Sovereign Default Risk and Currency Returns

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Abstract

Many currencies exhibit non-zero average returns with respect to US dollar, in an apparent violation of textbook uncovered and covered interest parities. I first show that in the cross-section of countries foreign currency returns are positively related to the sovereign default risk, and then reconcile this finding with the standard theory via the "peso problem". Market players collect premium for bearing the risk of sharp devaluation in case of default. Since defaults are rare in the data, default premium manifests itself in higher currency returns. To formalize the link between default risk and currency returns, I discipline quantitatively a model "with default" based on Arellano (2008) for a set of developing countries. I then use the implications of this model to construct an econometric model for cross-section of currency returns that I estimate using extended Fama and MacBeth (1973) method. I find strong evidence supporting the "peso problem" explanation: credit default swaps' spreads serving as proxy for the risk of default explain around 25% of the cross-country variation of average currency returns.

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Why don't forward exchange rates serve as unbiased predictions of future spot exchange rates? The prediction errors, referred to as *foreign currency returns*, vary over time, and average returns differ across countries.[1] They tend to be larger for developing countries and smaller or even negative for developed economies. This appears to be a puzzle in international finance literature, since if textbook uncovered and covered interest rate parities (UIP and CIP) hold, the returns should on average be equal to zero.[2]

This paper argues that a significant share of cross-country variation in currency returns can be attributed to the variation in sovereign default risk. There are almost no sovereign defaults observed in the available data, while the sovereign bonds' and credit default swaps' (CDS) spreads[3] indicate that markets price positive probabilities of these events. Thus the *default premium* that market players collect for bearing the risk of sharp depreciation in default manifests itself in higher expected returns.

The higher is the risk of default, conditional on observing no defaults in the data, the larger is this premium, thus the higher are currency returns *ceteris paribus*. As a result, the developing countries that are at higher risk of default tend to have higher returns, than the developed economies (Figure 1). This explanation originates in the so-called *peso problem* literature, that I describe in more details in Section 3. It complements the existing literature that links currency returns to exposure to global factors and US consumption growth, which together allows to address the existence of negative and positive currency returns.

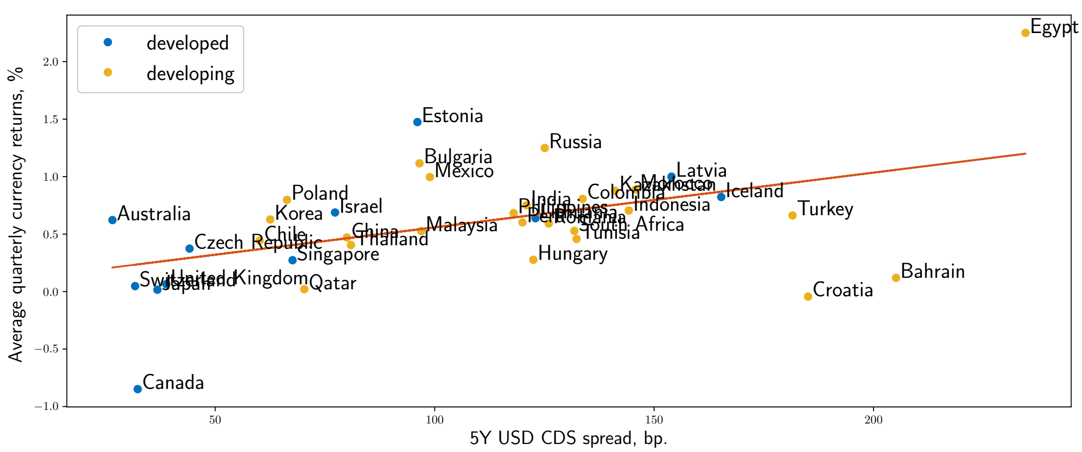

Figure 1: Currency returns and 5Y USD CDS spreads. Average returns and CDS spreads were calculated for the whole non-balanced panel starting in 2004, for the periods when both measures were available.

[1]See Fama (1984), Krasker (1980), Gilmore and Hayashi (2011), Hassan (2013), among others.

[2]See Appendix A for derivations

[3]Credit Default Swaps (CDS) are derivatives that serve as insurance against the credit risk. According to the definition provided in Chapter 25 of Hull (2014) textbook for corporate bonds, "The buyer of insurance obtains the right to sell bonds issued by the company for their face value when a credit event occurs and the seller of the insurance agrees to buy the bonds for their face value when a credit event occurs." (p. 572). The CDS are usually quoted as "spreads" – the payment as a share of the face value of the bond that the buyer of the derivative provides on a regular basis, measured in basis points.

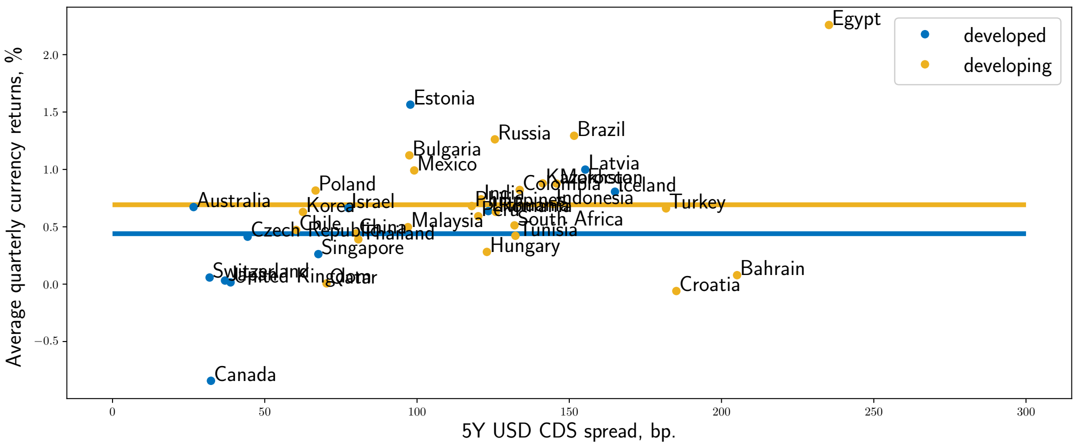

Figure 2: Currency returns and 5Y USD CDS spreads. Average returns and CDS spreads were calculated for the whole non-balanced panel starting in 2004, for the periods when both measures were available.

I first demonstrate that the expected currency returns *conditional on normal standing* of the country include a term corresponding to the *default risk*. It consists of the product of the probability of sovereign default, the spread between forward and spot rates, and of the unobserved term: difference in expected exchange rate dynamics in case of default comparing to normal standing (*relative depreciation*).

On the next step, I extend the small open economy (SOE) model "with default" à la Arellano (2008) to investigate the dynamics and cross-country differences in average *relative depreciation*. Introducing a money market and borrowing in domestic and foreign currency allows to explore the dynamics of nominal exchange rate and calculate currency returns in the model. This parsimonious model is calibrated separately for a number of developing countries to match average currency returns and standard calibration benchmarks in the "sovereign default" literature. This allows to examine the *relative depreciation* both in the time (business cycle) dimension, and across countries. The simulations of the model suggest that fluctuations of the *relative depreciation* are rather small over the business cycle, and also that the average depreciation is quite similar for some countries: about 50%, which is consistent with the existing evidence.[4] Moreover, the model allows to fit foreign currency returns without excessively sacrificing the fit of the rest of the moments.

Obtaining these results allows me to assume that the *relative depreciation* is constant over time and across countries. Using this assumption I derive a simple representation of expected currency returns in the form of an econometric model, that incorporates both the *default premium* and the pricing factors traditionally considered in the literature. I then apply the Fama and MacBeth (1973) approach to estimate the model and to test for the presence of the *default premium* in the cross-section of currencies.

For calibration of the SOE model and subsequent empirical work I use USD-national currency pairs,

[4] Na et al. (2018), Mano (2013)

measure exchange rates in units of local currency per USD (e.g., peso per dollar), and consider currency returns from a US investor's standpoint. This is motivated mostly by the dominant share of dollar in foreign exchange turnover[5], and by the availability of data on USD-denominated CDS. I find strong evidence supporting the presence of the *default premium*, and the results suggest that the default risk alone accounts for about 25% of the cross-country variation in foreign currency returns. Moreover, the estimate suggests that the market participants price in a 50 % depreciation of national currency in case of default, which is consistent with the results of the SOE model and is not an uncommon value for the defaults that happened in the past.[6] Thus, my results suggest that the "peso problem" is responsible for a significant share of variation in currency returns, and empirical approaches further exploring the determinants of the returns should take this into account. More broadly it implies that the sovereign default risk is an important factor for determining the exchange rates that are used in international trade and financial operations.

The approach applied in this paper switches the focus from the relation of returns to the stochastic discount factor which has been in the spotlight of the international finance literature, to country-specific risks related to sovereign default. The contribution of this paper is in developing a model and formulating the corresponding econometric procedure to find supporting evidence for the presence of sovereign default risk in foreign currency returns. While there's a vast literature exploring the relation of returns in exchange rate trading strategies with credit risk (Coudert and Mignon, 2013, Foroni et al., 2018, Della Corte et al., 2020), this paper is the first, to the best of my knowledge, to derive explicitly and estimate a structural model within the *peso problem* framework in this context and apply it in cross-sectional dimension to individual currency pairs. Moreover, the econometric procedure leverages the insights from quantitatively disciplined SOE model "with default", which has not be employed in the studies of currency or carry trade returns yet. Thus, this paper combines the *peso problem* approach to treating the data with the depreciation upon default mechanism and exposure of currency returns to international pricing factors in order to capture wider aspects of currency returns' determinants.

Below I review the relevant literature. In Section 3 I derive a no-arbitrage condition that describes relation between sovereign default risk and currency returns, based on modified UIP and CIP conditions. After that, I construct a model of small open economy "with default" à la Arellano (2008) and calibrate it for several developing countries in Section 4. The simulation results of the model allow to impose additional assumptions on the relation derived in Section 3 and test for the presence of the "default premium" in currency returns in the econometric setup. In Section 5 I estimate the econometric model to find support for the theory in the panel data for developing and developed countries. Section 6 concludes.

Related literature

The paper relates to several strands in the literature. The idea of presence of rare event premium in asset prices (such as default premium in this paper) originates from the *rare disasters* and *peso problem* literature.

[5]BIS Triennial Central Bank Survey

[6]Historical depreciations upon default are presented in Mano (2013).

The *rare disasters* concept is discussed in the seminal paper Rietz (1988) that aims to explain the equity risk premium with the presence of priced risk of rare and large economic downturns. Later work expands this idea and examines the historical probabilities of rare disasters both in the US and international contexts (Barro, 2006, 2009, Nakamura et al., 2013). Parra-Alvarez et al. (2021) uses the peso problem approach to estimate the consumption-based capital asset pricing model (CAPM). One approach to working with models with rare disaster is to add additional constant terms into estimation moments as in Parker and Julliard (2005). The alternative approach, that I am using in this paper, is model-based correction of moments that are being estimated. This approach allows to address the fundamental mechanisms that produce negative returns, rather than simply substitute them with additional parameters, as the aforementioned approach does. In application to exchange rates the *rare disasters* or, as they are usually referred to in this context, *crashes* were explored in Farhi and Gabaix (2015), Farhi and Gabaix (2016), and later in Chernov et al. (2018).

The term *peso problem* was coined from observing the currency premium on the Mexican peso market and goes back to Milton Friedman (Sill, 2000). The *peso problem* literature argues that not only the *rare disasters* exist, but they are also undersampled in the data available to researchers (Engel, 2014). Thus, the econometrician observes mostly (or only, as assumed in Farhi et al. (2009)) the premium that market players receive for bearing the crash risk, but not lthe osses that they incur as a result of these crashes. Both the *rare disasters* and the *peso problem* literature focus mostly on fluctuations in the stochastic discount factor (Burnside et al. (2011), Farhi et al. (2009) among others). Burnside et al. (2010) explicitly test whether the *peso problem* is associated with the risk of sharp fluctuation in the exchange rate, or in the associated stochastic discount factor, and finds support for the latter. There is still no clear consensus on the role of this mechanism: Jurek (2014) suggests that only a small portion of carry trade returns can be attributed to *peso problem*. While these papers study general risk embedded in exchange rates or SDF dynamics, there's also vast literature devoted specifically to the dynamics of exchange rate in case of sovereign default. The relation of sovereign default and the exchange rate fluctuations in this period are characterized in the literature as “Twin D” – default and devaluation. This relation is discussed in detail in Na et al. (2018) paper, and more recently additional evidence has been explored in Augustin et al. (2020). Mano (2013) provides number of historical examples of depreciation upon default, and while the range of exchange rate fluctuations in quite large, in the majority of cases the default was accompanied by depreciation. Earlier Popov and Wiczer (2014) illustrated the connection between depreciation and default within a tractable real model in Arellano (2008) style. While there seems to be a clear consensus in the literature regarding the depreciation of exchange rates in the period of default, the nature of relation of currency returns and the degree of risk of sovereign default remains the subject of active research.

