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CENTRE FOR FINANCE, CREDIT AND MACROECONOMICS

Working Paper 20/04

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Produced By:

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Is Reserve Volatility Inversely Related to Exchange Rate Flexibility?

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Abstract

When the pressure on the exchange rate is high, the government has to consider how much to resist such a speculative attack by spending reserves rather than allowing the exchange rate to change. Some authors have claimed that the best approach to classifying exchange rate regimes is to estimate to what extent exchange market pressure (EMP) is absorbed in reserve variability rather than exchange rate variability. Empirical evidence is presented on the variability of reserves and exchange rates over a large sample of countries from 1980 to 2019. Pegged regimes do not display any more reserve volatility than floats. In most regimes there is a small but statistically significant positive correlation between reserve accumulation and exchange rate appreciation in monthly data, but this effect is no stronger in less flexible regimes, where intervention is expected to be greater. An EMP-inspired flexibility index is constructed, based on the ratio of exchange rate flexibility to reserve volatility, and the two flexibility measures are compared by investigating their conformity with the IMF de facto classification. The EMP-inspired flexibility index does not improve the identification of pegs, but it helps to distinguish free floats from managed floats. Most likely this is because credible pegs need little intervention to support them.

Keywords: exchange rates regimes, inflation

JEL No.: F31

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1 Introduction

Most currencies are managed to some degree: according to the IMF de facto classification, from 1980 to 2019 freely floating currencies made up under 11% of the sample. The concept of exchange market pressure (EMP), measured as some weighted average of exchange rate appreciation and reserve accumulation, highlights different possible policy responses to excess demand for or supply of domestic currency. These alternative policy responses are likely to reflect how strongly the government wishes to stabilise the exchange rate by intervention in the foreign exchange market. It is therefore natural to think of a pegged exchange rate regime as characterised by intervention in the market to prevent the exchange rate from moving, thereby achieving exchange rate stability at the expense of reserve volatility, and there have been some efforts to construct exchange rate regime classifications based on this principle. Implicitly the argument is that the ratio of exchange rate variability to reserve variability (or "EMP ratio", as we shall call it) is a better indicator of the exchange rate regime than just the variability of the exchange rate, because it gives an estimate of how much the exchange rate is allowed to vary relative to what might have occurred with no intervention. Whether such an inverse correlation between exchange rate variability and reserve variability exists in reality has, however, been subject to surprisingly little empirical investigation.

There is an implicit assumption underlying the idea of defining an exchange rate regime by its EMP ratio, and that is that the marginal costs of reserve variability and exchange rate variability are continuous functions. That seems reasonable in the case of a managed float, where one can conceive of a government permitting more exchange rate movement when the pressure on reserves is greater. It is much more problematic for pegs or bands with preannounced ranges of variation about some central rate, for which there is a discontinuity in the marginal cost of exchange rate variation: within the band it is virtually zero, but at the edge of the band the marginal cost becomes very large. Unless EMP hits the level where the peg is abandoned, therefore, this discontinuity implies a wide range of reserve variability for essentially the same exchange rate variability (i.e. that which keeps it just within the band). If the peg is credible, then, as in target zone models, there will be a tendency to expect the exchange rate to revert towards the centre of the band, which obviates the necessity for intervention to keep the exchange rate within the band. In short, credible pegs need not have high reserve variability. We explore the hypothesis that the EMP ratio is not as useful as its proponents suggest for the purpose of distinguishing floats from pegs, but that it is relevant to establishing how tightly or loosely a floating exchange rate is managed.

In this paper we use a continuous measure of exchange rate flexibility to examine the relationship between exchange rate flexibility and reserve variability. Although there is a tendency for exchange rate appreciations to be associated with reserve accumulation more frequently than not in monthly data, we find that, when exchange rate flexibility and reserve variability are calculated over calendar years, their correlation tends to be positive rather than negative. Having a continuous measure of exchange rate flexibility gives us the opportunity to develop an EMP-inspired alternative measure of flexibility based on the EMP ratio. As judged by the degree of conformity with the IMF de facto exchange rate classification scheme, this EMP-inspired measure does not improve the identification of pegs, but it does somewhat improve the identification of free as opposed to managed floats.

The paper is structured as follows. Section Two introduces the measure of exchange rate flexibility. Preliminary issues are discussed in Section Three, and our main results are presented in Section Four. Section Five concludes.

2 Exchange Rate Flexibility

Most analyses of exchange rate regimes end up with a limited number of categories, such as “Pegs”, “Intermediate Regimes” and “Floats”, which may or may not be further disaggregated.

For current purposes, a continuous measure of exchange rate flexibility is needed in order to construct the EMP ratio. One such flexibility measure is that suggested by Bleaney and Tian (2017). They develop a method of measuring exchange rate flexibility and identifying exchange rate regimes by a regression similar to that previously used by Frankel and Wei (1995) and Slavov (2013) to identify the basket of anchor currencies for a pegged regime, while allowing also for a crawling peg and for one-off parity changes. The principle is that the movement of any currency X against a numeraire currency N will track closely the movement of other currencies A, B, C etc. against N if X is pegged to one or a weighted average of these currencies, so that this regression will be characterised by a low root mean square error (RMSE). If currency X is floating, the fit of this regression will be much poorer. Consequently this RMSE may be regarded as an indicator of exchange rate flexibility. End-of-month observations are used to generate a flexibility measure for each calendar year, with the Swiss franc as numeraire (Bleaney and Tian, 2017) or, in the further analysis of Bleaney and Tian (2020), with the Japanese yen as numeraire. The flexibility index is designed to be comprehensive, in that it caters for a single parity change with the exchange rate pegged before and after the change, and for crawling pegs as well as horizontal pegs.

Since the number of degrees of freedom in the regression is limited when only twelve observations are used, there is an issue of whether the accuracy of the measure can be improved by extending the number of months, although there is a trade-off here with the increased risk of a distortion of the measure by a regime change occurring during the period. For the sake of robustness, we present results for 18-month and 24-month regressions as well.

Although we have suggested an RMSE of below 0.01 as a suitable criterion for a peg, the majority of pegs are much tighter than this, with an RMSE of less than 0.001, which we label “Tight Pegs”. We examine whether there are any systematic differences between Tight

Pegs and Loose Pegs (i.e. those with an RMSE between 0.001 and 0.01); in particular we show that Tight Pegs are virtually 100 percent single-currency pegs, whereas Loose Pegs are not.

The analysis here is based on using the Japanese yen as the numeraire. The potential anchor currencies that we consider are the US dollar and the euro, but with others added in particular cases as listed in Bleaney and Tian (2017, p. 304). Up to 1998, when the euro had not yet been created, we use the German mark and the French franc instead. The regression relates exchange rate movements of currency i against the chosen numeraire currency N (in this case the Japanese yen) to movements of potential anchor currencies against N:

$$\Delta \ln E(i,N)_t = a + b\Delta \ln E(USD,N)_t + c\Delta lnE(EUR,N)_t + u_t \qquad (1)$$

where *USD* is the US dollar, *EUR* is the euro, $E(i, N)$ is the number of units of currency i per yen (so an increase represents a depreciation of currency i), and Δ is the first-difference operator. In a single-currency peg to the euro, the euro-yen exchange rate should have a coefficient equal to one, and any other exchange rate should have a coefficient of zero. In a basket peg, the coefficients of the currencies making up the basket should sum to one. If the government operates a crawling peg, with a steady devaluation rate of x% per month, the value of x can be estimated from the intercept term in the regression.

