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Real Exchange Rate Volatility: Is Sub-Saharan Africa Different?

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Abstract
Real effective exchange rate volatility is examined for 90 countries using monthly data for the period January 1990 to June 2006. Volatility increases with country size and the inflation rate, and is greater in developing countries. Volatility is particularly high in sub-Saharan Africa after controlling for these factors. Exchange rate regime effects, as identified by the IMF's current *de facto* methodology, are significant. Free floats have higher volatility than other regimes, and crawling pegs/bands appear to be a form of real exchange rate targeting. The results are robust to alternative volatility measures.

Keywords: Exchange rate regimes, inflation, volatility.

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The views expressed here are those of the authors and should not be taken to represent those of the World Bank or of its Executive Board or of any of its member countries.

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1. Introduction

Real exchange rate volatility has long been a concern for academics and policy-makers. A perennial issue is whether volatility adversely affects trade and growth (e.g. Aghion *et al*., 2006; Clark *et al*., 2004). Only a minority of countries (under 15% according to current IMF classifications) allow their exchange rates to float freely, which suggests that most policy-makers are anxious to control real exchange rate volatility. Despite this, we lack systematic studies of what makes currencies volatile. Consequently we do not know the answers to basic questions, such as the relative importance of geographical factors and macroeconomic shocks, and how much intervention can be expected to reduce volatility.

One strand of investigation has compared volatility in the advanced countries under the Bretton Woods system and subsequently. The unequivocal 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.

This is, however, not quite the same question as that of how an individual country's exchange rate regime affects its real exchange rate volatility *within any particular* *international monetary system*. This is particularly true at present. Under Bretton Woods, to float was to float against every other currency, and to peg was to peg against virtually every other currency. Now that at least some of any country's major trading partners are likely to be floating against one another, it is not possible to choose to peg against all trading partners. A basket peg or some form of real exchange rate targeting may well reduce real effective exchange rate volatility, but for single-currency pegs, which are much more common, the issue is less clear. It is not, therefore, a foregone conclusion that a country's exchange rate regime makes a great deal of difference to its real effective exchange rate volatility (or that pegs are, in general, less volatile than floats) under current international monetary arrangements.

Another issue is that of inflation. 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. Nevertheless, in the majority of countries pegs tend to be adjusted quite frequently, mostly because of inflation relative to the anchor currency. Inflation creates a tension between nominal and real exchange rate stability. If policy-makers attach some value to nominal exchange rate stability, real exchange rate volatility under a peg is likely to increase with the inflation rate. 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.

There are some studies of exchange rate volatility in cross-country samples. 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.

Although these cross-country studies have shed light on the structural determinants of real exchange rate volatility, they have ignored a possible inflation effect, and they have not always allowed for exchange rate regime influences, either out of a belief that they are of minor importance or because of the difficulties of allowing for regime switches.[1] In this study we analyse real effective exchange rate volatility in a sample of 90 countries over the period 1990-2006. Volatility is measured in various ways, but always over a period where the exchange rate regime has remained the same, according to the IMF's current *de facto* methodology. This enables us to take regime effects into account.

[1] Hau (2002) and Rose (1996) are two studies that do allow for regime effects.

2. 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 exchange rate index in month t, Δ is the first-difference operator, and a bar above a variable indicates a mean, then

$$MAC = \frac{100}{n-1}\sum_{t=2}^{n}\left|\Delta x_t\right|$$

$$SDC = \left(\frac{100}{n-1}\sum_{t=2}^{n}(\Delta x_t - \overline{\Delta x})^2\right)^{1/2}$$

$$RMSC = \left(\frac{100}{n-1}\sum_{t=2}^{n}(\Delta x_t)^2\right)^{1/2}$$

$$SDL = \left(\frac{100}{n-1}\sum_{t=1}^{n}(x_t - \bar{x})^2\right)^{1/2} \qquad (1)$$

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 several years rather than one month. Although this 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 dependent on particular shock realisations (because changes are not cumulated), and therefore less noisy.[2] 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.

3. 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 described in Table 1. Bubula and Ötker-Robe (2002) provide a revised classification for

[2] 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.

earlier years back to 1990 on the same principles. This is the data set that we use.[3] 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). Two of them are unsuitable for our present purposes since they only generate one classification for each calendar year. All statistical procedures have weaknesses, 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). We therefore confine our analysis to the period covered by the IMF's current procedures, as backdated by Bubula and Ötker-Robe (2002).

