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Transportation Costs, Country Size and Exchange Rate Dynamics

Chung-Fu Lai
Department of Applied Economics, Fo Guang University, Taiwan
E-mail: cflai@gm.fgu.edu.tw
Tel: +886-3-9871000 Ext.23515; Fax: +886-3-9870500

Abstract

This paper examines how exchange rate dynamics will be affected by an increase in the transportation cost, and investigates the role of country size with a two-country New Open Economy Macroeconomics. According to the results of theoretical analysis, we find that if the size of home country is larger (smaller) than the foreign country, a mis-adjustment (undershooting) path of exchange rate possesses with the higher transportation cost, if two countries are of equal size, the transportation cost doesn't affect the short-run exchange rate, but an increase in the transportation cost reduces long-run exchange rate. Furthermore, this paper also finds that an increases in the transportation cost increases the extent of exchange rate volatility with the higher the elasticity of the marginal utility of real money demand, the lower the elasticity of substitution between goods, the lower the percentage of local firms with pricing-to-market, or the lower the percentage of foreign firms with pricing-to-market, this is because the degree of correlation between money demand and consumption is lower with the existence of transportation cost, hence the exchange rate must present the excessive adjustment in order to re-achieve the new equilibrium position of the money market.

Keywords: Transportation Costs, Exchange Rate Dynamics, New Open Economy Macroeconomics, Pricing-to-Market, Country Size
JEL Classification: F19, F41

1. Introduction

The presence of the Cross-border transportation costs is universal phenomenon in the world, major problems include high tariffs, complicated customs clearance procedures, and high onshore transportation costs. How transportation costs affect the volatility of the long-run and short-run exchange rates is thus the topic of research of this paper. That is, this paper investigated the effect of transportation costs on exchange rate dynamics. Research of the transportation costs can be dated back to the 1980s. Due to the popularization of international trade and industrial clustering in that time, scholars began to notice the role of transportation costs. Krugman (1980) started related research by verifying that the transportation cost was one of the important factors affecting international trade and industrial clustering, by using the monopolistic competition model introduced by Dixit and Stiglitz (1977) and the "iceberg" type transportation cost proposed by Samuelson (1952)as the analysis foundation. Krugman and Venables (1995) also investigated the effect of trading cost on globalization by establishing the wage inequality model. Mihailov (2003)assumed an exogenous stochastic process for money supply and found that the exogenous shocks and trading cost will affect the correlation between exchange rate regime and trading volume. Coeurdacier (2005) found that raising trading costs would reduce product competitiveness and uncertainty to induce consumption home bias, reduce the risk of local income volatility, the incentive of holding foreign assets, and further attract the home bias of assets. It is clear that most traditional literature discussed the effects of transportation costs on microeconomics, while research on the former's role in an open macro economy was rare. This thus became the major motivation of this paper.

As the first to start the research of "exchange rate dynamics", Dornbusch (1976) investigated the effect of permanent monetary shock on exchange rate under the assumptions of perfect capital mobility, log linearization, and regressive expectation and found that the extent of volatility in the short-run exchange rate is greater than that of the long-run exchange rate when money supply increases, as the capital market can adjust faster than the commodity market. Such a result became the famous theory of "overshooting", it indicates that when the extent of volatility of the short-run exchange rate is greater than that of the long-run exchange rate, it is called overshooting; when it is the opposite, it is called under shooting; when the volatility of the long-run and short-run exchange rates is reserve, it is called mis-adjustment. From then on, many famous scholars began to investigate the correlation between the long-run and short-run exchange rate changes from different angles, and related topics were categorized as research of "exchange rate dynamics". Over the past few decades, a great number of studies on macroeconomics were conducted upon the prototype of Dornbusch (1976), such as Gray and Turnovsky (1979),Wilson (1979), Frenkel and Rodriguez (1982), and Aoki (1985). Although related research continues, as the work of Dornbusch (1976) lacks micro-foundations, the theory development and contribution of this basic model were limited. Fortunately, these problems were resolved after by Obstfeld and Rogoff (1995) with their paper, "Exchange Rate Dynamics Redux". Obstfeld and Rogoff (1995) constructed a two-country, price-sticky, and dynamic general equilibrium model with micro-foundations. This model assumed that firms are monopolistic competitors, there is no trade barrier, and local and foreign agents have the same preferences to investigate the effects of monetary policy on the long-run and short-run exchange rates. The introduction of "micro-foundations" by Obstfeld and Rogoff (1995) set a new milestone for the research of "exchange rate dynamics", and their analysis framework was called the New Open Economy Macroeconomics (hereinafter referred to as NOEM).Research of "exchange rate dynamics" in earlier times emphasized the extent of volatility of the long-run and short-run exchange rates caused by the change in money supply. Subsequent literature, however, has extended the focus of research outside of money supply. For example, Fender and Yip (2000) and Reitz and Slopek (2005) analyzing the effects of tariff shock and found that levying tariffs can reduce outputs and exchange rates, while the extent of the long-run and short-run appreciations will become consistent without overshooting.

