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**“What Makes Currencies Volatile? An Empirical  
Investigation”**

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**NIPE WP 22/ 2009**

NÚCLEO DE INVESTIGAÇÃO EM POLÍTICAS ECONÓMICAS  
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# What Makes Currencies Volatile? An Empirical Investigation

Michael Bleaney · Manuela Francisco

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**Abstract** Real effective exchange rate volatility is examined for 90 countries using monthly data from January 1990 to June 2006. Volatility decreases with openness to international trade and per capita GDP, and increases with inflation, particularly under a horizontal peg or band, and with terms-of-trade volatility. The choice of exchange rate regime matters. After controlling for these effects, an independent float adds at least 45% to the standard deviation of the real effective exchange rate, relative to a conventional peg, but most other regimes make little difference. The results are robust to alternative volatility measures and to sample selection bias.

**Keywords** Exchange rate regimes · Inflation · Volatility

**JEL Classification** F31

## 1 Introduction

What makes currencies volatile? The empirical analysis of real exchange rate volatility is a relatively neglected area, even though the topic has long been a concern for academics and policy-makers.<sup>1</sup> Although volatility is known to be

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<sup>1</sup>Academics have debated whether real exchange rate volatility adversely affects trade and growth (e.g. Aghion et al. 2006; Clark et al. 2004). Policy-makers seem very reluctant to allow exchange rates to fluctuate freely (under 15% of countries currently do so according to the IMF), and frequently complain about them when they do allow them to do so.

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M. Bleaney (✉)

School of Economics, University of Nottingham, Nottingham NG7 2RD, UK  
e-mail: michael.bleaney@nottingham.ac.uk

M. Francisco  
World Bank, Washington DC, USA

M. Francisco  
University of Minho, Barga, Portugal

higher in economies with a low ratio of international trade to GDP and with lower per capita income (e.g. Bravo-Ortega and di Giovanni 2006), we lack systematic studies of a large number of countries, or quantitative estimates of how much volatility can be reduced by various forms of intervention.

One strand of investigation in previous research has compared volatility in the advanced countries under the Bretton Woods system and subsequently. The clear conclusion is that real exchange rate volatility has increased, even though other dimensions of macroeconomic volatility have not (Baxter and Stockman 1989; Flood and Rose 1995; Mussa 1986; Rose 1996), a phenomenon identified by Obstfeld and Rogoff (2000) as one of the six major puzzles of macroeconomics. Using a century of data for real exchange rate volatility against the US dollar for the UK, Canada, Japan and France, Hasan and Wallace (1996) also find significantly greater volatility under floating rates.

These findings suggest that the exchange rate regime matters. It may, however, matter less than this implies if many of a country's trading partners are floating against one another, as is currently the case. In these circumstances, a single-currency peg may not achieve much greater stability than a float, and a basket peg that better reflects the pattern of countries' trade may achieve greater real effective exchange rate stability than a single-currency peg. It is also very much of an open question how much volatility can be reduced by managing a float. This is the type of issue that we investigate.

There are some studies of exchange rate volatility in cross-country samples. Klein and Shambaugh (2008) report significantly lower volatility in pegs than in floats. Devereux and Lane (2003) examine monthly nominal bilateral exchange rate volatility in a large sample of country pairs over the period 1995 to 2000, and find volatility to be negatively related to trade flows, business cycle asymmetry, financial development and external debt, and positively related to the product of the countries' GDP. Hau (2002) reports real effective exchange rate volatility to be negatively related to the ratio of trade to GDP. Bravo-Ortega and di Giovanni (2006) find volatility to be negatively related to trade openness and per capita GDP, and positively related to trade taxes and an index of remoteness (trade-weighted distance from the rest of the world). They conclude that trade costs (transport costs plus taxes) raise volatility. Hausmann et al. (2006) focus on the much higher real effective exchange rate volatility of developing countries in annual data over the period 1980–2000. They find that the difference cannot be explained by the greater variance of terms-of-trade shocks.

One variable that has typically not featured in these studies is inflation. We show that, even at low to medium levels, inflation is quite important for real effective exchange rate volatility, especially under some form of peg or band. Exchange rate regime influences have also been rather neglected.<sup>2</sup>

A distinctive feature of the present study is that we seek to identify the influence of the exchange rate regime in some detail. We use the IMF's current *de facto* methodology for identifying regimes. We then measure real effective exchange rate volatility over periods when there are no regime switches. This inevitably means that

<sup>2</sup> Hau (2002) and Rose (1996) are two studies that do allow for regime effects. Klein and Shambaugh (2008) focus exclusively on regime effects.

the episodes over which volatility is measured are of unequal length, but we show by experimenting with alternative minimum lengths that this makes little difference to the results. We also test the robustness of the results by using several different measures of volatility and by varying the threshold above which high-inflation observations are excluded. We use a sample of 90 countries over the period 1990–2006.<sup>3</sup> We show that regime effects are important and provide a quantitative estimate of them.

The remainder of the paper is organized as follows. After an informal theoretical discussion in Section 2, the different volatility measures are presented in Section 3. Section 4 discusses the classification system for exchange rate regimes. After some preliminary data analysis in Section 5, the main empirical results are presented in Section 6. Section 7 concludes.

## 2 Theoretical considerations

The micro-founded models currently popular in international macroeconomics assume monopolistically competitive firms and incorporate downward-sloping demand functions for a country's goods in international markets (e.g. Bergin 2006). It is a natural step from there to the concept of an equilibrium real exchange rate, to which the actual rate tends to revert. At the equilibrium, net trade will be at a value that, after adding net property income flows, will be consistent with a medium-run equilibrium in the current account balance. This is not a full stock equilibrium, because the country will normally be accumulating or losing net external assets, which will impart some trend to net property income flows and therefore to the equilibrium level of net trade and the real exchange rate. The medium-run equilibrium in the current account balance will reflect the savings and investment propensities of the country, which in turn will be influenced by its level of development, demographics, the fiscal balance and institutional and other characteristics (see Williamson and Mahar 1998, for a fuller discussion). More formally, let (the logarithm of) the real exchange rate (*REER*) consist of an equilibrium (*EQU*) and a disequilibrium component (*DIS*):

$$REER = EQU + DIS \quad (1)$$

The relationship between the current account balance (*CA*) and the real exchange rate is a function of factors such as net foreign assets (*NFA*), the terms of trade (*TOT*), the level of aggregate demand in the economy (*Y*) and trade policy (*POL*):

$$CA = f(REER, NFA, TOT, Y, POL) \quad (2)$$

This equation can be inverted, for *CA* set at its trend level,  $\overline{CA}$ , to solve for the equilibrium real exchange rate:

$$EQU = f^{-1}(\overline{CA}, NFA, TOT, Y, POL) \quad (3)$$

<sup>3</sup> Data for regime classifications using the IMF's current methodology are not available before 1990.

