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Choosing the Currency Structure for Sovereign Debt

A Review of Current Approaches*

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Abstract

This paper acknowledges the fact that some countries have to borrow in foreign currencies due to the various constraints they face. Starting from this point, the paper reviews approaches for determining the currency structure for sovereign debt, and discusses some issues inherent in these approaches. The review mainly focuses on the correlations of domestic fundamentals with the actual versus equilibrium exchange rate in light of the long-term perspective of a debt manager and changing exchange rate regimes. In addition, the paper makes some observations on the characterization of exchange rate volatilities in the existing approaches.

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1 Introduction

Sovereign borrowers often have large funding needs owing to their effort to stabilize income over time and across circumstances, increase income faster than it is possible when relying only on their own resources, support monetary policy, and develop domestic capital markets.[1] If the funding needs cannot be met by issuing debt denominated in the domestic currency, the government is forced to issue debt in a foreign currency and as a result can be exposed to foreign exchange (FX) risk by possibly having currency mismatches on its balance sheet. The currency mismatches could arise if, after matching the cash flows from assets[2] and liabilities denominated in similar currencies, there still remains an open position in any foreign currency. There are at least four candidate explanations for the constraints forcing sovereigns to borrow in foreign currencies.

First, the inability of developing countries' governments to issue desired amounts of debt denominated in domestic currencies can be attributed to the unwillingness of foreign investors to hold sovereign debt denominated in currencies of small developing countries. In this regard, the literature on the "original sin", see e.g. Eichengreen *et al.* (2003), Hausmann and Panizza (2003) and Chamon and Hausmann (2005), highlights the role of path dependence and international factors in foreign exchange borrowing while downplaying the importance of institutional and macroeconomic factors. This implies that there is not much leeway left for many emerging market economies in need of financing, as policy makers cannot alter the initial conditions, and improvements in policies and institutions do not seem to affect their ability to issue domestic currency debt offshore. In contrast to the evidence from the "original sin" literature, which finds mainly the country size explaining the sovereign debt's currency structure, Claessens *et al.* (*forthcoming*) find that institutional and

[1] The reason for government borrowing can be also more opportunistic by simply taking advantage of favorable market conditions for financing.

[2] Usually the most important asset of a government is the present value of its future revenues. As the revenues are most often denominated in the domestic currency borrowing in foreign currencies creates currency mismatches in government's balance sheet. In the case where the revenues are denominated in foreign currencies, e.g. oil revenues or royalties, borrowing entirely in domestic currency would also create currency mismatches.

macroeconomic factors are related to the currency composition of government bond markets when controlling for country size.[3]

Second, sovereigns can be constrained in issuing desired amounts of debt in domestic currency due to partial dollarization of the domestic economy. Dollarization is usually ascribed to decreasing monetary credibility, an argument put forth by e.g. Jeanne (2005). Low monetary credibility is then often an outcome of deficient independence of monetary policy and interference of fiscal policy with the way monetary policy is conducted. A lack of independent monetary policy implies higher inflation expectations and inflation volatility due to the possibility of the government trying to inflate the debt away (Togo, 2006; Burnside, 2003; Blinder, 1983; Sargent and Wallace, 1981). Monetary policy has long been considered an important determinant of debt composition in the literature on OECD countries - see e.g. Bohn (1990a) on debt currency composition and monetary policy, or Falcetti and Missale (2002) on debt currency composition and central bank independence.

The third explanation of the fact that sovereigns issue foreign currency debt is that this borrowing simply appears as less expensive when assuming that the FX risk is comparable to the interest rate risk or emphasizing the cost perspective in the cost/risk trade-off. Broner *et al.* (2007) offer an explanation of the emphasis of cost considerations in borrowing programs of emerging market economies. Such rather an opportunistic approach is not uncommon even among the OECD countries, see e.g. Wolswijk and de Haan (2005), where e.g. Austria, Finland and Sweden have more than 10 percent of sovereign debt denominated in foreign currencies. It is therefore the cost-risk perspective of the debt management authority, its debt management capacities, and the degree of government's preference for risk that are critical in this respect.

The fourth reason for a government not to issue as much domestic currency debt as possible, and rather opt for foreign-currency debt, can derive from its attempt to avoid crowding out domestic firms from domestic currency borrowing. This attempt

[3] More specifically, Claessens *et al.* find that economies with deeper domestic financial markets issue less foreign currency debt, and that increasing demand from foreign investors for foreign currency debt and less flexible exchange rate regimes are associated with more foreign currency issuance.

can stem from the recognition that in case the private sector has limited capacity to manage FX risk an elimination of the direct FX risk from a government's balance sheet can shift the FX risk to private sector's balance sheets and possibly increase the value of government's contingent liabilities.

The obvious solution to the problem of eliminating the FX risk from sovereign balance sheets is development of domestic government bond markets. This would entail gradual elimination of the constraints due to e.g. the lack of benchmark issues, institutional investors, and a liquid secondary market. Institutional factors are crucial in this respect, see. e.g. Burger and Warnock (2004), Santos and Tsatsaronis (2003), and Turner (2002), who stress among others the role of creditor-friendly policies and laws, sound debt management and public governance for domestic government bond market development. Since institutional factors show high persistence it is not likely that the sovereigns and debt managers in particular could eliminate FX risk inherent to their balance sheets in a rapid manner.[4] Moreover, the potential size of the domestic market might still not suffice for accommodating the demand for funds from the government and other entities in the domestic economy. The practical experience regarding relaxation of the domestic market's constraints in selected countries[5] is summarized in World Bank (2007).

This paper focuses on management of the FX risk in a government debt portfolio by choosing the optimal currency composition for the *unhedged* sovereign debt. The latter refers to an open, short position of a sovereign in a foreign currency. Such position occurs if the sovereign, after matching the financial characteristics of its asset and liabilities, is exposed to FX risk. The FX risk is usually considered one of the major risks in EMEs. It is also significantly higher than in industrialized economies, as the EMEs are more exposed to external shocks, such as those relating to the terms of trade and the cost of financing, in addition to financial contagion or natural disasters, see Caballero and Cowan (2006), and Claessens (2005). The importance of finding optimal currency benchmarks for sovereign debt portfolios has

[4] There are also transitional issues for many economies, relating to macroeconomic policies, that impact on exchange rates and overall monetary conditions.

[5] These are the 12 countries selected by the WB's Treasury for piloting its debt management diagnostic and associated advisory work.

been stressed by work of Caballero and Cowan (2006), Claessens (2006), and Bordo and Meissner (2006) who pointed out that although the FX risk in EMEs is high, the use of derivatives for hedging is limited and other types of hedging are costly (accumulation of FX reserves; foreign trade diversification). Although the use of derivatives among EMEs is increasing in recent years, their still deficient utilization in debt management stems from laws (rules) restricting instruments that can be used for debt management, a lack of leading examples, low staff capacity, and also a lack of markets for many EMEs currencies.[6] In this paper, we take a *long-term perspective*, as the debt managers should, in thinking about the foreign currency structure of sovereign debt portfolios, so as to minimize the FX risk of the benchmark portfolio and the use of add-on hedging products. What concerns the connection of our paper to existing literature, we acknowledge the fact that some countries have to borrow in foreign currencies due to the constraints they face. Taking off from this point we review approaches that one might want to use when trying to determine the optimal currency structure for sovereign debt, and discuss some issues inherent in these approaches. Hence, we do not attempt to contribute to the literature on the "original sin" or explain how currency mismatches come about, we take these circumstances as given.

Section two complements and follows up on the work of Bolder (2005) by reviewing recent analytical and numerical approaches that can be employed in choosing the optimal currency structure for sovereign debt. Section three discusses and points to some issues related to the concepts and parameters underlying those approaches. Section four concludes, and offers some policy implications and directions for future work.

[6] The limited use of derivatives also derives from the type and structure of the derivatives. Although, swapping one hard currency for another is readily available the feasibility of swapping a foreign hard currency into the domestic currency of a developing country can be limited due to much larger costs or constrained external convertibility of the domestic currency. Further, the structure of swaps can be seen as less convenient for budgeting purposes than e.g. options as the swap is settled in future whereas the premium for options is paid up-front.

