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International worker mobility and the effects of monetary policy shocks

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Abstract

In this paper, we develop a new open economy macroeconomics model that incorporates international worker mobility and nominal wage rigidities. The driving force for relocation of workers is differences in real wages between home- and foreign-located workers. An unanticipated domestic monetary expansion proves to produce not only changes in the nominal exchange rate, but also worker relocation through changes in the wage gap. We show that the degree of worker mobility provides the key to understanding the macroeconomic impacts of monetary expansion.

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1. Introduction

Recently, the international worker movement aimed at higher wage incomes has been expanding rapidly not only among emerging market economies (e.g., China, India, ASEAN, Mexico, Brazil and Turkey) and advanced economies (e.g., the United States, the European Union, Australia, Canada, the Republic of Korea and Japan), but also within their respective economies. This implies that the movement of workers can be affected by the nominal exchange rate between the two countries if nominal wages are rigid.[1] This is because the nominal exchange rate affects the price indices in both countries, thereby changing relative real wages, and consequently international worker movement occurs. Moreover, the reverse case can also be considered; that is, the international worker movement affects labor markets across countries, thereby changing national income, consumption and consequently the nominal exchange rate through money markets.

However, in the international finance and macroeconomics literature, no one has considered how interaction between the international worker movement and the exchange rates affects output and consumption. In the past two decades, there are several studies in the new open economy macroeconomics (henceforth NOEM) literature based on nominal wage rigidities; see, e.g., Obstfeld and Rogoff (1995, 1996), Hau (2000), Obstfeld and Rogoff (2000), Corsetti and Pesenti (2001), Kollmann (2001a, b), Benigno (2002), Céspedes et al (2004), Chu (2005) and Johdo (2015).[2] In this line of research, much effort has been devoted to showing the relationship between exchange rate patterns and aggregate economic activity extensively at the theoretical level. However, most NOEM models with nominal wage rigidity assume that workers are immobile across countries. Therefore, very few studies have attempted to investigate the relationship between international labor movement, the nominal exchange rate and aggregate economic activities.

In the international trade (henceforth IT) literature on international migration, static trade models with perfectly competitive markets have been used (see, for example, Krauss, 1976; Bhagwati and Srinivasan, 1983; Rivera-Batiz, 1983; Brecher and Choudhri, 1987). Almost all studies in the IT literature consider the effects of labor migration using a non-monetary model. Therefore, few studies address the impacts of monetary policy shocks on the international migration patterns of monopolistically competitive workers.[3]

In the above two lines of research (NOEM and IT literatures), the following questions remain unresolved: what is the relationship between monetary policy and the exchange rate when international worker mobility is taken into account? Moreover, how do changes in the money supply in one country affect another country's output and

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[1] This causal relationship is consistent with the evidence found in the literature (*e.g*., Han and Ibbott, 2005; Jajri and Ismail, 2014; Adiele and Umezuruike, 2021) on the relationship between exchange rates and the movements in labor between two countries.

[2] For a survey of the NOEM models, see Lane (2001).

[3] One possible exception is the work of Johdo (2010), which constructs a two-country monopolistic competition model including the migration of monopolistically competitive workers and examines the effects of a rise in wage tax on the international relocation of workers and terms of trade. However, this literature does not examine the effects of monetary policy shocks on international relocation of workers and other macroeconomic variables, including exchange rate and relative consumption.

consumption when international worker mobility is taken into account? In order to address these issues, we propose a new open economy macroeconomics model that incorporates the international movement of imperfectly competitive workers and nominal wage rigidities. In this model, the driving force in worker mobility is the workers' wage differential between the two trading countries. This implies that monetary policy shocks affecting the wage differential bring about the movement of workers across borders. Accordingly, the model allows us to show the interaction between worker movement and the nominal exchange rate and illustrates how these factors affect consumption in both countries.

We conclude that a home country monetary expansion leads to the relocation of some workers to the home (foreign) country and results in a proportionate decrease (increase) in relative home consumption levels through the exchange rate appreciation (depreciation) of the home currency when the degree of international worker mobility is large (small). In addition, we show that the global welfare effect of the monetary expansion is positive even if international worker movement occurs.

2. Model Structure

This paper analyzes the effect of a home country monetary expansion on international relocation of workers and other macroeconomic variables, including exchange rate and relative consumption based on the theoretical framework developed by Johdo (2015) which introduced international firm mobility into a general equilibrium NOEM model. Unlike the model of Johdo (2015), however, this paper endogenises the cross-border relocation of workers within the model of Johdo (2015), international relocation of firms is fixed instead.