In addition, this paper included price discrimination as an issue mainly because the existence of transportation costs (including tariffs, insurance fee, transportation fee, and so on) is considered as the main cause of price discrimination, or namely pricing-to-market (hereinafter referred to as PTM) (such as Krugman, 1987;Atkeson and Burstein,2006;Juvenal and Monteiro,2010). According to Betts and Devereux (1996; 2000), firms capable of market segmentation can make different prices for different regions, and this is called PTM. Regarding the application of PTM on NOEM, related literature includes Devereux and Engel (1998;2003), Obstfeld (2006),Zhang (2006), Duarte and Rogoff (2007), Marazzi and Sheets (2007), and Wang and Wu (1996). Most of these articles discussed the role of PTM in the process of exchange rates pass-through to prices. Obviously, existing literature tells the importance of PTM in the transmission process, and this paper thus included PTM as an issue of the research model. Betts and Devereux (1996; 2000) made a wonderful interpretation of PTM in the process of exchange rate adjustment, but the assumption that the percentage of the firms of both countries are capable of discriminating price at an equal rate cannot elaborate the effect of PTM inconsistency of these manufactures on exchange rates. In a comparison of international PTM ratios, Knetter (1993) found that the PTM ratio of Germany was 89%, Japan was 79%, the UK was 67%, and the USA was 45%. These suggested PTM on the international market is asymmetrical, and the research is incomplete by eliminating this phenomenon. This paper thus revised the symmetric PTM setting of

Betts and Devereux (1996; 2000) and investigated the effect of the transportation costs on the dynamic adjustment of exchange rate with NOEM.

Based on the results of theoretical deviation, this paper found that as transportation costs increase, mis-adjustment of exchange rates takes place as the size of the local country is larger than that of a foreign country; while undershooting arises when the size of the local country is smaller than the foreign country. In addition, country size determines the direction of influence of transportation costs on the long-run and short-run exchange rate; and the elasticity of marginal utility of real money demand, the elasticity of substitution among goods, the ratio of local PTM firms, and the ratio of foreign PTM firms determine the extent of influence of transportation costs on the long-run and short-run exchange rate. When the size of the local country is comparatively smaller, the level of short-run exchange rate falls as transportation costs increase; when the size of the local country is comparatively larger, the level of short-run exchange rate rises as transportation costs increase; and when the size of both countries are the same, the level of short-run exchange rate remains unchanged as transportation costs increase. Furthermore, the greater the elasticity of marginal utility of real money demand is, the smaller the elasticity of substitution among goods is, and the lower the ratio of local PTM firms or foreign PTM firms is, as well as the greater the extent of exchange rate volatility will be as transportation costs increases. This is because these factors have weakened the correlation between money demand and cross-border consumption, and it needs to increase the extent of exchange rate volatility to mitigate the impact of transportation costs and enable the money market to re-achieve equilibrium. In this paper, we found that the importance of country size was marked out due to the asymmetric PTM setting, and country size is the main cause of the asymmetric dynamic adjustment of economics due to changes in transportation costs and exchange rates.

This paper contains four sections. Aside from the introduction, Section 2 describes the setting of the oretical model. Section 3 analyzes the effect of transportation costs on the extent of volatility of short-run exchange rate and the process of dynamic adjustment of exchange rate, and Section 4 reports the conclusions and recommendations of this paper.

2. Theoretical Model

With the NOEM proposed by Obstfeld and Rogoff (1995) as the theoretical foundation, this paper made the following assumptions by expanding the analysis framework of Betts and Devereux (1996; 2000):

1) There are only two countries in the world: local country and foreign country.
2) In terms of production quantity, the continuum of local goods and foreign goods lies respectively within intervals $[0, n)$ and $[n, 1]$, that is, the local size is n and the foreign size is $1-n$. To distinguish the economic variables of the local and foreign countries, all economic variables of the foreign country are marked henceforth by an asterisk "*".
3) Each agent is both a consumer and a producer, produces with own labor, and consumers a unit of heterogeneous goods.
4) Representative agent pursues the maximization of expected lifetime utility and shares the profit of firm.
5) Producers are monopolistic competitors with pricing ability.
6) Prices are sticky and cannot be changed within the short-run, but prices can be re-adjusted to steady state equilibrium within the long-run.
7) There is s percent of local firms are capable of PTM, and $1-s$ percent of local firms are incapable of PTM (who adopting producer currency pricing (PCP)). There is s^* percent of foreign firms are capable of PTM and $1-s^*$ percent adopt PCP. Unlike existing literature, this paper allowed an asymmetry of firms adopting PTM in both countries, that is, $s \neq s^*$.
8) Transportation costs appeared in the "iceberg" type, which exists in the economic system.