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

Notes. 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 ±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.

[3] We are grateful to Harald Anderson of the IMF for providing the data.

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 volatility 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. 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 freely 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 varying 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.

4. 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 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 2/3 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, but more like 0.7 for the mean absolute monthly change. The average episode is 18.4 quarters in length, with a standard deviation of 5.9.

Table 2. Some Basic Statistics

Variable	Mean	St. Deviation	Minimum	Maximum
Real exchange rate volatility measures				
Mean absolute change (MAC)	1.44	1.07	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
Other variables				
Length of episode (quarters)	18.41	5.89	4	30
ln per capita GDP (2000 $US)	8.19	1.60	4.45	10.52
ln area (sq. km)	11.66	2.44	5.77	16.61
Monthly CPI inflation	0.61	0.60	-0.03	2.76

Notes. 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.

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	0.868	1	
RMSC	0.878	0.998	1
SDL	0.763	0.805	0.813

Notes. These statistics refer to the 274 episodes of minimum length four quarters with mean inflation below 0.03. For definitions see equation (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)), 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 some tendency for larger countries to have more flexible regimes.

Table 4. Basic Statistics by Exchange Rate Regime

Regime	Episodes	St. dev of REER level	Monthly inflation	ln (GDP p.c.)	ln (area)
1 /2	45	6.78	0.315	8.02	10.38
3	54	6.17	0.381	8.13	10.81
4	32	3.43	0.381	9.64	11.61
5/6	38	4.91	0.992	7.86	12.27
7	55	7.76	0.917	7.40	12.27
8	50	8.10	0.462	8.59	12.62
All	*274*	*6.45*	*0.608*	*8.19*	*11.62*

Notes. 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.

5. Empirical Results

In this section we develop an empirical model of real effective exchange rate volatility in steps. First we consider geographical factors, which have been emphasised in previous research. This section uncovers a sub-Saharan Africa puzzle that has not been previously recognised. In Section 5.2 we add inflation to the model; this is also extremely significant. In Section 5.3 we introduce exchange rate regime dummies. Section 5.4 discusses whether inflation targeting reduces real exchange rate volatility at a given inflation rate, or whether the evidence that it does so just reflects the reduction in inflation. Section 5.5 provides some robustness tests.

5.1 *Geographical Factors*

In Table 5 we regress volatility measures on the length of the episode, a dummy for developing countries and a dummy for sub-Saharan Africa. These last two dummies are highly significant. The higher volatility of real effective exchange rates in developing countries is known from previous work, but the exceptionally high volatility in sub-Saharan Africa has not, to our knowledge, been previously identified. Since episode length is entered in the regression as a deviation from the mean, the constant indicates the mean volatility for industrial countries for an episode of average length. For developing countries outside sub-Saharan Africa, volatility is at least 30% higher, and for sub-Saharan Africa, more than double that for industrial countries. It will be seen that, as more explanatory variables are added, the coefficients of these dummies decline somewhat, but remain highly statistically significant. Unless otherwise stated, all the regressions presented here omit episodes shorter than four quarters in length and with monthly inflation greater than three percentage points.

Table 5. An Initial Regression for Real Effective Exchange Rate Volatility

	Volatility Measure		
	MAC	RMSC	SDL
Independent variables			
Constant	1.10** (12.5)	1.33** (12.9)	4.21** (11.7)
Episode length (qu)	-0.0374** (-2.89)	-0.0337 (-1.71)	0.0463 (0.86)
Developing country dummy	0.366** (3.92)	0.832** (5.58)	1.58** (3.21)
Sub-Saharan Africa dummy	0.984** (4.82)	2.08** (3.76)	5.59** (5.08)
Observations	274	274	274
R-squared	0.219	0.178	0.190
Standard error	0.955	2.14	5.07

Notes. 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 equation (1).

In Table 6 we add openness to international trade (trade divided by GDP), and various geographical factors that tend to be correlated with trade openness (a dummy for landlockedness, land area, population density and GDP-weighted average distance from other countries). Of these, land area is the only consistently significant one, although some others, such as trade openness, become significant if land area is omitted. Together these geographical factors add about five percentage points to the R-squared, raising it from around 20% to about 25%.

