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An Alternative Framework for Foreign Exchange Risk Management of Sovereign Debt

Martin Melecky

The World Bank
Banking and Debt Management Department
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Abstract

This paper proposes a measure of synchronization in the movements of relevant domestic and foreign fundamentals for choosing suitable currency for denomination of foreign debt. The selection of explanatory variables for exchange rate volatility is motivated using a New Keynesian Policy model. The model predicts that not only traditional optimal currency area variables, but also variables considered by the literature on currency preferences, such as money velocity, should be relevant for explaining exchange rate volatility. The findings show that measures of inflation synchronization, money velocity synchronization, and interest rate synchronization can be useful indicators for decisions on the currency denomination of foreign debt.

This paper—a product of the Banking and Debt Management Department—is part of a larger effort in the department to improve management of foreign exchange risk in sovereign debt portfolios. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at mmelecky@worldbank.org.

An Alternative Framework for Foreign Exchange Risk Management of Sovereign Debt*

Martin Melecky†
Banking and Debt Management Department
World Bank

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†Banking and Debt Management Department, World Bank, 1818H Street NW, DC 20433, USA, email: mmelecky@worldbank.org

1 Introduction

Governments are often forced to issue debt in a foreign currency if their funding needs cannot be met by issuing debt denominated in the domestic currency due to various constraints. The latter can arise due to underdevelopment of domestic bond markets and an attempt to avoid crowding out domestic firms from domestic currency borrowing (Turner, 2002), the "original sin" (Eichengreen *et al.*, 2003), low monetary credibility (Jeanne, 2005), or an emphasis of the cost perspective in the cost/risk trade-off (Broner *et al,* 2007). A suitable tool for managing foreign exchange (FX) exposures is the use of financial (currency) derivatives. Although the use of derivatives among emerging market economies (EMEs) is increasing in recent years, their still low 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 (viz. Caballero and Cowan, 2006; Claessens, 2006; and Bordo and Meissner, 2006).[1] As a result governments can be exposed to FX risk by possibly having currency mismatches on their balance sheets. 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. I thus focus in this paper on management of the FX risk inherent in an *unhedged* government debt portfolio[3] while acknowledging the fact that some countries have to borrow in foreign currencies due to the constraints they face. Hence, I do not attempt to contribute to the literature on the "original sin" or explain how currency mismatches come about, I take these circumstances as given.

[1] 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.

[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.

[3] The latter refers to an open, short position of a sovereign in any foreign currency.

Based on the review of current approaches to FX risk management of government debt, provided in Bolder (2005) and Melecky (2007), solutions of typical economic problems dealing with optimal allocation of foreign currency debt across a spectrum of available currencies imply that the optimal currency structure of foreign debt is largely determined by relative magnitudes of variances of exchange rates, with respect to the considered foreign currencies, and covariances between domestic fundamentals and the exchange rates. In practice, however, not much guidance can be expected from the estimated covariances of nominal exchange rates with the domestic primary balance, see e.g. Bohn (1990a). This is due to, in general, existing inability of fundamentals to forecast exchange rates, see e.g. Engel and West (2005) and the high degree of noise incorporated in exchange rates (De Grauwe and Grimaldi, 2005; and Melecky, 2007) which precludes an analyst from extracting the sought after information from historical data. Also, the application of fixed exchange rate regimes precludes fair treatment across currencies in the decisions on currency denomination of foreign debt, and it is not clear why debt managers should rely on the promise of the central bank to sustain a peg to certain currency, especially in EMEs.

In this paper I propose a macroeconomic approach that one could use as a complement to existing finance (portfolio) approaches (see e.g. Bohn, 1990b; or Giavazzi and Missale, 2004) when choosing the currency structure of foreign debt. The underlying idea of this paper can be summarized as follows. Consider the bilateral exchange rate defined as the relative value of two currencies. Unfavorable shocks to domestic economy will result *ceteris paribus* in depreciation of the domestic currency relative to the foreign currency. The same is true for the foreign currency value which rises with favorable shocks and falls with the unfavorable ones. Consider now three scenarios. In the first scenario, if the domestic and foreign economies are converging in the sense that the shocks hitting both 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 foreign currency is rising as well. In the second scenario, 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. In the third scenario, 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 case (i) or (ii).

Along these lines I suggest to look across a spectrum of foreign currencies available for foreign debt denomination and pick those for which the domestic shocks and foreign shocks are positively correlated. Furthermore, it is not only the correlation of the shocks but their transmission into domestic and foreign fundamentals, that underlie the domestic and foreign currency values, what matters. I thus propose to use a measure of synchronization in the movements of relevant domestic and foreign fundamentals when choosing currency(ies) for denomination of foreign debt. The proposed approach can be linked to the literature on optimum currency areas (OCA; e.g. Bayoumi and Eichengreen, 1998), the literature on modelling the bilateral exchange rate volatility (e.g. Devereux and Lane, 2003) and the literature on currency preferences (e.g. Kingston and Melecky, 2007). In this paper the interplay between exchange rate volatility and exchange rate regimes is handled by using the exchange market pressure index (EMPI) following Eichengreen *et al.* (1996). Further, I attempt to frame the selection of explanatory variables for exchange rate volatility into a conventional New Keynesian Policy model that predicts that not only traditional OCA variables but also those considered by the literature on currency substitution and complementarity, such as money velocity, should be relevant for explaining exchange rate (EMPI) volatility.

The empirical analysis carried out in this paper focuses on middle-income countries (MICs) for three reasons. First, the high-income countries have usually well-developed domestic markets or are able to issue debt in their own currencies offshore, i.e. they do not suffer from the "original sin". On the other hand, LICs rely heavily on official assistance from multilateral and bilateral donors that is provided at concessional rates, and thus the choice of currency denomination for their debt is usually determined by the supply side.[4] Second, the size of shocks varies significantly for developed and emerging market economies, see e.g. Caballero and Cowan (2006). Third, the institutional frameworks of HICs, MICs and LICs can differ considerably and one may prefer to analyze a more homogenous group of countries that is constrained to borrow in foreign currency, and for which the required data are readily available.

Based on the empirical analysis in this paper, I find that countries trying to select a suitable currency for denomination of their sovereign debt can use the measures of inflation synchronization, money velocity synchronization and interest rate synchronization as indicators, in order to minimize the expected variance of their FX debt charges due to exchange rate volatility. However, if a country is increasingly using interest rate differentials to intervene in the foreign exchange markets the interest rate synchronization should be viewed as the main indicator when selecting the currency structure of foreign debt. If, on the other hand, the country is intervening in foreign exchange markets using its FX reserves to manage an exchange rate(s) the main indicator to be used is inflation synchronization.

