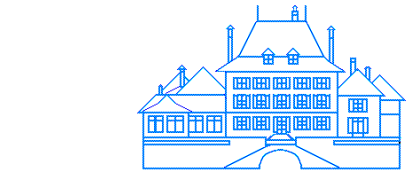

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Understanding Reserve Volatility in Emerging Markets:

A Look at the Long-Run.

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Understanding Reserve Volatility in Emerging Markets:

A Look at the Long-Run

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Abstract

In this paper, we examine long-run determinants of cross-country variation in reserve volatility for 30 emerging market economies from 1973 to 2000. Reserve holdings and openness are found to be the most important explanatory variables of reserve volatility. The empirical results are robust for a range of control variables, including monetary variables, the degree of financial development, and the level of indebtedness. We view these results as establishing interesting stylized facts that may be helpful in evaluating reserve volatility as a crisis indicator.

Keywords: Reserve Volatility, Emerging Markets, Openness
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Introduction

The importance of reserve volatility arises frequently in policy discussions of international finance. Aizenman and Marion (2002) argue that a high level of reserve volatility can reduce international credit if such information signals a more pessimistic outlook about a country's ability to fulfil its debt obligations. Reserve volatility is also used to identify events or regimes. Kaminsky and Reinhart (1999) construct an index of currency market turbulence measured as a weighted average of exchange rate changes and reserve changes. In their index, reserve volatility enters as a weight for reserve loss. Alternatively, Calvo and Reinhart (2002) and Levy Yeyati and Sturzenegger (1999) rely on reserve volatility to determine whether the official classifications of a country's exchange rate arrangement provides an adequate representation of actual country practice.

Until now, empirical studies using reserve volatility concentrate on the indicator properties of reserve volatility as a signal to identify specific events in the short run. When reserve volatility for a particular country exceeds an exogenous threshold, the defined indicator model signals an exchange rate crisis or a debt crisis. The fear-of-floating hypothesis of Calvo and Reinhart (2002) or the international credit problem analyzed by Aizenman and Marion (2002) assume that reserve volatility is associated with credibility problems and if left unchecked can spillover into a crisis. Missing in the empirical literature on reserve volatility is a long-run perspective that tries to understand the cross-country differences in reserve volatility.

Our contribution is to determine whether long-run factors are important in explaining reserve volatility. The question is of importance because long-run factors have not been considered in the indexes of Levy Yeyati-Sturzenegger (1999) or Calvo and Reinhart (2002) when making comparative statements about a country's fluctuations in reserves. It is imaginable that certain variables such as openness are positively correlated with reserve volatility. If this is the case then the omitted variables need to be accounted for when indicator models based on reserve volatility are used to predict exchange rate crises or regime changes.

A plot of the monthly percentage change in foreign exchange reserves of twelve leading emerging market countries in Figure 1 reveals that it is difficult to make generalizations about reserve volatility across countries. The largest fluctuations for the post-Bretton Woods era are not always concentrated around the time of well-known episodes such as the Asian Crisis of 1997. Nor is it clear whether the fluctuations have increased or decreased over the three decades. From a cross-country perspective, it is of interest to learn whether long-run factors are responsible for the differing behavior in reserve volatility or whether it is simply noise.[1]

To test the hypothesis that reserve volatility is influenced by long-run factors, the empirical methodology uses a cross-country setup. The empirical analysis focuses on 30 emerging market economies. A wide range of potential indicators stemming from the currency crisis literature is considered for the 1973-2000 period. A key finding is that the level of reserves and openness are important contributing factors for reserve volatility. More important, these variables are not necessarily linked to monetary policy or financial development; i.e., variables that the currency crisis literature has emphasized.

The paper is organized as follows. Section 1 briefly reviews the implications of reserve volatility for emerging market economies. In particular, it discusses theoretical and empirical priors about reserve volatility. Section 2 defines the empirical strategy: measures of reserve volatility, the economic determinants of reserve volatility, and the empirical methodology. Section 3 presents the main cross-country findings for the long-run factors. Section 4 considers specifications with the long-run factors together with the crisis and regime variables to test the robustness of the empirical findings from the previous section. Section 5 considers whether the cross-country results based on averaged data hold equally for panel estimates based on annual data. Section 6 offers concluding remarks for practitioners that use reserve volatility as an indicator variable.

[1] Several studies including Neely (2000) and Lee (1997) suggest that reserves are an imperfect proxy for foreign exchange interventions or other transactions such as government payment of debt denominated in foreign currency.

1. Reserve Volatility and Theoretical Priors

The intention of this section is to highlight how reserve volatility enters the different discussions of international finance. While there are an infinite number of channels that can generate fluctuations in reserve holdings, to our knowledge there is no explicit theoretical model that seeks to explain reserve volatility as a macroeconomic policy objective.[2] Moreover, central banks have been quiet as to how reserve volatility should behave. The smoothing or minimization of reserve volatility is not regarded to be an objective of central banks.[3] Reserve volatility enters, however, as a contributing factor in various theoretical and empirical models. In each of these cases, reserve volatility acts as a causal variable to explain another variable or to predict a specific event.

Theoretical Links

One economic linkage involving reserve volatility is through the transaction models of money demand used to determine the optimal size of a country's international reserves. The buffer stock model of Frenkel and Jovanovic (1981) says that central banks choose an optimal level of reserves to balance the macroeconomic adjustment costs incurred in the absence of reserves with the opportunity cost of holding reserves. The optimal stock of reserves yields the optimal combination of being able to finance a deficit by drawing on reserves and of having to adjust in the face of a deficit by reducing expenditures relative to income. Higher reserve volatility means that reserves hit their lower bound more frequently. The monetary authority is therefore willing to restock a larger amount of reserves and tolerate greater opportunity costs to incur the adjustment cost less frequently.

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[2] The strategic objectives for reserve management are generally defined as maximizing returns subject to the maintenance of sufficient security of the assets and adequate liquidity for meeting the calls on reserves, see Nugée (2000).