The relation of CDS spreads and currency returns has been explored in the literature in several dimensions. Several papers leverage the presence of credit derivatives denominated both in local currencies and the USD, to infer local currency depreciation or to construct or to explore trading strategies based on this: Mano (2013), Della Corte et al. (2020), Augustin et al. (2020). The joint dynamics of credit and currency risk and the role of local factors influencing both has been studied in Chernov et al. (2020). Calice and

Zeng (2021) explores the term structure of CDS to analyze cross-sectional predictability of currency returns.

The size of currency returns has also been linked to exposure of foreign currency returns to the domestic (US) consumption growth in CAPM (or factor model) style (Lustig and Verdelhan, 2007)[7], and to exposure to global factors (Lustig et al., 2011). Assumption of risk-aversion of foreign investor also allows to consider the risk premium generated by *rare disasters* (Farhi and Gabaix, 2015), and to link returns to country size (Hassan (2013)).

This paper incorporates insights from all these strains of the literature, taking rather *ad hoc* approach to CDS spreads, applying *peso problem* approach to interpreting the data, and focusing on extracting information about depreciation in case of default directly from currency returns.

2 Three period model.

3 Peso problem and foreign currency returns

The papers exploring the crash risk in currency returns tend to consider the *carry trade returns*, i.e. the returns that investors gain by borrowing in one currency, and lending in another one (Brunnermeier et al., 2009). In this paper I refer to the definition of currency returns directly related to the classical formulation of the *peso problem*, and the original "Fama regression" approach (Fama, 1984). Thus, in this paper the foreign currency returns are defined in the following way:

Definition 1 *Time $t+1$ gross foreign currency returns for currency i with respect to USD are:*

$$\frac{F_{i,t}}{S_{i,t+1}} \tag{3.1}$$

where $F_{i,t}$ is the forward exchange rate (e.g., pesos per USD) as defined in a forward contract signed at t with execution in $t+1$, and $S_{i,t+1}$ is the spot rate in $t+1$, and i denotes a country (currency).

To simplify notation, in most of the cases I would write $+1$, although the time period can be divisible (e.g., below we would consider daily data for quarterly forwards). Also, I do not focus on reference currencies other than USD, and i index may be omitted, but always implied.

The explanation of the relation of foreign currency returns and the sovereign default risk suggested in this paper is based on the classical *peso problem* literature. Originating in Milton Friedman's and Kenneth Rogoff's work (Sill, 2000), this term describes the effect that small probability events have on asset prices or other financial variables in small samples. Following the explanation provided in Engel (2014), denote the true probability of event, e.g. currency crash, as p, and let d indicate the event. Then, the expected value of currency returns is:

$$\varepsilon_{cr} = (1-p)\mathbb{E}\left(\frac{F_t}{S_{t+1}}\Big| d=0\right) + p\mathbb{E}\left(\frac{F_t}{S_{t+1}}\Big| d=1\right) \tag{3.2}$$

[7]This approach is challenged in (Burnside, 2011) and the subsequent line of discussion with the authors.

However, due to small sample of observations and the rare occurrence of the events, econometrician would observe them at frequency $p' < p$. Then, in fact the observed average return better reflects the following object:

$$\phi_{cr} = (1-p')\mathbb{E}\left(\frac{F_t}{S_{t+1}}\Big| d=0\right) + p'\mathbb{E}\left(\frac{F_t}{S_{t+1}}\Big| d=1\right) \tag{3.3}$$

Since it's reasonable to expect that the currency is weaker in the situation of default,$\varepsilon_{cr} < \phi_{cr}$

Below I will argue that in the context of sovereign default, when the *events* are truly rare and mostly excluded from the available data, the right way to treat the data is to consider moments *conditional* on good standing (no default). While CDS spreads and the spreads of sovereign bonds over the US benchmarks imply that the market participants price a non-zero risk of default,

This means bringing the logic of (3.3), (3.2) to extreme and, while considering p as the market's estimate of probability of default that can be inferred from CDS spreads or the bonds' spreads, set $p' = 0$.

This logic can explain the phenomenon that forward rate F_t is a biased predictor of the future spot exchange rate (Kaminsky (1993), Krasker (1980), and Evans (1996) for an overview). Below I focus on discussing further the *peso problem* explanation of currency returns in the context of their relation to sovereign default risk.

3.1 Peso problem and small sample issue

I present a numerical example that clarifies the small sample issue. Assume that there's a random variable x_t, the distribution of which depends on the realization of another variable d_t. x_t can be thought of as an asset return, and d_t – as an indicator of an event, such as the sovereign default. More specifically, assume $x_t\big|d_t = 0 \sim N\left((1-d_t)\mu_1 + d_t\mu_2, \sigma^2\right)$, and $d_t \sim Bernouilli(p)$. I simulate $N = 100$ series of length $T = 120$, assuming $p = .01$, $\mu_1 = 1$, $\mu_2 = 2$, and $\sigma^2 = .01$.

I pick one of the series $i'$with 0 realizations $d_t = 1$, and plot two t expanding window averages. One is for this series i', and the other is for all series $i = 1, \ldots, N$. The averages are calculated as:

$$\bar{x}_t = \frac{1}{t}\sum_{\tau=1}^{t} x_\tau; \quad \bar{x}_t^N = \frac{1}{tN}\sum_{\tau=1}^{t}\sum_{i=1}^{N} x_{\tau i} \tag{3.4}$$

We can see on Figure 3 that $\bar{x}_T^N$ is close to the expected value of x_t, while $\bar{x}_T$ undershoots the theoretical value and is closer to μ_1.

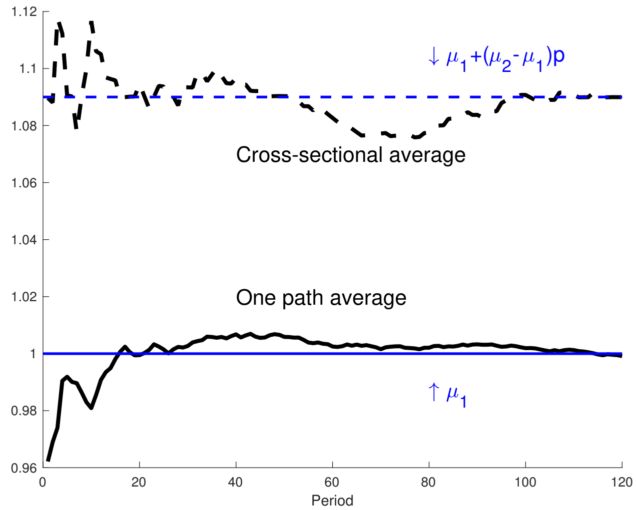

Figure 3: Average based on multiple series, and on one series.

While in this example I've cherry-picked a particular path $\{x_t, d_t\}$, the probability of observing a path of 120 "no event" periods $(d_t = 0,\, t = 1, ..., 120)$ is around .3. This warns *econometrician* regarding the mechanical application of the *analogy principle*. While both $\bar{x}_T$ and $\bar{x}_T^N$ were *a priori* consistent estimates of the mean of the process, in small samples, such as the 120 observations path above, it can be more reasonable to use $\bar{x}_T$ as the sample analogue of $\mathbb{E}\left(x_t \middle| d_t = 0\right)$.

Similar logic can be applied to different moments, including expectations conditional on some time-dependent information sets, used in standard macroeconomic and asset pricing models. At the same time μ_1 from this example doesn't have to be a fixed number, it rather can be a function of a vector of random variables $\mu_{1t}(\mathbf{Z}_t)$. In this case *econometrician* working with the data is likely to observe the correlation of x_t and $\mathbf{Z}_t$.

3.2 Foreign currency returns

To derive the relation of foreign currency returns with sovereign default risk, I start from a no-arbitrage condition between two one-period risk-free bonds: domestic and foreign. On the one hand it allows me to present in a clear way the main mechanism of the "peso problem" theory which in the application to the currency returns is about the exchange rate depreciation upon default, and not about the loss of part of the value of the bonds experienced by bond holders *per se*. On the other hand it demonstrates that the "peso problem" explanation does not require strict assumption about the bonds – neither about the recovery rate (share of value the investors get back upon default), nor about the maturity structure.

For the purpose of exposition I assume that there are no additional liquidity constraints for the investors, there are no other market frictions, while the investors are rational and have full information about the economic system. Investor with the stochastic discount factor of period $t+1$ cash flow $m_{t,t+1}$ should be indifferent between investing in foreign and domestic bonds (otherwise there is an arbitrage opportunity that allows to extract infinite profits). In case of foreign bonds denominated in foreign currency (peso), the US investors have to exchange their money first when buying bonds (period t), and then exchange currency back upon receiving the interest and the principle ($t+1$). The exchange in period $t+1$ can be performed either through the spot market, or through the forward market. It is assumed that in period t there exist two-party binding contracts that constitute the exchange of a particular amount of money (in this case – gross interest on debt in peso) in period $t+1$, that are called forward contracts, and the rate at which the exchange happens is denoted F_t (peso per dollar). The exchange rate on the spot market in period t is S_t, following the notation above. The price growth in domestic economy from t to $t+1$ is denoted as π_{t+1}.[8]

The two non-arbitrage conditions can be formulated for the case when in period $t+1$ investors exchange currency at the spot rate, and they sign a forward in t with delivery $t+1$.

$$(1+i_t)\mathbb{E}_t\left(m_{t,t+1}\frac{1}{\pi_{t+1}}\right) = (1+i_t^*)\mathbb{E}_t\left(m_{t,t+1}\frac{S_t}{S_{t+1}}\frac{1}{\pi_{t+1}}\right) \tag{3.5}$$

$$(1+i_t)\mathbb{E}_t\left(m_{t,t+1}\frac{1}{\pi_{t+1}}\right) = (1+i_t^*)\frac{S_t}{F_t}\mathbb{E}_t\left(m_{t,t+1}\frac{1}{\pi_{t+1}}\right) \tag{3.6}$$

These two conditions can be thought of as generalized textbook uncovered and covered interest rate parities. Next, investors are assumed to be residents of a low-inflation country, where in shot-run the inflation rate is close to zero, and hence it's reasonable to neglect $\pi_{t+1} = 1$ for simplicity.

Assume that there's an event that affects the exchange rates and the investor's consumption, that takes place in $t+1$ with an exogenous[9] probability p. Then, combining the two conditions and decomposing the expectation into *E* (event) and *NE* (no event) cases, I get:

$$p\mathbb{E}_t\left(m_{t,t+1}\frac{1}{S_{t+1}}\Big|E_{t+1}\right) + (1-p)\mathbb{E}_t\left(m_{t,t+1}\frac{1}{S_{t+1}}\Big|NE_{t+1}\right) = \frac{1}{F_{t+1}}\mathbb{E}_t\left(m_{t,t+1}\right) \tag{3.7}$$

$$\mathbb{E}_t\left(m_{t,t+1}\frac{F_t}{S_{t+1}}\Big|NE_{t+1}\right) = 1 + p\frac{F_t}{S_t}\left[\mathbb{E}_t\left(m_{t,t+1}\frac{S_t}{S_{t+1}}\Big|NE_{t+1}\right) - \mathbb{E}_t\left(m_{t,t+1}\frac{S_t}{S_{t+1}}\Big|E_{t+1}\right)\right] \tag{3.8}$$

If in addition to that, I assume risk-neutrality of the investor, I can get an intuitive representation of gross currency returns:

$$\mathbb{E}_t\left(\frac{F_t}{S_{t+1}}\Big|NE_{t+1}\right) = 1 + p\frac{F_t}{S_t}\left[\mathbb{E}_t\left(\frac{S_t}{S_{t+1}}\Big|NE_{t+1}\right) - \left(\frac{S_t}{S_{t+1}}\Big|E_{t+1}\right)\right] \tag{3.9}$$

This expression illustrates that in the absence of event the investor "collects" the *event premium*, which can be positive or negative, depending on how the dynamics or the exchange rate in case of event differs from the dynamics in case of no event. For developing economies relevant events may affect the exported commodities' prices – for instance, outcomes of OPEC meetings, weather conditions having impact on harvest, some broader outcomes of political processes.

[8] For simplicity assume that there's a single good, that the utility of investor depends upon, and that π_{t+1} corresponds to the price of this good.

[9] Conditional in information available in period t.

Following the evidence suggested on Figure 1, I explore the peso problem approach applied to the situation when E is the sovereign default of the respective country. Even though the sovereign defaults are quite heterogeneous events[10], they are discrete considering the context of currency returns (country is either in default or not, according to existing definitions). Also the probability of defaults, i.e. time-varying p in the setup above, is taken into account by the market participants when pricing sovereign bonds and credit default swaps (CDS). The latter is, in simple words, insurance for the case of sovereign default. Finally, bonds' spreads and CDS spreads both imply non-zero probabilities of sovereign default, and for most of countries defaults don't happen in the available sample at all. Thus, these events are undersampled which is the setup for the application of the "peso problem" theory.