The remainder of the paper is organized as follows. Section two presents theoretical motivation of the empirical framework used in the paper. Section three describes the data and estimation methodology. In section four, the empirical analysis is performed using regressions. And, section five concludes.

2 Theoretical Underpinning

By engaging in FX risk management, a debt manager, on behalf of its government, aims to minimize the impact of unexpected movements in relevant exchange rates on the fiscal budget through debt-service charges. The debt managers thus use their policy instrument, the currency composition of foreign debt, to minimize the FX risk

[4] For example, LICs borrowing from the World Bank (IDA) get their funds denominated in SDRs. And similarly, bilateral donors from e.g. Japan or Germany would lend in Japanese yens or euros, respectively.

of the government financing strategy.[5] The benchmark portfolio for foreign currency debt is then determined by complying with the risk preference of the government.

The debt manager's objective pertaining to FX risk of the public debt portfolio is specified in this paper in a way that relates to the tax-smoothing idea. Namely, the objective funtion focuses on minimizing the fluctuations in government budget finacing requirements to avoid disruptive changes in taxes, unexpected inflation, or government borrowing under unfavorable circumstances, i.e. at a very high cost. Therefore, formaly the debt manager aims to[6]

$$\min_{\mathbf{ex}_t} \mathbf{var}\left(F_t^{FX}\right) \tag{1}$$

where $\mathbf{ex}_t$ is a vector of chosen currency exposures, and F_t^{FX} represents the government financing requirements subjected to FX risk management. F_t^{FX} is the difference between the primary balance, PB_t, i.e. the difference between government revenues and non-financial expenditure, and debt-service charges exposed to FX risk, C_t^{FX}:[7]

$$F_t = PB_t - C_t^{FX} \tag{2}$$

Given the definition of C_t^{FX}, its movements will be determined by $\triangle \mathbf{s}_t$ the changes in the exchange rates to which the debt portfolio is exposed, assuming the debt manager issued a fixed-interest bond.[8] Using the formula for writing out the variance of a difference between two variables[9] we can express the objective function for FX

[5] Although the debt managers' objective is commonly expressed as minimizing borrowing cost subject to an acceptable level of risk, I emphasize the risk minimization perspective in the context of FX risk as its magnitude is potentially much higher than the difference in the borrowing cost across major currencies.

[6] I use here an objective function that focuses on the flows but the objective for this problem can be equivalently expressed while focusing on the stocks.

[7] I thus condition here on the foreign interest rate movements as these constitute a part of interest rate risk.

[8] For this to hold at all times the bond has to be perpetual.

[9] $\mathbf{var}(X-Y) = \mathbf{var}(X) + \mathbf{var}(Y) - 2\mathbf{cov}(X,Y)$

risk management as

$$\min_{\mathbf{ex}_t} \left[\mathbf{var}\left(PB_t\right) + \mathbf{var}\left(\triangle \mathbf{s}_t\right) - 2\mathbf{cov}\left(PB_t, \triangle \mathbf{s}_t\right)\right] \tag{3}$$

A debt manager's goal is thus to choose a currency for denomination of foreign debt for which the exchange rate *vis-a-vis* the domestic currency is relatively stable and the covariance of the exchange rate and the primary balance is strongly positive, all subject to cost considerations. In other words, a debt manager cannot influence either the variability of primary balance or of the exchange rates but can manage exposures to those unexpected variations. The debt manager selects the net exposure to a foreign currency by issuing net foreign debt in that particular currency. The exposure will vary as the domestic economy, including the exchange rate, and the government balance sheet are hit by various shocks. The covariance terms then represents the aim of the debt manager to select such a foreign currency for denomination of FX debt that at times primary balance is worsening the exchange rate with respect to the selected foreign currency is improving (appreciating).[10]

It is important for a debt manager to try to understand each term of equation (3) to effectively manage the exposure to FX risk. In this paper I will mainly focus on the second terms of equation (3), $\mathbf{var}\left(\triangle \mathbf{s}_t\right)$ for the following reason. In practice, it might be difficult to justify large fluctuations of debt-service charges due to exchange rate movements by pointing to a larger net primary balance or fiscal revenues arising at the same time. Although this is something economically correct the political economy constraints may be binding in this respect. Especially, public debt managers in developing countries therefore often choose to initially minimize the variance of the service charges on their debt portfolio while minimizing the long-term costs of their borrowing strategies. The volatility of debt-service charges due to excessive exchange rate risk are then captured by the exchange rate volatility. This paper thus tries to

[10] Each economy is likely to be influenced by exchange rate variations to a different extent, given its country-specific pass-through of exchange rates to the overall domestic price level and the degree of openness of the economy. Moreover, government revenues can be to a different degree dependent on income from tradables as opposed to non-tradables. This implies that the primary balance is affected by exchange rate variability to a different degree. The latter interdependencies between the primary balance and exchange rates are captured by the covariance term in equation (3).

provide some practical guidance in the first step of understanding the term $\mathbf{var}\left(\triangle \mathbf{s}_t\right)$ of equation (3).

Next, I will focus on identification of possible empirical indicators for selecting foreign currencies with relatively low volatility of exchange rates with respect to a domestic currency. I motivate and frame the selection of candidate explanatory variables for exchange rate volatility using the New Keynesian Policy model ala Clarida *et al.* (1999):

$$y_t = \rho_y E_t y_{t+1} - \delta_R \left(i_t - E_t \pi_{t+1}\right) + \varepsilon_t^{IS} \tag{4}$$

$$\pi_t = \rho_\pi E_t \pi_{t+1} + \lambda_y y_t + \lambda_m \varepsilon_t^{MD} + \varepsilon_t^{AS} \tag{5}$$

$$m_t = y_t - \gamma_i i_t + \varepsilon_t^{MD} \tag{6}$$

$$i_t = \phi_\pi \pi_t + \phi_y y_t + \varepsilon_t^{MP} \tag{7}$$

where y_t is the output growth, π_t is inflation, m_t is the deviation of real money balances from their steady state value, and i_t is the short-term, money market interest rate. ε_t's represent structural shocks with attached superscripts identifying their type. E_t stands for model consistent rational expectations conditional on information available to the agents at time t. The Greek letters with respective subscripts are coefficients.

