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Article

Fiscal shocks, the exchange rate, and worker migration

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Abstract. This paper employs a new open economy macroeconomic model that incorporates cross-border worker migration to analyze the effects of government spending shocks. In this paper, we demonstrate that when the elasticity of substitution between products produced within the same country is close to 1, a relative increase in government spending in the home country reduces the relative level of consumption at home, depreciates the home currency, and leads to worker migration from the home country to the foreign country. The model demonstrates that as international worker mobility rises, the effect of a government expenditure shock on the relative home consumption diminishes, while the impact on the exchange rate intensifies. Moreover, the model demonstrates that an increase in government spending in the home country invariably leads to a deterioration in global welfare.

Keywords: government spending, migrant workers, exchange rate, consumption, welfare

JEL classification: E62, F31, F41, J61

1. Introduction

Fiscal policy, which serves the functions of economic stabilization, resource allocation, and income redistribution, is employed by governments around the world to address issues that are not resolvable through market mechanisms. The role of fiscal policy as a stabilizing policy has been a subject of debate in macroeconomics for some time. This debate began with classical Keynesian models and continued with New Keynesian models that incorporated microeconomic foundations. This phenomenon has emerged as a prominent research subject within the domain of dynamic stochastic general equilibrium (DSGE) models, which are designed to capture shocks in a probabilistic manner. The DSGE model itself originated in Christiano et al. (2005) and Smets and Wouters (2003), and many researchers have since developed estimation models incorporating country-specific institutional factors. The strength of DSGE models lies in their ability to incorporate realistic consumption preferences, such as consumption habits and home bias, and market imperfections, such as nominal wage stickiness, while focusing on the impact on supply and demand balances in each market and the optimal response of households to those shocks. This approach enables the prediction of future impacts and the verification of the reproducibility of the estimation model. Subsequent researchers have extended this microfounded DSGE model to open-economy

models, enabling the assessment of monetary policy and the impact of productivity shocks by incorporating exchange rates, trade balances, and domestic-foreign interest rate differentials. However, while many researchers have employed closed-economy DSGE models to analyze the impact of fiscal policy shocks, there are fewer studies using open-economy models to do so.¹ Among the latter studies, Ratto et al. (2009), Pedersen and Ravn (2013), Bhattarai and Trzeciakiewicz (2017), Kotera and Sakai (2018), and Konebayev (2023) have examined the role of fiscal policy using open-economy DSGE models. These studies have verified the reproducibility of their estimated models and confirmed that fiscal policy in each country plays a certain role as a policy to stabilize the economy. A number of studies have employed open-economy DSGE models to forecast the prospective ramifications of fiscal policy shocks on the macroeconomy. These studies include those by Coenen et al. (2013), Clancy et al. (2016), Bhattarai and Trzeciakiewicz (2017), and Hickey et al. (2020). These studies employ quantitative methods to estimate the future impact of fiscal policy in open economies, utilizing welfare multipliers as a primary analytical tool.

As previously stated, while analyses of the macroeconomic effects of fiscal policy shocks have already been conducted using open-economy DSGE models, a consistent research gap remains. This is due to the fact that all of the aforementioned open-economy DSGE models utilize small open economy models that assume international worker (or labor) mobility is fixed and foreign economies are exogenous. Bilateral worker mobility is an economic phenomenon that exerts influence not only on the home country but also on the foreign economy. Furthermore, international labor mobility also affects foreign economies and global economic welfare through exchange rates and bilateral trade. Consequently, in order to endogenize international worker migration and assess its impact on foreign economies, it is necessary to employ a two-country model rather than a small open economy model.

The objective of this study is to utilize theoretical frameworks to elucidate the impact of fiscal policy shocks on bilateral economies and global welfare through international worker migration. This subject has been a notable research gap, even within DSGE models. To achieve this objective, we employ a new open economy macroeconomics (NOEM) model, which utilizes a two-country model as the standard. A considerable body of research has examined fiscal policy shocks through the lens of the NOEM model. Among macroeconomic models that consider price stickiness, the NOEM model boasts a model structure that lends itself readily to exchange rate fluctuations and international worker migration. Among studies that have analyzed the impact of fiscal policy shocks using the NEOM model, one representative example related to this paper is the Redux model by Obstfeld and Rogoff (1995), which was a precursor to the NEOM model. The Redux model elucidates the manner in which a government spending shock in one country influences the terms of trade and production and consumption in both countries. This occurs through exchange rate fluctuations and international income redistribution effects through taxation to raise funds. Moreover, a considerable body of research has emerged in the form of extension studies of the Redux model. A notable example is Ganelli's (2003) study, which advanced the Redux model through the incorporation of government

¹ A review of the extant literature on the effects of fiscal policy shocks in closed-economy DSGE models reveals a substantial body of research, including contributions by Coenen and Straub (2005), Galí et al. (2007), Forni et al. (2009), Leeper et al. (2010), Christiano et al. (2011), Eggertsson (2011), Zubairy (2014), Drautzburg and Uhlig (2015), Boehm (2020), Drygalla et al. (2020), Takyi and Leon-Gonzalez (2020), Iqbal and Majeed (2025), and Ma and Lyu (2025).

services, inseparable from consumption, into household utility functions. Ganelli (2005a) incorporated a Blanchard (1985)-style overlapping generation structure into the Redux model and analyzed the effects of several representative alternative debt policies on macroeconomic variables in situations where Ricardian equivalence does not hold. Ganelli (2005b) and Di Giorgio et al. (2015) incorporated a home bias in household consumption toward public services into the Redux model and compared the impact of fiscal shocks with a Redux model without home bias. Johdo (2019) incorporates international firm relocation into the Redux model, thereby providing a comprehensive analysis of the role of firm relocation in the international spillover effects of government spending shocks. A number of studies have also employed simulation analyses to model fiscal shocks, drawing upon the Redux model. For instance, Tervala (2008) examines government expenditure, demonstrating its capacity to enhance corporate productivity through positive external effects. The study further elucidates that productive government expenditure exerts a favorable influence on the exchange rate, thereby promoting economic welfare both domestically and internationally. Ganelli and Tervala's (2010) study is focused on the trade-off between productivity-enhancing public infrastructure and household utility-enhancing public consumption. The authors examine the impact of differences in the allocation of public spending between these two categories on each country's economic welfare during a public spending shock. Tervala and Watson's (2022) analysis of the output and welfare multipliers of fiscal stimulus measures in recessions employs a model that utilizes total factor productivity and output hysteresis. As previously stated, while there is extant literature analyzing the macroeconomic impact of fiscal policy shocks in the NOEM model, very little research has considered international worker mobility. The sole exception is Johdo (2022), who presents a NOEM model that incorporates international worker mobility. However, Johdo's (2022) analysis is limited in scope, as it exclusively examines monetary policy shocks, thereby omitting the examination of fiscal policy shocks. Furthermore, Johdo's (2022) model employs a uniform elasticity of substitution for all goods, a departure from the DSGE model formulation that has gained traction in macroeconomics in recent years. The latter distinguishes between the elasticity of substitution between home and foreign goods and between product varieties within a country.²

The primary contribution of this paper is that it is the first to theoretically demonstrate the macroeconomic effects of government spending shocks on international worker mobility. This topic has not been previously analyzed in conventional open economy DSGE models or NOEM models. Furthermore, this paper follows the formulation of open economy DSGE models and standard extensions of the Redux framework (e.g., Tille, 2001), which have been mainstream models in recent years for analyzing the impact of government spending shocks on exchange rates. It adopts a more realistic model that distinguishes between the elasticity of substitution between home and foreign goods and between two goods within the same country.

