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Exchange Rates and Sovereign Risk: a Nonlinear Approach Based on Local Gaussian Correlations

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Abstract

We empirically assess the interlinkages between sovereign risk, measured in terms of CDS spreads, and exchange rates for a sample of emerging markets. Our period of analysis includes episodes of severe stress, such as the Global Financial Crisis, the COVID-19 pandemic, and the Ukrainian War. Exploiting recent developments in local Gaussian partial correlation analysis and the associated nonlinear Granger causality tests, we are able to uncover linkages between assets across different segments of their joint distributions. Disentangling the effect of global factors, we show that the information on sovereign risk of other emerging economies is more relevant for the sovereign risk-exchange rate relationship than the state of developed markets risk for all countries in our sample and for all segments of the assets distribution. The same considerations apply for the movements of the US dollar relative to other currencies, where changes in emerging market currencies is of particular interest. Nonlinear Granger causality tests show bi-directional causality for most countries, confirming the importance of multiple transmission channels. Taken together, our results highlight the importance of understanding the interlinkages between sovereign risk and exchange rates across their entire joint asset returns distribution, which can guide policymakers in debt and currency management, with coordinated regional responses potentially proving more effective than individual national actions. In terms of portfolio management, our documented bidirectional causality offers valuable insights into predicting currency fluctuations based on sovereign risk, supporting hedging and investment strategies in periods of financial stress.

Keywords: CDS; correlation; emerging markets; exchange rate; nonlinear causality; sovereign risk

JEL classification: F31; G15

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1. Introduction

We empirically assess the interlinkages between sovereign risk and exchange rates at different segments of their distributions, based on a sample of open emerging market economies. Emerging markets are more vulnerable to sovereign risk than developed economies, given their limited fiscal space, with higher debt-to-GDP burdens (especially in the wake of the COVID-19 pandemic), higher refinancing risks (given the shorter average maturity of their debt), past history of defaults[1] (which increases the market-perceived risk of default - see, e.g., *Reinhart et al., 2003)*, and high bank exposure to sovereign debt (IMF, 2021), thereby intensifying the risk of "doom loops" (Mitchener and Trebesch, 2023). Furthermore, a sovereign downgrade reduces, on average, firms' investment ratios by almost 17% (IMF, 2022), confirming the prominent importance of sovereign risk for these countries, given its potential negative repercussions on investment and growth prospects.

Importantly, as a consequence of their higher dependence on foreign-denominated sovereign debt (see, e.g., the discussions on their "original sin" in Eichengreen and Hausmann, 2019, and Hausmann and Panizza, 2003), emerging markets are more vulnerable to exchange rate fluctuations, due to their relatively less developed financial systems (Kearns and Patel, 2016). The relationship between exchange rates and sovereign risk is influenced by different channels postulating different signs and causality links between the two. Yet, in spite of its topical importance for policymakers and investors, it is a relatively under-researched area. The possibility of different interlinkages across the different segments of the distribution of CDS and exchange rates, to the best of our knowledge, has not been considered, as existing literature has relied on global measures of correlations. Furthermore, existing studies have traditionally used a linear framework for causality testing, ignoring potential nonlinear links. We aim to address these limitations with our research.

While we focus on sovereign risk, our findings are also useful for corporate debt, given the relationship between the two embedded in the sovereign ceiling (i.e., the fact that the risk associated with corporate bonds in a given country cannot exceed its sovereign risk), with strong empirical evidence in favour of the presence of event risk transfer, in the form of credit risk transmission from sovereign to corporate, following sovereign downgrades (see, e.g., Fornari and Zaghini, 2022). We contribute to the literature by addressing the following original research questions: (i) what is the nature of the relationship between sovereign risk and exchange rates for the case of emerging economies?, (ii) does this relationship change across different segments of the assets distribution?, and (iii) can we identify the causality link between exchange rates and sovereign risk allowing for possible nonlinearities? Our chosen empirical methodology is based on the most recent developments of the Local Gaussian Partial Correlation (LGPC), using daily data on sovereign risk and exchange rates. The LGPC allows us to evaluate correlations considering all segments of the returns distribution, and to condition on global factors which could impact this relationship. Within this framework, we test for asymmetries and nonlinear causality links which are not detected within traditional linear causality tests.

[1]In particular, the Latin American countries in our sample have experienced different episodes of debt restructuring/defaulting, particularly during the Latin American Debt Crisis (Mexico, Peru, Brazil, Chile). Similar considerations apply to some of the Asian economies, Thailand in particular, which experienced defaults/debt restructuring during 1997-2007. Poland defaulted in 1981 and Turkey in 1992.

Our main findings show a negative correlation between sovereign risk and exchange rates, implying that increases in sovereign risk are associated with currency depreciations, which resonates with the financial and political economy channels documented in the literature. By considering the interlinkages at different segments of the distribution, we show that the negative correlations are stronger in extreme segments, indicating that surges in sovereign risk are associated with more substantial currency depreciations. Further to this, we find evidence of nonlinear and bi-directional causality between sovereign risk and exchange rates, emphasising that changes in one can predict changes in the other. Our results also suggest that the relationship between sovereign risk and exchange rates in emerging markets is more intimately connected to other emerging markets than to developed economies.

Collectively, our results are of interest to policymakers, as understanding the interdependence between sovereign risk and exchange rates in different parts of their distributions is fundamental for effective debt and currency management. As our findings also suggest that policies in one emerging market can significantly affect others, this implies that coordinated regional responses to financial crises might be more effective than individual national policies. For investors, our insights provide valuable information for managing risk in emerging market portfolios. In particular, the bi-directional causality between the two asset returns for most countries in our sample suggests that movements in sovereign risk can help predict currency fluctuations and vice versa, which could improve hedging strategies and investment decisions during periods of financial stress.

2. Literature Review

From the seminal works of Eaton and Taylor (1986) and further research fuelled by the Latin American debt crisis, the concept of sovereign risk has been extensively explored, given the long history of debt in many emerging economies and the complexities associated with the legal definition of a sovereign default/restructuring, triggering CDS payments (see, e.g., the discussion in Fang et al., 2021). Most of the literature has focussed on the pricing of sovereign risk (see, e.g., Beirne and Fratzscher (2013) and literature therein), or the costs and consequences of sovereign defaults (see, e.g., Borensztein and Panizza (2009) and literature therein).

In contrast to the above, the literature examining the relationship between exchange rate risk and sovereign risk is rather scant, in spite of its topical importance, and is unable to provide an unambiguous link. Earlier literature, following Reinhart (2002), Reinhart and Rogoff (2009) and Manasse and Roubini (2009) has focussed on the twin D, showing that defaults are typically associated with currency devaluations/depreciations, based on datasets of historical defaults. In particular, Reinhart (2002) shows that 84% of the defaults in her sample are preceded by currency crises. As actual defaults are relatively rare events, more recent literature tends to focus on the risk of a sovereign default.

From a theoretical perspective, considering the *trade channel*, other things being equal, a domestic appreciation is expected to have a contractionary effect on the domestic economy, due to the resulting loss in international competitiveness, which is associated with a decrease in net exports and a subsequent contraction in output. Such contractions will put pressure on public finances, resulting in an increased sovereign risk. This implies a positive link between sovereign risk and exchange rates, with a causality direction arising from the exchange rate to the sovereign risk. The trade channel should nevertheless work in different ways for net importers/exporters.

The *financial channel*, on the other hand, postulates that a domestic appreciation (depreciation) decreases (increases) the value of liabilities denominated in foreign currency, hence reducing (increasing) the risk of sovereign default, pointing to a negative association between exchange rates and sovereign risk, with a causality direction from exchange rates to sovereign risk.

The *currency risk premium channel*, documented by Della Corte et al. (2022), shows that countries that experience an increase in their sovereign risk exhibit, at the same, a significant depreciation in their exchange rate. This points to a contemporaneous negative relationship between sovereign risk and exchange rates. A plausible explanation relies on the existence of a risk-based channel linking sovereign risk and currency markets: an increase in the perceived sovereign risk of a given country will make investors require a higher risk premium for holding assets denominated in that currency in their portfolios (see, e.g., Lustig et al., 2011).

