phi)^{1/2}((\theta - 1)/\theta)^{3/2}(1/\kappa)^{1/2}(\hat{E}^A - \hat{E}^B), \quad (23)$$

$$\hat{m} = (3\gamma/2)((\phi - 1)/\phi)^{1/2}((\theta - 1)/\theta)^{3/2}(1/\kappa)^{1/2}\hat{E}^B. \quad (24)$$

Equation (23) 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 .⁸ 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., $\hat{y}^A - \hat{y}^B = \theta(\hat{E}^A - \hat{E}^B)$.⁹ This increases the relative profits of country A -located firms, and consequently, firms located in country B relocate to the country A . Equation (23) also shows that nominal exchange rate changes have greater effects the greater is the flexibility of relocation (the larger is

⁸ 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).

⁹ 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'.

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 impact of E^B in equation (24) on the international relocation of firms between countries B and C can be explained analogously.

5. Monetary policy shocks

Now, we consider the effects of an unanticipated permanent monetary policy shock in each country.

5.1. The case of $\hat{M}^A = \bar{M}^A > 0, \hat{M}^B = \bar{M}^B = \hat{M}^C = \bar{M}^C = 0$

In this subsection, we focus on the impacts of a permanent monetary shock in country A : $\hat{M}^A = \bar{M}^A > 0$. In this case, the closed-form solutions for the six key variables are as follows:

$$\hat{E}^A - \hat{E}^B = \left[\frac{\alpha_2 M_2 - \alpha_1 M_1}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^A > 0, \quad (25)$$

$$\hat{E}^B = \left[\frac{\alpha_2 M_1 - \alpha_1 M_2}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^A > 0, \quad (26)$$

$$\hat{n} = 3\gamma\theta_1 \left[\frac{\alpha_2 M_2 - \alpha_1 M_1}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^A > 0, \quad (27)$$

$$\hat{m} = (3\gamma/2)\theta_1 \left[\frac{\alpha_2 M_1 - \alpha_1 M_2}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^A > 0, \quad (28)$$

$$\hat{C}^A - \hat{C}^B = \hat{M}^A - (\hat{E}^A - \hat{E}^B) = \left\{ 1 - \left[\frac{\alpha_2 M_2 - \alpha_1 M_1}{(\alpha_2)^2 - (\alpha_1)^2} \right] \right\} \hat{M}^A > 0, \quad (29)$$

$$\hat{C}^A - \hat{C}^C = (\hat{E}^A - \hat{E}^B) + \hat{E}^B > 0, \quad (30)$$

where

$$M_1 = \delta^{-1} \left\{ 1 + 2\tilde{\theta} \left[\frac{(6\gamma\theta_1 + \theta)(1 + 6\gamma\theta_1 + \theta) - 9\gamma^2\theta_1^2}{(1 + 6\gamma\theta_1 + \theta)^2 - 9\gamma^2\theta_1^2} \right] - \tilde{\theta} \right\} + 1 > 0, \quad (31)$$

$$M_2 = -\delta^{-1} \left[\frac{6\gamma\theta_1\tilde{\theta}}{(1 + 6\gamma\theta_1 + \theta)^2 - 9\gamma^2\theta_1^2} \right] < 0, \quad (32)$$

$$\alpha_1 = M_1 + \tilde{\theta}(\theta - 1) + 6\gamma\theta_1\tilde{\theta} > 0, \quad (33)$$

$$\alpha_2 = M_2 - 3\gamma\theta_1\tilde{\theta} < 0, \quad (34)$$

$$\theta_1 = ((\phi - 1)/\phi)^{1/2} ((\theta - 1)/\theta)^{3/2} (1/\kappa)^{1/2} > 0, \quad (35)$$

$$\tilde{\delta} \equiv (1 + \delta)/\delta, \quad \tilde{\theta} \equiv (\theta - 1)/\theta, \quad \tilde{\phi} \equiv (\phi - 1)/\phi.$$