Equation (4) is the familiar closed economy IS curve derived from a intertemporal optimization of consumption, where the current output growth increases in response to positive expectations about future output growth and a decline in the *ex ante* real interest rate.

Equation (5) is the Phillips curve describing the dynamics of inflation in a closed economy where I have augmented the traditional form of the Phillips curve to embed the response of inflation to disequilibriums in money (asset) markets along the lines of the empirically justified P-star model (see e.g. Hall *et al.*, 1991; Tatom, 1992; Garcia-Herrero and Vasant, 1998; Tsionas, 2001; or Nachane and Lakshmi, 2002). Inflation is thus assumed to increase if there are high inflation expectations, increasing output growth, and a positive deviation of money supply from money demand.

Equation (6) describes equilibrium in the money (asset) market where the real money demand increases in response to increasing output growth and declining interest rate. ε_t^{MD} then represents the deviation of money supply from the existing demand for money.

Equation (7) is a simple Taylor rule that characterizes the response of the central bank to inflation and output growth. Namely, the central bank is assumed to increase its policy instrument, the interest rate, in response to positive inflation and increasing output growth[11] to stabilize the economy. In order to ensure stability the central bank increases the nominal interest rate more than one-to-one with increasing inflation so that $\phi_\pi > 1$.

Consider a foreign economy that can be described using an identical model to the one described by equations (4)-(7) with the foreign counterparts being indicated by $*$. Further, assume that the exchange rate is given by the UIP condition, such that

$$E_t \triangle s_{t+1} = i_t - i_t^* \tag{8}$$

Equation (8) seems to imply that one should look at the synchronization of interest rates only, when assessing the exchange rate volatility. However, note that the solution for i_t (and also i_t^*) from the model in (4)-(7) can be expressed as a combination of the structural shocks $\varepsilon_t^{IS}, \varepsilon_t^{AS}, \varepsilon_t^{MD}$ and ε_t^{MP}. Therefore, one may want to look at the pairwise synchronization of corresponding shocks in the domestic and foreign economy. Equation (8) then implies that the variability of exchange rate is going to be relatively larger if the shocks of the domestic economy are highly asynchronous to those of the foreign economy. More precisely, this would be the case when the element-by-element correlations of the vector of domestic shocks and the vector of foreign shocks are generally negative. However, if the coefficients attached to the model variables differ for each country, i.e. $\rho_y \neq \rho_y^*$ etc., the transmission of the shocks would be different as well, and one has to take this into account.

It is therefore better to look into how strongly the movements in fundamental

[11] Although I use short-term output growth in this model instead of the output gap, which is traditionally included in this type of models, the short-term output growth merely represents a different type of detrending of GDP and should thus be seen as analogous to the traditional output gap measure.

variables, i.e. y_t, π_t, m_t and i_t, are synchronized across the two countries. Also, the restrictions of the exchange rate model in (8) would constrain us to focusing on synchronization of interest rates only, however, one would like to encompass in the analysis a wider range of exchange rate models such as the relative PPP:

$$\triangle s_t = \pi_t - \pi_t^* \tag{9}$$

or the portfolio model of exchange rates:

$$\triangle s_t \approx (m_t - m_t^*) - (y_t - y_t) + (i_t - i_t^*) \tag{10}$$

Looking across the examples of plausible exchange rate models provides a good motivation for including the synchronization measures of the movements in y_t, π_t, m_t and i_t into the exchange rate regression in an unconstrained manner. In the spirit of current open-economy New Keynesian models with a limited pass-through, see for instance Monacelli (2005), I add the terms of trade, t_t, to the vector of fundamental determinants of exchange rates.

When trying to understand and model the exchange rate variance one faces the problem that in practice the exchange rate variance is often to a varying degree managed for some currencies while for others is not. To overcome this I propose to consider another variable that could be used as a substitute for $\mathbf{var}(\triangle \mathbf{s}_t)$ and that captures the underlying variance in exchange rates. It is the exchange market pressure index, $EMPI_t$, which I define in accord with Eichengreen *et al.* (1996)[12]:

$$EMPI_t = \alpha \triangle s_t + \beta \triangle (i_t - i_t^*) - \gamma (\triangle rs_t - \triangle rs_t^*) \tag{11}$$

where $(i - i^*)_t$ is the interest rate differential, rs_t stands for FX reserves and α, β and γ are weights. The rationale for this index is as follows. If capital inflows reverse, the government can let the exchange rate depreciate. Alternatively, it can defend

[12] One can argue that capital controls should be brought into the equation as well to broaden the set of available tools for exchange rate management to reflect the practice. I leave this for future research due to low data availability and refer the reader to Edwards and Rigobon (2005) for useful insights.

the currency by running down reserves or by increasing interest rates (Sachs *et al.*, 1996). In addition, the index captures some important links to asset and liability management (ALM). First, adjustments in the interest rate differential are expected to affect government revenues and thus the primary balance. For instance, an increasing domestic interest rate will result in decreasing inflation and output growth, and thus government revenues. Similarly, depletion of FX reserves will result in a lower ability of a government[13] to explore natural hedges, or the only hedges which it has available if constrained from using currency derivatives. When determining the weights α, β and γ, the relative importance of the EMPI's components, I again follow Eichengreen *et al.* (1996) and set them so that all components are equally important. Namely, α, β and γ are given by the inverse of the median standard deviation of each components across countries. I use the median to avoid the leverage effect of huge outliers present in my sample, such as Argentina. Since the willingness of monetary policy to trade variability in one EMPI component for another most likely varies according to the circumstances of individual economies, see e.g. Hausmann *et al.* (2001)[14], I also use an unweighted average of the three components to construct an alternative measure of EMPI to check how robust the acquired results are to different values of α, β and γ. In the unweighted EMPI index α, β and γ are all set to one. By trying to understand the determinants of the EMPI variance across countries we try to understand why exposures to certain foreign currencies are relatively less risky for a given country.

In an attempt to acquire a better understanding of why exposures to certain

[13] Here the government is defined in a broader sense including also the central bank, a government's agent with separate objectives but working in coordination with the principal. Therefore, the broader ALM approach considers a consolidated balance sheet including the central government and the central bank.