Above, it was assumed that there's an available risk-free bond. This could be a plausible assumption for short-term horizons, but it seems to be unreasonable to consider as risk-free sovereign debt of developing economies at horizons of one quarter and above. I provide similar derivations for the case, in which only a risk-bearing sovereign bond is available. Assume again that a U.S. investor chooses between investing in the domestic and foreign bonds. The foreign bonds are denominated in foreign currency (e.g., peso). The foreign country should be thought about as a risky small open economy, that can default on the sovereign debt, i.e. those bonds. The investor can use the spot and the forward currency markets for converting USD into local currency and back. This setup leads to the formulation of two no-arbitrage conditions, which are the analogues of the CIP and the UIP for risk-free bonds. Then, I illustrate that, if the investor uses the forward currency market buying risk-bearing foreign bonds, it doesn't eliminate the exchange rate risk – since in case of default on the debt the bank is still obliged to deliver the currency according to the forward contract. Exploiting the two no-arbitrage conditions, I derive an expression for expected currency returns in a good standing, which explicitly links it to sovereign default risk and the difference in currency's dynamics between the default and the good standing cases. Below, I formalize this line of reasoning in Proposition 1.

Proposition 1 *Consider a small open economy (SOE) with floating exchange rates that imposes no capital controls. Let*

1. *Expectations be well-defined (exist) and probability of default of the country be exogenous;*
2. *SOE borrow in home currency-denominated one-period asset with predetermined return;*
3. *Markets be complete;*
4. *Inflation in the foreign country be negligible.*

Then, the expected foreign currency returns are:

[10] Gordon and Guerron-Quintana (2019)

$$\mathbb{E}_t\left(\frac{F_t}{S_{t+1}}-1\Big|d_{t+1}=0\right)=p\frac{F_t}{S_t}\frac{\left[\mathbb{E}_t\left(m_{t,t+1}\frac{S_t}{S_{t+1}}\Big|d_{t+1}=0\right)-\mathbb{E}_t\left(m_{t,t+1}\frac{S_t}{S_{t+1}}\Big|d_{t+1}=1\right)\right]}{\mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=0\right)}- \tag{3.10}$$
$$-\frac{Cov_t\left(m_{t,t+1},\frac{F_t}{S_{t+1}}|d_{t+1}=0\right)}{\mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=0\right)}+p\frac{\left[\mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=1\right)-\mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=0\right)\right]}{\mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=0\right)},$$

where d_{t+1} is a random variable that denotes whether economy is in the default state in period $t+1$: $d_{t+1}=1$ in case of sovereign default in period $t+1$, and $d_{t+1}=0$ otherwise, S_t is spot exchange rate, F_t is a t to $t+1$ forward contract, and p is the probability of default in period $t+1$ conditional on time t information set.

Proof.

For generality, at first assume that the markets are complete, and thus there exists a unique pricing kernel for the foreign investor. The no-arbitrage condition between investing in foreign risk-free bonds and in domestic risk-bearing bonds for the foreign investor is:

$$(1-p)(1+i_t^*)\mathbb{E}_t\left(m_{t,t+1}\frac{S_t}{S_{t+1}}\Big|d_{t+1}=0\right)+p\mu(1+i_t^*)\mathbb{E}_t\left(m_{t,t+1}\frac{S_t}{S_{t+1}}\Big|d_{t+1}=1\right)=(1+i_t)\mathbb{E}_t\left[m_{t,t+1}\right], \tag{3.11}$$

which I am going to refer to as the *modified UIP* condition or UIP*. it is less trivial to find the *modified CIP* condition. The essential element of this equation is that the currency forward is a bilateral commitment of the two parties to provide a transaction. Thus, even in case of default the foreign investor is still obliged to provide domestic currency for the $t+1$ period transaction. Following this logic, the CIP* can be written as:

No default: $$(1-p)(1+i_t^*)\frac{S_t}{F_t}\mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=0\right)+ \tag{3.12}$$

Default: recovered μ portion: $$p\mu(1+i_t^*)\frac{S_t}{F_t}\mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=1\right)+ \tag{3.13}$$

Default: still has to deliver: $$p\Big[-(1-\mu)(1+i_t^*)\mathbb{E}_t\left(m_{t,t+1}\frac{S_t}{S_{t+1}}\Big|d_{t+1}=1\right)+ \tag{3.14}$$

Default: gets from contract: $$(1-\mu)(1+i_t^*)\frac{S_t}{F_t}\mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=1\right)\Big]= \tag{3.15}$$

$$=(1+i_t)\mathbb{E}_t\left[m_{t,t+1}\right]$$

Combining the two conditions, we can obtain 3.10.

■

Corollary 1 *Assume also that the international investor is risk-neutral, the currency returns can be expressed as a function of the probability of default, the forward to spot rate spread, and the expected difference in exchange rate* *dynamics between the default and the good standing states (relative depreciation).*

$$\mathbb{E}_t\left(\frac{F_t}{S_{t+1}}\Big|d_{t+1}=0\right) = 1 + p\frac{F_t}{S_t}\left[\mathbb{E}_t\left(\frac{S_t}{S_{t+1}}\Big|d_{t+1}=0\right) - \mathbb{E}_t\left(\frac{S_t}{S_{t+1}}\Big|d_{t+1}=1\right)\right] \tag{3.16}$$

Corollary 2 *Assume :*

1. *the risk-neutral relative depreciation upon default is constant over time*

$$\frac{\mathbb{E}_t\left(m_{t,t+1}\frac{S_t}{S_{t+1}}\Big|d_{t+1}=0\right) - \mathbb{E}_t\left(m_{t,t+1}\frac{S_t}{S_{t+1}}\Big|d_{t+1}=1\right)}{\mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=0\right)} = \alpha_1 \tag{3.17}$$

2. *expected stochastic discount factor's difference in case of default and in case of normal standing is constant:*

$$\frac{\mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=1\right) - \mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=0\right)}{\mathbb{E}_t\left(m_{t,t+1}\Big|d_{t+1}=0\right)} = \alpha_3 \tag{3.18}$$

Then, the unconditional on time expected currency returns can be expressed as:

$$\mathbb{E}\left[\frac{F_t}{S_{t+1}} - 1\Big|d_{t+1}=0\right] = \alpha_1\mathbb{E}\left[p_t\frac{F_t}{S_t}\Big|d_{t+1}=0\right] - \frac{cov\left(m_{t,t+1}, \frac{F_t}{S_{t+1}}\Big|d_{t+1}=0\right)}{\mathbb{E}\left(m_{t,t+1}\Big|d_{t+1}=0\right)} + \alpha_3\mathbb{E}\left[p_t\Big|d_{t+1}=0\right] \tag{3.19}$$

Corollary 2 sheds light on the set of assumptions that can be imposed in order for the *peso problem* - base theory to address the cross-country differences in currency returns. Further in Sections 4 and 5 use a calibrated SOE model and SDF in order to establish whether these assumptions are consistent with the data.

4 Model "with default"

The goal of this section is to introduce a small open economy model "with default" that allows to assess the quantitative relevance of the *peso problem* - based explanation provided in Section 3 – and obtain additional restrictions that would allow to formulate an econometric model to test the theory. It is important to demonstrate that this model can be disciplined quantitatively to match important moments usually considered in the international finance literature (see overview in Aguiar et al. (2016)), and currency returns at the same time. The performance of the model needs to be explored for a set of countries in order to ensure that the results are stable.

I am interested in matching the data for developing countries because, as stated above, the *peso problem* explanation is likely more prevalent for emerging markets, while for developed countries with near-zero and negative currency returns, where the default probabilities are negligible, the main focus should be on the pricing factors, in the manner they are explored in Lustig et al. (2011).[11]

[11] The defaults in developed countries that can be considered as SOEs – such as Australia, Canada or the UK – should be related to some global disasters, which produces too much uncertainty for the modeling purposes.

The model describes a small open endowment economy à la Arellano (2008), and allows for borrowing in two currencies – local one, which I am refer to as *peso*, and the foreign currency – *dollar*. I formulate the model in terms of a hand-to-mouth consumer and a benevolent government, as it was done in Ottonello and Perez (2019).

There is a hand-to-mouth consumer, who receives transfers from the government T_t (expressed in pesos in the budget constraint). The consumer owns the stochastic endowment of traded good y_t and consumes c_t. Then, the budget constraint can be expressed as:

$$c_t P_t = y_t P_t + T_t, \tag{4.1}$$

where P_t denotes the price in pesos, c_t is in units of the traded good. The endowment follows a log AR(1) process:

$$\log(y_t) = \rho \log(y_{t-1}) + \sigma \epsilon_t; \quad |\rho| < 1 \tag{4.2}$$

The benevolent government conducts operations on the fixed income market and transfers the resulting outcomes T_t to the consumers in order to maximize their expected utility function:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t) \tag{4.3}$$

The government borrows and lends externally either in dollars B^* or pesos B, at prices of the debt q^* and q, respectively. The notation for the exchange rate is the same as previously, S_t (pesos per dollar). Then, in nominal terms the budget constraint can be expressed as:

$$\underbrace{q_t B_{t+1}}_{\text{borrowing dom curr}} + \underbrace{q_t^* B_{t+1}^* S_t}_{\text{borrowing for curr}} = \tag{4.4}$$
$$= \underbrace{B_t}_{\text{repayment dom}} + \underbrace{B_t^* S_t}_{\text{repayment for}} + T_t + \underbrace{\phi(\cdot) P_t}_{\text{adjustment cost}}$$

where $\phi(\cdot)$ is the adjustment cost paid in units of traded good, which allows to better discipline the model in terms of the trade-off between borrowing in domestic and foreign currencies. In the quantitative exercise I assume that the function is a quadratic function of foreign and domestic currency borrowing expressed in real terms.

The government starts the period with some levels of debt (B_t and B_t^*). Then, the government chooses whether to default ($d_t = 1$) or not ($d_t = 0$). The government is limited in its borrowing by a no-Ponzi game condition.

If the government defaults, I assume that the recovery rate for both domestic currency and foreign currency borrowing is 0, and the economy enters the state of financial autarky. This is an intentional simplification – to improve quantitative properties of the model it's possible to assume μ to be at the average level of haircuts conducted previously in defaults. In autarky the economy suffers a loss of output $L(y_t)$, which in the numerical solution is specified as in Arellano (2008).

I assume that the purchasing power parity holds, which implies that the real exchange rate between the country and the outside world is equal to 1. I also normalize the foreign price level and assume an absence of inflation: $P^* \equiv 1$. In this case $S_t = P_t$ – the nominal exchange rate is equal to the price of the traded good in pesos.

Define the real values of debt as:

$$b_t = \frac{B_t}{P_{t-1}} \qquad b_t^* = B_t^* \quad (P_t^* \equiv 1) \qquad S_t = P_t \tag{4.5}$$

Then, the government constraint in real terms is:

$$q_t b_{t+1} + q_t^* b_{t+1}^* = \tau_t + \frac{b_t P_{t-1}}{P_t} + b_t^* + \phi(\cdot), \tag{4.6}$$

where $\tau_t = \frac{T_t}{P_t}$, and the adjustment costs are defined in real terms as:

$$\phi(b, b^*) = \phi_0 \left(b - \phi_1 b^*\right)^2 \tag{4.7}$$

The foreign investor is assumed to be a risk-neutral agent that has access to risk-free bonds (assume US government liabilities are risk-free), with net interest rate r. This is another simplification made to stress the focus of this paper on default risk, even in the absence of risk averse investor. As shown in Lizarazo (2013) and in Arellano (2008), adding risk averse investor can quantitatively improve the behavior of the model.

I can obtain the following simple formulas for the price of the debt:

$$q_t^* = \frac{1 - p_t(d_{t+1} = 1)}{1 + r} \tag{4.8}$$

$$q_t = \frac{1 - p_t(d_{t+1} = 1)}{1 + r} \mathbb{E}_t \left(\frac{S_t}{S_{t+1}} \Big| d_{t+1} = 0 \right) \tag{4.9}$$

Also, using the derivations from above, I can write the pricing formula[12] for the forward rate:

$$F_t = \frac{S_t}{(1 + r) q_t^* + p_t(d_{t+1} = 1) \mathbb{E}_t \left[\frac{S_t}{S_{t+1}} \Big| d_{t+1} = 1 \right]} \tag{4.10}$$

Note that this model uses modified CIP and UIP conditions under risk neutrality, which makes it consistent with all previous derivations from Section 3.

I would also assume that country can save in the foreign currency abroad, but cannot save in the local currency.[13]

Then, to pin down the price level and exchange rate, I introduce a simple model of the money market. The demand for real money balances is assumed to be proportional to the endowment:

$$\frac{\mu_M^{d_t} M_t}{P_t} = y_t \tag{4.11}$$

[12] Forward has to be priced inside the model via the modified CIP condition. This variable and CIP are not necessary to "close" the model.

[13] For instance, Russia saves the commodity-generated budget surpluses in foreign currency within a stand-alone sovereign wealth fund.

and I assume money supply to be fixed (for simplicity $M_t^s = 1$, and it can be adjusted in order to obtain the exchange rate levels observed in the data (S_t). The implications and the realism of this assumption is discussed in the Discussion section 4.6 below.

In addition to that, I introduce multiplier $\mu_M > 1$ that plays a role in the period of default. This is an *ad hoc* way to allow for a more flexible devaluation in period of default (modeled in a structural way in Na et al. (2018)). From the economic standpoint it can reflect either an increase in *velocity*, or a round or expansionary monetary policy, or both. The realism of these assumptions in discussed below (4.6). This simple model of the money market, together with the assumption of one traded good (as opposed to traded and non-traded goods usually used in the literature), serve two, mainly technical, purposes. First, they allow me to obtain the solution of consumption as an explicit function of the states, which simplifies the numerical solution. Second, the amount of state variables increases only by 2 – comparing to the benchmark Arellano (2008) I need to keep track only of the $t-1$ output, and borrowing in both currencies. Another specification of nominal economy "with default" is used Engel and Park (2018), where the authors introduce the cost of inflation in utility function.

