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Diversified Currency Holdings and Exchange Rate Dynamics

Chung-Fu Lai[1]*, Shan-Kai Tsai[2]

[1]Department of Applied Economics, Fo Guang University, Yilan County, Taiwan, [2]Department of Applied Economics, Fo Guang University, Yilan County, Taiwan. *Email: cflai@gm.fgu.edu.tw

ABSTRACT

In this study, we incorporate diversified currency holdings into the New Open Economy Macroeconomics (NOEM) model to explore the issue of exchange rates dynamics. The findings show that exchange rate overshooting occurs when diversified currency holdings are included in a two-country dynamic optimizing NOEM model, and the extent of the overshoot depends on the level of diversified currency holdings. Regarding welfare analysis, an expansionary monetary policy of the home country increases domestic welfare. Also, we find that current account plays an important role in the effect of monetary policy on exchange rates, the increase in the domestic money supply stimulates domestic consumption expenditure through the effects of current account improvements, resulting in exchange rate appreciation.

Keywords: Diversified Currency Holdings, Exchange Rate Dynamics, Micro-foundations
JEL Classifications: F31, F41

1. INTRODUCTION

Dornbusch (1976) was the first one to analyze the issue of exchange rate dynamics. In his study, Dornbusch (1976) assumed perfect capital mobility and perfect foresight in a log-linear model to investigate the effects of permanent money shocks on exchange rates volatility in the short- and long-run, respectively. The results indicated that an increase in the money supply causes the asset markets to adjust more rapidly than the goods markets, which is a result of the short-run exchange rate volatility exceeding the volatility in the long-run, this is known as "overshooting." Subsequently, many scholars have analyzed the relationship between short- and long-run changes in exchange rates from various perspectives, these studies are categorized as the research of "exchange rate dynamics." Regarding research on macroeconomics, numerous extant studies in the past decades have been successfully conducted based on the original models proposed by Dornbusch (1976), such as Gray and Turnovsky (1979); Wilson (1979); Frenkel and Rodriguez (1982); Aoki (1985); Lai and Chu (1986). Additionally, after collating these studies, we find that exchange rate dynamics can be roughly divided into the following three influential factors: (1) The degree of capital mobility (e.g. Frenkel and Rodriguez, 1982); (2) the extent of asset substitution (e.g. Kouri, 1976; Calvo and Rodriguez, 1977; Branson, 1977; Turnovsky, 1981; Livitan, 1981; Park, 1987); and (3) the process of expectation formation (e.g., Mathieson, 1977; Gray and Turnovsky, 1979; Wilson, 1979; Bhandari, 1981; Levin, 1994).

However, the original overshooting model proposed by Dornbusch (1976) lacks the rigorous micro-foundations and the discussion of the role of current account (i.e. international bond holdings) on exchange rates is overlooked. Fortunately, these critical issues were addressed in the study conducted by Obstfeld and Rogoff (1995). Obstfeld and Rogoff (1995) proposed a two-country, dynamic general equilibrium model to develop an analysis framework based on monopolistic competition and price-stickiness. This model predicted the effects of monetary policy on short- and long-run exchange rates under the assumption of a symmetric economy, the findings indicated that, the exchange rates in short-run returns immediately to its long-run steady state after a permanent monetary shocks, and overshooting does not occur.

Since the pioneering work of Obstfeld and Rogoff (1995), discussions on exchange rate dynamics reached a new milestone. Obstfeld and Rogoff (1995)'s model has become known as the New Open Economy Macroeconomics (NOEM), the foundation was extended and expanded in many subsequent studies.

Examples of NOEM adaptations include trade friction analysis (the imperfect financial market) proposed by Sutherland (1996); the expansion of various price adjustment methods offered by Kollmann (1997); the small-scale open economy model revision examined by Lane (1997); the investigation of different pricing strategies and the issue of the choice between fixed and flexible exchange-rate regimes proposed by Devereux and Engel (1998); inclusion of random shocks in NOEM adopted by Obstfeld and Rogoff (1998); the significance of pricing to market proposed by Betts and Devereux (2000); the analysis of tariff policy effects on exchange rate dynamics conducted by Fender and Yip (2000); and the roles of factor intensity, price rigidity, and non-traded goods in the monetary international transmission processes examined by Hau (2000). Additionally, Corsetti and Pesenti (2001) defined the elasticity of substitution for home and foreign goods as 1, and further investigated the welfare effects of monetary and financial policies under the assumption that home and foreign manufacturers receive fixed revenue shares; Tille (2001) loosened the restrictions of the NOEM model, which assumes that the elasticity of substitution for home and foreign goods equals the elasticity of substitution between various home goods; and Obstfeld and Rogoff (2002) investigated the issue of the effects of monetary policy coordination on the welfare. In our study, we selected one independent factor as the research subject, that is, diversified currency holdings. The behavior of diversified currency holdings significantly influences exchange rate volatility in an open economy, but the role of diversified currency holdings still lacks generalized and integrated investigations. Therefore, the objective of this study was to examine whether the result of no-overshoot obtained by Obstfeld and Rogoff (1995) continue to occur when considering diversified currency holdings behavior.

In the analysis of the issue of diversified currency holdings, until now, it was not clearly to distinguish the terms between “currency preferences” and “currency substitution” in previous studies (e.g. He, 2002; Daniels and VanHoose, 2003; Kingston and Melecky, 2007). He (2002) adopted a standard NOEM model as the framework to examine the behavioral effects of currency substitution. His study assumed home and foreign currencies holding behavior in the same fashion and then incorporated them into a representative individual utility function. The process was defined as the “perfect substitution.” However, the definition of currency substitution based on the model settings established by He (2002) differed significantly from that of other conventional studies (e.g. Miles, 1978; 1981; Uribe, 1999). Specifically, we contend that “diversified currency holdings” or “currency preferences” would be a more appropriate definition for the model settings established by He (2002). Previous research proposed by Daniels and VanHoose (2003), and Kingston and Melecky (2007) also used “currency preferences” and “currency substitution” interchangeably. Strictly speaking, “currency substitution” should be defined as the behavior of adjusting currency portfolios when individuals experience the exogenous shocks, in theoretical analysis, should be emphasized the role of elasticity of substitution between home and foreign currencies especially. And, “diversified currency holdings” refers to the changes in currency preferences caused by a change in risk aversion, personal hobby, the response of exogenous shocks, etc.

Corrado (2008) developed a small-country model to investigate the effects of currency substitution using the NOEM framework. He applied a more formal setting which given the elasticity of substitution between the home and the foreign currencies, and accorded more with the research objectives of currency substitution compared to the model proposed by He (2002). However, we find that Corrado (2008)’s small-country model settings lacked welfare analysis, and the numerical simulation was required to obtain closed form solutions because of the complexity. Furthermore, although the study conducted by He (2002) trended toward the research of “diversified currency holdings,” the advantages of his study were that closed form solutions for the model could be obtained without simulation, and a more complete welfare analysis was conducted. In this paper, we extend the model proposed by He (2002). He (2002) assumed the preferences of the home and foreign currencies in the same fashion, however, these settings would be more suitable as “imperfect substitution” to emphasize substitution imperfections characteristics of home and foreign currencies holding behavior. Therefore, we adopt the NOEM model to analyze the dynamic effects of monetary shock on exchange rate dynamics and welfare with diversified currency holdings, and further attempt to address the gap in extant literature.