Where this regression covers the twelve months of a calendar year, as in Bleaney and Tian (2017, 2020), the precise procedure is as follows. The classification is based on the root mean square error (RMSE) of this regression, which we shall call Regression A. To allow for the possibility of one parity change per year, Bleaney and Tian (2017) estimate 12 extra regressions, each with a dummy variable equal to one in one month only added to Regression A. Call these regressions B(1) to B(12). If none of the dummy variables is statistically significant enough, Regressions B(1) to B(12) are ignored, and that country-year is coded a Fix if RMSE < 0.01, and a Float otherwise. If any of the dummy variables is significant enough, the B regression with the most significant dummy variable becomes the focus of attention.[1] If the RMSE < 0.01 in the chosen B regression, that country-year is coded as a Peg with a Parity Change, and otherwise a Float. We impose two exceptions to this rule, however. (1) If the estimated parity change is very small (< ±0.02), we treat it as a movement within an unchanged band rather than a shift in the central rate, and the observation is coded a Fix. (2) Since revaluations are in practice rare, except where one is known to have occurred, if the estimated parity change is a revaluation of > 0.02, this is assumed to be spurious, and the B regressions are ignored, the coding instead being based on Regression A.[2] This classification is available up to 2019.

3 Some Preliminary Issues

3.1 The Time Span of the Regression

In choosing the time span of the regression used for measuring exchange rate flexibility, there is clearly a trade-off between accuracy and the possibility of regime change. With a longer time span, the regression has more degrees of freedom, but it is more likely that there has been a regime change during the period. To address this issue we consider regressions of length 18 and 24 months as well as twelve months, with the number of B regressions estimated being correspondingly increased. To be absolutely clear, the RMSE attributed to the year 2019 is based on January to December 2019 in the 12-month case, July 2018 to December 2019 in the 18-month case, and January 2018 to December 2019 in the 24-month case.

When applied on a 12-month basis for a calendar year, as in Bleaney and Tian (2017, 2020), the degrees of freedom in this regression are nine in the case where no parity change is

[1] Bleaney and Tian (2017) suggest an F-statistic > 30 for the addition of the dummy variable as the critical value.
[2] We treat Germany 1983 and China 2005 as genuine parity changes.

identified (twelve observations and three regressors), and only eight when there is a parity change. This is reduced further in the small number of cases when potential anchor currencies other than the US dollar and the euro are added. It is possible that this small number of degrees of freedom biases the estimated RMSE downwards (since as the degrees of freedom approach zero, so does the RMSE). It is also likely that the volatility of a floating currency varies considerably from year to year, and that a more consistent estimate would be obtained from a longer regression. On the other hand, a regime switch during the period biases the measure upwards (Bleaney and Tian, 2020), and a longer regression increases the chance of a regime switch.

To address this issue, we compare the results for different regression lengths for a number of currencies. Table 1 show some statistics for six currencies that were known to be freely floating in the years 2000 to 2019, so there is no regime change issue. For each country, the RMSE from equation (1) is shown for a regression of 12 months (January of year T to December of year T), eighteen months (July of year T-1 to December of year T) and 24 months (January of year T-1 to December of year T). Table 1 provides the mean RMSE for each country over these twenty years, together with its standard deviation.

The mean shows a slight tendency to increase, the maximum being about five percent, between the 12-month regression and the 24-month one. This suggests that the downward bias from the relatively small degrees of freedom in the 12-month regression is quite limited. On the other hand, the differences in standard deviations are much more marked. The reduction in the standard deviation in the 24-month regression compared with the 12-month regression is about 14 percent for Canada, about 15 percent for the US and the UK, and more than 25 percent for Japan, Australia and New Zealand. This provides a strong indication that a longer regression is better, in the sense of producing more consistent results from period to period, so long as one can be sure that the regime has not changed during the period.

Table 1. The Effects of the Regression Span on the RMSE for selected countries 2000 to 2019

Country	24 months	18 months	12 months
		Mean	
United States	2.03	2.05	1.93
United Kingdom	1.75	1.74	1.75
Canada	2.13	2.12	2.07
Japan	2.27	2.25	2.20
Australia	2.35	2.27	2.27
New Zealand	2.74	2.66	2.64
		Standard Deviation	
United States	0.507	0.546	0.600
United Kingdom	0.525	0.641	0.659
Canada	0.630	0.651	0.733
Japan	0.644	0.718	0.885
Australia	0.417	0.510	0.732
New Zealand	0.550	0.622	0.910

Notes. The statistics are the mean and standard deviations of the RMSEs, both multiplied by 100, for the years 2000 to 2019 derived from estimating equation (1) over 24-month, 18-month and 12-month horizons, as described in the text.

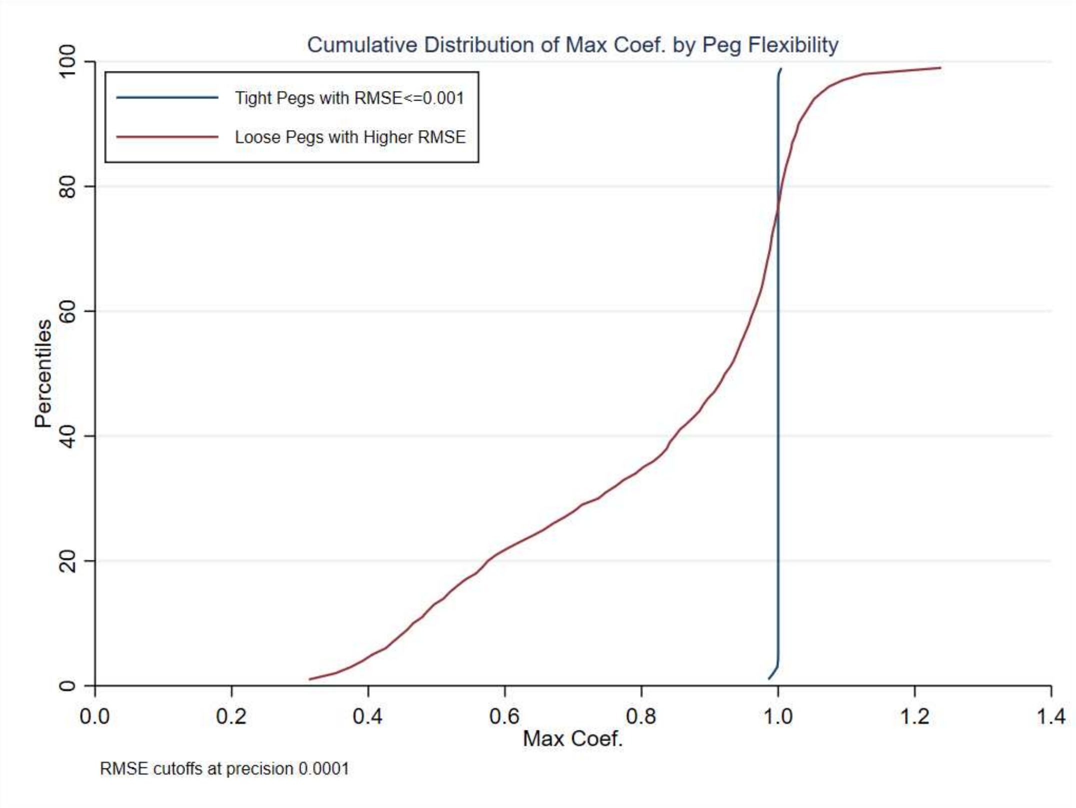
3.2 Tight and Loose Pegs

Although we have suggested that an RMSE of less than 0.01 should define a peg, there is a considerable preponderance of pegs with very small RMSEs (< 0.001). In this section we investigate whether these Tight Pegs, as we label them, tend to be significantly different from Loose Pegs (RMSE between 0.001 and 0.01). For instance, are they more likely to be single-currency pegs? This seems likely to be the case because of the transparency of a single-currency peg (it is extremely easy for agents to check whether the announced regime is being adhered to), and also because Loose Pegs may include heavily managed floats that aim only to keep the exchange rate within a certain range, as well as committed peggers.

