Mikael Bask

Exchange rate volatility without the contrivance of fundamentals and the failure of PPP

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Bank of Finland Research
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8 • 2006

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An earlier version of this paper has benefited from a presentation at a seminar at the Bank of Finland. Of cource, the usual disclaimer applies.

http://www.bof.fi

ISBN 952-462-274-2
ISSN 0785-3572
(print)

ISBN 952-462-275-0
ISSN 1456-6184
(online)

Helsinki 2006

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Bank of Finland Research
Discussion Papers 8/2006

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Abstract

Since the magnitude of exchange rate overshooting may not be the same for different exchange rates of a currency, a monetary expansion or contraction in, for example, the EMU, will affect the exchange rate between the U.S. dollar and the yen, even though there are no changes in monetary fundamentals in the U.S. or Japan. This fact is demonstrated in a sticky-price monetary model due originally to Dornbusch (1976) that is enlarged with currency traders that use Chartism in the form of moving averages. It is also demonstrated that purchasing power parity (PPP) does not necessarily hold in long-run equilibrium. These results are interesting since, according to the empirical literature, there are often large movements in nominal exchange rates that are apparently unexplained by macroeconomic fundamentals, and there is also a weak support for PPP.

Key words: Chartism, foreign exchange, macroeconomic fundamentals, moving averages, overshooting and PPP

JEL classification numbers: F31, F41

Nimellisen valuuttakurssin vaihtelut, talouden perustekijät ja poikkeamat ostovoimapariteetista

Suomen Pankin tutkimus
Keskustelualoitteita 8/2006

Mikael Bask
Rahapolitiikka- ja tutkimusosasto

Tiivistelmä

Tässä tutkimuksessa osoitetaan teoreettisesti, että esimerkiksi rahapolitiikan keventäminen tai kiristäminen euroalueella vaikuttaa vaihtelevasti euron dollari- ja jenikurssiin ilman, että Yhdysvaltain tai Japanin rahataloudelliset perustekijät olisivat muuttuneet. Tätä yksittäisen valuutan eri valuuttakurssien vaihtelevassa määrin toteutuvaa yliampumista tarkastellaan Dornbuschin (1976) hitaasti sopeutuvan hintason teknisellä kaupankäynnillä täydennetyssä monetaarisessa valuuttakurssimallissa. Tarkasteluissa osoitetaan myös, että ostovoimapariteetti ei ole voimassa kansantalouden pitkän aikavälin tasapainossa. Tulokset ovat mielenkiintoisia kahdessa suhteessa: empiirisen evidenssin mukaan kansantalouden reaali- ja rahataloudelliset perustekijät eivät nähtävästi selitä nimellisen valuuttakurssin suuria havaittuja vaihteluita ja ostovoimapariteetille löytyy vain vähän tukea kansantalouden tilastoista.

Avainsanat: chartismi, ulkomaanvaluutta, kokonaistaloudelliset perustekijät, liukuva keskiarvo, yliampuminen, ostovoimapariteetti

JEL-luokittelu: F31, F41

Contents

1 Introduction

That chartism is used extensively in currency trade is confirmed in several questionnaire surveys made at currency markets around the world. Examples include Cheung and Chinn (2001), who conducted a survey at the U.S. market; Lui and Mole (1998), who conducted a survey at the Hong Kong market; Menkhoff (1997), who conducted a survey at the German market; Oberlechner (2001), who conducted a survey at the markets in Frankfurt, London, Vienna and Zurich; and Taylor and Allen (1992), who conducted a survey at the London market.[1] According to the surveys, the relative importance of technical versus fundamental analysis in the currency market depends on the time horizon in currency trade. For shorter time horizons, more weight is placed on chartism, while more weight is placed on fundamental analysis for longer horizons. Thus, during periods of time when currency trade is more short-sighted, trade in foreign exchange is mostly determined by other factors than the economies' macroeconomic performance.