In this section, we construct a two country model with international relocation of workers. Home and foreign households have perfect foresight and share the same utility function. The size of the world population is normalized to unity. Workers in the interval $[0, n_t]$ locate in the home country, and the remaining $(n_t, 1]$ workers locate in the foreign country, where n_t is endogenous. On the production side, monopolistically competitive firms exist continuously in the world in the $[0, 1]$ range, each of which produces a single differentiated product that is freely tradable. In addition, we assume that, firms in the interval $[0, s]$ locate in the home country, and the remaining $(s, 1]$ firms locate in the foreign country, where s is exogenous. Finally, all profit flows from firms are distributed to their owners according to their share of holdings.

Households in each country derive utility from consuming a group of differentiated goods (defined later), gain from money holdings through liquidity services, and incur the cost of expending labor effort. The intertemporal objective of household $i \in (0, n_t)$ in the home country at time 0 is to maximize the following lifetime utility:

$$U^i_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C^i_t + \chi \log(M^i_t/P_t) - (\kappa/2)(\ell^{si}_t)^2\right), \quad (1)$$

where E_0 represents the mathematical expectation conditional on the information set made available to household i in period 0, β is a constant subjective discount factor $(0 < \beta < 1)$, ℓ^{si}_t is the amount of labor supplied by household i in period t, and the consumption index C^i_t is defined as $C^i_t = \left(\int_0^1 C^i_t(j)^{(\theta-1)/\theta} dj\right)^{\theta/(\theta-1)}$, here θ is the elasticity of substitution between any two differentiated goods $(\theta > 1)$, $C^i_t(j)$ is the consumption of good j in period t for household i. The second term in (1) is real money balances (M^i_t/P_t), where M^i_t denotes nominal money balances held at the beginning of period $t+1$, and P_t is the home country consumption price index (CPI), which is defined as $P_t = (\int_0^1 P_t(j)^{1-\theta}dj)^{1/(1-\theta)}$, where $P_t(j)$ is the home-currency price of good j in period t. Analogously, the foreign country CPI is $P_t^* = (\int_0^1 P_t^*(j)^{1-\theta}dj)^{1/(1-\theta)}$, where $P_t^*(j)$ is the foreign-currency price of good j in period t. Under the law of one price, we can rewrite the price indexes as $P_t = (\int_0^s P_t(j)^{1-\theta}dj + \int_s^1 (\varepsilon_t P_t^*(j))^{1-\theta}dj)^{1/(1-\theta)}$ and $P_t^* = (\int_0^s (P_t(j)/\varepsilon_t)^{1-\theta}dj + \int_s^1 P_t^*(j)^{1-\theta}dj)^{1/(1-\theta)}$. Because there are no trade costs between the two countries, the law of one price holds for any variety j; i.e., $P_t(j) = \varepsilon_t P_t^*(j)$, where ε_t is the nominal exchange rate, defined as the home currency price per unit of foreign currency. Given the law of one price, a comparison of the above price indexes implies that purchasing power parity (PPP) is represented by $P_t = \varepsilon_t P_t^*$. In this context, we assume that there is an international risk-free real bond market and that real bonds are denominated in units of the composite consumption good. 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. Therefore, the household budget constraint can be written as:

$$P_t B^i_{t+1} + M^i_t = P_t(1+r_t)B^i_t + M^i_{t-1} + W^i_t \ell^{si}_t + (\alpha/s)\left(\int_0^s \Pi_t(j)dj + \int_s^1 \varepsilon_t \Pi_t^*(j)dj\right) - P_t C^i_t + P_t \tau^i_t. \qquad (2)$$

where B^i_{t+1} denotes real bonds held by home agent i in period $t+1$; r_t denotes the real interest rate on bonds that applies between periods $t-1$, and t; $W^i_t\ell^{si}_t$ is nominal labor income, where W^i_t denotes the nominal wage rate of household i in period t; α denotes the extent to which firms are domestically owned; thus, α/s (resp. $\alpha^*/(1-s)$) denotes the share of firms' total profit flows that are repatriated to each home (resp. foreign) agent, where $0 < \alpha < 1$, $0 < \alpha^* < 1$, and $\alpha + \alpha^* = 1$; $\int_0^s \Pi_t(j)dj$ (resp. $\int_s^1 \varepsilon_t \Pi_t^*(j)dj$) represents the total nominal profit flows of firms located in home (abroad) from sales of products in period t; $P_t C^i_t$ represents nominal consumption expenditure; and τ^i_t denotes real lump-sum transfers from the government in period t. Note that all variables in (2) are measured in terms of per unit of labor endowments. In the government sector, we assume that government spending is zero and that all seigniorage 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 the home country is $0 = \tau_t + [(M_t - M_{t-1})/P_t]$, where M_t is aggregate money supply, and $\tau_t = \int_0^{n_t} \tau^i_t di$.

