Fiscal Policy, Relocation of Firms, and the Exchange Rate

Wataru Johdo

This study incorporates international firm mobility into a new open economy macroeconomic model to analyze the question of how allowing for the international relocation of firms affects the impact of government spending shock on consumption and exchange rate. The study shows that the government spending shock of a home country results in a proportionate decrease in the relative home consumption level and a depreciation of the home currency. In addition, depreciation increases (decreases) the relative real profits of firms located in the home country (abroad), and consequently, firms relocate to the home country. The study also shows that an increase in the degree of firm mobility weakens the effects of government spending shocks on relative consumption and exchange rate.

Keywords: Fiscal policy, Relocation of firms, Exchange rate, Consumption, Firm mobility

JEL Classification: E62, F31, F41

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I. Introduction

The international spillovers of fiscal policies have been studied extensively in new open economy macroeconomics (NOEM) literature, *e.g.*, the works of Obstfeld and Rogoff (1995, 1996), Betts and Devereux (2000), Caselli (2001), Corsetti and Pesenti (2001), Cavallo and Ghironi (2002), Chu (2005), Ganelli (2003, 2005a, 2005b), and Di Giorgio *et al.* (2015).[1] The literature has focused on how the macroeconomic activity of each country and the exchange rate are influenced by unanticipated fiscal shocks under monopolistic distortions and sticky nominal prices.

Since the publication of the work of Obstfeld and Rogoff (1995), most NOEM models have assumed that firms are immobile across countries, and they have shown that changes in foreign output following domestic government spending shocks are the main sources of the international transmission effect. Although the effects of government spending shocks can be explored feasibly as a framework, recent empirical evidence (*e.g.*, Cushman 1985 and 1988; Froot and Stein 1991; Campa 1993; Klein and Rosengren 1994; Goldberg and Kolstad 1995; Blonigen 1997; Goldberg and Klein 1998; Bénassy-Quéré *et al.* 2001; Chakrabarti and Scholnick 2002; Farrell *et al.* 2004; Miyagawa *et al.* 2004) suggests that exchange rates affect the production locations and foreign direct investments of firms. In addition, the entry regulations that govern multinational firms in developed and newly emerging countries have become substantially liberalized in recent years. As a result, multinational firms from the US, Japan, South Korea, and China have extensively and actively invested across national borders.

In the NOEM literature, the studies on the topic at hand (*i.e.*, how allowing for the international relocation of firms affects the impact of government spending shocks on consumption and exchange rates) are limited. One exception is the work of Johdo (2015), which presents a NOEM model with international relocation of firms. Johdo (2015) contrasts the standard NOEM model with the NOEM model with international relocation and subsequently succeeds in showing explicitly the effects of a country's monetary expansion on both relative

[1] Other related references include Senay (1998), Lombardo and Sutherland (2004), Pierdzioch (2004), Choi (2005), Ganelli and Tervala (2010) and Di Giorgio *et al.* (2018). For surveys of the NOEM literature examining fiscal policy issues, see Lane and Ganelli (2003) and Coutinho (2005).

consumption level and exchange rate in a world where firms can relocate across countries. However, the literature does not consider the impact of government spending shock on international relocation of firms and other macroeconomic variables, including relative consumption level and exchange rate.

In this study, we extend the model of Johdo (2015) to include government consumption spending. A novel feature of our model is that the international relocation of firms responds to exchange rate movements caused by government spending shocks.

We conclude that government spending shock in a home country leads to a proportionate decrease in relative home consumption, and the home currency depreciates correspondingly. In addition, depreciation increases (decreases) the relative real profits of firms located in the home country (abroad), and consequently, firms relocate to the home country. Moreover, an increase in the degree of firm mobility weakens the effect of government spending shocks on relative home consumption and exchange rate.

The remainder of this paper is structured as follows. In Section II, we outline the features of the dynamic optimizing model. In Section III, we present symmetric equilibrium with flexible nominal wages. In Section IV, we define a log-linearized version of the model. In Section V, we examine how an unanticipated government spending shock affects relative home consumption, exchange rate, and international allocation of firms. The final section summarizes the findings.

II. Model

We assume a two-country (home country and foreign country) world economy. The models for the home and foreign countries are the same, and an asterisk is used to denote foreign variables. The markets for goods and labor have a monopolistic competition, whereas the markets for money and international bonds are perfectly competitive. Monopolistically competitive firms exist continuously in the world in the [0, 1] range, and therefore, the total number of firms is fixed. Each firm uses local labor as an input and produces a single differentiated product. Each product is freely traded, and firms earn positive pure profits. Firms are mobile internationally, but their owners are not. Producers in the interval $[0, n_t]$ locate in the home country in period t, and the remaining $(n_t, 1]$ producers locate in the foreign country, where n_t is

endogenous. The size of the world population is normalized to unity. We assume that households inhabit the interval [0, s] in the home country and households inhabit the interval (s, 1] in the foreign country.

Home and foreign households share the same utility function. The intertemporal objective of household $i \in (0, s)$ in the home country at time t is used to maximize the following lifetime utility:

$$U_t^i = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t}(logC_\tau^i + \chi log(M_\tau^i / P_\tau) - (k/2)(\ell_\tau^{si})^2), \tag{1}$$

where E_t represents 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 in period t; and the consumption index C_t^i is defined as $C_t^i = (\int_0^1 C_t^i(j)^{(\theta-1)/\theta} dj)^{\theta/(\theta-1)}$, where θ (> 1) is the elasticity of substitution between any two differentiated goods, and $C_t^i(j)$ is the consumption of good j in period t for household i. The second term in (1) represents real money balances (M_t^i / P_t), where M_t^i denotes nominal money balances held at the beginning of period $t + 1$, and P_t is the home country's 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's CPI is defined as $P_t^* = (\int_0^1 P_t^*(j)^{1-\theta} dj)^{1/(1-\theta)}$, 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 corresponding price indexes to $P_t = (\int_0^{n_t} P_t(j)^{1-\theta} dj + \int_{n_t}^1 (\varepsilon_t P_t^*(j))^{1-\theta} dj)^{1/(1-\theta)}$ and $P_t^* = (\int_0^{n_t} P_t(j) / \varepsilon_t)^{1-\theta} dj + \int_{n_t}^1 P_t^*(j))^{1-\theta} dj)^{1/(1-\theta)}$. By ignoring the 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, which is 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) can be represented by $P_t = \varepsilon_t P_t^*$. In this context, we assume for an international risk-free real bond market, in which both home and foreign representative households can lend and borrow at the same interest rate, and real bonds are denominated in the 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 follows:

$$P_t B_{t+1}^i + M_t^i = P_t(1 + r_t)B_t^i + M_{t-1}^i + W_t^i \ell_t^{si} \\ +(\int_0^{n_t} \Pi_t(j)dj + \int_{n_t}^1 \varepsilon_t \Pi_t^*(j)dj) - P_t C_t^i - P_t \tau_t^i, \tag{2}$$

where B_{t+1}^i 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; $W_t^i \ell_t^{si}$ is nominal labor income, where W_t^i denotes the nominal wage rate of household i in period t; $\int_0^{n_t} \Pi_t(j)dj(\int_{n_t}^1 \varepsilon_t \Pi_t^*(j)dj)$ represents the total nominal profit flows of firms located at home (abroad) from sales of products; $P_t C_t^i$ represents nominal consumption expenditure; and τ_t^i denotes real lump-sum taxes. All variables in (2) are measured in per capita terms. In the government sector, we assume that government spending is purely dissipative and financed by lump-sum taxes and seigniorage revenues derived from printing the national currency. Hence, the government budget constraint in the home country is $sG_t = \tau_t + [(M_t - M_{t-1})/P_t]$, where sG_t denotes aggregate government spending, M_t is aggregate money supply, and $\tau_t = \int_0^s \tau_t^i di$.

In the home country, firm $j \in [0, n_t]$ locally hires a continuum of differentiated labor inputs and produces a unique product in a single location according to the CES production function of $y_t(j) = (s^{-1/\phi} \int_0^s \ell_t^{di(\phi-1)/\phi} di)^{\phi/(\phi-1)}$, where $y_t(j)$ denotes the production of home-located firm j in period t, $\ell_t^{di}(j)$ is firm j's input of labor from household i in 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 function for household i's labor input is expressed as follows:

$$\ell_t^{di}(j) = s^{-1}(W_t^i / W_t)^{-\phi} y_t(j), \tag{3}$$

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

We now consider the dynamic optimization problem of households. In the first stage, households in the home (foreign) country maximize the consumption index $C_t^i(C_t^{i*})$ subject to a given level of expenditure $P_t C_t^i = \int_0^1 P_t(j) C_t^i(j) dj (P_t^* C_t^{i*} = \int_0^1 P_t^*(j) C_t^{i*}(j) dj)$ by optimally allocating differentiated goods. This static problem yields the following demand functions for good j in the home and foreign countries:

$$C_t^i(j) = (P_t(j) / P_t)^{-\theta} C_t^i, \; C_t^{i*}(j) = (P_t^*(j) / P_t^*)^{-\theta} C_t^{i*}. \tag{4}$$

In accordance with the NOEM literature, we assume that the

consumption index of the government is the same as that of the household sector, which is given by C_t^i. Therefore, the demand functions of the government for good j in the home and foreign countries are the same as those of the household sector. Aggregating the demands in (4) across all households worldwide and equating the resulting equation to the output of good j produced in the home country, as denoted by $y_t(j)$, yield the following market-clearing condition for any product j in period t:

$$y_t(j) = sC_t^i(j) + (1-s)C_t^{i*}(j) + sG_t + (1-s)G_t^* = (P_t(j)/P_t)^{-\theta}(C_t^W + G_t^W), \quad (5)$$

where $P_t(j)/P_t = P_t^*(j)/P_t^*$ is from the law of one price, and $C_t^w \equiv (sC_t^i + (1-s)C_t^{i*})$ and $G_t^w \equiv (sG_t + (1-s)G_t^*)$ are aggregate per capita world consumption and government spending, respectively. Similarly, for product j of foreign-located firms, we obtain $y_t^*(j) = (P_t^*(j)/P_t^*)^{-\theta}(C_t^w + G_t^w)$. In the second stage, households maximize (1) subject to (2). The first-order conditions for this problem with respect to B_{t+1}^i and M_t^i can be written as $1/C_t^i = \beta E_t[(1+r_{t+1})/C_{t+1}^i]$ and $M_t^i/P_t = \chi C_t^i((1+i_{t+1})/i_{t+1})$, respectively, where i_{t+1} is the nominal interest rate for home-currency loans between periods t and $t+1$ and defined as usual by $1 + i_{t+1} = (1 + r_{t+1})E_t[(P_{t+1}/P_t)]$. The former formula is the Euler equation for consumption, and the latter formula is for the money-demand schedule.

In monopolistic goods markets, each firm has some monopolistic power over pricing. Considering that home-located firm j locally hires labor, given W_t, P_t, C_t^w, G_t^w, and n_t, subject to (3) and (5), home-located firm j faces the following profit-maximization problem: $\max_{P_t(j)} \Pi_t(j) = P_t(j)y_t(j) - \int_0^s W_t^i \ell_t^{di}(j)di = (P_t(j) - W_t)y_t(j)$. By substituting $y_t(j)$ from equation (5) 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: $P_t(j) = (\theta/\theta - 1))W_t$. Moreover, W_t is a given; thus, from the price mark-up, all home-located firms charge the same price. Subsequently, we define the above identical prices as $P_t(j) = P_t(h)$, $j \in [0, n_t]$. The 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.*, $\ell_t^{id}(j) = \ell_t^{id}(h)$, $j \in [0, n_t]$, in which firm index j is omitted because of symmetry. The price mark-ups of foreign-located firms are identical because $P_t^*(j) = P_t^*(f)$, $j \in (n_t, 1]$. By substituting (5) and the price mark-ups into the real profit flows of home- and foreign-located firms (*i.e.*, $\Pi_t(h)/P_t$ and $\Pi_t(f)^*/P_t^*$, respectively), we obtain

$$\begin{aligned} \Pi_t(h) / P_t &= (1/\theta)(P_t(h) / P_t)^{1-\theta}(C_t^w + G_t^w), \\ \Pi_t(f)^* / P_t^* &= (1/\theta)(P_t^*(f) / P_t^*)^{1-\theta}(C_t^w + G_t^w). \end{aligned} \tag{6}$$