Chartism utilizes past exchange rates to detect patterns that are extrapolated into the future. Focusing on past exchange rates is not considered as a shortcoming for traders using any of these techniques since a primary assumption behind technical analysis is that all relevant information about future exchange rate movements is contained in past movements. Thus, chartism is purely behavioristic in nature and does not examine the underlying reasons of currency traders. According to Lui and Mole (1998) and Taylor and Allen (1992), the most commonly used technical trading technique is moving averages in which buying and selling signals are generated by two moving averages; a short-period moving average and a long-period moving average, where a buy (sell) signal is generated when the short-period moving average of past exchange rates rises above (falls below) the long-period moving average of past rates.

The purpose of this paper is to implement the aforementioned observations theoretically, where the baseline model used in fundamental analysis is a sticky-price monetary model due originally to Dornbusch (1976). This model is enlarged with currency traders using moving averages as the technical trading technique, and the relative importance of technical versus fundamental analysis in the currency market depends on the time horizon in currency trade as described above. It is demonstrated in the paper that since the magnitude of exchange rate overshooting may not be the same for different exchange rates of a currency, a monetary expansion or contraction in, for example, the EMU, will affect the exchange rate between the U.S. dollar and the yen, even though there are no changes in monetary fundamentals in the U.S. or Japan. It is also demonstrated that PPP does not necessarily hold in long-run equilibrium. These results are interesting since, according to the empirical literature, there are often large movements in nominal exchange rates that are apparently unexplained by macroeconomic fundamentals, and there is also a weak support for PPP.

[1] An extensive exploration of the psychology in currency trade may also be found in Oberlechner (2004) that is based on surveys conducted at the European and the North American markets.

Frankel and Froot (1987) conclude the following from their survey data analysis, which may give an idea about the starting point of this paper:

> 'It may be that each respondent is thinking to himself or herself, 'I know that in the long run the exchange rate must return to the equilibrium level dictated by fundamentals. But in the short run I will ride the current trend a little longer. I only have to be careful to watch for the turning point and to get out of the market before everyone else does" (p. 264).

There are not many papers that incorporate technical analysis in a foreign exchange model, and we believe there are two reasons for this. The first is that most researchers do not believe that currency traders using chartism can survive in the market, and the second reason is that even if some researchers are aware of the use of chartism in currency trade, most of them argue that it is of uttermost importance to explain *why* these traders survive in the market. We are sympathetic to this standpoint, but we also believe that this may be a hindrance to a better understanding of the *effects* of chartism in currency trade since it is not easy to develop a theoretical framework to explain human behavior at the currency market or any financial asset market.

The remainder of this short paper is organized as follows: The baseline model and the expectations formations in currency trade are presented in Section 2, and the formal analysis of the model developed is carried out in Section 3. Section 4 concludes the paper.

2 Theoretical framework

The baseline model is outlined in Section 2.1, whereas a no arbitrage condition at the currency market is stated and discussed in Section 2.2. In Section 2.3, the expectations formations in currency trade are presented and discussed.

2.1 Baseline model

The model developed is a three-country model that consists of a real sector and a monetary sector, where the goods market in each country constitute the real sector and the money and the international asset markets in the same countries constitute the monetary sector. The structure of the model is presented below, where all variables, except the interest rates, are in natural logarithms and Greek letters denote positive structural parameters. The indexation of countries, parameters and variables in the model are explained in Figure 1.

(2.1)–(2.2) below constitute the real sector, where (2.1) describes a Phillips curve for each country and (2.2) describes the determinants of aggregate demand in each country. The Phillips curves are described by

$$\frac{dp_j}{dt} = \alpha_j \left(y_j^d - \overline{y_j} \right), \quad j = 0, 1, 2, \tag{2.1}$$