[14] The authors point out the importance of the relative strength of the credit and balance sheet channels. While reductions in interest rate can have expansionary effect through the credit channel, the depreciation induced by the interest rate reduction can be contractionary through the balance sheet channel. Therefore, as the importance of foreign exchange debt increases the monetary authority can choose less exchange rate flexibility.

currencies could be less risky for a give country, I run the following regression:

$$\mathbf{stdev}\left(EMPI_t\right)_i = \mathbf{stdev}\left(X_t./X_t^*\right)_i \boldsymbol{\theta} + \xi_i \tag{12}$$

where $X_t \equiv [y_t, \pi_t, v_t, i_t, t_t]$ and v_t is money velocity, i.e. the money demand per unit of local currency. I use the money velocity instead of money balances themselves as the former appeared to be useful in identification of currency complements and currency substitutes[15], see e.g. Kingston and Melecky (2007) or Brittain (1981). $\mathbf{stdev}(\cdot)$ stands for standard deviation of a variable, $\boldsymbol{\theta}$ is a vector of estimated coefficients, ξ_i is an error term, and the subscript i denotes cross-section observations. ./ stands for element-by-element division. Next, I will discuss the data employed in the estimation and the estimation methodology.

3 Data and Estimation Methodology

3.1 Data

As described by equation (12) the dependent variable in my estimations is the standard deviation of the EMPI index. The standard deviations of $EMPI_t$ and $X_t./X_t^*$ (the ratios of the domestic and foreign fundamentals) are estimated over the period $1976 - 2006$ using annual data to maximize the coverage of countries. This implies that $t = 1...30$. The standard deviations are computed for a sample covering 44 middle-income countries[16], where I use as reference currencies the four most traded currencies, i.e. the U.S. dollar, the euro, the Japanese yen and the British pound. This implies that I have available 176 observations, such that $i = 1...176$.[17] In the

[15] Currency complements are defined as currencies with positively correlated money velocities, while currency substitutes have negatively correlated money velocities. Hence, in the case of currency complements the money demand is highly synchronized whereas in the case of currency substitutes highly asynchronous.

[16] Table (1) presents the list of countries included in the regression analysis.

[17] I also worked with a larger sample including high-income, middle-income and low-income countries (75 countries in total) and the results where quite similar. The reason for this is the fact that the MICs dominated in this larger sample.

actual regressions I work with two measures of the EMPI. The first one, as discussed above, is constructed by setting α, β and γ to the inverse of the median standard deviation of the relevant components across countries. The second, alternative measure is constructed as an unweighted average of the EMPI components outlined in (11), i.e. when setting $\alpha = \beta = \gamma = 1$. I use the two different measures of exchange rate volatility under interventions to ensure that the obtained results are reasonably robust to a simple change in government preferences regarding the applied tools for exchange rate management.

The exchange rate series of MICs' currencies *vis-a-vis* the U.S. dollar were obtained from the IMF's International Financial Statistic where I used the end-of-period values. The exchange rates for the EUR, JPY and GBP were calculated using cross-currency exchange rates where the synthetic USD/EUR exchange rate was taken from the DataStream. The interest rate series used are the money market interest rates from the IMF's International Financial Statistic where the pre-1999 data for the euro area were obtained from the Fagan *et al.* (2001) dataset. The data series of countries' official foreign exchange (FX) reserves and narrow money (money) were obtained from the IMF's International Financial Statistic where the series for the euro area was taken from the DataStream and the FX reserves series extended from 1997 back to 1976 using growth rates of German FX reserves.

The series of GDP growth rates and inflation were acquired from the GDF & WDI Central database of the World Bank where GDP growth rates and inflation for the euro area were taken from the Fagan *et al.* (2001) dataset and the DataStream, respectively. The money velocity was constructed as the ratio of nominal GDP and money obtained from the GDF & WDI Central database of the World Bank where the euro area equivalents were taken from the Fagan *et al.* (2001) dataset and the DataStream, respectively. The terms of trade series were taken from the GDF & WDI Central database of the World Bank and the terms of trade series for the euro area was constructed as an average of the euro area 12 countries.[18] The measures of synchronization of movements in y_t, π_t, v_t, i_t and t_t are based on ratios of the national

[18] I constructed also an average using the four biggest countries Germany, France, Italy and Spain but the series was very similar to that for the euro area 12 countries.

fundamentals with respect to those of the U.S., the euro area, Japan and the UK so that they correspond to the constructed EMPI *vis-a-vis* the U.S. dollar, the euro, the Japanese yen and the British pound.

Given that the vector of explanatory variables contains second moments of the constructed ratios one can expect that possible collinearities will be subdued. Nevertheless, for the sake of completeness I report the pairwise correlations in matrix (13) below, where $\sigma(\cdot)$ stands for standard deviation of a variable:

	$\sigma(y_t/y_t^*)_i$	$\sigma(\pi_t/\pi_t^*)_i$	$\sigma(v_t/v_t^*)_i$	$\sigma(i_t/i_t^*)_i$	$\sigma(t_t/t_t^*)_i$
$\sigma(y_t/y_t^*)_i$	1.000				
$\sigma(\pi_t/\pi_t^*)_i$	0.406	1.000			
$\sigma(v_t/v_t^*)_i$	−0.213	0.033	1.000		
$\sigma(i_t/i_t^*)_i$	0.187	0.106	−0.087	1.000	
$\sigma(t_t/t_t^*)_i$	0.096	0.070	0.033	0.011	1.000

(13)

* would indicate significance at the 5% level

The only sizable correlation appears between the synchronization measure of output and inflation, however, even this is not significant at the 5 % level.

3.2 Estimation Methodology[19]

When estimating equation (12) for the sample of 44 MICs, using 176 observations with respect to the U.S., the euro area, Japan and the UK, by OLS the regression residuals indicate presence of major outliers and these are those associated with Argentina. However, when observations on Argentina are given zero weights in the regression some other less obvious outliers emerge, e.g. in the case of Brazil. One

[19]The structure of my data set could allow to use a panel data estimation approach, provided that one can calculate the within-year variance of the exchange rates (EMPI index) employing e.g. monthly data, and is happy to use within-year variance which might be seen as a somewhat different concept of the dependent variable. Further, a low synchronization of two economies can manifest itself immediately or with a short or longer lag, and especially in an environment of managed exchange rates this manifestation can be delayed substantially, but not avoided as I try to argue. For this reason I prefer to use cross-country regression rather than panel regression, but I see the two approaches as complementing each other.

certainly does not want his regression to be contaminated by the presence of huge outliers but at the same time would like to retain some rigor in the procedure of detecting such outliers and giving weights to individual observations in the regression. For this purpose I employ the robust regression methodology.[20]