The model assumes that the driving force of relocation to another country is the difference in real profits between two countries. Following the formulation of Johdo (2015), the above adjustment processes for relocation are formulated as follows:

$$n_t - n_{t-1} = \gamma[\Pi_t(h) / P_t - \Pi_t(f)^*/P_t^*] = \gamma[\Pi_t(h)/P_t - \varepsilon_t\Pi_t(f)^* / P_t], \tag{7}$$

where the third term can be rewritten by using PPP, and γ ($0 \leq \gamma < \infty$) is a constant positive parameter used to determine the degree of firm mobility between two countries. A larger value of γ implies higher firm mobility between two countries. In (7), the adjustment of the home country's share of firms is a linearly increasing function of the difference between the real profit of a representative home-located firm and the real profit of a representative foreign-located firm.

As previously explained, in our model, each firm provides one type of goods, and a productive activity cannot be simultaneously carried out in both countries. In addition, the total number of firms in the world is fixed and normalized to unity. Therefore, n_t ($1 - n_t$) can be used to measure the home (foreign) country's share of firms. This definition implies that an increase in the number of firms located in the home country simultaneously decreases the number of firms located in the foreign country. Assuming that n_t ($1 - n_t$) firms are owned by immobile owners living in the home (foreign) country, if a firm moves from a foreign country to the home country (*i.e.*, an increase in n_t or a decrease in ($1 - n_t$)), then firm ownership also moves to the home country. This scenario implies that asset redistribution can arise compulsorily across two countries by the cross-border relocation of firms. In resolving such problem, in accordance with our model, we assume that all firms are owned equally by each country's households. Given this assumption, even with the cross-border relocation of firms, the influence of government spending shocks can still be considered without taking into account compulsory asset redistribution.

Following the work of Corsetti and Pesenti (2001), we introduce nominal rigidities into the model in the form of one-period wage contracts. The nominal wages in period t are predetermined at time $t - 1$. In monopolistic labor markets, 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 can be expressed as $\ell_t^{si} = \int_0^{n_t} \ell_t^{di}(j)dj, i \in [0, s]$ and $\ell_t^{si*} = \int_{n_t}^1 \ell_t^{di*}(j)dj, i \in [s, 1]$, respectively. By taking W_t, P_t, $y_t(j)$, and n_t as a given, then by substituting $\ell_t^{si} = \int_0^{n_t} \ell_t^{di}(j)dj$ and equation (3) into the budget constraint given by (2), and finally by maximizing the lifetime utility given by (1) with respect to W_t^i, we obtain the following first-order condition:

$$\phi(W_t^i / P_t)^{-1} E_{t-1}[\kappa \ell_t^{si2}] = (\phi - 1)E_{t-1}[(\ell_t^{si} / C_t^i)] \tag{8}$$

The equilibrium condition for the integrated international bond market is given by $\int_0^s B_{t+1}^i di + \int_s^1 B_{t+1}^{*i} di = 0$. Money markets are always assumed to be clear in both countries. Hence, the equilibrium conditions are given by $M_t = \int_0^s M_t^i di$ and $M_t^* = \int_s^1 M_t^{*i} di$.

III. Symmetric Steady State

In this section, we derive the solution for a symmetric steady state in which all endogenous and exogenous variables are constant, the initial real bond holdings of the home country are zero ($B_0 = 0$), and $G_0 = G_0^* = 0$ and $s = s^* = 1/2$. The superscript i and the index j are omitted because households and firms make the same equilibrium choices within and between countries. Then, we denote the steady-state values by using the subscript ss. In the symmetric steady state, given the Euler equation for consumption, the steady-state real interest rate is given by $r_{ss} = (1 - \beta / \beta \equiv \delta$, where δ is the rate of time preference. The steady-state allocation of firms is $n_{ss} = 1/2$. Hence, from (8), we obtain

$$\ell_{ss}^s = \ell_{ss}^{s*} = C_{ss} = C_{ss}^* = C_{ss}^w = y_{ss}(h) = y_{ss}^*(f) = ((\phi - 1) / \phi)^{1/2}((\theta - 1)\theta)^{1/2}(1 / \kappa)^{1/2}. \tag{9}$$

Substituting C_{ss}^w from equation (9) into equation (6) yields the steady-state levels of real profit for home- and foreign-located firms, which have equal values.

$$\Pi_{ss}(h) / P_{ss} = \Pi_{ss}(f)^* / P_{ss}^* = (1 / \theta)((\phi - 1) / \phi)^{1/2}((\theta - 1) / \theta)^{1/2}(1 / \kappa)^{1/2} \tag{10}$$

IV. Log Linearization around the Steady State

The macroeconomic effects of unanticipated permanent government spending shocks need to be examined. Thus, we solve a log-linear approximation of the system around the initial zero-shock steady state with $B_{ss,\,0} = 0$, as described in the previous section. Following the work of Obstfeld and Rogoff (1995, 1996), 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 the subscript 1 denotes the period in which the shock has occurred. These short-run percentage deviations are consistent with the length of nominal wage contracts. Thus, nominal wages and prices of goods 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 $\bar{X}$ to denote "long run" percentage deviations from the initial steady-state value, *i.e.*, $\bar{X} = dX_2 / X_{ss,0} = dX_{ss} / X_{ss,0}$, which is consistent with flexible nominal wages. $X_2 = X_{ss}$ because a new steady state is reached at period 2.

V. Government Spending Shocks

We examine how an unanticipated government spending shock affects exchange rate, relocation of firms, and cross-country differences in consumption. By log-linearizing equation (7) around the symmetric steady state and by setting $\hat{P}(h) = \hat{P}^*(f) = 0$, we obtain the following log-linearized expression for the home country's share of firms[2]:

$$\hat{n} = 2\gamma \left(\frac{\phi - 1}{\phi}\right)^{1/2} \left(\frac{\theta - 1}{\theta}\right)^{3/2} \left(\frac{1}{\kappa}\right)^{1/2} \hat{\varepsilon}. \tag{11}$$

Equation (11) shows that exchange rate depreciation induces the relocation of firms toward the home country.[3] Intuitively, with fixed

[2] See Appendix for the derivation of Equation (11).

