Exchange rate dynamics with currency substitution: the case of Ghana, Paraguay and Uruguay

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Abstract

This paper presents a monetary exchange rate model with imperfect capital mobility, slow adjustment of goods prices in the short-term and currency substitution. As in Dornbusch's model (1976), an exogenous monetary shock can lead to an initial exchange rate overshooting. In our model, this phenomenon derives from the presence of currency substitution. The Johansen co-integration technique is applied to this model using data for three developing countries, Ghana, Paraguay and Uruguay. For each of them, we find at least one long-run relationship between the exchange rate and the macroeconomic fundamentals. Moreover, in Uruguay, the error-correction model allows us to identify an overshooting phenomenon.

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1. Introduction

With the advent of generalized floating in 1973, most economists thought that exchange rates would adjust to parities determined by national price levels. However, exchange rates rapidly fluctuated to a greater degree than price levels. As early as 1976, Dornbusch gave a new theory explaining the volatility of exchange rates in a floating exchange rate regime. The structure of his model is similar to the monetary model, but instead of a financial assets price which was supposed to adjust rapidly to any disequilibrium, he introduced a slowly adjusting goods price. The implication of Dornbusch's model is that the nominal exchange rate may in the short-run overshoot its long-run equilibrium level in response to a change in relative money supplies.

There were many studies which attempted to test a monetary model of exchange rate determination. Development of time series methods, using the concepts of co-integration and error-correction models, have contributed to a renewal of this empirical literature (see MacDonald and Taylor, 1991,1993, 1994; McNown and Wallace, 1994; Kim and Mo, 1995; Diamandis and Kouretas, 1996; Choudhry and Lawler, 1997; and Makrydakis, 1998 among others). Most of these studies concluded that the monetary model provides a plausible explanation of long-term exchange rates. However, the majority of them failed to explain the dynamics of short-run adjustment. Thus, the foundation of the overshooting process described by Dornbusch, i.e. the discrepancy between domestic and foreign interest rates in a context of perfect capital mobility, is not highlighted.

Another limit to these empirical studies is the fact that most of them concern the currencies of large industrial countries, in general Japan, Germany, the United Kingdom and France in terms of the U.S. dollar. Few studies concern developing countries, except that of McNown and Wallace (1994) which considers Argentina, Chile and Israel, and that of Makrydakis (1998), dealing with South Korea. On the one hand, this limited number of studies for developing countries might partly be due to the small number of durable floating experiences in these countries[1]. In addition, characteristics of Dornbusch's model, which explain the short-term dynamics of nominal exchange rates, were obviously selected according to the macroeconomic structure of industrial countries. Therefore, they are not particularly consistent with those of developing countries.

Indeed, this model supposes that only domestic currency circulates in the various countries, that interest rates are freely determined by the markets, and finally, that there is perfect capital mobility between countries. However, in some developing countries, there has been a sharp decline in real balances of domestic currency during periods of high and variable inflation rates, large balance of payments deficits and recurrent currency devaluations. In these countries, the use of foreign money has become widespread. And it is precisely for these reasons that some of them have abandoned fixed exchange rate regimes for floating exchange rate regimes. In addition, in many developing countries and in spite of a general movement towards financial liberalization, monetary policy still uses quantitative control instruments and interest rates remain largely controlled by the Central Bank. Finally, international capital movements are generally regulated and, even in the absence of such a regulation, domestic financial assets are not perfectly substitutable for foreign financial assets because of institutional weakness in the domestic financial system.

The purpose of this paper is to suggest an explanation of exchange rate volatility during floating experiences consistent with the context of developing

[1] Although forty developing countries have adopted an independently floating exchange rate regime since the beginning of the 1980s, only three were in this situation before 1985 (South Africa, Lebanon and Uruguay) and in most of them this change was not implemented before the beginning of the 1990s (we consider only the experiments which lasted at least 24 months consecutively). Cf. IMF, *Report on Exchange Arrangements and Exchange Restrictions* (various issues).

countries. Section 2 provides a theoretical model for exchange rate overshooting in a context of currency substitution and compares it with that of Dornbusch (1976). Section 3 presents the empirical methodology and tests the presented model on three developing countries: Ghana, Paraguay and Uruguay. These countries were selected because of their monetary characteristics corresponding to the basic assumptions of the model, i.e. the existence of partial dollarization[2] and a control on interest rates and on capital account. In addition, these countries had adopted an independently floating exchange rate for a sufficiently long time (since 1987, 1989 and 1983 respectively), so that exchange rate volatility is similar to that of the industrial countries and that sufficient data are available. Finally, section 4 presents our conclusions.

2. A theoretical analysis of exchange rate determination in countries with currency substitution

Our approach is similar to that of Dornbusch (1976). While the flexible-price monetary approach of exchange rates is valid in the long-run, in the short-run the prices of goods are assumed to react slowly to monetary expansion so that the exchange rate diverges from its long-run equilibrium. However the short-run dynamics proposed here differ from those of Dornbusch's.

2.1. The long-run equilibrium of the exchange rate

In a floating exchange rate regime, the exchange rate is determined by the supply and demand of domestic against foreign currencies. According to the monetary approach, the exchange rate is the relative price of these two assets and it is

[2] Here and in the remainder of the paper, the terms currency substitution and dollarization are alternatively used.

determined by the equilibrium conditions of the domestic and foreign money markets (see Frenkel, 1976; Mussa, 1976). So we have:

$$m - p = fy - l\,i \qquad (1)$$

$$m^* - p^* = f^* y^* - l^* i^* \qquad (2)$$

where m, p and y denote the natural logarithm of the nominal quantity of money, the price level and the real income and where i denotes the interest rate, an asterisk signifying the corresponding foreign variable.

Purchasing power parity (PPP) is assumed to hold, at least in the long-run:

$$\bar{e} = \bar{p} - \bar{p}^* \qquad (3)$$

where e denotes the natural logarithm of the nominal exchange rate (in domestic currency terms). We use bars to denote long-term equilibrium values.

So, solving equation (1) and (2) for p and p^*, and substituting in (3), we obtain the basic monetary exchange rate model:

$$\bar{e} = \bar{m} - \bar{m}^* - f\bar{y} + f^*\bar{y}^* + l\,\bar{i} - l^*\bar{i}^* \qquad (4)$$

However, long-run international purchasing power parity is not necessarily valid, even in the long-run, in developing countries where the per capita GDP level differs from that of their trading partners (Balassa-Samuelson effect, Balassa, 1964; Samuelson, 1964) and where international capital mobility is restricted (see Rogoff, 1992; De Gregorio et al., 1994a, 1994b). The difference between the exchange rate and purchasing power parity level may simply be taken into account by a constant (c) or a trend (t) added to equation (4):

$$\bar{e} = c + t + \bar{m} - \bar{m}^* - f\bar{y} + f^*\bar{y}^* + l\,\bar{i} - l^*\bar{i}^* \qquad (5)$$

On the other hand, we suppose that goods prices are sticky in the short-run and then we relax the continuous PPP condition (Dornbusch, 1976). Under this assumption, the monetary model allows short-run overshooting of the nominal exchange rate above its long-run value. Here, however, we propose an alternative explanation to that developed by Dornbusch.

2.2. The Dornbusch model of exchange rate overshooting (1976)

In Dornbusch's model, as neither goods price nor production vary instantaneously, disequilibrium in the money market induced by monetary expansion must be matched by a variation of interest rates (see equations (1) and (2)). Thus, a persistent increase in the nominal quantity of money reduces the domestic interest rate and leads:

"to the anticipation of a deprecation in the long-run and, therefore, at the current exchange rate, to the expectation of a depreciating exchange rate. Both factors serve to reduce the attractiveness of domestic assets, lead to an incipient capital outflow, and thus cause the spot rate to depreciate. The extent of that depreciation has to be sufficient to give rise to the anticipation of appreciation at just sufficient a rate to offset the reduced domestic interest rate. The impact effect of a monetary expansion is, therefore, to induce an immediate depreciation in the spot rate and one that exceeds the long-run depreciation, since only under these circumstances will the public anticipate an appreciating exchange rate and thus be compensated for the reduced interest on domestic assets" (Dornbusch, 1976, p.1168).

However, the lower interest rate and relative price of non-traded goods due to the depreciation of the spot exchange rate will induce an increase in aggregate demand and "will cause domestic prices to rise and therefore be reflected in falling real money balances, rising interest rates and an appreciating exchange rate. The adjustment process of rising prices over time restores the economy to the initial real equilibrium"[3](Dornbusch, 1976, p.1171).