Figure 1 shows the cumulative distribution function of the size of the largest exchange rate coefficient in each regression for Tight and Loose Pegs separately. In most cases this is just the larger of the euro and US dollar coefficients. For single-currency pegs, this statistic should be very close to one, whereas for basket pegs or for floats that are very tightly managed it will tend to be rather smaller, because of the weight attached to other currencies. In Figure 1, the percentile is on the vertical axis and the statistic is on the horizontal axis. For Tight Pegs (1901 cases), the cumulative distribution is very close to being a vertical line at one, indicating virtually 100 percent single-currency pegs. For Loose Pegs (1850 cases), the picture is much more varied: the 25^{th} percentile is 0.647, and the 50^{th} percentile is 0.921, which suggests that only about half of Loose Pegs are single-currency pegs or something very close to it.[3]

[3] The figures are based on the 24-month regressions (results for 18 months and 12 months are very similar). Currency unions are counted once only. For more data, see Appendix Table A1.

Fig. 1. The cumulative distribution of the largest exchange rate coefficient for pegs



Note: based on 24-month regressions

4 The Volatility of International Reserves and the Exchange Rate Regime

Some exchange rate classification schemes are based exclusively on the behaviour of the exchange rate (e.g. Bleaney and Tian, 2017; Shambaugh, 2004; see Tavlas et al., 2008, for a survey). There are other authors who have argued that exchange rate regime classifications should take account of movements in international reserves as well as in exchange rates. For example, Frankel and Wei (2013, p. 7) condemn "…the folly of judging a country's exchange rate regime by looking simply at variation in the exchange rate" and they go on to say: "One must focus on exchange rate variability *relative to* reserve variability to gauge where a country sits on the spectrum of fixed to floating." A similar assertion of the necessity of a multi-dimensional approach to exchange rate regime classification appears in Levy-Yeyati and Sturzenegger (2005, p.1608).

This argument for a multi-dimensional approach draws on the extensive literature on exchange market pressure (Girton and Roper, 1977; Weymark, 1995), which recognises that, in the event of excess demand (supply) for the domestic currency at the current exchange rate, the government must either soak it up by accumulating (spending) reserves or by reducing (raising) interest rates, or allow the currency to appreciate (depreciate). Exchange market pressure in its most basic form is measured as the sum of the percentage exchange rate appreciation (usually relative to the US dollar) and the percentage increase in international reserves. This may be refined by some combination of (a) normalisation of the components of EMP by subtracting the sample mean and dividing by the sample standard deviation and/or (b) adding in the change in interest rate differentials (foreign minus domestic) (Aizenman et al., 2012; Aizenman and Binici, 2016).

It is a natural extension of this concept to think of the proportion of EMP represented by exchange rate changes as an indicator of exchange rate flexibility. If exogenous shocks to EMP vary significantly in magnitude over currencies and time, the argument is that taking the *relative* importance of reserves and exchange rate variability is a better measure than just using exchange rate variability. To express it another way, the authorities' policy preferences are expressed in the EMP ratio, and observed exchange rate variability will be a function of the EMP ratio and the size of EMP shocks during the period. To the extent that EMP shocks are relatively similar in size across the sample, we would expect to observe a negative correlation between reserve variability and exchange rate variability. In the classification scheme of Levy-Yeyati and Sturzenegger (2005), cluster analysis is used to identify combinations of low exchange rate variability and high reserve variability as pegs.

The concept of exogenous exchange rate shocks, reflecting factors such as natural disasters, resource discoveries, commodity price movements or political uncertainties, is relatively uncontroversial, as is the idea that these shocks might be larger for some countries than others. For example, Bleaney and Francisco (2010) find that real effective exchange rates are significantly more volatile in poorer countries, those with higher inflation and greater terms-of-trade volatility, and in those with a lower ratio of international trade to GDP. The natural volatility of countries' real exchange rates, even if they were all freely floating, would not be the same, and it is a weakness of a flexibility index like RMSE that it does not take this into account. But a measure like EMP reflects the capital account as well as the current account, and capital account flows can be influenced by the exchange rate regime itself. If a government announces a peg regime, it creates a significant political cost in abandoning the peg. As a result, the marginal cost of exchange rate variability becomes discontinuous, contrary to the implicit assumptions underlying the EMP ratio. Moreover, the credibility of the peg is likely to affect the EMP ratio. In particular, a highly credible peg (one which the government is strongly committed to defend) will tend not to be subject to speculative attacks, because the market believes that the government would always do what it takes to defend the peg, and this itself will create an expectation of mean-reversion in the exchange rate that makes intervention unnecessary (Svensson, 1993). The observed values of EMP may therefore turn out to be quite low in credible pegs, and rather higher in less credible ones, when in fact the government's commitment to defending the peg is higher in the former than the latter. In other words, exchange market pressure is likely to depend not only on exogenous factors but also on the credibility of the exchange rate regime. A further point is that, for pegs which lack 100% credibility, EMP is not constant over time, but tends to arrive in waves, so that reserve variability is likely to change over time even though the exchange rate regime remains fundamentally the same. Thus, whatever the merits of taking reserve variability into account in theory, its practical application is likely to be problematic because of the discontinuity in the marginal cost of exchange rate variability associated with a peg.

There is a gap in the literature here, since there has been little empirical examination of the relationship between the variability of reserves and of exchange rates, and the overall picture is unclear. Calvo and Reinhart (2002, Fig. 1) focus on the proportion of months in which reserves increase or decrease by more than 2.5 percent, and find that this proportion is much the same over different types of exchange rate regime in a sample of 39 countries from January 1970 to November 1999. They interpret this as widespread "fear of floating" (i.e. fear of an independent float without intervention to manage the exchange rate), but an alternative interpretation might be that pegs do not have EMP ratios as low as expected for the reasons given above. Ahmad and Pentecost (2020) examine a relatively small sample of eight African countries from 1970 to 2019 and use a similar statistical approach, based on the proportion of monthly exchange rate and reserve movements that exceed a certain threshold (±1 percent or ±2.5 percent). They find that the proportion of the time that the exchange rate movement exceeds either of these thresholds is similar between pegged and floating regimes, but that reserve movements exceed the thresholds *more* often, not *less* often, under floating, which seems in direct contradiction to the predictions of EMP theory.

In this study, we use a large cross-country sample of monthly data between 1980 and 2019 to investigate the relationship between exchange rate flexibility and reserve variability.