The first investigation regarding whether an agent could simultaneously holding both home and foreign currencies was conducted by Chen (1973). Chen (1973) found that flexible exchange rates could not completely isolate the effects of exogenous shocks with diversified currency holdings. Since this groundbreaking article was published, asset substitution began to appear widely in literature, researchers regarding the effects of asset substitution on exchange rate dynamics include the following: Kouri (1976) assumed that people can possess two asset types, specifically, home currency and foreign bonds; Branson (1977) assumed that people can own three asset types, specifically, home currency, home bonds, and foreign bonds; and Park (1987) also assumed that people can possess three asset types: Home currency, foreign currency, and inflation-aversion assets (e.g. gold or real estate). Calvo and Rodriguez (1977); Livitan (1981); Chen and Tsaur (1983); Chen et al. (1989) all assumed that people could only choose between home and foreign currency to emphasize the influences of currency substitution on exchange rate dynamics. Calvo and Rodriguez (1977) found that the expansion of money supply depreciates short-run exchange rates if currency substitution exists in the economy, although long-run exchange rates are not affected. Livitan (1981) extended the framework proposed by Calvo and Rodriguez (1977), and further considered the dynamic effects with infinite planning horizon. Livitan (1981) found that the expansion of money supply induced short-run exchange rate appreciation, but the long-run exchange rates remained unaffected. In addition, numerous studies of currency substitution have also included micro-foundations setting (e.g. Calvo and Rodriguez, 1977; Livitan, 1981), but some studies still adopted an “ad hoc” analysis (e.g. Chen and Tsaur, 1983; Chen et al., 1989). Furthermore, although theoretical studies are increasingly emphasizing the significance of micro-foundations, discussions regarding the effects that current account changes on exchange rate volatility remain overlooked, hence, these studies were not perfect in their design, our paper attempts to seek the breakthrough.

Therefore, we analyze the effects of exchange rate dynamics and welfare with diversified currency holdings using the NOEM model. This paper not only resolves the insufficiency in micro-foundations analysis but also consider the role of current account when analyzing the effects that diversified currency holdings on exchange rate dynamics. According to the theoretical analysis, the findings confirm that the behavior of diversified currency holdings is an important factor of exchange rate overshooting.

This paper is organized as follows: Section 1 provides a background introduction. In Section 2, we construct the theoretical model. In Section 3, we derive the flexible and sticky price solutions of the model. Section 4 analyzes the effects of money supply expansion on welfare with diversified currency holdings, and in Section 5, we present our conclusions and suggestions.

2. THE MODEL

We model the world consists of two equal-sized countries, the home country and foreign country. Both the home and foreign countries are inhabited by a continuum of individuals on intervals (0, 1/2). Each individual engage in consumption and simultaneously produce output. Producers possess monopolistic competition characteristics and hire labor to help them produce heterogeneous goods. To differentiate between the home and foreign variables, we mark all foreign economic variables with a "*" superscript.

2.1. Preferences

Assuming that all individuals have identical preferences, the representative consumer's lifetime utility depends positively on consumption (C), home real money balances (M/P), and foreign real money balances (EM^*/P), but negatively on output (y). Therefore,

$$U_t = \sum_{s=t}^{\infty} \beta^{s-t} \left[\log C_s + \frac{\chi}{1-\varepsilon}\left(\frac{M_s}{P_s}\right)^{1-\varepsilon} + \frac{\chi'}{1-\varepsilon}\left(\frac{E_s M_s^*}{P_s}\right)^{1-\varepsilon} - \frac{k}{2} y_s(z)^2 \right], \quad \varepsilon > 0 \tag{1}$$

Where, β denotes the subjective discount rate ($0 < \beta < 1$), ε denotes the elasticity of marginal utility of real money demand ($\varepsilon > 0$), χ, χ', and κ separately denote the significance of home real money balances, foreign real money balances, and output in the utility function, E denotes the exchange rate, and z denotes a specific good for z.

The representative consumer's consumption index is assumed to take the standard constant elasticity of substitution,

$$C = \left[\int_0^{1/2} c(z)^{\frac{\theta-1}{\theta}} dz + \int_0^{1/2} c(z^*)^{\frac{\theta-1}{\theta}} dz^* \right]^{\frac{\theta}{\theta-1}}, \quad \theta > 1 \tag{2}$$

Where, $c(z)$ denotes the home consumption for specific home good z, $c(z^*)$ denotes the home consumption for specific foreign good z^*, and θ denotes the elasticity of substitution between home and foreign goods.

By the equation (2), we can derive the price index for home country as,

$$P = \left[\int_0^{1/2} p(z)^{1-\theta} dz + \int_0^{1/2} q(z^*)^{1-\theta} dz^* \right]^{\frac{1}{1-\theta}} \tag{3}$$

Similarly, the foreign price index is,

$$P^* = \left[\int_0^{1/2} p^*(z)^{1-\theta} dz + \int_0^{1/2} q^*(z^*)^{1-\theta} dz^* \right]^{\frac{1}{1-\theta}} \tag{4}$$

Where, $p(z)$ denotes the price of the home good z in the home currency, $p^*(z)$ denotes the price of home good z in the foreign currency, $q(z^*)$ denotes the price of foreign good z^* in the home currency, and $q^*(z^*)$ denotes the price of foreign good z^* in the foreign currency.

The law of one price holds for each product, is given by,

$$p(z) = Ep^*(z) \quad \text{and} \quad q(z^*) = Eq^*(z^*) \tag{5}$$

Equation (5) indicates that goods sell for the same price worldwide.

Using equations (2) and (3), we can further get the consumption for home goods and foreign goods by the home representative agent as,

$$c(z) = \left[\frac{p(z)}{P}\right]^{-\theta} C \tag{6}$$

$$c(z^*) = \left[\frac{q(z^*)}{P}\right]^{-\theta} C \tag{7}$$

Similarly, we can also derive the consumption for home goods and foreign goods by the foreign representative consumer as,

$$c^*(z) = \left[\frac{p^*(z)}{P^*}\right]^{-\theta} C^* \tag{8}$$

$$c^*(z^*) = \left[\frac{q^*(z^*)}{P^*}\right]^{-\theta} C^* \tag{9}$$

The price indices for home and foreign countries equations (3) and (4) can further be simplified as,

$$P = \left[\frac{1}{2} p(z)^{1-\theta} + \frac{1}{2} q(z^*)^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{10}$$

$$P^* = \left[\frac{1}{2} p^*(z)^{1-\theta} + \frac{1}{2} q^*(z^*)^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{11}$$

2.2. Asset Market

Assume that the presence of an international asset market where only a riskless real bond can be traded between two countries. The Fisher equation states the relationship between the real and nominal rates of return on the international bond, is written as

$$1 + i_t = \frac{P_{t+1}}{P_t}(1 + r_t) \tag{12}$$

Additionally, uncovered interest rate parity explains the relationship between home and foreign nominal rates of return on the bond, is given by

$$1+i_t=\frac{E_{t+1}}{E_t}(1+i_t^*) \tag{13}$$

This equation denotes the asset market equilibrium condition, and further indicates that when capital possesses international mobility, it inevitably shifts toward country with high return rates until the equilibrium is achieved.