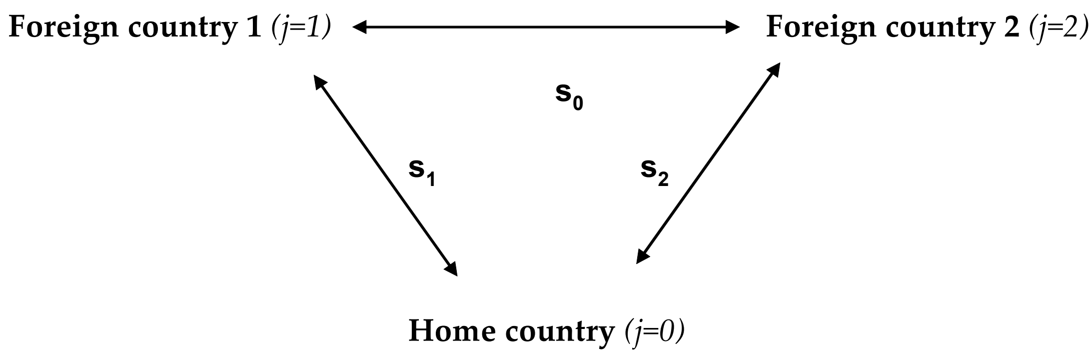

Figure 1: Indexation of countries and exchange rates. All parameters and variables, except the ex-change rates, the time horizons in currency trade and the long-period moving averages, are indexed as the corresponding country. The time horizons and the moving averages are in-dexed as the corresponding exchange rate. Finally, the first index in a parameter in (2.2) refers to the country, but the second index is just a number.

where $\frac{dp}{dt}$, y^d and $\overline{y}$ denote the domestic inflation rate, aggregate demand for domestic goods and aggregate supply of domestic goods, respectively. Goods prices are assumed to be sticky. This means that they respond to market disequilibria, but not fast enough to eliminate the disequilibria instantly. Two extremes are obtained by letting $\alpha \to \infty$, which is the case of perfectly flexible goods prices, and by setting $\alpha = 0$, which is the case of completely rigid goods prices.

Aggregate demand for domestic goods in each country is described by[2]

$$\begin{cases} y_0^d = \beta_{01}(s_1 + p_1 - p_0) + \beta_{02}(s_2 + p_2 - p_0) + \gamma_0 \overline{y_0} \\ y_1^d = \beta_{11}(s_1 + p_0 - p_1) + \beta_{12}(s_0 + p_2 - p_1) + \gamma_1 \overline{y_1} \\ y_2^d = \beta_{21}(s_2 + p_0 - p_2) + \beta_{22}(s_0 + p_1 - p_2) + \gamma_2 \overline{y_2} \end{cases}, \tag{2.2}$$

where s and p denote the spot exchange rate and the price level, respectively. The exchange rates s_1 and s_2 are defined as the amount of the *domestic currency* one has to pay for one unit of *foreign currency 1* and *foreign currency 2*, respectively, and s_0 is the amount of *foreign currency 2* one has to pay for one unit of *foreign currency 1*. The first two terms at the right-hand side in each equation in (2.2) represent net exports to the foreign countries that depend on the real exchange rates. The third term in each equation represent income-dependent demand for domestic goods.

(2.3)–(2.4) below constitute the monetary sector and are the equilibrium conditions at the money and the international asset markets, respectively. The money markets in each country are described by

$$m_j - p_j = \delta_j \overline{y_j} - \zeta_j i_j, \quad j = 0, 1, 2, \tag{2.3}$$

where m and i denote the money supply and the interest rate, respectively. The equilibrium conditions in (2.3) are maintained by the assumption of perfectly flexible interest rates.

[2] A consultation of Figure 1 would facilitate the interpretation of the equations in (2.2).

The international asset markets are described by

$$i_j = i_k + E\left(\frac{ds_k}{dt}\right), \quad j,k = 0,1,2, \; j \neq k, \tag{2.4}$$

where $E\left(\frac{ds}{dt}\right)$ denotes the expected rate of change of the spot exchange rate. These asset market equilibrium conditions, also known as uncovered interest rate parities (UIP), are based on the assumption that all assets are perfect substitutes, which can only be the case if there is perfect capital mobility. Since the capital mobility is assumed to be perfect, only the slightest difference in expected yields will draw the entire capital into the asset that offers the highest expected yield. Thus, the international asset markets can only be in equilibrium if all assets offer the same expected yield. The equilibrium conditions in (2.4) are maintained by the assumption of perfectly flexible exchange rates.