Barisone *et al.* (2006) provide evidence from six major countries that the actual rate reverts towards an equilibrium that is estimated using this approach. The variance of the real effective exchange rate is given by:

$$\text{var}(REER) = \text{var}(EQU) + \text{var}(DIS) + 2 \text{cov}(EQU, DIS) \quad (4)$$

The variance of the equilibrium component will reflect the variance of the factors shown in Eq. (3), of which we now provide an informal discussion. For example a country that is poor in capital might undertake major reforms to address institutional problems that were previously inhibiting capital inflows, thus appreciating its equilibrium real exchange rate. The covariance term captures how disequilibrium movements in the real exchange rate might affect the equilibrium itself. For example, a real exchange rate appreciation reduces the domestic currency price of imports; with quantitative controls on imports, this raises the tariff equivalent of the quantitative controls, thus effectively tightening trade policy and pulling the equilibrium real exchange rate towards the actual one, implying a positive covariance. With net foreign assets the effect can work in either direction, depending on the relative size and on the currency composition of assets and liabilities.<sup>4</sup> More generally, in the traditional Mundell-Fleming approach, any shock to net capital flows will cause a change in the equilibrium real exchange rate.

The variance of the disequilibrium component is likely to reflect different factors. Bravo-Ortega and di Giovanni (2006) show theoretically that country-specific productivity shocks have larger real exchange rate effects in more closed economies because of greater geographical and artificial obstacles to trade adjustment. The intuition is that country-specific shocks change the relative price of non-tradeables across countries more than the relative price of tradeables. Hau (2002) suggests that less open economies have more volatile real exchange rates because nominal exchange rate shocks have smaller import price effects. When currencies are viewed as assets, their volatility under floating is likely to be determined by the range over which there is no clear evidence of misalignment. Bleaney (2008) shows that this implies greater volatility if the ratio of international trade to GDP is smaller, because of the tendency to use GDP as the denominator in defining long-run current account sustainability.<sup>5</sup>

The exchange rate regime is potentially an important determinant of the disequilibrium component of volatility. In a target zone, for example, the authorities' intervention policy may co-ordinate mean-reverting speculative activity that might otherwise be outweighed by momentum traders (Reitz and Taylor 2008). An important caveat is that this is only likely to be true if the equilibrium rate is within, or not far outside, the target zone. If the authorities are trying to maintain an exchange rate that is significantly away from its equilibrium value, an exercise which is futile in the long run, their interventions in the foreign exchange market

<sup>4</sup> In richer countries, where liabilities tend to be denominated in domestic currency, an appreciation tends to worsen the net asset position, whereas in poorer countries, with liabilities denominated in foreign currency and liabilities exceeding assets, it tends to improve it (Lane and Shambaugh 2007). The covariance would thus tend to be negative for richer countries and positive for poorer ones.

<sup>5</sup> This argument assumes that the elasticity of trade flows with respect to real exchange rate movements is similar across countries, so that a given real exchange rate movement has a larger impact on the trade balance as a proportion of GDP in more open economies.

may actually increase volatility. For example, policy-makers may attach some value to nominal exchange rate stability (and to stability against some particular currency rather than against a trade-weighted average), and allow some real appreciation in the presence of inflation. This ultimately has to be corrected, and implies that real exchange rate volatility under some forms of exchange rate management may increase with the inflation rate. Frankel (2005) shows that finance ministers are more likely to lose their jobs after a devaluation. This provides a rationale for the assumption, frequently made in currency crisis models, that there is a fixed cost of adjusting a peg. If true, this imparts a significant element of nominal rigidity to a pegged rate system. More generally, inflation creates a tension between nominal and real exchange rate stability, particularly as high inflation rates tend also to be highly volatile. Certainly high-inflation episodes are characterised by exceptionally high real exchange rate volatility (Bleaney 1996, Table 1; Gonzaga and Terra 1997), although these could perhaps be dismissed as exceptional cases. Thus the effect of exchange rate intervention on the disequilibrium component of real exchange rate volatility can operate in both directions.

By including exchange rate regime dummies along with structural and other variables in our volatility regression, we attempt to control for the disequilibrium as well the equilibrium components of volatility.

### 3 Measurement of volatility

We consider four different ways to measure volatility, all based on the log of the real effective exchange rate index as given in *International Financial Statistics*. The four measures are (1) the mean absolute monthly change (*MAC*); (2) the standard deviation of monthly changes (*SDC*); (3) the root mean square monthly change (*RMSC*); and the standard deviation of the level (*SDL*), all multiplied by 100 so that the numbers approximate to percentages. Formally, if  $x_t$  is the log real effective

**Table 1** Regime classifications

1	No separate legal tender
2	Currency board arrangements
3	Conventional fixed pegs
4	Horizontal bands
5	Crawling pegs
6	Crawling bands
7	Managed float
8	Independent float

No separate legal tender includes currency unions as well as the use of a foreign currency as legal tender. Categories 3 and 5 are defined by a maximum fluctuation of  $\pm 1\%$  around the central parity; a wider range is classified in category 4 or 6, as appropriate. In categories 5 and 6 the central parity is adjusted relatively frequently by small amounts. Category 7 covers cases where the monetary authority attempts to influence the exchange rate without any specified path or target. In category 8 the exchange rate is market-determined

exchange rate index in month  $t$ ,  $\Delta$  is the first-difference operator, and a bar above a variable indicates a mean, then

$$\begin{aligned} MAC &= \frac{100}{n-1} \sum_{t=2}^n |\Delta x_t| \\ SDC &= \left( \frac{100}{n-1} \sum_{t=2}^n (\Delta x_t - \overline{\Delta x})^2 \right)^{1/2} \\ RMSC &= \left( \frac{100}{n-1} \sum_{t=2}^n (\Delta x_t)^2 \right)^{1/2} \\ SDL &= \left( \frac{100}{n-1} \sum_{t=1}^n (x_t - \bar{x})^2 \right)^{1/2} \end{aligned} \quad (5)$$