Bond holdings reflects the loan relationships between individuals of the two countries, and further satisfies $(1/2)B_t+(1/2)B_t^*=0$, that is

$$B_t^*=-B_t \tag{14}$$

Where, B_t is the international bond holdings for home agents, B_t^* is the international bond holdings for foreign agents.

2.3. Government

To simplify the analysis, we assume that government spending is zero and the seigniorage revenue is redistributed to households in a lump-sum fashion. Therefore, the government budget constraint is,

$$0=T_t+\frac{M_t-M_{t-1}}{P_t} \tag{15}$$

Where, T denotes lump-sum transfer payments.

2.4. Budget Constraints

The budget constraint of the representative individual is set as

$$P_tB_t+M_t+E_tM_t^*=P_t(1+r_{t-1})B_{t-1}+M_{t-1}+E_tM_{t-1}^*+ p_t(z)y_t(z)-P_tC_t+P_tT_t \tag{16}$$

In equation (16), the consumer's revenue in period t include, returns from bonds $(P_t(1+r_{t-1})B_{t-1})$, home money balances (M_{t-1}) foreign money balances (M_{t-1}^*) during period $t-1$, the output revenue $(p_t(z)y_t(z))$ and the nominal transfer payment (P_tT_t) during period t. Subsequently, during period t, the consumer can put revenue into consumption (P_tC_t), bond expenditures (P_tB_t), and money holdings (M_t).

2.5. Aggregate Demand

From the equations (6) and (8), the demand for home good z ($y^d(z)$) can be expressed as,

$$y^d(z)=\frac{1}{2}c(z)+\frac{1}{2}c^*(z)=\frac{1}{2}\left[\frac{p(z)}{P}\right]^{-\theta}C+\frac{1}{2}\left[\frac{p^*(z)}{P^*}\right]^{-\theta}C^* \tag{17}$$

Similarly, from the equations (7) and (9), we have,

$$y^{*d}(z^*)=\frac{1}{2}c(z^*)+\frac{1}{2}c^*(z^*)=\frac{1}{2}\left[\frac{q(z^*)}{P}\right]^{-\theta}C+\frac{1}{2}\left[\frac{q^*(z^*)}{P^*}\right]^{-\theta}C^* \tag{18}$$

2.6. Currency Demand

The home currency demand function comprises home currency demand from both home and foreign agents, is defined by,

$$M_t=\frac{1}{2}M_t(h)+\frac{1}{2}M_t(f) \tag{19}$$

Similarly, the foreign currency demand function comprises foreign currency demand from both home and foreign agents, is given by,

$$M_t^*=\frac{1}{2}M_t^*(h)+\frac{1}{2}M_t^*(f) \tag{20}$$

Where, $M(h)$ represents the home demand for home currency, $M(f)$ is the foreign demand for home currency, $M^*(h)$ is the home demand for foreign currency, and $M^*(f)$ is the foreign demand for foreign currency.

2.7. First-Order Conditions

The first-order conditions for utility maximization problem are,

$$C_{t+1}=\beta(1+r_t)\cdot C_t \tag{21}$$

$$\frac{M_t(h)}{P_t}=\left(\frac{(1+i_t)\chi}{i_t}C_t\right)^{\frac{1}{\varepsilon}} \tag{22}$$

$$\frac{M_t^*(h)}{P_t}=\left(\frac{(1+i_t)\chi'}{E_ti_t}C_t\right)^{\frac{1}{\varepsilon}} \tag{23}$$

$$y_t(z)^{\frac{\theta+1}{\theta}}=\left(\frac{\theta-1}{k\theta}\right)(C_t^W)^{\frac{1}{\theta}}C_t^{-1} \tag{24}$$

Where, equation (21) is called the Euler equation for consumption; equations (22) and (23) are the home demands for home and foreign money that explain the substitution relationship between real money and consumption; and equation (24) is the labor supply equation that explains the substitution relationship between labor supply and consumption. In equation (24), C_t^W denotes the world consumption, and $C_t^W=(1/2)C_t+(1/2)C_t^*$.

2.8. Derivation of Equilibrium

To investigate the long-run effect of diversified currency holdings on exchange rate dynamics, we initially derive the long-run steady state of the two-country economy and set an initial state (0-steady state) as the baseline for comparison. Below, the variables without subscripts are used to present the variables in the long-run steady states. Conversely, variables with "0" subscripts denote the variables in 0-steady state. For example, C and C_0 denote consumption in the steady state and 0-steady states, respectively.

2.8.1. Derivation of steady state equilibrium

Long-run steady state explains that an economy enters a convergent state after experiencing shock. In the long-run steady state, all variables achieve consistency. Additionally, $C_{t+1}=C_t$ holds in the long-run steady state. Therefore, using the consumption Euler equation (equation 21), we can derive the real interest rate (r) in the long-run steady state is $\beta(1+r)=1$, that is

$$r=\frac{1-\beta}{\beta} \tag{25}$$

Equation (25) explains that the real interest rate depends on the discount rate in the long-run steady state.

By inserting government budget constraints equation (15) into private budget constraints equation (16) then gives,

$$C_t = (1+r_{t-1})B_{t-1} - B_t + \frac{p_t(z)y_t(z)}{P_t} \quad (26)$$

By a similar rationale, we have,

$$C_t^* = (1+r_{t-1}^*)B_{t-1}^* - B_t^* + \frac{q_t^*(z^*)y_t^*(z^*)}{P_t^*}$$

Using equation (14), we further have,

$$C_t^* = -(1+r_{t-1}^*)B_{t-1} + B_t + \frac{q_t^*(z^*)y_t^*(z^*)}{P_t^*} \quad (27)$$

Subsequently, in the long-run steady state, $B_{t+1} = B_t$ Therefore, equations (26) and (27) can be rewritten as,

$$C = rB + \frac{p(z)y(z)}{P} \quad (28)$$

$$C^* = -rB + \frac{q^*(z^*)y^*(z^*)}{P^*} \quad (29)$$

Equations (28) and (29) express the budget constraints of home and foreign individuals in the steady state.