The present study demonstrates that when the elasticity of substitution between products produced within the same country is close to 1, a relative increase in government spending in the home country reduces the relative level of consumption at home, depreciates the home currency, and leads to worker migration from the home country to the foreign country. The model demonstrates

² Empirical studies demonstrate that the elasticity of substitution between domestic and foreign goods is subject to change over time in response to trade shocks, such as tariffs. These findings are supported by research conducted by Yilmazkuday (2019) and Boehm et al. (2023).

that as international worker mobility rises, the effect of a government expenditure shock on relative consumption diminishes, while the impact on the exchange rate intensifies. Moreover, the model demonstrates that an increase in government spending in the home country invariably leads to a deterioration in global welfare.

The remainder of this paper is organized as follows. In Section 2, we delineate the characteristics of the dynamic optimization model. In Section 3, we present a log-linearized version of this model and explain how exchange rate changes affect the international relocation of workers. In addition, we examine how a relative increase in home government spending affects the distribution of workers between two countries, the exchange rate, and cross-country differences in consumption. In Section 4, the world welfare effects of a relative increase in home government spending are examined. The final section of the paper offers a summary of the results and conclusions.

2. Model structure

In this model, the size of the world population is normalized to unity. The workers are located in the home country during the interval $[0, n_t]$ and in the foreign country during the interval $(n_t, 1]$. Monopolistic firms are continuously located within the interval $[0, s]$ in the home country and within the interval $(s, 1]$ in the foreign country. In this context, s is considered exogenous. It is posited that both home and foreign households (or workers) possess perfect foresight and share an identical utility function. Households in each country derive utility from consuming a group of differentiated home and foreign goods (to be defined later), gaining from money holdings through liquidity services, and incurring the cost of expending labor. The intertemporal objective of household $i \in [0, n_t]$ in the home country at time t is to maximize the following lifetime utility:

$$U_t^i = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left(\log C_\tau^i + \chi \log(M_\tau^i/P_\tau) - (\kappa/(1 + 1/v))(\ell_\tau^{si})^{1+1/v} \right), \quad (1)$$

where E_t is the mathematical expectation conditional on the information set made available to household i in period t . β is a constant subjective discount factor ($0 < \beta < 1$), ℓ_τ^{si} is the amount of labor supplied by household i , $v > 0$ is a parameter affecting the elasticity of labor supply, $\chi > 0$ and $\kappa > 0$ are parameters that affect the subjective weight of real money balances and labor effort on overall utility, respectively. The consumption index C_t^i is defined as follows:

$$C_t^i = \left[(s\alpha)^{1/\rho} (C_t^h)^{(\rho-1)/\rho} + (1-s\alpha)^{1/\rho} (C_t^f)^{(\rho-1)/\rho} \right]^{\rho/(\rho-1)}, \quad (2)$$

$$C_t^h = (s^{-1/\theta} \int_0^s C_t^h(j)^{(\theta-1)/\theta} dj)^{\theta/(\theta-1)}, \quad C_t^f = ((1-s)^{-1/\theta} \int_s^1 C_t^f(j)^{(\theta-1)/\theta} dj)^{\theta/(\theta-1)},$$

where $C_t^i(j)$ denotes the consumption of good j , $\rho > 0$ is a parameter affecting the elasticity of substitution between home and foreign goods. As in Tille (2001), Tervala (2019), and Tervala

and Watson (2022), $s\alpha$ denotes the proportion of home goods in the home consumption index, C_t^i . In this model, the parameter $\alpha > 1$ is used to measure the degree of home bias in consumption, and the parameter $s\alpha$ is assumed to be $0 < s\alpha < 1$. The parameter $\theta > 1$ is used to measure the elasticity of substitution between any two goods produced in the same country. Furthermore, the second term in equation (1) represents real money balances, denoted by M_t^i/P_t , where M_t^i signifies nominal money balances and P_t denotes the home country's consumption price index (CPI). According to Appendix A, the purchasing power parity (PPP) is defined as $P_t = \varepsilon_t P_t^*$, where ε_t denotes the nominal exchange rate. The assumption underpinning this analysis is the existence of an international risk-free real bond market, in which real bonds are denominated in units of the composite consumption good. At any given point in time, households receive returns on risk-free real bonds, earn wage income by supplying labor, and receive profits from firms they own located in the world. Consequently, a typical household in the home country faces the following budget constraint:

$$P_t B_{t+1}^i + M_t^i = P_t(1 + r_t)B_t^i + M_{t-1}^i + W_t^i \ell_t^{s_i} + \int_0^s \Pi_t^h(j) dj + \int_s^1 \varepsilon_t \Pi_t^{f*}(j) dj - P_t C_t^i - P_t \tau_t^i, \quad (3)$$

where B_{t+1}^i is employed to denote real bonds, while r_t is used to denote the real interest rate on bonds. $W_t^i \ell_t^{s_i}$ is used to denote nominal labor income, where W_t^i is used to denote the nominal wage rate of household i , $\int_0^s \Pi_t^h(j) dj$ ($\int_s^1 \varepsilon_t \Pi_t^{f*}(j) dj$) is defined as the total nominal profit flows of firms located in home (abroad). $P_t C_t^i$ represents nominal consumption expenditure, and τ_t^i denotes real lump-sum taxes. We assume that government spending is purely dissipative and that it is financed by lump-sum taxes and seigniorage revenues. Accordingly, the government budget constraint is expressed as follows: $\int_0^{n_t} G_t^i di = \tau_t + (M_t - M_{t-1})/P_t$, where $\int_0^{n_t} G_t^i di$ denotes aggregate government spending, M_t denotes the aggregate money supply, and $\tau_t = \int_0^{n_t} \tau_t^i di$. In the home country, firm $j \in [0, s]$ hires differentiated labor inputs and produces a unique product according to the following formula: $y_t^h(j) = (n_t^{-1/\phi} \int_0^{n_t} (\ell_t^{di})^{(\phi-1)/\phi} di)^{\phi/(\phi-1)}$, where $y_t^h(j)$ denotes the production of home-located firm j in period t , $\ell_t^{di}(j)$ is the firm j 's input of labor from household i , and $\phi > 1$ is the elasticity of input substitution. The labor demand for household i 's labor input by firm j , as derived from the home firm's cost minimization problem, is as follows:

$$\ell_t^{di}(j) = n_t^{-1} (W_t^i / W_t)^{-\phi} y_t^h(j), \quad (4)$$

where $W_t \equiv (n_t^{-1} \int_0^{n_t} W_t^{i(1-\phi)} di)^{1/(1-\phi)}$. We now consider the optimization problem of households. According to Appendix B, the market clearing condition for any product j in period t is as follows:

$$y_t^h(j) = (P_t^h(j)/P_t^h)^{-\theta} (P_t^h/P_t)^{-\rho} \alpha (C_t^w + G_t^w), \quad (5)$$

where $C_t^w \equiv (n_t \alpha C_t^h + (1 - n_t) \alpha^* C_t^{h*})$ and $G_t^w \equiv (n_t \alpha G_t^h + (1 - n_t) \alpha^* G_t^{h*})$ are aggregate per

capita world consumption and government spending, respectively. In a manner analogous to the aforementioned, for product j of the foreign-located firms, we obtain $y_t^{f*}(j) = (P_t^{f*}(j)/P_t^{f*})^{-\theta} (P_t^{f*}/P_t^*)^{-\rho} ((1 - s\alpha)/(1 - s))(C_t^w + G_t^w)$. Households maximize (1) subject to (2). The first-order conditions for this maximization problem with respect to B_{t+1}^i and M_t^i are expressed as follows:

$$1/C_t^i = \beta E_t[(1 + r_{t+1})/C_{t+1}^i], \quad (6)$$

$$M_t^i/P_t = \chi C_t^i((1 + i_{t+1})/i_{t+1}), \quad (7)$$

where i_{t+1} is the nominal interest rate, which is conventionally defined as follows: $1 + i_{t+1} = (1 + r_{t+1})E_t[(P_{t+1}/P_t)]$. Equation (6) represents the Euler equation for consumption, while (9) corresponds to the equation for money demand. The transversality condition is defined as $\lim_{T \rightarrow \infty} (1/\prod_{v=1}^{t+T} (1 + r_v)) [B_{t+T+1} + M_{t+T}/P_{t+T}] = 0$. In monopolistic goods markets, the following price markup is obtained from the profit-maximization problem (see Appendix C):