In the home country, firm $j \in [0, s]$ hires a continuum of differentiated labor inputs domestically and produces a unique product in a single location according to the constant elasticity of substitution production function, $y_t(j) = (n_t^{-1/\phi} \int_0^{n_t} (j)\ell^{di}_t{}^{(\phi-1)/\phi}di)^{\phi/(\phi-1)}$, where $y_t(j)$ denotes the production of home-located firm j in period t, $\ell^{di}_t(j)$ is the firm j's input of labor from household i in period t, n_t is predetermined spatial distribution of workers, and which is carried into period t, and $\phi > 1$ is the elasticity of input substitution. Given the home firm's cost minimization problem, firm j's optimal labor demand for household i's labor input is as follows:

$$\ell^{di}_t(j) = n_t^{-1}(W^i_t/W_t)^{-\phi}y_t(j) \tag{3}$$

where $W_t \equiv (n_t^{-1}\int_0^{n_t} W_t^{i\ (1-\phi)}di)^{1/(1-\phi)}$ is a price index for labor input.

We now consider the dynamic optimization problem of households. In the first stage, households in the home (resp. foreign) country maximize the consumption index C^i_t (resp. $C^i_t{}^*$) subject to a given level of expenditure $P_tC^i_t = \int_0^1 P_t(j)C^i_t(j)dj$ (resp. $P_t^*C^i_t{}^* = \int_0^1 P_t^*(j)C^i_t{}^*(j)dj$) by optimally allocating differentiated goods. This static problem yields the following demand functions for good j in the home and foreign countries, respectively: $C^i_t(j) = (P_t(j)/P_t)^{-\theta}C^i_t$, $C^i_t{}^*(j) = (P_t^*(j)/P_t^*)^{-\theta}C^i_t{}^*$. Aggregating the demands across all households worldwide and equating the resulting equation to $y_t(j)$ yields the following market clearing condition for any product j in period t:

$$y_t(j) = n_tC^i_t(j) + (1-n_t)C^i_t{}^*(j) = (P_t(j)/P_t)^{-\theta}\ C_t^w, \tag{4}$$

where $P_t(j)/P_t = P_t^*(j)/P_t^*$ from the law of one price, and $C_t^w \equiv (n_tC^i_t(j) + (1-n_t)C^i_t{}^*(j))$ is aggregate per capita world consumption. Similarly, for product j of the foreign located firms, we obtain $y_j^*(j) = n_tC^i_t(j) + (1-n_t)C^i_t{}^*(j) = (P_t^*(j)/P_t^*)^{-\theta}C_t^w$. In the second stage, households maximize (1) subject to (2). The first-order conditions for this problem with respect to B^i_{t+1} and M^i_t can be written as

$$1/C^i_t = \beta E_t[(1+r_{t+1})/C^i_{t+1}], \quad M^i_t/P_t = \chi C^i_t((1+i_{t+1})/i_{t+1}), \tag{5}$$

where i_{t+1} is the nominal interest rate for home-currency loans between periods t and $t+1$, defined as usual by $1 + i_{t+1} = (1 + r_{t+1})E_t[(P_{t+1}/P_t)]$.

In the monopolistic goods markets, each firm has some monopoly power over pricing. Because home-located firm j hires labor domestically, given W_t, P_t and $C^w{}_t$, and n_t and subject to (3) and (4), home-located firm j faces the following profit-maximization problem: $\max_{P_t(j)} \Pi_t(j) = P_t(j)y_t(j) - \int_0^{n_t} W_t^i\ell_t^{di}(j)di = (P_t(j) - W_t)y_t(j)$, where $\Pi_t(j)$ denotes the nominal profit of home-located firm j. By substituting $y_t(j)$ from equation (4) into the firm's profit $\Pi_t(j)$ and then differentiating the resulting equation with respect to $P_t(j)$, we obtain the following price mark-up:

$$P_t(j) = (\theta/(\theta-1))W_t. \tag{6}$$

Because W_t is given, from (6), all home-located firms charge the same price. In what follows, we define these identical prices as $P_t(j) = P_t(h)$, $j\in[0, s]$. These relationships imply that each home-located firm supplies the same quantity of goods, and hence each firm requires the same quantity of labor; i.e., $\ell^{id}_t(j) = \ell^{id}_t(h)$, $j\in[0, s]$, where the firm index j is omitted because of symmetry. The price mark-ups of foreign-located firms are identical because $P_t^*(j) = P_t^*(f)$, $j\in(s, 1]$. Substituting (4) and (6) into the real profit flows of the home- and foreign-located firms, $\Pi_t(h)/P_t$ and $\Pi_t(f)^*/P_t^*$, respectively, yields $\Pi_t(h)/P_t = (1/\theta)(P_t(h)/P_t)^{1-\theta}C^w{}_t$, $\Pi_t(f)^*/P_t^* = (1/\theta)(P_t^*(f)/P_t^*)^{1-\theta}C^w{}_t$.

The key feature of our model is that it allows workers to gradually adjust their locations. The driving force for their relocation to other countries is a difference in real wages between two bounded countries, and workers are not allowed to relocate instantaneously for the first period or the period during which a difference in wages arises. The above adjustment processes for relocation of workers are formulated as follows:

$$n_t - n_{t-1} = \gamma[W^i_t/P_t - W^{i*}_t/P_t^*] = \gamma[W^i_t/P_t - \varepsilon_tW^{i*}_t/P_t]. \tag{7}$$

where the third term can be rewritten by using PPP, γ ($0 \leq \gamma < \infty$) is a constant positive parameter that determines the degree of worker mobility between the two countries: a larger value of γ implies higher worker mobility between two countries. Intuitively, the parameter γ reflects the costs falling on mobile workers in their new locations. Examples include the costs of finding appropriate houses, learning the local language, and adapting to the local legal system. Because of these costs, workers cannot move instantaneously to a better location even if a wage gap between two countries provides the motivation. Here, 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 time $t-1$. In the monopolistic labor market, each household provides a single variety of labor input to a continuum of domestic firms. Hence, the equilibrium labor-market conditions for the home and foreign countries imply that $\ell^{si}{}_t = \int_0^s \ell_t^{di}(j)dj$, $i \in [0, n_t]$ and $\ell^{si*}{}_t = \int_s^1 \ell_t^{di*}(j)dj$, $i \in (n_t, 1]$, respectively, where the left-hand sides represent the amounts of labor supplied by household i and the right-hand sides represent firms' total demand for household labor i. Taking W_t, P_t, $y_t(j)$, and n_t as given, by substituting $\ell^{si}{}_t = \int_0^s \ell_t^{di}(j)dj$ and equation (3) into the budget constraint, given by (2), and maximizing the lifetime utility, given by (1), with respect to the nominal wage $W^i{}_t$, we obtain the following first-order condition:

$$\phi(W^i{}_t/P_t)^{-1}E_{t-1}[\kappa\ell^{si}{}_t{}^2] = (\phi-1)E_{t-1}[(\ell^{si}{}_t/C^i{}_t)]. \tag{8}$$

The right-hand side of (8) 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. Finally, the equilibrium condition for the integrated international bond market is given by $\int_0^{n_t} B_{t+1}^i di + \int_{n_t}^1 B_{t+1}^{i*} di = 0$. The money markets are assumed always to clear in both countries, so that the equilibrium conditions are given by $M_t = \int_0^{n_t} M_t^i di$ and $M^*{}_t = \int_{n_t}^1 M_t^{i*} di$, respectively.

3. Analysis of Monetary Policy Shocks

To examine the macroeconomic effects of an unanticipated permanent monetary shock, we solve a log-linear approximation of the system around the initial, zero-shock steady state with $B_{ss,0} = 0$, as described in Appendix. We assume that the economy starts from the zero-shock steady state at period 0, and at the end of period 1, nominal wage rates are determined by one-period contracts between the monopolistic labor suppliers and the firms, and these are carried into period 2. After the one-period wage contracts are completed, a monetary policy decision is made. This means that nominal wages signed at the end of period 1 cannot adjust instantaneously to an unanticipated monetary shock in period 1. In addition, the condition for the optimal nominal wage, equation (8), does not hold, and, therefore, households are willing to satisfy any level of labor demand at predetermined wage rates because their (real) wage rates dominate their marginal labor costs.[4] Moreover, in period 1, in which there is a shock, the relocation of workers