2.1 Representative Household

Assumed that all agents have the same preferences, the utility of representative agent covering consumption, real money balances, and leisure is expressed as follows:

$$U = \sum_{t=0}^{\infty} \beta^t \left[\log C_t + \frac{\gamma}{1-\varepsilon} (\frac{M_t}{P_t})^{1-\varepsilon} + \eta \log(1-h_t) \right], \quad \varepsilon > 0 \tag{1}$$

Where β is the discount factor ($0 < \beta < 1$), C is the consumption index, M represents the holding nominal money, P represents the local price level, M/P is the real money balances, h expresses total work hours, ε is the elasticity of marginal utility of real money demand,[1] γ and η represent respectively the degree of importance of real money balances and leisure in the utility function.

In Eq.(1),the consumption index is defined as the function of constant elasticity of substitution (CES) form, which is shown below:

$$C_t = \left[\int_0^1 c_t(z)^{\frac{\rho-1}{\rho}} dz \right]^{\frac{\rho}{\rho-1}}, \quad \rho > 1 \tag{2}$$

Where $c(z)$ is the consumption of specific product z by local consumers, ρ represents the elasticity of substitution of two products.[2]

As defined by Eq. (2), the local price index (P) under expenditure minimization can be derived as:

$$P_t = \left[\int_0^1 \delta_t(z)^{1-\rho} dz \right]^{\frac{1}{1-\rho}} \tag{3}$$

Where $\delta(z)$ is the local price of specific product z.

After including asymmetric PTM behaviors and transportation costs to Eq.(3), we could deduce that local price index (P)as:

$$P_t = \left[\int_0^n p_t(z)^{1-\rho} dz + \int_n^{n+(1-n)s^*} (p_t^*(z)/(1-\tau_t))^{1-\rho} dz + \int_{n+(1-n)s^*}^1 (Eq_t^*(z)/(1-\tau_t))^{1-\rho} dz \right]^{\frac{1}{1-\rho}} \tag{4}$$

Likewise, the foreign price index (P^*) is expressed as follows:

$$P_t^* = \left[\int_0^{ns} (q_t(z)/(1-\tau_t))^{1-\rho} dz + \int_{ns}^n (p_t(z)/E_t(1-\tau_t))^{1-\rho} dz + \int_n^1 q_t^*(z)^{1-\rho} dz \right]^{\frac{1}{1-\rho}} \tag{5}$$

Symbols in Eqs. (4) and (5) are defined as follows: $p(z)$ represents local good prices expressed in the local currency; $p^*(z)/(1-\tau)$ represents the selling price on the local market of foreign PTM goods (fraction is s^*); $Eq^*(z)/(1-\tau)$ represents the selling price on the local market of foreign PCP goods (fraction is $1-s^*$); $q(z)/(1-\tau)$ represents the selling price on the foreign market of local PTM goods (fraction is s); $(p(z)/E(1-\tau))$ represents the pricing on the foreign market of local PCP goods (fraction is $1-s$); $q^*(z)$ is the pricing of foreign goods in the foreign country; E is the nominal exchange rate; and τ represents cross-border transportation costs.

In Eqs.(4) and (5), transportation costs were set according to most literature, such as Obstfeld and Rogoff (2000) and Novy (2010), and blended with Samuelson's (1952) "iceberg" type assuming that some products are melted (or vaporized) during transportation. That is to say, when shipping one unit of products from the foreign country to the local country, only $1-\tau$ unit ($\tau < 1$) will arrive. Furthermore,

[1] The elasticity of marginal utility of real money demand is defined as the degree of reaction to the change in the marginal utility of money triggered by one percent change in real money demand.

[2] ρ is the change ratio of the consumption rate of two products triggered by one percent change in the marginal rate of substitution (MRS).

when it needs to receive an entire unit of products, $1/(1-\tau)$ units of products should be shipped from the foreign country. Transportation costs here include insurance fee and transportation fee.