$$P_t^h(j) = (\theta/(\theta-1))W_t. \quad (8)$$

Furthermore, from Appendix C, the real profits in the home and foreign countries are given by the following equations: $\Pi_t^h(h)/P_t = (1/\theta)(P_t^h(h)/P_t^h)^{1-\theta} (P_t^h/P_t)^{1-\rho} \alpha(C_t^w + G_t^w)$ and $\Pi_t^{f*}(f)/P_t^* = (1/\theta)(P_t^{f*}(f)/P_t^{f*})^{1-\theta} (P_t^{f*}/P_t^*)^{-\rho} ((1 - s\alpha)/(1 - s))(C_t^w + G_t^w)$. The model's distinguishing feature is its capacity to enable workers to adjust their migrations. The motivation for their migration to the other country is attributed to a disparity in real wages between the two countries. However, it is imperative to acknowledge that workers are not permitted to migrate instantaneously during the initial period or the period in which a discrepancy in wages emerges. The adjustment processes for the migration of workers are formulated as follows:

$$n_t - n_{t-1} = \gamma[W_t^i/P_t - W_t^{i*}/P_t^*] = \gamma[W_t^i/P_t - \varepsilon_t W_t^{i*}/P_t], \quad (9)$$

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. 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 this model, each household provides a single variety of labor input to a continuum of domestic firms. According to Appendix D, the following first-order condition is derived:

$$\phi(W_t^i/P_t)^{-1} E_{t-1} [\kappa(\ell_t^{si})^{1+1/\nu}] = (\phi - 1)E_{t-1} [\ell_t^{si}/C_t^i]. \quad (10)$$

The left-hand side of (10) signifies the marginal disutility of an increase in labor effort.

The right-hand side of the equation signifies the marginal consumption utility of additional labor income derived from an augmentation in labor effort. Hence, each household uses (10) to set its wage rate. Finally, the equilibrium condition for the integrated international bond market is determined as follows: $\int_0^{n_t} B_{t+1}^i di + \int_{n_t}^1 B_{t+1}^{i*} di = 0$. The money markets are given by the following equations: $M_t = \int_0^{n_t} M_t^i di$ and $M_t^* = \int_{n_t}^1 M_t^{i*} di$.

3. Analysis of government spending shocks

To examine the macroeconomic effects of an unanticipated permanent government spending 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 E. In the symmetric steady state, in which all variables are constant in both countries, given the Euler equation for consumption (equation (6)), 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. In this model, the economy starts from the zero-shock steady state at period 0, and then in period 1, nominal wage rigidities arise, and these are carried into period 2. After the one-period wage contracts are completed, a government spending policy decision is made. This means that nominal wages signed at the end of period 1 cannot adjust instantaneously to an unanticipated government spending shock in period 1. In addition, the condition for the optimal nominal wage, equation (10), 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.³ Moreover, in period 1, in which there is a shock, the international movement of workers occurs according to equation (9) after the unanticipated permanent government spending 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 (10). 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. These short-run percentage deviations are consistent with the length of nominal wage contracts. Thus, from equation (8), nominal wages and goods prices can be determined as $\hat{W} = \hat{W}^* = \hat{p}^h(h) = \hat{p}^{f*}(f) = 0$ 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, which is consistent with flexible nominal wages. By log linearizing equation (9) around the symmetric steady state and setting $\hat{p}^h(h) = \hat{p}^{f*}(f) = 0$, we obtain the following log-linearized expression for the international distribution of workers:

$$\hat{n} = -2\gamma((\theta-1)/\theta)\hat{\varepsilon}. \quad (11)$$

Equation (11) shows that a depreciation of the home country's currency induces a global

³ That is, the labor supply is demand determined in the period when there are nominal wage rigidities.

migration of workers from the home country to the foreign country. Intuitively, in the short run equilibrium characterized by $\widehat{W} = \widehat{W}^* = \widehat{P}^h(h) = \widehat{P}^{f^*}(f) = 0$, the depreciation of the home country's currency causes a decrease (increase) in the foreign (home) price level because $\widehat{P}^* = -(1/2)\widehat{\varepsilon}$ ($\widehat{P} = (1/2)\widehat{\varepsilon}$) from the definition of the price indexes. This increases (decreases) the relative real wage of foreign (home) workers and, as a result, some workers migrate from the home country to the foreign country. Equation (11) also shows that nominal exchange rate changes have larger effects the greater the flexibility of worker movements (the larger is γ).⁴ Furthermore, when θ is sufficiently close to 1, $\widehat{n} = 0$. This is because, when θ is sufficiently close to 1, the initial steady state real wages in both countries are close to zero ($W_{ss}/P_{ss} = W_{ss}^*/P_{ss}^* = (\theta - 1)/\theta$), and even if there is a wage gap between the two countries, the initial real wage level is sufficiently small, so it does not affect the direction of international worker migration. Similarly, by log-linearizing equation (9) in the long run, we obtain the following log-linearized expression for the long-run international migration of workers:

$$\bar{n} = -2\gamma((\theta-1)/\theta)(\widehat{\varepsilon} - (\bar{W} - \bar{W}^*)). \quad (12)$$

Equation (12) demonstrates that the direction of international worker migration is positively influenced by the disparity in nominal wages between two countries and negatively impacted by the exchange rate. As demonstrated by Equations (11) and (12), the exchange rate emerges as a pivotal factor influencing the international migration of workers. In the model, the nominal exchange rate and the terms of trade are equal in the short run when prices are sticky, but not in the long run when nominal wages and nominal prices are flexible. Indeed, the effect of an unanticipated permanent government spending shock on the home country's long-run terms of trade, as demonstrated in Appendix F, is as follows:

$$\bar{P}^h(h) - \bar{\varepsilon} - \bar{P}^{f^*}(f) = 2\delta H \bar{B} - H(\bar{G} - \bar{G}^*), \quad (13)$$

where $H \equiv \frac{1}{1 + \frac{1}{\rho}[\rho + 4\gamma((\theta-1)/\theta)] + ((\theta-1)/\theta)[\rho - 1 + 4\gamma((\theta-1)/\theta)]} > 0$.

According to the findings of equation (13), a home country's relative government spending shock has been shown to have a negative impact on the home country's terms of trade in a long-run equilibrium. This dynamic can be explained by the fact that the home country's relative government spending shock leads to an augmentation of its relative per capita labor supply in the long-run equilibrium. (See Appendix F for further details).

We proceed to examine the macroeconomic effects of unanticipated relative government spending shocks in the home country ($\widehat{G} - \widehat{G}^* = \bar{G} - \bar{G}^* > 0$) on the nominal exchange rate and on short- and long-run relative consumption. In accordance with Obstfeld and Rogoff's (1995) graphical analysis, the following MM and GG schedules are derived:

⁴ Despite the absence of empirical evidence demonstrating a direct correlation between exchange rates and international worker migration, some studies have examined the relationship between exchange rates and remittances to the home country (see Faini, 1994; Higgins, Hysenbegasi, & Pozo, 2004; Yang, 2008; Shin, 2021). The findings of these studies indicate that exchange rate fluctuations have a significant impact on the remittances sent by workers, thereby suggesting a correlation between exchange rate volatility and the migration patterns of workers across borders.