From a *political economy perspective,* debt held by non-residents presents an enhanced level of risk, given the difficulty in enforcing cross-border contracts in absence of a supra-national authority, enhanced by the fact of a lack of a creditor's rights to vote on domestic issues such as fiscal restructuring. As a result, an increase in the risk premium associated with government bonds will imply a welfare loss for the domestic economy, transferring resources abroad which is usually accompanied by depreciations in the exchange rate (Gros, 2013), implying therefore a causality from sovereign risk to exchange rates. Furthermore, as the costs of sovereign defaults are strongly connected to the value of a country's currency and will dramatically increase upon depreciations (Borensztein and Panizza, 2009), different incentives will be provided to policymakers.

Looking at the relevant empirical evidence, Longstaff et al. (2011) document that sovereign credit spreads increase when the local currency depreciates relative to the USD, within a monthly panel of emerging economies. In another study, Augustin et al. (2020) examine the joint dynamics of quanto spreads and USD/EUR exchange rates for 17 Eurozone countries, finding relevant comovements. A further study includes Della Corte et al. (2022), who use a dataset of monthly data over 40 developed and emerging countries from 2003 to 2017, identify a strong and robust negative contemporaneous relationship between CDS spreads and exchange rates: an increase in a country's sovereign risk is accompanied by a contemporaneous depreciation of its domestic currency. This effect becomes stronger when restricting the sample to countries with floating exchange rates and/or open capital accounts. Such result is aligned with the twin D theory, considering the risk of sovereign default rather than actual defaults.

Considering monthly data of 16 major emerging market economies, Bernoth and Herwartz (2021) find that a depreciation of the domestic currency against the USD increases sovereign risk. Moreover, Liu et al. (2023) empirically investigate the time-frequency comovements between sovereign CDS and exchange rates for a sample of BRICs and European countries, applying wavelet methodologies to monthly and weekly data. Their findings reveal that the relationship between CDS and exchange rates is mainly driven by market sentiments embedded by the VIX and the crude oil volatility index. Surprisingly, connectedness between the two is generally low and unaffected by the commodity importer/exporter status of the country investigated. That said, their use of lower frequency data implies that macroeconomic factors affecting such relationships have been mediated by the market sentiments. In a related paper, Feng et al. (2021) analyse the volatility spillovers between exchange rates and CDS for a sample of G7 and BRICS economies, finding evidence in favour.

Further empirical evidence is provided in Bluedorn and Leigh (2011), who use a sample of 173 fiscal consolidation episodes across 17 OECD countries to establish a robust link between exchange rate depreciations and fiscal consolidations. Similar results are found in Carrière-Swallow et al. (2021) for a sample of Latin American and Caribbean countries, where fiscal consolidations are shown to depreciate the exchange rate. Both studies imply a positive link between sovereign risk and exchange rates.

Overall, existing empirical evidence provides ambiguous results on the interlinkages between sovereign risk and exchange rates. We note nevertheless that the above studies are focussed on mean-based concepts of interlinkages and do not consider the different segments of the underlying assets distribution, consequently relying on linear measures of conditional independence. We aim to overcome the above described limitations with our proposed empirical methodology.

3. Methodology

We base our empirical analysis on the latest developments in the local Gaussian partial correlation. This measure overcomes the excessive restrictions of the Gaussian assumptions, by fitting a family of Gaussian distributions to a given multivariate distribution. It is, therefore, more adequate to study the behaviour of financial variables which typically exhibit skewness, excess kurtosis, and outliers. Our chosen methodology measures conditional dependence across the different segments of the assets distribution, improving on existing measures of dependence. Furthermore, our adoption of nonlinear Granger causality tests allows us to gain a better understanding of the relationship between CDS and exchange rates, capturing nonlinear links which will be undetected by traditional (linear) tests.

3.1. Local Gaussian correlation

Local Gaussian correlation has been introduced by Tjøstheim and Hufthammer (2013). The bivariate density f for two random variables X_1 and X_2 with observed values $(X_{1i}, X_{2i}), i = 1, ..., n$ is usually not Gaussian. The unknown density can be approximated locally with a family of Gaussian distributions. In a neighbourhood of each point $x = (x_1, x_2)$, we fit a Gaussian bivariate density to approximate the density $f(x)$:

$$\begin{aligned}\phi_x &= \phi(u, v, \mu_1(x), \mu_2(x), \sigma_1(x), \sigma_2(x), \rho(x)) \\ &= \frac{1}{2\pi\sigma_1(x)\sigma_2(x)\sqrt{1-\rho(x)^2}} exp\Bigg\{ -\frac{1}{2(1-\rho(x)^2)} \times \Bigg[\left(\frac{u-\mu_1(x)}{\sigma_1(x)}\right)^2 + \left(\frac{v-\mu_2(x)}{\sigma_2(x)}\right)^2 \\ &\quad - 2\rho(x)\left(\frac{u-\mu_1(x)}{\sigma_1(x)}\right)\left(\frac{v-\mu_2(x)}{\sigma_2(x)}\right)\Bigg]\Bigg\}\end{aligned} \tag{1}$$

The parameters $\mu(x), \sigma(x)$ and $\rho(x)$ depend on x. The approximation ϕ_x is close to f in a neighbourhood of x. The dependence structure of the pair of random variables is described by the correlation $\rho(x)$. By having a local approximation of the bivariate density, and hence an estimate of a local correlation, the approach is capable of detecting and quantifying nonlinear dependence structures. The Gaussian densities ϕ_x are fitted to f in the neighbourhood of x with the method of local likelihood (see Tjøstheim and Hufthammer, 2013).

3.2. Testing for asymmetry in tail dependence

In the spirit of the literature on exceedance correlation (see Longin and Solnik, 2001, and Ang and Chen, 2002), we test for symmetry in the correlation between CDS and exchange rates, for large increases and large decreases in sovereign risk. This is of particular relevance for policy purposes, allowing to verify how correlations change during extreme values of sovereign risk. We test the following hypothesis:

$$\begin{aligned} H_0^p &: \rho^-(p) = \rho^+(p) \\ H_1^p &: \rho^-(p) \neq \rho^+(p) \end{aligned}$$

with $\rho^-(p) = corr(X_{1t}, X_{2t} | x_{1t} < F_1^{-1}(p/100), x_{2t} < F_2^{-1}(p/100))$ and $\rho^+(p) = corr(X_{1t}, X_{2t} | x_{1t} > F_1^{-1}((100 - p)/100), x_{2t} > F_2^{-1}((100 - p)/100))$, whereby $F_j^{-1}(.)$ is a quantile function and $p \epsilon \{1, 2, 3, ...100\}$ is a selected percentile. We estimate the correlation in the tails by approximating the unknown density locally by Gaussian distributions using the local Gaussian method.[2]

We perform a t test using the following test statistic:

$$t^p = \frac{1}{p} \sum_{i=1}^{p} \frac{\hat{\rho}^-(i) - \hat{\rho}^+(i)}{\sqrt{\hat{se}(\hat{\rho}^-(i))^2 + \hat{se}(\hat{\rho}^+(i))^2}}, \tag{2}$$

where $\hat{\rho}^-(i)$ is the estimated local Gaussian correlation at the point (x_{1i}^-, x_{2i}^-) with $x_{1i}^- = \hat{F}_1^{-1}(i/100)$ and $x_{2i}^- = \hat{F}_2^{-1}(i/100)$ and $\hat{\rho}^+(i)$ is the estimated local Gaussian correlation at the point (x_{1i}^+, x_{2i}^+) with $x_{1i}^+ = \hat{F}_1^{-1}((100 - i)/100)$ and $x_{2i}^+ =$

[2]Using the local Gaussian approach is advantageous, as it is robust to the well known conditioning bias.

$\hat{F}_2^{-1}((100-i)/100)$.[3] The critical values of the test can be retrieved from the t distribution with $(n-2)$ degrees of freedom.