Table 6. Adding Trade Openness and Geographical Factors

	Volatility Measure		
	MAC	RMSC	SDL
Independent variables			
Constant	-1.69 (-0.81)	0.25 (0.06)	1.77 (0.14)
Episode length (qu)	-0.0299** (-2.30)	-0.0170 (-0.86)	0.0994 (1.90)
Developing country dummy	0.411** (3.01)	1.08** (3.98)	2.41** (3.06)
Sub-Saharan Africa dummy	0.860** (3.99)	1.87** (3.26)	4.88** (4.25)
Trade openness	-0.0748 (-0.20)	-0.0508 (-0.71)	-0.0954 (-0.57)
Landlockedness dummy	0.0671 (0.42)	-0.312 (-1.05)	-0.260 (-0.35)
ln (land area)	0.0982** (3.58)	0.174* (2.57)	0.604** (3.92)
ln (population density)	0.0342 (0.73)	-0.0273 (-0.26)	0.0732 (0.28)
ln (GDP-weighted distance from other countries)	0.308 (1.38)	0.159 (0.35)	0.250 (0.19)
Observations	274	274	274
R-squared	0.262	0.227	0.260
Standard error	0.937	2.09	4.89

Notes. 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 equation (1).

5.2 *Inflation*

We now add the average inflation rate during the episode to the regression. Table 7 shows the results, retaining land area as the only geographical variable, since the others do not add anything to the explanation. This pushes the R-squared up by nearly ten percentage points, averaged across the three measures. The importance of inflation can be gauged by the fact that, using the coefficients from any of the regressions in Table 7, increasing monthly inflation by 0.3 percentage points (about half a standard deviation) is estimated to raise real effective exchange rate volatility by more than does multiplying land area by a factor of ten (nearly one standard deviation). Thus inflation explains more of real exchange rate volatility than the geographical factors that are related to trade openness. For two of three measures, the developing country dummy is no longer significant, although the sub-Saharan Africa dummy remains highly significant.

Table 7. Adding Inflation

	Volatility Measure		
	MAC	RMSC	SDL
Independent variables			
Constant	0.784** (8.33)	0.715** (4.71)	2.51** (6.33)
Episode length (qu)	-0.0095 (-0.90)	0.0207 (1.05)	0.196** (4.04)
Developing country dummy	0.137 (1.24)	0.490** (2.90)	0.770 (1.66)
Sub-Saharan Africa dummy	0.781** (4.48)	1.66** (3.44)	4.40** (4.39)
ln (land area)	0.0409 (1.96)	0.125** (3.07)	0.398** (4.26)
Monthly inflation rate	0.734** (4.93)	1.32** (4.14)	3.51** (5.10)
Observations	274	274	274
R-squared	0.370	0.300	0.354
Standard error	0.861	1.98	4.54

Notes. 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 equation (1).

5.3 *Regime Effects*

We turn now to exchange rate regime effects. Does the inclusion of regime dummies improve on the model shown in Table 7? 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 this may help to stabilise the real effective exchange rate.

Table 8 shows the results. Altogether six regime dummies are added to the regression, and the F-test shows that they are collectively highly significant, although this is entirely due to the dummies for a crawl and an independent float. It appears that crawls significantly reduce volatility at a given inflation rate, and an independent float significantly increases it, relative to a conventional peg. On the other hand, a managed float does not, despite the high average volatility under managed floats shown in Table 4. This is because the model is already explaining this feature by inflation, which is relatively high under managed floats. The second F-test in Table 8 shows that regime dummies other than those for a crawl and an independent float are collectively insignificant.

Table 8. Testing for Regime Effects

	Volatility Measure		
	MAC	RMSC	SDL
Independent variables			
Constant	0.688** (3.04)	0.338 (1.19)	2.62** (3.44)
Episode length (qu)	-0.0110 (-0.92)	0.0104 (0.40)	0.186** (3.02)
Developing country dummy	0.314* (2.33)	0.891** (4.65)	1.39** (2.95)
Sub-Saharan Africa dummy	0.535** (2.72)	1.12* (2.29)	3.48** (3.27)
ln (land area)	0.0315 (1.37)	0.138** (2.62)	0.412** (3.08)
Monthly inflation rate	0.842** (5.48)	1.53** (4.49)	4.03** (5.72)
Regime dummies			
Hard peg (1 or 2)	-0.113 (-0.52)	0.302 (0.71)	-0.446 (-0.41)
Basket peg (subset of 3)	-0.019 (-0.06)	0.631 (0.61)	-0.134 (-0.05)
Horizontal band (4)	-0.279 (-1.37)	-0.018 (-0.07)	-1.15 (-1.45)
Crawl (5 or 6)	-0.660** (-3.43)	-1.16** (-3.64)	-3.30** (-3.29)
Managed float (7)	-0.091 (-0.48)	-0.177 (-0.51)	-1.11 (-1.24)
Independent float (8)	0.608** (2.69)	1.03** (2.73)	1.15 (1.26)
F-test of regime dummies F(6, 262)	8.20** [p=0.000]	5.17** [p=0.000]	3.90** [p=0.001]
F-test of subset F(4, 262)	0.59 [p=0.671]	0.24 [p=0.914]	0.59 [p=0.670]
Observations	274	274	274
R-squared	0.474	0.360	0.400
Standard error	0.795	1.92	4.43