The robust regression falls into a general class of the M-estimators, see e.g. Wooldridge (2007). The objective function of the estimator can be expressed as

$$\sum_{i=1}^{n} \rho\left(e_i\right) = \sum_{i=1}^{n} \rho\left(y_i - \mathbf{X}_i'\mathbf{b}\right) \tag{14}$$

where the function $\rho(\cdot)$ determines the contribution of each regression residual e_i to the objective function, e.g. least-squares estimation sets $\rho(e_i) = e_i^2$.[21] Differentiating the objective function with respect to $\mathbf{b}$, defining $\psi = \rho'$ to be a derivative of ρ, and setting the partial derivatives to zero, produces a system of estimating equations for the coefficients of interest, $\mathbf{b}$:

$$\sum_{i=1}^{n} \psi\left(y_i - \mathbf{X}_i'\mathbf{b}\right)\mathbf{X}_i' = 0. \tag{15}$$

Define the weight function $w(e) = \psi(e)/e$, and let $w_i = w(e_i)$. Then the estimating equations may be written as

$$\sum_{i=1}^{n} w_i\left(y_i - \mathbf{X}_i'\mathbf{b}\right)\mathbf{X}_i' = 0. \tag{16}$$

The weights, however, depend upon the residuals, the residuals upon the estimated coefficients, and the estimated coefficients depend upon the weights. An iterative solution, called iterative reweighted least-squares, is therefore required, see Fox (2002). In this paper, I use the *Huber* and *Tuckey biweight* estimators where first iterations using the Huber estimator are performed and then followed up by

[20] There are other robust estimation methods with low breakpoints, such as quantile regressions or the least-trimmed squares regression, that can be used alternatively.

[21] A reasonable $\rho(\cdot)$ should have certain properties, see e.g. Fox (2002).

Tuckey biweight iterations.[22] The weights for the Huber estimator decline when $|e| > k$, while the weights for the Tuckey biweight estimator decline as soon as e departs from 0, and are 0 for $|e| > k$. The *tuning constant* k for the Tuckey biweight estimator is set in the estimations performed in this paper to $k = 4.685\sigma$. I follow Fox (2002) and estimate σ as $\widehat{\sigma} = \text{MAR}/0.6745$, where MAR is the median absolute residual from the OLS regression.

4 Estimation Results

4.1 The Main Regression

The estimation of equation (12) using the robust regression method outlined in section 3.2 produces the results reported in Table (2) below. The estimations are carried out using both the EMPI ala Eichengreen *et al.* (1996) and EMPI for which $\alpha = \beta = \gamma = 1$. I also include the OLS estimation results for comparison and as an indication of how well equation (12) fits the data.

When looking at the first two columns under the Robust Regression heading, the estimation results suggest that the degree of synchronization[23] in output growth is not significant in explaining the EMPI's standard deviation. The results thus contradict the findings of Devereux and Lane (2003) who find a significant positive effect of business cycles synchronization on exchange rate variance for industrialized countries and a significant negative effect on exchange rate variance for developing countries. Also, Bayoumi and Eichengreen (1998) find that increasing synchronization of output growth decreases the variability of EMPI using a sample of industrialized countries. The two latter studies however do not include a measure of synchronization for inflation in the vector of explanatory variables which I do. At least in the short run, a part of the output growth can be inflationary thus inducing possible colinearity between output growth and inflation that can be reflected in the respective measures

[22] For the exact functional forms see again Fox (2002).

[23] Recall at this point that higher synchronization of two economic variables implies lower standard deviation of the ratio of the two variables.

of synchronization, see matrix (13) for some support of this explanation. In addition, the effect of increasing foreign demand (GDP growth in the US, euro area, Japan and the UK) can be transmitted into the economies of MICs with a lag so that the co-movements of business cycles might be better captured with an appropriate lead/lag structure. However, this investigation is outside the scope of this paper.

Indeed, we find a significant effect of inflation synchronization on EMPI variability, however, signing of this impact implies that higher inflation synchronization increases EMPI variability. This result is somewhat puzzling and I will return to its explanation when estimating regressions for the EMPI components later in the paper. For now, it is useful to keep in mind that it is not only the variances of the exchange rate, the interest rate differential and the FX reserves differential that determine the variability of the EMPI. It is also the covariances between the latter three terms that enter into this determination and which could be quite influential in periods of external or financial turbulence, and crises in particular.

The synchronization of money velocities is emphasized by the literature on currency preferences as a useful tool for detecting currency substitutes and currency complements, see e.g. Brittain (1981) or Kingston and Melecky (2007). Since the demand for (the marginal utility of) currency complements is positively correlated one would expect the exchange rates between currency complements to be less volatile. In other words, higher money velocity synchronization should result in lower EMPI volatility. This hypothesis is supported by the estimation results from the regression of the weighted EMPI at the 10 % significance level. However, the results from the regression of the unweighted EMPI turn out to be insignificant with a negative sign, making the overall interpretation inconclusive.

On the other hand, the impact of interest rate synchronization on EMPI variability is estimated to be significantly positive. Higher synchronization in interest rate movements thus significantly reduces the variability of EMPI. This result holds strongly both in the case of the weighted and unweighted EMPIs. Given that I have used short-term interest rates the interpretation can be possibly extended to cover synchronization in monetary policy settings. However, one could claim that this result arises purely due to the presence of the interest rate differential in EMPI. I have therefore run two more regressions using an identical set of explanatory variables and weighted and unweighted EMPIs excluding the interest rate differential. The latter could be interpreted as allowing the monetary authority to intervene in the foreign exchange markets using only FX reserves. The results are reported in Table (3) and support the previous finding that the degree of interest rate synchronization is a good indicator of EMPI volatility. Nevertheless, one can see, in the last two columns under the OLS heading, that the fit of the two regressions dropped from about 0.95 to about 0.40 as a result of excluding the interest rate differential from the EMPIs.

Finally, the effect of the terms of trade synchronization on the EMPI variability is estimated to be insignificant with an unintuitive, negative sign. This may support the hypothesis that the relative effect of capital flows and associated fundamentals, as e.g. interest rates, on exchange rates is more important in the case of MICs than the effect of real external shocks such as the terms of trade, which are relatively more important for LICs.