Of these, *MAC* yields the lowest numbers, because it attaches less weight to big changes than *SDC*, while *RMSC* is in effect a standard deviation about zero rather than about the mean change, and therefore takes account of drift. It differs from *SDC* only by the square of the mean change, which is small in many cases. Finally, *SDL* is the standard deviation of the level about the estimated sample mean, and will reflect the cumulative effect of monthly changes, including their persistence and any tendency to mean-reversion, as well as their absolute size. It is difficult to say *a priori* which is the best measure, because it depends on the time horizon and on the similarity of the time series properties of the series. Certainly firms investing in trading relationships or productive assets are likely to be more worried about how far the real exchange rate might move over a longer period, such as several years, rather than 1 month. Although this argument suggests *SDL* as the best measure, this might not be true under certain stringent conditions. If the real effective exchange rate series of different countries have very similar time series properties, then a measure based on changes should be less noisy because it is less dependent on particular shock realisations (since the stochastic element is cumulated in a levels measure).<sup>6</sup> This is a strong assumption to make, however, particularly since the exchange rate regime is likely to affect the time series properties of the real exchange rate. Rather than take a position on this issue, we present results with several alternative volatility measures.

#### 4 Exchange rate regime classifications

The IMF has always published information about the exchange rate regimes of its member countries. Unfortunately, until 1997, this was simply based on the countries' own classification of their regime, which was sometimes inaccurate. Because of this, since 1999, the IMF has published its own classification of a country's regime, as

<sup>6</sup> In previous work *SDC* and *SDL* have been the most commonly used measures. Suppose that in each country ( $i$ ), the relevant equation is:  $\Delta x_t = a_i + b_i \Delta x_{t-1} - c_i x_{t-1} + u_{it}$ , where  $u$  is a random error, and  $a_i$ ,  $b_i$  and  $c_i$  are parameters that are fixed for each country. If  $a$ ,  $b$  and  $c$  are identical across countries, but the variance of  $u_i$  is not, in the long run the variance of  $x$  should be proportional to the variance of  $u_i$ , and the variance of  $u_i$  is best estimated from changes in  $x$ . If the parameters vary across countries, the ratio of variances of  $x$  in different countries will also reflect different values of  $a$ ,  $b$  and  $c$ , which will only be captured in *SDL*. We show below that we get similar results whatever measure we use.



described in Table 1. Bubula and Ötoker-Robe I (2002) provide a revised classification for earlier years back to 1990 on the same principles. This is the data set that we use.<sup>7</sup> Alternative historical classifications, based on different statistical methodologies, have been provided by Levy-Yeyati and Sturzenegger (2005), Reinhart and Rogoff (2004) and Shambaugh (2004). Unfortunately, these disagree with each other as much as with countries' own reported classifications (Bleaney and Francisco 2007; see Tavlas et al. 2008, for a detailed survey). Two of them are in any case unsuitable for our present purposes since they only generate one classification for each calendar year. More generally, statistical procedures have limitations, and it would be difficult to claim that they are superior to the IMF's current methodology (the motivation for developing these alternative measures was the weaknesses in the old IMF procedure rather than in the new one). Indeed, since the volatility of the nominal exchange rate is an important ingredient of all statistically-based classification schemes, a statistical approach carries a significant risk of endogeneity bias with respect to real exchange rate volatility. This risk should be smaller, although probably not entirely absent, with a judgemental approach such as that currently used by the IMF. We therefore confine our analysis to the period covered by the IMF's current procedures, as backdated by Bubula and Ötoker-Robe (2002).

There is a choice to be made between measuring real exchange rate volatility in periods of fixed length, across all countries, even though there may have been a switch of exchange rate regime during the period, and measuring it over periods characterised by the same exchange rate regime, which will necessarily be of unequal length. We choose the latter option. To deal with the problem of varying episode length, in the empirical analysis we exclude episodes where the regime lasted for too short a time (less than four quarters), and we also split exceptionally long periods of the same regime into two or three shorter episodes. This helps to prevent countries with few regime switches from being too severely underrepresented. Any period of 48 quarters is split into three episodes of equal or nearly equal length, and any period of between 32 and 47 quarters is split into two episodes of equal or nearly equal length. Each episode thus defined represents an observation in the empirical analysis that follows. Thus, for the United States, which has been independently floating throughout, there are three 22-quarter episodes, lasting respectively from January 1990 to June 1995, July 1995 to December 2000, and January 2001 to June 2006, with real exchange rate volatility measured separately over each of these three episodes, each of which represents an observation in the regressions that follow. For some other countries, there are more than three episodes of shorter average length. By increasing the cut-off point for the minimum length of an episode to be included in the analysis, we can check that the inclusion of more episodes from some countries than others is not affecting the results.

## 5 Preliminary data analysis

In order to avoid the influence of outliers, all episodes where the mean monthly change in the logarithm of the consumer price index is greater than 0.03 (equivalent

<sup>7</sup> We are grateful to Harald Anderson of the IMF for providing the data.