[3] Central banks, in rare instances, set guidelines to motivate their demand for reserves. The Guidotti plan, for example, sought to set reserves at a level equivalent to a year's interest payment on foreign debt. See the Report of the Working Group on Transparency and Accountability (1998). www.ustres.gov/press/releases/docs/g22-wg1.htm. Alternatively, the Reserve Bank of New Zealand sets reserves at 10 weeks of imports (see Sherwin, 2000).

An alternative channel involving reserve volatility is through signaling. Moral hazard problems linked with domestic bailouts and credit availability have been cited by Corsetti, Pesenti, and Roubini (1998) and others as an important determinant of the Asian financial crisis. Aizenman and Marion (2002) show that reserve uncertainty can have nonlinear effects on the supply of credit for an emerging market economy. The authors assume that the private sector believes the domestic authority of an emerging market country will use its international reserves to bailout lenders. When the expected reserve position of an emerging market economy is large relative to the potential bailout in bad states of nature, reserve volatility does not matter. However, the same level of reserve volatility can cause a large reduction in the supply of international credit if the emerging market's foreign debt is large enough or if the collapse of output forces the private sector to downgrade its priors about repayment possibilities.

A further use of reserve volatility is to identify an exchange rate system. Pegged exchange-rate arrangements have been blamed for many of the currency crises in the last decade. Adherents of this view argue that emerging market economies should allow their currency to float freely. To test whether countries are doing what they are professing, Calvo and Reinhart (2002) and Reinhart (2002) analyze the behavior of exchange rates, international reserves, and monetary aggregates within a simple open economy model. A symptom of 'fear of floating' (i.e., saying that a country allows their exchange rate to float, but does not), is associated with high reserve volatility.

Each of the above linkages assumes that the monetary authority exercises considerable control over its reserves and reserve volatility. Others such as Lee (1997) argue that the opposite is closer to the truth. Monetary authorities of emerging market economies do not possess the necessary open market instruments to sterilize reserves when inflation or money growth is their policy objective. This is because their financial markets are underdeveloped. Supplementary tools, which include tightening the access of banks at the discount window, adjusting reserve requirements or the placement of government deposits, and using foreign exchange swap facility, yield the same effect as an open market operation. In practice, however, reserves become noisier and their interpretation more difficult.

Empirical Stylized Facts and Considerations

Flood and Marion (2001) and Lane and Burke (2001) offer cross-country evidence on reserve holdings that have relevance for the empirical specification of reserve volatility. Both studies consider industrial and non-industrial countries for relatively long time periods. The first study, restricting itself to the buffer stock framework of Frenkel and Jovanovic (1981), finds that reserve volatility is the only significant variable. Different measures of opportunity cost have little or no explanatory power. The second study does not consider reserve volatility among its list of potential variables and finds that openness is the most important contributing factor for reserve demand. For our purposes, it is of interest to determine whether the combination of openness and reserves unfolds any other linkages with reserve volatility.

An alternative channel that needs to be considered is the role of financial development. Recent studies by Goldfajn and Valdes (1997) and Kaminsky and Reinhart (1999) emphasize the interaction between currency crises and banking crises. The "twin crises" arise as a result of an internal or external shock that is amplified and propagated to the rest of the economy by liquidity creating financial intermediaries. The intermediaries generate large capital inflows, and at the same time, augment the risk of sudden capital outflows. Kaminsky and Reinhart (1999) show empirically that the twin crises have their origin in the deregulation of the financial system. Financial liberalization is followed by a rapid increase in the M2 multiplier and in credit growth. Kaminsky and Reinhart (1999) and Goldfajn and Valdes (1997) also show that this trend in the financial variables reverses abruptly before the outbreak of the currency crisis.

This last linkage underscores the view that the currency crises of the 1990s are fundamentally different from earlier periods. Feldstein (2002), Perrault (2002) and others note the evolution of different banking channels and private capital flows between the 1970s and 1990s. First, private capital flows to the emerging market countries were concentrated in Latin America in the 1970s and the 1980s. During the 1990s, the emerging market economies in Asia and Europe were the new destinations. Second, high expected returns on investment motivated capital flows to emerging market countries. In the 1990s, these flows were boosted by economic and financial liberalization, perceived

sound macroeconomic policies and, in some cases, explicit or implicit government guarantees. These recent developments suggest that it is important even in a cross-country context to account for shifts in the potential linkages over time.

2. Empirical Specifications, Data and Selected Variables

This section defines the empirical strategy used to determine the contributing factors that explain reserve volatility in the long run.

Cross Country Sample

There is considerable controversy as to what constitutes an emerging market economy. Definitions vary considerably and few studies motivate their selection. Our selection was guided by two considerations that are independent of the occurrence of a crisis episode. The first was data availability that covered the post-Bretton Woods period from 1973 to 2000. This eliminated many of the *so-called* economies in transition, creating a geographical vacuum for Eastern Europe. The second consideration was based on investment opportunities in the non-industrialized world. This is indirectly measured by foreign direct investment (FDI). Our selected sample of emerging market economies was thus defined as the top 30 non-industrialized countries that received FDI from 1973 to 2000.[4] A list of the countries included in the sample can be found in Appendix A1.

Econometric Model

We estimate a cross-sectional specification using data averaged over different time periods. The motivation for the estimation strategy rests in investigating whether specific control variables are important in explaining reserve volatility in the long run. Thus, we intentionally abstract from the cyclical fluctuations in reserves marked by particular episodes in capital flows or speculative attacks. The cross-country specification follows

[4] Our sample size of 30 countries is set arbitrary. Most empirical studies work with a smaller number of countries. However, because our estimation strategy is cross country with many control variables, we are forced to extend the sample to allow for a reasonable number of degrees of freedom.

Flood and Marion (2001) and Lane and Burke (2001) in their studies for the level of reserves and is defined as

$$VolRES_i = \alpha + \beta Z_i + \gamma X_i + \varepsilon_i, \quad (1)$$

where $VolRES_i$ is the reserve volatility of country i, Z_i is a set of control variables grouped into the following categories: monetary, external, financial development and structural, X_i is a set of indicator variables that signal currency and regime crises, and ε_i is the error term. Estimation is by OLS with heteroscedasticity using the Newey-West consistent covariances.