We first take a look inside the regressions used to generate our measure of exchange rate flexibility. If we imagine a government whose policy is to keep its currency (the peso) within a certain band of ±*x*% about a fixed central rate to the US dollar, then in our regressions the fitted value of the log change in pesos per yen will equal the log change in dollars per yen, and the residual will represent a depreciation in the peso relative to its central rate against the dollar. If the government is intervening in the foreign exchange market, that will be reflected in the change in reserves. The theory of EMP predicts that intervention to keep the exchange rate within the ±*x*% band will tend to take the form of sales of foreign currency when the exchange rate is depreciating within the band and purchases when it is appreciating. We therefore investigate the correlation between the residuals in each month of the regression and the change in the log of reserves. For each country-year observation this generates a correlation coefficient which, according to EMP theory, should be negative when the authorities are intervening to stabilise the exchange rate (since a depreciation is represented by a positive residual). We investigate the distribution of this correlation coefficient for all observations other than tight pegs, which are excluded because the exchange rate variation is too small.

The data on reserves are from IMF Financial Statistics and exclude gold. They are denominated in US dollars. Excluding gold takes out the effects of fluctuations in the price of gold, which would change total reserves without representing any intervention in the foreign exchange market. Excluding gold does however misrepresent intervention in months where gold is bought or sold in exchange for foreign exchange reserves, as happens occasionally.

Table 2 gives some data about the distribution of this correlation across the whole sample (excluding tight pegs), for the 12-month, 18-month and 24-month regressions and for different ranges of exchange rate flexibility. The mean and the median correlations are -0.078

and -0.087 respectively for the 12-month regressions, -0.079 and -0.088 for the 18-month regressions, and -0.084 and -0.090 respectively for the 24-month regressions. These numbers are all significantly different from zero, so there is evidence of the expected negative correlation, although the percentiles indicate that the correlation is negative in only about two-thirds of cases, and this tends to be true over the whole range of RMSE. Moreover one might expect the correlations to be more negative at the less flexible end of the spectrum, where EMP theory would predict that intervention would be more intense. This is not the case, however. The correlations are always less negative, not more negative, on average for pegs (RMSE < 0.010) than for RMSE ≥ 0.01, and the difference is highly statistically significant (the median is between -0.06 and -0.07 for Loose Pegs, and between -0.10 and -0.11 for floats. This is consistent with the argument that credible pegs need little intervention to keep the exchange rate within the announced range.

Table 2. Correlation between exchange rate movements and reserve accumulation

12-Month Window

	count	**mean**	min	max	p10	p25	**p50**	p75	p90
0.001≤RMSE<0.01	2032	**-0.058**	-0.958	0.945	-0.440	-0.268	**-0.062**	0.149	0.343
0.01≤RMSE<0.02	936	**-0.105**	-0.930	0.926	-0.493	-0.323	**-0.123**	0.093	0.310
RMSE>0.02	979	**-0.092**	-0.944	0.926	-0.546	-0.335	**-0.104**	0.135	0.364
Total (RMSE≥0.001)	3947	**-0.078**	-0.958	0.945	-0.480	-0.299	**-0.087**	0.133	0.344

18-Month Window

	count	**mean**	min	max	p10	p25	**p50**	p75	p90
0.001≤RMSE<0.01	1933	**-0.064**	-0.960	0.678	-0.382	-0.235	**-0.069**	0.102	0.258
0.01≤RMSE<0.02	997	**-0.093**	-0.917	0.908	-0.445	-0.275	**-0.110**	0.089	0.255
RMSE>0.02	1110	**-0.093**	-0.854	0.930	-0.476	-0.294	**-0.109**	0.088	0.298
Total (RMSE≥0.001)	4040	**-0.079**	-0.960	0.930	-0.424	-0.257	**-0.088**	0.095	0.264

24-Month Window

	count	**mean**	min	max	p10	p25	**p50**	p75	p90
0.001≤RMSE<0.01	1849	**-0.067**	-0.962	0.807	-0.349	-0.212	**-0.068**	0.075	0.221
0.01≤RMSE<0.02	1054	**-0.109**	-0.890	0.910	-0.421	-0.274	**-0.109**	0.037	0.192
RMSE>0.02	1216	**-0.088**	-0.879	0.862	-0.422	-0.282	**-0.102**	0.079	0.245
Total (RMSE≥0.001)	4119	**-0.084**	-0.962	0.910	-0.387	-0.248	**-0.090**	0.070	0.225

Notes. RMSE precision cut-off at 0.0001. Exchange rate: Domestic Currency Units per Numeraire Currency. The figures in each row relate to the distribution of the correlation between the regression residual and the change in the log of reserves over the 12, 18 or 24 months of the regression. For example the first row refers to the 2032 12-month regressions where the RMSE was between 0.001 and 0.01. The cases of RMSE<0.001 are omitted because the residuals are too small.

Next we turn to the question of the relationship between the variability of exchange rates and of reserves. The issue is whether the standard deviation of the log of reserves over a given period varies negatively and systematically with the degree of exchange rate flexibility over the same period, as EMP theory suggests. If there is less exchange rate flexibility, does there tend to be more reserve variability, either across the whole spectrum of regimes or, as we have suggested, perhaps only at the more flexible end of the spectrum?

Table 3 provides some relevant statistics. Results for 12-month, 18-month and 24-month regressions are all shown, but they all present a similar picture. Using the 24-month regression results (the last row in each panel of Table 3.), we can see that there is not a monotonic relationship between exchange rate flexibility and the standard deviation of reserve changes. For RMSE<0.001, the median reserve variability is 0.071, which is higher than for RMSE in the range 0.001 to 0.01 (0.058) or 0.01 to 0.02 (0.054), but very similar to RMSE greater than 0.02 (0.070). The picture is much the same for 12-month and 18-month regressions.

Before discussing this further, it is useful to construct a variable, which might be described as "EMP variability", as the standardised sum of exchange rate flexibility and reserve variability, and to investigate the distribution of this variable as well as the relationship between its two components. We compare the flexibility index described in Section Two, which was based purely on exchange rates, to a flexibility index based on the ratio of the two components of EMP variability.

We may construct a bivariate index of exchange rate flexibility in country j in year t ($BFLEX_{jt}$), after normalising the variables to have the same standard deviation over the whole sample, as follows. Define the variability of EMP ($EMPVAR_{jt}$) as the sum of ZE_{jt} and ZR_{jt}, where ZE_{jt} is 100 times the RMSE and ZR_{jt} is 100 times the standard deviation of the log of reserves (SDR), multiplied by the ratio of the sample standard deviation of RMSE (Y) to the sample standard deviation of SDR (X) (both 2 percent trimmed at the upper end):

$$EMPVAR_{jt} = ZE_{jt} + ZR_{jt} = 100 * RMSE_{jt} + 100 * \left(\frac{Y}{X}\right) SDR_{jt} \quad (1)$$

In this case the value of Y is 0.018 and of X is 0.087, so the standardisation coefficient 0.211. Equation (1) keeps the minimum possible value of EMPVAR at zero. The bivariate index of flexibility is the percentage of EMPVAR represented by ZE rather than by ZR, or in other words how much of EMP variability can be attributed to exchange rates rather than reserves:

$$BFLEX_{jt} = \left(\frac{ZE}{EMPVAR}\right)_{jt} \quad (2)$$

Table 4 presents some data about EMPVAR and BFLEX in relation to different degrees of exchange rate variability. EMPVAR is only slightly larger for RMSE between 0.001 and 0.01 than for RMSE < 0.001 (2.23 compared with 2.10 using the 24-month regression window), but jumps to 2.97 for RMSE between 0.01 and 0.02, and then more than doubles to 6.44 for RMSE > 0.02. The pattern for BFLEX is rather the opposite of that, with the smallest differences between the two highest categories of RMSE. When RMSE is very small (< 0.001), BFLEX is also very small (1.0 percent using a 24-month window), so there is very little difference between them for tight pegs. The average of BFLEX for looser pegs (RMSE between 0.001 and 0.01) is 29.6 percent, rising to 55.9 percent for RMSE between 0.01 and 0.02 and 68.6 percent for RMSE over 0.02.