The consumption of specific goods z of local representative consumer can be derived from Eqs. (2) and (4) as:[3]

$$c_t(z) = \left[\frac{\xi_t(z)}{P_t}\right]^{-\rho} C_t \tag{6}$$

In the above expression, $\xi(z) = p(z)$, $p^*(z)/(1-\tau)$, and $Eq^*(z)/(1-\tau)$ represent respectively the price of local specific good z, foreign specific PTM good z, and foreign specific PCP good z accepted by local consumers.

Likewise, the consumption of specific good z of foreign representative consumer is expressed as follows:

$$c_t^*(z) = \left[\frac{\varsigma_t(z)}{P_t^*}\right]^{-\rho} C_t^* \tag{7}$$

In Eq. (7), $\varsigma = q^*(z)$, $q(z)/(1-\tau)$, and $(p(z)/E(1-\tau))$ represent respectively the price of foreign specific good z, local specific PTM good z, and local specific PCP good z accepted by foreign consumers.

The budget constraint of local representative agent face in period t is expressed as follows:

$$P_t C_t + M_t = W_t h_t + \pi_t + M_0 + TR_t \tag{8}$$

In Eq. (8), the sources of income for the representative individual including: wage incomes (Wh), profit share from firm(π), government transfer revenue(TR), and previous money balances (M_0) that representative agent can spend on consumption (PC) and holding money (M).

The optimal choice for representative agent to pursue the maximization of utility function (Eq. (1)) under budget constraint (Eq. (8)) is expressed as follows:

$$P_{t+1} C_{t+1} = \beta P_t C_t \tag{9}$$

$$\frac{M_t}{P_t} = (\gamma C_t)^{1/\varepsilon} \tag{10}$$

$$\frac{\eta}{1-h_t} = \frac{W_t}{P_t C_t} \tag{11}$$

Where Eq.(9) is the Euler equation of local consumption describing the cross-period consumption behavior of representative agent. Eq. (10) is the money demand equation presenting the real money demand of representative agent.[4] Eq. (11) is the labor supply equation indicating the substitution relationship between labor supply and consumption.

Likewise, the situation in the foreign country is expressed as follows:

$$\frac{E_{t+1}}{E_t} P_{t+1}^* C_{t+1}^* = \beta P_t^* C_t^* \tag{12}$$

$$\frac{M_t^*}{P_t^*} = (\gamma C_t^*)^{1/\varepsilon} \tag{13}$$

$$\frac{\eta}{1-h_t^*} = \frac{W_t^*}{P_t^* C_t^*} \tag{14}$$

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[3] Eq. (6)can be derived from the following maximization problem and with the price index (Eq. (4)):

$$\max_{c_t(z)} C = \left[\int_0^1 c_t(z)^{\frac{\rho-1}{\rho}} dz\right]^{\frac{\rho}{\rho-1}} \quad \text{subject to } \int_0^1 \delta_t(z) c_t(z) dz = Z$$

[4] From Eq. (10), it is clear that $1/\varepsilon$ represents the consumption elasticity of money demand.

Eq.(12) is the Euler equation of the foreign country expressed in the local currency. Eq. (13) is the money demand equation of the foreign representative agent. Eq. (14) is the labor supply equation of the foreign country.

2.2 Firms

Assumed that labor is the unique production factor, and the production behavior of firms is expressed as follows:

$$y_t(z) = Ah_t(z) \tag{15}$$

Eq. (15) shows the production function of local firms. Where $y(z)$ expresses the production of product by firm z; $h(z)$ is the labor employment of firm z, and A, an assumed fixed constant, represents the local productivity shock.

There are two types of firms: those capable of PTM and those incapable of PTM (adopting PCP). For local PTM firms, the pricing can be divided into local and foreign market, the market of local PTM firms face is:

$$y_t(z) = x_t(z) + v_t(z)$$

Where $x(z)$ is the quantity of local goods sold in the local market (price is $p(z)$) and $v(z)$ is the quantity of local goods sold in the foreign market (price is $q(z)$).

The profit function of local PTM firms is as follows:

$$\pi_t(z) = p_t(z)x_t(z) + E_t(q_t(z)/(1-\tau_t))v_t(z) - \frac{W_t}{A}[x_t(z) + v_t(z)]$$

Using Eqs. (6) and (7), the pricing level of firms under profit maximization can be obtained as follows:

$$p_t(z) = \frac{E_t q_t(z)}{1-\tau_t} = \frac{\rho}{\rho-1}\frac{W_t}{A} \tag{16}$$

Eq.(16) explains that monopolistic competitors charge a price equal to a constant mark-up. The expression also presents the law of one price is not supported due to transportation costs. But PTM ratio does not affect the law of one price due to the elasticity of good demand and preferences remain unchanged.[5]

2.3 Government Sector

Assumed that the government does not purchase, the government budget constraint is expressed as follows:

$$TR_t = M_t - M_0 \tag{17}$$

Eq.(17) shows that the government transfer the seigniorage revenue ($M_t - M_0$) to agents in a lump-sum fashion (TR_t).