2.8.2. 0-Steady state

The 0-steady state explains the initial state of the economy. Assuming that the international bond holdings by the home and foreign individuals are zero $(B_0 = B_0^* = 0)$, and diversified currency holdings behavior is not present. From the equation (28), we can deduce that the budget constraint in 0-steady state is,

$$C_0 = \frac{p_0(z)}{P_0} y_0(z) \quad (30)$$

Assuming that the economy achieves equilibrium in 0-steady state, then,

$$C_0 = y_0(z) \quad (31)$$

Subsequently, by inserting equation (31) into (30) yields,

$$P_0 = p_0(z) \quad (32)$$

By a similar rationale, we have,

$$C_0^* = y_0^*(z^*);\ P_0^* = q_0^*(z^*) \quad (33)$$

The law of one price and the theory of purchasing power parity (PPP) in 0-steady state are,

$$p_0(z) = E_0 p_0^*(z);\ P_0 = E_0 P_0^*$$

From equations (31) and (33), we can determine that the world demand in 0-steady state is,

$$C_0^W = \frac{1}{2}C_0 + \frac{1}{2}C_0^* = \frac{1}{2}y_0(z) + \frac{1}{2}y_0^*(z^*) \quad (34)$$

Subsequently, by inserting the equations (31), (33), and (34) into the equation (24), we can derive the goods market equilibrium in 0-steady state is,

$$[y_0(z)]^{\frac{2\theta+1}{\theta}} = \left(\frac{\theta-1}{k\theta}\right)\left[\frac{1}{2}y_0(z) + \frac{1}{2}y_0^*(z^*)\right]^{\frac{1}{\theta}} \quad (35)$$

Similarly, regarding foreign country, we have,

$$[y_0^*(z^*)]^{\frac{2\theta+1}{\theta}} = \left(\frac{\theta-1}{k\theta}\right)\left[\frac{1}{2}y_0(z) + \frac{1}{2}y_0^*(z^*)\right]^{\frac{1}{\theta}} \quad (36)$$

By comparing the equations (35) and (36), we further have,

$$y_0(z) = y_0^*(z^*)$$

Subsequently, by re-inserting the above results into equation (35), we can obtain the output level of home firm in 0-steady state as,

$$y_0(z) = \left(\frac{\theta-1}{k\theta}\right)^{\frac{1}{2}}$$

Similarly, we can further obtain,

$$y_0^*(z^*) = \left(\frac{\theta-1}{k\theta}\right)^{\frac{1}{2}}$$

By summarizing last two equations, we can determine the output and consumption in 0-steady state as,

$$y_0(z) = y_0^*(z^*) = \left(\frac{\theta-1}{k\theta}\right)^{\frac{1}{2}} = C_0 = C_0^* = C_0^W \quad (37)$$

Equation (37) shows that output and consumption in 0-steady state are equivalent for home and foreign countries.

In 0-steady state, nominal and real interest rates are equal. Based on the real interest rates in the long-run steady state equation (25), we can obtain the nominal and real interest rates in 0-steady state are,

$$i_0 = r_0 = \frac{1-\beta}{\beta}$$

From the equations (22) and (31), we can solve the equilibrium of the home money market is,

$$\frac{M_0}{P_0} = \left(\frac{\chi}{1-\beta}y_0(z)\right)^{\frac{1}{\varepsilon}}$$

Similarly, regarding foreign country, we have,

$$\frac{M_0^*}{P_0^*} = \left(\frac{\chi}{1-\beta}y_0^*(z^*)\right)^{\frac{1}{\mu}}$$

By combining the two preceding equations, and further applying $y_0(z) = y_0^*(z^*)$, we can know that the money demand function in 0-steady state is,

$$\frac{M_0}{P_0} = \frac{M_0^*}{P_0^*} = \left(\frac{\chi}{1-\beta}y_0(z)\right)^{\frac{1}{\varepsilon}}$$

Subsequently, by inserting PPP in 0-steady state into the last equation, we can further find that the nominal interest rate in 0-steady state is,

$$E_0 = \frac{M_0}{M_0^*}$$

2.8.3. Log-linearization

Log-linearization is adopted to obtain closed form solutions for our model. Below, we log-linearize the variables around 0-steady state to determine their volatility. We use a "^" superscript to denote the variable values after log-linearization. For example, $\hat{X}_t$ is the result of X_t log-linearized around X_0. Therefore,

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

By applying the equations (5), (10) and (11), and employing log-linearization around 0-steady state, we have

$$\hat{P}_t = \frac{1}{2}\hat{p}_t(z) + \frac{1}{2}\left[\hat{E}_t + \hat{q}_t^*(z^*)\right] \quad (38)$$

$$\hat{P}_t^* = \frac{1}{2}\left[\hat{p}_t(z) - \hat{E}_t\right] + \frac{1}{2}\hat{q}_t^*(z^*) \quad (39)$$

Subsequently, by deducting equation (39) from (38), we then have

$$\hat{P}_t - \hat{P}_t^* = \hat{E}_t \quad (40)$$

Equation (40) is the PPP after log-linearization.

From the equations (26) and (27), we can express the equation of world consumption as

$$C_t^W = \frac{1}{2}C_t + \frac{1}{2}C_t^* = \frac{1}{2}\cdot\frac{p_t(z)y_t(z)}{P_t} + \frac{1}{2}\cdot\frac{q_t^*(z^*)y_t^*(z^*)}{P_t^*}$$

Subsequently, using log-linearization around 0-steady state, we can further determine that

$$\hat{C}_t^W = \frac{1}{2}\left[\hat{p}_t(z) + \hat{y}_t(z) - \hat{P}_t\right] + \frac{1}{2}\left[\hat{q}_t^*(z^*) + \hat{y}_t^*(z^*) - \hat{P}_t^*\right] \quad (41)$$

By log-linearizing the equations (17) and (18) around 0-steady state, and applying the equation (5), the equations (38) and (39) can be organized as,

$$\hat{y}_t(z) = \theta[\hat{P}_t - \hat{p}_t(z)] + \hat{C}_t^W \quad (42)$$

Similarly, regarding foreign country, we have,

$$\hat{y}_t^*(z^*) = \theta[\hat{P}_t^* - \hat{q}_t^*(z^*)] + \hat{C}_t^W \quad (43)$$

By log-linearizing the equation (24) around 0-steady state yields,

$$(1+\theta)\hat{y}_t(z) = -\theta\hat{C}_t + \hat{C}_t^W \quad (44)$$

By a similar rationale, we have,

$$(1+\theta)\hat{y}_t^*(z^*) = -\theta\hat{C}_t^* + \hat{C}_t^W \quad (45)$$

Further, by log-linearizing the equation (21) around 0-steady state, we can get,

$$\hat{C}_{t+1} = \hat{C}_t + (1-\beta)\hat{r}_t \quad (46)$$

With a similar equation derived for foreign country, we have,

$$\hat{C}_{t+1}^* = \hat{C}_t^* + (1-\beta)\hat{r}_t \quad (47)$$

By log-linearizing the equation (22) around 0-steady state, this produces,

$$\hat{M}_t(h) - \hat{P}_t = \frac{1}{\varepsilon}\left[\hat{C}_t - \beta\left(\hat{r}_t + \frac{\hat{P}_{t+1} - \hat{P}_t}{1-\beta}\right)\right] \quad (48)$$

A similar equation derived for foreign country is,

$$\hat{M}_t^*(f) - \hat{P}_t^* = \frac{1}{\varepsilon}\left[\hat{C}_t^* - \beta\left(\hat{r}_t + \frac{\hat{P}_{t+1}^* - \hat{P}_t^*}{1-\beta}\right)\right] \quad (49)$$

By log-linearizing the equation (23) around 0-steady state, we have,

$$\hat{M}_t^*(h) - \hat{P}_t = \frac{1}{\varepsilon}\left[\hat{C}_t - \beta\left(\hat{r}_t + \frac{\hat{P}_{t+1} - \hat{P}_t}{1-\beta}\right) - \frac{1}{1-\beta}\left(\hat{E}_t - \beta\hat{E}_{t+1}\right)\right] \quad (50)$$