Table 5 shows the correlation between RMSE and BFLEX across the sample. The correlation is very similar whatever the length of the regression window, and is 0.66 for the whole sample (using the 24-month figure). Within the category of loose pegs (RMSE between 0.001 and 0.01) it is still quite high, at 0.53, but it falls to 0.24 for RMSE in the range 0.01 to 0.02, and to only 0.15 for RMSE above 0.02. In tight pegs, where RMSE is very close to zero, the correlation is only 0.32. The relatively high value for the whole sample reflects the fact that if RMSE is very small, so is BFLEX, as Table 4 shows.

By regressing ZR on ZE in a quantile regression, we can examine the relationship between reserve variability and exchange rate flexibility across the whole spectrum of RMSE. Using the data from the 24-month regressions, Fig. 2 shows the point estimates of the coefficient at each decile of the distribution of RMSE, together with a 95% confidence interval (the shaded area); the OLS coefficient of 0.133, which has a t-statistic of 4.77, is shown as a horizontal line. The point estimate in Fig. 2 increases steadily from effectively zero at the first decile to 0.3 at the ninth decile, and the coefficient is significantly different from zero from the third decile upwards.[4]

Thus the picture we get is that there is no negative correlation between reserve variability and exchange rate flexibility in pegged exchange rates, and a positive correlation in more flexible regimes.

[4] The graphs for the 18-month and 12-month regressions are similar. The actual quantile regressions are reported in the Appendix.

Table 3. Distribution of the standard deviation of the log of reserves

	count	**mean**	min	max	p10	p25	**p50**	p75	p90
RMSE<0.001									
12m-Window	2359	**0.095**	0.000	0.526	0.022	0.039	**0.066**	0.113	0.201
18m-Window	2293	**0.095**	0.000	0.524	0.024	0.041	**0.067**	0.114	0.197
24m-Window	2236	**0.099**	0.000	0.528	0.026	0.044	**0.071**	0.117	0.208
0.001≤RMSE<0.01									
12m-Window	2022	**0.078**	0.000	0.520	0.019	0.032	**0.055**	0.092	0.167
18m-Window	1922	**0.079**	0.000	0.529	0.021	0.034	**0.056**	0.092	0.166
24m-Window	1840	**0.081**	0.002	0.528	0.022	0.035	**0.058**	0.095	0.163
0.01≤RMSE<0.02									
12m-Window	930	**0.066**	0.003	0.448	0.015	0.024	**0.045**	0.079	0.137
18m-Window	991	**0.070**	0.003	0.422	0.016	0.026	**0.049**	0.088	0.149
24m-Window	1046	**0.071**	0.003	0.507	0.018	0.029	**0.054**	0.089	0.146
RMSE>0.02									
12m-Window	966	**0.096**	0.000	0.518	0.018	0.032	**0.060**	0.122	0.231
18m-Window	1095	**0.100**	0.000	0.533	0.020	0.033	**0.063**	0.131	0.229
24m-Window	1194	**0.106**	0.002	0.531	0.021	0.036	**0.070**	0.147	0.250
Whole sample									
12-Window	6277	**0.085**	0.000	0.526	0.019	0.033	**0.058**	0.104	0.188
18-Window	6301	**0.087**	0.000	0.533	0.020	0.035	**0.060**	0.106	0.189
24-Window	6316	**0.091**	0.000	0.531	0.021	0.037	**0.063**	0.110	0.195

Notes. Both RMSE and the standard deviation of the log of reserves are trimmed by 2% at the top end. “p10” is the tenth percentile.

Table 4. EMP variability and a bivariate exchange rate flexibility index

	EMP variability (EMPVAR)	Exchange rate % of EMP variability (BFLEX)
12m-Window		
1: RMSE<0.001	1.803	1.251
2: 0.001<=RMSE<0.01	1.982	32.281
3: 0.01<=RMSE<0.02	2.702	60.700
4: RMSE>0.02	5.879	72.041
18m-Window		
1: RMSE<0.001	1.938	1.122
2: 0.001<=RMSE<0.01	2.124	30.822
3: 0.01<=RMSE<0.02	2.859	57.396
4: RMSE>0.02	6.135	70.224
24m-Window		
1: RMSE<0.001	2.102	1.041
2: 0.001<=RMSE<0.01	2.233	29.553
3: 0.01<=RMSE<0.02	2.965	55.902
4: RMSE>0.02	6.438	68.554

Notes. Mean values are shown. EMP variability = 100 *[RMSE + a * SD(dlnReserves)], where a = standardisation coefficient. BFLEX = 10000*RMSE/(EMPVAR).

Table 5. Correlation between RMSE and BFLEX

Regression length:	12 months	18 months	24 months
Whole sample	0.671	0.667	0.661
RMSE<0.001	0.361	0.351	0.324
0.001≤RMSE<0.01	0.525	0.528	0.538
0.01≤RMSE<0.02	0.246	0.223	0.245
RMSE≥0.02	0.147	0.139	0.149