3. Model Derivation

This section analyzed the effect of transportation costs on exchange rate dynamics based on the derivation results of long-run and short-run equilibrium and presented the role of country size and PTM. Long-run equilibrium describes the convergent status of the economic system after shock exposures. In the long-run, prices can be adjusted freely and all variables will reach steady state

[5] Betts and Devereux (1996;2000) and Otani (2002) also proposed that PTM would not affect the law of one price for the long-run; while Fender and Yip (2000) and Reitz and Slopek (2005)assumed that the tariffs would not affect the law of one price.

equilibrium. While in the short-run, however, prices are sticky, and the economic system will be dynamically adjusted as prices set in advance according to the local currency and cannot be adjusted.

In order to obtain the closed-form solution of exogenous and endogenous variables, we simplified analysis with log-linearization commonly used by NOEM related literature. In the following expressions, the superscript"^"represent the values of log-linearized variables. For example, if $\hat{X}_t$ is the result of X_t log-linearized at initial state X_0, then

$$\hat{X}_t = \frac{X_t - X_0}{X_0} = \frac{dX_t}{X_0} = \ln\left(\frac{X_t}{X_0}\right)$$

3.1 Equilibrium with Flexible Prices

When prices can be freely adjusted, all markets will reach an equilibrium position, and the consumption level is determined by the good market, thus we have:

$$C_{t+1} = Ah_{t+1} = y_{t+1} \quad (18)$$

$$C^*_{t+1} = Ah^*_{t+1} = y^*_{t+1} \quad (19)$$

By substituting Eq. (11) with Eq. (16), and make use of Eq. (18), we could get the labor employment of the local country(h) as:

$$h_{t+1} = \frac{(\rho-1)/\rho}{((\rho-1)/\rho)+\eta} \quad (20)$$

By subtracting Eq. (10) by Eq. (13), and make use of Eq. (16), the volatility of the exchange rate in the long-run equilibrium after log-linearized is expressed as follows:

$$\hat{E}_{t+1} = \hat{M}_{t+1} - \hat{M}^*_{t+1} - \frac{1}{\varepsilon}(\hat{C}_{t+1} - \hat{C}^*_{t+1}) - \hat{\tau}_{t+1} \quad (21)$$

From the above two equations, it is clear that under the equilibrium with flexible prices, neither transportation costs nor PTM changes will affect the labor inputs, but provided that transportation costs will affect the long-run exchange rate level.

3.2 Equilibrium with Sticky Price

First, the local price index (Eq. (4)) and foreign price index (Eq. (5)) can be simplified as:

$$P_t = \left[np_t(z)^{1-\rho} + (1-n)s^*\left(p^*(z)/(1-\tau_t)\right)^{1-\rho} + (1-n)(1-s^*)\left(E_t q^*_t(z)/(1-\tau_t)\right)^{1-\rho}\right]^{\frac{1}{1-\rho}} \quad (22)$$

$$P^*_t = \left[ns\left(q_t(z)/(1-\tau_t)\right)^{1-\rho} + n(1-s)\left(p_t(z)/E_t(1-\tau_t)\right)^{1-\rho} + (1-n)q^*_t(z)^{1-\rho}\right]^{\frac{1}{1-\rho}} \quad (23)$$

Under the sticky price equilibrium, prices are sticky and cannot be adjusted, the short-run equilibrium condition of money market is still to be Eqs. (10) and (13), as output is determined by demand in the short-run, the equilibrium conditions of the local and foreign good markets are expressed as follows:

$$y_t(z) = x_t(z) + v_t(z) = \left(\frac{p_t(z)}{P_t}\right)^{-\rho} nc_t + \left(\frac{p_t(z)}{E_t P^*_t(1-\tau_t)}\right)^{-\rho}(1-n)c^*_t \quad (24)$$

$$y^*_t(z) = x^*_t(z) + v^*_t(z) = \left(\frac{E_t q^*_t(z)}{P_t(1-\tau_t)}\right)^{-\rho} nc_t + \left(\frac{q^*_t(z)}{P^*_t}\right)^{-\rho}(1-n)c^*_t \quad (25)$$