[3] This result is consistent with the evidence found in the literature (*e.g.*, Cushman 1988; Caves 1989; Froot and Stein 1991; Campa 1993; Klein and Rosengren 1994; Blonigen 1997; Goldberg and Klein 1998; Baek and Okawa 2001; Bénassy-quéré *et al* 2001; Chakrabarti and Scholnick 2002; Bolling *et al* 2007; Udomkerdmongkol *et al* 2008) on the relationship between exchange rates and foreign direct investments.

nominal wages, which cause nominal product prices to be sticky because of the mark-up pricing by monopolistic product suppliers, depreciation increases relative home production through the expenditure-switching effect.[4] In turn, this phenomenon increases the relative profits of home-located firms, and consequently, other firms relocate to the home country to take advantage of high real profits. The above equation offers the key to understanding the effects of unanticipated government spending shocks on cross-country differences in consumption. Equation (11) also shows that an increase in γ magnifies the effect of exchange rate depreciation on the relocation of firms.

We then consider the macroeconomic effects of an unanticipated infinitesimal permanent rise in the relative spending level of the home government in period $1: \bar{G} - \bar{G}^* = \hat{G} - \hat{G}^* > 0$, where $\hat{G} \equiv dG_t / C^w_{ss,0}$ and $\bar{G} \equiv dG_{t+1} / C^w_{ss,0}$. The closed-form solutions for the three key variables are as follows:

$$\hat{C} - \hat{C}^* = -\left(\frac{1}{A}\right)\left(\frac{1+\delta}{\delta}\right)\left(\bar{G} - \bar{G}^*\right) < 0, \tag{12}$$

$$\hat{\varepsilon} = \left(\frac{1}{A}\right)\left(\frac{1+\delta}{\delta}\right)\left(\bar{G} - \bar{G}^*\right) > 0, \tag{13}$$

$$\hat{n} = \left(\frac{2\gamma}{A}\right)\left(\frac{\phi-1}{\phi}\right)^{1/2}\left(\frac{\theta-1}{\theta}\right)^{3/2}\left(\frac{1}{\kappa}\right)^{1/2}\left(\frac{1+\delta}{\delta}\right)\left(\bar{G} - \bar{G}^*\right) > 0, \tag{14}$$

where

$$A = \tilde{\delta} + \delta^{-1}\tilde{\theta}\left[\frac{\theta - 1 + 4\gamma\tilde{\phi}^{1/2}\tilde{\theta}^{3/2}\tilde{\kappa}^{1/2}}{\theta + 1 + 4\gamma\tilde{\phi}^{1/2}\tilde{\theta}^{3/2}\tilde{\kappa}^{1/2}}\right] + \tilde{\theta}^2[\theta + 4\gamma\tilde{\phi}^{1/2}\tilde{\theta}^{1/2}\tilde{\kappa}^{1/2}] > 0, \tilde{\delta} \equiv (1+\delta)/\delta,$$
$\tilde{\theta} \equiv (\theta - 1)/\theta$, and $\tilde{\phi} \equiv (\phi - 1)/\phi$, $\tilde{\kappa} \equiv 1/\kappa$.[5]

[4] An expenditure-switching effect arises because exchange rate depreciation causes a decline in the relative real price of home goods for consumers in both countries, so that world consumption demand switches from foreign goods to home goods.

[5] $\hat{\varepsilon} = \bar{\varepsilon}$ holds in money-market equilibrium conditions, and $\hat{C} - \hat{C}^* = \bar{C} - \bar{C}^*$ holds for Euler consumption equations. Thus, the short-run equilibrium also holds in the long run.

Equation (12) indicates that an unanticipated rise in domestic government spending leads to a proportionate decrease in relative home consumption level. The result in (12) can be explained intuitively as follows. First, with a given exchange rate, a rise in domestic government spending instantaneously leads to the crowding-out of home consumption because the rise in the home country's government spending does not increase the home output needed to sufficiently offset the rise in lump-sum taxes. Hereafter, we call this phenomenon the "wealth effect." Consequently, the decrease in home consumption leads to exchange rate depreciation. This scenario can be attributed to the demand for real money balances, which increases with consumption (as implied by the money-demand function), and the home currency must depreciate and reduce the supply of real money balances in the home country to restore money market equilibrium. In turn, exchange rate depreciation causes a consumption switching because the world consumption demand shifts toward the home goods given the fall in the relative price of home goods. This phenomenon causes firms located abroad to move to the home country because of the increase in the relative profits of firms located in the home country (*i.e.*, equation (11)). The relocation raises the relative labor income in the home country accordingly, and this rise in income also increases the relative consumption level in the home country.6 Hereafter, we call this phenomenon the "substitution effect." Consequently, the net effect on relative home consumption depends on the relative strengths of the wealth effect and the substitution effect. However, on the basis of equation (12), the negative wealth effect dominates the positive substitution effect, and therefore, a rise in government spending leads to a decrease in relative home consumption.

As for the changes in exchange rate, equation (13) indicates that a rise in unanticipated domestic government spending leads to a depreciation of the exchange rate. The exchange rate effect is determined by two conflicting mechanisms. On the one hand, as stated above, the rise in unanticipated government spending in the home country requires an instantaneous depreciation of its currency because of the fall in relative home consumption through the wealth effect. On the other hand,

[6] In our model, home currency depreciation leads to a redistribution of world labor income in favor of the home country through the international relocation of firms.

the rise in government spending reduces the real price of home goods relative to foreign goods because of the initial depreciation of the home currency, and this scenario causes the world demand to switch toward home goods. In turn, the demand shift increases the relative profits of home-located firms, and this phenomenon causes foreign firms to relocate to the home country. As a result, the relocation raises the relative labor income in the home country, and the short-run relative home consumption is also raised. Owing to the latter mechanism, the home currency must appreciate to restore market equilibrium in favor of real balances. Thus, the impact of the rise in government spending in the home country on the equilibrium exchange rate is ambiguous. However, on the basis of equation (13), the former scenario dominates the latter scenario, and therefore, a rise in government spending leads to a depreciation of the home currency.