$$\hat{\varepsilon} = -D^{-1}(\hat{C} - \hat{C}^*): \text{MM schedule}, \quad (14)$$

$$\hat{\varepsilon} = \left(\frac{1+\delta A}{\delta A[\rho-1+4\gamma((\theta-1)/\theta)]((\theta-1)/\theta)} \right) (\hat{C} - \hat{C}^*) + \left(\frac{A(1+\delta)}{\delta A[\rho-1+4\gamma((\theta-1)/\theta)]((\theta-1)/\theta)} \right) (\bar{G} - \bar{G}^*): \text{GG schedule}, \quad (15)$$

where

$$A \equiv \left(1 + ((\theta-1)/\theta) \left(\frac{\rho-1+4\gamma((\theta-1)/\theta)}{1+\frac{1}{\gamma}[\rho+4\gamma((\theta-1)/\theta)]} \right) \right)^{-1} > 0,$$

$$D \equiv \left(1 - 4\gamma \left(\frac{\theta-1}{\theta} \right) \left(\frac{\delta}{1+\delta} \right) \right) \left(1 + 4\gamma \left(\frac{\theta-1}{\theta} \right) \left(\frac{1}{1+\delta} \right) \left(\frac{1}{1+\frac{1}{\gamma}[\rho+4\gamma((\theta-1)/\theta)]} \right) \right)^{-1}.$$

In this paper, we assume $1 > 4\gamma((\theta-1)/\theta)(\delta/(1+\delta))$, and therefore $D > 0$, to examine the impact of a relative increase in home country government spending. Intuitively, the inequality $1 > 4\gamma((\theta-1)/\theta)(\delta/(1+\delta))$ is valid when θ is sufficiently close to 1 or δ is sufficiently close to zero, given γ as a finite value. The MM schedule illustrates the interplay between consumption-driven money demand and the exchange rate. Assuming the inequality $1 > 4\gamma((\theta-1)/\theta)(\delta/(1+\delta))$, which implies $D > 0$, a plausible relationship between consumption-driven money demand and the exchange rate is substantiated, as evidenced by the negative slope of the MM schedule. Because, under $D > 0$, the MM schedule indicates that a decline in home consumption relative to that of other countries results in a depreciation of the home currency through a reduction in the demand for real money balances. The GG schedule is derived by combining households' intertemporal budget constraints, equilibrium conditions in the goods and labor markets, and labor mobility. Through the lens of goods and labor market equilibrium, the GG schedule shows that home currency depreciation is necessary to increase relative home consumption per capita. This occurs because depreciation of the home currency causes real wages in the home country to fall and real wages in the foreign country to rise, leading workers to move from the home country to the foreign country. Thus, the GG schedule has a positive slope since the coefficient of the $\hat{C} - \hat{C}^*$ term on the right-hand side of the GG schedule is positive. Figure 1 shows the effects of government spending shocks. The solid line labeled GG represents the pre-shock equilibrium, where $\hat{G} - \hat{G}^* = \bar{G} - \bar{G}^* = 0$. The dashed line shows the post-shock GG schedule. On the other hand, if $1 > 4\gamma((\theta-1)/\theta)(\delta/(1+\delta))$, then $D > 0$ and the MM schedule is a downward-sloping straight line passing through the origin. The equilibrium exchange rate and the change in relative consumption lie at the intersection of the MM and GG schedules. Figure 1 shows that when there is unexpected relative home government spending, the exchange rate depreciates and home relative consumption falls.

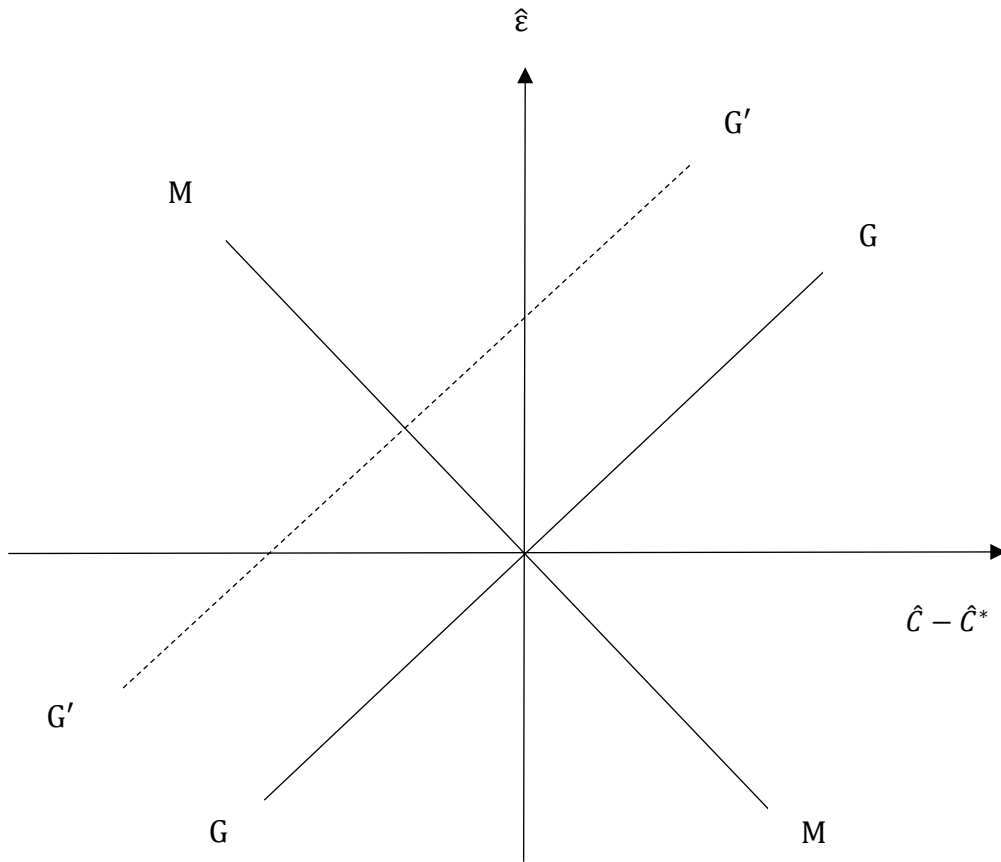


Figure 1. Government spending shocks.

When solving the MM and GG schedules, the equilibrium solutions are as follows:

$$\hat{\epsilon} = \left(\frac{A(1+\delta)}{D(1+\delta A) + \delta A[\rho - 1 + 4\gamma((\theta-1)/\theta)]((\theta-1)/\theta)} \right) (\bar{G} - \bar{G}^*), \quad (16)$$

$$\hat{C} - \hat{C}^* = - \left(\frac{DA(1+\delta)}{D(1+\delta A) + \delta A[\rho - 1 + 4\gamma((\theta-1)/\theta)]((\theta-1)/\theta)} \right) (\bar{G} - \bar{G}^*) = K(\bar{G} - \bar{G}^*), \quad (17)$$

where $K = - \left(\frac{DA(1+\delta)}{D(1+\delta A) + \delta A[\rho - 1 + 4\gamma((\theta-1)/\theta)]((\theta-1)/\theta)} \right)$.

According to equation (16), an increase in the home country's unanticipated relative government spending leads to exchange rate depreciation ($\hat{\epsilon} > 0$) if $1 > 4\gamma((\theta-1)/\theta)(\delta/(1+\delta))$ and therefore $D > 0$.⁵ Equation (17) demonstrates that an increase in the home country's government spending results in a proportional decrease in relative consumption levels ($\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* < 0$), provided that $1 > 4\gamma((\theta-1)/\theta)(\delta/(1+\delta))$ and therefore $D > 0$. The results of equations (16) and (17) can be explained intuitively as follows: First, at a constant exchange rate, an

⁵ Several studies have demonstrated that fiscal shocks result in exchange rate depreciation. These include works by Kim and Roubini (2008), Monacelli and Perotti (2010), Enders et al. (2011), Bouakez and Eyquem (2015), da Silva et al. (2015), Kim (2015), and Li and Zhu (2024).

increase in the home country's government spending leads to the crowding out of consumption in the home country. This phenomenon transpires due to the fact that the augmentation in government expenditure does not engender an adequate escalation in production or household income, thereby failing to counterbalance the diminution in income occasioned by elevated lump-sum taxes. Consequently, the exchange rate experiences depreciation in conjunction with the decline in consumption. This phenomenon can be attributed to the fact that a decline in consumption leads to a corresponding decrease in the demand for real money balances, as indicated by the money demand function. Moreover, a depreciation of the exchange rate has been shown to reduce the home country's relative real wage, thereby prompting migration of workers from the home country to the foreign country. This phenomenon leads to a reduction in the home country's demand for money, which in turn results in a further depreciation of the exchange rate. Consequently, in our model, an augmentation in the home country's government expenditure results in a depreciation of its currency and a decline in consumption.