Then, the recursive formulation of the problem is as follows:

$$J_n(b, b^*, y_{-1}, y) = \max_{d,b',b'^*} d\left[U(c_d^*(y) + \beta \mathbb{E} J_d(y')\right] +$$

$$+(1-d)\left[U(c_n^*(b, b^*, y_{-1}, y, b', b'^*)) + \beta \mathbb{E} J_n(b', b'^*, y, y')\right] \tag{4.12}$$

$$\text{s.t.} \qquad c_n^* = -b\frac{y}{y_{-1}} - b^* + y + qb' + q^*b'^* - \phi(b', b'^*) \tag{4.13}$$

$$q^* = \frac{1 - p(d' = 1)}{1 + r} \tag{4.14}$$

$$q = \frac{1 - p(d' = 1)}{1 + r}\mathbb{E}\left(\frac{S}{S'}\Big| d' = 0\right) \tag{4.15}$$

$$J_d(y) = U(c_d^*) + (1-\theta)\beta\mathbb{E}[J_d(y')] + \theta\beta\mathbb{E}J_n(0, 0, y - L(y), y') \tag{4.16}$$

$$c_d^* = y - L(y); \tag{4.17}$$

$$\frac{\mu_M^d M}{S} = y - dL(y); \tag{4.18}$$

$$\log(y') = \rho\log(y) + \sigma\epsilon' \tag{4.19}$$

where x denotes variables at current period of time and x' – their next period values.

Definition 2 *The model's recursive equilibrium is a collection of* (i) *decision rules* $b'(b, b^*, y_{-1}, y)$,$b'^*(b, b^*, y_{-1}, y)$, $c(b, b^*, y_{-1}, y, b', b'^*)$, $d(b, b^*, y_{-1}, y)$, $T(b, b^*, y_{-1}, y)$; (ii) *corresponding value functions* J_n, J_d, (iii) *probabilities of default* $P(b', b'^*, y)$, (iv) *prices of debt* $q(b', b'^*, y)$, (v) *exchange rates* $S(y, d)$, *and* (vi) *default set* $\mathcal{D} = \{(b, b^*, y_{-1}, y) | d(b, b^*, y_{-1}, y) = 1\}$ *such that:*

1. *c solves consumer's intratemporal maximization problem given y, T*

2. *$b'(b, b^*, y_{-1}, y)$, $b'^*(b, b^*, y_{-1}, y)$ satisfy the Bellman equations (4.13) - (4.14) both for normal and default states given (q, q^*, d)*

3. *T satisfies the government's budget constraint*

4. *$d(b, b^*, y_{-1}, y)$ solves (4.13) - (4.19)*

5. *$q(b', b'^*, y)$, $q^*(b', b'^*, y)$ satisfy the no-arbitrage condition for given P, S*

6. *$p(b', b'^*, y)$ is consistent with the default set $\mathcal{D}$*

Below I describe the data used for calibration of the SOE model and for the estimation of the econometric model.

4.1 Data

In this paper I work with daily Mid 5Y USD CDS data from Thomson Reuters Datastream assuming that I can consider those as *quanto* CDS, i.e. the CDS that don't expose the buyer to the exchange rate risk. The 5Y CDS market is considered as the most liquid (Pan and Singleton (2008))[14]. CDS spreads data in Datastream come from two sources: CMA Datavision CDS series and Thomson Reuters CDS series. The CMA data for most of the countries in the sample are reported from 2004 to 2010. These series are presented in one currency denomination only – for some countries, for instance, it could be Euro, and in this case I am not using it. The original Datastream data source presents a more comprehensive set of CDS, and for most of the countries it is possible to extract the USD CDS spreads. The Datastream data cover in most cases the time period from 2008 till 2019. I am merging the two sets of series in the periods of time when the series are numerically close for a long period of time. For forwards, following Hassan (2013), I am using 3 month deliverable rates, end of day daily data from Thomson Reuters Datastream.[15]

As a measure for the share of external debt denominated in local currency I am using the data provided by Arslanalp and Tsuda (2014). I divide the following two parts of debt owned by foreign entities to get the ratio: central government debt securities denominated in local currency and general government securities (available on the IMF website)[16]. Debt service to GDP is calculated based on debt service to GNI, GNI and GDP statistics provided by the World Bank. As Arellano (2008), I am using as spread J.P. Morgan Emerging Markets Bond Spread (EMBI) data provided by the World Bank Global Economic Monitor.

I am using McCracken and Ng (2016) dataset (FRED-MD) for the extraction of pricing factors, and I am also using the currency factors provided by Lustig et al. (2011). Additionally for robustness checks I use Gilchrist and Zakrajsek (2012) excess bond premium data provided in Favara et al. (2016).

[14]For the purpose of the regression analysis I obtain the risk-neutral 1 quarter ahead probabilities of default under assumption, following the logic of chapters 24-25 of Hull (2014): (1 - exp(CDSspread /10000$\times$ tenor / (recovery rate - 1))) /(4 $\times$ tenor).

[15]Details of methodology can be found on Refinitiv website.

[16]Table 2 in the supplemental Excel file. Arslanalp and Tsuda (2012) contains similar information for developed economies

4.2 Solution and calibration

The model is solved via a combination of value function iteration and policy function iteration algorithm as it is described in Arellano (2008). I begin from price schedules $q^{(0)}$ and $q^{*(0)}$, then iterate value functions for default and non-default states until convergence without updating the probabilities of default and exchange rates. After that I update the price schedules and default probabilities based on the default set $\mathcal{D}$. I then repeat the value function iterations with the new price schedule, and iterate price schedule until convergence.[17]

I discretize the endowment process using Tauchen (Tauchen, 1986) method with 21 states. I use 200 grid points for b and assume that b^* is a fixed share of b (this reduces the number of state dimensions by 1). To avoid Ponzi-game solution, the maximum size of debt service is capped at 15 % of maximum endowment. The solution in implemented in C++ using Nlopt optimization library and GPU parallelization with CUDA.[18]

All the parameters that are not indicated as calibrated, are taken from Arellano (2008): parameter of the loss function, as well as the relative risk aversion coefficient $\gamma = 2$. I calibrate the rest of the parameters using the standard simulated method of moments. I target the following moments: debt service to GDP (as Arellano (2008)), average level of foreign currency-denominated bonds' spread to the dollar risk-free rate, balance of trade's quarterly volatility, as well as average currency returns and forward to spot spread. I make sure that the moments are calculated for the periods when the country is not in default, since in the model those are mapped to the moments conditional on normal standing. This reflects the assumptions made in Section 3. In all the exercises I run 100,000 simulations.

I work with a set of developing countries, that intentionally excludes Argentina, that's frequently used for calibrating the models "with default" in the literature[19] I use data for Mexico, another country frequently used to calibrate models "with default", as well as Brazil, Colombia, Russia, Indonesia, and Turkey.[20]

[17]This solution is subject to Hatchondo et al. (2010) critique. However, varying number of grid points had almost no effect on the calculated moments, which supports the reliability of this approach.

[18]Using CUDA allows to achieve an approximately $\times 10$ improvement in the speed of the solution comparing to C++-implemented solution and estimation

[19]A good overview of the Argentinian defaults is provided in Hébert and Schreger (2017). First, Argentina defaulted in the XXI century, and the situation was more complicated than in the standard models "with default" – partial defaults and negotiations with the debt holders. Second, for country in default state there could be complications with the exchange rate statistics, as shown in Hébert and Schreger (2017). Moreover, the Argentinian currency was pegged to USD up to year 2002, which is not accommodated by the model.

[20]The data for trade balance volatility at the quarterly frequency is available only for some of the countries, and thus I use yearly data to predict this statistic for the rest.

Table 1: Calibration targets and parameters

Parameter	Notation	Conditional moment
Volatility of endowment	σ	Debt service to GDP
Persistence of endowment	ρ	Trade balance volatility
Return to the financial market	θ	Forward-spot spread
Discount rate	β	Bond spread
Monetary policy in default	μ_M	Currency returns

I calibrate the endowment process[21], discount rate, the probability to return to the financial market after default[22], and the monetary policy (change in money supply) conducted in case of sovereign default. To match the currency returns it is necessary to calibrate μ_M parameter. Even though the baseline money market equation with μ_M implies that in case of sovereign default the currency is weaker, since they are more likely to happen in low-endowment state, the volatility of the output process is not sufficient to reproduce currency returns. Additional depreciation caused by change in μ_M solves this problem, and it can be calibrated for every country separately.

4.3 Results

The model matches well the standard moments for the literature and, importantly, also demonstrates success in matching currency returns and the risk of default (Table 2 and Figure 4). The calibration parameters are provided in Table B.1. Importantly, β parameter is within reasonable range, and so is the probability to return to the financial market. Measured in quarters $1/(1-\theta)$ for $\theta = 0.95$ implies a 5 year expected time in autarky.

Table 2: Matched moments

Country	Debt serv. to GDP,%		EMB spread,%		FS spread,%		Curr. returns,%		Vol. of trade bal.,%		μ_M
	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	
Brazil	4.805	4.456	1.435	0.693	0.820	2.034	1.346	1.536	2.623	1.952	1.988
Colombia	4.982	4.982	0.534	0.575	0.899	0.867	0.986	0.987	1.484	1.461	3.038
Indonesia	5.433	5.538	0.341	0.479	1.429	1.832	0.806	0.924	1.558	1.987	1.955
Russia	4.540	4.594	1.495	0.595	0.906	1.612	1.173	1.173	2.693	2.885	1.612
Mexico	4.485	4.488	0.571	0.549	1.063	1.061	0.847	0.853	1.618	1.621	2.021
Turkey	8.040	8.236	1.491	0.779	2.051	2.489	0.480	0.469	1.907	2.829	1.108

The currency returns are matched almost perfectly by the model, while, as it is shown on the left panel

[21] The model is calibrated to quarterly data due to the frequency of the main variable of interest. Adjusting the endowment process to match the key moments in the data is the approach that I take to work with quarterly data. The main reason for this is that I do not have real quarterly growth rates comparable cross-country. Another reason is that there is a challenge with treating the seasonal component of the series. For these reasons it is a better decision to let the data indirectly inform the endowment process.

[22] Calibrating the parameter of loss function lead to poor moment matching results.

of the Figure 4, the countries do not demonstrate a perfect linear relation between the risk of default and the returns. The example of Turkey shows that the model is flexible enough to match countries for which the currency returns were affected by factors not directly associated with the probability of sovereign default[23]. The returns in Turkey were matched by lower μ_M than for the other countries.

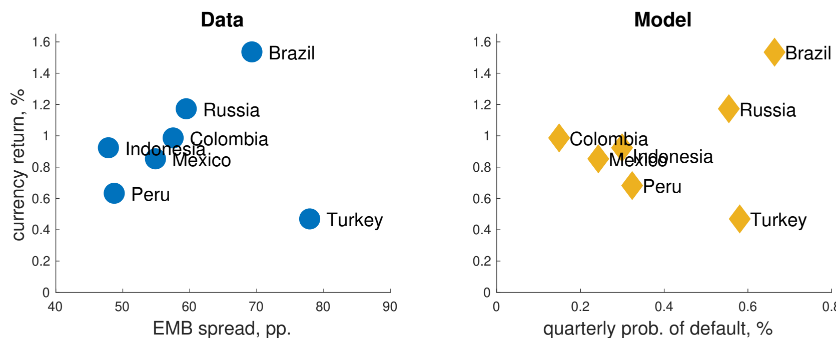

Figure 4: Calibration results: risk of default and currency returns

The results of the calibration highlight how the model matches the currency returns. Higher returns are implied by higher parameter of devaluation is case of default μ_M and on average higher probability of default. The model also matches almost perfectly the relation of debt service to GDP, which is one of the main benchmarks used in the literature (Arellano, 2008).

Interestingly, under the assumption of zero recovery the depreciation upon default doesn't enter the bond pricing formula. This means that without using forward data via either forward-spot spread or currency returns it's impossible to identify μ_M. It also implies that this parameter does not affect the remaining moments in the model in any way. Nevertheless, the good match of currency returns comes at the cost of having too frequents defaults in the model for countries like Brazil and Turkey – the bond spreads in the calibration are higher than in the model. For countries with lower spreads the model produces, respectively, lower simulated spreads. The main reason is that it it partly sacrifices these moments to match currency returns better. A more complicated model that includes partial default and risk-averse foreign investor may improve the quantitative results.[24]

The estimated model allows to run simulations for multiple countries examining the properties of the relative depreciation term, which I denote with

$$\alpha_{1it} = \left[\mathbb{E}_t\left(m_{t,t+1}\frac{S_{i,t}}{S_{i,t+1}}\middle|d_{i,t+1}=0\right) - \mathbb{E}_t\left(m_{t,t+1}\frac{S_{it}}{S_{i,t+1}}\middle|d_{i,t+1}=1\right)\right]/\mathbb{E}_t\left(m_{t,t+1}\middle|d_{i,t+1}=0\right),$$

where the i,t indexes stress that in general relative depreciation can vary over the business cycle, and α_{1it} can also be different across countries. Relative depreciation α_{1it} likely depends on the institutional

[23]The depreciation of lira in late 2010s, that is to large degree responsible for having a low currency return together with high default risk, coincided with the corporate debt issues. One can think of this debt crisis as a default event as well, in which case having lower returns is consistent with the theory.