By a similar rationale, we then have,

$$\hat{M}_t(f) - \hat{P}_t^* = \frac{1}{\varepsilon}\left[\hat{C}_t^* - \beta\left(\hat{r}_t + \frac{\hat{P}_{t+1}^* - \hat{P}_t^*}{1-\beta}\right) + \frac{1}{1-\beta}\left(\hat{E}_t - \beta\hat{E}_{t+1}\right)\right] \quad (51)$$

Through log-linearization equation (19) yields,

$$\hat{M}_t = \frac{\chi}{\chi + \chi'}\hat{M}_t(h) + \frac{\chi'}{\chi + \chi'}\hat{M}_t(f)$$

If $\eta = \frac{\chi}{\chi'}$, the previous equation can be rewritten as,

$$\hat{M}_t = \frac{\eta}{1+\eta}\hat{M}_t(h) + \frac{1}{1+\eta}\hat{M}_t(f) \quad (52)$$

In this equation, η denotes the level of diversified currency holdings. η > 1 (i.e., $\chi > \chi'$) indicates that home individual prefer home currency holdings.

By inserting equations (48) and (51) into equation (52), we obtain,

$$\hat{M}_t = \frac{\eta}{1+\eta}\left\{\frac{1}{\varepsilon}\left[\hat{C}_t - \beta\left(\hat{r}_t + \frac{\hat{P}_{t+1} - \hat{P}_t}{1-\beta}\right)\right] + \hat{P}_t\right\} + \frac{1}{1+\eta}\left\{\frac{1}{\varepsilon}\left[\hat{C}_t^* - \beta\left(\hat{r}_t + \frac{\hat{P}_{t+1}^* - \hat{P}_t^*}{1-\beta}\right) + \frac{1}{1-\beta}\left(\hat{E}_t - \beta\hat{E}_{t+1}\right)\right] + \hat{P}_t^*\right\} \quad (53)$$

With a similar equation derived for foreign country, we have,

$$\hat{M}_t^* = \frac{1}{1+\eta}\left\{\frac{1}{\varepsilon}\left[\hat{C}_t - \beta\left(\hat{r}_t + \frac{\hat{P}_{t+1} - \hat{P}_t}{1-\beta}\right) - \frac{1}{1-\beta}\left(\hat{E}_t - \beta\hat{E}_{t+1}\right)\right] + \hat{P}_t\right\} + \frac{\eta}{1+\eta}\left\{\frac{1}{\varepsilon}\left[\hat{C}_t^* - \beta\left(\hat{r}_t + \frac{\hat{P}_{t+1}^* - \hat{P}_t^*}{1-\beta}\right)\right] + \hat{P}_t^*\right\} \quad (54)$$

Additionally, log-linearized versions of equations (28) and (29) can be expressed as,

$$\hat{C} = r\hat{B} + \hat{p}(z) + \hat{y}(z) - \hat{P} \quad (55)$$

$$\hat{C}^* = -r\hat{B} + \hat{q}^*(z^*) + \hat{y}^*(z^*) - \hat{P}^* \quad (56)$$

3. FLEXIBLE AND STICKY PRICE EQUILIBRIUM

3.1. Flexible Price Equilibrium

In the following analysis, to categorize and differentiate the economic variables between short- and long-run, we use a "*t*" subscript to denote the variables in the short-run, and no subscript for the variable in the long-run. For example, $\hat{C}$ and $\hat{C}_t$ denote consumption variation in the long-run and short-run, respectively.

Deducting equation (43) from (42), the result is that,

$$\hat{y}(z) - \hat{y}^*(z^*) = \theta[\hat{E} - \hat{p}(z) + \hat{q}^*(z^*)] \quad (57)$$

Subtracting equation (45) from (44) results in,

$$\hat{y}(z) - \hat{y}^*(z^*) = -\frac{\theta}{1+\theta}\left(\hat{C} - \hat{C}^*\right) \quad (58)$$

Then subtracting equation (56) from (55) yields,

$$\hat{C} - \hat{C}^* = 2r\hat{B} + \hat{y}(z) - \hat{y}^*(z^*) - [\hat{E} - \hat{p}(z) + \hat{q}^*(z^*)] \quad (59)$$

Subsequently, insertion of equations (57) and (58) into equation (59), we can further obtain,

$$\hat{C} - \hat{C}^* = \left(\frac{1+\theta}{\theta}\right) r\hat{B} \quad (60)$$

The equations (53) and (54) can be rewritten as,

$$\hat{M} = \frac{\eta}{1+\eta}\left[\frac{1}{\varepsilon}\left(\hat{C} + \hat{P}\right)\right] + \frac{1}{1+\eta}\left[\frac{1}{\varepsilon}\left(\hat{C}^* + \hat{E} + \hat{P}^*\right)\right] \quad (61)$$

$$\hat{M}^* = \frac{1}{1+\eta}\left[\frac{1}{\varepsilon}\left(\hat{C} - \hat{E} + \hat{P}\right)\right] + \frac{\eta}{1+\eta}\left[\frac{1}{\varepsilon}\left(\hat{C}^* + \hat{P}^*\right)\right] \quad (62)$$

By subtracting these above two equations, and applying equation (4), we can organize and determine the following:

$$\hat{E} = \hat{M} - \hat{M}^* - \frac{1}{\varepsilon}\left(\frac{\eta-1}{\eta+1}\right)\left(\hat{C} - \hat{C}^*\right) \quad (63)$$

From equation (63), we can see that when the home country's consumption increases by 1 unit, home individuals' money demand does not also increase by 1 unit because of the existence of diversified currency holdings, hence the exchange rate does not increase by 1 unit. Instead, money portfolio is distributed between home and foreign money according to the level of diversified currency holdings (η), consequently limiting appreciation of the home currency.

3.2. Sticky Price Equilibrium

Assuming that the prices are fixed for period *t*, the prices of home and foreign goods are fixed according to the pricing established by producers in period *t*−1. Because prices are fixed in the short-run, prices cannot be adjusted in period *t*; that is, $\hat{p}(z) = \hat{q}^*(z^*) = 0$. However, after period t, prices can again be altered freely.