**Table 2** Some basic statistics

Variable	Mean	St. Deviation	Minimum	Maximum
<i>Real exchange rate volatility measures</i>				
Mean absolute change (MAC)	1.43	1.06	0.37	7.86
St. dev. of change (SDC)	2.16	2.31	0.49	22.31
Root mean sq. change (RMSC)	2.22	2.34	0.50	22.43
St. dev. of level (SDL)	6.45	5.60	0.98	43.27
<i>Other variables</i>				
Length of episode (quarters)	18.41	5.89	4	30
ln per capita GDP (2000 \$US)	8.19	1.60	4.45	10.52
Openness (trade/GDP)	0.618	0.225	0.187	1.332
Monthly CPI inflation	0.61	0.60	-0.03	2.76
Terms-of-trade volatility	8.41	8.96	0.04	51.0

These statistics refer to the 274 episodes of minimum length four quarters for which real effective exchange rate data exist, and with mean inflation below 0.03. Inflation is the month-to-month change in the logarithm of the consumer price index multiplied by 100. Terms-of-trade volatility is the standard deviation of the logarithm over 5 years centred on the mid-point of the episode, multiplied by 100. Terms of trade are calculated as (exports at current prices)/(exports at constant prices) divided by (imports at current prices)/(imports at current prices), or where this is not available as export unit values divided by import unit values, as given in *World Development Indicators*

to an annual inflation rate of 43.33%) are excluded, as are those containing fewer than four quarters. This reduces the observations from 330 to 274. Table 2 provides some basic statistical data for this sample. The mean absolute monthly change in the real exchange rate is only about two-thirds of the mean standard deviation of monthly changes, which is only just less than the mean root mean square monthly change, but the standard deviation of the level is about three times as large as these last two. The coefficient of variation is about one for most measures, but more like 0.7 for the mean absolute monthly change. Because volatilities cannot be negative, there is a significant positive skew, as indicated by the relative distances from the mean of the maximum and minimum. The average episode is 18.4 quarters in length, with a standard deviation of 5.9.

The correlations between the different volatility measures are given in Table 3. All the correlations are above 0.75, with that between the mean absolute change and the standard deviation of the level being the lowest. The correlation between the standard deviation of the change and the root mean square change is very close to one, which indicates that drift is not a major factor.

**Table 3** Correlations between alternative volatility measures

	MAC	SDC	RMSC
MAC	1		
SDC	0.886	1	
RMSC	0.896	0.998	1
SDL	0.777	0.805	0.813

These statistics refer to the 274 episodes of minimum length four quarters with mean inflation below 0.03. For definitions see Eq. (1)

Table 4 shows some basic statistics by regime. The two smallest categories (currency boards (2) and crawling bands (6)) have been amalgamated with a neighbouring category (no separate legal tender (1) and crawling pegs (5) respectively), but otherwise no regime represents more than 21% of the observations. Real exchange rate volatility tends to be highest under floats (with little difference between managed and independent floats), and lowest under some intermediate regimes (pegs with wide bands (4) and crawls (5 and 6)). Alternative volatility measures (not shown in the table) display a similar pattern. Inflation is distinctly higher in crawls and managed floats, and these regimes are more common in poorer countries. There is a slight tendency for openness to decline with regime flexibility, since larger countries tend to have more flexible regimes (Bleaney and Francisco 2008a). Somewhat surprisingly, the least flexible regimes tend to be associated with higher terms-of-trade volatility.

## 6 Empirical results

In this section we develop an empirical model of real effective exchange rate volatility. First we consider per capita GDP, trade openness, terms-of-trade volatility and inflation. We also control for episode length, which is significant for one volatility measure. Then we introduce dummies for different exchange rate regimes (treating a conventional peg as the omitted category), and finally we allow for the inflation effect to vary with the exchange rate regime. Thus the model is:

$$RVOL_{it} = a + bINF_{it} + cX_{it} + dERR_{it} + e(ERR_{it} * INF_{it}) + u_{it} \quad (6)$$

where  $RVOL_{it}$  is the volatility of the real effective exchange rate in episode  $t$  in country  $i$ ;  $INF$  is the inflation rate;  $X$  is a vector of other exogenous variables (e.g. openness);  $ERR$  is a vector of exchange rate regime dummies; and  $\mu$  is a stochastic term.

Table 5 shows the results for the basic model without regime effects or interaction terms. Unless otherwise stated, all the regressions presented omit episodes shorter than four quarters in length and with monthly inflation greater than three percentage points. The model explains 30% to 40% of observed volatility. Volatility increases

**Table 4** Basic statistics by exchange rate regime

Regime	Episodes	St. dev. of REER level	Monthly inflation	ln (GDP p.c.)	Openness	TOT volatility
1 / 2	45	6.78	0.315	8.02	0.675	11.90
3	54	6.17	0.381	8.13	0.710	11.89
4	32	3.43	0.381	9.64	0.649	9.55
5/6	38	4.91	0.992	7.86	0.537	6.63
7	55	7.76	0.917	7.40	0.625	8.79
8	50	8.10	0.462	8.59	0.501	6.35
All	274	6.45	0.608	8.19	0.618	8.41

These statistics refer to episodes of minimum length four quarters with mean inflation below 0.03. For definitions of regimes see Table 1. For definitions of variables see Table 2

**Table 5** An initial regression for real effective exchange rate volatility

	<i>Volatility Measure</i>		
	MAC	RMSC	SDL
<i>Independent variables</i>			
Constant	1.26** (6.79)	1.77** (4.76)	5.09** (5.84)
Episode length (quarters)	-0.0040 (-0.38)	0.0281 (1.30)	0.219** (4.38)
ln (per capita GDP)	-0.106* (-2.38)	-0.251* (-2.49)	-0.446* (-2.16)
Openness	-0.659** (-3.08)	-1.19* (-2.30)	-3.70** (-3.31)
TOT volatility	0.0264** (3.55)	0.0579** (3.55)	0.140** (3.70)
Monthly inflation rate	0.723** (4.97)	1.32** (4.52)	3.70** (5.38)
Observations	274	274	274
R-squared	0.416	0.317	0.341
Standard error	0.821	1.96	4.59
F-statistic (4, 264)	0.98 ( $p=0.419$ )	1.76 ( $p=0.137$ )	3.00* ( $p=0.019$ )