In Dornbusch's model, a key role is played by the sluggish adjustment of goods prices compared to asset prices. Therefore, the expected rate of variation of the spot exchange rate is proportional to the discrepancy between the long-run rate and the current spot rate:

$$(\Delta e)^a = q\,(\bar{e} - e) \qquad (6)$$

where $(De)^a$ is the expected rate of appreciation of the foreign currency[4] and $\theta<1$,

According to Dornbusch's hypothesis of rational expectations formation and perfect foresight, the speed of adjustment q depends on the reaction of aggregate demand to the variation of the interest rate and spot exchange rate and on the reaction of goods prices to excess demand. The greater the stickiness of prices, the lower the speed of adjustment. If, on the contrary, the prices were perfectly flexible, the spot rate would adjust instantaneously to its long-run level and q would equal one.

As perfect capital mobility is assumed, the domestic interest rate equals the foreign interest rate plus the expected rate of appreciation of the foreign currency:

$$i = i^* + (\Delta e)^a \qquad (7)$$

Combining (6) and (7) we obtain:

$$e = \frac{1}{q}(i^* - i) + \bar{e} \qquad (8)$$

with $\frac{1}{q}$ greater than one since $q<1$.

With a money demand expressed as in equation (1) and as the long-run change in the exchange rate is just equal to the change in money stock ($d\bar{e} = dm$), we obtain an

[3] Here, as in the first part of Dornbusch's article, we suppose that the level of production is given in the short-run.
[4] We recall that the exchange rate is in domestic currency terms.

expression for the size of the exchange rate overshooting following a monetary expansion[5]:

$$\frac{de}{dm} = 1 + \frac{1}{lq} > 1 \qquad (9)$$

The extent of the overshooting depends on the interest rate semi-elasticity of the demand for money (l) and the speed of the exchange rate adjustment to its long-run level (q which is a function of the price stickiness). Thus, if the interest response of money demand is high, a given money supply growth will require just a small reduction in the interest rate in order to restore money market balance. So, the expected rate of appreciation of the domestic currency necessary to restore uncovered interest rate parity will be low. The discrepancy between the current spot exchange rate and the equilibrium rate, in other words the overshooting, will be reduced. We can apply a similar interpretation to the coefficient of adjustment, since if q is high, it means that the prices are not very sticky in the short-run.

2.3. A model of exchange rate overshooting with currency substitution

In Dornbusch's model, the dynamic aspects of exchange rate determination arise from the assumption that exchange rates and asset markets adjust fast relative to goods markets. This assumption is relevant for developing countries as well as industrial ones. On the other hand, within the financial context of developing countries, we will drop the assumption of perfect capital mobility and we will take into account foreign-currency holdings by domestic residents. So, our model is based on the following hypothesis:

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[5] We substitute expected appreciation of the foreign currency in (7) by its expression in (6). Then, we introduce the result in (1) in order to obtain an exchange rate equation. We remember that domestic prices, domestic income and the foreign interest rate are rigid in the short-term.

- goods prices are fixed in the short-run, whereas they move in the long-run so that international purchasing power parity prevails

- international capital mobility is imperfect and domestic interests are given

- currency substitution, i.e. foreign currency substitution for domestic money as a store of value, unit of account and medium of exchange, has become a pervasive phenomenon so that domestic money demand may be supposed to depend on the expected exchange rate depreciation.

Indeed, in countries with currency substitution, domestic and foreign moneys are held simultaneously for transaction motive: economic agents use domestic currency for small expenses and foreign currency for large transactions. The equilibrium condition in the holding of the two currencies implies that the marginal yield of the domestic money balances is equal to that of the foreign currency balances. This yield depends on the expected rate of depreciation of the domestic currency. Thus, this rate must be introduced into the conventional domestic money demand equation.

We now study the process of adjustment to a monetary expansion in the developing economy defined previously. A persistent increase in the nominal quantity of domestic money has to be matched in the long-run by higher prices. But for the moment, we suppose that prices, as well as production and domestic interest rates, are given so that domestic money supply is larger than demand. Economic agents hold too much domestic currency compared to foreign currency and the implicit yield of domestic money (as a means of payment) falls below the yield of foreign currency holdings. Therefore they will be incited to substitute foreign currency for domestic money. This induces a depreciation of the exchange rate. The extent of that depreciation has to be sufficient to give rise to an anticipation of appreciation at just sufficient a rate to offset the reduced marginal yield of domestic balances. It incites economic agents to preserve their domestic balances. Thus, the exchange rate will overshoot its long-run equilibrium.

If expectations are quite unanimous, the exchange rate depreciates instantaneously without important trading of currencies as in Dornbusch's model, where the reduced interest rate may induce an immediate exchange rate depreciation without large capital outflows. Then, with the adjustment process of rising prices over time, the domestic money demand increases and the exchange rate appreciates towards its long-run equilibrium level.

However, the reaction of economic agents to monetary expansion is probably slower in developing countries than in the industrial economies concerned by Dornbusch's model. In our model with currency substitution, economic agents switch from domestic money balances to foreign ones rather than from non-monetary financial assets denominated in domestic currency to assets denominated in foreign currency. Furthermore, money (domestic and foreign) is held more extensively than other financial assets. Thus, we may imagine that information about the relative yield of domestic and foreign money circulates more slowly than information about the relative return of domestic and foreign bonds. Therefore, the reaction of the public should be slower. So, there exists a second kind of rigidity with regard to the money market, but we still suppose that the latter adjusts more quickly than goods markets. Moreover, this rigidity should be weaker in a highly dollarized economy.

The exchange rate equation is derived from that of domestic money demand, which includes the expected exchange rate depreciation, i.e.:

$$m - p = fy - li - j\,(\Delta e)^a \qquad (10)$$

where the coefficient j denotes the elasticity of substitution between domestic and foreign currency according to the expected rate of appreciation of the foreign currency.

By using equation (6) which defines the expectation of exchange rate change, we can express the nominal exchange rate according to the expected change in the exchange rate and to its long-run level:

$$e = -\frac{1}{q}(\Delta e)^{a} + \bar{e} \qquad (11)$$

The money demand expressed in (10) allows us to express the expected change in the exchange rate according to the nominal quantity of money, the real income level, the interest rate and the price level:

$$(\Delta e)^{a} = -\frac{1}{j}(m - p - fy + l\,i) \qquad (12)$$

This yields:

$$e = \frac{1}{qj}(m - p - fy + l\,i) + \bar{e} \qquad (13)$$

Finally, it appears from (13) that[6]:

$$\frac{de}{dm} = 1 + \frac{1}{j\,q} > 1 \qquad (14)$$

By comparing equation (9) from Dornbusch's model and equation (14), we see that the overshooting effect of the exchange rate depends on the speed of adjustment of goods prices (q) as in Dornbusch's model, and on the elasticity of substitution between domestic and foreign money according to the expected rate of appreciation of the foreign currency (j) instead of the interest rate semi-elasticity of the money demand (l). If this elasticity j is high, a given growth in the domestic

[6] Here, domestic prices, national income and domestic interest rate are rigid in the short-term period.

money supply will require a low expected appreciation of the exchange rate in order to restore money market equilibrium, and thus exchange rate overshooting will be low.

3. Econometric estimation of exchange rate dynamics in three developing countries: Ghana, Paraguay and Uruguay

As we have already seen, very few studies about exchange rate determination concern developing countries, except McNown and Wallace (1994) for Argentina, Chile and Israel[7] and Makrydakis (1998) for South Korea[8]. For each country they study, McNown and Wallace (1994) find at least one long-term relationship between the variables of interest (nominal exchange rate, relative money supply, relative income and relative interest rate) but the estimated coefficients seldom have the right sign. Moreover, the short-term dynamics are not considered. Makrydakis (1998) examines the monetary model of the exchange rate between the Korean won and the U.S. dollar. He finds three long-term relationships between these variables and he concludes in favour of the validity of the monetary model as a valid explanation of the long-run nominal won-dollar exchange rate. Then he wants to know whether the flexible-price model better explains the won-dollar exchange rate than the Dornbusch's sticky price model, basing on long-term elasticities. However, both variants of the monetary approach produce the same long-run conclusions. The differences between the two are only observable in short period through the interest rate semi-elasticity of the exchange rate. Therefore, the study of short-term

[7] The data are of monthly frequency. The relevant time periods are 1977:3-1986:12 for Argentina, 1973:6-1985:6 for Chile and 1979:1-1998:10 for Israel.
[8] The data are of monthly frequency spanning the period 1980:1 to 1995:12.

dynamics, i.e. an error-correction model, is necessary if one wants to distinguish between these two models.

