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EXCHANGE RATE RISK

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Abstract

Many countries try to smooth their exchange rate movements by means of capital controls or otherwise. By the use of statistical extreme value analysis, we investigate if capital controls succeed in lowering foreign exchange rate (forex) volatility. We define forex volatility as the risk of extreme depreciations. For a sample of developed and emerging markets we find that capital controls are not effective in reducing this extreme depreciation risk. On the contrary, extreme depreciation risk is almost twice as high compared to an exchange rate regime without capital controls.

Keywords

Capital controls, Exchange Rates, Extreme Value Theory, Exchange rate risk, Extreme quantiles.

JEL Codes: F21, F31

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1. Introduction

Recent history has shown that large swings in exchange rates are not uncommon: from the Asian tigers to Russia and Argentina, most emerging markets experienced a currency crash during the last decade of the 20th century. However, investors and policymakers typically dislike large and abrupt exchange rate fluctuations. Especially large depreciations of the domestic currency are met with concern. Calvo and Reinhart (2002) document an endemic ‘fear of floating’. Although many countries have officially moved away from a fixed exchange rate to a floating regime, they find that many still actively use policy measures to control exchange rate movements. This ‘fear of floating’ is rooted in the fact that large exchange rate swings come at a cost. Bordo et al. (2001) calculate that the average currency crisis entailed a cost of around 8 to 9% of GDP in the second half of the twentieth century.

Imposing capital controls constitutes one of the most far-reaching policy measures to control exchange rate movements. Capital controls enable governments to directly limit the possibility of speculating on the currency. Although capital controls might seem too heavy a tool to use to smooth exchange rate returns, many countries do seem to use them for — at least partly — this reason. (de Grauwe, 2000; von Hagen and Zhou, 2005)

This paper investigates the extent to which capital controls succeed in curbing extreme currency fluctuations. There is already a body of literature on the effectiveness of capital controls. However, earlier studies mainly focused on Chile (see for instance De Gregorio et al., 2000; Edwards and Rigobon, 2005; Herrera and Valdes, 1999)¹. These papers established that the effects of the Chilean capital controls on the exchange rate were limited. Taking a wider cross-section of countries that includes both developed and emerging markets constitutes a first contribution of this study. The second contribution consists of the application of statistical extreme value analysis (EVT) to measuring the impact of capital controls on the tail behavior of currency returns (extreme events). It is well known that financial returns — forex returns do not constitute an exception — are non-normally distributed and exhibit “heavy tails”, see e.g. Mandelbrot (1963) for an early reference. Loosely speaking, the heavy tail feature implies that the empirical distribution of exchange rate returns contains more probability mass in the tails than under the normal. The tail decay of heavy-tailed process is typically characterized by a Pareto law whereas the tail probabilities of normally distributed processes decline exponentially to zero. The parameter governing the Pareto tail decline is the well-known “tail index” and fluctuates between 2 and 4 for most financial returns. For earlier applications of EVT to the tails of exchange rate returns, see e.g. Koedijk et al. (1990, 1992) or Hols and de Vries (1991). More recent applications of EVT in

¹The unremunerated reserve requirement of Chile is, together with the Malaysian controls, the most well-known example of capital controls.

the economic literature include the identification of currency crises (Pozo and Amuedo-Dorantes, 2003; Damte Haile and Pozo, 2006) and the measurement of extreme linkages between markets (Straetmans et al., 2008; Quintos et al., 2001).

Although extreme value analysis has gained ground in the literature, studies that tests for the structural stability of tail risk are relatively rare. Koedijk et al. (1990) tested whether the introduction of the European Monetary System had a dampening effect on forex tail risk. More recently, Candelon and Straetmans (2006) apply an endogenous structural change test to find out whether breaks in the tail index coincide with shifts in foreign exchange rate regimes. Structural breaks in forex tail risk around periods of financial liberalization constitute relevant information for both policymakers and investors. To governments, breaks signal whether their policies were effective and desirable. To investors, breaks in tail risk imply that they need to update their information on the Value-at-Risk (VaR) of their currency trading portfolios.

To preview our results, we find that capital controls are not effective in reducing the potential for extreme forex depreciations. Instead, periods of capital controls are associated with larger exchange rate depreciations. The rest of this paper is structured as follows. In section 2 the EVT and the tail and quantile estimators are described. The dataset is explained in section 3. All the results are presented in section 4 and 5 ends with the concluding remarks.

2. Theory

Consider a stationary sequence $X_1, X_2, \dots, X_n$ of independent and identically distributed (i.i.d.) random variables with a cumulative distribution function F (c.d.f. F). Define the maximum of this sequence of random draws by:

$$M_n = \max(X_1, X_2, \dots, X_n). \quad (1)$$

The probability that this maximum is below an arbitrary level x is given by

$$P\{M_n \leq x\} = F^n(x). \quad (2)$$

Extreme value theory studies the limiting distribution of the (appropriately scaled) order statistic M_n . Under fairly general conditions there exists a limiting asymptotic d.f. $G(x)$ that characterizes extreme values:

$$P\{a_n(M_n - b_n) \leq x\} \xrightarrow{w} G(x), \quad (3)$$

This “extreme value” d.f. $G(x)$ can take three functional forms: one has thin tails (Gumbel), one is bounded from above (Weibull), and one is characterized by fat tails (Fréchet). Exchange rate returns exhibit fat tails and are in principle unbounded, which leaves the Fréchet distribution as the only relevant distribution:

$$G(x) = \begin{cases} 0 & , \quad x \leq 0 \\ e^{-x^{-\alpha}} & , \quad x > 0. \end{cases} \quad (4)$$

where α represents the tail index. The lower the value of the tail index α , the slower the probability density's decay as one moves further in the tail. This indicates a higher probability mass concentrated in the tails and hence fatter tails. Additionally, the tail index α can be interpreted as the maximum amount of bounded moments². Different heavy-tailed distributions all exhibit this common limiting behavior, e.g. the class of symmetric stable distributions ($\alpha < 2$), the student-t distribution or the GARCH process. However, when studying tail behavior, we do not need to know which parametric heavy-tailed model is effectively valid over the full distributional support.