Deducting equation (54) from (53), the result is that,

$$\hat{M}_t - \hat{M}_t^* = \frac{1}{\varepsilon}\left(\frac{\eta-1}{\eta+1}\right)\left(\hat{C}_t - \hat{C}_t^*\right) - \frac{\beta}{1-\beta}\left[\hat{E}_{t+1} - \left(\frac{\eta-1}{\eta+1}\hat{E}_t\right)\right] \quad (64)$$

Subtracting equation (47) from (46) results in,

$$\hat{C} - \hat{C}^* = \hat{C}_t - \hat{C}_t^* \quad (65)$$

Insertion of equation (65) into (63) yields,

$$\hat{E} = \hat{M} - \hat{M}^* - \frac{1}{\varepsilon}\left(\frac{\eta-1}{\eta+1}\right)\left(\hat{C}_t - \hat{C}_t^*\right) \quad (66)$$

Subsequently, assuming that monetary shock is permanent, that is,

$$\hat{M} - \hat{M}^* = \hat{M}_t - \hat{M}_t^* \quad (67)$$

By inserting equation (67) into (66), and further re-inserting to equation (64), then gives exchange rate volatility in the short-run:

$$\hat{E}_t = \frac{1}{1-\beta(1-\psi)}\left(\hat{M}_t - \hat{M}_t^*\right) - \frac{1}{\varepsilon}\left(\frac{\psi}{1-\beta\left(1-\psi\right)}\right)\left(\hat{C}_t - \hat{C}_t^*\right) \quad (68)$$

In this equation, $\Psi = (\eta-1)/(\eta+1)$, and $\eta > 1$. Therefore, $0 < \Psi < 1$. Both η and Ψ can be explained as the level of home currency preference, where high values of η and Ψ denote that individuals have high preferences for home currency.

Comparing equations (66) and (68), we obtain,

$$\hat{E} = \left[1 - \beta(1-\psi)\right]\hat{E}_t \quad (69)$$

From equation (69), we can find that short-run exchange volatility exceeds long-run exchange volatility, resulting in overshooting. And, the extent of overshooting depends on the level of the discount factors and diversified currency holdings. That is, the greater the discount rate (β), the greater the extent of overshooting. Furthermore, the higher the preferences for foreign currency (the smaller the Ψ), the greater the extent of overshooting. However, without diversified currency holdings (Ψ=1) short-run exchange rates immediately return to the long-run equilibrium, and overshooting does not occur. This implies that in the long-run, increases in home money supply cause home money to depreciate, and that overshooting caused by home expansionary monetary policy depends on whether short-run diversified currency holdings are present. Without diversified currency holdings, the magnitude of short-run home money depreciation corresponds to the magnitude of long-run depreciation and overshooting does not occur. Conversely, with diversified currency holdings, depreciation leads to an increase in home individual foreign money demand and a decrease in home money demand. This scenario causes the extent of short-run money depreciation to exceed long-run depreciation and induces overshooting. The greater the preference for foreign currency by home individuals, the greater the extent of overshooting. In addition, current account plays an important role in exchange rate transmission. The increase in home money supply simulates home consumption through current account improvements, and subsequently induces an increase in exchange rates.

From these derivational results, we present a transmission mechanism to explain the role of diversified currency holdings on overshooting. We find that overshooting is not caused by differences between asset market and product market prices; instead, it is triggered by diversified currency holdings. The transmission channels can be explained in the subsequent two stages. In the first stage, home money supply expansion simulates home consumption by improving current account. This causes an increase in money demand and stimulates exchange rate appreciation. In the second stage, home exchange rate appreciation causes an increase in foreign individual home money demand when diversified currency holdings are present, which further enhances money appreciation. From these two explanatory stages, we can understand the role of diversified currency holdings in overshooting. However, if the effects of diversified currency holdings are considered during the first stage, the exchange rate appreciation will be suppressed, reducing the effects of the second stage.

4. WELFARE ANALYSIS

The utility function comprises consumption, home real money balances, foreign real money balances, and output. Therefore, utility function can be expressed as

$$u_t = u_t^C + u_t^M + u_t^{M^*} + u_t^y \tag{70}$$

Where,

$$u_t^C = \sum_{j=0}^{\infty} \beta^j \ln(C_{t+j}) \quad , \quad u_t^M = \frac{\chi}{1-\varepsilon}\sum_{j=0}^{\infty}\beta^j\left(\frac{M_{t+j}}{P_{t+j}}\right)^{1-\mu} ,$$

$$u_t^{M^*} = \frac{\chi'}{1-\varepsilon}\sum_{j=0}^{\infty}\beta^j\left(\frac{M_{t+j}^*}{P_{t+j}}\right)^{1-\mu}, \text{ and } u_t^y = -\frac{k}{2}\sum_{j=0}^{\infty}\beta^j y_{t+j}^2 .$$

We adopt the settings used by Obstfeld and Rogoff (1995); He (2002), and did not consider the effects that real money balances on the welfare level of a country. Thus, in the following, we only consider and analyze the effects of diversified currency holdings on consumption and output.

4.1. Consumption

According to the utility function, the utility for consumption without diversified currency holdings is,

$$u_{t-1}^C = \ln(C_0) + \frac{\beta}{1-\beta}\ln(C_0)$$

With individuals present diversified currency holdings, the utility for consumption becomes,

$$u_t^C = \ln(C_t) + \frac{\beta}{1-\beta}\ln(C)$$

From these equations, we can determine that diversified currency holdings lead to changes in consumption, which causes changes in utility. The magnitude of utility changes can be expressed as,

$$\Delta u_t^C = \hat{C}_t + \frac{\beta}{1-\beta}\hat{C} \tag{71}$$

4.2. Output

Using the same analytical method, the disutility of output without diversified currency holdings can be expressed as,

$$u_{t-1}^y = \frac{-k}{2}\left[y_0^2 + \frac{\beta}{1-\beta}y_0^2\right]$$

After consider diversified currency holdings, the utility for output becomes,

$$u_t^y = \frac{-k}{2}\left[y_t^2 + \frac{\beta}{1-\beta}y^2\right]$$

From these equations, we can determine that diversified currency holdings result in output (labor) changes. The magnitude of utility changes can be expressed as,

$$\Delta u_t^y = \frac{-k}{2}\left[(y_t^2 - y_0^2) + \frac{\beta}{1-\beta}(y^2 - y_0^2)\right]$$

By adopting a first-order Taylor series similar to $y_t^2 = y_0^2 + 2y_0(y_t - y_0)$, we obtain,

$$\Delta u_t^y = -k\left[y_0^2\hat{y}_t + \frac{\beta}{1-\beta}(y_0^2\hat{y})\right] \tag{72}$$

In equation (72), $\hat{y}_t = \frac{y_t - y_0}{y_0}$ and $\hat{y} = \frac{y - y_0}{y_0}$.

By inserting the equation (37) into (72), we can determine that,

$$\Delta u_t^y = -\left(\frac{\theta-1}{\theta}\right)\left(\hat{y}_t + \frac{\beta}{1-\beta}\hat{y}\right) \tag{73}$$

Furthermore, we combine equation (71) with (73) results in,

$$\Delta u_t^C + \Delta u_t^y = \hat{C}_t - \left(\frac{\theta-1}{\theta}\right)\hat{y}_t + \frac{\beta}{1-\beta}\left(\hat{C} - \frac{\theta-1}{\theta}\hat{y}\right) \tag{74}$$

Inserting the obtained consumption and output level in the short- and long-run (see Appendix, Eqs. (A23), (A24), (A28) and (A29)) into equation (74), we obtain,

$$\Delta u_t^C + \Delta u_t^y = \left(\frac{\beta + \varepsilon(1-\beta)}{\theta}\right)\hat{M}_t^W +$$

$$\frac{1}{2}\left(\frac{\beta(1-\psi)}{1-\beta(1-\psi)}\right)\left[(1-\beta(1-\psi))A + \psi\right]^{-1}\left(\hat{M}_t - \hat{M}_t^*\right) \tag{75}$$

From equation (75), we can find that the home expansionary monetary policy increases home welfare. However, the effect of foreign expansionary monetary policy on home welfare is ambiguous. With diversified currency holdings ($0 < \Psi < 1$), foreign expansionary monetary policy has an enhanced effect on home welfare when the elasticity of substitution between home and foreign goods (θ) is <2. Conversely, foreign expansionary monetary policy reduces home welfare when the elasticity of substitution between home and foreign goods (θ) is >2. In addition, without diversified currency holdings ($\Psi = 1$), home welfare will increase despite home or foreign expansionary monetary policy.