2 Applicable Approaches

The current methods dealing with currency allocation of foreign debt applied by practitioners comprise but are not limited to (i) the minimum variance portfolio, (ii) matching the currency structure of FX reserves, foreign trade or capital flows, or (iii) relying on the promise of the national central bank to maintain a peg against chosen currency. Employing the minimum variance portfolio approach for the currency choice is limited in its success as this approach is aiming at optimal diversification and does not consider the link to government revenues and the time-varying ability of government to service its debt. Matching of currency structure of foreign reserves, foreign trade or capital flows goes beyond efficient diversification and embraces the idea of an asset and liability management (ALM) approach. Nevertheless, it is hard to see through the interplay of foreign trade and capital flows so that in practice the guidance is limited. Further, mimicking the structure of foreign reserves has its limitations due to the fact that most countries do not apply *de facto* free-floating exchange rate regime, intervene in the FX markets, and thus alter the free-float level and composition of FX reserves. A more sophisticated methods combining optimal portfolio allocation and the ALM approach have been developed the literature.

To discuss the substance and implications of the theory underlying the choice of currency denomination of the sovereign debt we review in this section selected analytical approaches that have been recently adopted to support or justify policy decisions and deliberations[7]. Namely, we extend the approaches proposed by Licandro and Masoller (2000) and Giavazzi and Missale (2004) for choosing optimal weights of domestic inflation indexed debt, domestic nominal debt and foreign currency debt in a sovereign debt portfolio (the benchmark portfolio). These two approaches were recently applied in the cases of Uruguay and Brazil, respectively. We amend these approaches so that they solve the problem of choosing the optimal weights for debts in several foreign currencies. The approaches of Licandro and Masoller (2000) and Giavazzi and Missale (2004) differ in several aspects. Licandro and Masoller consider

[7] Note that there are other approaches in spirit similar to those that we review in this paper see for instance Missale (1999, chapter 5) or Bohn (1990a).

tax smoothing as the government's (debt manager's) objective while Giavazzi and Missale employ stabilization of the debt-to-GDP ratio as the objective function in their setup. However, both approaches emphasize the role of the exchange rate risk (variation) and co-movements of domestic fundamentals and exchange rates as the key concepts in determining the optimal portfolio weights. In addition, Giavazzi and Missale find covariances between the returns (costs) of different debt instruments as being vital for determination of their weights in the debt portfolio, where positive covariance of the returns characterizes the related debt instruments as substitutes.

In a nutshell, the two approaches discussed below emphasize the importance of co-movements of the exchange rate with determinants of government revenues, negative correlation of an exchange rate with government expenditure, and the overall riskiness of a given foreign currency - the exchange rate's variance.

2.1 The Approach of Licandro and Masoller

In this section we extend the approach of Licandro and Masoller (2000)[8] to a multi-currency case. When deriving the optimal decision rule for choosing the currency structure of sovereign debt Licandro and Masoller set up a two-period problem[9] in which the government wants to smooth out the variation in future tax rates,

$$\min_{\theta, \boldsymbol{\theta}^*} E_t \left[\tau^2 / 2 \right], \tag{1}$$

where θ is the relative weight given to the local-currency nominal debt, $\boldsymbol{\theta}^*$ is a vector of relative weights given to different foreign-currency nominal debts, and τ is the tax rate. E_t represents expectations conditional on an information set available to agents at time t. The latter implies that all variables dated t are known with certainty in this problem whereas variables dated $t+1$ are uncertain (stochastic). The government is subject to the following constraints:

[8] Licandro and Masoller build on Calvo and Guidotti (1992), Goldfajn (1998) and Missale (1997) when setting up their optimization problem.

[9] We will denote the first and the second period in their problem as t and $t+1$, respectively.

$$
\begin{aligned}
\tau_{t+1} &= G_t \frac{(1+w_{t+1})}{(1+y_{t+1})} + B_t \frac{1}{(1+y_{t+1})} \times \\
& \left[\theta \frac{(1+R_t)}{(1+\pi_{t+1})} + \boldsymbol{\theta}^* \frac{(1+\boldsymbol{R}_t^*)(1+\boldsymbol{e}_{t+1})}{(1+\pi_{t+1})} + (1-\theta-\boldsymbol{\theta}^*)\left(1+R_t^I\right) \right] \quad (2)
\end{aligned}
$$

$$
(1+R_t) = (1+\boldsymbol{R}_t^*)(1+E_t\boldsymbol{e}_{t+1})(1+\boldsymbol{FP}) = \left(1+R_t^I\right)(1+E_t\pi_{t+1})(1+IP) \quad (3)
$$

$$
0 \leq \theta \leq 1, \text{ and } 0 \leq \boldsymbol{\theta}^* \leq 1 \quad (4)
$$

where G_t is the government expenditure-to-GDP ratio, w_t the growth rate of real government expenditure, y_t is the real GDP growth rate, B_t is the debt-to-GDP ratio, R_t is the interest rate on the local-currency debt, π_t is the inflation rate, $\boldsymbol{R}_t^*$ is a vector of interest rates on foreign-currency debts, $\boldsymbol{e}_t$ is a vector of exchange rates, and R_t^I is the real interest rate on the local-currency debt (inflation indexed debt). Constraint (2) states that the future tax has to be equivalent to future government expenditure plus future servicing costs of the government's debt all expressed as percentages of GDP. Constraint (3) is an arbitrage condition that makes the borrowing cost of nominal debt in local currency, nominal debt in foreign currencies, and inflation-indexed debt in local currency equivalent. For the arbitrage condition to hold two types of risk premia are introduced. $\boldsymbol{FP}$ is a vector of risk premia the government has to pay on local-currency nominal debt relative to nominal debt in foreign currencies. Similarly, IP is the risk premium the government has to pay on nominal debt in local currency relative to inflation-indexed debt in local currency. Expression (4) constrains the weights on different borrowing instruments to be between 0 and 1.

Licandro and Masoller solve the problem specified in equations (1)-(4) using the

Lagrangian method and arrive at the following solution

$$\begin{aligned}\theta\left(Var\left(\pi_t\right)+IP^2\right) &= \boldsymbol{\theta}^* B_t\left[\boldsymbol{Cov}\left(\pi_t,\boldsymbol{q}_t\right)+IP\left(\boldsymbol{FP}-IP\right)\right] \\ &+G_t\left(Cov\left(w_t,\pi_t\right)-Cov\left(y_t,\pi_t\right)\right) \\ &+G_tB_t\left(\boldsymbol{Cov}\left(\pi_t,\boldsymbol{R}_t^*\right)-Cov\left(\pi_t,y_t\right)\right)-G_t\boldsymbol{k}IP\end{aligned} \tag{5}$$

$$\begin{aligned}\boldsymbol{\theta}^*\left[\boldsymbol{Var}\left(\boldsymbol{q}_t\right)+\left(\boldsymbol{FP}-IP\right)^2\right] &= \theta B_t\left[\boldsymbol{Cov}\left(\pi_t,\boldsymbol{q}_t\right)+IP\left(\boldsymbol{FP}-IP\right)\right] \\ &+G_t\left(\boldsymbol{Cov}\left(y,\boldsymbol{q}_t\right)-\boldsymbol{Cov}\left(w_t,\boldsymbol{q}_t\right)\right) \\ &+G_tB_t\left(\boldsymbol{Cov}\left(y_t,\boldsymbol{q}_t\right)-\boldsymbol{Cov}\left(\boldsymbol{R}_t^*,\boldsymbol{q}_t\right)\right) \\ &+G_t\left(\boldsymbol{FP}-IP\right)\boldsymbol{k}\end{aligned} \tag{6}$$

where

$$\boldsymbol{k}=G_t\left(1+E_tw_{t+1}-E_ty_{t+1}\right)+B_t\left(1+E_t\boldsymbol{R}_{t+1}^*+E_t\boldsymbol{q}_{t+1}-E_ty_{t+1}+\boldsymbol{FP}-IP\right). \tag{7}$$

and $\boldsymbol{q}_t$ is a vector of real exchange rate defined as $q_t = e_t - \pi_t$ and $Var(.)$ and $Cov(.)$ denote variance and covariance conditional on information available at time t . We focus in our interpretations of the solution results on the choice among different currency denominations of foreign debt and refer the reader to the original work of Licandro and Masoller (2000) for interpretation of remaining parts of the solution, i.e. those for the domestic debt[10]. Our main quantity of interest is thus $\boldsymbol{\theta}^*$ a vector of weights put on foreign debt denominated in foreign currencies relative to local-currency inflation-indexed debt. Note that θ, i.e. the weight on local-currency nominal relative to inflation-indexed bonds, is still part of the solution for $\boldsymbol{\theta}^*$. However, we condition on the value of θ and take it as identical for all foreign currencies. Recall at this point that we seek the optimal allocation of debt that is *constrained* to be issued in foreign currencies. Further, this foreign currency

[10]Licandro and Masoller further simplify the solution by disregarding the possibility of issuing nominal debt in local currency. This is based on their empirical argument that local-currency nominal bonds are prohibitively costly due to low credibility of macroeconomic policies and past crises episodes. We keep the framework general and at the theoretical level.

debt cannot be naturally hedged and hedging using financial derivatives is costly or not available. Equation (7) states that the expectations about future developments in foreign interest rates and exchange rates determine the optimal currency structure of foreign debt. One can derive from equation (6) that the variance of an exchange rate $Var(q_t)$, and the covariances of an exchange rate with domestic fundamentals, here inflation π_t, output growth y_t, and growth of government expenditure w_t, are key in determining the optimal currency structure. Finally, there is also a role for the risk premia on the domestic nominal debt relative to the debt denominated in various foreign currencies, $\boldsymbol{FP}$.