To estimate the tail index α , we will employ the popular Hill (1975) estimator. Let $X_{(1)} \leq X_{(2)} \leq \dots \leq X_{(n)}$ be the ascending order statistics of the sequence of r.v. $X_1, X_2, \dots, X_n$. The Hill statistic is then defined as:

$$\hat{\alpha}_n = \left[\frac{1}{m} \sum_{j=0}^{m-1} (\ln X_{(n-j)} - \ln X_{(n-m)}) \right]^{-1}, \quad (5)$$

where m is the number of highest order statistics. Further details on the Hill estimator and related procedures to estimate the tail index are provided in Jansen and de Vries (1991) and the monograph by Embrechts et al. (1997). Notice that the estimation approach is semi-parametric in nature in the sense that we only have to know the value of the threshold parameter m and the order statistics in order to calculate the estimator.

The selection of the number of highest order statistics m constitutes an important problem in extreme value analysis. Loretan and Phillips (1994) and Embrechts et al. (1997) suggest picking m in a region where the estimate of α is more or less stable. One knows that such a region exists because of the well-known bias-variance trade-off for tail estimators like the Hill statistic. More formally, one chooses m such that the asymptotic mean-squared error (AMSE) of the estimate is minimized (Goldie and Smith, 1987). This study uses the Beirlant et al. (1999) algorithm to select m ³.

With knowledge of the tail index estimate $\hat{\alpha}$, we would also like to estimate the accompanying quantiles at the boundary of the historical sample or beyond. Given a very small exceedance probability $p \sim 1/n$, the tail quantile estimator $\hat{q}(p)$ formulated in de Haan et al. (1994) reads

$$\hat{q} = X_{(n-m)} \left(\frac{m}{pn} \right)^{\frac{1}{\hat{\alpha}}}, \quad (6)$$

²Consequently, a tail index lower than 2 implies that the 2^{nd} moment (variance) of the unconditional distribution function does not exist.

³Loosely speaking, this technique requires running an exponential regression model (ERM) on the basis of the scaled log-spacings between the subsequent extreme order statistics from a Pareto-type distribution. The Ordinary Least Squares (OLS) that can be run on this data returns the empirical AMSE for different values of m . Here, m will be chosen at the minimum of the empirical AMSE.

where the “tail cut-off point” $X_{n-m,n}$ is the $(n-m)$ -th ascending order statistic (or loosely speaking the m -th smallest return) from a sample of size n such that $q > X_{n-m,n}$. At first sight, the quantile results may seem redundant once the tail index has been reported. However, looking at definition (6) it can be seen that q_p is both a function of the tail index α as well as of the scale parameter $X_{(n-m)}$. Estimators of the tail index, such as the Hill estimator used here, are scale invariant, however. Thus it might very well be that there are no significant shifts in α while there are shifts in q_p , or vice versa⁴.

We are not merely interested in the values of the tail indexes and quantiles themselves, but rather the parameter stability over the two different capital account regimes. Temporal constancy tests for (5) and (6) are fairly easily established upon knowing the asymptotic behavior of these two estimators. Asymptotic normality has been established for both estimators under fairly general conditions (mainly the requirement that return series are identically and independently (i.i.d.) distributed and thus do not exhibit any nonlinear dependence over time). More specifically, for $m/n \rightarrow 0$ as $m, n \rightarrow \infty$, it has been shown that the tail index statistic $\sqrt{m}(\hat{\alpha} - \alpha)$ and tail quantile statistic $\frac{\sqrt{m}}{\ln(\frac{m}{pn})} \left[\frac{\hat{q}(p)}{q(p)} - 1 \right]$ are both asymptotically normal. See e.g. Hall (1982) or Haeusler and Teugels (1985) for the former result and de Haan et al. (1994) for the latter result. Structural change tests for estimates of the tail index α and the tail quantile q can now be based on the following statistics

$$T_\alpha = \frac{\hat{\alpha}_1 - \hat{\alpha}_2}{\sqrt{\frac{\hat{\alpha}_1^2}{m_1} + \frac{\hat{\alpha}_2^2}{m_2}}}, \quad (7)$$

and

$$T_q = \frac{\hat{q}_{p,1} - \hat{q}_{p,2}}{\sqrt{\left[\frac{1}{\alpha_1 \sqrt{m}} q_{p,1} \ln \left(\frac{m_1}{pn_1} \right) \right]^2 + \left[\frac{1}{\alpha_2 \sqrt{m}} q_{p,2} \ln \left(\frac{m_2}{pn_2} \right) \right]^2}}. \quad (8)$$

One can safely assume that the above test statistics come sufficiently close to normality for the relatively large empirical sample sizes employed in this study, see e.g. Hall (1982), Embrechts et al. (1997) or Hartmann et al. (2004).

3. Data

We use nominal bilateral exchange rates for European and emerging currencies against the US \$. Data are downloaded from Datastream. The European currency data

⁴Intuitively this makes sense. Let us consider two sequences of i.i.d. student-t distributions with the same degrees of freedom $\nu_1 = \nu_2 = \nu$, but with $\sigma_1^2 > \sigma_2^2$. Both will be characterized with the same value of the tail index α , which is given by ν . At the same time $X_{(n-m),1}$ will be larger than $X_{(n-m),2}$, given the larger variance of the first s.r.v.; ergo, $q_{p,1} > q_{p,2}$. The converse also holds true. If $\sigma_1^2 = \sigma_2^2$, but $\nu_1 < \nu_2$, $q_{p,1}$ will also be larger than $q_{p,2}$.

start on January 1st 1973 and ends at December 31st 1998 (introduction of the euro)⁵. The starting point of the emerging country data differs from currency to currency due to lack of data availability. The data runs until December 31st 2006, the last year for which we have capital control data available. Table 3, in the results section, reports the exact number of observations available for the complete sample and both subsamples.