In what follows, we will consider the monetary model with currency substitution described above, with data relative to Ghana, Paraguay and Uruguay. We will analyse long-term relations between the exchange rate and its determinants, but also short-term dynamics. First, we briefly present the studied countries, estimation method and data properties.

3.1. Countries choice

In order to test the monetary model with currency substitution we selected three developing countries that have experienced independently floating exchange rate regimes according to IMF official classification[9] for several years and for which sufficient data are available. The countries examined and relevant time periods are Ghana (1987-1998[10]), Paraguay (1989-1997) and Uruguay (1982-1992). In each of these three countries, at the time of the adoption of this exchange rate regime, the nominal exchange rate was sharply depreciated in terms of the U.S. dollar. Thus, the Ghanaian cedi in the first quarter of 1987, like Uruguayan peso in the fourth quarter of 1982, was depreciated by more than 44%, and in the first quarter of 1989 the Paraguayan guarani was depreciated by more than 27%. These depreciations are explained by the extent of the overvaluation that existed before the change in the exchange rate regime (Ghana and Paraguay abandoned a system of an exchange rate fixed to the dollar whereas Uruguay abandoned a system of "tablita"). However, after the first quarter of free floating, the exchange rate of each one of these three

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[9] It is thus a *de jure* classification and not a *de facto* one like that proposed in particular by Levy-Yeyati and Sturzenegger (2000). However, according to the latter, Paraguay and Uruguay had a floating exchange rate regime for the period studied whereas the results for Ghana show that for certain years there has been some interventions of the authorities.

[10] Ghana has maintained an independently floating exchange rate regime since 1998, but some data necessary for further analysis was not available after this year.

countries continued to depreciate for the entire period that this regime was maintained: between 1987 and 1998, the average quarterly depreciation of the cedi was 6.59%, between 1989 and 1997 that of the guarani was 2.15% and finally, between 1983 and 1992 that of the peso was 13.26%[11] (see Table 1). These trends primarily reflect the macroeconomic evolution of each of these countries since during the relevant periods, the yen and the mark appreciated in terms of the dollar. Table 1 also allow us to note that the quarterly instability of the cedi, guarani and peso was significant (7.82% for the cedi between 1987 and 1998, 4.09% for the guarani between 1989 and 1997 and 7.36% for the peso between 1983 and 1992), but slightly lower than that of the yen and the mark over corresponding periods[11].

Insert Table 1

The importance of domestic holdings of foreign currency in Uruguay is considerable. In 1982, the ratio of foreign currency deposits to M3[12] had already reached 60% (Savastano, 1996) and in 1992, it was near 80% (Baliño et al., 1999). This phenomenon also exists in the two other countries, even if it is much lower. In Paraguay, dollarization measured by the ratio of foreign currency deposits to M2, increased from nearly 25% in 1991 to 40% in 1997, whereas in Ghana, this ratio was on average around 18% between 1993 and 1998 (IMF, *Staff Country Reports* various issues). That dollarization explains exchange rate volatility appears to be a more likely explanation than that of Dornbusch since, in each of these three countries, there is no perfect capital mobility. Indeed, in Ghana and Paraguay, payment

[11] The trend evolution of the exchange rate is an average growth rate calculated around a deterministic trend ($e_t=ba^t$ i.e. $loge_t=logb+t.loga$). Instability is calculated as the average absolute deviation of the exchange rate from this trend (Coppock, 1977). We express this instability in percentage change.
[12] M3 is defined as the domestic monetary stock i.e. monetary stock without foreign currency and without foreign currency deposits.

restrictions existed on capital accounts over the relevant periods (IMF, *Report on Exchange Arrangements and Exchange Restrictions* various issues). Turning to Uruguay, even if such restrictions do not exist, domestic assets cannot be regarded as being perfect substitutes for foreign assets because of the institutional environment.

3.2. Estimation method

Tests of the long-run relationship between the exchange rate and the monetary variables which rely on the Engle-Granger (1987) two-step methodology suffer from a number of deficiencies. Thus, in order to test for co-integration, we use the multivariate co-integration technique proposed by Johansen (1988) and Johansen-Juselius (1990). The Johansen method applies the maximum likelihood procedure to determine the presence of co-integration vectors in non-stationary series. This technique is superior to the Engle-Granger method because it provides estimates of all the co-integrating vectors that exist within a vector of variables and offers a test statistic for the number of co-integrating vectors.

The Johansen method commences from a standard vector auto-regression (VAR) of the form:

$$X_t = \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \ldots + \Pi_k X_{t-k} + m + gt + yD_t + e_t, \qquad t=1,\ldots,T \qquad (15)$$

in which the elements of X_t ($\{e_t, m_t, m_t^*, y_t, y_t^*, i_t, i_t^*\}$) are $I(1)$, and m = constant term, t = trend, D_t = seasonal dummies and e = error term.

By lagging (15) and adding and subtracting $\Pi_i X_{t-i}$ for $i=1,\ldots,k-1$ on the right hand side, we can obtain a stationary system. This is the error-correction model, i.e. an equilibrium model which uses the lagged residuals from the co-integrating regressions in combination with short-run dynamics to adjust the model towards long-run equilibrium :

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-k} + m + gt + yD_t + e_t , \qquad t=1,\ldots,T \qquad (16)$$

where G_i are the dynamic vector parameters of the model and, the Π matrix contains the long-run parameters[13]. This Π matrix is the product of both the long-run relationships between the variables (*b'* matrix which contains the co-integrating vectors) and their error-correction effects (*a* matrix which contains error-correction parameters).

The estimation procedure is as follows:

(i) determination of the lag length *k* for the VAR and of the structural form of the deterministic component (constant and trend)

(ii) determination of the rank *r* of the Π matrix (i.e. test for the number of co-integrating vectors)

(iii) analysis of the significant co-integrating vector(s)

(iv) analysis of the short-term dynamics

The implementation of the co-integration method allows us to distinguish between the process of long-run equilibrium exchange rate determination and short-run exchange rate dynamics. Thus, validity of the monetary exchange rate model can be tested at two stages with this method. On the one hand, the existence of a co-integration relationship between the exchange rate and its determinants as described in relation (5) should validate monetary theory as a long-run theory. We will test proportionality between the exchange rate and money stock (domestic and foreign), rather than simply impose it.

On the other hand, according to the Granger representation theorem (Granger, 1987), if a co-integrating relationship exists between a series of *I*(1) variables, then a

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[13] $\Gamma_i = -(\mathrm{I} - \Pi_1 - \ldots - \Pi_i)$ and $\Pi = (\mathrm{I} - \Pi_1 - \ldots - \Pi_k)$

dynamic error-correction representation also exists. Thus, this model should validate overshooting theory. This is a representation of an auto-regressive distributed lag in $\{e_t, m_t, m_t^*, y_t, y_t^*, i_t, i_t^*\}$. But the general form of the dynamic exchange rate equation can be written as follows:

$$\Delta e_t = \sum_{i=1}^{k-1} t_{1,i}\Delta e_{t-i} + \sum_{i=0}^{k-1} t_{2,i}\Delta m_{t-i} + \sum_{i=0}^{k-1} t_{3,i}\Delta m_{t-i}^* + \sum_{i=0}^{k-1} t_{4,i}\Delta y_{t-i} + \sum_{i=0}^{k-1} t_{5,i}\Delta y_{t-i}^* + \sum_{i=0}^{k-1} t_{6,i}\Delta i_{t-i}$$
$$+ \sum_{i=0}^{k-1} t_{7,i}\Delta i_{t-i}^* + d_1 ec_{t-k}^1 + ... + d_r ec_{t-k}^r + m + gt + y D_t + e_t$$

(17)

where $ec_{t-k}^1, ..., ec_{t-k}^r$ denotes the co-integrating vectors normalized on e. Thus, a positive value of the error-correction term $(ec_{t-k} = e_{t-k} - \overline{e})$ implies that the exchange rate is above its long-run value in period *t-k*, and will tend to reduce in the next period or in other words to appreciate (d is negative). The coefficient on this term depends on the speed of adjustment of the exchange rate towards its long-run equilibrium value, i.e. rigidity level on goods market. However, whatever the speed of the adjustment, existence of an error-correction model should allow us to implicitly reject the pure flexible price monetary model which suggests no short-term disequilibrium (ec_{t-k}=0).