The hypothesis is the currency crisis literature has overlooked the importance of certain control variables; i.e., $\beta \neq 0$. Because the crises variables, X_i, are averaged, our prior for these indicator variables in the long-run setup is $\gamma = 0$. The variables in equation (1) are averaged over three periods: 1973-1980, 1981-1990 and 1991-2000. The division into decade averages is motivated by Feldstein (2002). He argues the currency crises of the 1990s are fundamentally different from earlier periods. Since we are interested in explaining the long-run fluctuations in reserves, the long-run contributing factors of reserve volatility should therefore be significant in each of the samples.

Reserve Volatility

The international reserve holdings of a country in this study are defined as foreign exchange reserves. Although it is common to work with the sum of gold, Special Drawing Rights, foreign exchange, and reserve position in the Fund, the most important variable in terms of size and international interest is foreign exchange reserves. This variable is denominated in end-of-period U.S. dollars.[5] Hereafter, when referring to reserves, we mean foreign exchange reserves.

Individual country holdings of reserves cannot be compared or traced through time unless they are scaled in some way to reflect differences in size. Our choice is to scale

[5] Preliminary estimates of the individual components of foreign reserves showed large differences with foreign exchange reserves offering the most promising results.

reserves by GDP.[6] Thus, we define the reserve volatility for country *i* as $VolRes_i = ln(std\ dev(\Delta\ Res_{i,t})/ave(GDP_i))$, where $Res_{i,t}$ denotes reserves and *t* time (in months).

Control Variables

The currency crisis literature identifies numerous control variables that may influence reserves and reserve volatility. Because there is no agreement on the theoretical model of reserve volatility, a broad approach is taken by considering a large number of potential empirical determinants. Definitions and sources of the variables are given in Appendix A2.

Our control variables are grouped into four categories: external, monetary, financial development, and structural. Our intention is to determine whether a particular group of variables is more closely associated with reserve volatility. The external determinants are macroeconomic variables that are strongly influenced by foreign developments or shocks from abroad. These variables include the level of reserves, foreign direct investment, exchange rate volatility, the current and capital account, and debt variables. The classification of reserves and exchange rate volatility as external is without contention. There are numerous reasons for holding reserves, yet almost all are related to concerns regarding foreign shocks. Similarly, exchange rate volatility could be grouped as a monetary variable, yet we assume that external shocks are primarily responsible for exchange rate fluctuations in emerging markets.

Monetary variables are defined to be instruments that are under the direct control of the monetary authority. These variables include interest rates and their volatility, capital controls, and the IMF's classification of exchange rate systems. The impact of the latter two policy variables is somewhat ambiguous.[7] On the one hand, a flexible exchange rate system or a high level of capital controls may diminish the risk of a speculative attack, reducing the need to hold reserves. On the other hand, capital controls may

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[6] Recently, Flood and Marion (2001) in their empirical study of the buffer stock model investigate several scaling methods. Their results are found to be independent of such transformations.

[7] As noted in Lane and Burke (2001) in the case of reserves, the monetary variables may be regarded as endogenous. Yet, we do not believe that the monetary variables are strongly influenced by reserve volatility over the longer horizon.

prevent access to external credit sources, increasing the importance of reserves in financing external transactions. In the case of the exchange rate system, the classification may be unimportant if the monetary authorities are unable to sterilize the purchase of domestic currency due to a weak financial system.

The control group defined by financial development includes the dates of financial innovation, M2/GDP, insurance premium/GDP and insurance premium/population. The first variable is a dummy variable denoting the date when financial innovation began. This variable is taken from Bekaerts and Harvey (2000) and assumes that earlier dates correspond with higher levels of financial development. The money variable scaled by GDP is frequently used in empirical studies as a measure of credit expansion. Alternatively we use insurance premia as a broad measure of financial development that goes beyond the banking system covered by M2 deposits. A higher volume of insurance premia is consistent with a higher level of financial development.

The structural variables are GDP per capita, population density, openness, corruption, central bank independence, and country credit rating. These variables reflect in part institution building (i.e., central bank independence corruption and country credit rating) that are viewed to be important for a country's long-run development. In the same spirit, political stability is captured through the country credit rating. While structural may be an unsatisfactory label for GDP per capita, it enters in this category by mutual exclusion of the other control categories.

Crisis and Regime Variables

The crisis and regime variables are treated separately from our control variables. The motivation is twofold. First, studies, such as Calvo and Reinhart (2002), use the crisis and regime variables to identify events. This is primarily a short-run forecasting exercise, which depends on indicator variables that are constructed with the help of reserve volatility. Second, the indicator variables rely on an exogenous threshold level to define excess reserve fluctuations. The analysis thus defines a country's excess volatility in reserves to be equal for all countries irrespective of the degree of openness or other country specific characteristics.

We rely on two sources for our crisis variables. The first is the Kaminsky-Reinhart index of currency market turbulence, which is based on monthly changes in the exchange rate and in reserves.[8] The second source is from Glick and Hutchison (1999). They provide dates of banking, currency and twin crisis for the years 1975 to 1997.

Fluctuations in reserves are also used to define de facto exchange rate regimes. The motivation for treating this variable not as a long-run control is the following. The IMF dejure classifications rarely change over the samples, whereas the defacto classifications, which are dependent on reserve volatility, exhibit considerable fluctuations. We test the Levy Yeyati and Sturzenegger (1999) index and the Glick and Wihlborg (1997) measure of exchange rate flexibility. The first index is constructed with the use of cluster analysis to group different regimes according to changes in the nominal exchange rate and changes in international reserves. The index has four classifications (floating = 1, dirty = 2, crawling peg =3, and fixed = 4) for each year from 1990 to 1998. The Levy Yeyati and Sturzenegger index fluctuates considerably from year to year and the index's analysis is used to identify specific events or regime changes.