4.2 Regressions of the EMPI Components

This section is intended to provide a more detailed insight into the results obtained from the main regression and facilitate better interpretation of the acquired general results especially that of the significant negative effect of the degree of inflation synchronization on EMPI variability. For this purpose I decompose the variance of

EMPI as follows[24]:

$$\begin{aligned}\mathbf{var}\left(EMPI_t\right) &= \mathbf{var}\left(\alpha\triangle s_t + \beta\triangle\left(i_t - i_t^*\right) - \gamma\left(\triangle rs_t - \triangle rs_t^*\right)\right) \\ &= \mathbf{var}\left(\alpha\triangle s_t\right) + \mathbf{var}\left(\beta\triangle\left(i_t - i_t^*\right)\right) + \mathbf{var}\left(\gamma\left(\triangle rs_t - \triangle rs_t^*\right)\right) \\ &\quad +2\mathbf{cov}\left(\alpha\triangle s_t, \beta\triangle\left(i_t - i_t^*\right)\right) - 2\mathbf{cov}\left(\alpha\triangle s_t, \gamma\left(\triangle rs_t - \triangle rs_t^*\right)\right) \\ &\quad -2\mathbf{cov}\left(\beta\triangle\left(i_t - i_t^*\right), \gamma\left(\triangle rs_t - \triangle rs_t^*\right)\right)\end{aligned} \quad (17)$$

What I am interested in is the impact of the explanatory variables, i.e. the vector $\mathbf{stdev}\left(X_t./X_t^*\right)_i$ where $X_t \equiv [y_t, \pi_t, v_t, i_t, t_t]$ on the individual components of the EMPI variance described in equation (17). I have therefore run six more regressions for the case of the weighted EMPI[25] and the results for the variance terms, i.e. $\mathbf{var}\left(\alpha\triangle s_t\right)$, $\mathbf{var}\left(\beta\triangle\left(i_t - i_t^*\right)\right)$, and $\mathbf{var}\left(\gamma\left(\triangle rs_t - \triangle rs_t^*\right)\right)$ are reported in Table (4), whereas the results for the covariance terms. i.e. $\mathbf{cov}\left(\alpha\triangle s_t, \beta\triangle\left(i_t - i_t^*\right)\right)$, $\mathbf{cov}\left(\alpha\triangle s_t, \gamma\left(\triangle rs_t - \triangle rs_t^*\right)\right)$, and $\mathbf{cov}\left(\beta\triangle\left(i_t - i_t^*\right), \gamma\left(\triangle rs_t - \triangle rs_t^*\right)\right)$ are presented in Table (5).

4.2.1 Exchange Rate Variance

The first column of Table (4) reports the results of the regression for $\mathbf{var}\left(\alpha\triangle s_t\right)$. It appears that output synchronization is not significant in explaining exchange rate volatility. This somewhat contradicts the results obtained by Devereux and Lane (2003, Table 4 and 5) who find that for a broad pool of developing countries increasing output synchronization significantly increases exchange rate volatility. Nevertheless, for other smaller pools of developing countries also Devereux and Lane find that output synchronization is rather insignificant in explaining exchange rate variability.

[24] I use here the formula from statistics for decomposition of the variance of a sum of three random variables, i.e.:

$$var\left(X+Y+Z\right) = var\left(X\right) + var\left(Y\right) + var\left(Z\right) + 2cov\left(X,Y\right) + 2cov\left(X,Z\right) + 2cov\left(Y,Z\right)$$

[25] I apply the decomposition to the weighted EMPI and report the estimation results for its components, but the estimation results for the unweighted EMPI 's components are identical only the estimated coefficients are scaled accordingly.

Also, the explanatory power of my regression and theirs appear to be very close and both rather low with R squared around 0.15.

Inflation synchronization, on the other hand, appears to be significant in explaining exchange rate variance. Namely, increasing inflation synchronization seems to significantly decrease exchange rate volatility. This result is consistent with the underlying theory unlike the analogous one obtained from the main regression for the EMPI.

Similarly, the money velocity synchronization is estimated to significantly affect the exchange rate volatility. The more synchronized are the movements in money velocities between two currencies the less volatile is their respective exchange rate. This result supports some implications of the literature on currency substitution and complementarity (see e.g. Kingston and Melecky, 2007), namely, that the exchange rate between currency complements should experience less volatility than the exchange rate between currency substitutes.

Also interest rate synchronization appears to be significant in explaining exchange rate volatility where higher interest rate synchronization for a given two currencies is predicted to decrease the volatility of their respective exchange rate.

Finally, synchronization of the movements in the terms of trade seems to be insignificant in explaining exchange rate volatility of MICs currencies with respect to the four major currencies. This finding again points in the direction of capital flows being much more influential than terms of trade changes when it comes to the determination of exchange rates and external balances of MICs.

I have also run the same regression as the one described in the first column of Table (4) with 25 % of the cross-section observations with the lowest exchange rate volatility eliminated from the sample. The results were very similar to those reported in Table (4) regarding both the coefficient estimates and the explanatory power of the regression. Only the effect of inflation synchronization on exchange rate volatility increased about ten times.

4.2.2 Variance of Interest Rate Differentials

When looking at how the underlying regression explains the EMPI component proportional to the volatility of the interest rate differential I estimate two regressions. The first one including the interest rate synchronization to see what could be happening in the main EMPI regression, and the second one excluding the interest rate synchronization to see how well the remaining variables explain the variability of the interest rate differential and whether their coefficient estimates change, since in the first regression the effect of interest rate synchronization on the volatility of the interest rate differential is almost tautological.

As we can see in the second and third columns of Table (4) the estimated effect of output synchronization on the interest differential volatility seems to be negative and significant. One can probably explain this effect through synchronization of the transmission mechanisms related to the credit channels in the domestic and foreign economies, i.e. managing output volatility implies higher interest rate volatility. The effect of inflation synchronization on the interest differential volatility appears to be negative in the regression including interest rate synchronization. This result supports the overall negative signing of inflation synchronization in the EMPI regression. However, when the interest rate synchronization is removed from the regression the coefficient on $\sigma\left(\pi_t/\pi_t^*\right)_i$ becomes significantly positive. The money velocity synchronization does not seem to significantly contribute to variability in interest rate differentials. Similarly, the terms of trade appear to be insignificant in explaining the volatility of interest rate differentials.