Turning to the short-term dynamics between the exchange rate and the domestic interest rate (t_6), it should not be decisive because of the short-term rigidity of the interest rate. More precisely, the coefficient in front of this variable (expressed in change since it is the error-correction model) should not be significant or possibly positive as in the long-run, while the coefficient in front of the foreign interest rate (t_7) should be negative. On the other hand, in a world of perfect capital mobility, i.e. according to Dornbusch's model, the coefficients in front of the domestic and foreign interest rate should be respectively negative and positive and higher than one in absolute value (see equation (8)). Indeed, in this model, the instantaneous change of exchange rate following a change in monetary policy is explained by the discrepancy between the domestic interest rate and the foreign interest rate. Thus, these coefficients should allow us to validate one or the other of these two models. We will also observe the coefficient in front of the domestic money supply change (t_2). Indeed, we expect that it is larger than one in absolute value (see equation (13) of our model) or at least that the short-term money elasticity of the exchange rate is larger than that for the long term. It could be interpreted as an evidence of the overshooting phenomenon. Finally, one expects that the impact of the change in foreign money supply be exerted mainly through the long-term exchange rate, and thus by the difference to this rate in the short-run (i.e. ec_{t-k}).

In the following sections, we will estimate the error-correction model. However, it is first necessary to determine the order of integration of the series used ($\{e_t, m_t, m_t^*, y_t, y_t^*, i_t, i_t^*\}$).

3.3. Data definitions and characteristics

The data for this study are all taken from the International Monetary Fund's *International Financial Statistics* database. They are of quarterly frequency, spanning the period of the freely floating exchange rate regime for each country. The United States is the base country (foreign country). The nominal exchange rate is units of domestic currency per unit of U.S. dollar. M1 is the measure used for the money supply. Thus, a rise in the domestic interest rate should reduce the domestic money demand, as in the theoretical model. We measure income as the GDP at constant prices (base year 1990) which are only available on a quarterly basis for the United States. For Ghana, Paraguay and Uruguay we only have annual data. We thus used an interpolation method[14] in order to obtain quarterly data. Finally, the domestic interest rate is a savings deposit rate whereas the foreign interest rate is a money market rate. Seasonal dummies also were added, as the series are seasonally unadjusted.

Prior to testing for co-integration, we need to examine the time series properties of the variables. Indeed, for variables to be co-integrated, they must be integrated of the same order, that is they become stationary after differentiating each time series the same number of times. Then, the orders of integration of the series were determined using an augmented Dickey-Fuller test (Dickey and Fuller, 1981; Said and Dickey, 1984). In Appendix A, our tests for a unit root indicate that all series used, i.e. exchange rate, money supply, income and interest rate and their foreign counterparts are $I(1)$ or $I(1,t)$ processes for the relevant periods. However, there are three exceptions, exchange rate and domestic income for Paraguay and domestic income for Uruguay. These three series are trend-stationary. Nevertheless, it has been suggested that augmented Dickey-Fuller methodology does not test adequately for the existence of deterministic trend-stationary series. Thus, in what follows, we will treat these series as first-difference stationary. The possible existence of an error-correction model should confirm our opinion.

[14] The regressors used for this interpolation are exports (X) and imports (M), available on a quarterly basis. The estimation results obtained with annual data are as follows (standard deviations are in parentheses):

$$\text{Ghana}: y = \underset{(0.699)}{25.850} + \underset{(0.006)}{0.020}\ trend + \underset{(0.015)}{0.029}\ X + \underset{(0.018)}{0.024}\ M$$

$$\text{Paraguay}: y = \underset{(0.512)}{21.467} + \underset{(0.007)}{0.033}\ trend + \underset{(0.055)}{0.020}\ X + \underset{(0.042)}{0.011}\ M$$

$$\text{Uruguay}: y = \underset{(2.057)}{19.690} + \underset{(0.081)}{0.054}\ trend - \underset{(0.114)}{0.232}\ X + \underset{(0.133)}{0.181}\ M$$

3.4. Co-integration analysis and the long-run exchange rate

In order to implement the Johansen (1988) procedure, a lag length must be chosen for the VAR. According to Dornbusch's model, we should expect a rapid reaction of the exchange rate after a monetary shock and thus introduce just one lag. But we have noted that in developing countries, reaction could be slower: therefore, we chose to introduce two lags in the VAR system for each of the three countries ($k=2$). Because of the dimension of our data, we could not introduce more lags. However, with two lags, the residuals in any equation proved to be white noise (see Appendix B). Thus, we retain this specification. At this stage, we must choose how to characterize the deterministic component of the model, which consists of a constant and a trend. We compare the trace statistic for each possible specification and it appears that a constant in both the levels of the vector X_t and in the co-integrating vector(s), and a deterministic linear trend in the co-integrating vector(s) are needed (see Appendix C). The presence of this trend in the long-term model can be explained by the impact of the Balassa-Samuelson effect on the PPP condition (cf. *supra*).

Now, we can determine the number of co-integrating vectors. It is the rank[15] of the Π matrix that determines whether there are any significant co-integrating vectors between the variables of the vector X_t. In order to determine this rank, we use the trace test[16]. In Table 2 we report the trace statistics. These indicate the presence

[15] If the Π matrix has zero rank, it means that Π contains no co-integrating vectors. Thus, there is no long-run relationship in the data. The appropriate model will be a VAR in first-differences. If Π is of full rank n, it means that all the variables in X_t are stationary in level. Finally, if Π has reduced rank ($0<r<n$), there are $r<n$ co-integrating vectors in b matrix.

[16] Osterwald-Lenum (1992) provides the appropriate critical values for this co-integration test (see Appendix 2 for the test statistic). We start with the null hypothesis that the Π matrix has zero rank (H_0: $r = 0$) against the alternative hypothesis that $r \geq 1$. If we can not reject the null hypothesis, it means that there are no co-integrating vectors. If we reject H_0, it means that there are one or more co-integrating vectors. We therefore redefine the null as H_0: $r \leq 1$. If we do not reject this hypothesis, it means that there is one co-integrating vector. If we reject H_0, it means that there is more than one co-integrating vector. We continue the procedure until H_0 is not rejected.

of two statistically significant co-integrating vectors among the series for Ghana ($r=2$), five for Paraguay ($r=5$) and four for Uruguay ($r=4$).

Insert Table 2

The values of the coefficients in these co-integrating vectors are reported in Tables 3 and the significant co-integrating vectors are given economic meaning using normalization on the log of the exchange rate. These results lead us to conclude that the monetary model should be considered at least as a long-run representation of the behaviour of exchange rates for each country studied over the relevant periods.

Insert Table 3A

Insert Table 3B

Insert Table 3C

Having established the existence of co-integration, we can proceed with testing the restrictions on the coefficients of the co-integrating vectors, concerning the long-run proportionality relationship between the exchange rate and money supply (domestic and foreign). The tests are conducted on two co-integrating vectors in the case of Ghana, five vectors in the case of Paraguay and four in the case of Uruguay. The results, which are presented in Table 4, indicate that the two restrictions are rejected at the 5% significance level.

However, the signs of the coefficients of the vector corresponding to the largest eigenvalue are close to those predicted by economic theory if we except foreign money supply and domestic income for Ghana and foreign money supply for

Paraguay (see line 1 in Tables 3). Moreover, we can observe that the trend shows an appreciation of the long-term exchange rate in the case of Ghana and Paraguay as predicted by the Balassa-Samuelson effect. Then, for each country, we selected this vector as representative of the long-run exchange rate.

Finally, our findings are as favourable to the monetary model as those of MacDonald and Taylor (1993, 1994)[17] who study the mark-dollar and the sterling-dollar exchange rates, and those of Choudhry and Lawler (1997)[18] who study the Canadian dollar-U.S. dollar exchange rate. Thus, we think that the nominal exchange rate of each of the three countries studied has a long-term dynamics similar to that of the exchange rate of the industrial countries. It means that independent floating can at least work in developing countries as well as in industrial countries.

Insert Table 4

With regard to adjustment coefficients (a), these measure the speed of the short-run response to a disequilibrium in endogenous variables in the system. We focus on the first co-integrating vector identified as an exchange rate equation. The first coefficient in a matrix (i.e. a_{11}) represents the speed at which the exchange rate converges to its long-run equilibrium and the negative coefficient implies that lagged excess depreciation induces an appreciation of the current exchange rate. Its numerical value for Paraguay and Uruguay implies rapid adjustment of the exchange

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[17] MacDonald and Taylor (respectively [1993] and [1994]) apply the Johansen procedure to the mark-dollar exchange rate and to the sterling-dollar exchange rate using monthly data (1976:1-1988:12). They find evidence in favour of the existence of up to three significant co-integrating vectors between the exchange rate, relative money supply, relative income and relative interest rates. They also show that coefficient restrictions are rejected when imposed on the full set of the co-integrating vectors, although at least one of the significant co-integrating relationships is not greatly different from the predictions of the monetary model.