3.3. Local Gaussian partial correlation

Otneim and Tjøstheim (2022) introduce the local Gaussian partial correlation, which is a measure for conditional dependence. Assuming three random variables X_1, X_2 and X_3 with observed values $(X_{1i}, X_{2i}, X_{3i}), i = 1, ..., n$, the partial correlation between X_1 and X_2 conditioning on X_3 is studied.[4] The procedure of estimating the local Gaussian approximation can be simplified by first transforming each variable X_j into a standard normal variable $Z_j = \Phi^{-1}(F_j(X_j))$ with F_j being the cumulative distribution function of X_j and Φ is the standard normal cumulative distribution function (Otneim and Tjøstheim, 2017, 2018). The transformation allows to simplify the local Gaussian approximation by writing the density of f_Z of Z at the point $z = (z_1, z_2, z_3)$ as:

$$f_Z(z) = \psi(z, R(z)) = \frac{1}{|2\pi R(z)|^{1/2}} exp\{-\frac{1}{2} z^T R^{-1}(z) z\}, \tag{3}$$

whereby local means and standard deviations are fixed, $\mu_j(z) \equiv 0$ and $\sigma_j^2(z) \equiv 1$, and where $R(z) = \rho_{jk}(z)$ is the local correlation matrix. The local Gaussian partial correlation $\alpha(z) = R_{12|3}(z)$ between Z_1 and Z_2 given Z_3 can be computed using $R(z)$ (see Otneim and Tjøstheim, 2022).

3.4. Testing for conditional independence - nonlinear Granger causality

We adopt a nonlinear version of the Granger causality test, based on the local Gaussian partial correlation. When the local Gaussian partial correlation $\alpha(z) \equiv 0$, it corresponds to conditional independence, $X_1 \perp X_2 \mid X_3$, so $X_1|X_3$ and $X_2|X_3$ are independent. A measure of global conditional dependence can be computed as the following test statistic:

$$T_{n,b}^{CI} = \int_S h(\hat{\alpha}(z))\, dF_n(z), \tag{4}$$

where $h(.)$ is a nonnegative real-valued function, we use $h(x) = x^2$, S is an integration area and b is chosen by the plug-in bandwidth selector.[5] The critical values of this test are calculated using the bootstrap under the null hypothesis by independently resampling replicates from the conditional density estimates $\hat{f}_{X_1|X_3}(x_1|x_3)$ and $\hat{f}_{X_2|X_3}(x_2|x_3)$ using an

[3] As distribution functions $F_j(x)$ are unknown, we replace them by the empirical distribution functions $\hat{F}_j(x)$. Note that due to our definition of the exchange rate that a decrease in the exchange rate is a devaluation of the local currency, we are interested in the negative diagonal in the second and fourth quadrant. We estimate 99 local Gaussian correlations on a diagonal grid between CDS changes and exchange rate returns at percentiles (1, 99), (2, 98), ... up to (99,1). The test statistic is an average of p t-values covering a selected percentile of the tails. In the empirical part, we present results for t^5, t^{10} and t^{33}. It is reasonable to increase the number of points of measurement when testing for a larger quantile, for example we use 5 points of measurement when we test for asymmetry in a tail of 5 percentiles, while we use 10 points of measurement when we test for asymmetry in a larger tail of 10 percentiles. One could raise the number of points of measurement, but the results are not sensitive to this choice.

[4] The components, X_j, could be of higher dimension, for example X_3 can be a vector of several conditioning variables.

[5] We use the R package 'lg', see Otneim (2021) for details. Obtaining cross-validated bandwidths is very slow, and due to our large sample size not feasible.

approximated accept-reject algorithm.

We use the conditional independence test to test for Granger causality. When the null hypothesis can be rejected, it is an indication of causality from X_t to Y_t:

$$H_0 : Y_t \perp X_{t-1} \mid Y_{t-1}$$

4. Data

We use daily data up to 2023/05/17 on CDS and exchange rates against the USD for a selection of emerging economies (Brazil, Chile, Colombia, Mexico, Peru, Czech Republic, Hungary, Poland, South Africa, Turkey, China, India, Indonesia, Malaysia, Philippines and Thailand) across different continents (Americas, Europe, Middle East & Africa, and Asia). Our dataset includes periods of severe contemporary crises, such as the Global Financial Crisis, the COVID-19 pandemic, and the Ukrainian War. We identify the emerging market countries, following the MSCI annual market classification review 2022 for emerging markets.[6] Some of the countries from the MSCI list are not included in this study due to having fixed exchange rates (e.g., Qatar, UAE) or due to data availability (e.g., Egypt, South Korea, Taiwan).

We measure a country's sovereign risk in terms of the spread on its sovereign CDS. Sovereign CDS contracts perform as insurance contracts, allowing investors to buy protection against the negative event of a sovereign default or restructuring, in exchange for a premium, the CDS spread, paid over the contract's tenor in case of no default. In the case of default, the buyer could sell the defaulted debt to the protection seller at its par value.[7] We use the USD denominated contracts with a tenor of 5 years, as they represent the most liquid segment of the sovereign CDS market.

The starting dates of the daily samples differ for the different countries due to data availability in a range between 2007 and 2010.[8] CDS spreads are available from CMA (Credit Market Analysis Ltd.) via Bloomberg for the following fixings: Tokyo 8:30, London 16:30 and New York 21:30 (in UK time). To ensure the same daily information set for CDS spreads and exchange rates, care needs to be taken to select an appropriate fixing for the selection of countries. Some of the Asian currencies are traded only several hours per day (e.g., Malaysia 01:00-11:00 or Philippines 02:00-09:00). For the Asian countries, we use the Tokyo fixing, which corresponds to currency cross rate fixing F033 in Bloomberg. For all other countries we use the London fixing, and the currency fixing F113. We remove the days for a country, where at least one index, CDS spread or exchange rate, did not move at all.

To capture the relevance between global and local factors, we condition on global CDS spreads, which are computed out of 37 country values, the 16 emerging market countries plus 21 developed economy countries (United States, Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Israel, Italy, Netherlands, Norway, Portugal,

[6] msci.com/our-solutions/indexes/market-classification

[7] For a detailed analysis of CDS contract provisions, see Pan and Singleton (2008).

[8] The data for India starts at 2013.

Spain, Sweden, Switzerland, United Kingdom, Australia, Hong Kong, Japan, and New Zealand). We generate global CDS spreads for the London fixing and for the Tokyo fixing. For each of the emerging markets, we compute country specific global CDS spreads, where we exclude the own country values in the mean, hence the global averages are computed out of 36 country values.

We construct an US effective exchange rate by using currency trading volume for the weights. We retrieve the information on trading volume from BIS " Triennial Central Bank Survey - OTC foreign exchange turnover in April 2022", see page 13 of the document: "OTC foreign exchange turnover by currency pair". The weights are time-varying, changing every three years from 2010 to 2022. For the years before 2010, we use the 2010 weights. We construct US effective exchange rate returns by computing a weighted return out of 21 country[9] returns, $rfx_t^e = \frac{1}{n}\sum_{i=1}^{n} w_{it} rfx_{it}$, for $i = 1, ..., n$. For each of our emerging markets, we compute country-specific "rest-of-the-world" US effective rates by excluding the own country data from the weighted average. For the Asian countries, we compute country-specific US effective rates by using the Tokyo fixing, for all other countries we use the London fixing.

We also construct an unweighted US Dollar average exchange rate, where we include additionally to the 21 currencies, the 9 emerging country currencies of our study which are not included in the earlier weighted average selection. This total number of 30 currencies we decompose in a group of developed countries (11) and emerging countries (19).

5. Results and discussion

In what follows, we present the results for all countries in our sample, illustrating the plots of local Gaussian correlations, as well as disentangling global factors in CDS spreads and exchange rates. We also consider possible asymmetries in tail dependence, as well as nonlinear Granger causality tests.

5.1. Contemporaneous dependence

Our sample of daily data across 16 emerging economies allows us to evaluate the CDS/foreign exchange links also during periods of extreme turbulence associated with the Global Financial Crisis, the COVID-19 pandemic, as well as the Ukrainian War, which have created remarkable uncertainty in global financial markets and consequently enhanced the rewards for investors to take up risk. Such periods of stress have been typically associated with increases in sovereign risk (see, e.g., Lane, 2012, on the link between the GFC and the sovereign debt crisis; Augustin et al., 2022, on COVID-19 and sovereign risk; and Sulong et al., 2023, on the negative impact of the Russian invasion of Ukraine on sovereign debt markets), which is apparent in Figure 1, showing the corresponding peaks in CDS spreads. There is a remarkable cross-sectional difference in CDS in the different countries considered, with values ranging from the

[9]Using the selection of most strongly traded currencies versus the US Dollar according to BIS: rEU, rJP, rGB, rCN, rCA, rAU, rCH, rHK, rSG, rKR, rIN, rMX, rNZ, rSE, rTW, rNO, rZA, rBR, rPL, rTR, rAE.