Figures in parentheses are heteroscedasticity-robust *t*-statistics. \* (\*\*) denotes significantly different from zero at the 0.05 (0.01) level. For definition of volatility measures see Eq. (1). Sample excludes all episodes shorter than four quarters and with monthly inflation  $>0.03$ . The F-statistic refers to a joint test of zero coefficients on four omitted geographical variables: land area, population density, GDP-weighted average distance from other countries (all in logs), and a dummy for landlockedness

significantly with the length of the episode for the *SDL* measure only, which is not surprising because *MAC* and *RMSC* are calculated using changes rather than levels. Volatility decreases with per capita GDP and openness, and increases with inflation and terms-of-trade volatility. In terms of the effect of an increase of one standard deviation (i.e. multiplying the coefficients in Table 5 by the standard deviations in Table 2), inflation is the most important factor. The second most important factor is terms-of-trade volatility. Openness lags some way behind: for all volatility measures, a one-S.D. change has only about a third of the effect of a one-S.D. change in the inflation rate. As the last row of Table 5 indicates, four other geographical variables (land area, population density, GDP-weighted distance from other countries and a dummy for landlockedness) were collectively (and also individually) insignificant except in the case of *SDL*, and were omitted from the model. All of these variables tend to be correlated with openness, so this implies that openness is a sufficient variable to capture the effects of geography.<sup>8</sup>

There is a possible concern that these results are unduly influenced by the inequality in episode lengths (and the consequent overrepresentation of countries with more regime changes), or by the particular choice of threshold for excluding high-inflation episodes. In the Discussion Paper version of this article (Bleaney and Francisco 2008b), we show that we get similar results with different episode lengths and different inflation thresholds.

<sup>8</sup> In the *SDL* regression, land area is significant, and when it is included, openness becomes insignificant. For simplicity, however, we keep the same specification for *SDL* as for the other two volatility measures.

## 6.1 Regime effects

We turn now to exchange rate regime effects. Does the inclusion of regime dummies improve on the model shown in Table 5? As well as including a dummy for each regime (as aggregated in Table 4, and using a conventional peg to a single currency as the omitted category), we also allow pegs to a basket of currencies to be different from pegs to a single currency, since they may help to stabilise the real effective exchange rate.

There is a possible concern about the effect of outliers, particularly at the upper end (since volatility is bounded at zero at the lower end). We consider two ways of dealing with this problem: by robust regression techniques (weighted least squares estimation) and by taking the logarithm of the dependent variable.

Table 6 shows the results using robust regression. Although altogether six regime dummies were added to the regression, those for three of them (those for a hard peg, a basket peg, and a conventional band) are consistently insignificant. Independent floats have a consistently highly significant positive coefficient. Managed floats also

**Table 6** Adding exchange rate regime dummies (robust regression)

	<i>Volatility Measure</i>		
	MAC	RMSC	SDL
<i>Independent variables</i>			
Constant	1.00** (7.96)	1.36** (7.33)	3.70** (4.97)
Episode length (quarters)	0.0013 (0.25)	0.0065 (0.87)	0.167** (5.56)
ln (per capita GDP)	-0.130** (-6.24)	-0.188** (-6.15)	-0.505** (-4.12)
Openness	-0.296* (-2.42)	-0.340 (-1.89)	-0.773 (-1.07)
TOT volatility	0.0178** (5.49)	0.0179** (3.74)	0.0623** (3.25)
Monthly inflation rate	0.446** (8.44)	0.495** (6.34)	1.95** (6.24)
<i>Regime dummies</i>			
Hard peg (1 or 2)	-0.078 (-0.78)	-0.176 (-1.21)	-1.32* (-2.27)
Basket peg (subset of 3)	-0.046 (-0.36)	0.188 (0.99)	-1.22 (-1.61)
Conventional band (4)	0.040 (0.38)	0.124 (0.80)	0.244 (0.39)
Crawl (5 or 6)	-0.218* (-2.12)	-0.147 (-0.97)	-1.02 (-1.69)
Managed float (7)	0.252** (2.71)	0.362** (2.64)	0.704 (1.28)
Independent float (8)	0.634** (6.60)	0.792** (5.60)	2.47** (4.35)
Observations	274	274	274
With zero weight	8	18	14
0 < weight < 0.25	6	9	10
Mean weight	0.871	0.842	0.835

Figures in parentheses are heteroscedasticity-robust *t*-statistics. \* (\*\*) denotes significantly different from zero at the 0.05 (0.01) level. For definition of volatility measures see Eq. (1). Sample excludes all episodes shorter than four quarters and with monthly inflation >0.03. The estimation method is the Stata “*treg*” command, which uses weighted least squares, with weights based on the absolute size of the residual, after omitting all observations for which Cook’s distance exceeds one. The omitted regime category is a conventional single-currency peg

**Table 7** Using logarithmic volatility measures

	<i>Volatility Measure</i>		
	ln (MAC)	ln (RMSC)	ln (SDL)
<i>Independent variables</i>			
Constant	-4.68** (-36.7)	-4.39** (-29.3)	-3.25** (-20.4)
Episode length (quarters)	-0.352 (-0.76)	0.283 (0.51)	3.48** (5.26)
ln (per capita GDP)	-0.099** (-5.34)	-0.121** (-5.21)	-0.088** (-3.42)
Openness	-0.243* (-2.08)	-0.270 (-1.79)	-0.348* (-2.32)
TOT volatility	1.67** (4.49)	1.91** (4.24)	1.63** (4.14)
Monthly inflation rate	37.7** (7.51)	43.4** (7.03)	49.9** (6.79)
<i>Regime dummies</i>			
Hard peg (1 or 2)	-0.041 (-0.48)	0.006 (0.05)	-0.099 (-0.76)
Basket peg (subset of 3)	-0.045 (-0.37)	0.046 (0.27)	-0.214 (-1.12)
Conventional band (4)	-0.018 (-0.20)	0.063 (0.63)	-0.092 (-1.12)
Crawl (5 or 6)	-0.167 (-1.63)	-0.192 (-1.71)	-0.346* (-2.57)
Managed float (7)	0.162 (1.84)	0.174 (1.69)	0.036 (0.31)
Independent float (8)	0.564** (6.30)	0.561** (5.41)	0.389** (3.14)
Observations	274	274	274
R-squared	0.640	0.568	0.465
Standard error	0.359	0.457	0.526