Equation (12) also shows that an increase in γ weakens the decreasing effects of government spending shock on the relative home consumption level. Intuitively, as the relocation of firms becomes much more flexible (as γ increases), a greater relative increase in home labor income is achieved because more firms relocate to the home country, and therefore, the positive substitution effect is greater.[7] Thus, an increase in γ weakens the reduction in short-run relative home consumption through the larger substitution effect. In addition, an increase in γ weakens the effect of government spending shock on exchange rate depreciation. This scenario can be explained by the impact of government spending shock on exchange rate, in which the impact depends on the scale of response of relative home consumption toward the same shock.

The primary focus of this study is to determine how the international relocation of firms affects the impact on cross-country differences in consumption and the exchange rate of fiscal policy shocks, particularly by comparing our analysis with the predictions of previous studies that ignored the relocation of firms. The central difference between our main findings and those of the previous studies are as follows. In the previous studies, given the assumption of fixed allocation of firms, the home government's expenditure falls on both domestic and foreign

[7] Equation (14) shows that an increase in γ magnifies the response of the relocation of firms into a government spending shock.

goods, while the taxes that finance the expenditure are borne entirely by home-located households. Hence, in the previous studies, given a set of nominal prices or wage rigidities, the increase in production of foreign goods is the main source of the international transmission mechanism. By contrast, in the present study, by considering the Rudux model of Obstfeld and Rogoff (1995), we endogenize the proportion of firms located in the home country versus that in the foreign country; these two elements in the original model are fixed. A novel feature of our model is that the home country's share of firms responds to exchange rate movements caused by government spending shocks. By using the model, we find that the rise in unanticipated government spending causes home consumption to decrease relative to the foreign consumption, and the exchange rate depreciates when nominal wage rigidities prompt foreign firms to relocate to the home country. These scenarios imply that the present model generates an added transmission effect of the government spending shock on the foreign country through the international relocation of firms. This finding has been overlooked by the NOEM literature.

VI. Conclusion

In this study, we extend the NOEM model to include international relocation of firms. We use a generalized model and consider the question of how allowing for the relocation of firms affects the responses of relative consumption and exchange rate toward government spending shocks. The main findings of our analysis are as follows: i) a home country's government spending shock leads to a proportionate decrease in relative home consumption level and depreciation of the home currency; ii) the depreciation then increases (decreases) the relative real profits of firms located in the home country (abroad), and consequently, firms relocate to the home country; and iii) an increase in the degree of firm mobility weakens the effects of government spending shocks on relative consumption and exchange rate.

Appendix

A. Long-run equilibrium conditions

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

$$\bar{P} = \bar{M} - \bar{C},\ \bar{P}^* = \bar{M}^* - \bar{C}^*, \tag{A.1}$$

$$\begin{aligned}\bar{C} = \delta\bar{B} + ((\theta-1)/\theta)\left(\bar{W}(h) - \bar{P} + \bar{\ell}^s\right) \\ + (1/2\theta)\left[\bar{\Pi}(h) + \bar{\Pi}(f)^* + \bar{\varepsilon}\right] - (1/\theta)\bar{P} - \bar{G},\end{aligned} \tag{A.2}$$

$$\begin{aligned}\bar{C}^* = -\delta\bar{B} + ((\theta-1)/\theta)\left(\bar{W}^*(f) - \bar{P}^* + \bar{\ell}^{*s}\right) \\ + (1/2\theta)\left[\bar{\Pi}(h) - \bar{\varepsilon} + \bar{\Pi}(f)^*\right] - (1/\theta)\bar{P}^* - \bar{G}^*,\end{aligned} \tag{A.3}$$

$$\bar{y} = \theta\left(\bar{P} - \bar{P}(h)\right) + \bar{C}^W + \bar{G}^W,\ \ \bar{y}^* = \theta\left(\bar{P}^* - \bar{P}^*(f)\right) + \bar{C}^W + \bar{G}^W, \tag{A.4}$$

$$\begin{aligned}\bar{C}^W + \bar{G}^W &\equiv (1/2)\bar{C} + (1/2)\bar{C}^* + (1/2)\bar{G} + (1/2)\bar{G}^* \\ &= (1/2)\bar{y} + (1/2)\bar{y}^* \equiv \bar{y}^W,\end{aligned} \tag{A.5}$$

$$\bar{y} = \bar{\ell}^d, \bar{y}^* = \bar{\ell}^{d^*}, \tag{A.6}$$

$$\bar{\ell}^s = \bar{n} + \bar{\ell}^d, \bar{\ell}^{s^*} = -\bar{n} + \bar{\ell}^{d^*}, \tag{A.7}$$

$$\bar{n} = (2\gamma/\theta)\left((\phi-1)/\phi\right)^{1/2}\left((\theta-1)/\theta\right)^{1/2}(1/\kappa)^{1/2}\left(\bar{\Pi}(h) - \bar{\Pi}^*(f) - \bar{\varepsilon}\right), \tag{A.8}$$

$$\begin{aligned}\bar{\Pi}(h) &= (1-\theta)\bar{P}(h) + \theta\bar{P} + \bar{C}^W + \bar{G}^W, \\ \bar{\Pi}^*(f) &= (1-\theta)\bar{P}^*(f) + \theta\bar{P}^* + \bar{C}^W + \bar{G}^W,\end{aligned} \tag{A.9}$$

$$\begin{aligned}\bar{P} &= (1/2)\bar{P}(h) + (1/2)\left[\bar{\varepsilon} + \bar{P}^*(f)\right], \\ \bar{P}^* &= (1/2)\left[\bar{P}(h) - \bar{\varepsilon}\right] + (1/2)\bar{P}^*(f),\end{aligned} \tag{A.10}$$