The Glick and Wihlborg index is intended to capture the variance of the actual exchange rate change relative to the variance of the change that would have occurred in the absence of exchange rate interventions. The index ranges between 0 and 1 and is constructed with monthly data as in Glick and Wihlborg (1997) for the periods 1973 to 1980, 1981 to 1990, and 1991 to 2000. The exchange rate is fixed if the index yields values close to 0, that is, if there are no unanticipated changes in the exchange rate or if the variance of reserve changes is infinity large.

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[8] This index is constructed mechanically such that

$$+1 \text{ when } |I_t - \bar{I}|/\sigma_I > 3 \quad \text{where } I_t = \Delta e_t/e_{t-1} - \alpha\Delta RES_t/RES_{t-1}$$

$$\text{and } \alpha = \sigma_e/\sigma_{RES},$$

0 otherwise,

where σ denotes the standard deviation, e_t the exchange rate and *RES* reserves. Kaminsky and Reinhart (1999) filter the data for high inflation periods. Our procedure raises the threshold level for a crisis from 3 to 4 when inflation is more than 150% during a six-month period.

3. Cross Country Estimates: Some Preliminary Results

This section presents the cross-country estimates of reserve volatility. Because our prior is the crisis indicators do not influence reserve volatility in the long run, the crisis variables are intentionally excluded at first. This is done to maintain a respectable number of degrees of freedom. The next section examines the influence of the crisis variables for reserve volatility.

The selection strategy examines first the regressions between reserve volatility and individual determinants. If a control variable on its own is not significant at the 5% level, it is thrown out. The second phase of the bottom-up strategy looks at whether the variables in consideration remain significant with other control variables. This strategy is continued for higher combinations of variables until a satisfactory specification is found.

The search was simplified in that two variables (i.e., reserves and openness) were able to explain a large share of the cross-country differences in reserve volatility. Table 1 summarizes the empirical regressions. The results show only the regressions of those variables that were significant with reserve volatility in the first phase of the estimation strategy (i.e., significant variables in a regression for reserve volatility without additional control variables). The constant, which is included in each of the regressions, is not shown in the tables. Because the empirical results are dominated by the inclusion of reserves, the discussion of the empirical results is divided into two parts: estimates with and without reserves.

Reserve Volatility and Reserves

The bottom up strategy yielded a parsimonious specification for reserve volatility. The final specifications were dominated by two or three variables. The control variables that were significant in the specification search were correctly signed with the priors, except openness defined by the import-GDP ratio for the 1973-1980 period. For this sample, the import-GDP ratio is negatively correlated with reserve volatility. The Frankel and Romer index, Openness (FR) in Table 1, is found to be a better proxy for openness for the 1973-1980 period, whereas the opposite is true for the import-GDP ratio when considering the other decades.

The first phase of the specification strategy was dominated by external and structural variables. In particular, openness, FDI, and total debt/GDP were found to be significant for all samples. None of the financial development variables and monetary variables has a *p*-value lower than 0.05 for more than one sample.

The second round results yield three main findings. The first finding is that the level of reserves dominates all other explanatory variables. Reserves explain between 50% and 70% of the cross-country differences in reserve volatility for the post-Bretton Woods period. This result says that a country with a high level of reserves is expected to experience greater reserve volatility. The importance of reserves is not surprising when considering the empirical results from the risk minimization model of Ben-Bassat (1980) and the reverse causality results with the buffer stock specification of Flood and Marion (2001). Both of these studies show that the first two moments of reserves are highly correlated with each other.

The second finding is that monetary variables and financial development variables do not enter the final cross-country specification. Monetary variables such as exchange rate volatility and interest rate volatility are never significant with reserve volatility for the three samples. Other variables that demonstrate a weak correlation with reserve volatility (i.e., significant in the first phase for a single decade, but not with other control variables) are central bank independence, M2/GDP, the amount of insurance premia/GDP, short-term debt, population density, and exchange rate arrangement, and country credit ratings.

The third finding is that the empirical specifications for the 1990s differ with respect to the earlier periods. The level of reserves as an explanatory variable does not explain reserve volatility equally well across the three decades. The R^2s are lower for the 1990s. Of greater interest is the significance of other variables in the specification for the 1990s. Total debt and M2/GDP are found to be significant for the sample covering the last decade. The R^2s of these two latter variables in regressions without reserves and openness however are low, suggesting that these variables offer only limited additional information in explaining reserve volatility.

Reserve Volatility without Reserves

The dominance of reserves in Table 1 may be criticized on the grounds of reverse causality in equation (1). While we do not have a direct test for the simultaneity problem, two routes are taken to tackle this issue. The first is to offer empirical results without reserves and to determine whether our previous findings still hold. The second is to consider alternative measures of reserve volatility that adjust for reserves and test for the significance of reserves as a control variable.

When the level of reserves are dropped from the cross-country regression, the results in Table 1 hold.[9] Column 2 in Table 1 show regression results where openness without reserves is highly significant across all samples and is able to explain a considerable share of reserve volatility. The positive correlation between reserve volatility and openness suggests that more open countries are exposed to external shocks and this is reflected in higher reserve fluctuations. The results (not shown) find that again monetary and financial variables do not enter the final cross-country specification. To note, however, is the significance of GDP per capita for the 1981-1990 period and FDI and country credit ratings matter for the 1991-2000 period.

An alternative way to understand the influence of reserves in the Table 1 is to adjust *VolRes* for average reserves i.e., $VolRes^* = \ln(\text{std dev}(\Delta RES_i)/\text{ave}(RES_i)\text{ave}(GDP_i))$ and $VolRes^{**} = \ln(\text{std dev}(\Delta RES_i)/\text{ave}(\Delta \ln RES_i)\text{ave}(GDP_i))$. The two definitions of volatility embed a standard volatility measure with average reserves and their change. The latter definition may be interpreted as an inverse sharp ratio, which attempts to adjust a return by its risk. To see whether the specifications of Table 1 are robust to these alternative measures of reserve volatility, the same regressions were rerun with *VolRes* and VolRes***.[10] The results (not shown) find that reserves remain significant for each of the three sample periods, except *VolRes*** for the 1980s. The result that countries with higher reserve levels observe higher reserve volatility holds also for *VolRes** and *VolRes***. The

[9] The full set of regressions results are available upon request.