2.2 No arbitrage condition

The no arbitrage condition at the currency market holds when

$$s_0 = s_1 - s_2. \tag{2.5}$$

The principal aim of this paper is to investigate under what conditions s_0 is affected by a change in the money supply in the *home country* when the no arbitrage condition in (2.5) holds, ie, an expression for $\frac{ds_0}{dm_0}$ will be derived, where, according to (2.5)

$$\frac{ds_0}{dm_0} = \frac{ds_1}{dm_0} - \frac{ds_2}{dm_0}. \tag{2.6}$$

For example, one may think of the effect of a change in the EMU's money supply on the exchange rate between the U.S. dollar and the yen when deriving an expression for $\frac{ds_0}{dm_0}$. Thus, in this case, the countries using the euro are the *home country* and Japan and the U.S. are *foreign country 1* and *foreign country 2*, respectively.

2.3 Expectations formations

According to questionnaire surveys (see cited references in Section 1), the relative importance of technical versus fundamental analysis in the currency market depends on the 'artificial' time horizon in currency trade, τ. For shorter time horizons, more weight is placed on chartism, while more weight is placed on fundamental analysis for longer horizons. This observation is formulated as

$$\begin{aligned} & E\left(\frac{ds_j}{dt}\right) \\ = \; & E_c\left(\frac{ds_j}{dt}\right)\exp(-\tau_j) + E_f\left(\frac{ds_j}{dt}\right)(1-\exp(-\tau_j)), \quad j = 0,1,2, \end{aligned} \tag{2.7}$$

where $E_c(\cdot)$ and $E_f(\cdot)$ denote exchange rate expectations based on chartism and fundamental analysis, respectively, and $E(\cdot)$ denotes a weighted average of these expectations, where the time horizon in currency trade determines the weights. Thus, $E(\cdot)$ is the market's exchange rate expectations.

The most commonly used technique by currency traders using chartism is moving averages (eg, Lui and Mole (1998) and Taylor and Allen (1992)). According to this technique, buying and selling signals are generated by two moving averages; a short-period moving average and a long-period moving average, where a buy (sell) signal is generated when the short-period moving average rises above (falls below) the long-period moving average. In its simplest form, the short-period moving average is the current exchange rate and the long-period moving average is an exponentially weighted moving average of current and past exchange rates.

Thus, when chartism is used, it is expected that the exchange rate will increase (decrease) when the current exchange rate is higher (lower) than an exponentially weighted moving average of current and past exchange rates, MA

$$E_c\left(\frac{ds_j}{dt}\right) = \eta_j\left(s_j - MA_j\right), \quad j = 0, 1, 2. \tag{2.8}$$

The long-period moving average can be written as

$$MA_j(t) = \int_{-\infty}^{t} \omega(\mu)\, s_j(\mu)\, d\mu, \quad j = 0, 1, 2, \tag{2.9}$$

where the weights given to current and past exchange rates 'sum up' to 1

$$\int_{-\infty}^{t} \omega(\mu)\, d\mu = \int_{-\infty}^{t} \exp(\mu - t)\, d\mu = 1. \tag{2.10}$$

Note that we assume that the weight function, $\omega(\cdot)$, is the same for all long-period moving averages in (2.9).

Finally, when fundamental analysis is used in currency trade, it is expected that the exchange rate will adjust to its fundamental value according to a regressive adjustment scheme

$$E_f\left(\frac{ds_j}{dt}\right) = \theta_j\left(\overline{s_j} - s_j\right), \quad j = 0, 1, 2, \tag{2.11}$$

where $\overline{s}$ is the spot exchange rate in long-run equilibrium.

3 Formal analysis of the model

It is first demonstrated, in Section 3.1, that the quantity theory of money holds in long-run equilibrium, but not necessarily PPP. However, we state a necessary and sufficient condition for PPP to hold in the long-run. Thereafter, in Section 3.2, it is demonstrated that the magnitude of exchange rate overshooting is larger than in Dornbusch (1976) when chartists are introduced into the model. To be more specific, the impact effect of a monetary disturbance varies negatively with the length of the time horizon in currency trade.

In Section 3.3, it is demonstrated that a monetary expansion or contraction in, for example, the EMU, will affect the exchange rate between the U.S. dollar and the yen, even though there are no changes in monetary fundamentals in the U.S. or Japan. Since we will derive an expression for $\frac{ds_0}{dm_0}$ when the no arbitrage condition in (2.6) holds, the focus in the analysis will first be on the behavior of s_1 and s_2, and, thereafter, on the behavior of s_0.