[18] Choudhry and Lawler (1997) apply the Johansen procedure to the Canadian dollar-U.S. dollar exchange rate using monthly data (1950:10-1962:05). They find evidence in favour of the existence of one significant co-integrating vector between the exchange rate, relative money supply, relative income and relative interest rates. Despite the rejection of the unit coefficient restrictions on the money supply terms and despite the wrong sign of the coefficient relating to the Canadian income, they conclude in favour of the validity of the monetary approach as a long-run theory of the exchange rate.

rate (approximately 80 percent in a quarter). It suggests that rigidity on goods market is short-term stickiness. In the Ghanaian case, only 19% of a deviation is corrected in one quarter.

3.4. Short-run dynamics adjustment

We demonstrated in the previous section that, for the exchange rates we studied and over the relevant periods, co-integration relationships exist and one of them corresponds to the monetary approach exchange rate equation. Now, we can seek to analyse short-term dynamics through the error-correction model. In our case, this model is a system of seven dynamic equations since X_t includes seven variables. But the weak exogeneity property could allow us to model a single equation that captures the short-run exchange rate dynamics without loss of information. Thus, given that long-run relationships have been established, we wish to investigate whether the error-correction terms from the estimated co-integrating vectors enter each dynamic equation significantly. In fact, we wish to know whether $\Delta m_t, \Delta m_t^*, \Delta y_t, \Delta y_t^*, \Delta i_t, \Delta i_t^*$ are weakly exogenous with respect to Δe_t. If this assumption of weak exogeneity is not accepted for all the variables, we will be able however to only estimate the exchange rate dynamics by the method of instrumental variables.

In order to test the presence of weak exogeneity, we just need to impose restrictions on the a matrix. The ith variable is exogenous if the corresponding row of a is zero (see Johansen, 1992). The null hypothesis of this test is the existence of weak exogeneity. If the null is not rejected, disequilibrium in the co-integrating relationship does not feed back onto that variable. Appendix D reports the results of χ^2 tests. It appears that weak exogeneity is only accepted for domestic income and foreign interest rate in the case of Ghana, foreign income in the case of Paraguay and foreign income and foreign interest rate in the case of Uruguay.

Consequently, estimation of the error-correction model is effected in three stages. In the first, we estimate exchange rate dynamics (see equation (17)) by the ordinary least squared method. But not all the coefficients in this equation may be statistically significant, and greater efficiency may be gained by eliminating non-significant variables. Thus, we eliminated the non-significant explanatory variables gradually and individually and we obtained equation (a) in Tables 5 (for each country, the equation with all the variables and all the lags is in Appendix E). However, we retain all terms of error-correction, whatever their significance.

Then, we re-estimated this equation using the instrumental variables method, since we saw that certain variables were not weakly exogenous (equation (b) in Tables 5). The instruments used are the current and lagged variables not included in the model, because of their non-significance (see Adam, 2000).

Finally, we eliminated non-significant endogenous variables (equation (c) in Tables 5). Our comments are based on the results of this last estimate.

Results from the error-correction model are presented in Table 5. In the three cases, the lagged error-correction term ec_{t-2}^{1} is significant at the 5% level. This, then, confirms the existence of an error-correction model. If the exchange rate and the domestic income in the case of Paraguay and if the domestic income in the case of Uruguay were trend-stationary rather than first-difference stationary, this coefficient would not be significant. This confirms our first opinion concerning these time series properties.

In addition, the negative sign of the error-correction term implies that the exchange rate appreciates (depreciates) in the subsequent quarter in response to an excess depreciation (appreciation). There is then an overshooting phenomenon in the exchange rate in the short-run which is corrected in the long-run.

The size of the coefficient of this error term shows that in Paraguay and Uruguay, almost all the adjustment towards long-run equilibrium takes place in one quarter as we had previously noted. Therefore, adjustment of the exchange rate towards its long-term equilibrium is quite rapid. In addition, it would seem that this speed is higher in highly dollarized economies. This phenomenon is larger in Uruguay, followed by Paraguay and Ghana and the coefficient of the error term is also larger for Uruguay, followed by Paraguay and Ghana. This can be explained by the fact that highly dollarized economies are those which suffered from chronic inflation (high and durable) and subsequently economic agents are used to adapt the goods price rapidly to any market disequilibrium.

Finally, the coefficient in front of the current change of the domestic interest rate is never significant. Only the coefficient in front of the lagged change of the domestic interest rate for Ghana is significant and positive. These results do not fit the conclusion of Dornbusch's model and then, the overshooting mechanism is probably better explained by currency substitution. Indeed, the coefficient in front of domestic money supply is significantly superior to one in the case of Uruguay. Although this is not the case for the two other countries (even though the standard deviation of the estimated coefficient is high for Ghana), this short-term elasticity remains significant (at the 10% level for Ghana) and positive and, in particular, larger than that of the long-term for Ghana. Finally, we can observe that the domestic money supply affects the exchange rate without lag. This finding is in conformity with the assumption of rapid reaction of economic agents concerning the required composition of their portfolio.

Insert Table 5A

Insert Table 5B

Insert Table 5C

4. Conclusion

In this paper, we analysed the validity of the monetary exchange rate model with currency substitution for three developing countries, Ghana, Paraguay and Uruguay, under the assumptions of long-term price flexibility, controls on capital accounts and especially currency substitution. We used Johansen (1988) and Johansen and Juselius (1990) methodology concerning time series data. We used a quarterly bilateral exchange rate expressed in terms of U.S. dollar. For each country, our results showed some support to the monetary model, interpreted as a long-run model, since we found evidence of at least one co-integration relationship between the exchange rate, relative money supply, relative income and relative interest rates. As a whole, estimated coefficients of the most significant co-integrating vector are close to of those predicted by economic theory, even if they are not entirely in conformity. That suggests nevertheless that macroeconomic fundamental variables can help to explain the nominal exchange rate in the long-run. Therefore, the results seem rather attractive.

Then, using these co-integrating vectors, we estimated the short-term dynamics of the exchange rate. The results of the error-correction models showed that, following a monetary shock, exchange rates overshoot their long-run level. This is particularly true for Uruguay where it appeared without ambiguity that in the short-run, an increase in the domestic money supply involved a more than proportional change in the nominal exchange rate. The results also showed that the speed of adjustment of the exchange rate to its long-run equilibrium could be relatively high, since in two of the countries studied, Paraguay and Uruguay, an exchange rate deviation from its long-run level is almost corrected after only one quarter.

We explained the overshooting mechanism by the existence of a dollarization phenomenon in the economies studied rather than by Dornbusch's model dynamics. Indeed, the introduction of currency substitution in the money demand led us to show the existence of an overshooting mechanism of the exchange rate in the short-run following an exogenous monetary shock. Consequently, the choice of an independently floating exchange rate regime in a context of currency substitution should induce short-term exchange rate volatility, even if capital is not perfectly mobile. However, exchange rate volatility not only has a negative impact on international trade growth, it also weakens the domestic banking system. Thus, if dollarization could promote the domestic financial sector (while allowing domestic banks to compete with off-shore establishments) or could be part of the re-monetarization of the economy following high price volatility and capital outflows, it also presents risks for developing countries with independently floating exchange rate regimes since it increases money demand instability and thus exchange rate volatility.

This is why currency substitution should be taken into account in the choice of an exchange rate regime. Of course, the speed of exchange rate adjustment to its long-run equilibrium seems quite high and it goes against the idea according to which an independently floating exchange rate regime cannot operate well in a developing country, being given its institutional and economic structures. However, the increase in exchange rate volatility supported by dollarization, suggests that adopting a fixed exchange rate regime could be a better choice in countries with currency substitution.

Appendix A. Augmented Dickey-Fuller Test Results

The augmented Dickey-Fuller equation test can be expressed as follows (allowing for a drift and a trend in the data generating process): $\Delta x_t = n + t + j x_{t-1} + \sum_{i=1}^{p} \Delta x_{t-i} + J_t$ where n = constant, t = trend, p = number of lagged differences and J = error term. Given the sample size for each country, we start with a maximum lag of four quarter, eliminating insignificant terms. The null hypothesis (H_0: $j = 1$) is that the variable in question is first-difference stationary, *I*(1) (or *I*(1,t) if a trend is necessary). Then, if the t-statistic is larger than the critical value (Dickey-Fuller, 1981, MacKinnon, 1990), the null hypothesis of non-stationarity can be rejected. ***, ** and * imply significance at 1%, 5% and 10% level respectively.