Table 1: Descriptive statistics

	Code	Start	Obs	Mean CDS	Std ΔCDS	Min ΔCDS	Max ΔCDS	Sk ΔCDS	Ku ΔCDS	Std rFX	Min rFX	Max rFX	Sk rFX	Ku rFX	Cor
Brazil	BR	2007-07-10	3985	197.18	10.15	-127.90	162.90	1.43	49.30	1.03	-7.80	6.45	-0.21	7.97	-0.54
Chile	CL	2007-03-01	3961	82.58	4.54	-42.40	61.50	1.37	37.67	0.75	-4.67	5.75	-0.19	7.12	-0.31
Colombia	CO	2007-11-14	3932	159.00	9.23	-135.70	174.00	1.24	70.63	0.83	-5.84	5.74	-0.18	6.81	-0.43
Mexico	MX	2007-03-01	4164	129.29	8.50	-134.20	167.00	2.55	92.31	0.78	-7.26	4.85	-0.74	10.82	-0.51
Peru	PE	2007-04-17	3889	118.68	6.83	-71.90	182.80	5.25	155.82	0.39	-3.20	2.76	0.22	12.78	-0.25
Czech Republic	CZ	2009-04-23	3345	59.79	2.69	-31.46	33.83	0.63	32.95	0.69	-5.47	3.42	-0.20	6.07	-0.21
Hungary	HU	2008-06-09	3650	208.21	9.39	-138.50	159.10	0.74	62.94	0.96	-6.36	5.63	-0.04	6.43	-0.40
Poland	PL	2008-08-05	3636	102.69	5.17	-58.80	63.00	0.34	34.24	0.91	-6.05	6.91	-0.08	8.10	-0.41
South Africa	ZA	2007-03-01	4161	203.08	9.38	-104.20	190.40	2.57	72.79	1.04	-10.60	6.65	-0.42	7.76	-0.48
Turkey	TR	2008-08-01	3805	306.60	12.53	-98.80	146.10	1.50	27.20	1.15	-15.84	35.70	6.68	269.48	-0.47
China	CN	2010-02-01	3257	76.21	3.09	-21.69	28.99	0.65	13.67	0.22	-1.81	1.88	0.16	14.43	-0.21
India	IN	2013-10-21	2367	118.94	4.17	-56.37	56.51	0.70	62.72	0.32	-1.43	1.36	-0.15	4.93	-0.05
Indonesia	ID	2010-02-01	3263	142.15	5.84	-45.96	57.58	0.67	16.48	0.50	-8.42	4.65	-0.93	40.11	-0.36
Malaysia	MY	2010-02-01	3284	93.02	4.07	-33.46	36.08	0.32	16.08	0.41	-2.34	2.85	0.29	7.73	-0.48
Philippines	PH	2010-02-01	3363	98.49	4.09	-42.41	35.31	0.20	18.76	0.31	-1.37	1.58	-0.19	4.58	-0.34
Thailand	TH	2010-02-01	3354	84.29	3.26	-28.89	28.66	0.25	14.98	0.34	-1.56	2.44	0.22	6.26	-0.29

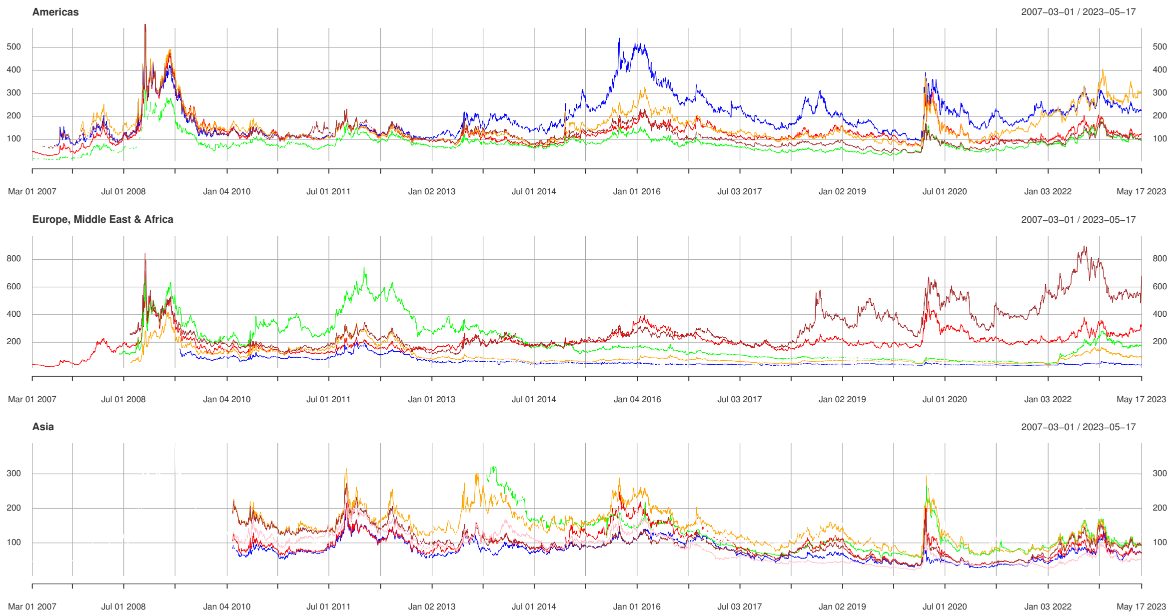

Figure 1: CDS spreads
Americas: Brazil (blue), Chile (green), Colombia (orange), Mexico (red), Peru (brown)
Europe, Middle East & Africa: Czech Republic (blue), Hungary (green), Poland (orange), South Africa (red), Turkey (brown)
Asia: China (blue), India (green), Indonesia (orange), Malaysia (red), Philippines (brown), Thailand (pink)

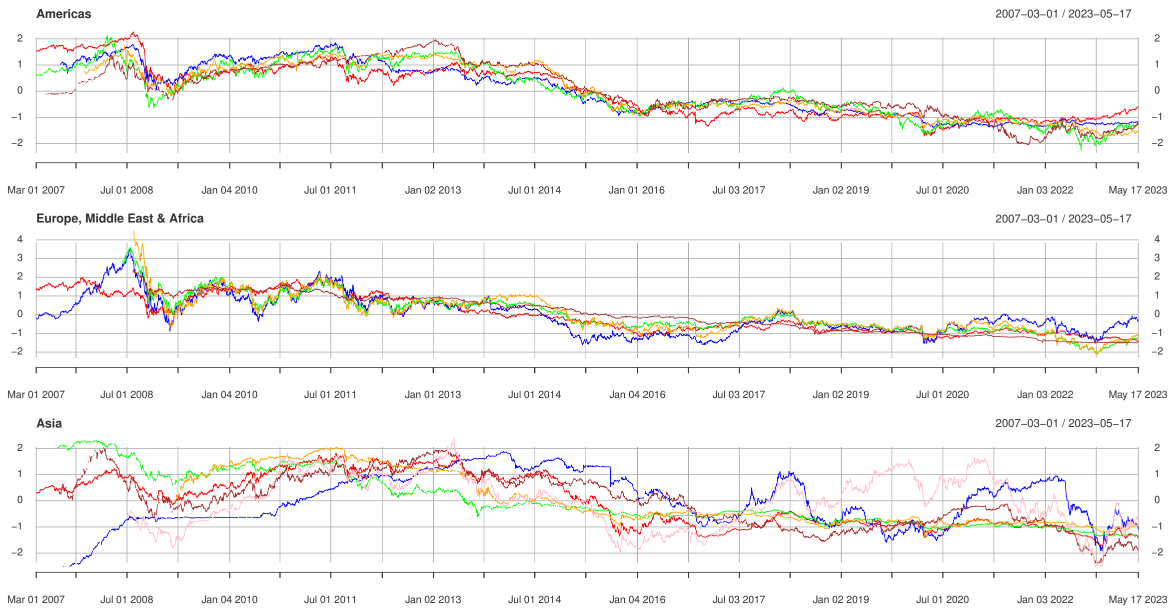

Figure 2: Exchange rates versus the US Dollar (standardized)
Americas: Brazil (blue), Chile (green), Colombia (orange), Mexico (red), Peru (brown)
Europe, Middle East & Africa: Czech Republic (blue), Hungary (green), Poland (orange), South Africa (red), Turkey (brown)
Asia: China (blue), India (green), Indonesia (orange), Malaysia (red), Philippines (brown), Thailand (pink)