In the short-run, the budget constraint that local and foreign households face is expressed as follows:

$$P_t C_t = n(1-s)p_t(z)y_t(z) + ns(p_t(z)x_t(z) + E_t(q_t(z)/(1-\tau_t))v_t(z)) \quad (26)$$

$$P_t^* C_t^* = (1-n)(1-s^*)p_t^*(z)y_t^*(z) + (1-n)s^*\left(\frac{p_t^*(z)}{E_t(1-\tau_t)}x_t^*(z) + q_t^*(z)v_t^*(z)\right) \tag{27}$$

In Eq. (26), the left side of the equation represents the consumption expenditure (PC) of local households, and the right side of Eq. (26) represents the sources of incomes, including the income from PCP good sales ($n(1-s)p(z)y(z)$) and from PTM good sales ($ns(p(z)x(z)+E(q(z)/(1-\tau))v(z))$). Eq. (27) shows the revenue and expenditure identity of the foreign household.

In the short-run, as prices are sticky ($\hat{p}_t(z) = \hat{q}_t(z) = \hat{p}_t^*(z) = \hat{q}_t^*(z) = 0$), the local and foreign price indices (Eqs. (22) and (23)) after log-linearization are:

$$\hat{P}_t = (1-n)(1-s^*)\hat{E}_t + (1-n)\hat{\tau}_t \tag{28}$$

$$\hat{P}_t^* = -n(1-s)\hat{E}_t + n\hat{\tau}_t \tag{29}$$

From Eqs.(28) and (29), it is clear that the higher the ratio of foreign (local) PTM firms or the smaller the foreign (local) country size is, the lower the effects of exchange rate volatility on the local (foreign) price index will be; and the smaller the local country size is, the higher (lower) the effect of transportation costs on the local (foreign) price index will be. When firms of both countries adopt PTM ($s = s^* = 1$), exchange rate volatility will not pass-through to prices.

By subtracting Eq. (28) by Eq. (29), the following expression is obtained:

$$\hat{P}_t - \hat{P}_t^* = \left[(1-n)(1-s^*) + n(1-s)\right]\hat{E}_t + (1-2n)\hat{\tau}_t \tag{30}$$

From Eq. (30), it is clear that the effect of transportation costs on the relative price of both countries is affected by country size(n), when the size of both countries is equal ($n = 0.5$), the transportation costs will not affect the relative price of both countries. When the local country size is relatively larger ($n > 0.5$), the relative price of both countries will fall with an increasing in transportation costs. When the local country size is relatively smaller ($n < 0.5$), the relative price of both countries will rise with an increasing in transportation costs. Country size(n) and the local (foreign) PTM ratio(s, s^*) affect the effects of exchange rate volatility on the relative price of both countries, as illustrated by the following two extreme examples:

1) When both countries were priced in home currency($s = 0$; $s^* = 1$), as the local country size expands, however, the effects of exchange rate volatility on the relative price of both countries will increase.
2) When both countries were priced based on the foreign currency($s = 1$; $s^* = 0$),as the foreign country size expands, the effects of exchange rate volatility on the relative price of both countries will increase.[6]

3.3 Transportation Costs and Exchange Rate Dynamics

Take the log-linearization of the money market equilibrium condition (Eqs. (10) and (13)) and subtract from each other, we get:

$$\hat{M}_t - \hat{M}_t^* = \hat{P}_t - \hat{P}_t^* + \frac{1}{\varepsilon}(\hat{C}_t - \hat{C}_t^*) \tag{31}$$

By substituting Eq. (31) with Eq. (30), the following expression is obtained:

$$\hat{E}_t = \frac{1}{[(1-n)(1-s^*) + n(1-s)]}\left[(\hat{M}_t - \hat{M}_t^*) - \frac{1}{\varepsilon}(\hat{C}_t - \hat{C}_t^*) - (1-2n)\hat{\tau}_t\right] \tag{32}$$

[6] Referring to Devereux et al.(2007), when both countries completely adopt the local currency pricing ($s = 0$; $s^* = 1$), this behavior complies with the home currency standard; when both countries completely adopt foreign currency pricing ($s = 1$; $s^* = 0$), this behavior complies with the foreign currency standard.

Eq. (32) explains that the relative money supply variation of both countries ($\hat{M}_t - \hat{M}_t^*$), the relative consumption variation of both countries ($\hat{C}_t - \hat{C}_t^*$), and transportation costs ($\hat{\tau}_t$)will affect the direction of exchange rate volatility; and country size (n) and PTM ratio (s, s^*)will affect the extent of exchange rate volatility.