	Ghana [1987Q2-1998Q4]				Paraguay [1989Q2-1997Q4]				Uruguay [1983Q1-1992Q4]			
Variable	Trend	Lags	ADF Stat.	Diagnosis	Trend	Lags	ADF Stat.	Diagnosis	Trend	Lags	ADF Stat.	Diagnosis
e	yes	1	-1.57	*I*(1)	yes	3	-6.85***	*I*(0,t)	yes	2	-3.02	*I*(1)
Δe	no	0	-7.47***		…	…	…		no	1	-5.88***	
m	yes	4	-2.83	*I*(1)	no	1	-1.72	*I*(1,t)	yes	4	-2.72	*I*(1,t)
Δm	no	2	-7.58***		yes	2	-7.98***		yes	2	-6.95***	
m^*	yes	4	-2.31	*I*(1)	yes	4	-2.74	*I*(1)	yes	4	-2.18	*I*(1)
Δm^*	no	2	-5.13***		no	2	-4.47***		no	2	-5.22***	
y	yes	1	-2.81	*I*(1)	yes	4	-3.36*	*I*(0,t)	yes	4	-3.39*	*I*(0,t)
Δy	no	0	-10.49***		…	…	…		…	…	…	
y^*	no	1	0.96	*I*(1,t)	yes	2	-1.90	*I*(1,t)	yes	1	-3.08	*I*(1,t)
Δy^*	yes	0	-5.18***		yes	0	-5.02***		yes	4	-4.68***	
i	yes	1	-2.49	*I*(1)	yes	0	-1.18	*I*(1)	yes	0	-2.69	*I*(1)
Δi	no	0	-7.88***		no	0	-4.75***		yes	0	-5.90***	
i^*	yes	1	-2.38	*I*(1)	yes	0	-1.02	*I*(1,t)	yes	1	-1.85	*I*(1)
Δi^*	no	1	-2.94**		yes	0	-3.78**		no	0	-4.55***	

Appendix B. VCEM residual diagnostic statistics

	BJ (Bera Jarque's test) H$_0$: residuals are distributed normally	AR(1) (LM test) H$_0$: residuals are not auto-correlated	ARCH(3) (Engle's test) H$_0$: residuals are homoscedastic (of order 3)	W (White's test) H$_0$: residuals are homoscedastic
GHANA [1987Q2-1998Q4]				
$X_t = \{e_t, m_t, m_t^*, y_t, y_t^*, i_t, i_t^*\}$	10.151 [0.750]	0.949 [0.570]	…	862.630 [0.290]
e	2.677 [0.262]	0.375 [0.545]	0.612 [0.615]	32.454 [0.347]
m	0.404 [0.817]	0.386 [0.540]	0.237 [0.870]	24.947 [0.728]
m^*	0.691 [0.708]	0.0186 [0.893]	0.429 [0.734]	28.216 [0.559]
y	0.504 [0.777]	0.147 [0.704]	0.774 [0.521]	30.670 [0.432]
y^*	3.127 [0.209]	0.364 [0.552]	1.036 [0.396]	21.657 [0.866]
i	4.094 [0.129]	1.019 [0.322]	0.969 [0.425]	39.211 [0.121]
i^*	0.738 [0.691]	0.091 [0.765]	0.787 [0.514]	37.523 [0.162]

For the vector X_t, BJ is distributed as a $\chi^2(14)$, AR(1) as a F(49,80), and W as a $\chi^2(840)$.
For each component of the vector X_t, BJ is distributed as a $\chi^2(2)$, AR(1) as a F(1,27), ARCH(3) as a F(3,22) and W as a $\chi^2(30)$.
*** denotes significance at the 1% level and ** denotes significance at the 5% level.

	BJ	AR(1)	ARCH(3)	W
PARAGUAY [1989 Q 2-1997Q4]				
$X_t = \{e_t, m_t, m_t^*, y_t, y_t^*, i_t, i_t^*\}$	21.419 [0.090]	1.223 [0.320]	…	…
e	0.762 [0.683]	1.312 [0.270]	0.794 [0.525]	…
m	0.295 [0.863]	3.707 [0.073]	0.440 [0.729]	…
m^*	0.129 [0.938]	0.561 [0.466]	0.123 [0.944]	…
y	6.828 [0.033]**	0.036 [0.853]	0.178 [0.909]	…
y^*	1.166 [0.558]	10.233 [0.006]***	0.478 [0.705]	…
i	1.916 [0.384]	3.505 [0.081]	0.215 [0.884]	…
i^*	7.278 [0.026]**	1.880 [0.191]	0.748 [0.548]	…

For the vector X_t, BJ is distributed as a $\chi^2(14)$ and AR(1) as a F(49,19).
For each component of the vector X_t, BJ is distributed as a $\chi^2(2)$, AR(1) as a F(1,15) and ARCH(3) as a F(3,10).
*** denotes significance at the 1% level and ** denotes significance at the 5% level.
Insufficient data do not allows us to realize White's test.

	BJ	AR(1)	ARCH(3)	W
URUGUAY [1983Q1-1992Q4]				
$X_t = \{e_t, m_t, m_t^*, y_t, y_t^*, i_t, i_t^*\}$	12.912 [0.530]	2.230 [0.000]***	…	836.960 [0.520]
e	1.269 [0.530]	0.003 [0.954]	0.121 [0.946]	29.329 [0.500]
m	1.878 [0.391]	0.445 [0.513]	0.287 [0.834]	30.437 [0.443]
m^*	0.846 [0.655]	9.819 [0.005]***	0.610 [0.619]	33.104 [0.318]
y	0.255 [0.880]	0.723 [0.405]	0.674 [0.581]	30.986 [0.416]
y^*	4.036 [0.133]	2.950 [0.101]	0.463 [0.712]	30.306 [0.450]
i	2.434 [0.296]	0.168 [0.686]	0.185 [0.905]	36.348 [0.197]
i^*	2.572 [0.276]	1.625 [0.217]	0.105 [0.956]	30.316 [0.450]

For the vector X_t, BJ is distributed as a $\chi^2(14)$, AR(1) as a F(49,45), and W as a $\chi^2(840)$.
For each component of the vector X_t, BJ is distributed as a $\chi^2(2)$, AR(1) as a F(1,20), ARCH(3) as a F(3,15) and W as a $\chi^2(30)$.
*** denotes significance at the 1% level and ** denotes significance at the 5% level.

Appendix C. Trace Statistics for Alternative Specifications of Deterministic Components in the VECM

We need to know if a trend must enter in the VAR model. If a trend is necessary, we have to determine if it enters both the levels of the vectors X_t and the co-integrating vector(s). It is important to undertake this research because the method of defining the deterministic component influences the results relating to the number of significant co-integrating vectors and the estimation of these vectors.

The three possible specifications of the deterministic component are the following:

$H_1(r)$: the constant and the trend are unrestricted. This means they enter both the levels of the vectors X_t and the co-integrating vector(s)

$H_2(r)$: the constant is unrestricted whereas the trend is restricted. It only enters the co-integrating space.

$H_3(r)$: the constant is unrestricted and the trend is not present.

(we do not retain here the assumption according to which the constant would be restricted, without a trend, neither that according to which there would be neither constant, nor trend).

We distinguish between these specifications by comparing the trace statistic under each restriction. The trace statistic is defined as: $Trace = -T\sum_{i=r+1}^{n}\ln(1-l_i)$, where r = rank of the Π matrix ($0<r<n$), l_i = ith largest eigenvalue of the Π matrix, n = number of variables and T = time periods. This statistic is distributed as χ^2. The most likely specification is the one for which the trace statistic is larger.