We date financial liberalization using the annual dummy from the IMF Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). It is the most widely used capital control proxy. After 1996, the IMF replaced the dummy variable by a new type of proxy that extends its coverage of capital controls. As an alternative, we therefore follow the procedure of Mody and Murshid (2005) and Chinn and Ito (2006) to complete the dummy series for the post-1996 era.

As for the European countries, we employ the more detailed liberalization datings of Kaminsky and Schmukler (2003) and Miniane (2004). Data limitations prevent the use of these two indices for the emerging economies. The liberalization dates are summarized in table 1.

Kaminsky and Schmukler (2003)(henceforth K & S) indicate, for each year, whether a market is either ‘repressed’, ‘partially liberalized’, or ‘fully liberalized’. The degree of control on the capital account is measured by monitoring regulations on offshore borrowing, multiple exchange rate regimes, and controls specific to capital outflows. A market is deemed ‘fully liberalized’ if there are no multiple exchange rates or restrictions on outflows, and only minor impediments to offshore borrowing. For this study we consider countries liberalized for the years in which the markets are classified ‘fully liberalized’ by K & S.

$$CAP_{i,t}^{K\&S} = \begin{cases} 0, & \text{if KS} = \text{‘fully liberalized’;} \\ 1, & \text{else.} \end{cases} \quad (9)$$

Miniane (2004) developed an index composed of 13 segments, which include capital markets, direct investment, financial institutions, and multiple exchange rates. The liberalization score is given by $\frac{n}{13}$, with n the number of controls in place. A score of 0 indicates a fully liberalized market, and a score of 1 a fully closed market. No country achieve a score of 0 (the US for instance has a score of 0.29) and the capital control proxy’s histogram exhibits two modes around 0.2 (open) and 0.8 (closed). We therefore classify all economies with a score of less than 0.5 as open, and economies with scores equal to 0.5 or above as closed (equation 10)⁶:

$$CAP_{i,t}^{Miniane} = \begin{cases} 0, & \text{if Miniane} < 0.5 \\ 1, & \text{if Miniane} \geq 0.5. \end{cases} \quad (10)$$

⁵Given that most countries in the European sample are part of the Euro, post-1998 data do not exhibit much cross-sectional variation.

⁶The results are not sensitive to varying the cut-off point over the interval [0.45; -0.55]

Table 1: Liberalization dates of capital controls.

Panel A: *K & S* and *Miniane* refer to liberalization measured according to (Kaminsky and Schmukler, 2003) and (Miniane, 2004), respectively. *IMF Dummy* refers to the position as reported in the IMF Annual Report on Exchange Arrangements and Exchange Restrictions. As Miniane and the IMF only report on capital controls annually, all liberalizations are set at the beginning of the year of the liberalization.

Panel B: The left-hand column indicates the state of the capital account at the beginning of the sample, which runs from March 1984 to November 2006. Liberalizations and closings refer to the position as reported in the IMF Annual Report on Exchange Arrangements and Exchange Restrictions. As the IMF only report on capital controls annually, all liberalizations and closings are set at the beginning of the year of the liberalization.

Panel A: Developed countries			
Country	K & S	Miniane	IMF Dummy
Denmark	September 1988	1988	1988
France	December 1989	1989	1993
Italy	December 1991	1988	1993
Norway	December 1987	1989	1995
Austria	n/a ^a	1991	1991
Portugal	July 1992	1991	1993
Spain	December 1992	1992	1994
Sweden	December 1988	1989	1993
Panel B: Emerging countries			
Country	Begin Sample	Closings	Liberalizations
Indonesia	Liberalized	1997	
Jamaica	Closed		1997
Kuwait	Liberalized	1997	
Lebanon	Liberalized	1998	
Venezuela	Liberalized	1985 2003	1997

^a Kaminsky and Schmukler do not have Austria in their sample.

Like the dummy variable, Miniane (2004) is based on the AREAER and only reports annually. We therefore make the simplifying assumption that all liberalizations reported have taken place at January 1st

4. Results

4.1. Unconditional Volatilities

As a benchmark for the rest of the analysis, we start by reporting unconditional standard deviations for liberalized and controlled periods of the capital account. Table 2 reports annualized standard deviations of daily exchange rate returns under both regimes, together with the Goldfeldt-Quandt test for heteroskasticity (the null hypothesis being that the unconditional standard deviation stays constant across subsamples). The emerging countries have on average a higher annualized standard deviation than the European countries, which is not surprising given the fact that emerging countries are more prone to currency crises, and tend to have larger swings in inflation and interest rates.

When looking at the temporal changes in standard deviations, almost all markets show larger movements in returns when they are controlled. All European currencies experience a drop in volatility after liberalization of around 2 percent. As for the emerging market volatilities, only Lebanon, Malaysia, and Mexico experienced lower volatility when capital controls were in place.

At first sight, the finding that exchange rate volatility is higher under regimes of capital account regulation might seem counterintuitive; indeed, when a capital tax is included in standard theoretical models of the exchange rate such as the Dornbusch model, they are shown to have a *decreasing* effect on exchange rate volatility (Frankel, 1996; Frenkel et al., 2002). However, other empirical studies also find higher exchange rate risk in the presence of capital controls. Capital controls increase the probability of a currency crisis occurring (Glick and Hutchison, 2005). A study of the Chilean Unremunerated Reserve Requirement (URR) also shows that for this control the unconditional exchange rate volatility increases with the size of the control (Edwards and Rigobon, 2005).

The problem with standard deviations as a measure of exchange rate risk is that they assume tail symmetry in the forex return distribution. However, the incidence of extreme appreciations and depreciations is not necessarily the same, which might distort measures that equally weight upward and downward movements such as the standard deviation. Moreover, we know that exchange rate returns are non-normally distributed and exhibit more tail probability mass than under the normal. Given the interpretation of the tail index as reflecting the maximal number of distributional moments that are defined and bounded (cf. theory section), it follows that processes with α below 2 do not exhibit finite variance; but tail characteristics like the tail index and resulting extreme quantiles can still be calculated.

Table 2: The impact of capital controls on unconditional variances.