All the later quantities are likely to vary across different currencies. The expectations about future foreign interest rates and exchange rates can be usually obtained from national central banks and market participants that put a considerable effort into producing successful forecasts.[11] The variances and covariances can be readily estimated from observed data, but we argue that those are critical for determining the optimal currency allocation of the foreign debt and that the estimations should respect the medium- to long-term perspective of debt managers. Regarding the foreign currency risk premia $\boldsymbol{FP}$ we claim that these are most likely endogenous to the exchange rate volatility $Var(q_t)$, as seen in (3), and the covariances of exchange rates with domestic fundamentals. In a nutshell, if the domestic economy converges to foreign economy A, i.e. the covariances of domestic and foreign fundamentals are generally positive, idiosyncratic shocks hitting the domestic economy will become less likely and the volatility of exchange rate, the most flexible price relating the domestic and foreign economies, will be decreasing and so will be the risk premium. On the other hand, a currency exchange rate with unrelated foreign economy B, will be more volatile and the foreign exchange premium high since all the shocks hitting the domestic economy will be idiosyncratic with respect to foreign economy B. We will discuss and elaborate on the role and estimation of the covariances and the exchange rate variance in section 3.

In addition, we will concentrate on the nominal costs of debt servicing and gov-

[11] For recent research on the predictive ability of economic fundamentals in exchange rate models see. e.g. Engel and West (2005).

ernment revenues and thus work with the nominal exchange rate. This is mainly due to difficulties with practical implementation of the real cost approach as the relevant deflator for each quantity of interest can differ, especially in high inflation environments. Further, the government budget is composed and planned in nominal terms.

2.2 The Approach of Giavazzi and Missale

Also the approach of Giavazzi and Missale (2004) can be readily extended to a multi-currency case. Giavazzi and Missale start from assuming that the objective of the government (the treasury) is to minimize the probability that debt stabilization efforts fail. In general, this can occur due to revenues falling short of the expected ones or the inability to cut expenditures. More formally, the government chooses the relative proportions of the nominal interest rate debt, s, foreign currency denominated debt, q, and domestic inflation index debt, h, in its total borrowing (debt) in order to

$$\min_{s,q,h} E_t \Pr\left[X > A_{t+1} - \triangle B_{t+1}^T\right] = \min_{s,q,h} E_t \int_{A_{t+1}-\triangle B_{t+1}^T}^{\infty} \phi\left(X\right) dx \tag{8}$$

where X and A_{t+1} are the uncertain and expected components of the fiscal adjustment, and B_{t+1}^T is the trend debt ratio. $A_{t+1} - \triangle B_{t+1}^T$ is therefore the planned reduction in the debt-to-GDP ratio, and $\phi\left(X\right)$ denotes the probability density function of the random variable X. In short, the government wants to minimize the probability that the planned reduction in the debt-to-GDP ratio, $A_{t+1} - \triangle B_{t+1}^T$, falls short of the actually needed reduction X which is uncertain (stochastic). While choosing s, q and h to achieve its objective the government is a subject to the following constraints.

First, the budget accumulation equation,

$$\triangle B_{t+1}^T = I_{t+1} B_t + \triangle e_{t+1} q B_t - S_{t+1}^T - \left(\triangle y_{t+1} + \triangle \pi_{t+1}\right) B_t, \tag{9}$$

where $I_{t+1} B_t$ are the interest rate payments, e_t is the log of the nominal exchange rate, S_{t+1}^T is the trend primary surplus, y_{t+1} is the log of output, and π_{t+1} is the inflation rate. The debt-to-GDP ratio (at market values) is thus determined by the interest payments on the outstanding debt, the size of the domestic currency depreciation, the trend in the primary surplus, and the growth of nominal GDP.

Second, the interest payments are equal to

$$I_{t+1}B_t = i_{t+1}sB_t + \left(R_t^* + RP_t\right)qB_t + \left(R_t^I + \pi_{t+1}\right)hB_t + R_t\left(1 - s - q - h\right)B_t \quad (10)$$

where i_{t+1} is the domestic interest rate, R_t^* is the foreign interest rate, RP_t is the risk premium, R_t^I is the real return on the inflation-linked bonds, and R_t is the long-term interest rate (of 1 year maturity). $(R_t^* + RP_t)$ is the approximation of the return on foreign currency bonds $(R_t^* + RP_t)(1 + \triangle e_{t+1})$, and $\left(R_t^I + \pi_{t+1}\right)$ is the total return on the inflation-indexed bonds.

Third, the ratio of the trend primary surplus to GDP, S_{t+1}^T, is uncertain because it depends on cyclical conditions and the inflation rate as follows

$$S_{t+1}^T = E_t S_{t+1}^T + \eta_y\left(y_{t+1} - E_t y_{t+1}\right) + \eta_\pi\left(\pi_{t+1} - E_t\pi_{t+1}\right). \quad (11)$$

When solving this optimization problem for s, q and h Giavazzi and Missale introduce several risk premia. Namely, these are the term premium on fixed-rate bonds, TP_t, that makes the terms structure of interest rates hold, i.e.

$$i_{t+1} - R_t = i_{t+1} - E_t i_{t+1} - TP_t, \quad (12)$$

the exchange rate risk premium, FP_t that completes the uncovered interest parity (UIP) condition

$$R_t^* + RP_t + e_{t+1} - e_t - R_t = e_{t+1} - E_t e_{t+1} - FP_t, \quad (13)$$

and the inflation risk premium, IP_t, that equalizes the interest payment on price-indexed and fixed rate bonds (the Fisher condition)

$$R_t^I + \pi_{t+1} - R_t = \pi_{t+1} - E_t\pi_{t+1} - IP_t. \quad (14)$$

When using the linear approximation[12] of $\phi(X)$ for a range of bad realizations of the fiscal adjustment, i.e. when $X > 0$, Giavazzi and Missale arrive at the following solution of the optimization problem described in (8)-(14). In the solution we use vector notation (in bold) to emphasize the extension to the multi-currency case:

$$\begin{aligned} s^* &= \frac{(n_y + B_t)}{B_t}\frac{Cov\left(y_{t+1}i_{t+1}\right)}{Var\left(i_{t+1}\right)} + \frac{(n_\pi + B_t)}{B_t}\frac{Cov\left(\pi_{t+1}i_{t+1}\right)}{Var\left(i_{t+1}\right)} - \boldsymbol{q}^*\frac{Cov\left(\boldsymbol{e}_{t+1}i_{t+1}\right)}{Var\left(i_{t+1}\right)} \\ &\quad -h^*\frac{Cov\left(\pi_{t+1}i_{t+1}\right)}{Var\left(i_{t+1}\right)} + TP_t\frac{\sqrt{2\,\mathrm{Pr}}}{1-\sqrt{2\,\mathrm{Pr}}}\frac{E_t\left(A_{t+1} - \triangle B_{t+1}^T\right)}{B_t Var\left(i_{t+1}\right)} \end{aligned} \tag{15}$$

$$\begin{aligned} \boldsymbol{q}^* &= \frac{(n_y + B_t)}{B_t}\frac{Cov\left(y_{t+1}\boldsymbol{e}_{t+1}\right)}{Var\left(\boldsymbol{e}_{t+1}\right)} + \frac{(n_\pi + B_t)}{B_t}\frac{Cov\left(\pi_{t+1}\boldsymbol{e}_{t+1}\right)}{Var\left(\boldsymbol{e}_{t+1}\right)} + s^*\frac{Cov\left(\boldsymbol{e}_{t+1}i_{t+1}\right)}{Var\left(\boldsymbol{e}_{t+1}\right)} \\ &\quad -h^*\frac{Cov\left(\pi_{t+1}\boldsymbol{e}_{t+1}\right)}{Var\left(\boldsymbol{e}_{t+1}\right)} + \boldsymbol{FP}_t\frac{\sqrt{2\,\mathrm{Pr}}}{1-\sqrt{2\,\mathrm{Pr}}}\frac{E_t\left(A_{t+1} - \triangle B_{t+1}^T\right)}{B_t Var\left(\boldsymbol{e}_{t+1}\right)} \end{aligned} \tag{16}$$