[10] The regression results are available upon request.

other findings that financial variables and monetary variables do not matter and that the specification for the 1990s differs from the earlier periods remain valid.

4. Cross Country Results with Event and Regime Variables

The main results in the previous section find that reserves and openness are the most important control variables explaining reserve volatility in the long run. In this section, we relax our prior of $\gamma = 0$ in equation (1) and test the hypothesis that reserves and openness explain reserve volatility better than the indicator variables used to predict crisis episodes and changes in exchange rate regimes.

Table 2 presents the results for the crisis indexes of Calvo and Reinhart (2002) and Glick and Hutchison (1999) with reserves and openness. The evidence finds that openness and reserves remain significant in the presence of the crisis indexes and that the newly introduced variables do not explain reserve volatility in cross-country regressions. The indexes are insignificant with or without the control variables and their coefficients exhibit no clear pattern. These results hold for all samples and are independent of the index type.

The cross-country results with the de facto exchange rate classifications are given in Table 3. The empirical results for the index for de facto classifications is mixed at best. While the coefficients for the de facto indexes are correctly signed (i.e., the greater is the commitment to defend a given value for the exchange; the larger is reserve volatility - positive correlation in the case of the Levy-Yeyati-Sturzenegger index and negative in the case of the Glick-Wihlborg index), the evidence for its significance is weak. The Levy-Yeyati-Sturzenegger index is exchange rate index is significant at the 5% critical level in the regressions for the 1990s, whereas the Glick-Wihlborg index is significant in only one regression covering the three samples.

5. Panel Estimation: Short- and Long-Run Determinants

A possible reason why the proxy variables for crisis episodes and de facto exchange rate regimes are insignificant in the cross-country regressions is simply that key episodes get washed out through averaging. Although our primary focus is on identifying the long-run determinants of reserve volatility, we are also interested in whether our cross-country results for openness and the level of reserves hold equally well in a setting that captures better the short-run factors. Panel estimation allows crises episodes to have a stronger impact on reserve volatility, enabling a comparison with the earlier cross-country estimates. The annual panel considers the control variables, reserves and openness, together with the de facto classifications and the crisis indexes from Tables 2 and 3.

The (unbalanced) panel estimates for fixed effects are given in Table 4.[11] The results can be summarized as follows. First, the panel estimates show that reserves and openness continue to be the most important explanatory variables for reserve volatility even in the presence of the event and regime variables. The variables of interest are significant in each of the panel regressions. This shows that the significance of reserves and openness is not dependent on the data averaging used in the cross-country analysis. Second, the control variables explain roughly 55% of the annual fluctuations in reserve volatility. In the best case, the crisis indexes are able to explain only 22% of the movements in reserve volatility in regressions that exclude openness and reserves. This result says that when analyzing reserve volatility across countries it is important to control for openness and the level of reserves even in the short run.

6. Summary and Policy Implications

The importance of reserve volatility arises in different policy discussions. The analysis centers primarily on the ability of reserve volatility and other information to signal specific crisis episodes in the short run. The objective of this paper instead focuses on understanding the contributing factors important in explaining reserve volatility in the

[11] The results for the random effects specification yield similar results.

long run. The question is of relevance because country specific variables such as the degree of openness are not considered in the indexes of Levy Yeyati-Sturzenegger (1999) or Calvo and Reinhart (2002) when making comparative statements about a country's fluctuations in reserves. Obviously, if long-run factors are responsible for explaining reserve volatility, then the signaling analysis even for the short run may be biased when such information is omitted. Our cross country and panel estimates suggest that this is the case.

Two empirical findings for practitioners emerge from our cross-country estimates. The first is that reserve volatility is dominated by two variables: the level of reserves and the degree of openness. Both variables, which are omitted from construction of the crisis and regime indexes, are positively correlated with reserve volatility and explain 50% to 70% of the cross-country differences in reserve volatility for the post-Bretton Woods period. The control variables proxying monetary and financial development yield limited additional information at best. Our regression results are indirectly supported by other cross-country studies seeking to uncover the determinants of the average level of reserves. The buffer stock studies by Frenkel and Jovanovic (1981) and others find that the first and second moment of reserves are highly correlated with each other, whereas Lane and Burke (2001) stress the importance of openness in explaining a country's reserves.

The second empirical finding pertains to the short and long-run analysis for reserve volatility. To understand reserve volatility and its indicator properties one must be careful when making short-run and long-run comparisons. Crisis episodes, whether defined as banking or currency crises, are not found to be a contributing factor for reserve volatility in the cross-country estimates using averaged data. Panel estimates using annual data instead show that several crisis indexes enter as important short-run determinants of reserve volatility along with reserves and openness. These issues of dynamics are important for understanding the arguments put forth by Calvo and Reinhart (2002), Levy Yeyati and Sturzenegger (1999) and others that seek to explain credibility problems for specific emerging market economies based on reserve volatility. Our empirical results show however that the practitioner needs to take into account the size of a country's reserves

and the degree of openness regardless when making short and long-run comparisons about a countries exchange rate regime based on reserve volatility.

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Appendix

A1. Sample of Emerging Market Countries

Argentina, Bahrain, Brazil, Chile, China, Hongkong, Colombia, Ecuador, Egypt, Hungary, India, Indonesia, Israel, Korea, Malaysia, Mexico, Nigeria, Pakistan, Peru, Philippines, Poland, Romania, Saudi Arabia, Singapore, South Africa, Thailand, Trinidad Tobago, Tunisia, Turkey, Venezuela.

A2. Control Variables

External Variables

Short-term debt is the natural log of average short-term debt in percent of total debt. (Source World Bank (2001) Global Development Finance CD-Rom).

Total debt is the natural log of average total debt divided by average GNP. (Source World Bank (2001) Global Development Finance CD-Rom).

Foreign direct investment is defined as the natural log of average foreign direct investment divided by average GDP. (Source IMF line 78bed).

Current account is defined as the natural log of average current account divided by average GDP. (Source IMF line 78ald).

Capital account is defined as the natural log of average capital account divided by average GDP. (Source IMF line 78bcd).