Equations (25) and (26) indicate that an unanticipated monetary expansion in country A leads to exchange rate depreciation in $E^A - E^B$ and E^B . Equation (27) shows that an unanticipated monetary expansion in country A causes country B's firms to relocate to country A. Equation (28) shows that an unanticipated monetary expansion in country A causes country C's firms to relocate to country B. Equations (29) and (30) show that the relative consumption levels of country A rise when there is an unanticipated monetary expansion in country A. The results (25), (27), and (29) can be explained intuitively as

follows. An unanticipated monetary expansion in country A requires an instantaneous depreciation of its currency to restore money market equilibrium for a given level of initial relative consumption. Under a given E^B , this then leads to a reduction in the real price of country A 's goods relative to country B 's goods because of the depreciation of country A 's currency (see equation (25)), which causes world demand to switch from country B 's goods to country A 's goods. Hereafter, we shall call this the 'expenditure-switching effect'. This demand shift increases the relative profits of firms located in country A , which causes firms located in country B to relocate to country A . Hereafter, we shall call this the 'relocation effect' (see equation (27)). As a result, the relocation raises the relative labor income of country A , which raises the relative consumption of country A (see equation (29)).

On the other hand, the results (26), (28), and (30) can be explained intuitively as follows. From the 'relocation effect' of (27), the consumption in country B decreases, which requires a depreciation of country B 's currency to restore money market equilibrium. Therefore, the monetary expansion in country A reduces the real price of country B 's goods relative to country C 's goods because of the depreciation of country B 's currency (see equation (26)), which causes world demand to switch from country C 's goods to country B 's goods. This demand shift increases the relative profits of firms located in country B , which causes firms located in country C to relocate to country B (see equation (28)). As a result, the relocation reduces the relative labor income of country C , which decreases the relative consumption of country C (see equation (30)). In sum, when relocation is included in the model, a permanent monetary shock in country A always benefits country A in terms of relative consumption level, while it can be detrimental not only to country B , but also to country C .

5.2. The case of $\hat{M}^B = \bar{M}^B > 0, \hat{M}^A = \bar{M}^A = \hat{M}^C = \bar{M}^C = 0$

In this subsection, we focus on the impacts of a permanent monetary shock in country B : $\hat{M}^B = \bar{M}^B > 0$. In this case, the closed-form solutions for the six key variables are as follows:

$$\hat{E}^A - \hat{E}^B = \left[\frac{(\alpha_1 + \alpha_2)(M_1 + M_2)}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^B < 0, \quad (36)$$

$$\hat{E}^B = \left[\frac{(\alpha_1 + \alpha_2)(M_2 - M_1)}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^B > 0, \quad (37)$$

$$\hat{n} = 3\gamma\theta_1 \left[\frac{(\alpha_1 + \alpha_2)(M_1 + M_2)}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^B < 0, \quad (38)$$

$$\hat{m} = (3\gamma/2)\theta_1 \left[\frac{(\alpha_1 + \alpha_2)(M_2 - M_1)}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^B > 0, \quad (39)$$

$$\hat{C}^A - \hat{C}^B = -\hat{M}^B - (\hat{E}^A - \hat{E}^B) = -\left\{ 1 + \frac{(\alpha_1 + \alpha_2)(M_1 + M_2)}{(\alpha_2)^2 - (\alpha_1)^2} \right\} \hat{M}^B < 0, \quad (40)$$

$$\hat{C}^B - \hat{C}^C = \hat{M}^B - \hat{E}^B = \left\{ 1 - \frac{(\alpha_1 + \alpha_2)(M_2 - M_1)}{(\alpha_2)^2 - (\alpha_1)^2} \right\} \hat{M}^B > 0. \quad (41)$$

The above results can be explained intuitively as follows. First, an unanticipated monetary expansion in country B requires an instantaneous depreciation of its currency to restore money market equilibrium for a given level of initial relative consumptions. Under a given E^A , this then leads to a reduction in the real price of country B 's goods

relative to both country A 's and country C 's goods because of the depreciation of country B 's currency (see equations (36) and (37)), which causes world demand to switch from both country A 's and country C 's goods to country B 's goods (the expenditure-switching effect). These demand shifts increase the relative profits of firms located in country B , which causes firms located in countries A and C to relocate to country B (the relocation effect; see equations (38) and (39)). As a result, the relocation increases the labor income of county B and decreases the labor incomes of countries A and C , which raises the relative consumptions of country B (see equation (40) and (41)). In sum, when relocation is included in the model, a permanent monetary shock in country B always benefits country B in terms of relative consumption level, while it can be detrimental both to country A and to country C .