Figures in parentheses are heteroscedasticity-robust *t*-statistics. \* (\*\*) denotes significantly different from zero at the 0.05 (0.01) level. For definition of volatility measures see Eq. (1). Sample excludes all episodes shorter than four quarters and with monthly inflation >0.03. The omitted regime category is a conventional single-currency peg

have a significantly positive coefficient in two out of three cases, but the coefficient is much smaller than that for independent floats, which strongly suggests that management of a float reduces real exchange rate volatility. Crawling pegs or bands have a negative coefficient that is statistically significant for one measure. The statistics at the foot of Table 6 show that concern about outlier effects is justified. Between five and ten per cent of observations are severely downweighted, in some cases to zero (i.e. effectively omitted).<sup>9</sup>

Table 7 shows the results using logarithms of the volatility measures. As well as reducing skewness, this greatly reduces the outlier problem, and makes the robust regression results (not shown for this case) much more similar to the OLS results. It also has the advantage that the coefficients of the regime dummies now represent estimated proportional effects, which makes them comparable across volatility measures. The regressions are pretty similar across measures, with per capita GDP, terms-of-trade volatility and inflation much the most significant variables. Openness is significant only at the 0.05 level, and as before episode length matters only for the levels measure (*SDL*). Relative to a conventional single-currency peg (the omitted

<sup>9</sup> See Bleaney and Francisco (2008b) for the OLS results. In OLS estimation managed floats are never significant, and crawling pegs and bands have a consistently negative coefficient.

category), independent floats are estimated to increase volatility by about 75 ( $=e^{0.56}$ )%, using either *MAC* or *RMSC*, and crawls to reduce it by an insignificant 15–20%. Using *SDL*, the independent float effect is estimated as +48( $=e^{0.39}$ )%, and the crawl effect at a significant  $-29(=e^{-0.35})\%$ . All of the regime dummies are less positive (or more negative) using *SDL*, which indicates that volatility is estimated to be higher in the omitted category of conventional pegs (relative to other categories) using this measure.

As mentioned earlier, the inflation effect on real exchange rate volatility may be stronger under a peg (other than a crawl, which is explicitly designed to adjust for relative inflation rates). To test this, we now allow the inflation effect to be different for regime categories 1 to 4 (horizontal pegs and bands) relative to categories 5 to 8 (crawls and floats), by including an additional variable that is equal to the inflation rate for regimes 1 to 4, and equal to zero for regimes 5 to 8. The results are shown in Table 8. The new variable is always significantly positive at the 0.05 level, and with a coefficient similar to that of the inflation rate, which implies that the inflation effect

**Table 8** Allowing for regime-specific inflation effects

	<i>Volatility Measure</i>		
	ln (MAC)	ln (RMSC)	ln (SDL)
<i>Independent variables</i>			
Constant	-4.80** (-38.7)	-4.56** (-30.4)	-3.38** (-21.2)
Episode length (quarters)	-0.264 (-0.57)	0.407 (0.74)	3.58** (5.44)
ln (per capita GDP)	-0.098** (-5.38)	-0.120** (-5.28)	-0.088** (-3.41)
Openness	-0.213 (-1.89)	-0.228 (-1.57)	-0.315* (-2.16)
TOT volatility	1.66** (4.61)	1.91** (4.40)	1.63** (4.14)
Monthly inflation rate	30.4** (5.51)	33.3** (5.01)	41.9** (5.40)
Inflation times regimes 1 to 4 dummy	28.7** (2.81)	40.1** (3.03)	31.7* (2.03)
<i>Regime dummies</i>			
Hard peg (1 or 2)	-0.015 (-0.18)	0.043 (0.39)	-0.069 (-0.53)
Basket peg (subset of 3)	-0.103 (-0.89)	-0.035 (-0.21)	-0.278 (-1.51)
Conventional band (4)	0.000 (0.00)	0.089 (0.91)	-0.071 (-0.54)
Crawl (5 or 6)	0.100 (0.09)	0.055 (0.42)	-0.151 (-1.00)
Managed float (7)	0.331** (3.48)	0.410** (3.43)	0.222 (1.60)
Independent float (8)	0.700** (7.67)	0.752** (6.84)	0.539** (4.07)
Observations	274	274	274
R-squared	0.653	0.541	0.477
Standard error	0.353	0.471	0.521
Chow stat. F(9, 256)	0.63	0.49	0.46

Figures in parentheses are heteroscedasticity-robust *t*-statistics. \* (\*\*) denotes significantly different from zero at the 0.05 (0.01) level. For definition of volatility measures see Eq. (1). Sample excludes all episodes shorter than four quarters and with monthly inflation  $>0.03$ . The omitted regime category is a conventional single-currency peg. The Chow statistic refers to the hypothesis that the coefficients are identical between advanced and developing countries, and for enhanced power is based on a regression with only two regime dummies (managed and independent float). The 0.05 critical value is 1.89

is approximately twice as strong under a peg. This is consistent with the hypothesis that there are political costs to adjusting a peg.

The coefficients of the regime dummies have a different interpretation in Table 8 from in previous tables. For crawling pegs and bands and for floats, they now indicate only the estimated effect relative to a single-currency peg *at a zero inflation rate*. To calculate the regime effect at any positive inflation rate, the impact of the coefficient of the inflation rate times the dummy for regime 1 to 4 must also be taken into account. Crawling pegs and bands are now estimated to have no effect on volatility relative to a single-currency peg at zero inflation, which makes sense, while independent floats add  $71(= e^{0.54})$  to  $112(= e^{0.75})\%$  to volatility at zero inflation, and managed floats add 25 to 51%, depending on which volatility measure is used. At a monthly inflation rate of 1%, however, crawling pegs and bands would reduce inflation significantly; managed floats would make little difference; and independent floats would increase volatility but by substantially less than at zero inflation.<sup>10</sup>

This sheds a new light on the phenomenon of “fear of floating”, or the tendency for floats to be managed in the developing world (Calvo and Reinhart 2002). This has been widely interpreted, as the phrase implies, to mean that countries are intellectually convinced of the merits of an independent float but unwilling in practice to accept the resulting real exchange rate volatility. The results obtained here suggest an alternative interpretation: managed floats are adopted not out of any intellectual enthusiasm for floating but for the pragmatic reason that they are a more effective way of controlling real exchange rate volatility in the presence of significant inflation, given the reluctance to adjust the parity under a peg. This is consistent with the statistical association of managed floats with relatively high inflation rates, as shown in Table 4.