Country credit rating is from Institutional Investor for years 1980, 1985, 1990, 1995, 2001.

Export volatility is defined as *ln(std dev(Δ Exports)/ave(GDP)).* (Source IMF lines 70, 99bc).

Monetary Variables

Interest rate is the average three-month interest rate (i.e., *ln(ave* $i_{i,t}$*)*. The frequency is monthly (Source IMF line 60c).

Interest rate volatility is defined as the natural logarithm of the standard deviation of the monthly change in the three-month interest rate over time (i.e., *ln(std dev(Δ* $i_{i,t}$*))*. (Source IMF line 60c).

Exchange rate volatility is defined as logarithm of the standard deviation of the monthly change in the exchange rate with respect to the U.S. dollar (i.e.*ln(std dev(Δ* $s_{i,t}$*))*. (Source IMF line rf).

Capital controls index is taken from Cottarelli and Giannini (1997). The index is an average over the different periods.

Exchange rate system index is +1 for fixed and 0 for flexible exchange rate systems. The index, which is an average over the different periods, is taken from Cottarelli and Giannini (1997).

Financial Development Variables

Financial Development is measured in three ways. The first uses M2/GDP (source IMF line 35, 99b. The second uses the financial innovation dates from Bekaert and Harvey (2000). The third is proxied by the insurance premium density and insurance premium penetration. Premium density is defined as premium volume per capita, whereas premium penetration is the premium volume in percentage of GDP. Premium density and penetration are both published yearly by Swiss Re's research department.

Structural Variables

GDP per capita is *ln(ave GDP/ave Population).* (Source IMF line 99b.c, 99z).

Population density is specified as *ln(ave Population/country size).*

Openness is defined in two ways. The first uses the Frankel-Romer index (1999) denoted as Openness (FR) in the tables. This captures the natural level of trade openness by using the sum of the predicted bilateral trade shares from the geographical determinants in a gravity model. The measure is the ratio imports to GDP, which is defined as the natural log of average imports over average GDP. This variable is denoted as Openness (Import/GDP) in the tables. (Source IMF line 71, 99bc).

Central bank independence, both indexes for non industrial countries are taken from Cukierman (1992) and Cukierman et al. (1992).

Corruption index, this index is taken from Mauro (1995).

Figure 1: Monthly Percentage Change in Foreign Exchange Reserves

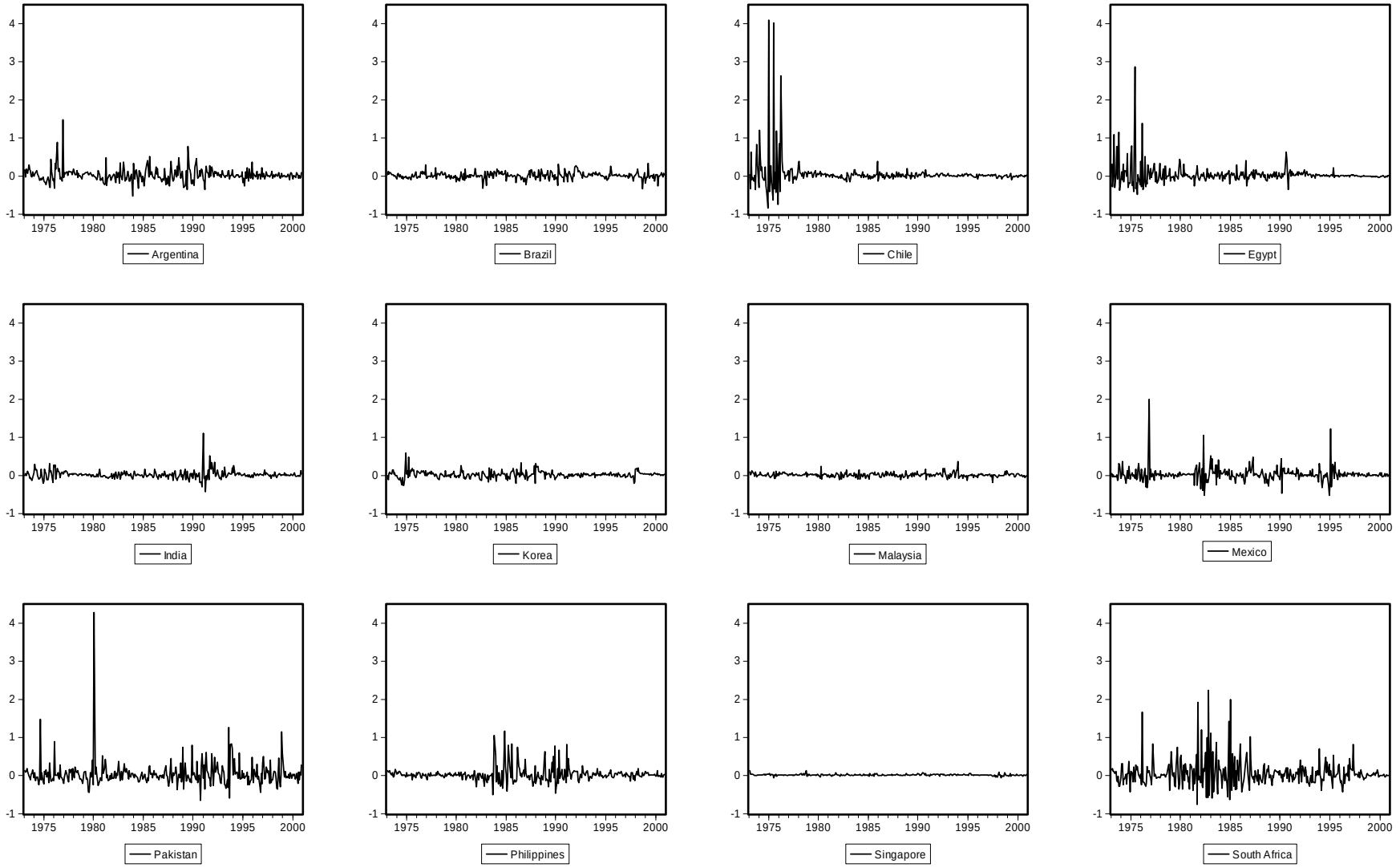

Table 1: Reserve Volatility and Long-Run Contributing Factors **(Estimation: OLS Cross-Country)**