Because the PTM ratio will not affect the long-run consumption level, by subtracting the consumption Euler equation of both countries (Eqs. (9) and (12)) after log-linearization, and make use of Eq. (16),the following expression is obtained:

$$\hat{C}_{t+1} - \hat{C}_{t+1}^* = (\hat{C}_t - \hat{C}_t^*) + \left[\left((1-n)(1-s^*) + n(1-s)\right) - 1\right]\hat{E}_t - \hat{\tau}_t \tag{33}$$

By eliminating transportation costs ($\hat{\tau}_t$=0) and maintaining $s = s^*$, $\hat{C}_{t+1} - \hat{C}_{t+1}^* = (\hat{C}_t - \hat{C}_t^*) - s\hat{E}_t$ is obtained to reduce to the Betts and Devereux's (1996) results.

Referring to the setting of Obstfeld and Rogoff (1995) and Fender and Yip (2000), assumed that the exogenous money and transportation costs are the permanent shock($\hat{M}_t = \hat{M}_{t+1}$; $\hat{M}_t^* = \hat{M}_{t+1}^*$; $\hat{\tau}_t = \hat{\tau}_{t+1}$), and combining Eqs. (21), (32), and (33), we have:

$$\hat{E}_{t+1} = \frac{1}{\Delta}\left[\frac{\varepsilon-1}{\varepsilon}(\Delta-1)(\hat{M}_t - \hat{M}_t^*) - \frac{1}{\varepsilon}(\hat{C}_t - \hat{C}_t^*) - \left((1-2n)+2\Delta\right)\hat{\tau}_t\right] \tag{34}$$

Where $\Delta \equiv [(1-n)(1-s^*) + n(1-s)] < 1$.

Comparing Eq.(32) with Eq.(34),we found that:

1) When the local country size is relatively larger ($n > 0.5$), an increase in transportation costs will cause the short-run and long-run exchange rates to change reversely to bring up the mis-adjustment phenomenon in exchange rate.
2) When the local country size is relatively smaller ($n < 0.5$), an increase in transportation costs will cause smaller volatility of the short-run exchange rate than long-run exchange bring up the undershooting phenomenon in exchange rate.
3) When the size of both counties is equal ($n = 0.5$), an increase in transportation costs will not affect the short-run exchange rate, while the long-run exchange rate will reduce.

In the long-run equilibrium with flexible prices, the price of imports rises as transportation costs increase regardless of country size(n). By reducing the demand for imports and foreign currency at the same time, the local currency will appreciate (exchange rate falls). In the short-run equilibrium of price stickiness, however, country size (n) determines the effect of transportation costs on exchange rate. When the local country size is comparatively larger ($n > 0.5$), the foreign country has smaller influence effect relatively to the local country. When goods of both countries are not perfectly substitutable, the demand for imports of the local country (comparatively larger) will still increase even transportation costs increase. This will push the demand for foreign currency and cause the local currency to depreciate (exchange rate rises), thus causing the mis-adjustment phenomenon in exchange rate. When the local country size is comparatively smaller ($n < 0.5$), the foreign country has larger influence effect relatively to the local country. As the demand for imports reduces when transportation costs increase, the demand for foreign currency reduces to cause the local currency to appreciate (exchange rate falls). Due to price stickiness in short-run, the extent of fall in the short-run demand for imports will be smaller than that of the long-run demand, thus causing the undershooting phenomenon in exchange rate. If the size of both countries is equal ($n = 0.5$), due to size symmetry and short-run price stickiness, transportation costs will not affect the exchange rate level. The above conclusion is drawn upon an asymmetric PTM behavior setting, which marks out the role of country size and causes the asymmetric adjustment of the relative price of both countries after changes in transportation costs and exchange rates.

By subtracting Eq. (26) by Eq. (27) after log-linearization and substituting the Eqs. (6), (7), and (30) with log-linearized, the short-run response of exchange rate is obtained as follows:

$$\hat{E}_t = \frac{(\hat{C}_t - \hat{C}_t^*) - (1-2n)\hat{\tau}_t}{\Delta(\rho - 1) + \left(ns + (1-n)s^*\right)} \tag{35}$$

By eliminating the transportation costs shock ($\hat{\tau}_t = 0$) and assumed that the PTM ratio of both countries is equal ($s = s^*$) in Eq. (35), the conclusion of Betts and Devereux (1996) is obtained.