5.3. The case of $\hat{M}^C = \bar{M}^C > 0, \hat{M}^A = \bar{M}^A = \hat{M}^B = \bar{M}^B = 0$

In this subsection, we focus on the impacts of a permanent monetary shock in country C : $\hat{M}^C = \bar{M}^C > 0$. In this case, the closed-form solutions for the six key variables are as follows:

$$\hat{E}^A - \hat{E}^B = - \left[\frac{\alpha_2 M_1 - \alpha_1 M_2}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^C < 0, \quad (42)$$

$$\hat{E}^B = - \left[\frac{\alpha_2 M_2 - \alpha_1 M_1}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^C < 0, \quad (43)$$

$$\hat{n} = -3\gamma\theta_1 \left[\frac{\alpha_2 M_1 - \alpha_1 M_2}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^C < 0, \quad (44)$$

$$\hat{m} = -(3\gamma/2)\theta_1 \left[\frac{\alpha_2 M_2 - \alpha_1 M_1}{(\alpha_2)^2 - (\alpha_1)^2} \right] \hat{M}^C < 0, \quad (45)$$

$$\hat{C}^B - \hat{C}^C = -\hat{M}^C - \hat{E}^B = -\left\{ 1 - \frac{\alpha_2 M_2 - \alpha_1 M_1}{(\alpha_2)^2 - (\alpha_1)^2} \right\} \hat{M}^C < 0, \quad (46)$$

$$\hat{C}^A - \hat{C}^C = -(\hat{E}^A - \hat{E}^B) - \hat{M}^C - \hat{E}^B = -\left\{ 1 - \frac{(\alpha_1 - \alpha_2)(M_1 + M_2)}{(\alpha_2)^2 - (\alpha_1)^2} \right\} \hat{M}^C < 0. \quad (47)$$

The above results can be explained intuitively as follows. First, an unanticipated monetary expansion in country C requires an instantaneous depreciation of country C 's currency to restore money market equilibrium for a given level of initial relative consumptions ($\hat{E}^A = \hat{E}^B < 0$, see equation (43)). Therefore, in this stage, country A 's currency relative to B 's remains unchanged because $\hat{E}^A - \hat{E}^B = 0$. Therefore, the monetary expansion in country C reduces the real price of country C 's goods relative to country B 's goods because of the depreciation of country C 's currency, which causes world demand to switch from country B 's goods to country C 's goods (the expenditure-switching effect). This demand shift increases the relative profits of firms located in country C , which causes firms located in country B to relocate to country C (the relocation effect; see equation (45)). The relocation then raises the labor income of country C and decreases the labor income of country B , which raises the relative consumption of country C (see equations (46)). Because of these effects, country B 's currency must depreciate to restore equilibrium in the market for real balances. This depreciation of country B 's currency weakens the initial appreciation of its currency, and consequently the relative change in country A 's currency is negative ($\hat{E}^A - \hat{E}^B < 0$, see equation (42)). Furthermore, this then leads to a reduction in the real price 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 causes firms located in country A to relocate to country B (see equation (44)). The relocation then decreases the labor income of country A , which decreases the relative consumption of country A (see equations (47)). In sum, when relocation is included in the model, a permanent monetary shock in country C always benefits country C in terms of relative consumption level, while it can be detrimental not only to country B , but also to country A .

6. Conclusion

In this paper, we have generalized the Corsetti *et al.* (2000) model, which allows for international relocation of firms among three countries. We have used this generalized model to consider the question of how allowing for international relocation of firms affects the responses of both consumption and exchange rates to monetary shocks. From this analysis, we succeeded in showing explicitly the effects of monetary policy shocks, which lead to firm relocation among three countries, and it was found that when relocation matters, a permanent monetary shock in one of the three countries always benefits that country, while it can be detrimental to the other two countries, in terms of relative consumption level.