Period: 1973-1980	1	2	3	4	5	6	7	8	9	10	11	12
Reserves	0.6162*		0.5710*	0.5662*	0.5077*	0.8437*	0.5874*	0.6445*	0.5880*	0.6307*	0.6500*	0.5829*
	(0.0929)		(0.1008)	(0.0949)	(0.1757)	(0.1593)	(0.1903)	(0.0859)	(0.1300)	(0.0843)	(0.0921)	(0.1243)
Openness (FR)		0.0252*	0.0046									
		(0.0059)	(0.0048)									
GDP per capita				0.0963								
				(0.1016)								
FDI					0.0571							
					(0.1030)							
Total Debt/GNP						0.3827						
						(0.2137)						
Capital Account							-36.7184					
							(27.6831)					
Population Density								-0.0727				
								(0.0484)				
Capital Control									-0.2417			
									(0.1827)			
Exchange Rate System										0.5640*		
										(0.1648)		
Country Credit Rating											-0.0059	
											(0.0042)	
Corruption												-0.0088
												(0.0332)
adj. R^2	0.688	0.294	0.681	0.687	0.517	0.624	0.568	0.693	0.631	0.720	0.694	0.574
degrees of freedom	24	25	23	23	15	16	8	23	21	21	23	19

Period: 1981-1990	1	2	3	4	5	6	7	8	9	10	11	12
Reserves	0.5435*		0.4618*	0.4071*	0.3943*	0.3843*	0.3994*	0.4790*	0.4184*	0.4172*	0.4543*	0.3955*
	(0.0755)		(0.0772)	(0.0695)	(0.0673)	(0.1378)	(0.1210)	(0.1426)	(0.0653)	(0.0621)	(0.0823)	(0.1034)
Openness (Import/GDP)		0.6388*	0.1772		0.0394	-0.0715	0.1875	0.0131	0.0070	0.0771	-0.0477	0.0405
		(0.1426)	(0.1607)		(0.1368)	(0.1375)	(0.1500)	(0.2874)	(0.1358)	(0.1445)	(0.1518)	(0.1599)
GDP per capita				0.2362*	0.2270*	0.1969	0.2190	0.0423	0.1588	0.2348*	0.2324	0.1599
				(0.0825)	(0.0896)	(0.1072)	(0.1083)	(0.1458)	(0.1091)	(0.0874)	(0.1193)	(0.3308)
FDI						0.0817						
						(0.0453)						
Total Debt/GNP							0.1801					
							(0.1130)					
Capital Account								1.6300				
								(2.3451)				
Exchange Rate System									0.2005			
									(0.2033)			
Country Credit Rating										-0.0052		
										(0.0057)		
Corruption											-0.0291	
											(0.0385)	
Premium Density												0.0266
												(0.1707)
adj. R^2	0.659	0.407	0.665	0.734	0.724	0.691	0.670	0.712	0.719	0.731	0.678	0.634
degrees of freedom	27	27	26	26	25	20	19	9	20	24	18	18

Note: Standard errors are given in parentheses and are corrected for heteroskedasticity using the Newey-West consistent covariances.
*denotes significance at the 5% level.
The regression´s constant is not shown. See Appendix A2 for definition of the variables.

Table 1 (Continued): Reserve Volatility and Long-Run Contributing Factors

Period: 1991-2000	1	2	3	4	5	6	7	8	9	10	11
Reserves	0.4811*		0.2542*	0.2397	0.1879	0.2181*	0.1683	0.2226*	0.2211*	0.2236*	0.3518*
	(0.0766)		(0.1135)	(0.1345)	(0.1205)	(0.0789)	(0.1051)	(0.0911)	(0.0883)	(0.0829)	(0.1077)
Openness (Import/GDP)		0.5827*	0.3732*	0.3560*	0.3407*	0.4043*	0.5017*	0.4061*	0.4181*	0.3991*	0.4714*
		(0.0912)	(0.1295)	(0.1231)	(0.1298)	(0.1580)	(0.1434)	(0.1642)	(0.1711)	(0.1655)	(0.1266)
GDP per capita				0.0349							
				(0.0717)							
FDI					0.1094						
					(0.1059)						
Total Debt/GNP						0.3896*	0.3769*	0.3856*	0.3941*	0.3852*	
						(0.1147)	(0.1174)	(0.1199)	(0.1150)	(0.1166)	
Population Density							-0.1109				
							(0.0685)				
Country Credit Rating								-0.0005			
								(0.0041)			
Interest Rate									0.0598		
									(0.0867)		
Current Account										-0.9481	
										(2.5677)	
M2											-0.2779*
											(0.0927)
adj. R^2	0.504	0.549	0.610	0.599	0.620	0.615	0.639	0.596	0.594	0.598	0.672
degrees of freedom	28	28	27	26	26	21	20	20	19	20	26

Note: Standard errors are given in parentheses and are corrected for heteroskedasticity using the Newey-West consistent covariances.
*denotes significance at the 5% level.
The regression´s constant is not shown. See Appendix A2 for definition of the variables.