[24]See Lizarazo (2013).

environment the monetary authorities work in, the structure of the financial markets, and more general economic and political circumstances. Table 3 provides simulation results for dynamics in both cases, as well as α_{1it}, and generally in case of no default the exchange rate remains stable, while in case of default currency sharply depreciates.

Table 3: Exchange rate dynamics in case of default

	Normal ER dynamics, %	Default ER dynamics, %	α_1
Brazil	1.137	-65.288	0.664
Turkey	0.600	-21.387	0.220
Russia	1.171	-56.622	0.578
Colombia	0.367	-76.004	0.764
Indonesia	0.534	-55.613	0.561
Mexico	0.463	-56.236	0.567

The calibration results reveal two properties of the *relative depreciation* that turn out to be very useful for finding empirical evidence of the presence of the default premium within the econometric framework (Table 4). First, the fluctuations of the *relative depreciation* over the business cycle are quite limited. They are small comparing to the fluctuations of the main driving force of the cycle – the endowment process – as well as of the main variable of interest – currency returns. Second, for many countries in the sample for which data are available the value of *relative depreciation* lies around 50-60% – the currency loses half of its value in case of default comparing to the normal standing counterfactual (Table 3). This number is in line with numbers provided in Mano (2013). These results are provided in Table 4 in the form of relative volatility.

Table 4: Calibration results: volatility and the *relative* size of *relative depreciation*

	$\sigma(\alpha_1)/\sigma(y)$, %	$\sigma(\alpha_1)/\sigma(F_t/S_{t+1})$, %
Brazil	1.893	0.135
Turkey	1.579	0.267
Russia	2.474	0.178
Colombia	1.179	0.173
Indonesia	0.758	0.144
Mexico	0.739	0.159

Obtaining these results provides support for further assuming that the *relative depreciation* is constant – both across countries and in time. This is a simple stylized model that is sufficient to deliver the main results, and adding more elements – such as risk aversion of creditors, trade balance adjustment costs and non-zero recovery rate – would improve its quantitative performance (Lizarazo, 2013, Arellano, 2008).

4.4 Extension: Seigniorage

[To do]

4.5 Extension: Risk averse voreign investors

[To do]

4.6 Discussion

This model does not treat explicitly the seigniorage. The role of seigniorage in developing economies is twofold. On the one hand, issuing additional currency relaxes the government budget constraint by explicitly supplying it with additional resources. On the other hand, the monetary expansion can be used to dilute the local currency-denominated debt – practically, it is default through devaluation (Ottonello and Perez, 2019). To keep the model decentralized I omit the first motive and focus on the second one.

In order to assess qualitatively the implications of the model I use the World Bank yearly data and Benjamin and Wright (2009) timing of sovereign defaults to calculate statistics in the year of default and in the year preceding it. Velocity was measured by dividing M3 by nominal GDP. Since the indicators are calculated at yearly frequency, they are likely to underestimate the actual effects of default, since they capture part of the year, when country was still in normal standing.

Table 5: Basic business cycle facts in default state.

	Excluding Rwanda			Excluding Rwanda and Ecuador		
	Mean, %	Median, %	St. dev., %	Mean, %	Median, %	St. dev., %
GDP growth	-0.819	-0.791	6.702	-1.235	-1.516	6.692
Inflation	4.207	0.602	12.959	1.158	-0.079	6.394
Velocity	4.907	-1.095	32.989	-1.287	-1.150	22.547
M growth	1.718	-0.608	5.311	1.328	-0.801	5.255
Exchange rate	9.015	8.403	32.592	15.827	10.395	17.071
Observations	17			16		

Notes:*Variables reported in yearly averages comparing to the previous normal standing year. All data is in differences (either percents, or percentage points, if the level was in percents). Countries included: Argentina, Cote d'Ivoire, Dominica, Ecuador, Gabon, Moldova, Myanmar, Nigeria, Paraguay, Russian Federation, Rwanda, Seychelles, Sierra Leone, Thailand, Ukraine, Uruguay, Zimbabwe. Source: World Bank*

Although the statistics need to be treated with precaution due to the high heterogeneity of the cross-country data and presence of influential observations, the major patterns are:

1. Defaults happened during economic downturns
2. Inflation was higher in default
3. Velocity on average increased, although this result may be caused by high growth rate in Ecuador
4. Default coincided with expansion of M3

5. Exchange rates unambiguously depreciated

Those are quite rough statistics measured at yearly frequency, but qualitatively the model reproduces these facts for all the 4 countries used for calibration.

Finally, it is important to discuss the relation of this stylized model and the *peso problem* - based theory in general with the data. One can also consider currency returns in the following way:

$$\mathbb{E}\left[\mathbb{E}_t\left[\frac{F_{i,t}}{S_{i,t+k}}\Big|d_{i,t+1},...,d_{i,t+k}=0\right]\Big|d_i\equiv 0\right] \tag{4.20}$$

where F_t denotes the forward with the delivery in $t+k$, S_t is the spot exchange rate (e.g. Mexican peso per USD), and d_t is the indicator of default of country i in period t. The expression (4.20) is formulated for a bond with the maturity of more than 1 "indivisible" period of time, to make the expression closer to the data. The main derivations provided above hold with appropriate adjustments of timing and the interpretation of p as the probability that the default would occur between t and $t+k$. Next, it is also important to notice that the formula

$$\frac{F_t}{S_t}\left[\mathbb{E}_t\left(\frac{S_t}{S_{t+k}}\Big|d_{i,t+1},...,d_{i,t+k}=0\right)-\mathbb{E}_t\left(\frac{S_t}{S_{t+k}}\Big|d_{i,t+1}+...+d_{i,t+k}=1\right)\right] \tag{4.21}$$

contains the expectation of the exchange rate dynamics preceding and including the period of the sovereign default. It means that the default-based explanation of currency returns suggested in this paper doesn't require the sharp depreciation exactly at the moment of default, for data to be consistent with the theory. For instance, the recent default of Argentina, that formally occurred in July 2014 (Hébert and Schreger (2017)), wasn't accompanied with a sharp depreciation exactly at the date of the default. However, the Argentinian peso was devalued half a year before that. Moreover, since the counterfactual path of the exchange rates is not observed, this devaluation doesn't have to be treated as the policy action that is directly (or, strongly, causally) related to default. We just need the observed exchange rate preceding the default to be different from the exchange rate path that would have been observed, if there were no default. For example, the Russian default in August 1998 was preceded by several rounds of devaluation, as described in Chiodo and Owyang (2002)), and this case doesn't contradict the provided theory[25].

Thus, the model qualitatively matches the basic changes in dynamics of macroeconomic variables that accompanied the defaults that we observed in the data. It is not reasonable to try to match these changes quantitatively, because of heterogeneity of macroeconomic dynamics of these countries (standard deviations in Table 5).[26]

5 Evidence

In this section I bring the model from Equation (3.10) to the data in order to provide evidence of the existence of the default premium or, in other words, supporting the *peso theory*. I start from reformulating

[25]In the Appendix C I show the dynamics of foreign currency returns and spot exchange rates around the dates of the default events – for Argentina and Russia.

[26]The results of simulations are quite robust. Similar exercise was provided using 25% recovery rate for the sovereign bonds.

expression (3.10) for N currencies:

$$\mathbb{E}_t\left(\frac{F_{it}}{S_{i,t+1}}\Big|d_{t+1}=0\right)=1+p_{i,t}(d_{i,t+1}=1)\frac{\left[\mathbb{E}_t\left(m_{t,t+1}\Big|d_{i,t+1}=1\right)-\mathbb{E}_t\left(m_{t,t+1}\Big|d_{i,t+1}=0\right)\right]}{\mathbb{E}_t\left(m_{t,t+1}\Big|d_{i,t+1}=0\right)}+ \tag{5.1}$$
$$+p_{i,t}(d_{i,t+1}=1)\mathbb{E}_t\frac{F_{it+1}}{S_{it}}\frac{\left[\mathbb{E}_t\left(m_{t,t+1}\frac{S_{it}}{S_{i,t+1}}\Big|d_{i,t+1}=0\right)-\mathbb{E}_t\left(m_{t,t+1}\frac{S_{it}}{S_{i,t+1}}\Big|d_{i,t+1}=1\right)\right]}{\mathbb{E}_t\left(m_{t,t+1}\Big|d_{i,t+1}=0\right)}-$$
$$-\frac{Cov_t\left(m_{t,t+1},\frac{F_{it}}{S_{i,t+1}}|d_{i,t+1}=0\right)}{\mathbb{E}_t\left(m_{t,t+1}\Big|d_{i,t+1}=0\right)}$$

where $i=1,...,N$, $t=0,...,T-1$. Due to the presence of unobserved counterfactuals: relative depreciation and deviation of stochastic discount factor in case of default – this equation does not represent a model that has testable implications in the data. To inform the econometric model I use the results from the exploration of *relative depreciation* from the SOE model (Section 4), in which this unobserved element can be extracted in simulations. Thus, I would assume that the relative depreciation is a constant term – across time and for all countries. Even without supporting results from the SOE model this assumption would not have been unreasonable. Defaults are a rare events, and historically every situation had unique features either from economic or political standpoint.[27] For that reason market players can have enough observations to make inference only for some average value of devaluation.

The next challenge is assessment of the deviation of the SDF in case of default.

$$\alpha_3=\frac{\mathbb{E}_t\left[m_{t,t+1}|d_{t+1}=1\right]-\mathbb{E}_t\left[m_{t,t+1}|d_{t+1}=0\right]}{\mathbb{E}_t\left[m_{t,t+1}|d_{t+1}=0\right]}$$

which is an unobserved element, even if the true SDF process m was available in the data. In this situation I choose to illustrate that the main results of the estimation hold under number of assumptions regarding the SDF. First, I assume that it is constant for all countries and over time. It means that the difference in weight with which investor discounts future cash flows in case if in future period default occurs and if it doesn't, does not depend on the business cycle, and is the same for defaults in all countries.

Due to low cross-country variation of F_t/S_t, variables p and $p\frac{F_t}{S_t}$ are highly correlated, which doesn't allow to use them in regression together, at least in a small cross-country sample (below in Table 7 column "CDS and FS spread"). Then, α_3 has to be estimated separately. Assuming that the markets are not segmented and thus the SDF is the same for all currencies, I calibrate durable and non-durable consumption-based SDF (Yogo, 2006, Lustig and Verdelhan, 2007) to match pricing moments for S&P500 and 3 month T-bills, using standard GMM approach. Having the estimate for the SDF, I assess whether there is a tight relation between the variation in SDF and sovereign defaults. Generally, there are two main channels where the relation between the SDF and the defaults can be coming from.

[27] For instance, Gordon and Guerron-Quintana (2019) explore just few dimensions of the heterogeneity, and Gordon and Guerron-Quintana (2021) consider the migration factor for sub-national level defaults.

Channel 1 (Cost)

- Higher risk-free (policy) rate in the US
- **Lower** $\mathbb{E}_t m_{t,t+1}$
- Costlier borrowing for the developing country
- **More likely to default**

Conclusion
$\mathbb{E}_t\left[m_{t,t+1}\middle|d_{t+1}=1\right] > \mathbb{E}_t\left[m_{t,t+1}\middle|d_{t+1}=0\right]$

Channel 2 (Global factor)

- Recession in the US
- Small or negative consumption growth
- **Higher** $\mathbb{E}_t m_{t,t+1}$ if it's consumption-based
- Recession in the developing country (e.g., from drop in demand for commodities)
- **More likely to default**

Conclusion
$\mathbb{E}_t\left[m_{t,t+1}\middle|d_{t+1}=1\right] < \mathbb{E}_t\left[m_{t,t+1}\middle|d_{t+1}=0\right]$

These two channels have different implications for the sign of α_3. I will use additional data and assumptions to separate $\left[m_{t,t+1}\middle|d_{t+1}=1\right]$ and $\left[m_{t,t+1}\middle|d_{t+1}=0\right]$. As documented in Mendoza and Yue (2012) and prior work of Tomz and Wright (2007) and Yeyati and Panizza (2011), sovereign defaults tend to occur in the periods of recessions, although evidence studied in Benjamin and Wright (2009) suggests that the relation is more complicated. Assuming negative correlation between the probability of default and the business cycle, I report correlations between the cyclical components of the extracted stochastic discount factor and the real GDP in the Appendix. Tables D.2 and D.3 show that the consumption-based SDFs demonstrate a rather weak correlation with countries' business cycles – just for few large countries, among which there are developed only. This allows to assume that $\alpha_3 = 0$ in the baseline specification.