Table 2: Normality test results

		ΔCDS		rFX	
		χ^2	p value	χ^2	p value
Brazil	BR	357,657***	[0.000]	4,135***	[0.000]
Chile	CL	199,817***	[0.000]	2,828***	[0.000]
Colombia	CO	751,104***	[0.000]	2,403***	[0.000]
Mexico	MX	1,389,799***	[0.000]	11,014***	[0.000]
Peru	PE	3,806,208***	[0.000]	15,543***	[0.000]
Czech Republic	CZ	125,378***	[0.000]	1,344***	[0.000]
Hungary	HU	547,395***	[0.000]	1,791***	[0.000]
Poland	PL	148,104***	[0.000]	3,953***	[0.000]
South Africa	ZA	849,841***	[0.000]	4,052***	[0.000]
Turkey	TR	94,387***	[0.000]	1,198,579***	[0.000]
China	CN	15,703***	[0.000]	17,775***	[0.000]
India	IN	352,569***	[0.000]	378***	[0.000]
Indonesia	ID	24,985***	[0.000]	187,926***	[0.000]
Malaysia	MY	23,504***	[0.000]	3,114***	[0.000]
Philippines	PH	34,894***	[0.000]	370***	[0.000]
Thailand	TH	20,133***	[0.000]	1,520***	[0.000]

Notes: The test statistics and p values for Jarque-Bera tests on changes in CDS spreads and exchange rate returns.

* significant at 10% level, ** significant at 5% level, *** significant at 1% level.

relatively lower risk of China and the Czech Republic, exhibiting an average spread of 76 and 60 points respectively, to the higher risk attributed by financial markets to countries such as Turkey (307) and Colombia (159). This will allow us to studythe relationship between exchange rates and CDS for a wide range of market-perceived risk values.

Figure 2 plots the exchange rates of the local currencies against the USD. Remarkable depreciations of local currencies occurred during the Global Financial Crisis, driven by the associated increase of risk aversion across the globe, that has enhanced the demand for USD given its safe haven status. Regarding the Chinese Yuan, the data show its appreciation during the Ukrainian war, where it has replaced the USD as most traded currency in Russia, due to the sanctions imposed by the US, EU and other advanced economies. The active intervention on the foreign exchange by the People's Bank of China is also apparent, in particular during the GFC, to boost foreign demand of Chinese exports by halting appreciations of the Yuan[10].

Considering the Pearson's correlation coefficients between CDS spreads and exchange rates, reported in Table 1, these are generally negative, ranging from -0.05 (India) to -0.54 (Brazil). These global data do not discern across the different parts of the assets distribution, and Tjøstheim et al. (2022) point out that Pearson's correlation are particularly weak in non-normality, outliers and heavy tails, and non-linearity. Given the non-normality observed in the CDS spreads and exchange rates returns observed for the sample of countries included in our study, see Tables 1 and 2, applying a nonlinear approach based on local Gaussian correlations is particularly appropriate.

Figure 3 reports our estimated local correlations. We note that correlations are generally negative for all countries in our sample and for most segments of the distributions. This means that increases in sovereign risk are generally associated with currency depreciations, a finding consistent with the financial, risk premium and political economy channels. While our results align with Bernoth and Herwartz (2021) for emerging market economies, as well as Della Corte et al. (2022) and Longstaff et al. (2011), we are able to further reveal that the identified negative correlations apply to most segments of the assets distribution. In particular, we show that correlations are usually higher in absolute value in the tails of the distributions, when changes in CDS spreads and in exchange rates are large.

Instead of focussing on the full two-dimensional plain, we focus in the following on the negative diagonal of the bi-variate distributions. In Figure 4, one can see the baseline model (i.e. the local Gaussian correlation between CDS and exchange rates on the diagonal) in blue lines. Correlations are negative, and higher in general in the tails. For Czech Republic and India, a positive correlation is found in the centre of the CDS distribution: increases in sovereign risk are accompanied by appreciations of the local currency, but only for average changes of sovereign risk; whilst for the tails of the distribution the negative correlation prevails, in line with the rest of the countries in our sample.

5.2. Asymmetry in tail dependence

We test for asymmetry in tail dependence to ascertain whether the correlations between CDS and foreign exchange rates are similar for increases vs decreases in risk. Our empirical methodology uses all observations when computing

[10]For further details and an historical analysis on China's managed float, see Das (2019).

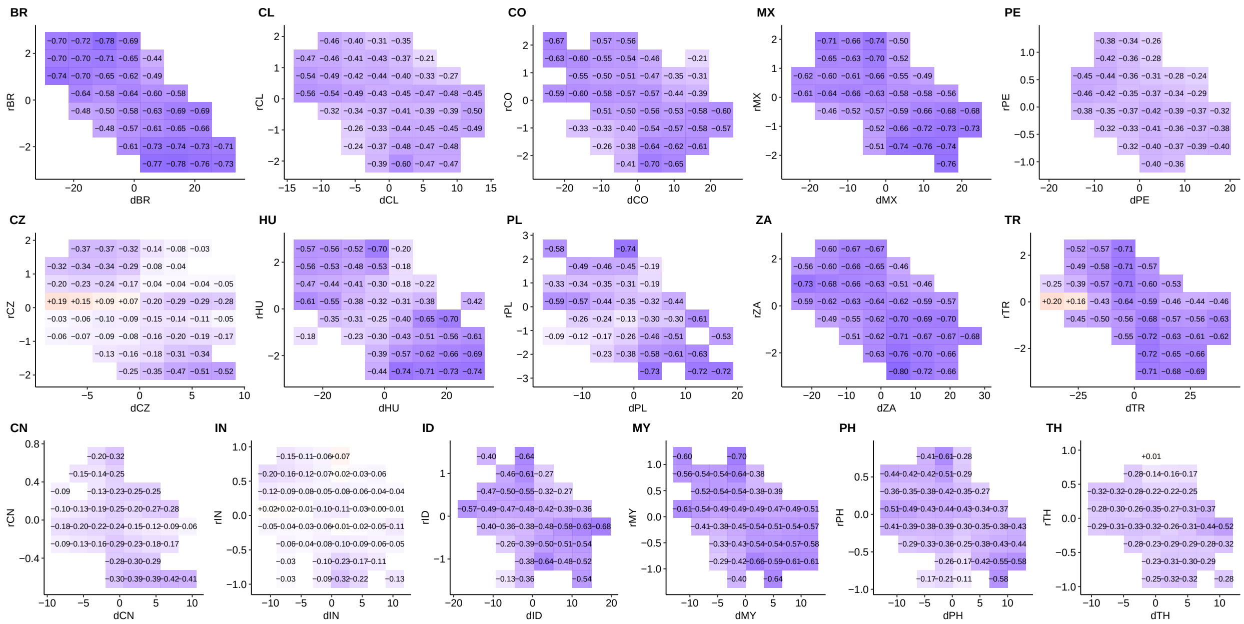

Figure 3: Local Gaussian correlation between changes in CDS spreads and exchange rate returns. Americas (top row) - Europe, Middle East & Africa (middle row) - Asia (bottom row). Please see country codes in Table 1. The local Gaussian correlations are computed on a grid between 1^{st} and 99^{th} percentile. Values are displayed for areas where data densities are above a threshold level.

correlations, rather than focussing only on observations in the tails. Moreover, it does not suffer from conditioning bias when computing correlations (see Longin and Solnik, 2001), providing more reliable results.

The null hypothesis of equal tail dependence can only be rejected for a few countries, in particular for Turkey, China and the Philippines, see Table 3. As Turkey experienced significant depreciations and increases in sovereign risk during our sample, with the highest levels of CDS spreads in our cross-section, some loss in confidence by investors might have contributed to the higher dependence in the high risk tail.