The Chow statistics at the foot of Table 8 show that there is no significant difference in coefficients between developing countries (199 observations) and advanced countries (75 observations). It is interesting, therefore, to use these regressions to examine the contribution of each variable to the model’s “explanation” of the much higher average volatility in developing countries. Table 9 shows that the observed average difference is rather smaller (although still substantial) using the standard deviation of the real exchange rate level rather than changes. About half of this average difference is explained by factors other than per capita GDP (which might be interpreted as the element the model has failed to explain), mainly inflation and terms-of-trade volatility. Developing countries’ choice of exchange rate regime (principally a much lower frequency of independent floats) has helped to reduce volatility.

## 6.2 Further hypotheses

In this section we consider three further hypotheses. The first is that capital controls reduce volatility by inhibiting speculative capital flows (as is intended in Chile, for example). To test this we introduce a zero-one dummy for the existence of controls

<sup>10</sup> This can be seen by subtracting 0.01 times the coefficient of (inflation times regime 1 to 4 dummy) from the coefficient of the dummy for the relevant exchange rate regime.



**Table 9** Explaining higher volatility in developing countries

Average difference between developing and advanced countries	Volatility Measure		
	ln (MAC)	ln (RMSC)	ln (SDL)
Observed	+0.51	+0.59	+0.38
<i>Explained by:</i>			
Episode length	−0.01	−0.01	−0.07
Per capita GDP	+0.25	+0.31	+0.22
Openness	−0.01	−0.01	−0.01
TOT volatility	+0.14	+0.16	+0.18
Inflation	+0.16	+0.17	+0.21
Inflation x peg dummy	+0.03	+0.04	+0.03
Managed float dummy	+0.07	+0.08	+0.05
Independent float dummy	−0.17	−0.18	−0.13

The table shows the difference in mean values of each variable between developing and advanced countries, multiplied by the coefficients of the relevant regression in Table 8

on capital transactions, as reported in the IMF *Annual Report on Exchange Arrangements and Exchange Restrictions*. Secondly we test whether inflation targeting reduces real effective exchange rate volatility relative to what would be expected, given that it tends to be associated with floating rates, as is suggested by the results of Rose (2007) for a more limited sample. For this we use a dummy for an inflation targeting regime, based on the data in Rose (2007, Table A1). Finally we test whether financial development, as measured by the log of one plus the ratio of M3 to GDP, reduces volatility, as found by Devereux and Lane (2003). Table 10 shows the effects of adding these two variables to the regressions shown in Table 8.

In Table 10, the four insignificant regime dummies (hard peg, basket peg, conventional band and crawling peg and band) have been omitted. Since they tended to have negative coefficients, their omission makes the dummies for managed and independent floats more positive and more significant.

Capital controls have a consistently positive coefficient, contrary to the view that they reduce volatility, although it is never statistically significant. The most likely explanation for this is reverse causality—that countries with naturally greater real exchange rate volatility are more tempted to impose capital controls in an attempt to reduce it. The fact that the estimated coefficient is positive shows that any effect of controls in reducing volatility is either negligible or too small to outweigh this selection effect. Nevertheless the issue of the relationship between capital controls and real exchange rate volatility merits further investigation, since a zero-one dummy as used here does not capture the varying intensity of controls.

The inflation targeting dummy is also insignificant in all three cases, and (perhaps surprisingly) positive. The difference between this result and that of Rose (2007) is probably explained by the fact that we control for the inflation effect. Since inflation targeting reduces inflation, it will tend to reduce real exchange rate volatility through this mechanism.

**Table 10** Inflation targeting and financial development

	<i>Volatility Measure</i>		
	ln (MAC)	ln (RMSC)	ln (SDL)
<i>Independent variables</i>			
Constant	-4.79** (-48.7)	-4.46** (-34.6)	-3.44** (-25.5)
Episode length (quarters)	-0.427 (-1.01)	0.336 (0.68)	3.34** (5.47)
ln (per capita GDP)	-0.0842** (-3.95)	-0.0926** (-3.51)	-0.0779* (-2.50)
Openness	-0.215 (-1.92)	-0.241 (-1.69)	-0.281 (-1.91)
TOT volatility	1.57** (4.50)	1.63** (3.91)	1.64** (4.03)
Monthly inflation rate	29.6** (6.41)	31.0** (5.40)	38.6** (5.22)
Inflation times regimes 1 to 4 dummy	25.7** (2.98)	38.1** (3.36)	33.7* (2.50)
<i>Regime dummies</i>			
Managed float (7)	0.344** (5.35)	0.393** (4.99)	0.338** (3.60)
Independent float (8)	0.710** (11.2)	0.743** (9.42)	0.622** (6.82)
<i>Extra variables</i>			
Capital controls dummy	0.066 (1.22)	0.103 (1.54)	0.009 (0.11)
Inflation targeting dummy	0.058 (0.92)	0.008 (0.12)	0.100 (1.08)
Financial development [ln(1 + M3/GDP)]	-0.125 (-0.83)	-0.250 (-1.34)	-0.155 (-0.69)
Observations	271	271	271
R-squared	0.657	0.596	0.476
Standard error	0.352	0.444	0.522

Figures in parentheses are heteroscedasticity-robust *t*-statistics. \* (\*\*) denotes significantly different from zero at the 0.05 (0.01) level. For definition of volatility measures see Eq. (1). Sample excludes all episodes shorter than four quarters and with monthly inflation >0.03. The omitted regime category is a conventional single-currency peg

Although the financial development variable always has a negative coefficient, as expected, it also is never statistically significant.