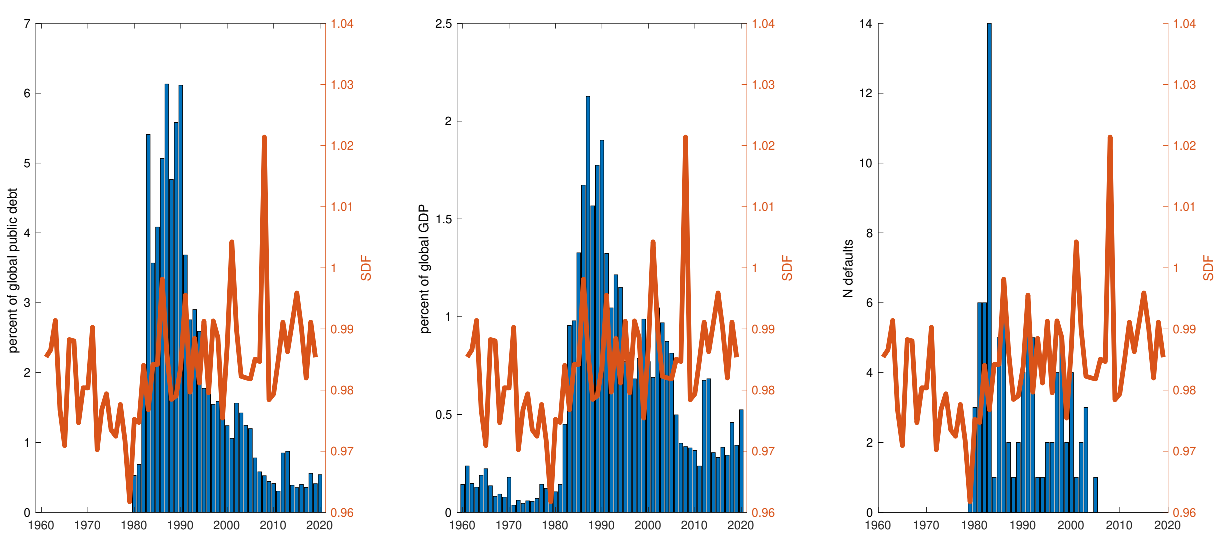

Figure 5: Estimated stochastic discount factor, default count (Benjamin and Wright, 2009), volume of debt in default to total and to world GDP (Beers et al., 2021)

Nevertheless, in order to make sure that this assumption is not crucial for finding the "default premium", I also consider an alternative strategy. Namely, I use Benjamin and Wright (2009) defaults data to get information about "rare default" and "frequent default" periods. I assume that in the 'frequent default" periods the probability of default $p \to 1$, and in "rare default" periods it goes to 0. Then, the average real SDF in "frequent" periods can serve as an approximation of $\mathbb{E}\left[\hat{m}_{t,t+1}\middle|d=1\right]$, and "rare" periods – of $\mathbb{E}\left[\hat{m}_{t,t+1}\middle|d=0\right]$. This naive approach allows to obtain a very rough approximation of the difference in the SDF, and is likely to underestimate it.

I use different quantiles of the number of defaults to define these two periods (see Table 6), and calculate α_3 as the deviation of average SDF values in these periods. I also consider alternative indicators reported in Beers et al. (2021) dataset (Figure 5, results are presented in the same table).

Table 6: Deviation of stochastic discount factor in case of default under different measures of *rare default* and *frequent default* states.

Quantiles	Debt in default / total	Debt in default / GDP	Number of defaults
50 and 50 quantiles	-0.23	0.29	0.32
25 and 75 quantiles	-0.39	0.46	0.67
10 and 90 quantiles	-0.80	0.73	-0.11
5 and 95 quantiles	-0.87	0.31	-0.11

Finally, the third assumption that I am going to make is standard for the finance literature: the SDF is a linear combination of a number of factors. Technically, the three assumptions are:

A1 $\left[\mathbb{E}_t\left(m_{t,t+1}\frac{S_{i,t}}{S_{i,t+1}}\middle|d_{i,t+1}=0\right)-\mathbb{E}_t\left(m_{t,t+1}\frac{S_{it}}{S_{i,t+1}}\middle|d_{i,t+1}=1\right)\right]/\mathbb{E}_t\left(m_{t,t+1}\middle|d_{i,t+1}=0\right)$ is constant (Relative depreciation α_1).

A2 $\left[\mathbb{E}_t\left(m_{t,t+1}\middle|d_{i,t+1}=1\right)-\mathbb{E}_t\left(m_{t,t+1}\middle|d_{i,t+1}=0\right)\right]/\mathbb{E}_t\left(m_{t,t+1}\middle|d_{i,t+1}=0\right)=\hat{\alpha}_3$

A3 $m_{t,t+1}$ is known: estimated via GMM **or** $m_{t,t+1}=\sum_{j=1}^{J}\omega_j f_{j,t+1}$, where f_j is a factor.

Then, they allow to write the model in the following way:

$$\mathbb{E}_t\left(\frac{F_{it}}{S_{i,t+1}}-1\middle|d_{t+1}=0\right)=\alpha_0+\alpha_1 p_{it}\frac{F_{it}}{S_{it}}+\alpha_2\frac{Cov_t\left(m_{t,t+1},\frac{F_{it}}{S_{i,t+1}}|d_{i,t+1}=0\right)}{\mathbb{E}_t\left(m_{t,t+1}\middle|d_{i,t+1}=0\right)}+\alpha_3 p_{it} \tag{5.2}$$

To estimate this model, I apply an extension of two-stage Fama and MacBeth (1973) procedure, that was used in this context by Lustig and Verdelhan (2007). These assumptions allow to write down the model in a simplified form:

$$\mathbb{E}_t\left(\frac{F_{it}}{S_{i,t+1}}-1\Big|d_{i,t+1}=0\right)=\alpha_0+\alpha_1 p_{it}\frac{F_{it}}{S_{it}}+\underbrace{\frac{Cov_t\left(m_{t,t+1},\frac{F_{it}}{S_{i,t+1}}|d_{i,t+1}=0\right)}{Var_t\left(m_{t,t+1}|d_{i,t+1}=0\right)}}_{\beta}\underbrace{\alpha_2\frac{Var_t\left(m_{t,t+1}|d_{i,t+1}=0\right)}{\mathbb{E}_t\left(m_{t,t+1}\Big|d_{i,t+1}=0\right)}}_{\lambda}+\alpha_3 p_{it} \tag{5.3}$$

Step 1 For each country (currency) i estimate a time series regression of $\frac{F_{it}}{S_{i,t+1}}$ on $\{f_j\}_{j=1}^{J}$ factors to obtain set of estimates $\hat{\beta}_{ij}$

Step 2 Then, I estimate the model

$$\overline{\frac{F_{i,t}}{S_{i,t+1}}-1\Big|d_i\equiv 0}-\hat{\alpha}_{3,t}\overline{p_{it}}=\alpha_0+\alpha_1\overline{\left[p_{it}\frac{F_{i,t}}{S_{i,t}}\right]}+\sum_{j=1}^{J}\lambda_j\hat{\beta}_{ij}+\varepsilon_i \tag{5.4}$$

where $\overline{X}_i$ denotes time average for country i. Notice that the difference between this model and the specification estimated in Lustig et al. (2011) is in the first two variables.

To take into account the generated regressor ($\hat{\beta}_{ij}$), I calculate bootstrap confidence intervals. I apply a two-stage bootstrap procedure: on the first stage I draw blocks from time series data to produce new estimates of β_{ij}, and then I use these generated regressors in cross-section to get bootstrap distribution of $\hat{\alpha}$ and $\hat{\lambda}$. I then calculate 95% bootstrap confidence intervals as they are described in Hansen (2014).[28]

α_1 is the key parameter for the explanation provided here. α_1 has to be positive to be consistent with peso theory (and "Twin D" Na et al. (2018)). Moreover, α_1 has a structural interpretation – *relative depreciation*. Thus, its value should be consistent with the existing evidence although the value in the model is risk-adjusted.

5.1 Results

Table 7 provides the main results of the econometric analysis for the cross-section of countries – the second stage of the Fama and MacBeth (1973) regression. I first show the regression of currency returns on average CDS spread in column "CDS". This regression manifests the positive relation between the returns and the spreads in the cross-section of countries: higher risk is associated with higher currency returns, on average (also demonstrated on Figure 1).[29] The explained variance already constitutes around 20%, which, given the amount of factors that affect exchange rates, is quite a high number.

After providing this illustration I present a more model-based approach. The regression of currency returns on the product of forward to spot spread is taking Equation 3.10 to the data under the assumption

[28] So called Efron's interal: $[q(\hat{\theta}^*, 0.025), q(\hat{\theta}^*, 0.975)]$, where q denotes percentile of empirical distribution, and $\hat{\theta}^*$ are bootstrap estimates of the model's parameters.

[29] With the caveat that the CDS spread in fact is a complicated function of interest rates, recovery rate and probability of default, see a more profound analysis in Mano (2013), among others. Nevertheless, there should be little doubt that the cross-sectional cardinal relation reflects the relative risk of different sovereigns.

of risk-neutrality. Estimates in column "FS spread" are thus central for the paper. This regression suggests that alone, without considering the pricing factor, i.e. in the absence of risk premium coming from the risk aversion of market players, the *default premium* explains about 25% of variation in currency returns. The rest of the regressions take into account the presence of the SDF.

I consider several options for factors f. First, I use Lustig et al. (2011) 2 currency factors (average currency returns, and HML), denoted as "LRV" in Table 7. I both use the factors provided by the authors (in Table below), and calculate them myself to make them specific for the dataset I am using.

Next, I consider macro factors, that are supposed to reflect the US economic conditions or the global factors that can influence currency returns. I use McCracken and Ng (2016) dataset (FRED-MD), which contains macroeconomic and financial data at monthly frequency for the US. I first transform the dataset using the authors' code (log, first and second difference transformations for different series). I then apply additional transformation to the data in order for it to reflect the 3-month SDF, instead of the 1-month one implied by the default transformation of the data[30], and I exclude the exchange rate data. Motivated by Lustig et al. (2011), I extract the first two components from the dataset.[31]

Using the factors in the regression allows to reconcile the "peso problem" theory with the traditional approach in finance. From econometric standpoint it means testing the presence of the default premium controlling for the exposure to pricing factors. In columns "LRV" and "PC" (for "principle components") I show how the pure CAPM-style (or *factor*) approach performs in this sample. After that in the last two columns I put the default premium and the factor betas together into the regression.

[30]This approach suffers from Working (1960) critique

[31]for robustness we try to use dimension reduction methods to extract several variables that demonstrate the highest correlation with currency returns for the highest share of countries on the first estimation stage. In order to do that I use lasso approach, varying the loss function parameters. After the selection step, I apply standard OLS procedure – this approached is called *post lasso* in the literature (Belloni and Chernozhukov, 2013).

Table 7: Baseline regression's results. Dependent variable – quarterly returns $100 \times (F_t/S_{t+1} - 1)$.

	CDS	FS spread	CDS and FS spread	LRV	PC	LRV plus	PC plus
CDS spread	50.846		-2055.832				
	[13.461 , 91.663]		[-3398.113 , -81.433]				
CDS spread ×		0.507	20.608			0.531	0.465
× fs spread		[0.139 , 0.897]	[1.339 , 33.852]			[0.136 , 0.886]	[0.076 , 0.870]
Factor 1				0.005	-0.934	0.009	-1.697
				[-0.015 , 0.018]	[-3.423 , 1.933]	[-0.010 , 0.017]	[-2.321 , 2.120]
Factor 2				-0.002	0.723	0.005	-1.158
				[-0.022 , 0.019]	[-2.185 , 2.258]	[-0.013 , 0.019]	[-2.218 , 1.792]
Const	0.081	0.077	0.345	0.626	0.723	0.006	0.151
	[-0.342 , 0.539]	[-0.342 , 0.536]	[-0.104 , 0.690]	[0.444 , 0.826]	[0.512 , 0.855]	[-0.388 , 0.486]	[-0.290 , 0.603]
R-sq	0.242	0.252	0.434	0.010	0.103	0.276	0.303
R-sq adj	0.221	0.231	0.401	-0.046	0.051	0.212	0.242
N	38	38	38	38	38	38	38

Bootstrap 95 % confidence intervals (250 draws) in parentheses

Notes: *Eurozone countries and Argentina excluded from sample, and 10% trimming was applied to currency returns and CDS spreads to exclude outliers. Countries with all types of floating exchange rate arrangements according to IMF (2000-2019) classification are included. Countries: Australia, Bahrain, Brazil, Bulgaria, Canada, Chile, China, Colombia, Croatia, Czech Republic, Egypt, Estonia, Hungary, Iceland, India, Indonesia, Israel, Japan, Kazakhstan, Latvia, Lithuania, Malaysia, Mexico, Morocco, Peru, Philippines, Poland, Qatar, Romania, Russia, Singapore, South Africa, South Korea, Switzerland, Thailand, Tunisia, Turkey, United Kingdom.*

The econometric analysis provides support for the peso problem explanation, since the estimated coefficient at the interaction of CDS spread and forward - spot spread is positive. This result is robust for all considered specifications. Moreover, since the interpretation of the coefficient is the *relative depreciation* upon default, it implies that the investors price an approximately 50% (risk-adjusted) depreciation upon default. This coefficient, first, is consistent with the estimates obtained for different countries in the SOE framework. Second, this number lies within a reasonable range of devaluations and depreciations that were documented in the past (Mano (2013) provides excellent historical dataset, and the 50% depreciation is slighly on the higher side of the data). Note also that the *relative depreciation* is the difference between exchange rate dynamics, so the *depreciation* itself would likely be expected to be lower. If economic conditions improve, developing countries' currencies are likely to appreciate.[32] Quantitatively, a 1 pp. higher probability of sovereign default is associated with a 0.5 pp. higher currency return.[33] The significant share of explained variation by the default risk alone, i.e. under the assumption of risk-neutral investor, illustrates that the presence of the default premium is necessary for understanding the magnitude of currency returns, and omitting it may lead to biased results when analyzing the pricing factors for currency returns.