3.1 Failure of PPP

The long-period moving averages in long-run equilibrium, $\overline{MA}$, are equal to the corresponding long-run equilibrium exchange rates

$$\overline{MA_j} = \int_{-\infty}^{t} \omega(\mu)\, \overline{s_j} d\mu = \overline{s_j} \int_{-\infty}^{t} \omega(\mu)\, d\mu = \overline{s_j}, \quad j = 1, 2. \tag{3.1}$$

Thus, according to the technical trading technique used in foreign exchange, constant exchange rates are expected in long-run equilibrium

$$E_c \left(\frac{ds_j}{dt} \right) \bigg|_{\substack{\text{long-run} \\ \text{equilibrium}}} = \eta_j \left(\overline{s_j} - \overline{MA_j} \right) = \eta_j \left(\overline{s_j} - \overline{s_j} \right) = 0, \quad j = 1, 2, \tag{3.2}$$

which also are expected according to fundamental analysis

$$E_f \left(\frac{ds_j}{dt} \right) \bigg|_{\substack{\text{long-run} \\ \text{equilibrium}}} = \theta_j \left(\overline{s_j} - \overline{s_j} \right) = 0, \quad j = 1, 2. \tag{3.3}$$

Consequently, the whole market expects constant exchange rates in long-run equilibrium

$$\begin{aligned} & E \left(\frac{ds_j}{dt} \right) \bigg|_{\substack{\text{long-run} \\ \text{equilibrium}}} \\ = \; & 0 \cdot \exp(-\tau_j) + 0 \cdot (1 - \exp(-\tau_j)) = 0, \quad j = 1, 2. \end{aligned} \tag{3.4}$$

The equilibrium conditions at the money and the international asset markets, ie, (2.3)–(2.4), can be solved to give the long-run equilibrium price level, $\overline{p}$, in the *home country*[3]

$$\overline{p_0} = m_0 - \delta_0 \overline{y_0} + \zeta_0 i_j, \quad j = 1, 2, \tag{3.5}$$

where (3.4) is utilized in the derivation. Thus, the quantity theory of money holds in long-run equilibrium in the *home country*

$$\frac{d\overline{p_0}}{dm_0} = 1. \tag{3.6}$$

[3] Note that (3.5) implies that the interest rates in *foreign country 1* and *foreign country 2* are equal to each other, $i_1 = i_2$.

However, which is the main result in this subsection, PPP does not necessarily hold in long-run equilibrium. See Proposition 3.1 below. This result is interesting for two reasons. The first is that PPP often is a factor in common in monetary foreign exchange models, and the second reason is that there is a weak empirical support for this parity condition in the literature.

Proposition 3.1 *A necessary and sufficient condition for PPP to hold in long-run equilibrium,*

$$\frac{d\overline{s_j}}{d\overline{p_0}} = 1, \quad j = 1, 2, \tag{3.7}$$

is that

$$\beta_{11}\beta_{22} = \beta_{12}\beta_{21}. \tag{3.8}$$

Thus, Proposition 3.1 also means that a sufficient condition for PPP to hold in the long-run is that the real exchange rate elasticities and the income elasticities in (2.2), respectively, are equal across countries. Finally, note that the failure of PPP still holds even if there is no technical trading in foreign exchange.

3.2 Exchange rate overshooting

Since $\frac{ds(\mu)}{ds(t)} = 0$, $\forall \mu < t$,

$$\begin{aligned} \frac{dMA_j(t)}{dm_0} &= \frac{dMA_j(t)}{ds_j(t)} \frac{ds_j(t)}{dm_0} \\ &= \frac{d}{ds_j(t)} \int_{-\infty}^{t} \omega(\mu) s_j(\mu) d\mu \cdot \frac{ds_j(t)}{dm_0} \\ &= \omega(t) \cdot \frac{ds_j(t)}{ds_j(t)} \frac{ds_j(t)}{dm_0} \\ &= \exp(t - t) \cdot \frac{ds_j(t)}{dm_0} \\ &= \frac{ds_j(t)}{dm_0}, \quad j = 1, 2, \end{aligned} \tag{3.9}$$