This table reports the unconditional standard deviations for the daily exchange rate returns. The two left-hand columns report the annualized standard deviation of the daily exchange rate returns; the first column representing the controlled regime and the second column the liberalized regime. For each country, the regime with the highest standard deviation is marked with a dagger. The two right-hand columns report the variance ratio (significance calculated with the Goldfeld-Quandt test for heteroskedasticity). A *, **, or *** indicates rejection of homoskedasticity at 10, 5, or 1 percent significance levels respectively.

Panel A: Developed Countries			
Country	<i>Std.Con.</i>	<i>Std.Lib.</i>	Variance Ratio
Austria	12.87% [†]	11.70%	1.21***
Denmark	12.16% [†]	11.44%	1.13***
France	12.58% [†]	10.72%	1.38***
Italy	12.42% [†]	10.70%	1.35***
Norway	11.14%	11.36% [†]	1.04
Portugal	13.99% [†]	11.00%	1.62***
Spain	13.02% [†]	10.56%	1.52***
Sweden	15.82% [†]	13.12%	1.45***
Panel B: Emerging Countries			
Country	<i>Std.Con.</i>	<i>Std.Lib.</i>	Variance Ratio
Chile	17.72% [†]	9.49%	3.48***
Ecuador	23.45% [†]	14.52%	2.60***
Egypt	12.42% [†]	6.95%	3.19***
El Salvador	18.96% [†]	5.26%	12.00***
Gambia	18.48% [†]	13.43%	1.89***
Guyana	39.57% [†]	11.55%	11.74***
Honduras	25.80% [†]	16.15%	2.55***
Indonesia	31.12% [†]	15.54%	4.01***
Jamaica	28.93% [†]	11.64%	6.18***
Jordan	14.84% [†]	1.13%	171.20***
Lebanon	1.40%	30.41% [†]	469.58***
Malaysia	7.61%	15.77% [†]	4.29***
Mexico	8.57%	32.77% [†]	14.62***
Trin. & Tob.	20.88% [†]	10.03%	4.34***
Uruguay	27.21% [†]	19.60%	1.93***
Venezuela	32.55% [†]	29.96%	1.18***
Zambia	44.85% [†]	17.08%	6.89***

4.2. Tail Indices

Table 3 reports Hill-estimates for the data set of emerging and developed currency returns. The reported $\hat{\alpha}$ refer to the right tail of the return distribution, i.e., the extreme depreciation tail. We further distinguish between full sample and subsample (controlled and liberalized) results. As concerns the full sample results, the European countries show tail indexes between 3.0 and 4.1, while the emerging countries have estimates ranging between 1.5 and 2.3. These results are in line with previous studies such as Koedijk et al. (1992). Strikingly, emerging countries exhibit lower tail indices than developed currencies and often even fall below 2, which suggests that the variance for these series may not be defined.

The European currency tail indices significantly increase after liberalization at the 1% level for a majority of cases. The jumps in α also seem economically significant: on average the α s increase by almost 2 units. In the controlled period the developed currency average is 3.3 — almost equal to the lowest observation in the complete period; whereas the average jumps to 5.3 in the liberalized period. Moreover, the result is robust to the choice of the liberalization variable. Using the more advanced measures of Miniane (2004) and Kaminsky and Schmukler (2003), the signs of the differences do not change, and the magnitude and significance levels are also roughly similar, with most countries still showing a significant change at the 1% level (the results are given in table 6 in the appendix).

In the emerging sample the evidence is more mixed. Lebanon, Malaysia, and Mexico show higher values of the tail index, i.e. thinner tails, when capital controls are in place, which seems in line with previous results on standard deviations⁷.

On the other hand, and similar to the European outcomes, Chile, Indonesia, Jamaica, Uruguay, and Zambia all have thinner tails in the liberalized period (significant at the 1% level). Prior to liberalization all values for these countries are below 2, while after liberalization, they increase to levels above 2. In the case of Chile, the tail index even rises above 6, indicating thinner tails than most developed countries. Egypt, Guyana, Jordan, and Venezuela are mixed cases with both significantly fatter tails and lower standard deviations after liberalization.

The results point in the same direction as those of Koedijk et al. (1992): they found that exchange rate returns have fatter tails under fixed exchange rate regimes than under floating exchange rate regime, both for a sample of EMS currencies and for a number of emerging countries.

Although pegging the currency is not identical to imposing capital controls, both

⁷The results for Malaysia, however, might be due to the IMF classification of capital controls. According to the IMF AREAER, Malaysia was liberalized at the time of the Asia crisis, when it experienced most volatility; however, Malaysia did reimpose temporary controls during the crisis; in fact it is one of the most quoted examples of the use of controls on outflows. This makes the interpretation of the results for this country very difficult.

Table 3: The impact of capital controls on the tail index.

This table reports the tail index estimates α based on the Hill-estimator. The complete sample is split into the part with capital controls — *con* —, and the liberalized sample — *lib*. Sample sizes n and the number of order statistics m used to calculate the Hill-estimator are reported in the first four columns. m is calculated on the basis of Beirlant et al. (1999). The t-statistic $\tau_{\alpha_{con}=\alpha_{lib}}$ tests for the equality of the tail index in both samples. A *, **, or *** refers to the rejection of the null at 10, 5, or 1 percent significance levels respectively.