For China, although correlations across the distribution are relatively low, the right tail, corresponding to the highest values of sovereign risk, shows higher values of the (negative) correlations with exchange rates. Such a result resonates with the findings of Li et al. (2020) who explain that, given the Yuan's managed float, only larger depreciations are linked with rises in risk. This finding relates to the fact that sharp depreciations of the domestic currency damage firms with non-hedged foreign-denominated liabilities, whilst mild appreciations in turn might increase investors' confidence.

Finally, we find no indication of asymmetry in tail dependence for the countries of the Americas, showing consistently low test statistics.

5.3. Global versus country specific sovereign risk

We estimate local Gaussian *partial* correlations to consider the impact of global CDS movements (calculated from the average of developed and emerging countries). This provides a better insight into the country-specific factors affecting

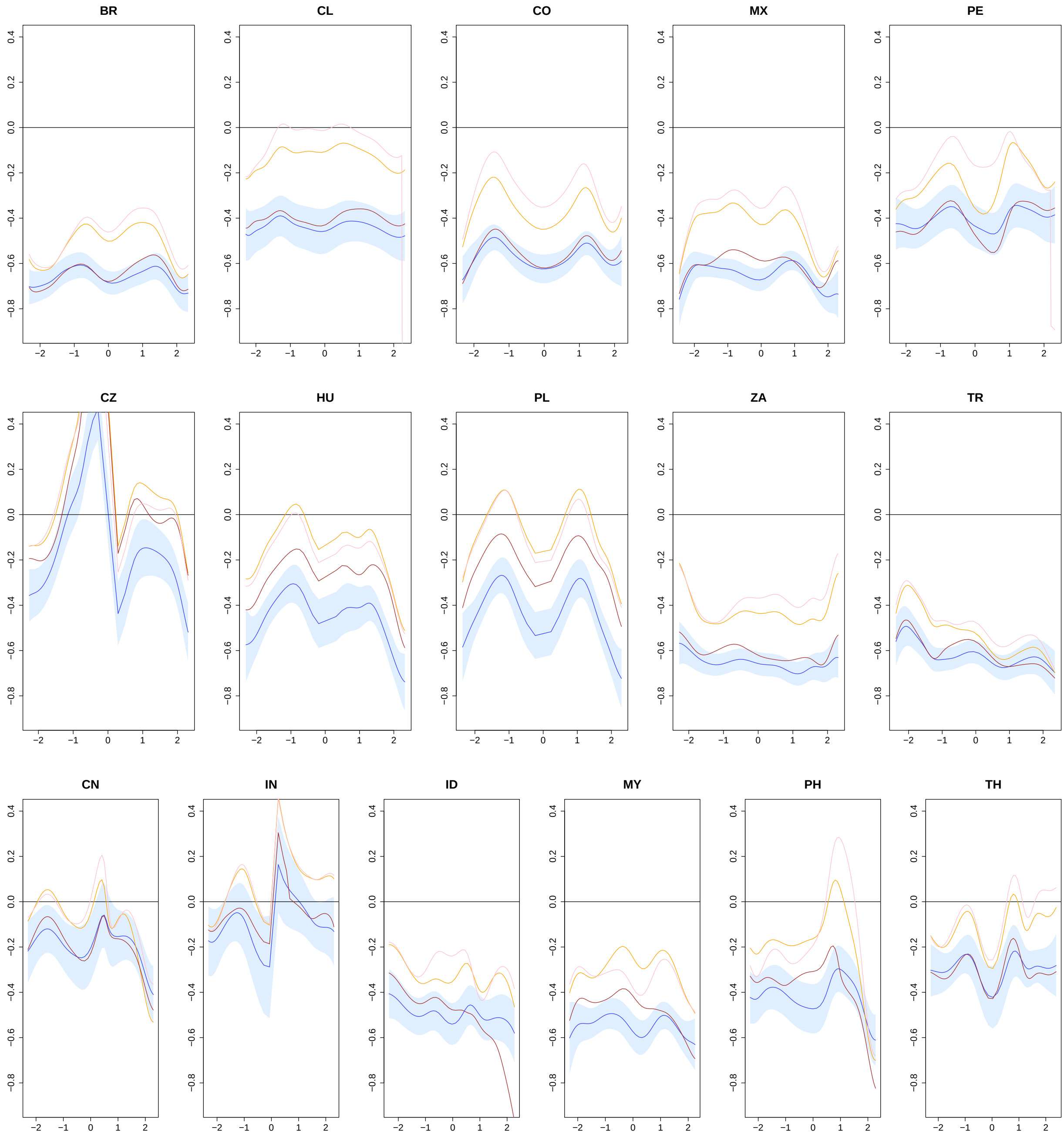

Figure 4: Americas (top row) - Europe, Middle East & Africa (middle row) - Asia (bottom row). Please see country codes in Table 1.
Blue line: Local Gaussian correlation between ΔCDS and rfx on the negative diagonal with 95% confidence bands (horizontal axis shows ΔCDS in standard deviations).
Orange line: Local Gaussian partial correlation, conditioning on average global CDS changes equal to zero, hence measuring correlation of country specific sovereign risk with exchange rates.
Brown line: Local Gaussian partial correlation, conditioning on average developed countries CDS changes equal to zero.
Pink line: Local Gaussian partial correlation, conditioning on average emerging countries CDS changes equal to zero.

Table 3: Asymmetry in tail dependence test results

		t^5	p value	t^{10}	p value	t^{33}	p value
Brazil	BR	0.507	[0.612]	0.522	[0.602]	0.350	[0.726]
Chile	CL	0.077	[0.938]	0.100	[0.92]	0.250	[0.802]
Colombia	CO	-0.950	[0.342]	-0.769	[0.442]	0.316	[0.752]
Mexico	MX	-0.106	[0.916]	0.189	[0.85]	1.756*	[0.079]
Peru	PE	-0.431	[0.666]	-0.417	[0.677]	-0.737	[0.461]
Czech Republic	CZ	1.686*	[0.092]	1.417	[0.156]	0.222	[0.825]
Hungary	HU	1.647*	[0.099]	1.740*	[0.082]	1.874*	[0.061]
Poland	PL	1.463	[0.144]	1.596	[0.11]	2.205**	[0.027]
South Africa	ZA	0.952	[0.341]	0.970	[0.332]	0.802	[0.422]
Turkey	TR	2.077**	[0.038]	2.280**	[0.023]	1.978**	[0.048]
China	CN	2.076**	[0.038]	2.129**	[0.033]	1.568	[0.117]
India	IN	-0.465	[0.642]	-0.543	[0.587]	-0.292	[0.771]
Indonesia	ID	1.906*	[0.057]	1.759*	[0.079]	1.010	[0.313]
Malaysia	MY	0.391	[0.696]	0.540	[0.589]	0.577	[0.564]
Philippines	PH	2.276**	[0.023]	2.205**	[0.027]	1.276	[0.202]
Thailand	TH	-0.213	[0.831]	-0.206	[0.837]	-0.158	[0.875]

Notes: The test statistics, t^5, t^{10} and t^{33}, are average t-values covering a selected percentile of the tails, see equation (2). * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

the relationship between CDS and exchange rates, having disentangled the global factors. In a first experiment, we study the sovereign risk/exchange rate relationship while conditioning on the information that globally, sovereign risk is not changing ($\Delta CDS^g = 0$). In a further step, we split up our global variable in two components, emerging countries and developed countries.

Considering the global CDS movements and the American countries (Figure 4), the shape of the correlations are similar across the different methodologies. Interestingly, disentangling the global factors, correlations are now generally lower and the state of sovereign risk in other emerging markets seems to be the main driver, while the average CDS of developed economies does not have a remarkable impact, as show by the closeness between the blue and the brown lines in Figure 4. Correlations in the tails of the distributions generally exhibit higher absolute values. Plausible explanations are that emerging markets have become an increasingly important asset class for international investors as a portfolio diversification strategy due to their potential economic and financial growth rates; emerging sovereigns are among the largest high yield borrowers in the world; emerging markets have a heightened exposure to global and regional shocks, making them more unstable relative to advanced economies; and emerging markets appear to be connected under crisis even if their economic fundamentals appear to be weakly correlated (see Ballester et al., 2019, and references therein).