Finally, the following expression is obtained by combining Eqs. (32)and (35):

$$\hat{E}_t = \frac{\varepsilon(\hat{M}_t - \hat{M}_t^*) - (1+\varepsilon)(1-2n)\hat{\tau}_t}{\Delta(\varepsilon + \rho - 1) + \left(ns + (1-n)s^*\right)} \tag{36}$$

From Eq.(36), it is clear that local currency depreciates as local money supply increases, and country size(n) determines the direction of influence of short-run exchange rate by the increase of transportation costs, while the elasticity of marginal utility of real money demand (ε), the elasticity of substitution among goods (ρ), the ratio of local PTM firms (S), and the ratio of foreign PTM firms (S^*) determine the extent of short-run exchange rate volatility. When the local country size is comparatively smaller ($n < 0.5$), the level of short-run exchange rate falls as transportation costs increase. When the local country size is comparatively larger ($n > 0.5$), the level of short-run exchange rate rises as transportation costs increase. When the size of both countries is equal ($n = 0.5$), the level of short-run exchange rate remains unaffected as transportation costs increase. In addition, the greater the elasticity of marginal utility of real money demand (ε) is, the smaller the elasticity of substitution among goods (ρ) is, and the lower the ratio of local PTM firms (s) or foreign PTM firms (S^*) is, as well as the greater the extent of exchange rate volatility will be as transportation costs increases. This is because the smaller the elasticity of consumption of money demand ($1/\varepsilon$) and the elasticity of substitution among goods (ρ) are, and the lower the ratio of local PTM firms (S) or foreign PTM firms (S^*) is, the connection between money demand and cross-border consumption will reduce. This needs to increase the extent of exchange rate volatility to mitigate the impact of transportation costs and enable the money market to re-achieve equilibrium.

4. Conclusions and Recommendations

Although the research of transportation costs has extended from microeconomics to macroeconomics(For example, Nguyen and Tongzon (2010); Tong et al. (2014)), there lacks a generalized model to interpret the effects of transportation costs in an open macro economy. Because exchange rate is an important economic indicator of an open economy, this paper investigated the effects of transportation costs on the long-run and short-run exchange rates. On the other hand, although subsequent scholars treat the research of "exchange rate dynamics" is an important issue, and existing literature has pointed out the role of PTM in this topic, related studies are limited to investigate symmetric PTM behaviors without specifying the change resulting from the asymmetric PTM of both countries. Furthermore, although NOEM has been used for nearly 20 years since its introduction, research of the effects of transportation costs was rare. For these reasons, this paper thus revised the PTM proposed by Betts and Devereux (1996; 2000) into asymmetric PTM based on the NOEM theoretical framework and to investigate the effects of country size and PTM on exchange rate dynamics when countries face the transportation costs This paper hopes that the findings of this research can serve as a reference for decision-making of relevant authorities.

Based on the results of theoretical derivation, we found that when the size of the local country is larger, the short-run and long-run exchange rates change reversely as transportation costs increase, and mis-adjustment is presented in exchange rates. When the size of the local country is smaller, the extent of volatility of short-run exchange rate is greater than that of the long-run exchange rate as transportation costs increase, and undershooting of exchange rate occurs. When the size of both countries is equal, although transportation costs will not affect the short-run exchange rate, long-run exchange rate falls. In addition, country size determines the direction of influence of transportation costs on short-run exchange rate, while the elasticity of marginal utility of real money demand, the elasticity of substitution among goods, and the ratio of local (foreign) PTM firms determine the extent of influence. When the size of the local country is relatively smaller, short-run exchange rate will fall as transportation costs increase; and when the size of the local country is relatively larger, short-run exchange rate will rise as transportation costs increase. In addition, the greater the elasticity of marginal utility of real money demand, the smaller the elastic substitution among goods, and the lower the ratio of local or foreign PTM firms are, as well as the greater the extent of exchange rate volatility will be as transportation costs increases. This is because these factors will weaken money demand and cross-border consumption, and it needs greater extent of exchange rate volatility to mitigate the effect of transportation costs and enable the money market to re-achieve equilibrium. In an open economy, transportation policies will affect transportation costs and affect macroeconomic variables such as price, consumption, output and exchange rate. Unlike most literature emphasizing the effects the long-run policies, this paper found that transportation costs have different degrees of effects on the long-run and short-run exchange rate through theoretical analysis. This paper thus recommends relevant authorities to review transportation policies at any time in line with monetary, financial, and trading policies, so as to effectively reduce economic volatility.

Lastly, it is necessary to note that to simplify analysis, this paper assumed that money is the only asset with reference to Betts and Devereux (1996) and Fender and Yip (2000), and the role of interest rate was thus disregarded, which is one of the limitations of this paper. Then, although NOEM has demonstrated its importance in economic issues, to find solutions more easily, it is necessary to make many assumptions. By releasing one assumption or setting (such as the consumption and leisure function in the utility function), however, the outcome may be different. This will be considered as another limitation of this paper.

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