$$\bar{P}(h) = \bar{W} \quad \bar{P}^*(f) = \bar{W}^*, \tag{A.11}$$

$$\bar{\varepsilon} = \bar{P} - \bar{P}^*, \tag{A.12}$$

$$\bar{\ell}^s = \bar{W} - \bar{P} - \bar{C}, \ \bar{\ell}^{s^*} = \bar{W}^* - \bar{P}^* - \bar{C}^*, \tag{A.13}$$

where $\bar{B} \equiv dB_{t+1} / C^W_{ss,0}$ and $\bar{G} \equiv dG_{t+1} / C^W_{ss,0}$,, in which $C^W_{ss,0}$ is the initial value of world consumption. The equations in (A.1) correspond to the money-demand equations. Equations (A.2) and (A.3) represent the long-run change in incomes (returns on real bonds, real labor incomes, and real profit incomes), which are equal to the long-run changes in consumption in each country. The equations in (A.4) represent the world-demand schedules for home and foreign products. Equation (A.5) is the world goods–market equilibrium condition. The equations in (A.6) represent the production technology, and those in (A.7) represent the long-run labor-market clearing conditions for both countries. Equation (A.8) is the dynamic relocation equation. The equations in (A.9) are the nominal profit equations for representative home and foreign firms. The equations in (A.10) are the price index equations. The equations in (A.11) represent the optimal pricing equations for firms in each country. Equation (A.12) is the purchasing power parity equation. The equations in (A.13) represent the first-order conditions for optimal wage setting.

Subtracting (A.3) from (A.2) yields the long-run (from period t+1 onward) response of relative per capita consumption levels.

$$\bar{C} - \bar{C}^* = 2\delta\bar{B} + \left((\theta - 1)/\theta\right)\left(\bar{W} - \bar{W}^* - \left(\bar{P} - \bar{P}^*\right) + \bar{\ell}^s - \bar{\ell}^{s^*}\right) - \left(\bar{G} - \bar{G}^*\right) \tag{A.14}$$

Substituting (A.9), (A.10), (A.11), and (A.12) into equation (A.8) yields

$$\bar{n} = 2\gamma\left(\frac{\phi - 1}{\phi}\right)^{\frac{1}{2}}\left(\frac{\theta - 1}{\theta}\right)^{\frac{3}{2}}\left(\frac{1}{\kappa}\right)^{\frac{1}{2}}\left(\bar{\varepsilon} - \left(\bar{W} - \bar{W}^*\right)\right). \tag{A.15}$$

From equations (A.4), (A.6), (A.7), and (A.11), we obtain

$$\bar{\ell}^s - \bar{\ell}^{s*} = 2\bar{n} + \theta\left[\bar{\varepsilon} - \left(\bar{W} - \bar{W}^*\right)\right]. \tag{A.16}$$

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

$$\bar{\ell}^s - \bar{\ell}^{s*} + \bar{C} - \bar{C}^* = \bar{W} - \bar{W}^* - \bar{\varepsilon}. \tag{A.17}$$

From (A.12) and (A.14), we obtain

$$\bar{C} - \bar{C}^* = 2\delta\bar{B} + \left((\theta - 1)/\theta\right)\left(\bar{W} - \bar{W}^* - \bar{\varepsilon} + \bar{\ell}^s - \bar{\ell}^{s*}\right) - \left(\bar{G} - \bar{G}^*\right). \quad \text{(A.18)}$$

Substituting (A.17) into equation (A.18) yields

$$\bar{C} - \bar{C}^* = 2\delta\bar{B} + \left((\theta - 1)/\theta\right)\left(2\left(\bar{\ell}^s - \bar{\ell}^{s*}\right) + \bar{C} - \bar{C}^*\right) - \left(\bar{G} - \bar{G}^*\right). \quad \text{(A.19)}$$

Substituting (A.17) into equation (A.15) yields

$$\bar{n} = -2\gamma\left(\frac{\phi - 1}{\phi}\right)^{\frac{1}{2}}\left(\frac{\theta - 1}{\theta}\right)^{\frac{3}{2}}\left(\frac{1}{\kappa}\right)^{\frac{1}{2}}\left[\bar{\ell}^s - \bar{\ell}^{s*} + \bar{C} - \bar{C}^*\right]. \quad \text{(A.20)}$$

Substituting (A.17) and (A.20) into equation (A.16) yields

$$\bar{\ell}^s - \bar{\ell}^{s*} = -\left[\frac{\theta + 4\gamma\left(\frac{\phi - 1}{\phi}\right)^{\frac{1}{2}}\left(\frac{\theta - 1}{\theta}\right)^{\frac{3}{2}}\left(\frac{1}{\kappa}\right)^{\frac{1}{2}}}{\theta + 1 + 4\gamma\left(\frac{\phi - 1}{\phi}\right)^{\frac{1}{2}}\left(\frac{\theta - 1}{\theta}\right)^{\frac{3}{2}}\left(\frac{1}{\kappa}\right)^{\frac{1}{2}}}\right]\left(\bar{C} - \bar{C}^*\right). \quad \text{(A.21)}$$

Substituting (A.21) into (A.19) yields

$$\begin{aligned}\bar{C} - \bar{C}^* = {} & 2\delta\left\{1 + \left(\frac{\theta - 1}{\theta}\right)\left[\frac{\theta - 1 + 4\gamma\left(\frac{\phi - 1}{\phi}\right)^{\frac{1}{2}}\left(\frac{\theta - 1}{\theta}\right)^{\frac{3}{2}}\left(\frac{1}{\kappa}\right)^{\frac{1}{2}}}{\theta + 1 + 4\gamma\left(\frac{\phi - 1}{\phi}\right)^{\frac{1}{2}}\left(\frac{\theta - 1}{\theta}\right)^{\frac{3}{2}}\left(\frac{1}{\kappa}\right)^{\frac{1}{2}}}\right]\right\}^{-1}\bar{B} \\ & - \left\{1 + \left(\frac{\theta - 1}{\theta}\right)\left[\frac{\theta - 1 + 4\gamma\left(\frac{\phi - 1}{\phi}\right)^{\frac{1}{2}}\left(\frac{\theta - 1}{\theta}\right)^{\frac{3}{2}}\left(\frac{1}{\kappa}\right)^{\frac{1}{2}}}{\theta + 1 + 4\gamma\left(\frac{\phi - 1}{\phi}\right)^{\frac{1}{2}}\left(\frac{\theta - 1}{\theta}\right)^{\frac{3}{2}}\left(\frac{1}{\kappa}\right)^{\frac{1}{2}}}\right]\right\}^{-1}\left(\bar{G} - \bar{G}^*\right).\end{aligned} \quad \text{(A.22)}$$