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[4] That is, the labor supply is demand determined in the period when there are nominal wage rigidities.

occurs according to equation (7) after the monetary policy shock was implemented by a country. We refer to the period of the shock as the 'short run'. Thereafter, in periods 2 and beyond, nominal wages adjust perfectly to their new steady-state values to be consistent with the optimal wage conditions, given by (8). The spatial distribution of workers also adjusts perfectly to its new steady-state value. In what follows, the time from period 2 onwards is referred to as the 'long run'. Following the work of Obstfeld and Rogoff (1995), 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 and with the period over which the locations of workers are adjusted. Thus, nominal wages and goods prices can be determined as $\hat{W} = \hat{W}^* = \hat{P}(h) = \hat{P}^*(f) = 0$ 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.

By log linearizing equation (7) around the symmetric steady state and setting $\hat{P}(h) = \hat{P}^*(f) = 0$, we obtain the following log-linearized expression for the international distribution of workers:

$$\hat{n} = -2\gamma((\theta - 1)/\theta)\hat{\varepsilon}. \tag{9}$$

Equation (9) shows that an exchange rate depreciation induces global relocation of workers towards the foreign country. Intuitively, with fixed nominal wages, which cause nominal product prices to be sticky because of mark-up pricing by monopolistic product suppliers, the depreciation causes a decrease (increase) in the foreign (home) price level because $\hat{P}^* = -(1/2)\hat{\varepsilon}$ ($\hat{P} = (1/2)\hat{\varepsilon}$) from the price indexes. This increases (decreases) the relative real wage of foreign-located (home-located) workers, and consequently, other workers relocate to the foreign country. Equation (9) 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 sufficiently high ($\gamma = 0$), nominal exchange rate changes have a negligible effect on the relocation of firms. In the long run, we obtain $\overline{n} = 0$.

As assumed in the previous paragraph, the economy starts from the zero-shock steady state in period 0, and nominal wage rigidities and the relocation of workers characterize the economy for period 1. We now consider the macroeconomic effects of a one-off unanticipated infinitesimal permanent increase in the relative level of the home money supply in period 1. This means that relative money supplies must change because $\overline{M} - \overline{M}^* = \hat{M} - \hat{M}^* > 0$. Here, we analyze the influence of the monetary shock on three key variables: the nominal exchange rate, the international distribution of workers and short-run relative consumption. The closed-form solutions for three key variables are as follows:

$$\hat{\varepsilon} = \left\{ \frac{\delta_1}{\delta_1 + (\theta/2)((\theta - 1)/\theta)^2 - 2\gamma((\theta - 1)/\theta)\delta_2} \right\} (\hat{M} - \hat{M}^*) \tag{10}$$

$$\hat{C}-\hat{C}^{*}=\left\{\frac{((\theta/2)+2\gamma)((\theta-1)/\theta)^{2}}{\delta_{1}+(\theta/2)((\theta-1)/\theta)^{2}-2\gamma((\theta-1)/\theta)\delta_{2}}\right\}\left(\hat{M}-\hat{M}^{*}\right). \tag{11}$$

$$\hat{n}=\left\{\frac{-2\gamma((\theta-1)/\theta)\delta_{1}}{\delta_{1}+(\theta/2)((\theta-1)/\theta)^{2}-2\gamma((\theta-1)/\theta)\delta_{2}}\right\}\left(\hat{M}-\hat{M}^{*}\right). \tag{12}$$

where

$$\delta_{1}=\frac{1}{2}\left[\frac{((1+\theta)/\theta)+((\theta-1)/\theta)^{2}}{\delta((1+\theta)/\theta)}+1\right]>0 \text{ and } \delta_{2}=\left[\left(\frac{1}{\theta}\right)+\left(\frac{\theta-1}{\theta}\right)^{2}\left(\frac{\theta}{1+\theta}\right)\left(\frac{1}{1+\delta}\right)\right]>0.$$

From (10), the impact of a monetary expansion in the home country on the equilibrium exchange rate is ambiguous. Therefore, to determine the sign, we consider the range of parameter space of the degree of worker mobility γ. This is because equation (10) indicates that the size of γ plays an important role in determining whether the effect is positive or negative. By noting (10), we find that if γ is large, the unanticipated domestic money expansion leads to exchange rate appreciation. The opposite mechanism is valid when γ is small: a monetary expansion leads to exchange rate depreciation.