An increase in home money supply causes home currency to depreciate. Diversified currency holdings exacerbate the extent of home currency depreciation, increase the home consumption and welfare. Conversely, an increase in foreign money supply causes home currency to appreciate. Diversified currency holdings enhance the appreciation of home money and reduce the consumption and output of the home country. Under this condition, when the price elasticity of demand (θ) is <2, the decline in home consumption caused by goods price changes due to home currency appreciation is mitigated, and the potential increase in home welfare. Conversely, when the price elasticity of demand (θ) is >2, the decline in home consumption caused by home currency appreciation is enhanced, and the potential reduction of home welfare.

The transmission mechanism of the effects of home expansionary monetary policy on welfare can be addressed in two dimensions, specifically, consumption and output. Regarding consumption, home consumption is stimulated when the increase in home money supply results in depreciation, and welfare increases. Conversely, home consumption decreases when the expansion of foreign money supply results in appreciation, and welfare decreases. In addition, with diversified currency holdings, the extent of welfare changes increases. Regarding output, the expansion of home money supply increases home consumption and stimulates an increase in home output, although the magnitude is reduced because of the characteristics of short-run price-stickiness. That is, the welfare reduction effects are mitigated. Conversely, the expansion of foreign money supply that reduces the home output, and induces an increase in welfare. The magnitude of this increase depends on the price elasticity of demand. When the price elasticity of demand (θ) is <2, the decline in home output caused by price changes due to home money appreciation is greater, and the increase in welfare is enhanced. However, when the price elasticity of demand (θ) is >2, the decline in home output caused by price changes due to home money appreciation is smaller, and the increase in welfare is reduced. By offsetting the consumption and output dimensions, we find that home expansionary monetary policy increased home welfare, whereas the effect of foreign expansionary monetary policy on home welfare was ambiguous.

5. CONCLUSIONS AND SUGGESTIONS

To compensate for the role of current account in exchange rate volatility not being included in discussions and the lack of micro-foundations in extant exchange rate dynamics literature, we investigated the effects of diversified currency holdings on exchange rate dynamics and welfare under the NOEM framework with the introduction of micro-foundations and the role of current account. The original model proposed by Dornbusch (1976) used an "*ad hoc*" setting to investigate the effects of money shocks on exchange rate dynamics and the findings indicated that overshooting occurs when asset markets adjust fast relative to goods markets to a permanent monetary shock. This paper is different from the research of Dornbusch (1976), we adopted the NOEM model as the theoretical basis. Not only can welfare analysis be conducted through our model to obtain more complete analysis, but the role of current account in exchange rate transmissions can also be considered to address the gap in extant literature. We found that overshooting is not caused by differences on adjustment speeds between goods and asset markets, but is instead triggered by diversified currency holdings.

Previously, He (2002) and Corrado (2008) applied the NOEM framework to investigate the effects of diversified currency holdings and currency substitution. He (2002) contended that the existence of currency substitution weakens the effects of international transmissions of home monetary supply shock, and the effects on welfare depended on the country size and the elasticity of substitution. Additionally, Corrado (2008) indicated that increasing foreign currency holdings can mitigate inflation risks, stimulate consumption, and influence money demands. Furthermore, increased foreign currency holdings cause exchange rate volatility, and the magnitude of exchange rate volatility depends on the degree of currency substitution. Although these two studies integrated diversified currency holdings and currency substitution into the NOEM model, the role of diversified currency holdings in exchange rate dynamics was not clearly explained and lacked detailed derivation and explanation regarding exchange rate dynamics and welfare analysis. In this study, we extend the framework established by He (2002) to investigate the effect of individuals' imperfect preferences toward home and foreign currencies on exchange rate dynamics. Subsequently, in order to find the closed form solutions, we adopted the two countries of equal size setting. This assumption does not analyze the role of country scale, but can be used to obtain closed form solutions more easily compared to the model proposed by Corrado (2008).

This paper indicates that exchange rate overshooting occurs when diversified currency holdings are included in the NOEM model, and the extent is determined by the degree of currency preferences. If diversified currency holdings are not incorporated, the magnitude of short-run home money depreciation is consistent with long-run depreciation, and overshooting does not occur, return to the conclusion drawn by traditional NOEM model. If individuals present diversified currency holdings behavior, the home currency depreciation will increase home individuals' foreign currency demand and reduce home currency demand, and further enhances the effects of depreciation, which increases the short-run depreciation of the home currency and causes overshooting, and the higher the home individuals' foreign currency preferences, the greater the extent of overshooting. Regarding welfare analysis, we find that home expansionary monetary policy increases home welfare, whereas the effect of foreign expansionary monetary policy on home welfare is ambiguous. With diversified currency holdings, foreign expansionary monetary policy only has an elevated effect on welfare when the elasticity of substitution for home and foreign goods is <2. Conversely, foreign expansionary monetary policy reduces home welfare when the elasticity of substitution for home and foreign goods is >2. In addition, without the occurrence of diversified currency holdings, home welfare increases despite home or foreign expansionary monetary policy. Furthermore, overshooting transmission channels can be explained in the subsequent two stages. In the first stage, home money supply expansion simulates home consumption through current account improvements. This subsequently increases money demand and generates exchange rate appreciation. In the second stage, home exchange rate appreciation increases foreign individuals' home money demand when diversified currency holdings behavior exists, which further increase the extent of currency appreciation.

Although this paper achieved interesting results and addressed gaps in extant literature, the following limitations and inadequacies were present: (1) For the convenience of analysis, we adopted the two-country with equal size setting in our model. This setting uses strong assumptions for the basis of analysis, that country scale asymmetry analysis had to be eliminated from this study, (2) we ignored the analysis of the cost of foreign currency holdings, (3) the NOEM model we used in this paper involved many parameters and variables result in complexity in our analysis. Although we examined the role of current account regarding the effects of diversified currency holdings on exchange rate dynamics transmission processes, we focused only on explaining the transmission mechanism between single variables, which was not completed. The likelihood that transmissions of various endogenous variables have interlocking effects and interactive complexities is high; thus, to providing a complete explanation would be extremely difficult. Finally, by expanding the settings for elasticity of substitution between home and foreign goods and including issues such as capital mobility and government consumption spending in our model can be considered the objectives for future research.