$$\begin{aligned} h^* &= \frac{(n_y + B_t)}{B_t}\frac{Cov\left(y_{t+1}\pi_{t+1}\right)}{Var\left(\pi_{t+1}\right)} + \frac{(n_\pi + B_t)}{B_t} - \boldsymbol{q}^*\frac{Cov\left(\boldsymbol{e}_{t+1}\pi_{t+1}\right)}{Var\left(\pi_{t+1}\right)} \\ &\quad -s^*\frac{Cov\left(\pi_{t+1}i_{t+1}\right)}{Var\left(\pi_{t+1}\right)} + IP_t\frac{\sqrt{2\,\mathrm{Pr}}}{1-\sqrt{2\,\mathrm{Pr}}}\frac{E_t\left(A_{t+1} - \triangle B_{t+1}^T\right)}{B_t Var\left(\pi_{t+1}\right)} \end{aligned} \tag{17}$$

where $Var(.)$ and $Cov(.)$ denote variance and covariance conditional on the information available at time t and Pr is the probability of a debt crisis as perceived by the government.

When interpreting the problem solutions we again focus on the part that deals with foreign currency debt[13], namely, optimal distribution of the foreign debt across different currencies. This implies that our main quantity of interest is $\boldsymbol{q}^*$, i.e. how much of the foreign debt should be denominated in a given currency. We again con-

[12] The linear approximation of $\phi(X)$ implies triangular probability density function equal to

$$\phi(X) = \frac{\overline{X} - X}{\overline{X}^2}$$

where $X > 0$ and $\overline{X}$ is the worst possible realization of the fiscal adjustment.

[13] We refer the reader to Giavazzi and Missale (2004) for further discussion of the solution results.

dition upon the other choice variables, i.e. s^* and h^*, in the sense that we treat them as if they were determined first, and then think about the elements of the vector $\boldsymbol{q}^*$. From the practical point of view this implies that the debt manager determines first the amount of local-currency debt that will be issued and then thinks about how to divide the foreign debt into planned currency denominations. We can observe in (16) that the key measures for determination of the optimal currency structure of foreign debt are the covariances of exchange rates with domestic fundamentals, namely output, $Cov\left(y_{t+1}\boldsymbol{e}_{t+1}\right)$, inflation, $Cov\left(\pi_{t+1}\boldsymbol{e}_{t+1}\right)$, and the interest rate, $Cov\left(\boldsymbol{e}_{t+1}i_{t+1}\right)$, the variance of exchange rates, $Var\left(\boldsymbol{e}_{t+1}\right)$, and the forward premia $\boldsymbol{FP}_t$. We again claim that $\boldsymbol{FP}_t$ can be to a large extent endogenized with respect to the covariances and the exchange rate variance. What we intend to discuss further in section 3 is the estimation of the covariances and how to look at them, and possibly a better way of employing the exchange rate variance in risk analysis. Our discussion is motivated by the fact that both measures are intended as predictors of future developments and that the perspective of a debt manager is medium- to long-term rather than short-term.

Before we proceed with a review of other related approaches it is worth pointing out that the reviewed theoretical approaches employ a number of simplifying assumptions so that their results may not apply as directly as implied by the models. In particular, these approaches assume bonds of one-period tenor which results in debt charges being determined entirely by contemporaneous values of relevant financial variables whereas in reality the debt charges will depend on both current and past values of relevant financial variables. The numerical approaches reviewed in the next section try to overcome this limitations, but at the cost of requiring much more detailed information and structure to be imposed. As consequence the range of insights one can acquire from the numerical approaches is limited by the latter.

2.3 Other Related Approaches

There are other, numerical approaches that deal with minimization of a government loss function while taking into account the structure of the government balance sheet and possible shocks the government may face. The numerical approaches do not provide an explicit analytical solution that would guide one conceptually in the choice of the currency structure for foreign debt, and thus serve as a base for a more judgemental analysis. These approaches provide one with "exact" numbers as an output from the numerical optimization encompassing simulations out of macroeconomic or econometric models and financial accounting. In order to make our literature review comprehensive we broadly group the recent numerical approaches according to the indicators they produce and briefly discuss their substance, insights and limitations. The indicators each numerical method produces constitute key inputs into the government's candidate objective function as their values should be minimized or maximized in accord with government preferences. We look at the following broadly specified indicators: (i) cost at risk (CaR) or value at risk (VaR), (ii) default probability based on specified government's debt-to-GDP default ratio, and (iii) default probability based on a distress barrier. Although the indicators ultimately look at the same risk we prefer to draw a slight distinction among the three groups with regard to the structures of the numerical approaches.

(i) The first group includes work conducted at, for instance, the Bank of Canada, see Bolder (2002, 2003); Danmarks Nationalbank, see Danmarks National Bank (2006); Korea, see Hahm and Kim (2004); the UK DMO, see UK DMO Annual Review (2006) and Pick (2005); Swedish DMO, see Bergstom and Holmlund (2000); or Peruvian Ministry of Economy and Finance, see Peru Ministry of Economy and Finance (2005). The main indicator of interest that concerns this group is the CaR measure. The latter expresses the risk as the percentile distance, typically between the 50th and 95th percentile of the simulated cost allocation[14]. The larger the percentile distance, the higher the risk of the government liability portfolio. The cost is typically measured as a ratio to GDP and can be expressed either in nominal or real terms. The standard parts of the simulation underlying the CaR computation is a model simulating the paths of the underlying economic/financial variables, such as interest rates, output growth, inflation, exchange rate etc., and a financial accounting framework for computation of the cost measure for each generated scenario. Since

[14]For a detailed exposition of this method see Danmarks Nationalbank (2000).

the financial accounting framework is deterministic and fixed for each model[15] the crucial part in this case is the model simulating the paths of the underlying economic variables. The work at the Bank of Canada, Danmarks Nationalbank focuses on simulation of the term structure of interest rates as the interest rate risk is of a major focus there. Korean model combines the concept of the efficient frontier and CaR penalties to derive the optimal benchmark portfolio for government debt. In the Peruvian model the process used to generate discrete-time observations of financial variables is derived from a multivariate continuous-time model. On the other hand, the Swedish model is a discrete-time model based on univariate autoregressive processes with regime switches characterizing the data generating processes (DGPs) of the economic variables. Finally, the UK model uses a reduced form of an implicit structural model in combination with regime switches to generate the likely paths of economic variables.

(ii) The second group includes work of e.g. Garcia and Rigobon (2004), or Xu and Ghezzi (2004). In general, this approach again uses simulated paths of economic variables and the debt structure to compute the corresponding government debt-to-GDP ratios. The numerous possible paths of the variables give rise to a distribution of the debt/GDP realizations at each point in time. The probability mass in the tail of these distributions cut off by the specified debt/GDP default threshold is then used as a measure of the probability that the government finances will be considered unsustainable at a given point in time. The two referenced approaches differ mainly in the aspect of using discrete- and continuous-time model specifications, respectively. Garcia and Rigobon (2004) use an unrestricted vector autoregressive (VAR) model to simulate the economic variables whereas Xu and Ghezzi (2004) use a system of Brownian motions as the basis for their simulation.

(iii) Gapen, Gray, Lim and Xiao (2005), Gray, Merton and Bodie (2005) work with an explicit measure of sovereign credit risk derived from a contingent claim analysis. The latter uses option pricing formulas to capture possible non-linearities in the relationships of interest. They start from determining a distress barrier analogous to

[15] The fixed structure can however differ across models depending on the selected level of aggregation of the borrowing instruments (categories).

the default threshold in (ii) which is to some extent endogenized in this framework. The distress barrier is determined based on seniority of the consolidated government's liabilities. More specifically, Gapen *et al.* (2005) assume that the distress barrier is equal to the book value of the short-term external debt plus interest and one-half of the long-term external debt[16]. The value of domestic currency liabilities is then modelled as an implicit call option on sovereign assets in this framework. In a nutshell, the distance to distress and the measure of sovereign credit risk is derived from the probability mass in the tail of the distribution for the value of assets at a given point in time. The tail containing probability of default is cut off by the distress barrier. The derived indicator corresponds to default (credit) risk and appears to well track the EMBI time-variations.