Notes. 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 equation (1). The F-test of the subset tests the joint significance of hard peg, basket peg, crawl and managed float dummies.

Two important implications of this are that exchange rate intervention works, and that, as far as the volatility of the real effective exchange rate is concerned, it largely does not matter what form it takes. If exchange rates are market-determined, as they are in an independent float, volatility is significantly higher. Although reducing volatility may be an important motivation for an interventionist regime, explicit real exchange rate targeting is relatively rare. The significantly smaller volatility for crawling pegs and bands suggests that these regimes tend to represent a form of real exchange rate targeting.

5.4 *Inflation Targeting*

Rose (2007) finds that countries with an inflation targeting regime have lower real effective exchange rate volatility than those that do not. Using Rose's dating of inflation targeting (Rose, 2007, Table A1), 40 out of our 274 episodes refer to countries with inflation targets. The mean monthly inflation rate in these 40 episodes is 0.22, compared with 0.67 in the remainder. Thus inflation targeters have below-average inflation, which in itself would tend to reduce real exchange rate volatility, according to our analysis so far. In Table 9 we investigate whether an inflation targeting regime is characterised by significantly lower volatility, after controlling for the effects identified previously. The answer is that it does not – the inflation targeting dummy is always highly insignificant.

Table 9. Inflation Targeting

	Volatility Measure		
	MAC	RMSC	SDL
Independent variables			
Constant	0.418** (4.51)	0.412* (1.98)	1.87** (4.55)
Episode length (qu)	-0.0098 (-0.98)	0.0225 (1.13)	0.197** (3.98)
Developing country dummy	0.400** (3.61)	0.860** (5.33)	1.58** (3.60)
Sub-Saharan Africa dummy	0.510** (2.96)	1.17* (2.53)	3.38** (3.22)
ln (land area)	0.0323 (1.58)	0.122** (2.69)	0.396** (3.84)
Monthly inflation rate	0.844** (5.63)	1.51** (4.55)	3.93** (5.52)
Regime dummies			
Crawl (5 or 6)	-0.573** (-3.77)	-1.17** (-3.77)	-2.63** (-3.08)
Independent float (8)	0.730** (4.29)	1.01* (2.24)	1.90* (2.46)
Inflation targeting	0.019 (0.18)	-0.154 (-0.69)	-0.104 (-0.19)
Observations	274	274	274
R-squared	0.470	0.354	0.395
Standard error	0.794	1.91	4.42

Notes. 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 equation (1).

5.5 *Robustness Tests*

In this section we conduct a series of robustness tests. First we add per capita GDP to the regression. This is highly collinear with the developing country dummy, as Table 10 shows. Per capita GDP tends to be slightly less significant than the developing country dummy, but highly significant in the absence of this dummy. When it is included the sub-Saharan Africa dummy tends to be less significant (it is significant only at the 0.10

level for two of the three volatility measures) and somewhat smaller than when only the developing country dummy is included. Thus poverty is clearly part of the explanation for the sub-Saharan Africa effect.

Tables 11 and 12 examine the sensitivity of the basic results to choosing different upper limits for inflation (varying from two to five per cent per month) and different lower limits for episode length (eight, twelve and sixteen quarters), using the *SDL* measure of volatility in each case. The results appear robust.