Equation (A.22) shows that the trade surplus of a home country permanently raises home consumption relative to foreign consumption. Given (A.1) and (A.12), subtracting the foreign money-demand equation from its home counterpart yields

$$\bar{\varepsilon} = \bar{M} - \bar{M}^* - \left(\bar{C} - \bar{C}^*\right). \quad \text{(A.23)}$$

Equation (A.23) states that the long-run change in exchange rate depends on the difference between the long-run change in nominal money supply and relative change in long-run consumption.

B. Short-run equilibrium conditions

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

$$\bar{C} = \hat{C} + \left(\delta / (1+\delta)\right)\bar{r},\ \bar{C}^* = \hat{C}^* + \left(\delta / (1+\delta)\right)\bar{r}, \tag{A.24}$$

$$\begin{aligned} \hat{M} - \hat{P} &= \hat{C} - \bar{r} / (1+\delta) - \left(\bar{P} - \hat{P}\right) / \delta, \\ \hat{M}^* - \hat{P}^* &= \hat{C}^* - \bar{r} / (1+\delta) - \left(\bar{P}^* - \hat{P}^*\right) / \delta, \end{aligned} \tag{A.25}$$

$$\begin{aligned} \bar{B} = &-\left((\theta-1)/\theta\right)\hat{P} + \left((\theta-1)/\theta\right)\left(\hat{n} + \hat{\ell}^d\right) \\ &+ (1/2\theta)\left[\hat{\Pi}(h) + \hat{\Pi}(f)^* + \hat{\varepsilon} - 2\hat{P}\right] - \hat{C} - \hat{G}, \end{aligned} \tag{A.26}$$

$$\begin{aligned} -\bar{B} = &-\left((\theta-1)/\theta\right)\hat{P}^* + \left((\theta-1)/\theta\right)\left(-\hat{n} + \hat{\ell}^{d*}\right) \\ &+ (1/2\theta)\left[\hat{\Pi}(h) - \hat{\varepsilon} + \hat{\Pi}(f)^* - 2\hat{P}^*\right] - \hat{C}^* - \hat{G}^*, \end{aligned} \tag{A.27}$$

$$\hat{y} = \theta\hat{P} + \hat{C}^W + \hat{G}^W,\ \hat{y}^* = \theta\hat{P}^* + \hat{C}^W + \hat{G}^W, \tag{A.28}$$

$$\hat{y} = \hat{\ell}^d,\ \hat{y}^* = \hat{\ell}^{d*}, \tag{A.29}$$

$$\hat{\Pi}(h) = \theta\hat{P} + \hat{C}^W + \hat{G}^W,\ \hat{\Pi}^*(f) = \theta\hat{P}^* + \hat{C}^W + \hat{G}^W, \tag{A.30}$$

$$\hat{n} = (2\gamma/\theta)\left((\phi-1)/\phi\right)^{1/2}\left((\theta-1)/\theta\right)^{1/2}(1/\kappa)^{1/2}\left[\hat{\Pi}(h) - \hat{\Pi}^*(f) - \hat{\varepsilon}\right], \tag{A.31}$$

$$\begin{aligned} \hat{C}^W + \hat{G}^W &\equiv (1/2)\hat{C} + (1/2)\hat{C}^* + (1/2)\hat{G} + (1/2)\hat{G}^* \\ &= (1/2)\hat{y} + (1/2)\hat{y}^* \equiv \hat{y}^W, \end{aligned} \tag{A.32}$$

$$\hat{P} = (1/2)\hat{\varepsilon},\quad \hat{P}^* = -(1/2)\hat{\varepsilon}, \tag{A.33}$$

$$\hat{\ell}^s = \hat{n} + \hat{\ell}^d, \ \hat{\ell}^{s*} = -\hat{n} + \hat{\ell}^{d*}, \tag{A.34}$$

where we set nominal wages and prices of goods as $\hat{W} = \hat{W}^* = \hat{P}(h) = \hat{P}^*(f) = 0$ for the above short-run log-linearized equations. The equations in (A.24) are the Euler equations. The equations in (A.25) describe equilibrium in the money markets in the short run. The equations in (A.26) and (A.27) are linearized short-run current account equations. The equations in (A.28) represent the world-demand schedules for representative home and foreign products. Equation (A.29) is the production function. The equations in (A.30) are the nominal profit equations for representative home and foreign firms. Equation (A.31) is the dynamic relocation equation. Equation (A.32) is the world goods–market equilibrium condition. Equation (A.33) is the price index equation in the short run. The equations in (A.34) represent the short-run labor-market clearing conditions for both countries. Subtracting (A.27) from (A.26) yields

$$\begin{aligned} 2\bar{B} = &-\left((\theta-1)/\theta\right)\left(\hat{P}-\hat{P}^*\right) + 2\left((\theta-1)/\theta\right)\hat{n} + \left((\theta-1)/\theta\right)\left(\hat{\ell}^d - \hat{\ell}^{d*}\right) \\ &+ (1/\theta)\left[\hat{\varepsilon} - \left(\hat{P}-\hat{P}^*\right)\right] - \left(\hat{C}-\hat{C}^*\right) - \left(\hat{G}-\hat{G}^*\right) \end{aligned} \tag{A.35}$$

Given equations (A.28), (A.29), and (A.33), and by subtracting the foreign labor-demand equation from its home counterpart, we obtain

$$\hat{\ell}^d - \hat{\ell}^{d*} = \hat{y} - \hat{y}^* = \theta\hat{\varepsilon}. \tag{A.36}$$