Panel A: Developed Countries									
	n_{con}	m_{con}	n_{lib}	m_{lib}	α	α_{con}	α_{lib}	$\tau_{\alpha_{con}=\alpha_{lib}}$	
Austria	4695	116	4393	60	3.73	3.61	4.97	-1.88	**
Denmark	3913	63	5175	148	3.86	3.72	4.51	-1.33	*
France	5218	112	3870	70	3.45	3.37	6.39	-3.65	***
Italy	5218	171	3870	85	3.50	3.01	5.90	-4.24	***
Norway	5739	113	3349	140	3.09	3.21	4.20	-2.12	***
Portugal	5218	179	3870	85	3.02	2.53	5.01	-4.31	***
Spain	5479	160	3609	64	3.19	2.89	6.22	-4.11	***
Sweden	5218	164	3870	63	3.80	3.73	5.51	-2.36	***
Panel B: Emerging Countries									
	n_{con}	m_{con}	n_{lib}	m_{lib}	α	α_{con}	α_{lib}	$\tau_{\alpha_{con}=\alpha_{lib}}$	
Chile	7306	463	781	20	1.87	1.75	6.15	-3.19	***
Ecuador	3150	66	1304	58	1.04	1.73	1.73	0.01	
Egypt	2107	38	2607	91	2.01	3.25	2.03	2.13	**
El Salvador	1847	110	2607	42	2.12	2.10	1.86	0.69	
Gambia	542	47	3912	110	1.84	1.55	1.92	-1.25	
Guyana	1847	159	2607	88	1.70	1.75	1.29	2.36	***
Honduras	3150	153	1304	129	1.43	1.57	1.40	0.93	
Indonesia	2607	249	6262	184	1.87	1.38	2.68	-6.04	***
Jamaica	4692	320	2607	51	1.46	1.39	3.19	-3.96	***
Jordan	3388	193	2346	151	1.13	2.22	1.78	2.01	**
Lebanon	2346	39	6523	647	1.31	4.13	1.21	4.41	***
Malaysia	6262	222	2607	49	1.98	3.03	2.09	2.60	***
Mexico	2868	82	6001	583	1.55	3.08	1.43	4.77	***
Trin. & Tob.	4170	364	3129	153	1.73	2.01	1.70	1.76	**
Uruguay	2869	216	6000	176	1.61	1.51	2.33	-4.01	***
Venezuela	4173	127	4696	270	1.99	2.30	1.69	2.69	***
Zambia	6262	331	2607	118	1.65	1.60	2.33	-3.16	***

policy measures constitute attempts by the government to exert (direct) control over the currency. Through this control of the exchange market, the government increases the costs to investors of speculating on the exchange rate market and makes it unattractive for speculators to arbitrage away small deviations from perceived equilibrium levels. However, once the exchange rate misalignment exceeds a critical level, a sudden large shift can be expected. In other words, exchange rate control may replace frequent small movements with infrequent large movements: tails become fatter.

4.3. Quantile Estimates

The unconditional variance and the tail index are useful intermediary concepts to express the risk that is present in currency returns; but in the end what matters most to investors is how likely an extreme movement in the exchange rate of a given magnitude will be or, conversely, how large a sudden sharp drop in the exchange rate with a given probability of occurrence will be. The latter problem amounts to estimating the quantile of the unconditional distribution of exchange rate returns (One can also think of it as the unconditional Value-at-Risk of an open position in forex). As we are interested in extreme movements of the exchange rate, we want to calculate quantiles close to the boundary of the historical sample. The marginal exceedance probabilities (or significance levels) are set equal to $1/0.5n$, $1/n$, and $1/2n$ (i.e., corresponding with extreme quantiles that are in-sample, at the boundary of the sample and out-of-sample, respectively).

For the developed countries, the number of observations per sub-sample varies between 3,600 and 5,500. The probability levels are calibrated to approximately $\frac{1}{2,500} \approx \frac{1}{0.5n}$, $\frac{1}{5,000} \approx \frac{1}{n}$, and $\frac{1}{10,000} \approx \frac{1}{2n}$, which corresponds to 0.04%, 0.02%, and 0.01% respectively. The sub samples sizes of the emerging countries are much more heterogeneous, making it more difficult to pick probabilities that lie close to the historical sample boundary. The emerging country significance levels are set to $\frac{1}{1,000}$ (0.1%), $\frac{1}{2,500}$ (0.04%), and $\frac{1}{10,000}$ (0.01%)⁸.

The full sample and subsample quantile estimates for developed and emerging currencies are given in tables 4 and 5, respectively. Table 7 in the appendix reports estimated developed currency quantiles using two alternative liberalization dates⁹. As an example of how to interpret the numbers, consider the quantiles estimated for Austria. Given a probability of 0.04%, the quantile of Austria is 3.97% for the whole sample. That is, a daily (log) depreciation *larger* than 3.97% is observed with a probability of

⁸The first probability is a proxy for $1/n$ for the smallest samples (2 samples have $n < 1,000$), and $\frac{1}{10,000}$ proxies for $1/n$ for the largest sample ($n = 7306$). In addition, two of the three probabilities chosen correspond to those chosen for the developed countries in order to facilitate comparisons between the two samples.

⁹As for emerging countries, there was only one proxy available for capital controls.

Table 4: The impact of capital controls on quantiles, developed countries.

This table reports the quantile estimates q based on different exceedance probabilities p . These exceedance probabilities roughly correspond to $1/0.5n$, $1/n$, and $1/2n$. The complete sample is split into the part with capital controls – *con* –, and the liberalized sample – *lib*. The t-statistic $\tau_{q_{con}=q_{lib}}$ tests for the equality of the quantiles in both samples. A *, **, or *** refers to the rejection of the null at 10, 5, or 1 percent significance levels respectively. Sample sizes and the number of order statistics are equal to those reported in table 3.

Country	p = 0.04%					p = 0.02%					p = 0.01%				
	q	q_{con}	q_{lib}	$\tau_{q_{con}=q_{lib}}$	q	q_{con}	q_{lib}	$\tau_{q_{con}=q_{lib}}$	q	q_{con}	q_{lib}	$\tau_{q_{con}=q_{lib}}$	q	q_{con}	$\tau_{q_{con}=q_{lib}}$
Austria	3.97%	4.34%	3.05%	2.40 ***	4.78%	5.26%	3.51%	2.32 **	5.76%	6.37%	4.03%	2.25 **			
Denmark	3.78%	4.24%	3.16%	1.85 **	4.52%	5.11%	3.68%	1.72 **	5.41%	6.16%	4.29%	1.62 *			
France	4.20%	4.88%	2.27%	4.60 ***	5.14%	6.00%	2.53%	4.26 ***	6.28%	7.37%	2.82%	3.98 ***			
Italy	4.20%	5.47%	2.42%	4.80 ***	5.12%	6.89%	2.72%	4.52 ***	6.24%	8.67%	3.06%	4.28 ***			
Norway	4.46%	4.49%	3.17%	2.23 **	5.58%	5.57%	3.73%	2.16 **	6.98%	6.91%	4.41%	2.10 **			
Portugal	5.12%	7.18%	2.74%	4.57 ***	6.44%	9.44%	3.15%	4.29 ***	8.10%	12.41%	3.61%	4.04 ***			
Spain	4.45%	5.51%	2.28%	4.82 ***	5.53%	7.00%	2.55%	4.53 ***	6.87%	8.90%	2.85%	4.28 ***			
Sweden	4.60%	5.12%	3.02%	3.94 ***	5.52%	6.16%	3.43%	3.71 ***	6.63%	7.42%	3.89%	3.53 ***			