The difference between our model and the traditional Redux model is that, in our model, the level of exchange rate depreciation is greater than it would be if international worker mobility were fixed. To illustrate, consider a scenario in which γ is large. First, since the slope of the MM schedule is negative, a decrease in relative per capita consumption in the home country leads to depreciation of the home currency. If γ were larger, the decline in real wages due to currency depreciation would lead to a greater outflow of workers from the home country to the foreign country. This indicates that relative money demand in the home country decreases as γ increases. Thus, the greater the value of γ , the greater the exchange rate depreciation in response to a decrease in relative per capita consumption in the home country. Therefore, the slope of the MM schedule becomes steeper as γ increases. Conversely, the slope of the GG schedule flattens as γ increases, according to equation (15). Intuitively, this can be explained as follows: As γ increases, more workers move from the home country to the foreign country due to the real wage gap caused by the exchange rate depreciation. This increases the relative home labor income per capita, which increases relative home consumption per capita. Therefore, the larger γ becomes, the flatter the GG schedule slope becomes. As Figure 2 shows, the greater the value of γ , the greater the exchange rate's response to an increase in government spending in the home country.

Figure 2 shows that an increase in γ mitigates the negative impact of government spending shocks on relative consumption levels in the home country. Intuitively, this occurs because a larger relative increase in per capita labor income in the home country due to worker outflows offsets the initial negative impact of tax burdens on consumption. Next, short-run changes in the international migration of workers are as follows:

$$\hat{n} = - \left(\frac{2\gamma A((\theta-1)/\theta)(1+\delta)}{D(1+\delta A) + \delta A[\rho - 1 + 4\gamma((\theta-1)/\theta)]((\theta-1)/\theta)} \right) (\bar{G} - \bar{G}^*) < 0. \quad (18)$$

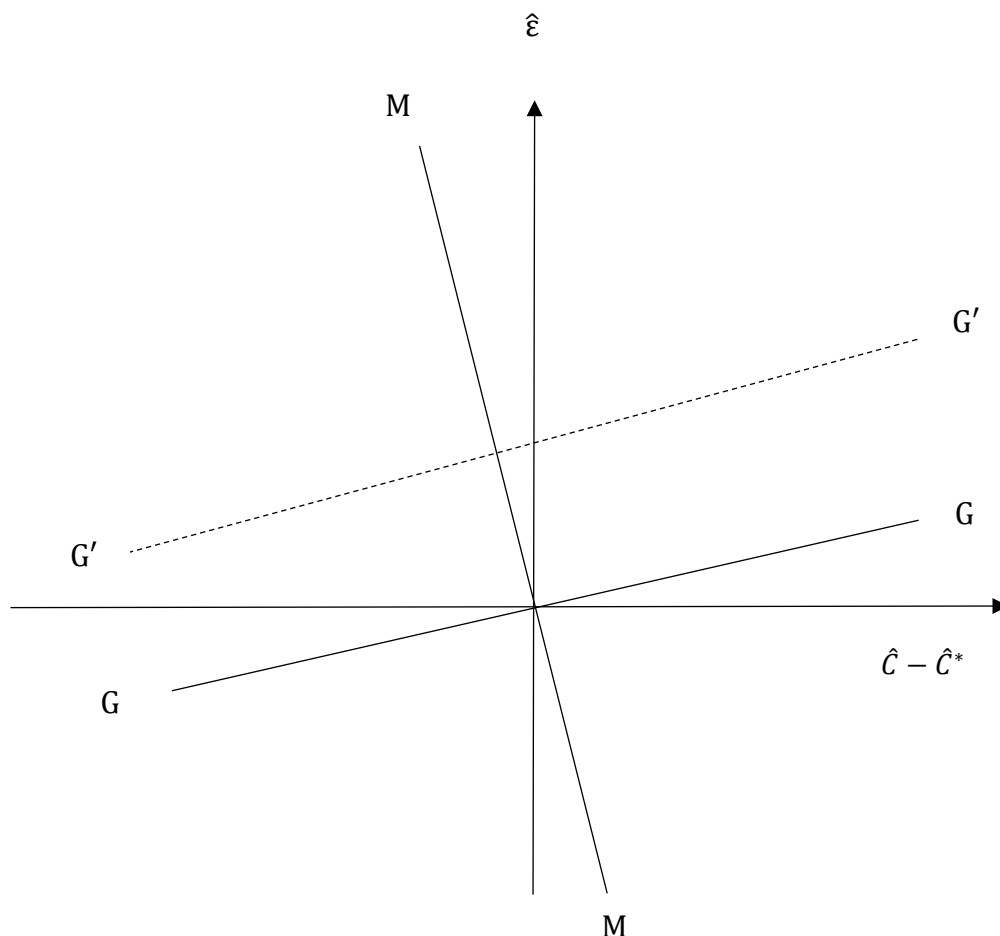


Figure 2. MM and GG schedules when γ is large.

The result in (18) shows that an unanticipated increase in the home country's government spending relative to the foreign country's spending leads to migration of workers from the home country to the foreign country when $1 > 4\gamma((\theta-1)/\theta)(\delta/(1+\delta))$. This occurs because the exchange rate depreciation from (16) causes a decrease in the foreign price level and an increase in the home price level. This increases the relative real wage of foreign-located workers and decreases that of home-located workers. Consequently, workers relocate from the home country to the foreign country. Similarly, the long-run effect of unanticipated relative government spending shocks in the home country on the direction of international worker migration is as follows:

$$\bar{n} = - \left(\frac{2\gamma((\theta-1)/\theta)}{1 + \frac{1}{\gamma}[\rho + 4\gamma((\theta-1)/\theta)]} \right) \left(\frac{DA(1+\delta)}{D(1+\delta A) + \delta A[\rho - 1 + 4\gamma((\theta-1)/\theta)]((\theta-1)/\theta)} \right) (\bar{G} - \bar{G}^*) < 0. \quad (19)$$

Similar to the results of (18), result (19) shows that an unanticipated increase in the home country's permanent government spending leads to migration of workers from the home country to the foreign country under $1 > 4\gamma((\theta-1)/\theta)(\delta/(1+\delta))$. To assess the long-run effects of unanticipated permanent government spending shocks on international worker migration, we must

first consider equations (10) and (12), which are meaningful in long-run equilibrium. The left-hand side of equation (10) represents the marginal disutility of an increase in work effort. The right-hand side of equation (10) represents the marginal consumption utility of the additional labor income resulting from an increase in labor effort. In the model, each worker uses equation (10) to determine his or her wage rate. Equations (10) and (12) show that the long-run effects of unanticipated permanent government spending shocks on the direction of international worker migration can be divided into two effects. First, in our model, an increase in the price level occurs in the home country and a decrease occurs in the foreign country due to the home country's currency depreciation. Consequently, equation (12) shows that the real wage in the home country is lower than in the foreign country. This causes home workers to migrate to the foreign country. This paper defines this effect as the exchange rate effect. The second effect occurs through a labor-leisure trade-off condition, as shown in equation (10). Equation (10) shows that when $1 > 4\gamma((\theta-1)/\theta)(\delta/(1+\delta))$ and the relative consumption of the home country decreases ($\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* < 0$), the marginal utility of consumption associated with labor supply on the right side of equation (10) increases. Therefore, in this case, workers in the home country lower their nominal wage to satisfy equation (10) and increase their labor supply. This decreases the real wage in the home country relative to the foreign country, providing an incentive for workers to migrate from the home country to the foreign country. This effect is called the labor-leisure trade-off effect. As shown in equation (12), the total effect of unanticipated permanent government spending shocks on the long-run international migration of workers is equal to the sum of the magnitudes of the exchange rate and labor-leisure trade-off effects. Therefore, in the long run, unanticipated permanent government spending shocks cause workers to migrate from the home country to the foreign country when $1 > 4\gamma((\theta-1)/\theta)(\delta/(1+\delta))$. Additionally, as with short-run changes in worker migration, $\bar{n} = 0$ is obtained when γ is sufficiently close to 0 or θ is sufficiently close to 1 because, according to equation (E4) in Appendix E, the real wages in both countries are close to zero. This occurs because, despite a wage gap between the countries, the initial real wage level is so low that it does not impact the direction of international worker migration. Table 1 summarizes the effects of unanticipated, permanent government spending shocks on changes in international worker migration, the nominal exchange rate, and the home country's relative consumption level.