References

Aizenman, J., 1994. Monetary and real shocks, productive capacity and exchange rate regimes. *Economica* 61, 407–434.

- Andersen, T.M., Beir, N.C., 2005. International transmission of transitory and persistent monetary shocks under imperfect information. *Journal of International Economics* 66, 485–507.
- Bénassy-quéré, A., Fontagné, L., Lahréche-révil, A., 2001. Exchange-rate strategies in the competition for attracting foreign direct investment. *Journal of the Japanese and International Economies* 15, 178–198.
- Benigno, P., 2002. A simple approach to international monetary policy coordination. *Journal of International Economics* 57, 177–196.
- Bergin, P.R., Corsetti, G., 2006. Towards a theory of firm entry and stabilization policy. NBER Working Paper, 11821.
- Bergin, P.R., Feenstra, R.C., 2001. Pricing-to-market, staggered contracts, and real exchange rate persistence. *Journal of International Economics* 54, 333–359.
- Betts, C., Devereux, M., 2000a. Exchange rate dynamics in a model of pricing-to-market. *Journal of International Economics* 50, 215–244.
- Betts, C., Devereux, M., 2000b. International monetary policy coordination and competitive depreciation: A reevaluation. *Journal of Money, Credit, and Banking* 32, 722–745.
- Blonigen, B.A., 1997. Firm-specific assets and the link between exchange rates and foreign direct investment. *American Economic Review* 87, 447–465.
- Blonigen, B.A., 2005. A review of the empirical literature on FDI determinants. University of Oregon and NBER.

- Bolling, C., Shane, M., Roe, T., 2007. Exchange rates and U.S. foreign direct investment in the global processed food industry. *Agricultural and Resource Economics Review* 36, 230–238.
- Campa, J.M., 1993. Entry by foreign firms in the united states under exchange rate uncertainty. *Review of Economics and Statics* 75, 614–622.
- Cavallari, L., 2004. Optimal monetary rules and internationalized production. *International Journal of Finance and Economics* 9, 175–186.
- Cavallari, L., 2005. Globalisation and the international monetary transmission. Manuscript, University of Rome III.
- Cavallo, M., Ghironi, F., 2002. Net foreign assets and the exchange rate: Redux revised. *Journal of Monetary Economics* 49, 1057–1097.
- Chakrabarti, R., Scholnick, B., 2002. Exchange rate expectations and foreign direct investment flows. *Weltwirtschaftliches Archiv* 138, 1–21.
- Chu, H., 2005. Welfare and public: The role of internationalized production. *Economic Inquiry* 43, 542–557.
- Corsetti, G., Pesenti, P., Roubini, N., Tille, C., 2000. Competitive devaluations: toward a welfare-based approach. *Journal of International Economics* 51, 217–241.
- Corsetti, G., Pesenti, P., 2001. Welfare and macroeconomic interdependence. *Quarterly Journal of Economics* 116, 421–444.
- Corsetti, G., Pesenti, P., 2005. International dimensions of optimal monetary policy. *Journal of Monetary Economics* 52, 281–305.
- Corsetti, G., Martin, P., Pesenti, P., 2005. Productivity, terms of trade, and the ‘home market effect’. *Journal of International Economics* 73, 99–127.

- Cushman, D.O., 1985. Real exchange rate risk, expectations, and the level of foreign direct investment. *Review of Economics and Statistics* 67, 297–308.
- Cushman, D.O., 1988. Exchange rate uncertainty and foreign direct investment in the United States. *Weltwirtschaftliches Archiv* 124, 322–336.
- Devereux, M.B., 2004. Should the exchange rate be a shock absorber? *Journal of International Economics* 62, 359–377.
- Devereux, M., Engel, C., 2001. The optimal choice of exchange rate regime: price setting rules and internationalized production, in *Topics in Empirical International Economics*, Blomstrom M, Goldberg L (Eds.). University of Chicago Press: Chicago.
- Devereux, M., Engel, C., 2002. Exchange rate pass-through, exchange rate volatility, and exchange rate disconnect. *Journal of Monetary Economics* 49, 913–940.
- Eckel, C., Egger, H., 2009. Wage bargaining and multinational firms. *Journal of International Economics* 77, 206–214.
- Engel C., 2002. The responsiveness of consumer prices to exchange rates: A synthesis of some new open economy macro models. *Manchester School* 70, 1–15.
- Farrell, R., Gaston, N., Sturm, J.M., 2004. Determinants of Japan's foreign direct investment: An industry and country panel study, 1984–1998. *Journal of the Japanese and International Economies* 18, 161–182.
- Froot, K.A., Stein, J.C., 1991. Exchange rates and foreign direct investment: An imperfect capital markets approach. *Quarterly Journal of Economics* 106, 1191–1217.