Why does the large (small) labor mobility generate an exchange rate appreciation (depreciation)? The intuitive explanation behind the relationship between the degree of worker mobility and the exchange rate in equation (10) is as follows. First, an unanticipated monetary expansion in the home country requires an instantaneous depreciation of its currency to restore money market equilibrium for a given level of initial relative consumption. The exchange rate depreciation then causes consumption switching as world consumption demand shifts towards home goods because of the fall in their relative price. This increases labor demand and thereby home labor income and consumption (hereafter we shall call this the 'consumption switching effect'). In addition, with fixed nominal wages, which cause nominal product prices to be sticky because of mark-up pricing by monopolistic product suppliers, the depreciation causes an increase (decrease) in the home (foreign) price level because $\hat{P}=(1/2)\hat{\varepsilon}$ ($\hat{P}^{*}=-(1/2)\hat{\varepsilon}$) from the price indices. This decreases (increases) the relative real wages of home-located (foreign-located) workers, and consequently workers relocate to the foreign country. Moreover, this leads to an increase in the per capita labor demand for workers in the home country. This is because the distribution of firms is assumed to be fixed so that the total labor demands remains unchanged in each country even if worker relocation occurs. As a result, the worker relocation raises the relative labor income in the home country, which then raises the relative consumption level in the home country via the intertemporal consumption-smoothing channel (hereafter we shall call this the 'labor relocation effect'). Because of the above two effects, the home currency must appreciate to restore equilibrium in the market for real balances. This is because the real money demand for liquidity services is increasing with aggregate consumption. Furthermore, other exchange rate effect because of the worker relocation should not be overlooked: worker relocation leads to a decrease in total demand for the home currency because the number of workers located in the home country decreases due to the relocation towards the foreign country. Therefore, this induces the home currency to depreciate to restore equilibrium in the market for real balances (hereafter we shall call this the 'market contraction effect'). Thus, the two effects composed of the consumption switching effect and the labor relocation effect and other two effects composed of the market contraction effect and the initial depreciation effect have opposite effects on the exchange rate. Therefore, as already noted, the impact of a monetary expansion in the home country on the equilibrium exchange rate is ambiguous. To determine the sign, we consider the range of parameter space of the degree of worker mobility. This is because the degree of worker mobility provides the key to determining the net effect of the monetary expansion. By noting (10), we find that if γ is large (small), the unanticipated domestic money expansion leads to exchange rate appreciation (depreciation). Intuitively, as the relocation of workers becomes more flexible (as γ increases), there is a greater increase in the per capita relative home labor income because more workers relocate, and therefore, the increase in the per capita relative home consumption is greater. Thus, given that the demand for real money balances is increasing with consumption, the home currency must appreciate and raise the supply of real money balances in the home country to restore money market equilibrium. The opposite mechanism is valid when γ is small: a monetary expansion leads to exchange rate depreciation. Here, it is important to note that in the above discussion we showed that the market contraction effect due to worker relocation decreases the money demand in the home country, and hence requires the home currency to depreciate to restore money market equilibrium. Therefore, this effect also depends on the degree of worker mobility, γ: the more mobility is the labor relocation, the lower is the demand for the home currency. However, the result of (10) shows that the labor relocation effect, which increases money demand, always dominates the market contraction effect. Therefore, the net effect of the monetary expansion on money demand positively depends on the degree of worker mobility, γ, and hence, the monetary expansion results in exchange rate appreciation (depreciation) when γ is large (small).

Equation (11) shows that a home country monetary expansion results in a proportionate decrease (increase) in relative consumption levels when γ is large (small). The intuition behind equation (11) is as follows. First, from (10), an unanticipated monetary expansion in the home country leads to appreciation of the home currency when γ is large. The exchange rate appreciation then causes consumption switching as world consumption demand shifts towards foreign goods because of the rise in the relative price of home goods. This decreases labor demand and thereby home labor income and consumption (the consumption switching effect). In addition, the appreciation causes a decrease (increase) in the home (foreign) price level because $\hat{P} = (1/2)\hat{\varepsilon}$ ($\hat{P}^* = -(1/2)\hat{\varepsilon}$). This increases (decreases) the relative real wage of home-located (foreign-located) workers, and consequently, workers relocate to the home country. As explained in (10), this leads to a decrease in the labor demand for workers per capita in the home country, and lowers relative home labor incomes per capita, which lowers relative home consumption (the labor relocation effect). Thus, from the consumption switching effect and the labor relocation effect, the impact of a monetary expansion in the home country on the relative consumption is negative when γ is large. Similarly, the opposite mechanism is valid when γ is small: a monetary expansion results in a proportionate increase in relative home consumption levels.