### 6.3 Sample selection bias

There is a possibility that the results are subject to sample selection bias, because real effective exchange rate indices are not available for many countries. To test for this, we have constructed measures of the standard deviation of the level of the real bilateral exchange rate against the US dollar, using consumer price indices. This expands the sample to 158 countries and 492 episodes. We estimate a regression for the log of bilateral real exchange rate volatility that is identical in structure to that in Table 8, except that we also include the log distance from the United States and a dummy for attachment to a currency that has floated against the US dollar (this dummy is equal to one for all countries in Europe and North Africa that are on a peg, and for countries pegged to the South African rand). We then re-estimate this regression for countries with and without real effective exchange rate data, and calculate the Chow statistic. The results are shown in Table 11. The Chow is just significant at the 0.05 level. The difference in coefficients between the two sub-

**Table 11** Testing for sample selection bias

	<i>Dependent variable: ln (standard deviation of the US\$ bilateral real exchange rate)</i>		
	Full sample	With REER data	Without REER data
<i>Independent variables</i>			
Constant	-6.22** (-11.5)	-7.44** (-9.38)	-4.73** (-6.12)
Episode length (quarters)	3.77** (6.83)	3.27** (4.23)	4.32** (5.52)
ln (per capita GDP)	-0.044 (-1.84)	-0.0042 (-0.13)	-0.129** (-3.05)
Openness	-0.460** (-3.19)	-0.473** (-2.61)	-0.217 (-0.81)
TOT volatility	0.584 (1.21)	0.827 (1.51)	0.518 (0.67)
Monthly inflation rate	37.2** (5.79)	31.7** (3.35)	50.4** (5.01)
Inflation times regimes 1 to 4 dummy	21.5 (1.88)	34.3* (2.04)	-2.20 (-0.13)
Dummy for non-US\$ attachment	0.717** (7.37)	0.720** (5.81)	0.818** (4.17)
ln(distance from US)	0.315** (5.35)	0.443** (5.21)	0.136 (1.54)
<i>Regime dummies</i>			
Hard peg (1 or 2)	0.642** (5.80)	0.604** (3.94)	0.674** (4.30)
Basket peg (subset of 3)	0.318** (2.40)	0.260 (1.41)	0.419* (2.29)
Conventional band (4)	0.335** (2.84)	0.309* (2.01)	0.472* (2.35)
Crawl (5 or 6)	0.088 (0.62)	0.146 (0.86)	0.090 (0.35)
Managed float (7)	0.697** (5.87)	0.934** (5.46)	0.430* (2.52)
Independent float (8)	0.952** (7.94)	1.11** (7.24)	0.596** (2.99)
Observations	492	265	227
R-squared	0.415	0.488	0.401
Standard error	0.630	0.588	0.662
Chow stat. F(15, 463)		1.71*	
Equality of regime dummy coeffs F(7, 470)		1.55	

Figures in parentheses are heteroscedasticity-robust *t*-statistics. \* (\*\*) denotes significantly different from zero at the 0.05 (0.01) level. Sample excludes all episodes shorter than four quarters and with monthly inflation >0.03. The omitted regime category is a conventional single-currency peg. The 0.05 critical value of F(15, 463) is 1.70 and of F(7, 470) is 2.03

samples appears to be concentrated in the control variables in the upper half of the Table, since the regime dummies are not significantly different across the sub-sample, as the last line of the Table shows.<sup>11</sup>

## 7 Conclusions

This paper has presented a new analysis of real effective exchange rate volatility, using a sample of 90 countries. After controlling for other factors, volatility is higher in poorer countries and those with more terms-of-trade volatility. Volatility increases markedly

<sup>11</sup> The coefficients are a bit different in some cases for real bilateral rates, but that is an issue for another paper.

with the inflation rate, even at moderate levels (observations with inflation above three per cent per month were excluded throughout). The inflation effect is stronger in pegged regimes, which is consistent with the view that adjusting a peg is costly. Inflationary problems and greater terms-of-trade volatility explain about half of the 40–60% higher volatility in developing countries in this sample. Geographical factors, as reflected in the ratio of international trade to GDP, are marginally significant but of minor importance relative to inflation, terms-of-trade volatility and per capita GDP.

The choice of exchange rate regime can make a substantial difference to real effective exchange rate volatility over and above these effects. At average inflation rates, an independent float adds about 48% to volatility (measured as the standard deviation of the level), or alternatively about 75% (using measures based on monthly changes) relative to a conventional peg. A crawling peg or band tends to reduce volatility by about 20% (but to a statistically significant degree only for one out of three measures). Crawls seem to represent the closest approximation to a regime of real exchange rate targeting. Real exchange rate volatility under other regimes is not significantly different from under a conventional peg: for instance there is no evidence that basket pegs deliver significantly lower real effective exchange rate volatility than single-currency pegs, even though they might be expected to do so, since the basket is usually a better reflection of a country's trade pattern.

Under less flexible regimes, real effective exchange rate volatility is significantly more sensitive to inflation than under more flexible regimes. This probably reflects a reluctance to adjust the parity to offset inflation differentials, either through inertia or because of perceived political costs. Managed floats are better than conventional pegs at delivering lower real exchange rate volatility at higher inflation rates, and it is noticeable that managed floats are more frequently observed in higher-inflation situations. This suggests that managed floats are adopted more out of pragmatic considerations than out of an intellectual conviction of the merits of floating. They probably represent a “reluctance to peg” in inflationary situations more than a “fear of floating”.

We found no evidence that capital controls or inflation targeting reduce exchange rate volatility. Finally, although real effective exchange rate data are absent for many countries, estimation of a similar equation using bilateral real exchange rate volatility against the US dollar does not suggest major problems of sample selection bias.

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## Appendix

### Countries in the sample

#### *Industrial countries (23)*

Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States

*Developing countries (67)*

Algeria, Antigua and Barbuda, Armenia, Bahamas, Bahrain, Belize, Bolivia, Bulgaria, Burundi, Cameroon, Central African Republic, Chile, China, Colombia, Costa Rica, Côte d'Ivoire, Croatia, Cyprus, Czech Republic, Democratic Republic of Congo, Dominica, Dominican Republic, Ecuador, Equatorial Guinea, Fiji, Gabon, Gambia, Ghana, Grenada, Guyana, Hungary, Iran, Israel, Lesotho, Malawi, Malaysia, Malta, Moldova, Morocco, Netherlands Antilles, Nicaragua, Nigeria, Pakistan, Papua New Guinea, Paraguay, Philippines, Poland, Romania, Russia, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, Samoa, Saudi Arabia, Sierra Leone, Singapore, Slovak Republic, Solomon Islands, South Africa, Togo, Trinidad and Tobago, Tunisia, Uganda, Ukraine, Uruguay, Venezuela, Zambia.

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