Table 5: The impact of capital controls on quantiles, emerging countries.

This table reports the quantile estimates q based on different exceedance probabilities p . These exceedance probabilities are constructed as follows: $p = 0.1\%$ corresponds to roughly $1/2n$ for the small samples, $p = 0.01\%$ corresponds to a little more than $1/2n$ for the large subsamples, while $p = 0.04\%$ is somewhere in between. The complete sample is split into the part with capital controls – *con* –, and the liberalized sample – *lib*. The t-statistic $\tau_{q_{con}=q_{lib}}$ tests for the equality of the quantiles in both samples. A *, **, or *** refers to the rejection of the null at 10, 5, or 1 percent significance levels respectively. Sample sizes and the number of order statistics are equal to those reported in table 3.

Country	p = 0.1%					p = 0.04%					p = 0.01%				
	q	q_{con}	q_{lib}	$\tau_{q_{con}=q_{lib}}$	q	q_{con}	q_{lib}	$\tau_{q_{con}=q_{lib}}$	q	q_{con}	q_{lib}	$\tau_{q_{con}=q_{lib}}$	q	q_{con}	$\tau_{q_{con}=q_{lib}}$
Chile	9.7%	11.3%	2.2%	7.14 ***	15.9%	19.1%	2.6%	6.36 ***	33.3%	42.1%	3.2%	5.37 ***	33.3%	42.1%	5.37 ***
Ecuador	48.3%	18.4%	10.5%	1.58 *	116.3%	31.2%	17.8%	1.23	438.5%	69.6%	39.8%	0.92	438.5%	69.6%	0.92
Egypt	6.0%	5.2%	3.1%	2.26 **	9.4%	6.9%	4.8%	1.20	18.7%	10.6%	9.6%	0.26	18.7%	10.6%	0.26
El Salvador	5.4%	8.1%	1.8%	4.06 ***	8.3%	12.5%	2.9%	3.22 ***	16.0%	24.2%	6.1%	2.41 ***	16.0%	24.2%	2.41 ***
Gambia	9.3%	17.4%	8.3%	1.23	15.3%	31.5%	13.4%	1.12	32.6%	76.9%	27.7%	0.99	32.6%	76.9%	0.99
Guyana	8.9%	12.0%	7.1%	1.53 *	15.2%	20.2%	14.4%	0.80	34.2%	44.7%	42.4%	0.09	34.2%	44.7%	0.09
Honduras	13.2%	10.8%	13.9%	-0.69	25.0%	19.3%	26.7%	-0.71	66.1%	46.7%	71.6%	-0.72	66.1%	46.7%	-0.72
Indonesia	11.7%	33.4%	5.5%	3.96 ***	19.1%	64.9%	7.8%	3.48 ***	40.0%	177.7%	13.1%	2.93 ***	40.0%	177.7%	2.93 ***
Jamaica	20.0%	26.5%	5.1%	4.70 ***	37.5%	51.2%	6.9%	4.17 ***	96.9%	138.7%	10.6%	3.52 ***	96.9%	138.7%	3.52 ***
Jordan	25.0%	7.5%	0.7%	6.79 ***	56.3%	11.3%	1.2%	5.46 ***	191.9%	21.1%	2.7%	4.17 ***	191.9%	21.1%	4.17 ***
Lebanon	25.7%	0.6%	37.8%	-6.59 ***	51.8%	0.7%	80.6%	-5.53 ***	149.7%	1.0%	253.4%	-4.44 ***	149.7%	1.0%	-4.44 ***
Malaysia	4.7%	2.6%	6.5%	-2.94 ***	7.5%	3.6%	10.1%	-2.44 ***	15.0%	5.6%	19.6%	-1.98 **	15.0%	5.6%	-1.98 **
Mexico	14.8%	3.3%	21.5%	-6.32 ***	26.8%	4.5%	40.8%	-5.57 ***	65.7%	7.0%	107.6%	-4.68 ***	65.7%	7.0%	-4.68 ***
Trin. & Tob.	11.0%	9.7%	7.5%	1.23	18.7%	15.3%	12.8%	0.68	41.8%	30.4%	28.9%	0.15	41.8%	30.4%	0.15
Uruguay	15.4%	8.4%	10.4%	-0.99	27.3%	15.4%	15.4%	0.00	64.6%	38.6%	28.0%	0.84	64.6%	38.6%	0.84
Venezuela	13.4%	14.1%	10.7%	1.40 *	21.3%	21.0%	18.4%	0.53	42.8%	38.4%	42.0%	-0.28	42.8%	38.4%	-0.28
Zambia	21.2%	26.3%	8.5%	4.67 ***	36.9%	46.7%	12.6%	4.16 ***	85.6%	111.2%	22.9%	3.59 ***	85.6%	111.2%	3.59 ***

Figure 1: Quantiles before and after financial liberalization.