Considering the global CDS movements and the European, African and Middle Eastern countries (Figure 4), correlations are also generally negative and the shape of the correlations is, once again, generally similar across the different methodologies. Disentangling the global factors has the effect of reducing the size of correlations across all segments of the CDS distribution. Unlike the previous case, we note a high positive correlation for the Czech Republic (consistent across all methodologies) in correspondence of minus one standard deviation. The risk in developed countries seem to matter more for Czech Republic, Hungary, and Poland, compared to all countries considered so far, whilst the emerging market risk confirms its remarkable importance in driving the correlations analysed. The findings for the Czech Republic, Hungary and Poland might be associated with their appurtenance to the European Union, making them more vulnerable to advanced economies shocks[11].

Considering the global CDS movements and the Asian economies (Figure 4), correlations are also generally negative and lower compared to the other countries analysed, and the shape of the correlations is generally similar across the different methodologies. India exhibits positive correlations especially in the higher part of the distribution. Disentangling the global factors has once again the effect of reducing the size of correlations across all segments of the CDS distribution.

5.4. US Dollar movements versus country specific depreciations

We consider local vs global movements in the exchange rates against the USD, by holding the trading-volume-weighted USD exchange rate returns constant and estimating the partial correlations between country-specific de-

[11] The Czech Republic, in particular, is undergoing assessment to join the ERM-II as a pre-requisite for eurozone appurtenance.

preciations and sovereign risks (red lines, Figure 5). While these results demonstrate a more weakened inverse relationship between country-specific information captured in exchange rate returns and sovereign risk relative to the baseline unconditional relationship estimations (blue lines, Figure 5), it is still relatively strong for most countries in our sample - the five Latin American countries, Hungary, South Africa, Turkey, Indonesia, Malaysia, Philippines - over the joint asset returns distribution. In the case of holding unweighted average US dollar exchange rate returns constant (orange lines, Figure 5), we observe that the partial correlation between the country-specific exchange rate returns and CDS returns considerably weaken across all countries in our sample. The difference in the results obtained when setting the trading-volume-weighted and unweighted USD exchange rates equal to zero are driven by the high weight of developed countries in the trading-volume-weighted USD exchange rate, as it is strongly determined by the Euro, the Japanese Yen, Pound Sterling and other developed country currencies, while in the simple unweighted USD exchange rate, emerging currencies have a significant weight.

When we hold USD exchange rate returns for developed countries (brown lines, Figure 5) versus emerging countries (pink lines, Figure 5) constant, we document relatively stronger partial correlations between foreign exchange rate depreciations and sovereign risk across countries by setting developed countries USD exchange rate returns equal to zero. This highlights the important contribution emerging market currencies make in the relationship between currency depreciations and sovereign risk. A possible reason relies in the appetibility for international investors, since they provide substantial equity-like excess returns against major currencies, with low volatility, and a relatively high forward premium that considerably raises portfolio returns (Gilmore and Hayashi, 2011). In general, we once again note that the partial correlations conditioned on different exchange rate information primarily affects the magnitude of the relationships between the exchange rate and CDS returns rather than the shape of the relationship over the joint asset returns distribution.

5.5. Nonlinear Granger causality tests

In the following, we discuss the results of nonlinear causality tests, whereby hypothesis H_0^1 focusses on causation from exchange rates to CDS spreads and hypothesis H_0^2 studies the opposite direction of causality. If both hypothesis can be rejected, bi-directional causality is present:

$$H_0^1 : \Delta CDS_t \perp rfx_{t-1} \mid \Delta CDS_{t-1}$$
$$H_0^2 : rfx_t \perp \Delta CDS_{t-1} \mid rfx_{t-1}$$

Causality tests tend to show a bi-directional causality across most of the countries in our sample, see Table 4. This sheds some further light on the relationship between sovereign risk and exchange rates, emphasising the importance of the different channels linking sovereign risk to exchange rates, as outlined in the literature. The only exceptions to bi-directional causality are represented by Brazil, Turkey, and China (showing a unilateral causality from CDS spreads

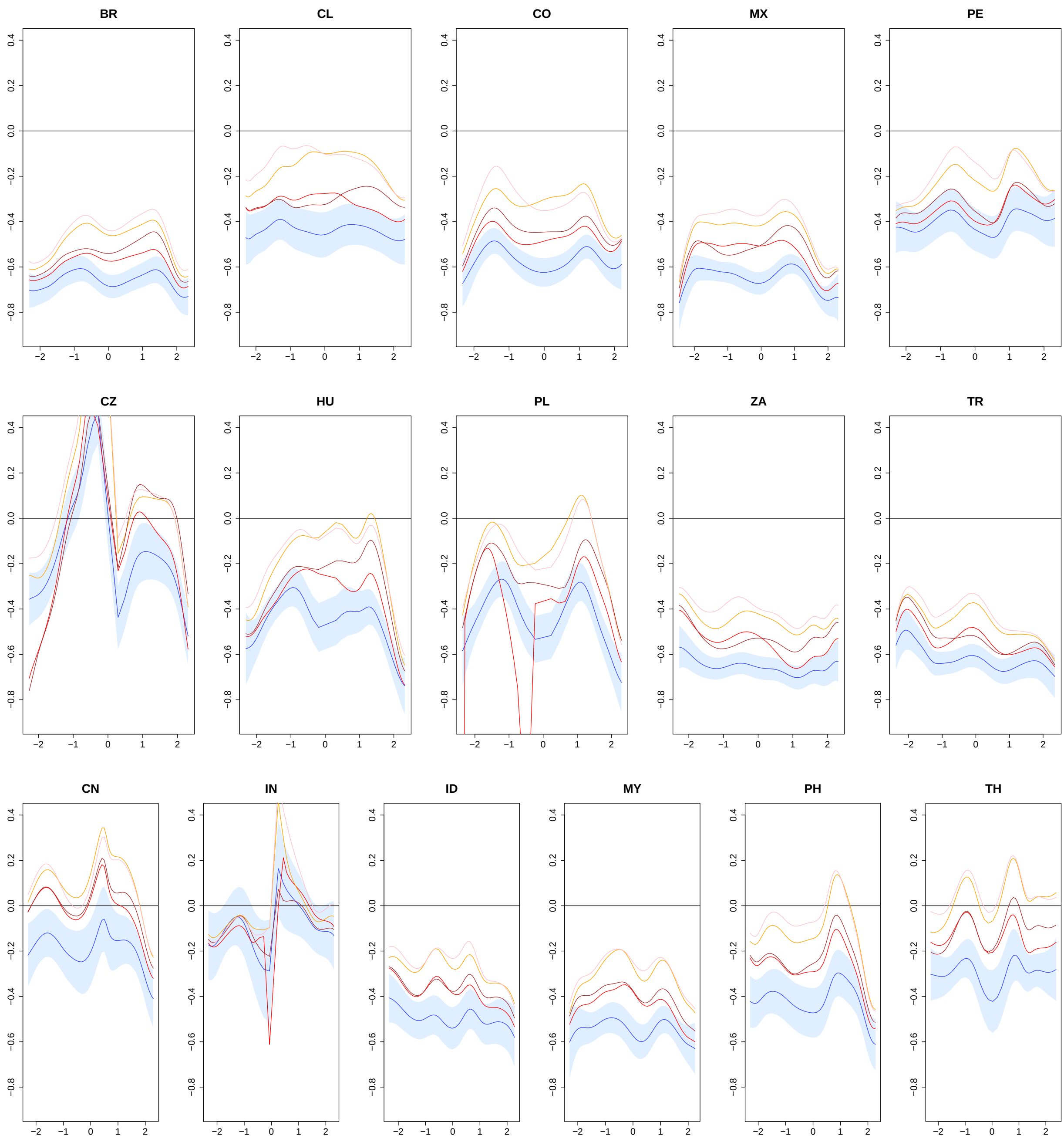

Figure 5: Americas (top row) - Europe, Middle East & Africa (middle row) - Asia (bottom row). Please see country codes in Table 1.
Blue line: Local Gaussian correlation between ΔCDS and rfx on the negative diagonal with 95% confidence bands (horizontal axis shows ΔCDS in standard deviations).
Red line: Local Gaussian partial correlation, conditioning on effective US Dollar exchange rate returns equal to zero (trading volume weights).
Brown line: Local Gaussian partial correlation, conditioning on unweighted average effective US Dollar exchange rate returns for developed country currencies equal to zero.
Orange line: Local Gaussian partial correlation, conditioning on unweighted average effective US Dollar exchange rate returns equal to zero.
Pink line: Local Gaussian partial correlation, conditioning on unweighted average effective US Dollar exchange rate returns for emerging country currencies equal to zero.

to exchange rates only) and India and Indonesia, exhibiting a unilateral causality from exchange rates to CDS spreads. The results are of particular importance for policy-makers, as the presence/absence of feedback between exchange rates and sovereign risk will be relevant for the adequate planning economic policies, particularly as the simultaneous occurrence of currency and sovereign debt crises is a common phenomenon (Dreher et al., 2006). In particular, fiscal consolidation policies aimed at reducing sovereign risk, in the presence of feedback from CDS to exchange rates, will result in the appreciation of the local currency, with relevant consequences on the economies.