4.2.3 Variance of the Relative Changes in FX Reserves

The estimated results from the regression of the variability in the relative changes in FX reserves are reported in the last column of Table (4). The output synchronization is estimated to have a significantly negative effect on variability of the reserves differential. On the other hand, inflation synchronization appears to have a significant positive effect on this dependent variable. The remaining explanatory variables, i.e. the money velocity synchronization, the interest rate synchronization, and the terms of trade synchronization do not seem to be significant in explaining the variance of the relative changes in FX reserves. The most important finding here is that the effect of inflation synchronization is significantly positive while interest rate synchronization is insignificant in the regression.

4.2.4 The Covariance Terms

Table (5) reports the estimation results from regressions of the covariance terms on the vector of employed explanatory variables. Looking across all three regressions one can observe that the effect of output synchronization on the covariance terms is insignificant in the case of the covariance of exchange rates and interest rate differentials, $\mathbf{cov}\left(\alpha\triangle s_t, \beta\triangle\left(i_t - i_t^*\right)\right)$, and the covariance of interest rate differentials and relative movements in FX reserves, $\mathbf{cov}\left(\beta\triangle\left(i_t - i_t^*\right), \gamma\left(\triangle rs_t - \triangle rs_t^*\right)\right)$, and significantly negative in the case of the covariance of exchange rates and relative movements in FX reserves, $\mathbf{cov}\left(\alpha\triangle s_t, \gamma\left(\triangle rs_t - \triangle rs_t^*\right)\right)$.

The impact of inflation synchronization on the covariance terms is significant in all three cases, however, signing of these effects varies. For the covariance of exchange rates and interest rate differentials, and the covariance of interest rate differentials and relative movements in FX reserves the coefficients on the inflation synchronization are significantly negative, where the coefficient corresponding to the former regression is of substantially higher magnitude than other coefficients on the inflation synchronization measure in the remaining regressions for the EMPI components. On the other hand, in the regression for the covariance of exchange rates and relative movements in FX reserves the effect of the inflation synchronization is significantly positive.

The measure of money velocity synchronization appears to be consistently insignificant in explaining the covariance terms, i.e. the covariance of exchange rates and interest rate differentials, the covariance of exchange rates and relative movements in FX reserves, and the covariance of interest rate differentials and relative movements in FX reserves.

On the other hand, synchronization of interest rates is found to have a positive effect on all three covariance terms, the covariance of exchange rates and interest rate differentials, the covariance of exchange rates and relative movements in FX reserves, and the covariance of interest rate differentials and relative movements in FX reserves. However, only in the case of the first and third covariance terms the coefficients turn out to be significant. The significant coefficient attached to interest rate synchronization in the regression for the covariance of exchange rates and interest rate differentials is much higher in terms of its magnitude than the coefficients on interest rate synchronization in the remaining regressions for the EMPI components.

Finally, the effect of the terms of trade synchronization is estimated to be significant only in the case of the covariance of exchange rates and relative movements in FX reserves. In the latter case, the effect of the terms of trade synchronization appears to be positive and significant at the 10 % level.

4.3 Summary of the Estimation Results

It is useful at this point to summarize the detailed estimation results obtained from the regressions for the EMPI components and relate those to the estimation results from the main regression. From the main regression we have inferred that the effect of interest rate synchronization on EMPI variability is significantly positive by regressing EMPIs including and excluding the interest rate differential. The significantly positive effect of the interest rate synchronization was confirmed in the regressions for the EMPI components. Most importantly, the significantly positive effect of the interest rate synchronization held also in the regression of the exchange rate volatility on the employed vector of explanatory variables. In addition, an interesting finding is that the interest rate synchronization appears to be insignificant in all EMPI components regression where the relative movements in FX reserves are involved.

Further, I find a significant negative effect of the inflation synchronization in the main regression that was viewed as puzzling. The regressions of the EMPI components have been very insightful in explaining this puzzling result from the main regression. Namely, I have found that the estimated negative coefficient on inflation synchronization in the main regression is most likely attributable to the significant negative effect of inflation synchronization on the covariance between the exchange rates and interest rate differentials, on the covariance between the interest rate differentials and relative movements in FX reserves, and also on the variability of the interest rate differential. On the other hand, the effect of inflation synchronization on exchange rate variance itself is significantly positive and consistent with the underlying theory.

In addition, I find the synchronization of money velocities to be highly significant in explaining the exchange rate volatility. The increasing money velocity synchronization between two currencies, that identifies currency complements, significantly decreases the variability of the respective exchange rate.

Based on these results I draw the following preliminary conclusions. Namely, that countries trying to select a suitable currency for denomination of their sovereign debt can use the measures of inflation synchronization, money velocity synchronization and interest rate synchronization as indicators, in order to minimize the expected variance in their FX debt charges due to exchange rate volatility. However, if a country is increasingly using interest rate differentials to intervene in the foreign exchange markets the interest rate synchronization should be viewed as the main indicator when selecting the currency denomination of foreign debt. If, on the other hand, the country is intervening in foreign exchange markets using its FX reserves to manage an exchange rate(s) the main indicator to be used is the inflation synchronization.

5 Conclusion

In this paper I have made an attempt to propose a macroeconomic framework for management of foreign currency debt that can be used in conjunction with or as an alternative to the existing financial (portfolio) approaches to selecting suitable currencies for foreign debt denomination. The proposed framework is aimed at selecting such a currency for denomination of foreign debt that will minimize the variability of debt charges on foreign exchange debt. For practical purposes the default variable that I was trying to explain was the exchange market pressure index. The latter controls for the possibility of exchange rate management using interest rate differential and foreign exchange reserves when one tries to model the shadow exchange rate between a pair of currencies equivalent to free floating exchange rate. Such controlling is important since changes in the domestic interest rate affect domestic output and inflation and thus government revenues, and because fluctuations in foreign exchange reserves create uncertainty about available natural hedges for foreign debt. The vector of explanatory variables used in the empirical regressions was motivated using a New Keynesian policy model which predicts that not only traditional optimum currency area variables but also variables considered by the literature on currency preferences, such as money velocity, should be relevant for explaining exchange rate (exchange market pressure index) volatility.

I find that countries trying to select a suitable currency for denomination of their sovereign debt can use the measures of inflation synchronization, money velocity synchronization and interest rate synchronization as suitable indicators in order to minimize the variance in their foreign exchange debt charges due to exchange rate volatility. However, if a country is increasingly using interest rate differentials to intervene in the foreign exchange markets the interest rate synchronization should be viewed as the main indicator when selecting the currency denomination of foreign debt. If, on the other hand, the country is intervening in foreign exchange markets using its FX reserves the main indicator to be used is the inflation synchronization.