where (2.9)–(2.10) are utilized in the derivation. Thereafter, substitute the equations that describe exchange rate expectations based on chartism and fundamental analysis in *foreign country 1* and *foreign country 2*, ie, (2.8) and (2.11), as well as the relevant equilibrium conditions at the money and the international asset markets, ie, (2.3)–(2.4), into (2.7)

$$\begin{aligned} &\eta_j (s_j - MA_j) \exp(-\tau_j) + \theta_j (\overline{s_j} - s_j)(1 - \exp(-\tau_j)) \\ = &\frac{\delta_0 \overline{y_0} - m_0 + p_0 - \zeta_0 i_j}{\zeta_0}, \quad j = 1, 2. \end{aligned} \tag{3.10}$$

Differentiating (3.10) with respect to the money supply, the spot exchange rates, the spot exchange rates in long-run equilibrium and the long-period moving average give, after a few manipulations

$$\frac{ds_j}{dm_0} = \frac{d\overline{s_j}}{dm_0} + \frac{1}{\zeta_0 \theta_j \left(1 - \exp\left(-\tau_j\right)\right)} > \frac{d\overline{s_j}}{dm_0}, \quad \tau_j \neq 0, \ j = 1, 2, \tag{3.11}$$

where (3.9) is utilized in the derivation. Thus, in the immediate-run, before goods prices have time to react, the exchange rates will rise (fall) more than the money supply, and, consequently, more than is necessary to bring the exchange rates to long-run equilibrium.

By letting $\tau_1 \to \infty$ and $\tau_2 \to \infty$, the market expectations coincide with the exchange rate expectations based on fundamental analysis. Therefore, the immediate-run effects of a monetary expansion in Dornbusch (1976) are obtained

$$\left.\frac{ds_j}{dm_0}\right|_{Dornbusch\,(1976)} = \frac{d\overline{s_j}}{dm_0} + \frac{1}{\zeta_0 \theta_j}, \quad j = 1, 2. \tag{3.12}$$

Moreover, the magnitudes of overshooting in the exchange rates are larger in the model developed than in the Dornbusch (1976) model, where the magnitudes of overshooting depend inversely on the time horizons in currency trade

$$\left.\frac{ds_j}{dm_0}\right|_{Dornbusch\,(1976)} \leq \tag{3.13}$$

$$\left.\frac{ds_j}{dm_0}\right|_{\tau = \tau_j'} < \left.\frac{ds_j}{dm_0}\right|_{\tau = \tau_j''}, \quad \tau_j' > \tau_j'' > 0, \ j = 1, 2.$$

This means that during periods of time when market expectations are more short-sighted, a given level of monetary disturbances will cause relatively more volatile exchange rates.

3.3 Overshooting without fundamentals

Now, by focusing on the principal aim of this paper, the immediate-run effects on the exchange rates of a monetary disturbance in (3.11) are substituted into the no arbitrage condition in (2.6), which give, after a few manipulations

$$\frac{ds_0}{dm_0} = \frac{\theta_2 \left(1 - \exp\left(-\tau_2\right)\right) - \theta_1 \left(1 - \exp\left(-\tau_1\right)\right)}{\zeta_0 \theta_1 \theta_2 \left(1 - \exp\left(-\tau_1\right)\right)\left(1 - \exp\left(-\tau_2\right)\right)}, \quad \tau_1 \neq 0, \ \tau_2 \neq 0. \tag{3.14}$$

As can been seen in (3.14), there are two sources to a volatile exchange rate between *foreign currency 1* and *foreign currency 2*, ie, s_0, even if monetary fundamentals in those countries are constant. Instead, it is the monetary fundamental in the *home country* that is changing. The first source is a difference in the expected adjustment speeds of exchange rates s_1 and s_2 according to fundamental analysis, ie, $\theta_1 \neq \theta_2$, and the second source is a difference in the time horizons in currency trade, ie, $\tau_1 \neq \tau_2$.