Table 1. The effects of the unanticipated permanent government spending shocks.

The case of $1 > 4\gamma((\theta-1)/\theta)(\delta/(1+\delta))$	
Nominal exchange rate	$\hat{\epsilon} > 0$
Short-run migration	$\hat{n} < 0$
Long-run migration	$\bar{n} < 0$
Relative consumption levels	$\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^* < 0$

4. Welfare effects

Following Obstfeld and Rogoff (1995), who disregarded the welfare effects of real balances, we focus on the real component of an agent's utility, comprising terms involving consumption and labor effort. Defining this real component as U_0^R , we can rewrite equation (1) as $U_0^R = E_0 \sum_{\tau=0}^{\infty} \beta^\tau \left(\log C_\tau^i - (\kappa/(1+1/\nu)) (\ell_\tau^{si})^{1+1/\nu} \right)$. From Appendix G, the world welfare effect of unanticipated permanent government spending shocks is as follows:

$$\begin{aligned} dU^W = (1/2)(dU_0^R + dU_0^{R*}) = -((\phi-1)/\phi)((\theta-1)/\theta)\hat{G}^W + \\ -(1/(1+\nu)\delta)[1 + \nu((\phi-1)/\phi)((\theta-1)/\theta)]\bar{G}^W < 0 \end{aligned} \quad (20)$$

The intuitive explanation is as follows: First, an unanticipated increase in government spending in the home country leads to increased production and labor efforts in both countries. Second, an increase in government spending reduces domestic household consumption, which finances the spending, while increasing foreign household consumption. Thus, when relative home government spending increases, the increase in utility due to foreign household consumption may exceed the decline in utility due to decreased domestic household consumption and the negative utility effect of increased labor due to increased production in both countries. However, equation (20) suggests that, in our model, the increase in labor effort in both countries in response to an increase in relative home government spending always exceeds the increase in utility caused by increased foreign household consumption. This implies a decrease in global welfare.

5. Conclusion

This paper analyzed how allowing international relocation of workers affects the impact of government spending shocks on the exchange rate, consumption, and global welfare. Our analysis revealed the following main findings: First, an increase in government spending in the home country results in a decrease in relative home consumption levels and a depreciation of the home currency. Second, an increase in government spending in the home country leads to a decline in the real wage in that country and an increase in the real wage in the foreign country. This leads to an outflow of workers from the home country to the foreign country. Third, as international worker mobility rises, the effect of a government expenditure shock on the relative home consumption level diminishes while the impact on the exchange rate intensifies. Fourth, global welfare always worsens with an increase in government spending in the home country.

This paper used the NOEM model, which considers international worker mobility, to analyze the effects of government spending shocks on the exchange rate, consumption, and global welfare.

While this model is user-friendly, it has many limitations and allows for many extensions. For example, a framework incorporating a Taylor-type interest rate rule while excluding money would align with standard practices in modern DSGE literature and potentially yield more intriguing results. Additionally, this paper employs a model in which the elasticity of substitution between domestic and foreign goods remains constant over time. However, as shown in the empirical studies of Yilmazkuday (2019) and Boehm et al. (2023), the elasticity of substitution between foreign goods tends to increase over time. While our model distinguishes between short-run and long-run equilibria, it could be extended to cases where the elasticity of substitution varies between the two. Furthermore, this paper focuses on the theoretical aspects of the NOEM model that consider international labor mobility. Therefore, we must next consider whether the results of this paper are consistent with empirical evidence. Notably, there is a lack of empirical research on the relationship between fiscal shocks and international labor mobility. Finally, the model assumes that international labor migration is based solely on real wage differentials. However, it is necessary to empirically examine whether the derived relationship between exchange rate fluctuations and labor migration is justified in the real economy. These issues remain topics for future research.

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Appendix A: Theoretical derivation of PPP

The home country consumption price index (CPI), which is defined as $P_t = \left[s\alpha(P_t^h)^{1-\rho} + (1-s\alpha)(P_t^f)^{1-\rho} \right]^{1/(1-\rho)}$, where $P_t^h = (s^{-1} \int_0^s P_t^h(j)^{1-\theta} dj)^{1/(1-\theta)}$ is the price index corresponding to C_t^h , and $P_t^f = ((1-s)^{-1} \int_s^1 P_t^f(j)^{1-\theta} dj)^{1/(1-\theta)}$, is the price index corresponding to C_t^f , and $P_t^h(j)$ is the home-currency price of good j produced in the home country, and $P_t^f(j)$ is the home-currency price of good j produced in the foreign country. Analogously, the foreign country CPI is $P_t^* = \left[s\alpha(P_t^{h*})^{1-\rho} + (1-s\alpha)(P_t^{f*})^{1-\rho} \right]^{1/(1-\rho)}$, where $P_t^{h*} = (s^{-1} \int_0^s P_t^{h*}(j)^{1-\theta} dj)^{1/(1-\theta)}$ and $P_t^{f*} = ((1-s)^{-1} \int_s^1 P_t^{f*}(j)^{1-\theta} dj)^{1/(1-\theta)}$ are price indexes corresponding to C_t^{h*} (C_t^{f*}), $P_t^{h*}(j)$ is the foreign-currency price of good j produced in the home country, and P_t^{f*} is the foreign-currency price of good j produced in the foreign country. Under the law of one price, we can rewrite the price indexes as

$$P_t = \left[s\alpha \left(P_t^h(j) \right)^{1-\rho} + (1-s\alpha) \left(\varepsilon_t P_t^f(j) \right)^{1-\rho} \right]^{1/(1-\rho)}, \quad (A1)$$

$$P_t^* = \left[s\alpha \left(P_t^{h*}(j) / \varepsilon_t \right)^{1-\rho} + (1-s\alpha) \left(P_t^{f*}(j) \right)^{1-\rho} \right]^{1/(1-\rho)}. \quad (A2)$$

In this model, the law of one price holds for any variety j because there are no trade costs between the two countries; i.e., $P_t^h(j) = \varepsilon_t P_t^{h*}(j)$ and $P_t^f(j) = \varepsilon_t P_t^{f*}(j)$, where ε_t is the nominal exchange rate, defined as the price of one unit of the home currency in foreign currency. The law of one price and the price indexes (A1) and (A2) imply that purchasing power parity (PPP) is represented by $P_t = \varepsilon_t P_t^*$.