In order to establish the robustness of the results, I use estimated SDF, as well as alternatively specified factors. Importantly, I also show that the results hold if I expand the limits of possible deviation of the

[32]Relative depreciation in the econometric model is weighted by the SDF – given the possible range of values we obtained above, it's hard to determine how the weighting affects the expected depreciation value

[33]According to Longstaff et al. (2011) approximation and assuming 25% recovery rate, 1 p.p. probability corresponds to 75 CDS spread basis points.

SDF in default to 2% (Tables E.5 - E.6). These robustness checks are presented in the Appendix E.

6 Conclusion

In this paper I suggest a *peso problem* based theory that links the cross-country variation of foreign currency returns to the variation in the average risk of sovereign default. In the absence of sovereign defaults market players collect compensation for taking the risk of sharp depreciation upon default – *default premium*. Higher probability of default or larger expected depreciation upon default implies larger default premium. As a result, currencies of emerging economies in general demonstrate higher returns with respect to USD than the ones of developed countries.

Using a nominal small open economy model "with default", calibrated to a set of developing countries, I investigate the properties of the depreciation of national currency in case of sovereign default. According to the calibrated model, expected depreciation is relatively stable over the business cycle, and investors expect a similar (about 60%) depreciation upon default in the majority of these developing economies. Under this assumption, I estimate using Fama and MacBeth (1973) method the model of currency returns based on modified uncovered and covered interest rate parities for risk-bearing bonds. Under assumption of risk-neutral investor this model explains around 25% of variation of currency returns. Adding to this model estimated stochastic discount factor or factors in the spirit of Lustig et al. (2011) brings this number up to 30%.

Quantitatively, 1 percentage point higher average probability of default is associated with about 0.5 percentage point higher average currency returns. This implies that investors expect a 50% drop in exchange rate in case if default occurs – and this number is consistent with the results obtained in the small open economy model. Overall, this paper demonstrates how the *peso theory* (and *rare disaster*) explanation of the existence of risk premium in currency returns can be reconciled with CAPM (or factor model)-style approach within a tractable econometric model that can be estimated from the existing data.

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Appendices

A UIP and CIP

Denote as $1+i_t$ the US bond's gross interest rate, and with $1+i^*$ the foreign bond's interest rate, define spot rate S_t in foreign currency (e.g., peso) per unit of USD. Denote forward contract t to $t+1$ as F_t. Then, the no arbitrage conditions (referred to in the literature as uncovered and covered interest rate parities), would imply:

$$\left.\begin{array}{lll} \text{Uncovered:} & 1+i= & (1+i^*)\mathbb{E}_t\frac{S_t}{S_{t+1}} \\ \text{Covered:} & 1+i= & (1+i^*)\frac{S_t}{F_t} \end{array}\right\} \Rightarrow \mathbb{E}_t\frac{F_t}{S_{t+1}}=1 \overset{\text{LIME}}{\Longrightarrow} \mathbb{E}\frac{F_t}{S_{t+1}}=1$$

B Calibration results

Table B.1: Calibrated parameters

Country	β	σ	ρ	Loss param	θ	μ_M	Currency returns
Brazil	0.961	0.091	0.946	0.969	0.943	1.988	1.536
Colombia	0.993	0.040	0.980	0.969	0.968	3.038	0.987
Indonesia	0.994	0.032	0.906	0.969	0.929	1.955	0.924
Russia	0.961	0.091	0.947	0.969	0.940	1.612	1.173
Mexico	0.994	0.028	0.913	0.969	0.930	2.021	0.853
Turkey	0.985	0.040	0.861	0.969	0.908	1.108	0.469

C Default cases

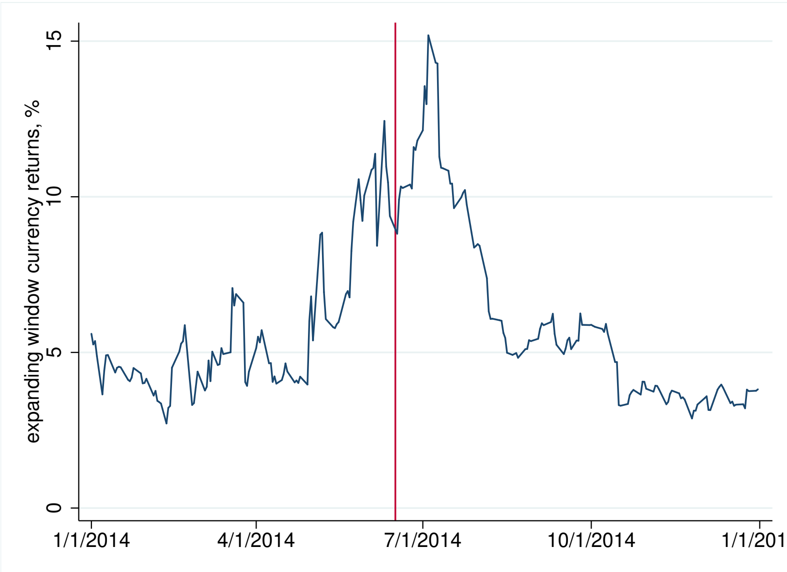
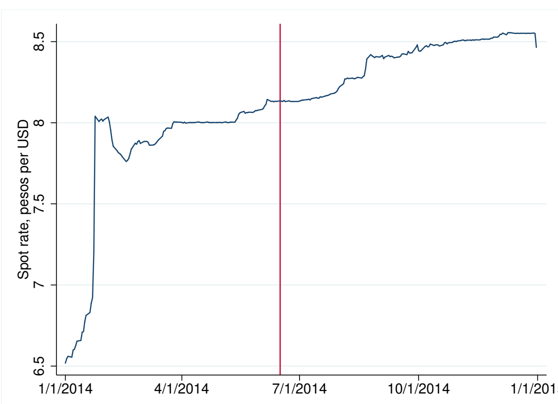
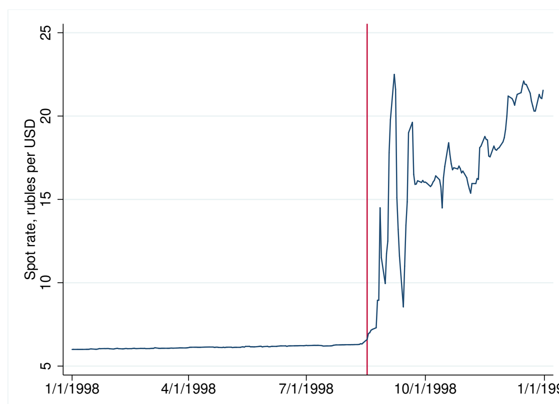


Figure C.1: Average currency returns (expanding window approach) for Argentina around the 2014 default. Source: *Thomson Reuters Datastream, date of default according to Du and Schreger (2016)*



(a) 2014 default in Argentina



(b) 1998 default in Russia

Figure C.2: Spot exchange rates around Argentinian and Russian defaults. Source: *Thomson Reuters Datastream, dates of default according to Chiodo and Owyang (2002) and Du and Schreger (2016)*

D SDF and GDP dynamics

Table D.2: correlation between HP-filtered m and HP-filtered real GDP.

Antigua and Barbuda: 0.02 (0.91)	Albania: -0.24 (0.24)	Armenia: 0.27 (0.35)	Angola: -0.40 (0.05)
Argentina: -0.05 (0.83)	Austria: -0.11 (0.60)	Australia: -0.58 (0.00)	Azerbaijan: 0.23 (0.44)
Bosnia and Herzegovina: 0.01 (0.98)	Barbados: -0.18 (0.39)	Bangladesh: 0.06 (0.78)	Belgium: -0.11 (0.61)
Burkina Faso: 0.02 (0.93)	Bulgaria: -0.04 (0.86)	Bahrain: 0.01 (0.98)	Burundi: -0.14 (0.50)
Benin: -0.03 (0.87)	Bermuda: -0.01 (0.95)	Brunei Darussalam: -0.19 (0.38)	Bolivia: 0.05 (0.82)
Brazil: -0.01 (0.95)	Bahamas: -0.32 (0.12)	Bhutan: -0.08 (0.71)	Botswana: -0.23 (0.27)
Belarus: 0.17 (0.56)	Belize: -0.09 (0.68)	Canada: -0.43 (0.03)	Congo: -0.33 (0.11)
Central African Republic: 0.19 (0.36)	Congo: 0.15 (0.49)	Switzerland: -0.02 (0.92)	Cote d'Ivoire: -0.08 (0.69)
Chile: -0.12 (0.55)	Cameroon: -0.10 (0.65)	China: -0.08 (0.70)	Colombia: 0.06 (0.77)
Costa Rica: -0.06 (0.76)	Cape Verde: -0.45 (0.03)	Cyprus: -0.14 (0.49)	Czech Republic: 0.09 (0.76)
Germany: -0.02 (0.92)	Djibouti: 0.16 (0.43)	Denmark: -0.03 (0.89)	Dominica: 0.08 (0.71)
Dominican Republic: -0.14 (0.52)	Ecuador: 0.11 (0.59)	Estonia: 0.35 (0.22)	Egypt: 0.13 (0.55)
Spain: -0.11 (0.61)	Ethiopia: 0.23 (0.28)	Finland: -0.25 (0.23)	Fiji: -0.23 (0.27)
France: -0.02 (0.93)	Gabon: -0.01 (0.96)	United Kingdom: -0.28 (0.17)	Grenada: -0.41 (0.04)
Georgia: 0.22 (0.46)	Ghana: -0.16 (0.44)	Gambia: 0.12 (0.58)	Guinea: -0.10 (0.65)
Equatorial Guinea: 0.06 (0.78)	Greece: -0.07 (0.73)	Guatemala: 0.12 (0.56)	Guinea-Bissau: 0.01 (0.96)
Hong Kong: -0.08 (0.70)	Honduras: 0.02 (0.92)	Croatia: 0.12 (0.69)	Hungary: -0.22 (0.29)
Indonesia: 0.06 (0.78)	Ireland: -0.08 (0.70)	Israel: 0.20 (0.33)	India: -0.22 (0.30)
Iraq: -0.36 (0.08)	Iran: 0.17 (0.43)	Iceland: -0.10 (0.64)	Italy: -0.09 (0.65)
Jamaica: -0.11 (0.59)	Jordan: -0.20 (0.34)	Japan: -0.06 (0.79)	Kenya: -0.08 (0.71)
Kyrgyzstan: 0.12 (0.67)	Cambodia: -0.16 (0.44)	Comoros: 0.18 (0.39)	Saint Kitts and Nevis: -0.35 (0.09)
Republic of Korea: -0.05 (0.80)	Kuwait: -0.45 (0.02)	Kazakhstan: 0.03 (0.93)	N Korea: 0.34 (0.10)
Lebanon: 0.06 (0.79)	Saint Lucia: -0.49 (0.01)	Lanka: -0.06 (0.77)	Liberia: -0.04 (0.84)
Lesotho: -0.09 (0.67)	Lithuania: 0.21 (0.47)	Luxembourg: -0.09 (0.65)	Latvia: 0.30 (0.30)
Morocco: -0.07 (0.75)	Moldova: 0.39 (0.16)	Montenegro: 0.24 (0.42)	Madagascar: 0.11 (0.61)
N Macedonia: 0.30 (0.30)	Mali: 0.22 (0.28)	Mongolia: -0.08 (0.72)	Macao: -0.10 (0.62)
Mauritania: -0.30 (0.14)	Malta: -0.08 (0.72)	Mauritius: -0.03 (0.89)	Maldives: 0.04 (0.84)
Malawi: 0.02 (0.93)	Mexico: 0.01 (0.95)	Malaysia: -0.17 (0.43)	Mozambique: 0.09 (0.67)
Namibia: -0.14 (0.52)	Niger: -0.00 (0.99)	Nigeria: 0.06 (0.78)	Netherlands: 0.02 (0.94)
Norway: 0.06 (0.78)	Nepal: 0.19 (0.36)	Zealand: -0.27 (0.19)	Oman: 0.03 (0.88)
Panama: 0.17 (0.42)	Peru: -0.05 (0.83)	Philippines: -0.12 (0.58)	Pakistan: -0.36 (0.07)
Poland: -0.29 (0.16)	Portugal: -0.10 (0.63)	Paraguay: -0.17 (0.42)	Qatar: -0.09 (0.65)
Romania: -0.18 (0.39)	Serbia: 0.13 (0.67)	Russia: -0.09 (0.75)	Rwanda: 0.03 (0.89)
Saudi Arabia: 0.03 (0.89)	Sudan: 0.19 (0.35)	Sweden: -0.20 (0.33)	Singapore: 0.03 (0.89)
Slovenia: 0.06 (0.85)	Slovakia: 0.23 (0.44)	Sierra Leone: 0.26 (0.21)	Senegal: -0.07 (0.74)
Suriname: 0.07 (0.74)	Tome and Principe: 0.24 (0.25)	Salvador: -0.10 (0.63)	Syria: -0.14 (0.50)
Swaziland: 0.06 (0.77)	Chad: -0.09 (0.68)	Togo: -0.25 (0.23)	Thailand: -0.07 (0.74)
Tajikistan: 0.40 (0.15)	Turkmenistan: 0.16 (0.58)	Tunisia: -0.07 (0.75)	Turkey: -0.02 (0.91)
Trinidad and Tobago: -0.08 (0.69)	Taiwan: -0.26 (0.20)	Tanzania: -0.10 (0.62)	Ukraine: -0.02 (0.94)
Uganda: -0.07 (0.72)	United States: -0.35 (0.08)	Uruguay: -0.10 (0.64)	Uzbekistan: 0.21 (0.47)
St Vincent: -0.02 (0.93)	Venezuela: 0.04 (0.86)	Viet Nam: 0.20 (0.35)	Yemen: -0.20 (0.47)
South Africa: -0.21 (0.31)	Zambia: 0.05 (0.83)	Zimbabwe: 0.20 (0.33)	

Table D.3: correlation between HP-filtered m and HP-filtered real GDP.