A final concern is that there are many countries for which the IMF does not publish real effective exchange rate data, and so the sample may incorporate a selection bias (towards richer countries, for example). In an effort to test if this bias is important, we have estimated a similar equation for the standard deviation of the level of real bilateral exchange rates against the US dollar. This enlarges the sample to 495 episodes using the same criteria (minimum length of four quarters; maximum monthly inflation of 3%), for 267 of which we have real effective exchange rate volatility measures. Table 13 shows the results for the whole sample, and for the two sub-samples with and without real effective exchange rate data. A Chow test shows that the differences in coefficients between the sub-samples are not significant at the 0.05 level, which suggests that our results are not unduly affected by sample selection bias.

Table 10. With per capita GDP

	Volatility Measure					
	MAC	MAC	RMSC	RMSC	SDL	SDL
Independent variables						
Constant	0.754** (3.92)	0.950** (9.68)	0.910** (2.80)	1.34** (6.04)	2.17* (2.41)	3.38** (6.39)
Episode length (qu)	-0.009 (-0.96)	-0.010 (-1.00)	0.022 (1.16)	0.021 (1.10)	0.196** (4.12)	0.194** (4.03)
Dev. co. dummy	0.221 (1.28)		0.484 (1.54)		0.136 (1.66)	
ln (GDP p.c.)	-0.086 (-1.26)	-0.13** (-3.05)	-0.203 (-1.31)	-0.31** (-3.02)	-0.122 (-0.37)	-0.417* (-2.06)
SSA dummy	0.360 (1.79)	0.319 (1.63)	0.839 (1.66)	0.749 (1.50)	3.18** (2.61)	2.93* (2.48)
ln (land area)	0.0248 (1.13)	0.0145 (0.81)	0.101* (2.39)	0.079* (2.13)	0.384** (3.42)	0.320** (3.41)
Monthly inflation rate	0.813** (5.32)	0.825** (5.34)	1.45** (4.53)	1.48** (4.64)	3.89** (5.43)	3.97** (5.48)
Regime dummies						
Crawl (5 or 6)	-0.58** (-3.81)	-0.56** (-3.71)	-1.18** (-3.83)	-1.14** (-3.70)	-2.64** (-3.10)	-2.52** (-3.03)
Independent float (8)	0.735** (4.53)	0.707** (4.26)	0.971* (2.35)	0.911* (2.11)	1.87* (2.55)	1.71* (2.24)
Observations	274	274	274	274	274	274
R-squared	0.475	0.472	0.359	0.356	0.396	0.391
St. error	0.790	0.791	1.91	1.91	4.42	4.43

Notes. 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 equation (1).

Table 11. Samples with Different Upper Limits for Inflation

	Volatility Measure			
	SDL	SDL	SDL	SDL
Including obs. with mean monthly inflation up to:	2.00	*3.00*	4.00	5.00
Independent variables				
Constant	1.31** (2.97)	*1.84*** *(4.30)*	2.11** (4.91)	2.31** (5.89)
Episode length (qu)	0.225** (4.88)	*0.196*** *(4.13)*	0.185** (3.57)	0.182** (3.48)
Developing country dummy	1.34** (3.17)	*1.61*** *(3.24)*	1.69** (3.17)	1.34** (3.17)
Sub-Saharan Africa dummy	3.16** (2.90)	*3.39*** *(3.24)*	3.51** (3.39)	4.02** (3.87)
ln (land area)	0.362** (3.71)	*0.395*** *(3.86)*	0.430** (3.89)	0.476** (4.10)
Monthly inflation rate	5.43** (5.25)	*3.93*** *(5.52)*	3.46** (5.43)	2.81** (5.99)
Regime dummies				
Crawl (5 or 6)	-2.64** (-2.83)	*-2.63*** *(-2.56)*	-2.71** (-3.24)	-2.46** (-3.07)
Independent float (8)	2.11** (3.08)	*1.87** *(2.56)*	1.50* (2.03)	1.40 (1.89)
Observations	261	*274*	278	285
R-squared	0.419	*0.395*	0.397	0.417
Standard error	4.25	*4.41*	4.49	4.58

Notes. 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 equation (1).