One can use the methods in (i)-(iii) to set up an optimization that would estimate the optimal weights on each currency considered for denomination of foreign debt. Proceeding along these lines one can take the calibrated model structures of the frameworks in (i)-(iii) as a set of constrains and minimize the value of a relevant indicator, say probability to default, while varying (optimizing over) the weights of individual currencies in the foreign debt portfolio. Such numerical approaches can provide a complementary insight to that of a more analytical or judgemental approaches so that the complex questions of debt managers are tackled using alternative modeling avenues. Although not so apparent as in the case of the analytical approaches the results from the numerical frameworks will hinge upon how the model structures that generate the economic variables are calibrated. The most crucial parameters in this respect will be again the covariances of variables or basic shocks generating those variables and their volatility. If the parameters are estimated then the assumption about conditional means of the modelled variables may considerably influence the estimates of shocks' covariances.

It is crucial that in practice the development of numerical models for supporting the decision-making process of debt managers follows a top-down route, i.e. responding to the questions raised at the managerial levels rather than introducing

[16] Although this approach treats fundamentally the distress barrier as fixed or deterministic (fixed for a certain period) from a practical point of view it can be also random and have a distribution.

unnecessary complexity and detail from the very start. In addition, given the limited capacity of debt management offices in developing countries we do not see the numerical procedures as the mainstream approach. Instead, we would suggest that forecasts of the expected paths for economic fundamentals, such as output growth, interest rates, inflation, exchange rates etc., including the associated confidence intervals are taken from the national central banks which have usually much higher capacity in this respect and put a considerable effort into forecasting of such variables. This can enable the debt managers to construct some baseline scenarios and perform a sensible scenario analysis. The use of macroeconomic predictions from the national central banks is also advisable in order to ensure consistency of macroeconomic policies and the assumptions on which they are based.

3 Issues with Current Approaches

Typical economic problems dealing with optimal allocation of sovereign debt portfolios imply that the optimal currency structure of foreign debt is to a large extent determined by magnitudes of covariances between domestic fundamentals and the considered exchange rates, and variances of the considered exchange rates - see section 2. In this section we aim to further discuss (i) the economic concept underlying the variances and covariances in the aforementioned economic problems, (ii) their empirical measures, and (iii) their role in risk analyses of sovereign debt portfolios.

3.1 Covariances of Exchange Rates and Domestic Fundamentals

Following the outlined structure we (i) discuss the economic concept underlying the role of the covariances in problems dealing with optimal currency denomination of foreign debt. The covariances appear in the solution results since the variables characterizing servicing costs of the debt and performance of the domestic economy are uncertain (random variables) and so is the economic structure relating all the economic variables in question. The main purpose of the covariances is thus to capture in a possible scope the structural links among the economic variables of interest. Essentially, one would like to capture a structure that is coherent in terms of available theory and stable over time. Nevertheless, especially in developing and emerging market economies the structural links between economic variables are evolving over time, and on occasions change substantially as the economies adjust their production, new economic policies are implemented, and the transition process to market economies is underway. Moreover, the covariances employed for characterization of the structural links among economic variables should reflect the perspective and decision (investment) horizon of a debt manager which usually cover the period of at least 3 to 5 years. The estimated covariances are thus intended to be sustained and forward looking, although most often higher frequency and historical data are used to estimate them.

This leads us to (ii) the discussion of empirical measures used to capture the covariances. There are essentially two ways how to proceed in this respect. First, one can work with the economic variables themselves or the underlying structural shocks driving those variables. Both approaches have their pros and cons. When working with the variables themselves one has to be careful about how the individual time-series components impact on the big picture one would like to obtain. The most basic characteristic of each variable over time would include a trend component (both deterministic and stochastic) and a cyclical (short-term) component[17]. The trend components will commonly dominate the cyclical components in estimations involving longer time-series although the cyclical components may deliver very different and sometimes more important story about the economic structure. The trend components mostly arise due to the transition and catching-up processes the developing countries are experiencing and its dominance is often valid not only from statistical but also an economic point of view.

Employing the economic variables themselves for estimation of covariances has the disadvantage of assuming that the conditional mean of the variables is constant and not putting any economic structure on the estimation. The latter refers to the

[17] We ignore seasonality in our discussion as this component is usually eliminated from the data before it is employed in analysis.

fact that ideally one would want to capture the underlying forces (structural shocks) that drive each variable and leave out the systematic component. The main challenge associated with this approach is the structural identification of the underlying shocks. Both Licandro and Masoller (2000) and Giavazzi and Missale (2004) do not apply structural identification of the underlying shocks and thus fail to capture the covariances of interest in their estimations. Licandro and Masoller (2000) use one-step ahead forecast errors from a VAR model to characterize the underlying shocks while Giavazzi and Missale (2004) use a reduced form[18] of an implicit structural model to do the same. In both cases the authors identify the structural shock as the estimated (forecast) error attached to a given variable, e.g. a demand shock as the residual from the output equation of their VAR. In fact, in both cases the identified shocks appear to be a combination of the structural shocks so that the estimated covariances among the shock do not provide the information the authors sought. It is essential to employ methods that allow structural identification of the underlying shocks in this respect such as structural VAR models or micro-founded models featuring rational expectations. However, in those models the structural shocks are often assumed to be uncorrelated for identification purposes so that any estimated empirical covariances should be zero to avoid contradictions with the *a priori* estimation assumptions.

Moreover, from an empirical point of view estimating the covariances between the exchange rates and the domestic fundamentals will most likely provide very little information that would help the debt manager decide on how to optimally allocate the foreign debt among various currencies. This is due to the fact that the covariances are usually very low or not statistically different from zero - see e.g. Bohn (1990b; Table 4, columns 2-3). This might be due to the failure of the fundamentals to predict exchange rates (Meese and Rogoff, 1983). On the other hand, Engel and West (2005) argue that although exchange rates cannot be predicted by economic fundamentals exchange rates themselves have some power in predicting the fundamentals. The

[18] One can object to this classification and claim that Giavazzi and Missale use a structural model. What is considered as structural model here is a system of equations in which the covariance matrix of endogenous variables is not simply an identity matrix, as in the case of Giavazzi and Missale where the structure would purely derive from lag selection. The classification used here is thus in line with the forms of structural VAR and New Keynesian models.

latter would suffice to produce at least some correlation between an exchange rate and the fundamentals that would guide debt managers in their decisions. What we see as a main problem is the use of relatively high frequency data and the *actual* exchange rate for estimation of the covariances between the model variables, here exchange rates and economic fundamentals, of the theoretical framework. This is due to the fact that the exchange rate observations carry substantial amount of noise[19] that blurs the information one strives to retrieve from the covariances. To illustrate this point consider the following example. Assume that the DGP for the exchange rate, s_t, is

$$s_t = \widetilde{s}_t + \varepsilon_{s,t} \tag{18}$$

where $\widetilde{s}_t$ is the fundamental (equilibrium) value of the exchange rate given by

$$\widetilde{s}_t = \pi_t - \pi_t^* \tag{19}$$

where π_t and π_t^* are the domestic and the foreign inflation, respectively, following simple AR(1) processes, i.e.

$$\pi_t = \rho\pi_{t-1} + \varepsilon_{AS,t} \tag{20}$$

$$\pi_t^* = \rho^*\pi_{t-1} + \varepsilon_{AS,t}^*. \tag{21}$$

Finally assume that the domestic output growth is generated as

$$y_t = \rho_y y_{t-1} + \varepsilon_{AS,t} + \varepsilon_{IS,t} \tag{22}$$

i.e. by a combination of the supply and demand shocks. We set $var(\varepsilon_{AS,t}) = var(\varepsilon_{IS,t}) = 1, var(\varepsilon_{AS,t}^*) = 0.5, var(\varepsilon_{s,t}) = 10$ using the common knowledge that *flexible* exchange rates are usually more volatile than other economic fundamentals; further, $\rho = \rho^* = 0.8$ and $\rho_y = 0.6$. We generate $10,000$ observations of the variables

[19] In the short run the trading in the exchange rate markets is not based on currencies' fundamentals and is driven largely by trends in the trade set by chartist. Fundamentalists come to trade only if there is a sizable adjustment needed to bring the exchange rate to its fundamental value see de Grauwe and Grimaldi (2005).

and compute the correlation of both the domestic output growth, y_t, and inflation, π_t, with the *actual* and *equilibrium* exchange rates, s_t and $\widetilde{s}_t$.