The future work on the macroeconomic approach to foreign exchange debt management should focus on incorporating the role of covariances between the government primary balance and exchange rates, from the flow perspective. Or equivalently, from the stock perspective, it can focus on incorporating the covariances between the net exposures in individual currencies and the relevant exchange rates into the present framework. Further, the set of considered indicators can be broadened to include other macroeconomic fundamentals, e.g. the term structure of interest rates.

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Algeria	Czech Rep.	Jordan	Namibia	St.Vinc.& Grenad.
Argentina	Dominica	Latvia	Panama	Swaziland
Armenia	Dominican Rep.	Lithuania	Paraguay	Thailand
Bolivia	El Salvador	Malaysia	Philippines	Tunisia
Brazil	Estonia	Maldives	Poland	Turkey
Bulgaria	Georgia	Mauritius	Russian Fed.	Ukraine
Chile	Grenada	Mexico	Slovak Rep.	Uruguay
Colombia	Guatemala	Moldova	South Africa	Venezuela, RB
Croatia	Indonesia	Morocco	Sri Lanka	

Table 1: Countries Included in the Regression Analysis

Dependent Variable $\text{stdev}(\text{EMPI}_t)_i$	Robust Regression (weighted)	Robust Regression (unweighted)	OLS (weighted)	OLS (unweighted)
$\sigma(y_t/y_t^*)_i$	-36.54	156.8	-183.0	83.48
	(0.35)	(0.30)	(1.13)	(0.14)
$\sigma(\pi_t/\pi_t^*)_i$	-11.43	-37.22	-11.05	-23.46
	(4.86)***	(3.15)***	(1.74)*	(1.22)
$\sigma(v_t/v_t^*)_i$	42.47	-34.57	4.44	-167.1
	(1.68)*	(0.26)	(0.11)	(1.10)
$\sigma(i_t/i_t^*)_i$	4.37	12.92	4.31	12.82
	(174.2)***	(71.89)***	(12.91)***	(6.70)***
$\sigma(t_t/t_t^*)_i$	-21.34	-4.17	22.36	120.1
	(1.20)	(0.05)	(0.61)	(0.94)
constant	-940.6	$-2812.$	316.7	$-5421.$
	(0.83)	(0.49)	(0.22)	(1.10)
R squared	na	na	0.9631	0.9350
No. of Obs.	174	174	176	176

Table 2: Estimation Results - EMPI volatility regressions

Dependent Variable $\text{stdev}(\text{EMPI}_t^{IRD})_i$	Robust Regression (weighted)	Robust Regression (unweighted)	OLS (weighted)	OLS (unweighted)
$\sigma(y_t/y_t^*)_i$	-0.88	-21.2	14.94	677.9
	(2.50)**	(2.87)***	(0.96)	(0.99)
$\sigma(\pi_t/\pi_t^*)_i$	0.03	0.74	0.13	5.20
	(4.05)***	(4.45)***	(0.51)	(0.46)
$\sigma(v_t/v_t^*)_i$	-0.04	-1.13	-5.29	-232.6
	(0.47)	(0.61)	(1.08)	(1.07)
$\sigma(i_t/i_t^*)_i$	0.001	0.015	0.07	2.95
	(3.54)***	(3.39)***	(1.39)	(1.38)
$\sigma(t_t/t_t^*)_i$	0.05	1.41	1.97	86.04
	(0.84)	(1.10)	(0.83)	(0.82)
constant	9.23	218.2	-175.6	$-7936.$
	(2.37)**	(2.69)***	(1.32)	(1.35)
R squared	na	na	0.3984	0.3960
No. of Obs.	173	173	176	176

Table 3: Estimation Results - EMPI (no IRD) volatility regressions

Dependent Variable	Robust Regression			
stdev$(\text{EMPI}_t)_i$ components	$\sigma(\triangle s_t)_i$	$\sigma(\triangle (i_t - i_t^*))_i$	$\sigma(\triangle (i_t - i_t^*))_i$	$\sigma(\triangle rs_t - \triangle rs_t^*)_i$
$\sigma(y_t/y_t^*)_i$	-0.009	-152.98	-5.913	-0.164
	(0.09)	(0.68)	** (2.02)	** (2.31)
$\sigma(\pi_t/\pi_t^*)_i$	0.002	-11.46	0.179	0.005
	*** (10.06)	** (2.23)	*** (2.67)	*** (2.87)
$\sigma(v_t/v_t^*)_i$	0.072	65.59	-0.523	-0.012
	*** (2.85)	(1.15)	(0.70)	(0.67)
$\sigma(i_t/i_t^*)_i$	0.001	5.05	na	0.001
	*** (27.3)	*** (86.0)	na	(0.15)
$\sigma(t_t/t_t^*)_i$	-0.020	-16.42	0.084	0.017
	(1.13)	(0.42)	(0.17)	(1.38)
constant	1.023	-874.19	68.95	1.852
	(0.92)	(0.35)	** (2.13)	** (2.37)
No. of Obs.	176	174	176	173
OLS R squared	0.1422	0.9377	0.6410	0.3939

Table 4: Estimation Results - Break-Down EMPI volatility regressions, part I

Dependent Variable	Robust Regression		
stdev$(\text{EMPI}_t)_i$ components	$\sigma(s_t; i_t - i_t^*)_i$	$\sigma(s_t; rs_t - \triangle rs_t^*)_i$	$\sigma(i_t - i_t^*; rs_t - \triangle rs_t^*)_i$
$\sigma(y_t/y_t^*)_i$	312.2	-2.521	106.5
	(0.30)	*** (3.39)	* (1.82)
$\sigma(\pi_t/\pi_t^*)_i$	-152.5	0.074	-4.787
	*** (6.43)	*** (4.38)	*** (3.60)
$\sigma(v_t/v_t^*)_i$	326.2	-0.229	6.808
	(1.24)	(1.22)	(0.46)
$\sigma(i_t/i_t^*)_i$	57.3	0.001	0.372
	*** (169.5)	(0.72)	*** (10.90)
$\sigma(t_t/t_t^*)_i$	-238.2	0.215	-15.17
	(1.32)	* (1.67)	(1.50)
constant	-16553	16.96	-461.3
	(1.45)	** (2.07)	(0.72)
No. of Obs.	173	173	173
OLS R squared	0.9217	0.3945	0.3939

Table 5: Estimation Results - Break-Down EMPI volatility regressions, part II