Appendix B: Market clearing condition

From the maximization by households in the home (foreign) country for the consumption index C_t^i (C_t^{i*}), we obtain the demand functions for good j in the home and foreign countries are as follows, respectively:

$$C_t^h(j) = (P_t^h(j)/P_t^h)^{-\theta} (P_t^h/P_t)^{-\rho} \alpha C_t^i, \quad (\text{B1})$$

$$C_t^f(j) = (P_t^f(j)/P_t^f)^{-\theta} (P_t^f/P_t)^{-\rho} ((1-s\alpha)/(1-s)) C_t^i, \quad (\text{B2})$$

$$C_t^{h*}(j) = (P_t^{h*}(j)/P_t^{h*})^{-\theta} (P_t^{h*}/P_t^*)^{-\rho} \alpha^* C_t^{i*}, \quad (\text{B3})$$

$$C_t^{f*}(j) = (P_t^{f*}(j)/P_t^{f*})^{-\theta} (P_t^{f*}/P_t^*)^{-\rho} ((1-s\alpha^*)/(1-s)) C_t^{i*}. \quad (\text{B4})$$

As in the NOEM literature, we also assume that the government's consumption index is the same as the household sector's, given by C_t^i . Therefore, the government's demand functions for good j in the home and foreign countries are the same as those of the household sector. Aggregating the demands across all households worldwide and equating the resulting equation to $y_t^h(j)$ yields the following market clearing condition for any product j in period t :

$$y_t^h(j) = n_t C_t^h(j) + (1-n_t) C_t^{h*}(j) + n_t G_t^h + (1-n_t) G_t^{h*} = (P_t^h(j)/P_t^h)^{-\theta} (P_t^h/P_t)^{-\rho} \alpha (C_t^w + G_t^w), \quad (\text{B5})$$

where $P_t^h(j)/P_t^h = 1$, $P_t^h/P_t = P_t^h(j)/P_t$ from the law of one price, and $C_t^w \equiv (n_t \alpha C_t^h + (1-n_t) \alpha^* C_t^{h*})$ and $G_t^w \equiv (n_t \alpha G_t^h + (1-n_t) \alpha^* G_t^{h*})$ are aggregate per capita world consumption and government spending, respectively.

Appendix C: Price mark-up and real profits

In the monopolistic goods markets, given W_t , P_t , C_t^w , and n_t and subject to (4) and (5), home-located firm j faces the following profit-maximization problem: $\max_{P_t^h(j)} \Pi_t^h(j) = P_t^h(j)y_t^h(j) - \int_0^{n_t} W_t^i \ell_t^{di}(j) di = (P_t^h(j) - W_t)y_t^h(j)$. By substituting $y_t^h(j)$ from equation (5) into $\Pi_t^h(j)$ and then differentiating the resulting equation with respect to the home-currency price of good j produced in the home country, $P_t^h(j)$, we obtain the following price mark-up:

$$P_t^h(j) = (\theta/(\theta-1))W_t. \quad (C1)$$

From (C1), all home-located firms charge the same price. In what follows, we define these identical prices as $P_t^h(j) = P_t^h(h)$, $j \in [0, s]$. These relationships imply that each firm supplies the same quantity of goods, and hence, $\ell_t^{di}(j) = \ell_t^{di}(h)$, $j \in [0, s]$, where the firm index j is omitted because of symmetry. The price mark-ups of foreign-located firms are identical because $P_t^{f*}(j) = P_t^{f*}(f)$, $j \in (s, 1]$. Substituting (C1) and the foreign counterpart into $\Pi_t^h(h)$ and $\Pi_t^{f*}(f)$, respectively, yields

$$\begin{aligned} \Pi_t^h(h)/P_t &= (1/\theta)(P_t^h(h)/P_t^h)^{1-\theta} (P_t^h/P_t)^{1-\rho} \alpha(C_t^w + G_t^w) \text{ and} \\ \Pi_t^{f*}(f)/P_t^* &= (1/\theta)(P_t^{f*}(f)/P_t^{f*})^{1-\theta} (P_t^{f*}/P_t^*)^{1-\rho} ((1-s\alpha)/(1-s))(C_t^w + G_t^w). \end{aligned}$$

Appendix D: Derivation of equation (10)

The equilibrium labor-market conditions for the home and foreign countries imply that $\ell_t^{si} = \int_0^s \ell_t^{di}(j) dj$, $i \in (0, n_t)$ and $\ell_t^{si*} = \int_s^1 \ell_t^{di*}(j) dj$, $i \in (n_t, 1]$, 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 , $y_t^h(j)$, and n_t as given, by substituting $\ell_t^{si} = \int_0^s \ell_t^{di}(j) dj$ and equation (4) into the budget constraint, given by (3), and maximizing the lifetime utility, given by (1), with respect to the nominal wage W_t^i , we obtain the following first-order condition:

$$\phi(W_t^i/P_t)^{-1} E_{t-1} [\kappa(\ell_t^{si})^{1+1/\nu}] = (\phi - 1) E_{t-1} [\ell_t^{si}/C_t^i]. \quad (D1)$$

Appendix E: 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 ($B_{ss,0} = 0$), $\alpha = \alpha^*$, and $s = 1/2$. 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 (6)), 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. In the symmetric steady state, $W_{ss}^h/P_{ss} = W_{ss}^{f^*}/P_{ss}^*$ must be satisfied. From $W_{ss}^h/P_{ss} = (W_{ss}^h/W_{ss})(W_{ss}/P_{ss}^h(h))(P_{ss}^h(h)/P_{ss})$, $W_{ss}^{f^*}/P_{ss}^* = (W_{ss}^{f^*}/W_{ss}^*)(W_{ss}^*/P_{ss}^{f^*}(f))(P_{ss}^{f^*}(f)/P_{ss}^*)$, $P_t = \varepsilon_t P_t^*$ and equation (8), we obtain $P_{ss}^h(h) = \varepsilon_{ss} P_{ss}^{f^*}(f)$. Given a symmetric equilibrium in which $P_t^h(j) = P_t^h(h)$ and $P_t^{f^*}(j) = P_t^{f^*}(f)$, $\forall j$, the real prices can be rewritten as

$$P_t^h(h)/P_t = (P_t^h(h)/\varepsilon_t)/P_t^* = \left[s\alpha + (1 - s\alpha) \left((\varepsilon_t P_t^{f^*}(f))/P_t^h(h) \right)^{1-\rho} \right]^{-1/(1-\rho)}, \quad (E1)$$

$$\varepsilon_t P_t^{f^*}(f)/P_t = P_t^{f^*}(f)/P_t^* = \left[s\alpha \left((\varepsilon_t P_t^{f^*}(f))/P_t^h(h) \right)^{\rho-1} + (1 - s\alpha) \right]^{-1/(1-\rho)}, \quad (E2)$$

where $P_t^h(h)/P_t$ and $\varepsilon_t P_t^{f^*}(f)/P_t$ are the real prices of the home and foreign goods, which equal $(P_t^h(h)/\varepsilon_t)/P_t^*$ and $P_t^{f^*}(f)/P_t^*$, respectively. Substituting $P_{ss}^h(h) = \varepsilon_{ss} P_{ss}^{f^*}(f)$ into equations (E1) and (E2) yields following steady-state real prices

$$P_{ss}^h(h)/P_{ss} = (P_{ss}^h(h)/\varepsilon_{ss})/P_{ss}^* = \varepsilon_{ss} P_{ss}^{f^*}(f)/P_{ss} = P_{ss}^{f^*}(f)/P_{ss}^* = 1. \quad (E3)$$

From (8), steady-state real wages are

$$W_{ss}/P_{ss} = W_{ss}^*/P_{ss}^* = (\theta - 1)/\theta. \quad (E4)$$

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

$$n_{ss} = 1/2. \quad (E5)$$

In addition, from (10), we obtain

$$\ell_{ss}^s = \ell_{ss}^{*s} = C_{ss} = C_{ss}^* = C_{ss}^w = ((\phi-1)/\phi)^{v/(1+v)} ((\theta-1)/\theta)^{v/(1+v)} (1/\kappa)^{v/(1+v)}. \quad (E6)$$

Equation (E6) shows that all households worldwide consume the same amount of output and supply the labor required to produce this output.