Table 1: Exchange Rates Simulation

	s_t	$\widetilde{s}_t$
y_t	0.0090	0.1208
π_t	0.0666	0.5003

The results illustrate our point that the large noise the actual exchange rate contains precludes the investigator to retrieve the desired information on structural links between the variables. Given this and the fact that the decision horizon of debt managers is medium- to long term one should employ some measure of an equilibrium exchange rate when trying to estimate the covariances between an exchange rate and domestic fundamentals to be used in the theoretical model. There are various concepts of the equilibrium exchange rate[20]. One of the most popular and suitable for EMEs would be the behavioral equilibrium exchange rate (BEER) discussed by e.g. Clark and MacDonald (1998). This concept is relatively simple and allows more empirically driven selection of the equilibrium exchange rate determinants.

Concerning (iii) the risk analysis, one should work, in addition to the concept of equilibrium exchange rate, with future scenarios that allow to bring in information on likely developments in the structure of foreign trade, intended utilization of comparative advantages, strategic diversification of exports and imports, possible financial markets integration and its impact on the currency structure of capital flows, or economic integration, such as accession to a trade or currency union. Further, working with equilibrium exchange rates allows the debt manager to carry out comprehensive risk analysis even when the local currency is pegged against certain foreign currency. Consider for example the Russian 1998 debt crises before which the government was happy to expose its balance sheet to potential movements in the RUB/USD rate since at that time the ruble was pegged against the dollar. How-

[20]NATREX, FEER, DEER, BEER etc. see MacDonald (2000) or Driver and Westaway (2005) for an overview.

ever, a severe misalignment of the RUB/USD exchange rate had developed and the 1998 debt crises was triggered by a currency crisis as the needed adjustment of the pegged rate towards the shadow market rate was exercised by the markets. More generally, if debt managers use the pegged rate in their analysis they focus entirely on risk minimization and ignore the covariance between the financing cost of foreign debt and domestic fundamentals of government primary balance altogether, as the covariance of domestic variables with a hard peg is essentially zero. The covariances can be deceiving under a peg in general, since the rate is rather sustained by central bank's interventions than market forces and fundamentals. Debt managers are thus interested in *relative* expected covariances of domestic fundamentals with exchange rates against candidate currencies for FX debt denomination. Employing equilibrium exchange rates[21] to perform such a relative comparison of the covariances across candidate currencies has the clear advantage of exercising an equal treatment.

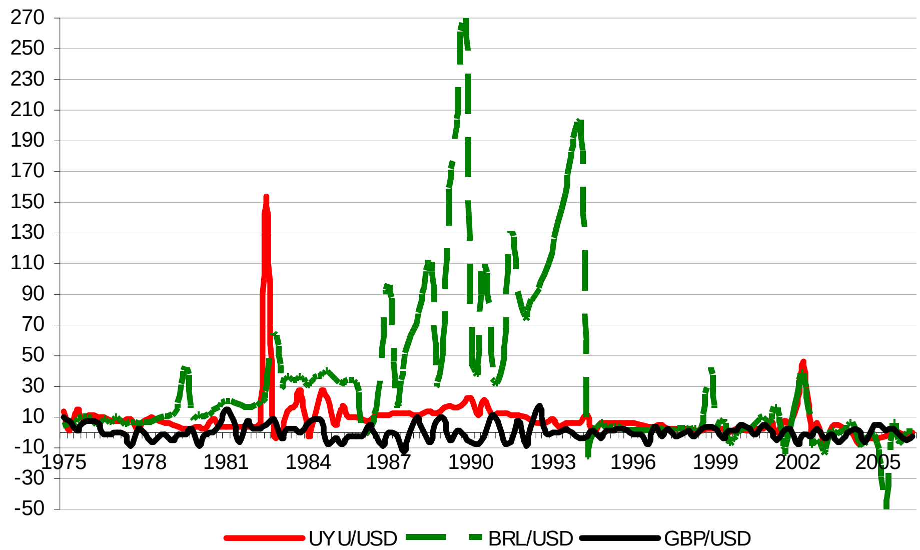
3.2 Exchange Rate Variance

(i) Another important parameter for the decision on currency denomination of foreign debt is the degree of uncertainty concerning future movements in exchange rates. This uncertainty is often approximated by estimated volatility (standard deviation) using historical data. Unlike the covariances that are intended to capture the economic structure and help in thinking about future trends in the economic development, i.e. the central tendency of variables, the exchange rate volatility is intended to capture the magnitude of likely deviations of the exchange rates from their future central tendencies. Similar to the covariances the exchange rate variance is intended to be forward-looking. Since the historical data of developing countries often cover relatively tranquil periods and periods of currency crises there appear to be large spikes in the data mostly in the direction of large depreciation. Apart from the possible isolated spikes in the exchange rate series of developing countries the

[21] The use of equilibrium exchange rate is probably not the ultimate solution due to the lack of a general agreement on a suitable model for equilibrium exchange rates. It is rather a step forward in the direction towards a more structural approach to FX risk management that is being currently developed in a companion paper.

series often show clustering of volatility in addition (see Figure (1)). This stems from the fact that one crisis is often followed by another, or triggers major restructuring or resetting of macroeconomic policies which themselves induce swings in the economic performance of a given country.

Figure 1: Historical Changes in Selected Exchange Rates



Note: Quarter-to-quarter percentage changes of the UYU/USD, BRL/USD and GBP/USD exchange rates over the period 1975Q1-2006Q3; calculated using the end-of-period local currency to USD markets rates from IMF's International Financial Statistics.

For determination of the currency benchmark for the foreign debt portfolio one requires an overall measure of riskiness of each currency, i.e. the overall measure of relevant exchange rate volatility. The estimation of volatility can be revised on a yearly basis and so can the currency benchmark for foreign-currency debt. However, one has to make a choice in regards to what period is to be covered in the estimation.

The estimation period can cover crises periods, different exchange rate regimes and macroeconomic policies. The estimation based on historical data can therefore be deceptive and one has to make some judgemental decisions when thinking about how risky each foreign currency is likely going to be in future. We illustrate how the choice of the estimation period matters by computing standard deviations for the three exchange rate series plotted in Figure (1) for different periods. The results are shown in Table (2) where uyu/usd, brl/usd and gbp/usd denote exchange rates of the Uruguayan peso, Brazilian real and British pound against the US dollar.

Table 2: FX Risk Estimation and the Time Span

	standard deviations of		
as of	$\triangle$ (uyu/usd)	$\triangle$ (brl/usd)	$\triangle$ (gbp/usd)
1975	14.9205	49.4310	5.1868
1985	7.6615	57.9931	4.9470
1995	7.6051	13.1201	3.3610

Lower cases denote logs and $\triangle$ is the first difference operator

Furthermore, if currency peg is exercised with respect to certain currency and not others the extremely low volatility in the case of the pegged rate can be deceptive since the central parity can be severely misaligned with respect to the equilibrium exchange rate that would restore external balance. If such a misalignment exists the potential realization of contingent liabilities in case of large depreciations constitutes risk that the debt manager is not taking into account when working with the *actual* as opposed to the *equilibrium* exchange rate. For the purpose of risk considerations we argue that one is better off working with some measure of equilibrium exchange rates as this ensures more conservative and comprehensive treatment of the FX risk and does not bias the relative magnitudes under different exchange rate regimes both across currencies and over time.

When it comes to (iii) the risk analysis, the current practise is to stress-test the scenarios involving possible future trends in domestic fundamentals and the exchange rates by generating disturbances from assumed Normal distributions of the relevant variables where the parameters of the distributions have been estimated on historical data. We do not think that this approach to stress testing of a debt portfolio or an entire balance sheet generates the insights one would like to acquire from such an exercise. Instead we would suggest following the argument started in the previous section on the covariances that also the variances employed to establish a currency benchmark for foreign debt are computed using some equilibrium measure of exchange rates. This addresses two possible misperceptions in estimations of expected exchange rate risk (volatility). First, a misperception could arise in regard to the choice of foreign debt denomination under fixed exchange rate regimes. If the debt managers rely on the promise of the national central bank to sustain the announced peg at all times they ignore the risk of mismanagement of the exchange rate regime, possible emergence of exchange rate misalignments and consequently speculative attacks. However, if equilibrium exchange rate is employed the debt managers get a better picture about the underlying forces behind medium-term exchange rate movements and their volatility relative to other foreign currencies. Second, if currency crises emerged and the exchange rate peg was abandoned one would not want to include into his expectations this period of excessive volatility and assume that the same event can occur under more flexible exchange rate regimes. Again, the equilibrium exchange rate can serve as a useful filter so that the expected volatility (risk) is measured consistently across candidate currencies. It is thus not the observed volatility *per se* that the debt managers want to get handle on, it is rather the *relative* expected volatility across exchange rates with respect to candidate currencies for FX debt denomination.