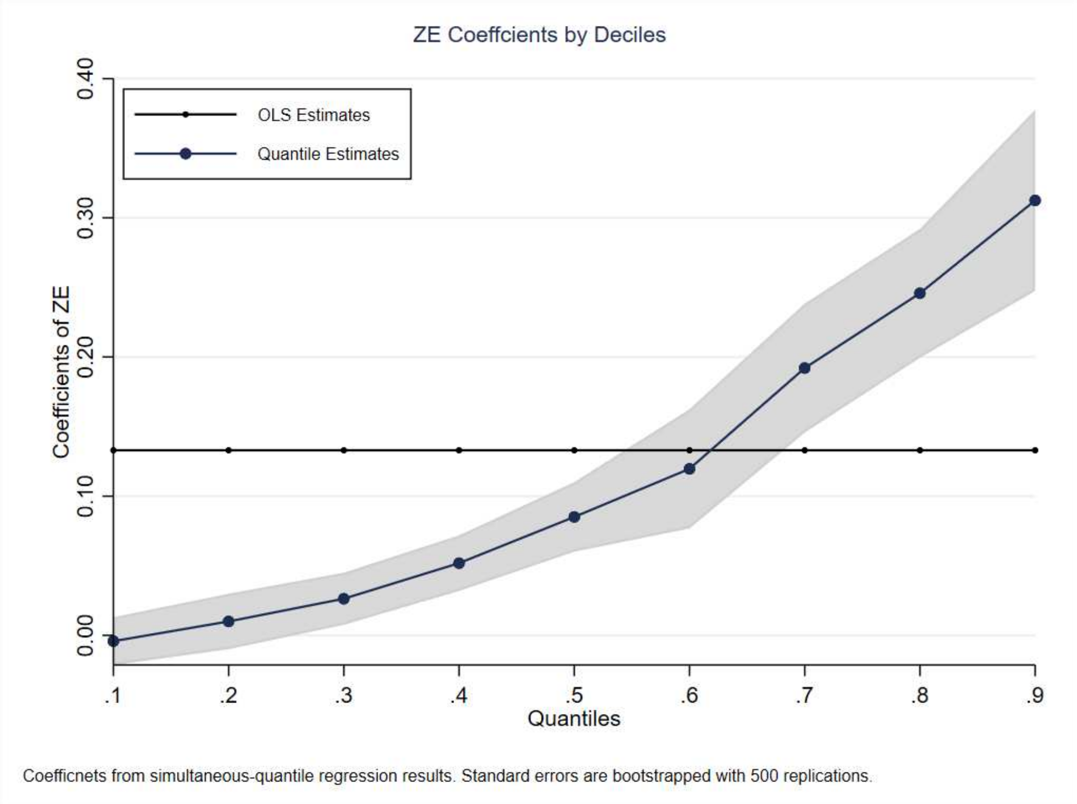


Figure 2. Quantile regression results of ZR on ZE (24-month regressions)

Finally, there is the question of whether BFLEX is a superior measure of exchange rate flexibility to RMSE. There is no straightforward way to address this question. We might compare them in some way with other exchange rate classification schemes, such as those of Klein and Shambaugh (2016) or Ilzetzki et al. (2017), and interpret greater agreement as greater accuracy, but to the extent that these other schemes are based on a statistical algorithm (as they essentially are), a greater degree of agreement would simply mean greater similarity between the algorithms applied, and not necessarily greater accuracy. There is a stronger case for treating the IMF de facto classification scheme as some sort of arbiter, since that is based on the judgement of informed observers at the time (according to guidelines that are similar for all countries) and is not purely statistical. Moreover it does take reserve movements into account, at least in deciding whether to classify a float as a free float or a managed one. The criteria for identifying a free float in the IMF classification have been clarified in recent years, having up to 2008 essentially relied on judgement (Habermeier et al., 2009).[5]

Of course in comparing the IMF classification with our flexibility measures, we are comparing a system of aggregating regimes into a small number of categories with a continuous measure. The procedure that we adopt is to examine how the different categories in the IMF classification are distributed across the flexibility indices.

The results are shown in Table 6. The table shows the count of the number of (a) IMF pegs and bands, (b) IMF floats of any kind and (c) IMF free floats appear in each decile of the distribution of RMSE and BFLEX, using the 24-month window results. Pegs represent 67.0% of the IMF sample, managed floats 22.6% and free floats 10.4%. Using the 24-month

[5] The new system is described as follows in Habermeier et al. (2009, p. 8): "As noted, once a de facto exchange rate arrangement has been identified as floating, it can be further qualified as free floating if there has been no intervention over the past six months, with the exception of limited intervention to address disorderly market conditions. If IMF staff responsible for the classification do not have sufficient information and data to verify whether this criterion has been met, the arrangement is classified as floating. Data and its availability, rather than subjective judgment, thus play the key role in assigning a country to the free floating category."

regressions, we find that 89.8% and 89.6% respectively of IMF pegs fall below the 60th percentile of RMSE and BFLEX. Moving up to the 70th percentile, these percentages fall to 84.5 and 84.4% respectively. This is a relatively high degree of agreement, compared with that between other pairs of classification schemes, as shown for example in Eichengreen and Razo-Garcia (2013) and Bleaney et al. (2017).[6] The similarity of the numbers for RMSE and BFLEX suggests that there is no advantage in using information on reserve variability to identify exchange rate pegs.

On the other hand, neither flexibility index is particularly good at separating free floats from managed floats. Of IMF free floats, only 141 out of 597 (23.6%) appear in the top decile of RMSE, and 198 (33.2%) in the top decile of BFLEX. Clearly, BFLEX is somewhat better at picking up free floats (although if we take the top two deciles, RMSE scores 351 (58.8%) and BFLEX 346 (58.0%)). The other 40+% of IMF free floats are spread further down the distribution, with 28 (4.7%) for RMSE and 48 (8.2%) for BFLEX even below the 60th percentile.

It is interesting to compare the frequency with which countries appear in the top decile of the two flexibility indices. The top half of Table 7 lists the countries which appear in the top decile of BFLEX in at least seven years more than in the top decile of RMSE, and the bottom half lists the countries which appear in the top decile of RMSE in at least seven years more than in the top decile of BFLEX.

[6] Levy-Yeyati and Sturzenegger (2016) report an agreement rate of 62.7% with the IMF de facto classification over the period 1974-2013, using three categories: fixed, intermediate and floating.

Table 6. Count of IMF Pegs, All Floats and Free Floats, by RMSE and BFLEX Deciles (24-month windows)

Percentile:	10	20	30	40	50	60	70	80	90	100	Total
Flexibility measure: RMSE											
Pegs	574	568	559	529	463	412	301	167	123	162	3858
All Floats	3	9	16	47	113	164	275	409	453	414	1903
Of which: Free Floats	0	1	1	1	7	18	77	141	210	141	597
Total	577	577	575	576	576	576	576	576	576	576	5761
Flexibility measure: BFLEX											
Pegs	572	564	566	503	479	414	309	201	153	97	3858
All Floats	5	12	10	73	97	162	267	375	423	479	1903
Of which: Free Floats	0	0	2	1	16	30	79	123	148	198	597
Total	577	576	576	576	576	576	576	576	576	576	5761

Notes. Peg = Hard Peg + Pegs + Crawls. Free Floats = Independent (before 2008) + Free Floats (after 2008). All Floats = Independent (before 2008) + Free Floats (after 2008) + Managed Floats(before 2007) + Other Managed (after 2007) + Floating (after 2007)

Table 7. Frequency of countries' appearance in the top deciles of RMSE and BFLEX

	Appearance in top decile of BFLEX 7+ times more frequently than in top decile of RMSE	
Country	RMSE frequency	BFLEX frequency
United States	6	29
United Kingdom	0	9
Canada	2	17
Japan	5	33
Turkey	11	19
Chile	6	19
Colombia	8	21
India	2	9
Nepal	0	8
Iraq	1	12
Israel	6	20
Indonesia	6	16
Singapore	0	11
South Korea	5	20
Thailand	3	14
Poland	6	14
	Appearance in top decile of BFLEX 7+ times less frequently than in top decile of RMSE	
Country	RMSE frequency	BFLEX frequency
Iceland	10	3
New Zealand	10	2
Argentina	12	5
Dem. Rep. Congo	15	2
Ghana	10	3
Guinea	8	0
Malawi	16	0
Nigeria	8	1
Sierra Leone	11	0
Tanzania	8	1
Zambia	16	6
Papua New Guinea	8	0
Romania	10	3

Notes. Based on 24-month regressions. The table shows the number of years between 1980 and 2018 that the country appears in the top decile of the flexibility index indicated. RMSE - exchange rate flexibility index; BFLEX – flexibility index based on exchange rate and reserve variability. Countries are listed in order of IFS code.

There is a distinct difference between the two lists. High-income and middle-income countries appear more frequently in the top decile of BFLEX, with the United States (29 years compared to 6) and Japan (33 years compared to 5) being especially prominent. Developing countries appear more frequently in the top decile of RMSE, with sub-Saharan African countries making up eight of the thirteen in the bottom half of Table 7. This suggests that there is much more intervention in the foreign exchange market amongst floating currencies in the latter group of countries, and that the former group are much closer to an independent float.