Appendix F: Terms of trade

Below we show the effect of government spending shocks on the terms of trade in the long-run equilibrium where nominal wages and prices are flexible. From equation (12), the log-linearized expression for the long-run international migration of workers is as follows:

$$\bar{n} = 2\gamma((\theta-1)/\theta)(\bar{W} - \bar{\varepsilon} - \bar{W}^*). \quad (12)$$

The optimal pricing equations for firms in each country are as follows:

$$\bar{P}^h(h) = \bar{W}, \bar{P}^{f^*}(f) = \bar{W}^*. \quad (F1)$$

From (12) and (F1), we obtain

$$\bar{n} = 2\gamma((\theta-1)/\theta) \left(\bar{P}^h(h) - \bar{\varepsilon} - \bar{P}^{f^*}(f) \right). \quad (F2)$$

The production technology for firms in each country is as follows:

$$\bar{y}^h(h) = \bar{n} + \bar{\ell}^d, \bar{y}^{f^*}(f) = -\bar{n} + \bar{\ell}^{d^*}. \quad (F3)$$

The long-run labor-market clearing conditions for both countries are as follows:

$$\bar{\ell}^s = \bar{\ell}^d, \bar{\ell}^{s^*} = \bar{\ell}^{d^*}. \quad (F4)$$

The world demand schedules for home and foreign products are as follows:

$$\bar{y}^h(h) = \rho(\bar{P} - \bar{P}^h(h)) + \bar{C}^W + \bar{G}^W, \bar{y}^{f^*}(f) = \rho(\bar{P}^* - \bar{P}^{f^*}(f)) + \bar{C}^W + \bar{G}^W. \quad (F5)$$

From (F3) and (F4), we obtain

$$\bar{\ell}^s - \bar{\ell}^{s^*} = \bar{y}^h(h) - \bar{y}^{f^*}(f) - 2\bar{n}. \quad (F6)$$

The purchasing power parity equation is as follows:

$$\bar{\varepsilon} = \bar{P} - \bar{P}^*. \quad (F7)$$

Substitution (F5) and (F7) into (F6) yields

$$\bar{\ell}^s - \bar{\ell}^{s^*} = -\rho \left(\bar{P}^h(h) - \bar{\varepsilon} - \bar{P}^{f^*}(f) \right) - 2\bar{n}. \quad (F8)$$

From (F2) and (F8), we obtain

$$\bar{\ell}^s - \bar{\ell}^{s^*} = -[\rho + 4\gamma((\theta-1)/\theta)] \left(\bar{P}^h(h) - \bar{\varepsilon} - \bar{P}^{f^*}(f) \right). \quad (F9)$$

The first-order conditions for optimal wage settings for both countries are as follows:

$$\bar{\ell}^s = v(\bar{W} - \bar{P} - \bar{C}), \bar{\ell}^{s^*} = v^*(\bar{W}^* - \bar{P}^* - \bar{C}^*). \quad (F10)$$

From equations (F1), (F7), (F10) and considering $v = v^*$, we obtain

$$\bar{\ell}^s - \bar{\ell}^{s^*} + v(\bar{C} - \bar{C}^*) = v \left(\bar{P}^h(h) - \bar{\varepsilon} - \bar{P}^{f^*}(f) \right). \quad (F11)$$

From (F9) and (F11), we obtain

$$\bar{\ell}^s - \bar{\ell}^{s^*} = - \left[\frac{\rho + 4\gamma((\theta-1)/\theta)}{1 + (1/v)[\rho + 4\gamma((\theta-1)/\theta)]} \right] (\bar{C} - \bar{C}^*). \quad (F12)$$

From (F9) and (F12), we obtain

$$\bar{C} - \bar{C}^* = [1 + (1/v)[\rho + 4\gamma((\theta-1)/\theta)]] \left(\bar{P}^h(h) - \bar{\varepsilon} - \bar{P}^{f^*}(f) \right). \quad (F13)$$

The long-run change in after tax incomes (returns on real bonds, real labor incomes, and real profit incomes), which equal the long-run changes in consumption in each country

$$\bar{C} = \delta\bar{B} + ((\theta-1)/\theta)(\bar{W} - \bar{P} + \bar{\ell}^s) + (1/2\theta)[\bar{\Pi}(h) + \bar{\Pi}(f)^* + \bar{\varepsilon}] - (1/\theta)\bar{P} - \bar{G}, \quad (F14)$$

$$\bar{C}^* = -\delta\bar{B} + ((\theta-1)/\theta)(\bar{W}^* - \bar{P}^* + \bar{\ell}^{s^*}) + (1/2\theta)[\bar{\Pi}(h) - \bar{\varepsilon} + \bar{\Pi}(f)^*] - (1/\theta)\bar{P}^* - \bar{G}^*. \quad (F15)$$

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Subtracting (F15) from (F14) and considering (F1) and (F7) yields the long-run (from period $t + 1$ onwards) response of relative per capita consumption levels,

$$\bar{c} - \bar{c}^* = 2\delta\bar{B} + ((\theta-1)/\theta)(\bar{P}^h(h) - \bar{\varepsilon} - \bar{P}^{f^*}(f) + \bar{\ell}^s - \bar{\ell}^{s^*}) - (\bar{G} - \bar{G}^*). \quad (\text{F16})$$

Substituting (F9) and (F13) into (F16) yields

$$\bar{P}^h(h) - \bar{\varepsilon} - \bar{P}^{f^*}(f) = 2\delta H \bar{B} - H(\bar{G} - \bar{G}^*), \quad (\text{F17})$$

where $H \equiv \frac{1}{1 + \frac{1}{\nu}[\rho + 4\gamma((\theta-1)/\theta)] + ((\theta-1)/\theta)[\rho - 1 + 4\gamma((\theta-1)/\theta)]} > 0$.

Appendix G: World welfare impact

The impact of unanticipated government spending shocks on domestic welfare is as follows:

$$dU_0^R = (1/2)((1 + \delta)/\delta)K(\bar{G} - \bar{G}^*) - \{(1/(1 + \nu)\delta)\bar{G}^W + ((\phi-1)/\phi)((\theta-1)/\theta)[\hat{G}^W + (1/2)Q(\bar{G} - \bar{G}^*)] + (1/\delta)((\phi-1)/\phi)((\theta-1)/\theta)[(\nu/(1 + \nu))\bar{G}^W + (1/2)V(\bar{G} - \bar{G}^*)]\}, \quad (G1)$$

where

$$Q \equiv - \left(\frac{[\rho + 4\gamma((\theta-1)/\theta)]A(1+\delta)}{D(1+\delta A) + \delta A[\rho - 1 + 4\gamma((\theta-1)/\theta)]((\theta-1)/\theta)} \right),$$

$$V = \left(\frac{\rho + 4\gamma((\theta-1)/\theta)}{1 + \frac{1}{\nu}[\rho + 4\gamma((\theta-1)/\theta)]} \right) \left(\frac{DA(1+\delta)}{D(1+\delta A) + \delta A[\rho - 1 + 4\gamma((\theta-1)/\theta)]((\theta-1)/\theta)} \right).$$

In the same way, the impact on foreign welfare is as follows:

$$dU_0^{R*} = -(1/2)((1 + \delta)/\delta)K(\bar{G} - \bar{G}^*) - \{(1/(1 + \nu)\delta)\bar{G}^W + ((\phi-1)/\phi)((\theta-1)/\theta)[\hat{G}^W - (1/2)Q(\bar{G} - \bar{G}^*)] + (1/\delta)((\phi-1)/\phi)((\theta-1)/\theta)[(\nu/(1 + \nu))\bar{G}^W - (1/2)V(\bar{G} - \bar{G}^*)]\}. \quad (G2)$$

From equations (G1) and (G2), we can derive the effect of unanticipated permanent government spending shocks on world welfare. For this purpose, we define world welfare as $U_t^W = n_t U_t^R + (1 - n_t) U_t^{R*}$, where $n_{ss,0} = 1/2$ denotes the initial steady-state distribution of workers, and $U_{ss,0}^R = U_{ss,0}^{R*}$. The world welfare effect of unanticipated permanent government spending shocks is then

$$dU^W = (1/2)(dU_0^R + dU_0^{R*}) = -((\phi-1)/\phi)((\theta-1)/\theta)\hat{G}^W - (1/(1 + \nu)\delta)[1 + \nu((\phi-1)/\phi)((\theta-1)/\theta)]\bar{G}^W < 0. \quad (G3)$$