- Ghironi, F., Melitz, M.J., 2005. International trade and macroeconomic dynamics with heterogeneous firms. *Quarterly Journal of Economics* 120, 865–915.
- Goldberg, L., Klein, M., 1998. Foreign direct investment, trade, and real exchange rate linkages in developing countries, in: Glick, R. (Eds.), *Managing Capital Flows and Exchange rates: Perspectives from the Pacific Basin*, Cambridge, UK: Cambridge University Press, 73–100.
- Goldberg, L., Kolstad, C., 1995. Foreign Direct Investment, Exchange rate variability and Demand Uncertainty. *International Economic Review* 36, 855–873.
- Hau, H., 2000. Exchange rate determination: The role of factor price rigidities and nontradeables. *Journal of International Economics* 50, 421–447.
- Helpman, E., Melitz, M.J., Yeaple, S.R., 2004. Exports versus FDI. *American Economic Review* 94, 300–316.
- Johdo, W., 2013. Does monetary expansion improve welfare under habit formation?. *Economics Bulletin* 33, 1959–1968.
- Johdo, W., 2015. Monetary policy, foreign welfare and international firm mobility, forthcoming in *International Journal of Economic Theory*.
- Kiyota, K., Urata, S., 2004. Exchange rate, exchange rate volatility and foreign direct investment. *The World Economy* 27, 1501–1536.
- Klein, M.W., Rosengren, E.S., 1994. The real exchange rate and foreign direct investment in the United States: Relative wealth vs. relative wage effects. *Journal of International Economics* 36, 373–389.

- Kollmann, R., 2001. Explaining international comovements of output and asset returns: The role of money and nominal rigidities. *Journal of Economic Dynamics and Control* 25, 1547–1583.
- Kollmann, R., 2002. Monetary policy rules in the open economy: effects on welfare and business cycles. *Journal of Monetary Economics* 49, 989–1015.
- Lane, P.R., 1997. Inflation in open economies. *Journal of International Economics* 42, 327–347.
- Lubik, T.A., Russ, K.N., 2006. Entry, multinational firms and exchange rate volatility. University of California, Davis, Working Paper No. 06-22.
- Obstfeld, M., Rogoff, K., 1995. Exchange rate dynamics redux. *Journal of Political Economy* 103, 624–660.
- Obstfeld, M., Rogoff, K., 2002. Global implications of self-oriented national monetary rules. *Quarterly Journal of Economics* 117, 503–535.
- Russ, K.N., 2007. The endogeneity of the exchange rate as a determinant of FDI: A model of entry and multinational firms. *Journal of International Economics* 71, 344–372.
- Smets, F., Wouters, R., 2002. Openness, imperfect exchange rate pass-through and monetary policy. *Journal of Monetary Economics* 49, 947–981.
- Sousa, T.V., 2013. Asymmetries in an open economy model. *Journal of International Money and Finance* 33, 358–380.
- Sutherland, A., 2005. Incomplete pass-through and the welfare effects of exchange rate variability. *Journal of International Economics* 65, 375–399.

Tille, C., 2008. Financial integration and the wealth effect of exchange rate fluctuations.

Journal of International Economics 75, 283–294.

Warnock, F.E., 2003. Exchange rate dynamics and the welfare effects of monetary policy in a two-country model with home-product bias. *Journal of International*

Money and Finance 22, 343–363.