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APPENDIX

Using equations (41), (42), (43), (44), (45), (55) and (56) to solve $\hat{C}$, $\hat{C}^*$, $\hat{C}^W$, $\hat{y}(z)$, $\hat{y}^*(z^*)$, $\hat{p}(z)-\hat{P}$, and $\hat{q}^*(z^*)-\hat{P}^*$, the result is that,

$$\hat{C}=\frac{1+\theta}{2\theta}r\hat{B} \tag{A1}$$

$$\hat{C}^*=-\frac{1+\theta}{2\theta}r\hat{B} \tag{A2}$$

$$\hat{C}^W=0 \tag{A3}$$

$$\hat{y}(z)=-\frac{1}{1+\theta}\hat{C} \tag{A4}$$

$$\hat{y}^*(z^*)=-\frac{1}{1+\theta}\hat{C}^* \tag{A5}$$

$$\hat{p}(z)-\hat{P}=\frac{1}{2\theta}r\hat{B} \tag{A6}$$

$$\hat{q}^*(z^*)-\hat{P}^*=-\frac{1}{2\theta}r\hat{B} \qquad \text{A7)}$$

1. Derivation of consumption and output in the short-run

Based on equations (38) and (39), the home and foreign price indices in the short-run could be expressed as

$$\hat{P}_t=\frac{1}{2}\hat{E}_t \tag{A8}$$

$$\hat{P}_t^*=-\frac{1}{2}\hat{E}_t \tag{A9}$$

Applying budget constraints equations (55) and (56) with short-run price indices equations (A8) and (A9), the current account response in the short-run is

$$\hat{B}_t=\hat{y}_t(z)-\frac{1}{2}\hat{E}_t-\hat{C}_t \tag{A10}$$

Regarding the foreign country, the current account response in the short-run can be expressed as

$$\hat{B}_t^*=\hat{y}_t^*(z^*)+\frac{1}{2}\hat{E}_t-\hat{C}_t^*=-\hat{B}_t \tag{A11}$$

Deducting equations (A11) from (A10), we can obtain

$$\hat{B}_t=\frac{1}{2}\left[\left(\hat{y}_t(z)-\hat{y}_t^*(z^*)\right)-\left(\hat{C}_t-\hat{C}_t^*\right)-\hat{E}_t\right] \tag{A12}$$

In the short-run, equation (57) can be rewritten as

$$\hat{y}_t(z)-\hat{y}_t^*(z^*)=\theta\hat{E} \tag{A13}$$

Inserting equations (A13) and (60) into equation (A12) produces

$$\hat{E}_t=\left[\frac{\beta}{1-\beta}\frac{2\theta}{\left(\theta^2-1\right)}+\frac{1}{\theta-1}\right]\left(\hat{C}_t-\hat{C}_t^*\right) \tag{A14}$$

Using the coupled method to solve equations (68) and (A14), we obtain

$$\hat{E}_t=\left[(1-\beta(1-\psi))+\frac{\psi}{A}\right]^{-1}\left(\hat{M}_t-\hat{M}_t^*\right) \tag{A15}$$

$$\hat{C}_t - \hat{C}_t^* = \left[\left(1-\beta(1-\psi)\right)A + \psi\right]^{-1}\left(\hat{M}_t - \hat{M}_t^*\right) \tag{A16}$$

Where, $A = \frac{\beta}{1-\beta}\frac{2\theta}{(\theta^2-1)} + \frac{1}{\theta-1}$.

Inserting equation (A15) into (A13), we further have

$$\hat{y}_t(z) - \hat{y}_t^*(z^*) = \theta\left[\left(1-\beta(1-\psi)\right) + \frac{\psi}{A}\right]^{-1}\left(\hat{M}_t - \hat{M}_t^*\right) \tag{A17}$$

Insertion of equations (A15), (A16), and (A17) into equation (A12), we obtain

$$\hat{B} = \left[\left(1-\beta(1-\psi)\right)A + \psi\right]^{-1} \cdot \frac{\beta}{1-\beta}\frac{\theta}{(\theta+1)}\left(\hat{M}_t - \hat{M}_t^*\right) \tag{A18}$$

Short-run changes in the world consumption can be determined by re-combining the long-run steady state changes in world consumption equation (A3) with short-run changes in consumption equations (46) and (47).

$$\hat{C}_t^W = -(1-\beta)\hat{r}_t \tag{A19}$$

By determining the weighted average of equations (53) and (54), we have

$$\hat{M}_t^W = \hat{C}_t^W - \beta\hat{r} - \frac{\beta}{1-\beta}\hat{M}_t^W \tag{A20}$$

By comparing equations (A19) and (A20), and applying world goods market equilibrium, we have

$$\hat{M}_t^W = \hat{C}_t^W = \hat{y}_t^W(z) \tag{A21}$$

From equations (A12) and (A13), we further obtain

$$\hat{y}(z) = \hat{M}_t^W + \frac{\theta}{2}\hat{E}_t \tag{A22}$$

Inserting equation (A15) into (A22), then yields

$$\hat{y}_t(z) = \frac{1}{2}\left\{1+\theta\left[\left(1-\beta(1-\psi)\right)+\frac{\psi}{A}\right]^{-1}\right\}\hat{M}_t + \frac{1}{2}\left\{1-\theta\left[\left(1-\beta(1-\psi)\right)+\frac{\psi}{A}\right]^{-1}\right\}\hat{M}_t^* \tag{A23}$$

Combining equations (A16) and (A21), we have

$$\hat{C}_t(z) = \frac{1}{2}\left\{1+\left[\left(1-\beta(1-\psi)\right)A+\psi\right]^{-1}\right\}\hat{M}_t + \frac{1}{2}\left\{1-\theta\left[\left(1-\beta(1-\psi)\right)A+\psi\right]^{-1}\right\}\hat{M}_t^* \tag{A24}$$

2. Derivation of Consumption and Output in the Long-run

From equations (48) and (51), we can get the price index in the long-run as

$$\hat{P} = \hat{M} - \frac{1}{\varepsilon}\hat{C} \tag{A25}$$

$$\hat{P}^* = \hat{M}^* - \frac{1}{\varepsilon}\hat{C}^* \tag{A26}$$

By re-inputting short-run prices equations (A8) and (A9) and long-run prices equations (A25) and (A26) into the log-linearized consumption demand equations equations (48) and (51), calculating the weighted average, and applying equation (A19), we obtain

$$\hat{r}_t = -\left(\varepsilon + \frac{\beta}{1-\beta}\right)\hat{M}_t^W \tag{A27}$$

By re-inserting equations (A27) and (A18) into equations (A1) and (A4), we can solve the consumption and output in the long-run as

$$\hat{C} = -\left(\varepsilon + \frac{\beta}{1-\beta}\right)\hat{M}_t^W + \frac{1}{2}\frac{\beta}{1-\beta}\left[\left(1-\beta(1-\psi)\right)A+\psi\right]^{-1}\left(\hat{M}_t - \hat{M}_t^*\right) \tag{A28}$$

$$\hat{y}(z) = \frac{1}{1+\theta}\left(\varepsilon + \frac{\beta}{1-\beta}\right)\hat{M}_t^W - \frac{1}{2(1+\theta)}\frac{\beta}{1-\beta}\left[\left(1-\beta(1-\psi)\right)A+\psi\right]^{-1}\left(\hat{M}_t - \hat{M}_t^*\right) \tag{A29}$$