This figure plots the empirical quantiles at $1/0.5n$ for the developed (0.04%) and emerging (0.1%) countries. The countries have been ordered according to their estimated quantile in the liberalized period (lowest on the left, highest on the right). The solid line plots the quantile post-liberalization and the dashed line the quantiles pre-liberalization. The lower panel plots the ratio between the two quantiles, with values above 1 indicating higher quantiles pre-liberalization. The left panel includes the European countries: France (FRA), Spain (SPA), Italy (ITA), Portugal (POR), Sweden (SWE), Austria (AUT), Denmark (DEN), and Norway (NOR). The right panels include the emerging economies: Jordan (JOR), El Salvador (ESD), Chile (CHI), Egypt (EGY), Jamaica (JAM), Indonesia (IND), Malaysia (MAL), Guyana (GUY), Trinidad and Tobago (TRT), Gambia (GAM), Zambia (ZAM), Uruguay (URU), Ecuador (ECU), Venezuela (VEN), Honduras (HON), Mexico (MEX), and Lebanon (LEB).

only 0.04%, i.e., once every $(1/0.0004)/360 \approx 7$ years.¹⁰ Unsurprisingly the (full sample) quantiles for the emerging countries (table 5) are much larger than those for the European countries. For the full sample and $p = 0.04\%$ the developing currency quantiles fluctuate between 7.5% (Malaysia) and 116.3% (Ecuador), while the European currency quantiles hover between 3.78% (Denmark) and 5.12% (Portugal).

If one compares the ‘controlled’ and ‘liberalized’ quantiles one clearly sees that most countries exhibit a stronger propensity towards extreme depreciations when capital controls are present. For all European countries, quantiles significantly drop after financial liberalization (table 4 and 7). For quantiles further in the tail, the statistical significance of the structural change test results is less striking but still present. Furthermore, the tables and figure 1 illustrate the economic significance of the break. First, for the European countries, the quantiles for a 0.01% probability in a liberalized period are still below the quantiles for a 0.04% probability when markets were controlled. Thus an extreme event which occurred on average only once every 28 years in liberalized markets, happens more than once every 7 years if capital controls are in place. Alternatively, if the probabilities are kept constant, a once in 7 years downward movement is slightly less than twice (1.9 on average) as large before liberalization compared to the period after liberalization. This ratio only becomes larger as we move further in the tail, as the tails are fatter pre-liberalization. Interestingly enough, it seems that the countries that have the highest exchange rate risk before liberalization, such as Portugal, Spain, and Sweden, are amongst those with the lowest risk after liberalization, i.e., financial liberalization does not seem to have the same effects on all countries.

For the sample of emerging countries (given in table 5 and figure 1), more than half of the countries show significant lower quantiles when the capital controls are liberalized. This result is somewhat tempered when we move further in the tail, but for most countries the drop in quantiles remains significant at the 1% level. The extent to which the risk drops after liberalization is remarkable. Looking at an event happening with an 0.1% probability (roughly speaking: once every 3 years) the expected depreciation decreases (on average) from 12.7% to 9.5%, or roughly by 25%. Mexico and Lebanon stand out from the other countries and remain puzzling. These two countries have significantly higher quantiles after liberalization. In comparison to the other developing countries they show both very low quantiles before liberalization and amongst the highest quantiles after liberalization.

5. Conclusion

This paper investigates the effect of financial liberalization on exchange rate risk. As many investors and regulators are particularly worried about sudden large exchange rate

¹⁰As for the emerging currency quantiles, the reported quantile estimates are extreme events that are expected to occur once every 3.5(0.1%), 14(0.02%), and 28(0.01%) years.

depreciations, we decided to exploit extreme value analysis (EVT) to proxy exchange rate risk by extreme depreciation quantiles that reflect small probability events. This study applies the EVT methodology to a wide cross-section of countries, spanning both European (developed) markets and emerging markets in all continents.

The use of extreme value analysis (EVT) in empirical finance has steadily gained in popularity because it requires no distributional assumptions other than that the return tails contain more probability mass than the normal distribution, i.e. the ‘heavy tail’ feature. The quantile analysis enables the distinction between appreciations and depreciations, i.e., one does not need to impose tail symmetry as with the standard deviation. Moreover, foreign exchange return tails can contain so much probability mass that the variance is no longer defined (finite). In the latter case, an extreme depreciation quantile provides a proper alternative as a forex risk measure¹¹.

The results suggest that financial liberalization is associated with lower extreme depreciation quantiles and this holds for both developed and emerging economies. As a matter of fact, extreme quantiles are almost twice as high under capital controls as compared to under liberalized capital account regime. Not surprisingly, the drop in tail risk after liberalization is more spectacular for those countries that exhibited the fattest tails when capital control restrictions were still in place. The results are robust to different definitions of financial liberalization.

The results corroborate previous empirical studies. Capital controls have been found to increase the probability of a currency crisis (Glick and Hutchison, 2005), which typically coincides with the most extreme currency fluctuations. Other forms of exchange rate control are also associated with thicker tails. Koedijk et al. (1992) find that any degree of ‘fixity’ of the exchange rate is associated with lower values of α .

Thus, although many countries exhibit a fear of floating, their control over the exchange rate market does not decrease the incidence of big depreciations (or devaluations) of their currency. Even worse, the likelihood of large depreciations seems to increase. It is true that capital controls can be implemented to achieve goals other than curbing exchange rate risk. However, this study shows that capital controls are not a good instrument for decreasing the risk of extreme depreciations.

¹¹More specifically, if the tail index α falls below 2, the variance is no longer defined but the quantiles calculated with EVT are still valid. Estimates of α for emerging currencies were often found to lie below 2, i.e., the reported standard deviation analysis is suspect and needed to be complemented with a methodology that explicitly takes into account the fat tails of foreign exchange rate returns.

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6. Appendix

Table 6: The impact of capital controls on the tail index, alternative proxy.

This table reports the tail index estimates α based on the Hill-estimator. Panel A contains the results with the liberalization dates based on the Miniane index, while panel B reports the results for the liberalization dates based on the Kaminsky & Schmukler index. The complete sample is split into the part with capital controls — *con* —, and the liberalized sample — *lib*. Sample sizes n and the number of order statistics m used to calculate the Hill-estimator are reported in the first four columns. m is set at 2.5% of the sample size. The t-statistic $\tau_{\alpha_{con}=\alpha_{lib}}$ tests for the equality of the tail index in both samples. A *, **, or *** refers to the rejection of the null at 10, 5, or 1 percent significance levels respectively.