	$H_1(r)$	$H_2(r)$	$H_3(r)$
GHANA [1987Q2-1998Q4]	170.89	181.79	163.99
PARAGUAY [1989Q2-1997Q4]	272.65	290.08	270.32
URUGUAY [1983Q1-1992Q4]	253.97	266.37	216.96

Appendix D. Weak exogeneity tests

	GHANA [1987Q2-1998Q4]	PARAGUAY [1989Q2-1997Q4]	URUGUAY [1983Q1-1992Q4]
m	$\chi^2(4)$ = 8.186 [0.017]**	$\chi^2(5)$ = 26.839 [0.000]***	…
m^*	$\chi^2(4)$ = 12.360 [0.002]***	$\chi^2(5)$ = 18.396 [0.003]***	…
y	$\chi^2(4)$ = 0.561 [0.755]	$\chi^2(5)$ = 16.340 [0.006]***	$\chi^2(4)$ = 28.449 [0.000]***
y^*	$\chi^2(4)$ = 6.410 [0.041]**	$\chi^2(5)$ = 3.306 [0.653]	$\chi^2(4)$ = 3.279 [0.512]
i	$\chi^2(4)$ = 9.897 [0.007]***	$\chi^2(5)$ = 13.981 [0.016]**	$\chi^2(4)$ = 18.412 [0.001]***
i^*	$\chi^2(4)$ = 0.656 [0.720]	$\chi^2(5)$ = 30.099 [0.000]***	$\chi^2(4)$ = 2.557 [0.635]

Notes: *** and ** indicate that the null hypothesis of weak exogeneity is rejected at the 1% and 5% significance levels respectively. We do not have the results for domestic and foreign money in Uruguay. However, the coefficients of the first two rows of the a matrix for Uruguay appear to be different from zero (cf. Table 3C). Therefore, m and m^* are not held as weakly exogenous.

Appendix E. Short-run error-correction model. Dependent variable $(\Delta e)_t$.

	GHANA [1987Q2-1998Q4]	PARAGUAY [1989Q2-1997Q4]	URUGUAY [1983Q1-1992Q4]
	(a) OLS	(b) OLS	(c) OLS
ec^1_{t-2}	-0.459*** (0.113)	-0.797*** (0.044)	-0.863*** (0.060)
ec^2_{t-2}	0.018 (0.016)	6^E-05 (0.072)	0.008 (0.061)
ec^3_{t-2}	…	-0.002 (0.016)	-0.019 (0.061)
ec^4_{t-2}	…	-2^E-04 (0.026)	-0.062 (0.094)
ec^5_{t-2}	…	-7^E-05 (0.001)	…
$(\Delta e)_{t-1}$	-0.224 (0.152)	-0.670*** (0.084)	-0.974*** (0.129)
$(\Delta m)_t$	0.231 (0.144)	0.070 (0.092)	0.180** (0.091)
$(\Delta m)_{t-1}$	0.122 (0.178)	0.193 (0.133)	0.015 (0.113)
$(\Delta m^*)_t$	0.010 (0.610)	0.595** (0.293)	-0.524 (0.334)
$(\Delta m^*)_{t-1}$	0.697 (0.568)	0.584** (0.267)	-1.160** (0.512)
$(\Delta y)_t$	0.544 (0.937)	-0.853 (0.634)	-0.296 (0.311)
$(\Delta y)_{t-1}$	1.262 (1.043)	-1.237 (0.931)	-0.436 (0.447)
$(\Delta y^*)_t$	-1.578** (0.776)	2.680** (1.188)	-3.610** (1.506)
$(\Delta y^*)_{t-1}$	2.689 (1.800)	1.672 (1.232)	-2.719 (1.894)
$(\Delta i)_t$	0.891*** (0.331)	0.328 (0.355)	0.121 (0.354)
$(\Delta i)_{t-1}$	1.889*** (0.331)	0.291 (0.391)	1.040* (0.541)
$(\Delta i^*)_t$	1.490 (1.496)	-4.085* (2.293)	1.107 (1.061)
$(\Delta i^*)_{t-1}$	-3.051* (1.625)	-1.787 (1.432)	-4.706*** (0.979)
constant	-132.802*** (43.207)	-53.175* (29.049)	44.806 (30.393)
R^2	0.69	0.99	0.96
DW	1.94	2.28	1.77
BJ	8.321 [0.016]**	0.036 [0.982]	6.689 [0.035]**
AR(1)	1.017 [0.379]	0.331 [0.803]	0.743 [0.542]
ARCH(3)	0.386 [0.765]	0.228 [0.874]	0.239 [0.868]

Notes: Coefficients on seasonal dummy variables are not reported. Figures in parentheses are standard errors with White correction. *** represents significance at the 1% level, ** represents significance at the 5% level and * represents significance at the 10% level. DW denotes Durbin-Watson statistic, BJ is Bera-Jarque's test, AR(1) is LM-test and ARCH(3) is Engle's test. In regression (a) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,25) and ARCH(3) as a F(3,22). In regression (b) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,10) and ARCH(3) as a F(3,7). In regression (c) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,16) and ARCH(3) as a F(3,13).

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Table 1
Quarterly percentage change and quarterly instability of the Ghanaian cedi, Paraguayan guarani, Uruguayan peso, Japanese yen and German mark

	Quarterly percentage change of the Ghanaian cedi	Quarterly percentage change of the Japanese yen	Quarterly percentage change of the German mark
1987Q2-1998Q4	6.59%	-0.53%	-0.21%
	Quarterly percentage change of the Paraguayan guarani		
1989Q2-1997Q4	2.15%	-1.00%	-0.29%
	Quarterly percentage change of the Uruguayan peso		
1983Q1-1992Q4	13.26%	-1.92%	-1.74%
	Quarterly instability of the Ghanaian cedi	Quarterly instability of the Japanese yen	Quarterly instability of the German mark
1987Q2-1998Q4	7.82%	9.31%	6.50%
	Quarterly instability of the Paraguayan guarani		
1989Q2-1997Q4	4.09%	8.16%	6.25%
	Quarterly instability of the Uruguayan peso		
1983Q1-1992Q4	7.36%	10.58%	9.09%

Table 2
Co-integrating rank analysis: Eigenvalues (λ_r) and Trace Statistics

	GHANA [1987Q2-1998Q4]		PARAGUAY [1989Q2-1997Q4]		URUGUAY [1983Q1-1992Q4]	
	λ_r	Trace Statistic	λ_r	Trace Statistic	λ_r	Trace Statistic
r=0	0.6720	181.79***	0.9683	290.08***	0.9250	266.37***
r≤1	0.6232	129.40***	0.8069	169.30***	0.7944	162.79***
r≤2	0.4682	83.52	0.6792	111.75***	0.5907	99.51***
r≤3	0.3983	53.85	0.5477	71.96***	0.4989	63.78**
r≤4	0.3198	29.97	0.4182	44.19**	0.3560	36.14
r≤5	0.1618	11.86	0.3524	25.24	0.2306	18.54
r≤6	0.0730	3.56	0.2491	10.03	0.1825	8.06

Note: *** indicates significant at 1% level and ** indicates significant at the 5% level

Table 3A
Co-integration analysis of the exchange rate for GHANA [1987Q2-1998Q4]
(*b'* co-integrating vectors normalized on the exchange rate and *a'* adjustments vectors)

b' matrix (normalized on the exchange rate and *r*=2)							
e	*m*	*m**	*Y*	*y**	*i*	*i**	*trend*
1.000	**-0.321**	**-1.138**	**-4.284**	**-2.131**	**-2.787**	**0.677**	**0.047**
1.000	-12.310	21.540	42.262	44.340	11.660	81.690	-0.153
a' matrix (*r*=2)							
De	*Dm*	*Dm**	*Dy*	*Dy**	*Di*	*Di**	
-0.187	0.451	-0.088	0.009	-0.022	0.150	-0.003	
0.038	-0.077	0.166	0.010	-0.041	0.217	0.009	

Table 3B
Co-integration analysis of the exchange rate for PARAGUAY [1989Q2-1997Q4]
(*b'* co-integrating vectors normalized on the exchange rate and *a'* adjustments vectors)

b' matrix (normalized on the exchange rate and *r*=5)							
e	*m*	*m**	*y*	*y**	*i*	*i**	*trend*
1.000	**-0.241**	**-1.068**	**2.818**	**-3.844**	**-0.768**	**0.743**	**0.007**
1.000	-36.731	-68.955	581.781	-429.532	-135.578	-129.991	0.696
1.000	-5.112	-13.617	22.820	-23.875	18.049	-15.484	0.391
1.000	0.763	-0.741	-18.380	-20.731	-0.801	30.195	0.251
1.000	22.485	-38.562	-97.340	160.067	20.903	-140.321	-1.038
a' matrix (*r*=5)							
De	*Dm*	*Dm**	*Dy*	*Dy**	*Di*	*Di**	
-0.822	-0.469	-0.049	-0.050	0.002	-0.006	0.003	
-0.146	0.300	-0.083	0.046	0.006	-0.027	0.021	
-0.040	-0.989	-0.262	0.023	0.021	0.243	-0.006	
0.208	1.339	0.665	0.090	-0.004	0.696	0.097	
-0.452	-2.598	0.592	-0.096	-0.338	0.119	-0.030	