From (A.36), the change in relative labor demand is proportional to the change in relative product demand, and hence, the changes depend on consumption switching. Substituting (A.30) and (A.33) into (A.31) yields the short-run change in relocation as follows:

$$\hat{n} = 2\gamma\left((\phi-1)/\phi\right)^{1/2}\left((\theta-1)/\theta\right)^{3/2}(1/\kappa)^{1/2}\,\hat{\varepsilon}. \tag{A.37}$$

(A.37) is equivalent to (11). Substituting (A.33), (A.36), and (A.37) into (A.35) yields

$$\begin{aligned} \bar{B} = &\left((\theta-1)/\theta\right)^2\left[\theta/2 + 2\gamma\left((\phi-1)/\phi\right)^{1/2}\left((\theta-1)/\theta\right)^{1/2}(1/\kappa)^{1/2}\right]\hat{\varepsilon} \\ &-(1/2)\left(\hat{C}-\hat{C}^*\right) - (1/2)\left(\hat{G}-\hat{G}^*\right). \end{aligned} \tag{A.38}$$

Given (A.24), and by subtracting the foreign Euler equation from its home counterpart, we obtain the following relative per capita consumption dynamics:

$$\bar{C} - \bar{C}^* = \hat{C} - \hat{C}^*. \tag{A.39}$$

From (A.25), subtracting the foreign money-demand equation from its home counterpart yields

$$\hat{M} - \hat{M}^* - \hat{\varepsilon} = \hat{C} - \hat{C}^* - \left(\bar{\varepsilon} - \hat{\varepsilon}\right) / \delta. \tag{A.40}$$

Subsequently, we assume that the nominal money supply is held constant in both countries in that $\hat{M} = \bar{M} = \hat{M}^* = \bar{M}^* = 0$.

Derivation of $\hat{\varepsilon}$, $\hat{C} - \hat{C}^*$, *and* $\hat{n}$

We consider the macroeconomic effects of a one-off unanticipated permanent increase in relative home government spending to occur in period 1, *i.e.*, the relative home government spending changes according to

$$\bar{G} - \bar{G}^* = \hat{G} - \hat{G}^*. \tag{A.41}$$

Substituting (A.39), (A.41), and $\hat{\varepsilon}$, from equation (A.40) into equation (A.23) yields

$$\hat{\varepsilon} = -\left(\hat{C} - \hat{C}^*\right). \tag{A.42}$$

A second schedule in $\hat{\varepsilon}$, and $\hat{C} - \hat{C}^*$, may be derived by using the short-run and long-run current account equations for both countries. Substituting equation (A.39) into equation (A.22) yields

$$\hat{C} - \hat{C}^* = 2\delta \left\{ 1 + \left(\frac{\theta - 1}{\theta}\right) \left[\frac{\theta - 1 + 4\gamma \left(\frac{\phi - 1}{\phi}\right)^{\frac{1}{2}} \left(\frac{\theta - 1}{\theta}\right)^{\frac{3}{2}} \left(\frac{1}{\kappa}\right)^{\frac{1}{2}}}{\theta + 1 + 4\gamma \left(\frac{\phi - 1}{\phi}\right)^{\frac{1}{2}} \left(\frac{\theta - 1}{\theta}\right)^{\frac{3}{2}} \left(\frac{1}{\kappa}\right)^{\frac{1}{2}}} \right] \right\}^{-1} \bar{B} \tag{A.43}$$

$$-\left\{1+\left(\frac{\theta-1}{\theta}\right)\left[\frac{\theta-1+4\gamma\left(\frac{\phi-1}{\phi}\right)^{\frac{1}{2}}\left(\frac{\theta-1}{\theta}\right)^{\frac{3}{2}}\left(\frac{1}{\kappa}\right)^{\frac{1}{2}}}{\theta+1+4\gamma\left(\frac{\phi-1}{\phi}\right)^{\frac{1}{2}}\left(\frac{\theta-1}{\theta}\right)^{\frac{3}{2}}\left(\frac{1}{\kappa}\right)^{\frac{1}{2}}}\right]\right\}^{-1}\left(\bar{G}-\bar{G}^{*}\right)$$

We can combine (A.38), (A.41), (A.42), and (A.43) to solve jointly for $\hat{\varepsilon}$, and $\hat{C}-\hat{C}^{*}$. From these equations, the exchange rate change is

$$\hat{\varepsilon}=\left(\frac{1}{A}\right)\left(\frac{1+\delta}{\delta}\right)\left(\bar{G}-\bar{G}^{*}\right)>0, \tag{A.44}$$

where

$$A=\tilde{\delta}+\delta^{-1}\tilde{\theta}\left[\frac{\theta-1+4\gamma\tilde{\phi}^{1/2}\tilde{\theta}^{3/2}\tilde{\kappa}^{1/2}}{\theta+1+4\gamma\tilde{\phi}^{1/2}\tilde{\theta}^{3/2}\tilde{\kappa}^{1/2}}\right]+\tilde{\theta}^{2}\left[\theta+4\gamma\tilde{\phi}^{1/2}\tilde{\theta}^{1/2}\tilde{\kappa}^{1/2}\right],$$
$$\tilde{\delta}\equiv(1+\delta)/\delta,\ \tilde{\theta}\equiv(\theta-1)/\theta,\ \tilde{\phi}\equiv(\phi-1)/\phi,\ \tilde{\kappa}\equiv 1/\kappa.$$

The relative consumption change is

$$\hat{C}-\hat{C}^{*}=-\left(\frac{1}{A}\right)\left(\frac{1+\delta}{\delta}\right)\left(\bar{G}-\bar{G}^{*}\right)<0. \tag{A.45}$$

(A.44) and (A.45) are equivalent to (13) and (12), respectively. Finally, from (A.37) and (A.44), we obtain

$$\hat{n}=\left(\frac{2\gamma}{A}\right)\left(\frac{\phi-1}{\phi}\right)^{1/2}\left(\frac{\theta-1}{\theta}\right)^{3/2}\left(\frac{1}{\kappa}\right)^{1/2}\left(\frac{1+\delta}{\delta}\right)\left(\bar{G}-\bar{G}^{*}\right)>0. \tag{A.46}$$

(A.46) is equivalent to (14).

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