Panel A: Miniane Index								
Country	n_{con}	m_{con}	n_{lib}	m_{lib}	α	α_{con}	α_{lib}	$\tau_{\alpha_{con}=\alpha_{lib}}$
Austria	4695	116	4393	60	3.73	3.61	4.97	-1.88 **
Denmark	3913	63	5175	148	3.86	3.72	4.51	-1.33 *
France	4174	100	4914	118	3.45	3.08	4.69	-3.03 ***
Italy	3913	125	5175	160	3.50	3.15	3.69	-1.32 *
Norway	4174	266	4914	232	3.09	2.65	3.58	-3.23 ***
Portugal	4695	295	4393	127	3.02	2.34	3.96	-4.30 ***
Spain	4956	263	4132	136	3.19	2.75	3.92	-3.13 ***
Sweden	4174	283	4914	112	3.80	3.09	4.98	-3.75 ***
Panel B: Kaminsky & Schmukler Index								
Country	n_{con}	m_{con}	n_{lib}	m_{lib}	α	α_{con}	α_{lib}	$\tau_{\alpha_{con}=\alpha_{lib}}$
Denmark	4109	68	4979	141	3.80	3.69	4.65	-1.62 *
France	4434	103	4654	112	3.45	3.17	4.74	-2.88 ***
Italy	4956	146	4132	125	3.50	3.24	3.75	-1.18
Norway	3913	249	5175	124	3.09	2.63	4.00	-3.45 ***
Portugal	5109	344	3979	101	3.02	2.37	3.96	-3.82 ***
Spain	2999	124	6089	154	3.19	2.18	4.39	-5.46 ***
Sweden	4174	283	4914	112	3.80	3.09	4.98	-3.75 ***

Table 7: The impact of capital controls on quantiles, alternative proxy.

This table reports the quantile estimates q based on different exceedance probabilities p . These exceedance probabilities roughly correspond to $1/0.5n$, $1/n$, and $1/2n$. Panel A reports the results with the liberalization dates based on the Miniane index, while panel B gives the results based on the Kaminsky & Schmukler index. The complete sample is split into the part with capital controls – *con* –, and the liberalized sample – *lib*. The t-statistic $\tau_{q_{con}=q_{lib}}$ tests for the equality of the quantiles in both samples. A *, **, or *** refers to the rejection of the null at 10, 5, or 1 percent significance levels respectively. Sample sizes and the number of order statistics are equal to those reported in table 6.

Panel A: Miniane index														
p = 0.04%					p = 0.02%					p = 0.01%				
Country	q	q _{con}	q _{lib}	τ _{q_{con}=q_{lib}}	q	q _{con}	q _{lib}	τ _{q_{con}=q_{lib}}	q	q _{con}	q _{lib}	τ _{q_{con}=q_{lib}}	q	τ _{q_{con}=q_{lib}}
Austria	3.97%	4.34%	3.05%	2.40 ***	4.78%	5.26%	3.51%	2.32 **	5.76%	6.37%	4.03%	2.25 **		
Denmark	3.78%	4.24%	3.16%	1.85 **	4.52%	5.11%	3.68%	1.72 **	5.41%	6.16%	4.29%	1.62 *		
France	4.20%	5.26%	2.98%	3.10 ***	5.14%	6.59%	3.45%	2.93 ***	6.28%	8.25%	4.00%	2.78 ***		
Italy	4.20%	5.01%	3.77%	1.73 **	5.12%	6.24%	4.55%	1.65 **	6.24%	7.77%	5.49%	1.58 *		
Norway	4.46%	5.19%	3.88%	1.88 **	5.58%	6.73%	4.71%	2.00 **	6.98%	8.74%	5.72%	2.08 **		
Portugal	5.12%	7.54%	3.67%	3.83 ***	6.44%	10.14%	4.37%	3.77 ***	8.10%	13.64%	5.20%	3.69 **		
Spain	4.45%	5.36%	3.58%	2.60 ***	5.53%	6.90%	4.28%	2.65 ***	6.87%	8.88%	5.10%	2.68 ***		
Sweden	4.60%	6.21%	3.45%	4.13 ***	5.52%	7.78%	3.97%	4.04 ***	6.63%	9.73%	4.56%	3.95 ***		
Panel B: Kaminsky & Schmukler index														
p = 0.04%					p = 0.02%					p = 0.01%				
Country	q	q _{con}	q _{lib}	τ _{q_{con}=q_{lib}}	q	q _{con}	q _{lib}	τ _{q_{con}=q_{lib}}	q	q _{con}	q _{lib}	τ _{q_{con}=q_{lib}}	q	τ _{q_{con}=q_{lib}}
Denmark	3.81%	4.29%	3.07%	2.13 **	4.57%	5.18%	3.56%	1.98 **	5.49%	6.25%	4.13%	1.87 **		
France	4.20%	5.08%	2.94%	3.13 ***	5.14%	6.33%	3.40%	2.96 ***	6.28%	7.87%	3.93%	2.81 ***		
Italy	4.20%	4.79%	3.68%	1.70 **	5.12%	5.93%	4.43%	1.62 *	6.24%	7.34%	5.34%	1.55 *		
Norway	4.46%	5.26%	3.52%	2.41 ***	5.58%	6.85%	4.19%	2.53 ***	6.98%	8.91%	4.99%	2.59 ***		
Portugal	5.12%	7.62%	3.48%	4.32 ***	6.44%	10.21%	4.14%	4.21 ***	8.10%	13.68%	4.94%	4.09 ***		
Spain	4.45%	7.79%	3.21%	3.04 ***	5.53%	10.70%	3.76%	2.93 ***	6.87%	14.70%	4.40%	2.81 ***		
Sweden	4.60%	6.21%	3.45%	4.13 ***	5.52%	7.78%	3.97%	4.04 ***	6.63%	9.73%	4.56%	3.95 ***		