Table 12. Samples with Different Minimum Episode Lengths

	Volatility Measure			
	SDL	SDL	SDL	SDL
Minimum episode length (quarters)	*4*	8	12	16
Independent variables				
Constant	*1.84*** *(4.30)*	1.79** (3.77)	1.61* (2.38)	0.96 (1.59)
Episode length (qu)	*0.196*** *(4.13)*	0.206 ** (3.29)	0.225* (2.41)	0.286** (4.17)
Developing country dummy	*1.61*** *(3.24)*	1.48** (3.17)	1.49** (3.30)	1.28** (3.04)
Sub-Saharan Africa dummy	*3.39*** *(3.24)*	3.64** (3.26)	3.72** (3.25)	4.12** (3.85)
ln (land area)	*0.395*** *(3.86)*	0.382** (3.57)	0.386** (3.53)	0.289** (3.22)
Monthly inflation rate	*3.93*** *(5.52)*	4.05** (516)	4.16** (4.78)	4.53** (5.11)
Regime dummies				
Crawl (5 or 6)	*-2.63*** *(-2.56)*	-2.53** (-2.64)	-2.64* (-2.54)	-2.27** (-2.78)
Independent float (8)	*1.87** *(2.56)*	1.77* (2.38)	1.80* (2.25)	2.47** (3.26)
Observations	*274*	252	234	215
R-squared	*0.395*	0.416	0.405	0.492
Standard error	*4.41*	4.33	4.42	3.78

Notes. 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 equation (1).

Table 13. Real Bilateral Exchange Rate Volatility Against the US Dollar

Dependent variable:	*Standard deviation of level of real bilateral exchange rate against US dollar*		
Episodes with:	All	REER data	No REER data
Independent variables			
Constant	7.24** (8.66)	7.18** (8.11)	7.95* (1.98)
Episode length (qu)	0.333** (6.60)	0.352** (5.02)	0.330** (4.48)
Developing country dummy	-0.60 (-0.67)	-1.94 (-1.89)	-0.78 (-0.19)
Sub-Saharan Africa dummy	3.35** (4.61)	4.90** (4.40)	2.35* (2.39)
ln (land area)	0.738** (5.97)	0.608** (3.54)	0.762** (4.07)
Monthly inflation rate	2.47** (57)	4.20** (5.36)	1.73** (3.23)
Regime dummies			
Crawl (5 or 6)	-3.41** (-3.42)	-3.68** (-3.11)	-3.35 (-1.80)
Independent float (8)	1.04 (1.22)	-0.07 (-0.01)	2.40 (1.67)
Observations	495	267	228
R-squared	0.250	0.317	0.217
Standard error	6.44	6.11	6.76
Chow statistic		$F(7,487) = 1.82$ [$p<0.05$]	

Notes. Figures in parentheses are *t*-statistics. * (**) denotes significantly different from zero at the 0.05 (0.01) level. For definition of volatility measures see equation (1).

6. Conclusions

This paper has presented a new analysis of real effective exchange rate volatility, using a sample of 90 countries. Volatility is higher in poorer countries, in larger countries and (most notably) increases significantly with the inflation rate, even at quite low levels of inflation. Independent floats have significantly higher volatility, after controlling for these factors, which suggests that currency intervention works. Beyond this, the only significant regime effect is that crawling pegs and bands have particularly low volatility. A natural interpretation is that these regimes represent a form of real exchange rate targeting. Inflation targeting regimes do not have abnormally low volatility, given their inflation rates. Sub-Saharan African countries tend to have more volatile real effective exchange rates than the model predicts.

It has been noted that emerging market countries tend to manage their floats, probably for fear of excessive real exchange rate volatility. Our results suggest that, when inflation is significant, managed floats deliver similar real exchange rate stability to pegs, but without frequent nominal devaluations. This makes them attractive to governments that find nominal devaluations humiliating. From this viewpoint, the increased popularity of floating probably reflects pragmatic considerations more than an intellectual appreciation of non-intervention.

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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

Sub-Saharan Africa (17)
Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Democratic Republic of Congo, Equatorial Guinea, Gabon, Gambia, Ghana, Lesotho, Malawi, Nigeria, Sierra Leone, South Africa, Togo, Uganda, Zambia

Other (50)
Algeria, Antigua and Barbuda, Armenia, Bahamas, Bahrain, Belize, Bolivia, Bulgaria, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Czech Republic, Dominica, Dominican Republic, Ecuador, Fiji, Grenada, Guyana, Hungary, Iran, Israel, Malaysia, Malta, Moldova, Morocco, Netherlands Antilles, Nicaragua, Pakistan, Papua New Guinea, Paraguay, Philippines, Poland, Romania, Russia, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, Samoa, Saudi Arabia, Singapore, Slovak Republic, Solomon Islands, Trinidad and Tobago, Tunisia, Ukraine, Uruguay, Venezuela.

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