Table 3C
Co-integration analysis of the exchange rate for URUGUAY [1983Q1-1992Q4]
(*b'* co-integrating vectors normalized on the exchange rate and *a'* adjustments vectors)

b' matrix (normalized on the exchange rate and *r*=4)							
e	*m*	*m**	*y*	*y**	*i*	*i**	*trend*
1.000	**-0.046**	**1.760**	**0.245**	**-0.553**	**-0.345**	**3.323**	**-0.140**
1.000	-0.482	0.011	-7.208	-4.498	-12.669	-2.185	0.005
1.000	-0.747	3.342	0.045	-7.546	-3.606	11.881	-0.011
1.000	0.549	-1.298	1.693	5.635	-1.823	0.845	-0.243
a' matrix (*r*=4)							
De	*Dm*	*Dm**	*Dy*	*Dy**	*Di*	*Di**	
-0.810	0.237	0.015	0.123	-0.014	-0.064	0.010	
0.033	-0.001	-0.020	-0.061	-0.002	-0.011	0.002	
0.495	0.759	-0.505	0.026	-0.026	0.367	0.024	
-0.158	-0.645	0.015	-0.160	0.008	0.199	0.026	

Table 4
Results of the restrictions imposed on the monetary model

	GHANA [1987Q2-1998Q4]	PARAGUAY [1989Q2-1997Q4]	URUGUAY [1983Q1-1992Q4]
H_1 : proportionality between the exchange rate and the domestic money stock	18.081 [0.000]***	40.613 [0.000]***	38.218 [0.000]***
H_2 : proportionality between the exchange rate and the foreign money stock	10.619 [0.005]***	56.464 [0.000]***	14.353 [0.006]***

Notes : Test statistics are distributed as χ^2 (*kr*) where *k* is the number of restrictions and *r* is the number of co-integrating vectors. Critical values are in parentheses. *** means restriction rejection at a confidence level of 99%.

Table 5A
Short-run error-correction model for GHANA [1987Q2-1998Q4]
Dependent variable $(\Delta e)_t$

	(a) OLS	(b) IV	(c) IV
ec^1_{t-2}	-0.247*** (0.052)	-0.103 (0.174)	-0.274*** (0.093)
ec^2_{t-2}	0.008 (0.006)	-0.001 (0.023)	0.004 (0.009)
$(\Delta m)_t$ ♦	0.142 (0.088)	0.275 (0.343)	0.705* (0.371)
$(\Delta m^*)_t$ ♦	0.319 (0.354)	0.780 (2.346)	…
$(\Delta y^*)_t$ ♦	0.566 (0.843)	7.423 (6.276)	…
$(\Delta i)_t$ ♦	0.713*** (0.192)	0.579 (0.931)	0.591 (0.611)
$(\Delta i)_{t-1}$	1.239*** (0.243)	1.415** (0.605)	1.782*** (0.573)
Constant	-67.486*** (17.273)	-16.999 (53.060)	-62.688** (31.180)
R^2	0.49	…	…
DW	2.10	…	…
BJ	9.274 [0.010]***	2.360 [0.307]	2.869 [0.238]
AR(1)	0.429 [0.733]	0.382 [0.767]	1.634 [0.199]
ARCH(3)	0.412 [0.745]	0.666 [0.580]	0.661 [0.582]

Notes : Coefficients on seasonal dummy variables are not reported. ♦ denotes endogenous variables in instrumental variables regression. Figures in parentheses are standard errors, with White correction for OLS estimations. *** represents significance at the 1% level, ** represents significance at the 5% level and * represents significance at the 10% level. In regression (a) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,33) and ARCH(3) as a F(3,30). In regression (b) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,33) and ARCH(3) as a F(3,30). In regression (c) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,35) and ARCH(3) as a F(3,32).

Table 5B
Short-run error-correction model for PARAGUAY [1989Q2-1997Q4]
Dependent variable $(\Delta e)_t$

	(a) OLS	(b) IV	(c) IV
ec^1_{t-2}	-0.758*** (0.030)	-0.786** (0.373)	-0.740*** (0.046)
ec^2_{t-2}	0.005*** (0.001)	0.008 (0.021)	0.005*** (0.001)
ec^3_{t-2}	0.008 (0.009)	0.025 (0.052)	0.006 (0.008)
ec^4_{t-2}	-0.016 (0.016)	-0.013 (0.084)	-0.009 (0.014)
ec^5_{t-2}	-3^E-04 (0.001)	4^E-04 (0.008)	-3^E-04 (0.000)
$(\Delta e)_{t-1}$	-0.462*** (0.053)	-0.448 (0.605)	-0.391*** (0.087)
$(\Delta m)_t$ ♦	0.070 (0.062)	0.017 (2.865)	0.205** (0.095)
$(\Delta m^*)_t$ ♦	0.039 (0.295)	-2.532 (16.290)	…
$(\Delta y)_t$ ♦	0.182 (0.314)	1.581 (29.230)	…
$(\Delta i)_t$ ♦	0.081 (0.334)	0.727 (4.210)	…
$(\Delta i^*)_t$ ♦	-1.108 (0.812)	0.240 (5.123)	…
Constant	-64.779*** (16.181)	-55.199 (100.700)	-56.526*** (13.440)
R^2	0.98	…	…
DW	2.50	…	…
BJ	0.979 [0.613]	0.759 [0.684]	5.165 [0.076]*
AR(1)	1.136 [0.363]	0.267 [0.848]	1.267 [0.311]
ARCH(3)	0.290 [0.832]	0.638 [0.603]	0.115 [0.950]

Notes : Coefficients on seasonal dummy variables are not reported. ♦ denotes endogenous variables in instrumental variables regression. Figures in parentheses are standard errors, with White correction for OLS estimations. *** represents significance at the 1% level, ** represents significance at the 5% level and * represents significance at the 10% level. In regression (a) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,17) and ARCH(3) as a F(3,14). In regression (b) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,17) and ARCH(3) as a F(3,14). In regression (c) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,21) and ARCH(3) as a F(3,18).

Table 5C
Short-run error-correction model for URUGUAY [1983Q1-1992Q4]
Dependent variable $(\Delta e)_t$

	(a) OLS	(b) IV	(c) IV
ec^1_{t-2}	-0.758*** (0.112)	-1.199*** (0.415)	-0.977*** (0.208)
ec^2_{t-2}	-0.047* (0.028)	0.103 (0.137)	0.064 (0.085)
ec^3_{t-2}	0.083 (0.075)	-0.317 (0.435)	-0.290 (0.321)
ec^4_{t-2}	-0.019 (0.070)	0.300 (0.319)	0.142 (0.183)
$(\Delta e)_{t-1}$	-0.618*** (0.179)	-0.683* (0.368)	-0.684*** (0.249)
$(\Delta m)_t$ ♦	0.327*** (0.087)	1.590 (0.976)	1.190** (0.519)
$(\Delta m^*)_t$ ♦	-0.611* (0.352)	-2.504 (2.376)	-2.067 (1.456)
$(\Delta m^*)_{t-1}$	-0.975** (0.380)	-3.765 (2.656)	-2.993* (1.722)
$(\Delta y)_t$ ♦	0.071 (0.165)	0.054 (1.354)	…
$(\Delta i)_t$ ♦	0.068 (0.419)	-1.682 (2.182)	…
$(\Delta i^*)_{t-1}$	-3.916*** (1.208)	-3.188 (5.908)	-3.834 (2.713)
constant	31.643** (14.458)	-19.640 (70.200)	-7.915 (49.210)
R^2	0.85	…	…
DW	1.82	…	…
BJ	4.268 [0.118]	2.908 [0.234]	2.326 [0.313]
AR(1)	0.387 [0.764]	0.666 [0.582]	1.314 [0.293]
ARCH(3)	0.069 [0.976]	1.037 [0.399]	0.379 [0.769]

Notes : Coefficients on seasonal dummy variables are not reported. ♦ denotes endogenous variables in instrumental variables regression. Figures in parentheses are standard errors, with White correction for OLS estimations. *** represents significance at the 1% level, ** represents significance at the 5% level and * represents significance at the 10% level. In regression (a) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,22) and ARCH(3) as a F(3,19). In regression (b) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,22) and ARCH(3) as a F(3,19). In regression (c) BJ is distributed as a $\chi^2(2)$, AR(1) as a F(3,24) and ARCH(3) as a F(3,21).