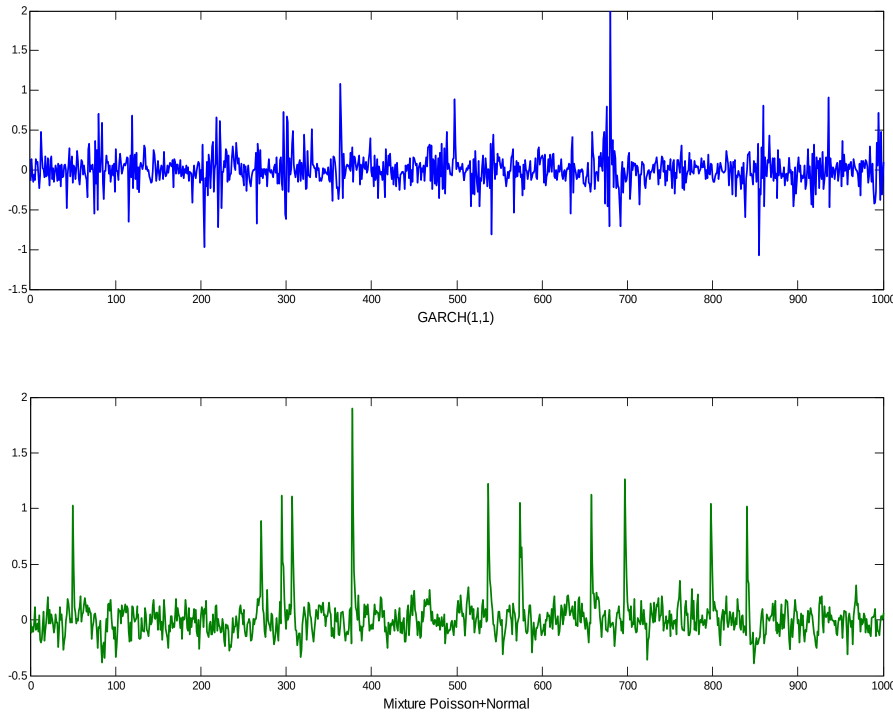
Further, the stress testing of a debt portfolio, if the capacity of the debt management office allows, could be performed by generating disturbances using more realistic processes.[22] What we mean by realistic are processes which can generate

[22] In the actual simulation two approaches can be adopted. The first one, a more simple, would involve just adding the suggested processes to univariate models of simulated variables. This is not different from shocking individual variables used to compute the baseline scenario e.g. for the expected future financing cost. The second approach involves covariance matrices of the variables being simulated or some endogenous transmission mechanism in which case the proposed "more realistic" processes for exchange rate shocks would be added as disturbances to the exchange rate equation in the model and transmitted through the system accoding to the assumed endogenous

infrequent spikes in the series of disturbances (the noise) and volatility clustering. Although such processes can be sometimes challenging to estimate we see them as much more comprehensive and insightful for the purpose of stress testing and risk analysis. Two classes of processes are at hand in this respect. Namely that of time-varying volatility or mixtures of distributions. The former class comprises DGPs such as generalized autoregressive conditional heteroscedasticity (GARCH) models, see Bollerslev (1986), or models of stochastic volatility, see e.g. Hull and White (1987). The latter class of processes features mixtures of distributions, see e.g. McLachlan and Basford (1988). Both classes of processes are well established in the financial econometrics literature and practice. We provide two simple examples to visually illustrate potential advantages of employing such processes. The upper panel of Figure (2) shows artificially generated series using a GARCH(1,1) model with t-distributed errors where the coefficients where set arbitrarily so that the generated series resembles patterns of the series in Figure (1). Similarly, the bottom panel of Figure (2) shows artificially generated series using AR(1) process with disturbances being a mixture of Poisson and Normal distributions; again all coefficients are set at arbitrary values.

structure.

Figure 2: Simulated Series of Exchange Rate Volatility



Note: Generated artificial series using a GARCH(1,1) model with Student's t-distributed errors, and an AR(1) process with disturbances being a mixture (a weighted sum) of Poisson and Normal distributions.

The two snapshots of processes of time-varying volatility and a mixture of distributions illustrate how the combination of volatility clustering and arrivals of infrequent large shocks can be incorporated into the risk analysis or more specifically the stress testing. In practice this process can be estimated on historical data or calibrated. Calibration might be preferred especially in the case of mixed distributions since estimation of distributions for infrequent large shocks can be challenging given the low number of observations on those events in typical real data samples.

3.3 The Covariances and the Variance

In this section we discuss possible interdependencies between the covariances of exchange rates with domestic fundamentals and the variances of exchange rates, the FX risk. In order to look into this relationship we take more macroeconomic approach. Consider first an exchange rate between a domestic and foreign currency and the shocks driving these currencies. Assume that the exchange rate is driven by domestic and foreign structural shocks where the exchange rate determination can be based on the UIP condition, the purchasing power parity or the monetary model of exchange rate determination. In either case the value of the domestic currency will rise with favorable domestic shocks (e.g. supply or demand shocks) and fall with unfavorable shocks. The same is true for the foreign currency value which rises with favorable shocks and fall with the unfavorable ones. Consider now three scenarios. (i) if the domestic and foreign economies are converging in the sense that the shocks hitting both the economies are becoming more correlated the relative value of the two currencies, the exchange rate, is becoming less volatile. This is because the value of domestic currency is rising at times when the value of the foreign currency is rising as well. (ii) if however the economies are not linked at all, shocks either in the domestic or foreign economy will be purely idiosyncratic and fully reflected in the relative price of the domestic and foreign currency, the exchange rate. (iii) if the shocks are in general negatively correlated the domestic economy is hit by an unfavorable shock and the domestic currency value is falling at times when the foreign economy is hit by a favorable shock such that the foreign currency is increasing in value, and *vice versa*. The relative value of the domestic and foreign currency will be significantly more volatile than in the case of (i) or (ii). In future research we plan to follow this avenue when proposing an alternative framework for FX risk management.

4 Conclusion

In this paper we have started from the observation that some countries are constrained to issue debt in foreign currencies and that debt managers have to choose or have the choice on the denomination of foreign debt. From the point of view of the World Bank's classification, IBRD countries have to choose the currency in which they want to borrow from the World Bank, whereas IDA countries have to borrow in SDRs. Nevertheless, even in the case of IDA countries the World Bank is not the sole lender and the countries often borrow from other sources in addition, such as bilateral donors. The latter often lend funds in certain currencies. If there are enough borrowing opportunities (donors) for an IDA country on similar terms the choice on the currency structure for external debt is effectively made.

The literature that would guide debt managers in their choice of the currency structure for foreign debt is rather inconclusive in its practical recommendations. In this paper, we have tried to review and discuss the relevant approaches that have recently appeared in the literature. The theoretical approaches point to the crucial role of exchange rate volatilities, and covariances of exchange rates and domestic fundamentals in determination of the optimal currency structure for foreign debt. We have thus focused on these two parameters and discussed their empirical measures.

We suggest based on the arguments discussed in this paper that the debt managers work with equilibrium exchange rates when employing the reviewed theoretical frameworks in practice. This suggestion is based on the fact that actual exchange rates carry a lot of noise which precludes the debt manager to get any useful guidance (information) from the data. Also, the concept of an equilibrium exchange rate is more consistent with the medium- to long-term perspective of debt managers. Further, both the covariances between domestic fundamentals and the exchange rates, and exchange rate volatility can be deceptive when a fixed exchange rate regime is being maintained since the risk of possible large depreciations of the domestic currency is not explicitly considered and the currency structure of the foreign debt thus not adequately diversified. Finally, when it comes to stress testing of a potential currency benchmark for foreign debt a scenario analysis considering likely future developments is often accompanied by a stochastic simulation that hinges on shocks generated from Normal distributions with constant volatility. We think that this approach does not provide the insights one would like to get from stress testing as the most important attributes of exchange rate shocks that one would like to capture are the possibility of infrequent large shocks and volatility clustering. Hence, we suggest that, for the purpose of stress testing, processes involving time-varying volatility or mixtures of distributions be adopted.