5. Conclusions

Most currencies are managed to some degree. The argument that exchange rate classifications should be based on exchange rate flexibility relative to reserve variability therefore has a natural appeal, because it captures to what degree the exchange rate is being managed by intervention. However, there are some significant problems in using the EMP ratio to identify exchange rate pegs and bands, where the marginal cost of exchange rate variability suddenly becomes very large at a certain threshold that represents movement outside the announced band, because the concept implicitly assumes continuity in the marginal cost of the two components of the EMP ratio. This suggests the hypothesis that the EMP ratio is more useful in distinguishing more from less tightly managed floats, where the assumed continuity of marginal cost is likely to hold, than in distinguishing floats from pegs.

There has been little research on the behaviour of reserves in relation to exchange rate movements. We have investigated the issue for a global sample of countries from 1980 to 2019. First of all we investigated whether month-to-month reserve accumulation is negatively correlated with exchange rate depreciation, as predicted by the theory of exchange market pressure. It turns out that this is the case in a comfortable majority of country-years (about two-thirds), but the correlation is weaker rather than stronger for the least flexible regimes, contrary to what might be expected. This may be because the least flexible regimes, which are almost all single-currency pegs (and therefore more transparent than basket pegs), tend to have high credibility and can rely on expectations of mean-reversion within the band to make intervention redundant.

We then examined the relationship between the variabilities of exchange rates and reserves over periods of 12, 18 and 24 months, and found that the correlation tends to be positive rather than negative, particularly at the more flexible end of the spectrum. So regimes with more stable exchange rates do not tend to have greater variability of international reserves. Finally we constructed a flexibility index as the ratio of exchange rate flexibility to the sum of exchange rate flexibility and standardised reserve variability, and investigated whether this bivariate flexibility index matched the IMF de facto regime classification better than a flexibility measure based purely on exchange rates. With respect to the splits between pegs or bands and some type of floating, taking reserves into account made very little difference: nearly 90% of IMF pegs (which represent about two-thirds of the sample) lie below the 60th percentile of either flexibility index. However, regimes classed by the IMF as free floats rather than managed ones (just over 10% of the sample) were more likely to be in the top 10% of the bivariate flexibility index than in the top 10% of one based purely on exchange rates, which suggests that a lack of reserve variability helps to identify freely floating currencies. This is consistent with the idea that the EMP ratio works better as a measure of the extent to which a float is managed than as a criterion for distinguishing floats from pegs.

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APPENDIX

Appendix Table A1. Maximum exchange rate coefficient for Tight and Loose Pegs

12-Month Window

	count	mean	min	max	p10	p25	p50	p75	p90
Tight Peg	1955	0.995	0.283	1.204	1.000	1.000	1.000	1.000	1.000
Loose Peg	2000	0.887	0.233	67.614	0.468	0.651	0.920	1.004	1.071
Total	3955	0.940	0.233	67.614	0.572	0.910	1.000	1.000	1.021

18-Month Window

	count	mean	min	max	p10	p25	p50	p75	p90
Tight Peg	1901	0.997	0.420	1.038	1.000	1.000	1.000	1.000	1.000
Loose Peg	1917	0.840	0.246	7.470	0.472	0.644	0.916	0.998	1.045
Total	3818	0.918	0.246	7.470	0.577	0.912	1.000	1.000	1.009

24-Month Window

	count	mean	min	max	p10	p25	p50	p75	p90
Tight Peg	1846	0.999	0.419	1.204	1.000	1.000	1.000	1.000	1.000
Loose Peg	1850	0.840	0.255	23.727	0.464	0.647	0.921	0.997	1.030
Total	3696	0.919	0.255	23.727	0.571	0.918	1.000	1.000	1.007

Notes. The table gives statistics for the distribution of the largest exchange rate coefficient in the regression for Tight Pegs (RMSE<0.001) and Loose Pegs (0.001<=RMSE<0.01); p10 denotes the tenth percentile of the distribution.

Appendix Table A2. Distribution of BFLEX for different ranges of RMSE_trm02

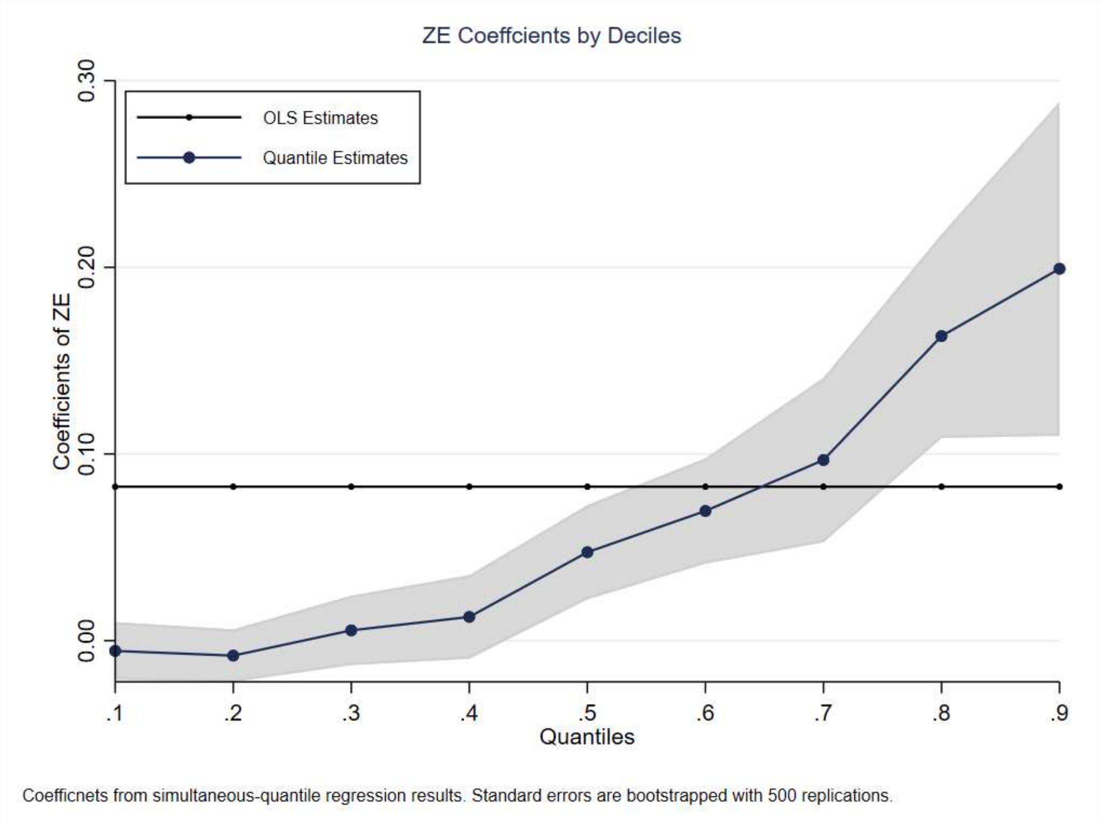
	count	mean	min	max	p10	p25	p50	p75	p90
RMSE<0.001									
12-Window	2359	1.251	0.000	100.000	0.000	0.000	0.002	0.004	0.719
18-Window	2293	1.122	0.000	100.000	0.000	0.000	0.001	0.003	0.186
24-Window	2236	1.041	0.000	100.000	0.000	0.000	0.001	0.003	0.018
0.001<=RMSE<0.01									
12-Window	2022	32.281	1.456	100.000	9.931	17.496	29.427	44.183	58.985
18-Window	1922	30.822	1.339	100.000	9.901	16.694	27.947	42.075	56.170
24-Window	1840	29.553	1.612	94.554	9.804	16.288	26.441	39.971	53.799
0.01<=RMSE<0.02									
12-Window	930	60.700	11.974	96.832	34.382	46.775	62.432	75.822	84.255
18-Window	991	57.396	10.541	95.934	31.130	44.034	57.935	71.143	81.860
24-Window	1046	55.902	11.827	95.228	30.062	42.815	56.084	70.221	79.955
RMSE>0.02									
12-Window	966	72.041	19.829	100.000	48.815	62.010	75.095	84.812	90.599
18-Window	1095	70.224	17.708	100.000	46.670	59.353	73.140	83.054	89.340
24-Window	1194	68.554	16.345	98.939	45.092	56.883	71.348	81.646	87.708
Total									
12-Window	6277	30.949	0.000	100.000	0.000	0.003	23.064	57.233	78.506
18-Window	6301	31.041	0.000	100.000	0.001	0.003	24.236	56.530	78.045
24-Window	6316	31.196	0.000	100.000	0.001	0.002	25.111	56.484	77.311