Table 4: Granger causality test results

		H_0^1	p value	H_0^2	p value
Brazil	BR	0.0246	[0.210]	0.0394***	[0.000]
Chile	CL	0.0443***	[0.000]	0.0163**	[0.022]
Colombia	CO	0.0260**	[0.034]	0.0652***	[0.000]
Mexico	MX	0.0553***	[0.002]	0.0395***	[0.000]
Peru	PE	0.0226***	[0.008]	0.0195**	[0.012]
Czech Republic	CZ	0.0573***	[0.000]	0.0376***	[0.000]
Hungary	HU	0.0613***	[0.000]	0.0665***	[0.000]
Poland	PL	0.0566***	[0.000]	0.0498***	[0.000]
South Africa	ZA	0.0255**	[0.016]	0.0122**	[0.044]
Turkey	TR	0.0187	[0.112]	0.0474***	[0.000]
China	CN	0.0055	[0.452]	0.0096*	[0.074]
India	IN	0.0275***	[0.000]	0.0097	[0.102]
Indonesia	ID	0.0224*	[0.072]	0.0134	[0.140]
Malaysia	MY	0.0512***	[0.000]	0.0434***	[0.000]
Philippines	PH	0.0369***	[0.006]	0.0307***	[0.002]
Thailand	TH	0.0569***	[0.000]	0.0105*	[0.084]

Notes: H_0^1 : $\Delta CDS_t \perp rfx_{t-1} \mid \Delta CDS_{t-1}$: no Granger causality from exchange rates to CDS spreads, H_0^2 : $rfx_t \perp \Delta CDS_{t-1} \mid rfx_{t-1}$: no Granger causality from CDS spreads to exchange rates. 500 bootstrap repetitions.

* significant at 10% level, ** significant at 5% level, *** significant at 1% level.

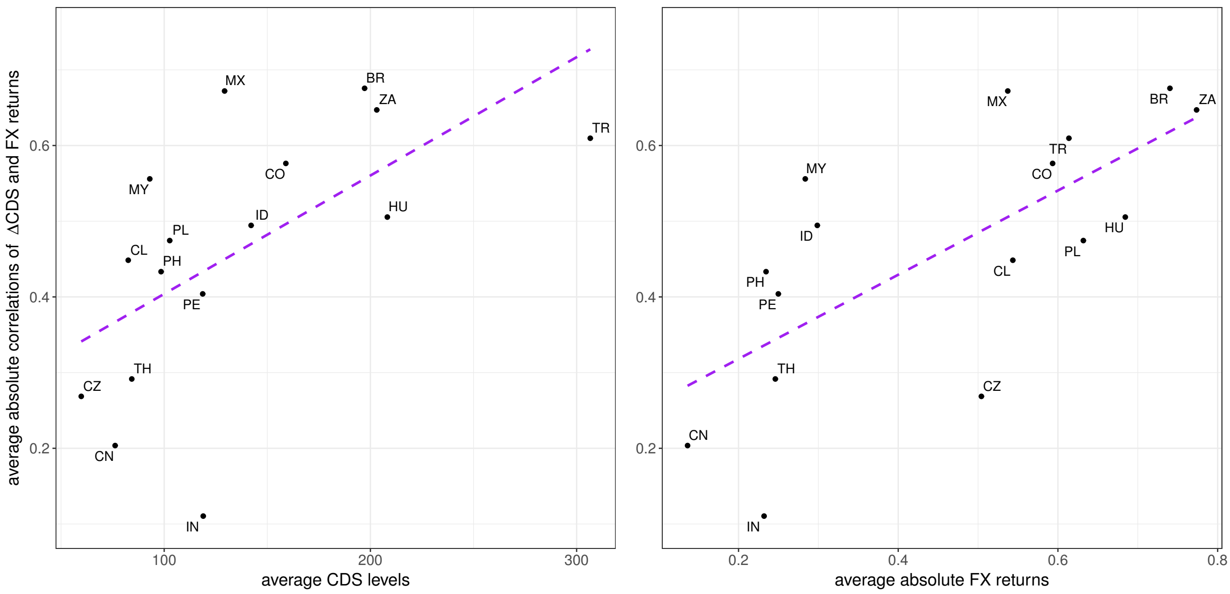

Figure 6: Cross-sectional view: dependence between CDS spread changes and FX returns versus CDS spread levels (left panel) and versus FX variation (right panel). Please see country codes in Table 1.

5.6. Sovereign risk and exchange rates - a cross-sectional perspective

In our cross-section of emerging economies, the dependence between our main variables varies significantly between countries. In the following, we attempt to dissect why some countries might have a stronger relationship between sovereign risk and exchange rates than other countries. The measure of dependence we are using is the average absolute correlation between CDS changes and fx returns on the negative diagonal of the bi-variate plain (baseline model in chapter 5.1). To explain the cross-sectional variation, we use two variables which we directly infer from our data,[12] average sovereign risk over the sample period and average variation of exchange rates. In the left panel of Figure 6, we document that countries with higher sovereign risk have a stronger dependence between risk and fx rates, for example Turkey, Hungary, South Africa, and Brazil. This sits well with the empirically verified proposition of Coudert and Mignon (2013) for emerging markets that the currency of a country with a high default risk should depreciate more severely during stress. Further, countries with higher exchange rate variation tend to have higher dependence between risk and fx rates, see Figure 6 right panel.[13]

[12] Using country fundamentals is beyond the scope of this paper.
[13] Simple OLS regressions show a slope coefficient t value of 2.79 and a R^2 of 0.36 for the left panel and a t value of 3.58 and a R^2 of 0.48 for the right panel.

6. Conclusions

We have examined the relationship between sovereign risk, measured by CDS spreads, and exchange rate returns in a sample of emerging economies with daily data covering major crises, such as the Global Financial Crisis, the COVID-19 pandemic, and the Ukrainian war. These events heavily strained public finances globally and significantly impacted emerging markets. Using the most recent developments in the local Gaussian partial correlation methodology, we have been able to uncover different channels through which the link between sovereign risk and exchange rates operates, even at the high frequency of our datasets. While global correlations are negative overall, analysing different segments of the joint distribution between CDS spreads and exchange rate returns reveals significant changes. In some countries, certain segments show significant episodes of positive correlation between the two assets. We have also shown that the information contained in CDS spreads and USD movements relative to developed economies matters much less than the information arising from other emerging markets for our correlations, and that non-linear causality linkages generally show a bi-directional causality.

Taken all together, our results are of particular relevance for the design of fiscal consolidation measures, given our documented link between sovereign risk and exchange rates. Our findings also offer important insights into debt and currency management. Indeed, the strong interdependence between sovereign risk and exchange rates across emerging markets underscores the need for coordinated regional responses to financial crises, which may prove more effective than isolated national efforts. For investors, our analysis provides valuable tools for risk management in emerging market portfolios. The established bi-directional causality between sovereign risk and exchange rates indicates that fluctuations in one can reliably predict changes in the other, informing hedging strategies and guiding investment decisions during periods of financial instability.

Disclaimer

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