The direction for future work will include development of a simple framework(s) that EMEs can use for FX risk management, and which is based on the idea that exchange rates between currencies of economies that converge or co-move are less volatile, and therefore less risky, than the exchange rates between currencies of economies that are not linked at all or negatively correlated. While developing this simple framework for FX risk management one might also want to look into the role of diversification in this context.

References

[1] Bergstrom, P. Holmlund, A. (2000). A simulation model framework for government debt analysis. SNDO Working Paper. Swedish National Debt Office. Stockholm.

[2] Blinder, A.S. (1983). Issues in the coordination of monetary and fiscal policy. NBER Working Paper 982. Cambridge.

[3] Bohn, H. (1990a). Tax smoothing with financial instruments. *American Economic Review* 5, vol. 80, 1217-1230.

[4] Bohn, H. (1990b). A positive theory of foreign currency debt. *Journal of International Economics* 29, 273-292.

[5] Bolder, D.J. (2005). Measuring and managing foreign currency risk in a sovereign liability portfolio. manuscript, Financial Markets Department, Bank of Canada. Ottawa.

[6] Bolder, D.J. (2003). A stochastic simulation framework for the government of Canada's debt strategy. Bank of Canada Working Paper 2003-10. Ottawa.

[7] Bolder, D. J. (2002). Toward a more complete debt strategy simulation framework. Bank of Canada Working Paper 2002-13. Ottawa.

[8] Bollerslev, T. (1986). Generalized autoregressive conditional heteroscedasticity. *Journal of Econometrics*, 31, 307-327.

[9] Bordo, M.D., Meissner, C.M. (2006). The role of foreign currency debt in financial crises: 1880-1913 vs. 1972-1997. Working Paper, University of Cambridge.

[10] Broner, F.A., Lorenzoni, G., Schmukler, S. (2007). Why do emerging economies borrow short term? CEPR Discussion Paper 6249. London.

[11] Burger, J.D., Warnock, F.E. (2004). Foreign participation in local-currency bond markets. International Finance Discussion Paper, Board of Governors of the Federal Reserve System.

[12] Burnside, C. (2005). *Fiscal sustainability in theory and practice.* World Bank. Washington, D.C.

[13] Caballero, R.J., Cowan, K. (2006). Financial integration without the volatility. Working Paper, MIT.

[14] Calvo, G., Guidotti, P. (1990). Indexation and maturity of government bonds: an exploratory model. in *Capital markets and debt management.* Dornbusch R. and Draghi M. (eds.). New York University Press. New York.

[15] Chamon, M., Hausmann, R. (2005). Why do countries borrow the way they borrow? in Eichengreen B. and Hausmann R. (eds.). *Other people's money: debt denomination and financial instability in emerging market economies.* University of Chicago Press, Chicago.

[16] Claessens, S. (2006). Reasons for limited risk management and how to improve it. manuscript, University of Amsterdam. Amsterdam.

[17] Claessens, S. (2005). Taking stock of risk management techniques for sovereigns. World Bank Policy Research Working Paper 3570, (April). Washington, D.C.

[18] Claessens, S., Klingebiel, D., Schmukler, S.L. (*forthcoming*). Government bonds in domestic and foreign currency: the role of institutional and macroeconomic factors. *Review of International Economics.*

[19] Clark, P., MacDonald, R. (1998). Exchange rates and economic fundamentals: a methodological comparison of BEERs and FEERs. IMF Working Paper 98/67. Washington, D.C.

[20] Danmarks Nationalbank (2006). Danish government borrowing and debt 2006. Danmarks Nationalbank. Copenhagen.

[21] Danmarks Nationalbank (2000). Danish government borrowing and debt 2000. Danmarks Nationalbank. Copenhagen.

[22] Driver, R.L., Westaway, P.F. (2005). Concepts of Equilibrium Exchange Rates. Bank of England Working Paper Series 248.

[23] Eichengreen, B., Hausmann, R., Panizza, U. (2003). Currency mismatches, debt intolerance and original sin: why they are not the same and why it matters. NBER Working Paper 10036. Cambridge.

[24] Engel, C., West, K.D. (2005). Exchange rates and fundamentals. *Journal of Political Economy* 3, vol. 113, 487-517.

[25] Falcetti, E., Missale, A. (2002). Public debt indexation and denomination with independent central bank. *European Economic Review* 46, 1825-50.

[26] Gapen, M.T., Gray, D.F., Lim, C.H., Xiao, Y. (2005). Measuring and analyzing sovereign risk with contingent claims. IMF Working Paper 155. Washington, D.C.

[27] Garcia, M., Rigobon, R. (2004) A Risk Management Approach to Emerging Market's Sovereign Debt Sustainability with an Application to Brazilian Data. NBER Working Paper 10336. Cambridge.

[28] Giavazzi F., Missale, A. (2004). Public debt management in Brazil. CEPR Discussion Paper 4293. London.

[29] De Grauwe, P. , Grimaldi, M. (2005). Heterogeneity of Agents, transactions costs and exchange rates. *Journal of Economics Dynamics and Control* 29, 691-719.

[30] Gray, D.F., Merton, R.C., Bodie, Z. (2005). A new framework for analyzing and managing macrofinancial risks of an economy. C.V. Starr Conference on Finance and Macroeconomics, New York University.

[31] Goldfajn, I. (1998). Public debt indexation and denomination: the case of Brazil. IMF Working Paper 98/18. Washington, D.C.

[32] Hahm, J., Kim, J. (2004). Cost-at-Risk and Benchmark Government Debt Portfolio in Korea. manuscript, Yonsei University, Seoul.

[33] Hausmann, R., Panizza, U. (2003). On the determinants of original sin: an empirical investigation. *Journal of International Money and Finance* 22, 957-990.

[34] Hull, J., A. White (1987). The pricing of options on assets with stochastic volatilities. *Journal of Finance* 42, 281-300.

[35] Jeanne, O. (2005). Why do emerging economies borrow in foreign currency? in Eichengreen B. and Hausmann R. (eds.). *Other people's money: debt denomination and financial instability in emerging market economies.* University of Chicago Press, Chicago.

[36] Licandro F.G., Masoller, O.A. (2000). The optimal currency composition of Uruguayan public debt. Working Paper, Central Bank of Uruguay.

[37] MacDonald, R. (2000). Concepts to calculate equilibrium exchange rates : an overview. Deutsche Bundes Bank Discussion Paper 03/00. Frankfurt am Main.

[38] Meese, R.A., Rogoff K.S. (1983). Empirical exchange rate models of the seventies: do they fit out of sample? *Journal of International Economics* 14, (February), 3–24.

[39] McLachlan, G.J., K.E. Basford (1988). *Mixture Models: Inference and Applications to Clustering*. Marcel Dekker, New York. xi+253.

[40] Missale, A. (1999). *Public debt management*. Oxford Press. University of Oxford.

[41] Missale, A. (1997). Tax smoothing with price-index-linked bonds: a case study of Italy and the United Kingdom. in *Managing public debt*, De Cecco, Marcello, Pecchi, Lorenzo, and Piga, Gustavo (eds.). Edward Elgar. Cheltenham, UK.

[42] Peru Debt Department, Ministry of Economy and Finance (2005). Government debt risk analysis in Peru. manuscript prepared for "Designing Government Debt Strategies", World Bank Workshop. Washington, D.C.

[43] Pick, A. (2005). A simulation model for the analysis of the UK's sovereign debt strategy. manuscript, UK Debt Management Office. London.

[44] Santos, J., Tsatsaronis, K. (2003). The cost of barriers to entry: evidence from the market for corporate Euro bonds underwriting. BIS Working Paper 134. Basel.

[45] Sargent, T.J., Wallace, N. (1981). Some unpleasant monetarist arithmetic. *Federal Reserve Bank of Minneapolis Quarterly Review* 5, (Fall) 1-17.

[46] Togo, E. (2006). Coordinating public debt management with fiscal and monetary policies: an analytical framework. manuscript, BCFBD, World Bank.

[47] Turner, P. (2002). Bond markets in emerging economies: an overview of policy issues. in *The development of bond markets in emerging economies*. BIS Paper 11. Basel.

[48] UK Debt Management Office (2006). DMO Annual Review. London

[49] Wolswijk, G., de Haan, J. (2005). Government debt management in the euro area: recent theoretical development and changes in practices. ECB Occasional Paper, 25. Frankfurt am Main.

[50] World Bank (2007). Managing public debt: from diagnostics to reform implementation. IBRD/World Bank, Washington, D.C.

[51] Xu, D., Ghezzi, P. (2004). From fundamentals to spreads: methodology update. Global Markets Research. Deutsche Bank. Frankfurt am Main.