Finally, the result in (12) shows that a home country monetary expansion leads to the relocation of workers away from the foreign country to the home country when γ is large. This is because when γ is large, the exchange rate appreciation (see equation (10)) causes a decrease (increase) in the home (foreign) price level because $\hat{P} = (1/2)\hat{\varepsilon}$ ($\hat{P}^* = -(1/2)\hat{\varepsilon}$), increasing (decreasing) the relative real wage of home-located (foreign-located) workers, and consequently workers relocate to the home country. Similarly, the opposite mechanism is valid when γ is small: a monetary expansion results in the relocation of workers to the foreign country.

4. Welfare Effects

It is of interest to look at global welfare. Indeed, although one country loses whereas the other gains, the net result is, *a priori,* indeterminate. Following Obstfeld and Rogoff (1995, 1996), who ignored the welfare effects of real balances, we focus on the real component of an agent's utility, which comprises terms involving consumption and labor effort. By defining this real component as U_0^R, we can rewrite equation (1) as $U_0^R = \sum_{t=0}^{\infty}\beta^t\left(log\, C_t - (\kappa/2)\ell_t^{s2}\right)$. The impact of unanticipated money shocks on domestic welfare is as follows

$$d\hat{U}^R = [1-((\phi-1)/\phi)((\theta-1)/\theta)]\hat{M}^W + (1/2\tilde{\theta})\Omega(\hat{M}-\hat{M}^*) \tag{13}$$

where $\tilde{\theta} = \delta_1 + (\theta/2)((\theta-1)/\theta)^2 - 2\gamma((\theta-1)/\theta)[(1/\theta)+((\theta-1)/\theta)^2(\theta/(1+\theta))(1/(1+\delta))]$,

$$\Omega = (1/2)((1+\delta)/\delta)((\theta-1)/\theta)(\theta+4\gamma)[((\theta-1)/\theta)-((\phi-1)/\phi)]$$
$$+(2\gamma/\theta)((\phi-1)/\phi)((\theta-1)/\theta)[((1+\delta)/\delta)+(1/\delta)((\theta-1)/\theta)^2(\theta/(1+\theta))].$$

Analogously, the impact on foreign welfare is

$$d\hat{U}^{R*} = [1-((\phi-1)/\phi)((\theta-1)/\theta)]\hat{M}^W - (1/2\tilde{\theta})\Omega(\hat{M}-\hat{M}^*). \tag{14}$$

From (13) and (14), we can derive the world welfare effect of a monetary expansion. For this purpose, we define world welfare as $U^W = n_{0,ss}U^R + (1-n_{0,ss})U^{R*}$, where $n_{0,ss}$ = 1/2 denotes the initial steady-state distribution of workers. The world welfare effect of a monetary expansion then is

$$d\hat{U}^W = (1/2)(d\hat{U}^R + d\hat{U}^{R*}) = [1-((\phi-1)/\phi)((\theta-1)/\theta)]\hat{M}^W. \tag{15}$$

From this result, the benefit arises because of the initial monopoly distortion; i.e., the larger is the value of θ, the lower is the welfare gain from a monetary shock.[5] This result is similar to that obtained from standard NOEM models in which the location of workers is assumed fixed.

5. Conclusion

The main findings of our analysis are that i) a home country monetary expansion leads to the relocation of some workers to the home (foreign) country when the degree of worker mobility is large (small), ii) a monetary expansion leads to exchange rate appreciation (depreciation) of the home currency when the degree of worker mobility is large (small), iii) monetary expansion in the home country results in a proportionate decrease (increase) in relative consumption levels when the degree of worker mobility is large (small), iv) the world welfare effect of the monetary expansion is positive even if international worker movement occurs.

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[5] In the extreme case of a competitive economy ($\theta \to \infty$ and $\phi \to \infty$), the impact of a monetary expansion anywhere in the world on world welfare is close to zero.