Antigua and Barbuda: -0.07 (0.76)	Albania: -0.05 (0.82)	Armenia: 0.28 (0.33)	Angola: -0.38 (0.06)
Argentina: -0.08 (0.71)	Austria: -0.17 (0.42)	Australia: -0.45 (0.02)	Azerbaijan: 0.25 (0.39)
Bosnia and Herzegovina: 0.05 (0.87)	Barbados: -0.04 (0.86)	Bangladesh: 0.02 (0.93)	Belgium: -0.11 (0.59)
Burkina Faso: 0.03 (0.88)	Bulgaria: -0.02 (0.94)	Bahrain: -0.08 (0.70)	Burundi: -0.13 (0.55)
Benin: 0.05 (0.83)	Bermuda: 0.19 (0.37)	Brunei Darussalam: -0.26 (0.21)	Bolivia: 0.06 (0.78)
Brazil: 0.03 (0.88)	Bahamas: -0.07 (0.75)	Bhutan: 0.02 (0.92)	Botswana: -0.10 (0.63)
Belarus: 0.19 (0.51)	Belize: -0.03 (0.89)	Canada: -0.19 (0.37)	Congo: -0.29 (0.15)
Central African Republic: 0.28 (0.18)	Congo: 0.18 (0.39)	Switzerland: 0.09 (0.66)	Cote d'Ivoire: 0.05 (0.82)
Chile: -0.22 (0.30)	Cameroon: 0.05 (0.82)	China: 0.04 (0.84)	Colombia: 0.01 (0.95)
Costa Rica: 0.06 (0.79)	Cape Verde: -0.31 (0.14)	Cyprus: -0.08 (0.69)	Czech Republic: 0.08 (0.78)
Germany: -0.07 (0.73)	Djibouti: 0.13 (0.53)	Denmark: 0.20 (0.33)	Dominica: -0.03 (0.89)
Dominican Republic: -0.09 (0.66)	Ecuador: -0.01 (0.95)	Estonia: 0.38 (0.18)	Egypt: 0.14 (0.52)
Spain: -0.14 (0.49)	Ethiopia: 0.35 (0.09)	Finland: -0.06 (0.79)	Fiji: -0.20 (0.34)
France: 0.02 (0.91)	Gabon: -0.12 (0.57)	United Kingdom: -0.09 (0.66)	Grenada: -0.37 (0.07)
Georgia: 0.25 (0.39)	Ghana: -0.05 (0.81)	Gambia: 0.02 (0.92)	Guinea: -0.06 (0.77)
Equatorial Guinea: 0.21 (0.32)	Greece: -0.14 (0.51)	Guatemala: 0.06 (0.79)	Guinea-Bissau: 0.07 (0.74)
Hong Kong: -0.15 (0.49)	Honduras: 0.00 (1.00)	Croatia: 0.12 (0.68)	Hungary: -0.18 (0.40)
Indonesia: -0.04 (0.84)	Ireland: 0.02 (0.94)	Israel: 0.20 (0.33)	India: -0.25 (0.24)
Iraq: -0.14 (0.51)	Iran: 0.04 (0.85)	Iceland: 0.01 (0.96)	Italy: -0.07 (0.73)
Jamaica: -0.14 (0.50)	Jordan: -0.11 (0.59)	Japan: -0.19 (0.37)	Kenya: 0.01 (0.95)
Kyrgyzstan: 0.10 (0.74)	Cambodia: -0.17 (0.42)	Comoros: 0.31 (0.13)	Saint Kitts and Nevis: -0.27 (0.19)
Republic of Korea: -0.11 (0.61)	Kuwait: -0.42 (0.04)	Kazakhstan: -0.02 (0.95)	N Korea: 0.26 (0.21)
Lebanon: 0.20 (0.35)	Saint Lucia: -0.45 (0.02)	Lanka: -0.01 (0.95)	Liberia: 0.13 (0.55)
Lesotho: -0.15 (0.49)	Lithuania: 0.22 (0.45)	Luxembourg: -0.10 (0.64)	Latvia: 0.34 (0.24)
Morocco: -0.05 (0.80)	Moldova: 0.37 (0.20)	Montenegro: 0.27 (0.36)	Madagascar: 0.34 (0.10)
N Macedonia: 0.40 (0.16)	Mali: 0.34 (0.09)	Mongolia: 0.07 (0.74)	Macao: -0.24 (0.24)
Mauritania: -0.38 (0.06)	Malta: -0.16 (0.44)	Mauritius: 0.01 (0.96)	Maldives: -0.02 (0.92)
Malawi: 0.04 (0.84)	Mexico: -0.07 (0.76)	Malaysia: -0.26 (0.21)	Mozambique: 0.12 (0.56)
Namibia: -0.00 (0.99)	Niger: -0.11 (0.62)	Nigeria: 0.04 (0.84)	Netherlands: 0.12 (0.55)
Norway: 0.21 (0.31)	Nepal: 0.17 (0.42)	Zealand: -0.11 (0.61)	Oman: -0.01 (0.98)
Panama: 0.10 (0.63)	Peru: 0.03 (0.88)	Philippines: -0.25 (0.23)	Pakistan: -0.31 (0.13)
Poland: -0.07 (0.74)	Portugal: -0.14 (0.50)	Paraguay: -0.35 (0.08)	Qatar: -0.15 (0.47)
Romania: -0.03 (0.87)	Serbia: 0.15 (0.60)	Russia: -0.09 (0.75)	Rwanda: 0.07 (0.72)
Saudi Arabia: -0.16 (0.44)	Sudan: 0.15 (0.47)	Sweden: 0.01 (0.95)	Singapore: -0.09 (0.67)
Slovenia: 0.11 (0.70)	Slovakia: 0.24 (0.41)	Sierra Leone: 0.12 (0.56)	Senegal: 0.10 (0.63)
Suriname: -0.02 (0.92)	Tome and Principe: 0.22 (0.29)	Salvador: 0.04 (0.86)	Syria: -0.15 (0.46)
Swaziland: 0.04 (0.85)	Chad: -0.02 (0.94)	Togo: -0.20 (0.33)	Thailand: -0.20 (0.33)
Tajikistan: 0.37 (0.19)	Turkmenistan: 0.24 (0.42)	Tunisia: -0.11 (0.60)	Turkey: 0.07 (0.74)
Trinidad and Tobago: -0.13 (0.54)	Taiwan: -0.20 (0.33)	Tanzania: -0.05 (0.81)	Ukraine: -0.08 (0.79)
Uganda: -0.05 (0.80)	United States: -0.09 (0.67)	Uruguay: -0.14 (0.50)	Uzbekistan: 0.22 (0.45)
St Vincent: -0.21 (0.32)	Venezuela: -0.00 (0.99)	Viet Nam: 0.19 (0.37)	Yemen: -0.13 (0.63)
South Africa: -0.14 (0.50)	Zambia: 0.22 (0.29)	Zimbabwe: 0.12 (0.57)	

E Estimation: robustness check

Table E.4: Baseline regression with assumption $\alpha_3 = -2\%$

	CDS	FS spread	CDS and FS spread	LRV	PC	LRV plus	PC plus
CDS spread	48.846		-2057.832				
	[11.461 , 89.663]		[-3400.113 , -83.433]				
CDS spread ×		0.487	20.608			0.512	0.445
× fs spread		[0.119 , 0.877]	[1.339 , 33.852]			[0.117 , 0.866]	[0.046 , 0.851]
Factor 1				0.005	-0.943	0.009	-1.696
				[-0.015 , 0.017]	[-3.401 , 1.906]	[-0.010 , 0.017]	[-2.342 , 2.120]
Factor 2				-0.001	0.699	0.005	-1.157
				[-0.021 , 0.019]	[-2.198 , 2.227]	[-0.013 , 0.019]	[-2.218 , 1.792]
Const	0.081	0.077	0.345	0.603	0.699	0.005	0.150
	[-0.342 , 0.539]	[-0.342 , 0.536]	[-0.104 , 0.690]	[0.422 , 0.802]	[0.492 , 0.831]	[-0.388 , 0.486]	[-0.290 , 0.620]
R-sq	0.228	0.237	0.423	0.011	0.102	0.261	0.289
R-sq adj	0.207	0.216	0.390	-0.046	0.051	0.196	0.227
N	38	38	38	38	38	38	38

Bootstrap 95 % confidence intervals (250 draws) in parentheses

Table E.5: Baseline regression with assumption $\alpha_3 = 2\%$

	CDS	FS spread	CDS and FS spread	LRV	PC	LRV plus	PC plus
CDS spread	52.846		-2053.832				
	[15.461 , 93.663]		[-3396.113 , -79.433]				
CDS spread ×		0.526	20.608			0.551	0.484
× fs spread		[0.159 , 0.916]	[1.339 , 33.852]			[0.156 , 0.905]	[0.096 , 0.890]
Factor 1				0.005	-0.925	0.009	-1.697
				[-0.015 , 0.018]	[-3.461 , 1.970]	[-0.010 , 0.017]	[-2.322 , 2.120]
Factor 2				-0.002	0.748	0.005	-1.159
				[-0.022 , 0.019]	[-2.173 , 2.282]	[-0.013 , 0.019]	[-2.218 , 1.792]
Const	0.081	0.078	0.345	0.649	0.748	0.006	0.151
	[-0.342 , 0.539]	[-0.341 , 0.536]	[-0.104 , 0.690]	[0.464 , 0.851]	[0.532 , 0.879]	[-0.387 , 0.486]	[-0.289 , 0.603]
R-sq	0.257	0.266	0.444	0.010	0.103	0.290	0.317
R-sq adj	0.236	0.246	0.413	-0.047	0.052	0.227	0.256
N	38	38	38	38	38	38	38

Bootstrap 95 % confidence intervals (250 draws) in parentheses

Table E.6: Baseline regression with assumption $\alpha_3 = 0\%$. Additional factors.

	CDS	FS spread	CDS and FS spread	LRV	PC	LRV plus	PC plus	MC	MCD	2 Factors
CDS spread	50.846		-2055.832							
	[13.461 , 91.663]		[-3398.113 , -81.433]							
CDS spread ×		0.507	20.608			0.531	0.465	0.508	0.509	0.532
× fs spread		[0.139 , 0.897]	[1.339 , 33.852]			[0.136 , 0.886]	[0.076 , 0.870]	[0.103 , 0.863]	[0.111 , 0.935]	[0.145 , 0.913]
Factor 1				0.005	-0.934	0.009	-1.697	0.058	-0.001	-5.790
				[-0.015 , 0.018]	[-3.423 , 1.933]	[-0.010 , 0.017]	[-2.321 , 2.120]	[-1.128 , 2.008]	[-2.334 , 1.198]	[-11.787 , 8.700]
Factor 2				-0.002	0.723	0.005	-1.158			0.179
				[-0.022 , 0.019]	[-2.185 , 2.258]	[-0.013 , 0.019]	[-2.218 , 1.792]			[-0.490 , 0.797]
Const	0.081	0.077	0.345	0.626	0.723	0.006	0.151	0.075	0.068	-0.010
	[-0.342 , 0.539]	[-0.342 , 0.536]	[-0.104 , 0.690]	[0.444 , 0.826]	[0.512 , 0.855]	[-0.388 , 0.486]	[-0.290 , 0.603]	[-0.408 , 0.522]	[-0.385 , 0.623]	[-0.610 , 0.542]
R-sq	0.242	0.252	0.434	0.010	0.103	0.276	0.303	0.252	0.252	0.295
R-sq adj	0.221	0.231	0.401	-0.046	0.051	0.212	0.242	0.209	0.209	0.232
N	38	38	38	38	38	38	38	38	38	38

Bootstrap 95 % confidence intervals (250 draws) in parentheses