Notes. RMSE_trm02: exchange rate flexibility (top 2% trimmed); BFLEX: bivariate flexibility index (see text). “12-window” denotes results using a 12-month regression window.

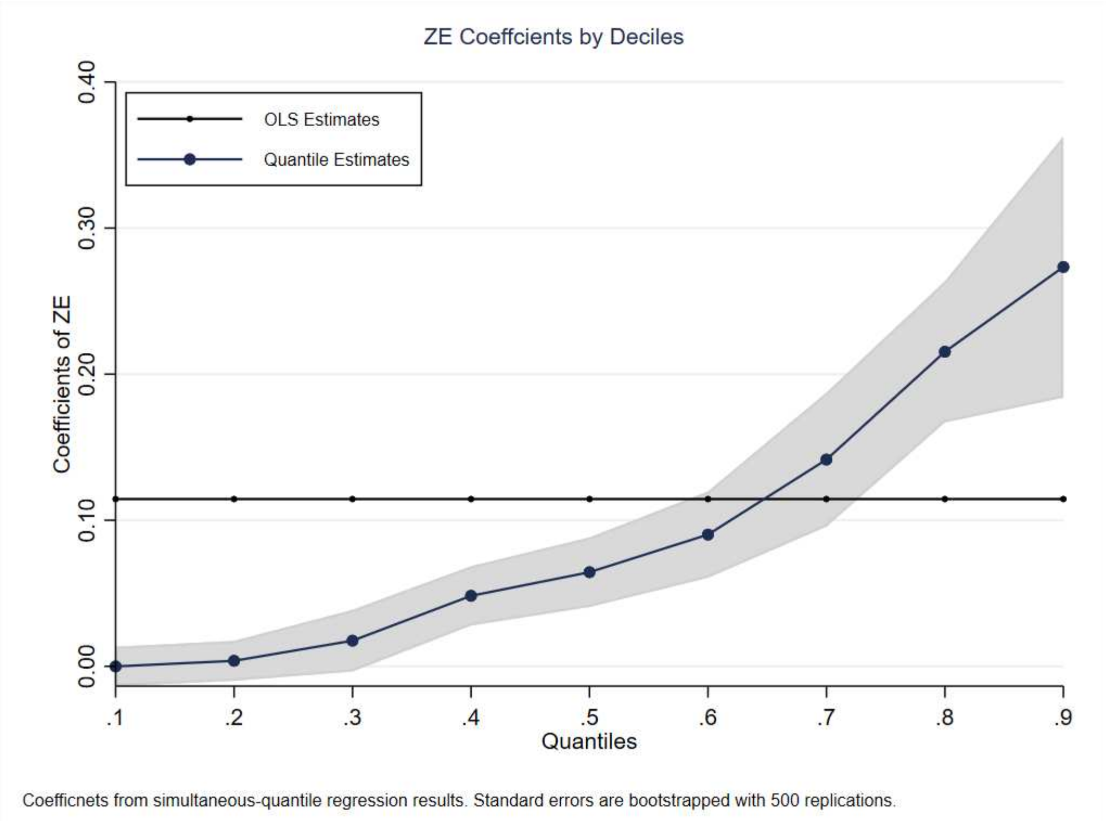
Appendix Table A3. Correlation between BFLEX and RMSE_trm02

	All	RMSE<0.001	0.001<=RMSE<0.01	0.01<=RMSE<0.02	RMSE>0.02
12-Window	0.671	0.361	0.525	0.246	0.147
18-Window	0.667	0.351	0.528	0.223	0.139
24-Window	0.661	0.324	0.538	0.245	0.149

Notes. See Notes to Table A2



Appendix Figure A1. Results from quantile regressions of standardised reserve variability on exchange rate flexibility using a 12-month regression window.



Appendix Fig A2. Results from quantile regressions of standardised reserve variability on exchange rate flexibility using an 18-month regression window.

Appendix Table A4. Simultaneous-Quantile Regression For ZR on ZE

Dep. Var : ZR

	12-Window	18-Window	24-Window
q10			
ZE	-0.005	-0.000	-0.004
	(-0.672)	(-0.010)	(-0.460)
_cons	0.368***	0.416***	0.462***
	(35.928)	(37.729)	(30.004)
q20			
ZE	-0.008	0.004	0.010
	(-1.150)	(0.522)	(0.991)
_cons	0.545***	0.607***	0.667***
	(52.395)	(53.645)	(46.046)
q30			
ZE	0.006	0.018*	0.026***
	(0.561)	(1.648)	(2.614)
_cons	0.705***	0.781***	0.854***
	(47.691)	(50.280)	(68.599)
q40			
ZE	0.013	0.048***	0.052***
	(1.179)	(4.588)	(4.974)
_cons	0.886***	0.957***	1.046***
	(52.346)	(72.931)	(66.321)
q50			
ZE	0.047***	0.064***	0.085***
	(3.660)	(5.109)	(6.670)
_cons	1.067***	1.166***	1.250***
	(68.534)	(74.022)	(70.028)
q60			
ZE	0.069***	0.090***	0.120***
	(4.946)	(5.568)	(5.308)
_cons	1.307***	1.420***	1.522***
	(68.304)	(64.962)	(62.433)
q70			
ZE	0.097***	0.142***	0.192***
	(4.611)	(6.182)	(7.895)
_cons	1.639***	1.763***	1.854***
	(57.959)	(59.698)	(58.014)
q80			
ZE	0.163***	0.215***	0.246***
	(5.857)	(8.607)	(10.854)
_cons	2.156***	2.289***	2.428***
	(49.373)	(48.516)	(52.659)
q90			
ZE	0.199***	0.273***	0.313***

	(4.731)	(5.943)	(9.159)
_cons	3.358***	3.525***	3.666***
	(52.658)	(48.442)	(52.931)
N	6277	6301	6316

Notes. ZR: standardised reserve variability; ZE: exchange rate flexibility. * ** *** 10% 5% 1%. Bootstrapped t-statistics in parentheses.