Appendix

Symmetric steady state

In this section, we derive the solution for a symmetric steady state in which all exogenous variables are constant, initial net foreign assets are zero ($B_0 = 0$), $s = \alpha = 1/2$. The superscript i and the index j are omitted because households and firms make the same equilibrium choices within and between countries. Henceforth, we denote the steady-state values by using the subscript ss. In the symmetric steady state, in which all variables are constant in both countries, given the Euler equation for consumption (equation (5)), the constant real interest rate is given by $r_{ss} = (1 - \beta)/\beta \equiv \delta$, where δ is the rate of time preference and r_{ss} is the steady-state real interest rate. As assumed in section 3, worker relocation is fully flexible in the steady state, and therefore, the equal-wage condition, $W^h_{ss}/P_{ss} = W^{f*}_{ss}/P^*_{ss}$, must be satisfied. From $W^h_{ss}/P_{ss} = (W^h_{ss}/W_{ss})(W_{ss}/P_{ss}(h))(P_{ss}(h)/P_{ss})$, $W^{f*}_{ss}/P^*_{ss} = (W^{f*}_{ss}/W^*_{ss})(W^*_{ss}/P^*_{ss}(f))(P^*_{ss}(f)/P^*_{ss})$, (6) and PPP, the equal-wage condition yields $P_{ss}(h) = \varepsilon_{ss}P_{ss}^*(f)$. From $P_t = (\int_0^s P_t(j)^{1-\theta}dj + \int_s^1 (\varepsilon_t P_t^*(j))^{1-\theta}dj)^{1/(1-\theta)}$ and $P_t^* = (\int_0^s (P_t(j)/\varepsilon_t)^{1-\theta}dj + \int_s^1 P_t^*(j)^{1-\theta}dj)^{1/(1-\theta)}$, given a symmetric equilibrium in which $P_t(j) = P_t(h)$ and $P_t^*(j) = P_t^*(f)$, $\forall j$, the real prices can be rewritten as

$$P_t(h)/P_t = (P_t(h)/\varepsilon_t)/P_t^* = [s + (1 - s)(\varepsilon_t P_t^*(f)/P_t(h))^{1-\theta}]^{-1/(1-\theta)}, \quad \text{(A1)}$$

$$\varepsilon_t P_t^*(f)/P_t = P_t^*(f)/P_t^* = [s(\varepsilon_t P_t^*(f)/P_t(h))^{\theta-1} + (1 - s)]^{-1/(1-\theta)}, \quad \text{(A2)}$$

where $P_t(h)/P_t$ and $\varepsilon_t P_t^*(f)/P_t$ are the real prices of the home and foreign goods, which equal $(P_t(h)/\varepsilon_t)/P_t^*$ and $P_t^*(f)/P_t^*$, respectively.[6] Substituting $P_{ss}(h) = \varepsilon_{ss}P_{ss}^*(f)$ into equations (A1) and (A2) yields steady-state real prices of

$$P_{ss}(h)/P_{ss} = (P_{ss}(h)/\varepsilon_{ss})/P_{ss}^* = \varepsilon_{ss}P_{ss}^*(f)/P_{ss} = P_{ss}^*(f)/P_{ss}^* = 1. \quad \text{(A3)}$$

From (10) and (14), steady-state real wages are

$$W_{ss}/P_{ss} = W_{ss}^*/P_{ss}^* = (\theta - 1)/\theta. \quad \text{(A4)}$$

Because symmetry, which implies $n_{ss} = 1 - n_{ss}$, holds, the steady-state allocation of workers is

$$n_{ss} = 1/2. \quad \text{(A5)}$$

In addition, from (8), we obtain

$$\ell^s_{ss} = \ell^{s*}_{ss} = C_{ss} = C^*_{ss} = C^w_{ss} = ((\phi-1)/\phi)^{1/2}((\theta - 1)/\theta)^{1/2}(1/\kappa)^{1/2}. \quad \text{(A6)}$$

Equation (A6) 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. From equations (8), (A5), (A6), $i_{ss} = r_{ss} = \delta$, $M_{ss} = n_{ss}M^h_{ss}$, and $M_{ss}^* = (1 - n_{ss})M^f_{ss}{}^*$ the real balances of home and foreign agents are identical in the steady state, as follows:

$$M_{ss}/P_{ss} = M_{ss}^*/P_{ss}^* = (\chi/2)((1+\delta)/\delta)((\phi-1)/\phi)^{1/2}((\theta - 1)/\theta)^{1/2}(1/\kappa)^{1/2}.$$

From these money demand equations, and given PPP, the steady-state nominal exchange rate is determined by the ratio of M_{ss} to M_{ss}^*; i.e., $\varepsilon_{ss} = M_{ss}/M_{ss}^*$.

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[6] We have used the index h to denote the symmetric values within the home country, and have used the index f for the foreign country.

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