Firstly, if it temporarily is assumed in (3.14) that the time horizons in currency trade are equal to each other, ie, $\tau = \tau_1 = \tau_2$, one can see that a difference in the expected adjustment speeds of exchange rates s_1 and s_2 according to fundamental analysis, ie, $\theta_1 \neq \theta_2$, is affecting the exchange rate s_0

$$\left.\frac{ds_0}{dm_0}\right|_{\tau=\tau_1=\tau_2} = \frac{\theta_2 - \theta_1}{\zeta_0 \theta_1 \theta_2 \left(1 - \exp\left(-\tau\right)\right)}, \quad \tau \neq 0. \tag{3.15}$$

For example, if it is assumed that $\theta_1 > \theta_2$, a positive (negative) monetary disturbance will cause *foreign currency 1* to be less (more) expensive in terms of *foreign currency 2*. Recall that s_0 is the amount of *foreign currency 2* one has to pay for one unit of *foreign currency 1*. However, if the expected adjustment speeds are equal to each other, ie, $\theta_1 = \theta_2$, the exchange rate s_0 is constant.

Secondly, if it temporarily is assumed in (3.14) that the expected adjustment speeds of exchange rates s_1 and s_2 according to fundamental analysis are equal to each other, ie, $\theta = \theta_1 = \theta_2$, one can see that a difference in the time horizons in currency trade, ie, $\tau_1 \neq \tau_2$, is affecting the exchange rate s_0

$$\begin{aligned} & \left.\frac{ds_0}{dm_0}\right|_{\theta=\theta_1=\theta_2} \\ = & \frac{\exp\left(-\tau_1\right) - \exp\left(-\tau_2\right)}{\zeta_0 \theta \left(1 - \exp\left(-\tau_1\right)\right)\left(1 - \exp\left(-\tau_2\right)\right)}, \quad \tau_1 \neq 0, \ \tau_2 \neq 0. \end{aligned} \tag{3.16}$$

For example, if it is assumed that $\tau_1 > \tau_2$, a positive (negative) monetary disturbance will cause *foreign currency 1* to be less (more) expensive in terms of *foreign currency 2*. However, if the time horizons are equal to each other, ie, $\tau_1 = \tau_2$, the exchange rate s_0 is constant.

4 Conclusions

PPP does not necessarily hold in long-run equilibrium in the three-country model developed in this paper, and this result still holds even if there is no technical trading in foreign exchange, which is an interesting result since there is a weak empirical support for this parity condition. It has also been demonstrated in this short paper that a monetary expansion or contraction in, for example, the EMU, will affect the exchange rate between the U.S. dollar and the yen, even though there are no changes in monetary fundamentals in the U.S. or Japan. For example, if trade in the euro-U.S. dollar exchange rate is more short-sighted than trade in the euro-yen rate, an expansionary monetary policy in the EMU would make the yen cheaper in terms of U.S. dollars (see (3.16)). This result is also interesting since there are often large movements in nominal exchange rates that are apparently unexplained by macroeconomic fundamentals.

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Appendix

Proof of Proposition 3.1

Firstly, evaluate the equations that describe the goods market in the *home country* as well as in the *foreign countries*, ie, (2.1)–(2.2), in long-run equilibrium and note that the price level in each country is constant, ie, $\frac{dp_j}{dt} = 0$, $j = 0, 1, 2$

$$\begin{cases} 0 = \alpha_0\beta_{01}\left(\overline{s_1} + \overline{p_1} - \overline{p_0}\right) + \alpha_0\beta_{02}\left(\overline{s_2} + \overline{p_2} - \overline{p_0}\right) + \alpha_0\left(\gamma_0 - 1\right)\overline{y_0} \\ 0 = \alpha_1\beta_{11}\left(\overline{s_1} + \overline{p_0} - \overline{p_1}\right) + \alpha_1\beta_{12}\left(\overline{s_0} + \overline{p_2} - \overline{p_1}\right) + \alpha_1\left(\gamma_1 - 1\right)\overline{y_1} \\ 0 = \alpha_2\beta_{21}\left(\overline{s_2} + \overline{p_0} - \overline{p_2}\right) + \alpha_2\beta_{22}\left(\overline{s_0} + \overline{p_1} - \overline{p_2}\right) + \alpha_2\left(\gamma_2 - 1\right)\overline{y_2} \end{cases}. \quad \text{(A.1)}$$

Secondly, differentiate (A.1) with respect to the long-run exchange rates and the long-run price levels, and put the equation system into matrix form

$$\begin{bmatrix} 0 & \alpha_0\beta_{01} & \alpha_0\beta_{02} \\ \alpha_1\beta_{12} & \alpha_1\beta_{11} & 0 \\ \alpha_2\beta_{22} & 0 & \alpha_2\beta_{21} \end{bmatrix} \begin{bmatrix} d\overline{s_0} \\ d\overline{s_1} \\ d\overline{s_2} \end{bmatrix} \quad \text{(A.2)}$$

$$= \begin{bmatrix} \alpha_0\left(\beta_{01} + \beta_{02}\right) & -\alpha_0\beta_{01} & -\alpha_0\beta_{02} \\ -\alpha_1\beta_{11} & \alpha_1\left(\beta_{11} + \beta_{12}\right) & -\alpha_1\beta_{12} \\ -\alpha_2\beta_{21} & -\alpha_2\beta_{22} & \alpha_2\left(\beta_{21} + \beta_{22}\right) \end{bmatrix} \begin{bmatrix} d\overline{p_0} \\ d\overline{p_1} \\ d\overline{p_2} \end{bmatrix}.$$

Thirdly, using Cramer's rule, we can solve for the following multipliers

$$\begin{aligned} \frac{d\overline{s_1}}{d\overline{p_0}} &= \frac{\begin{vmatrix} 0 & \alpha_0\left(\beta_{01} + \beta_{02}\right) & \alpha_0\beta_{02} \\ \alpha_1\beta_{12} & -\alpha_1\beta_{11} & 0 \\ \alpha_2\beta_{22} & -\alpha_2\beta_{21} & \alpha_2\beta_{21} \end{vmatrix}}{\begin{vmatrix} 0 & \alpha_0\beta_{01} & \alpha_0\beta_{02} \\ \alpha_1\beta_{12} & \alpha_1\beta_{11} & 0 \\ \alpha_2\beta_{22} & 0 & \alpha_2\beta_{21} \end{vmatrix}} \quad \text{(A.3)} \\ &= \frac{-\beta_{02}\beta_{12}\beta_{21} + \beta_{02}\beta_{11}\beta_{22} - \left(\beta_{01} + \beta_{02}\right)\beta_{12}\beta_{21}}{-\beta_{02}\beta_{11}\beta_{22} - \beta_{01}\beta_{12}\beta_{21}} \\ &= 1 - \frac{2\beta_{02}\left(\beta_{11}\beta_{22} - \beta_{12}\beta_{21}\right)}{\beta_{01}\beta_{12}\beta_{21} + \beta_{02}\beta_{11}\beta_{22}}, \end{aligned}$$

and

$$\begin{aligned} \frac{d\overline{s_2}}{d\overline{p_0}} &= \frac{\begin{vmatrix} 0 & \alpha_0\beta_{01} & \alpha_0\left(\beta_{01} + \beta_{02}\right) \\ \alpha_1\beta_{12} & \alpha_1\beta_{11} & -\alpha_1\beta_{11} \\ \alpha_2\beta_{22} & 0 & -\alpha_2\beta_{21} \end{vmatrix}}{\begin{vmatrix} 0 & \alpha_0\beta_{01} & \alpha_0\beta_{02} \\ \alpha_1\beta_{12} & \alpha_1\beta_{11} & 0 \\ \alpha_2\beta_{22} & 0 & \alpha_2\beta_{21} \end{vmatrix}} \quad \text{(A.4)} \\ &= \frac{-\beta_{01}\beta_{11}\beta_{22} - \left(\beta_{01} + \beta_{02}\right)\beta_{11}\beta_{22} + \beta_{01}\beta_{12}\beta_{21}}{-\beta_{02}\beta_{11}\beta_{22} - \beta_{01}\beta_{12}\beta_{21}} \\ &= 1 + \frac{2\beta_{01}\left(\beta_{11}\beta_{22} - \beta_{12}\beta_{21}\right)}{\beta_{01}\beta_{12}\beta_{21} + \beta_{02}\beta_{11}\beta_{22}}. \end{aligned}$$

Thus, (3.8) is a necessary and sufficient condition for PPP to hold in long-run equilibrium. Recall that all structural parameters are positive and the proof is completed.

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