Table 2: Reserve Volatility and Crisis Indexes **(Estimation: OLS Cross-Country)**

Period: 1973-1980	1	2	3	4	5	6	7	8	9	10	11	12
Reserves		0.5966*			0.6090*			0.5835*			0.6408*	
		(0.1056)			(0.1309)			(0.1162)			(0.0970)	
Openness (FR)			0.0269*			0.0360*			0.0406*			0.0265*
			(0.0083)			(0.0135)			(0.0148)			(0.0059)
(KR) Index (I.)	1.2559	-0.0433	-1.5577									
	(1.8105)	(1.0424)	(1.9270)									
(GH) Currency Crisis I.				-1.0656	0.7179	-0.5663						
				(1.3484)	(0.6786)	(1.2907)						
(GH) Banking Crisis I.							1.5938	1.5930	2.4460*			
							(1.1060)	(0.7858)	(0.8169)			
(GH) Twin Crisis I.										-0.3116	0.8089	0.5774
										(0.9533)	(0.4757)	(0.8770)
adj. R^2	-0.023	0.637	0.267	-0.252	0.617	0.241	-0.008	0.653	0.341	-0.038	0.696	0.274
degrees of freedom	23	22	22	19	18	18	19	18	18	24	23	23

Period: 1981-1990	1	2	3	4	5	6	7	8	9	10	11	12
Reserves		0.5558*			0.5015*			0.4684*			0.5482*	
		(0.0726)			(0.0831)			(0.0688)			(0.0738)	
Openness (Import/GDP)			0.6758*			0.6247*			0.5455*			0.7052*
			(0.1298)			(0.1431)			(0.1372)			(0.1406)
(KR) Index (I.)	0.3684	0.7379	0.8853									
	(0.7988)	(0.5145)	(0.6838)									
(GH) Currency Crisis I.				0.2979	0.6096	1.0500*						
				(0.5446)	(0.4202)	(0.4430)						
(GH) Banking Crisis I.							0.5446	0.2919	0.6524*			
							(0.3972)	(0.2305)	(0.2934)			
(GH) Twin Crisis I.										0.2059	0.2861	0.5494*
										(0.3866)	(0.2020)	(0.2656)
adj. R^2	-0.029	0.679	0.430	-0.038	0.622	0.377	0.043	0.606	0.398	-0.026	0.669	0.463
degrees of freedom	27	26	26	21	20	20	21	20	20	27	26	26

Period: 1991-2000	1	2	3	4	5	6	7	8	9	10	11	12
Reserves		0.4823*			0.5629*			0.5871*			0.5213*	
		(0.0773)			(0.0871)			(0.0784)			(0.0926)	
Openness (Import/GDP)			0.5861*			0.6052*			0.6196*			0.6291*
			(0.0894)			(0.0908)			(0.1034)			(0.0919)
(KR) Index (I.)	-0.2375	0.0563	-0.3608									
	(0.6821)	(0.4576)	(0.3718)									
(GH) Currency Crisis I.				-0.6039	0.7457	0.4900						
				(0.9853)	(0.5228)	(0.6288)						
(GH) Banking Crisis I.							-0.2373	0.3784	0.2469			
							(0.4083)	(0.2245)	(0.2828)			
(GH) Twin Crisis I.										-0.2237	0.4086	0.4160
										(0.3843)	(0.3194)	(0.2925)
adj.R^2	-0.031	0.486	0.543	-0.032	0.584	0.552	-0.029	0.603	0.560	-0.026	0.515	0.562
degrees of freedom	28	27	27	22	21	21	22	21	21	28	27	27

Note: Standard errors are given in parentheses and are corrected for heteroskedasticity using the Newey-West consistent covariances.
*denotes significance at the 5% level.
The regression´s constant is not shown. See Appendix A2 for definition of the variables.

Table 3: Reserve Volatility and De Facto Exchange Rate Indexes **(Estimation: OLS Cross-Country)**

	Period: 1973-1980			Period: 1981-1990			Period: 1991-2000			Period: 1991-2000		
Reserves		0.6451*			0.5405*			0.4447*			0.5053*	
		(0.1014)			(0.0827)			(0.0862)			(0.0815)	
Openness (Import/GDP)			0.0234*			0.0225*			0.0152*			0.0147*
			(0.0060)			(0.0058)			(0.0065)			(0.0071)
Glick-Wihlborg	-11.1116	-25.3115*	-4.2474	-0.9415*	-0.2538	-0.1856	-0.1996	-0.2582	0.2246			
Classification (de facto)	(17.7225)	(8.6985)	(12.4166)	(0.3638)	(0.2096)	(0.5418)	(0.2562)	(0.1535)	(0.3647)			
Levy Yeyati-Sturzenegger										0.2634*	0.2361*	0.2099*
Classification (de facto)										(0.0995)	(0.0505)	(0.0906)
adj. R^2	-0.028	0.693	0.281	0.084	0.700	0.339	-0.028	0.464	0.163	0.208	0.713	0.243
degrees of freedom	22	21	21	24	23	23	25	24.000	24	21	20	20

Note: Standard errors are given in parentheses and are corrected for heteroskedasticity using the Newey-West consistent covariances.
*denotes significance at the 5% level. For the sample 1973 - 1980, Openness (FR) is used.

Table 4: Panel (Fixed Effect) Estimates of Long and Short-Run Factors of Reserve Volatility

Period: 1973-2000	1	2	3	4	5	6	7	8	9	10
Reserves	0.2113*	0.2270*	0.2514*	0.2230*	0.2547*	0.2244*	0.1191*	0.0184	0.1954*	0.2425*
	(0.0351)	(0.0346)	(0.0411)	(0.0391)	(0.0354)	(0.0614)	(0.0400)	(0.0872)	(0.0386)	(0.0423)
Openness (Import/GDP)	0.3582*	0.2659*	0.4301*	0.4924*	0.3670*	0.4383*	0.3953*	0.5670*	0.4684*	0.3555*
	(0.0809)	(0.0773)	(0.0881)	(0.0896)	(0.0804)	(0.1313)	(0.0815)	(0.1807)	(0.0914)	(0.0988)
(KR) Currency Crisis		0.2818*								
		(0.0453)								
(GH) Currency Crisis I.			0.3115*							
			(0.0535)							
(GH) Banking Crisis I.				0.1701*						
				(0.0497)						
(GH) Twin Crisis I.					0.2345*					
					(0.0453)					
Interest Rate Volatility						0.0812*				
						(0.0202)				
Exchange Rate Volatility							0.0278*			
							(0.0054)			
Levy Yeyati-Sturzenegger Exchange Rate Classification								0.0713*		
								(0.0310)		
Current Account									1.1212*	
									(0.2994)	
Country Credit Rating										-0.0090*
										(0.0029)
adj. R^2	0.577	0.598	0.592	0.580	0.612	0.674	0.580	0.525	0.600	0.587
degrees of freedom	715	710	504	504	632	338	587	160	656	549

Note: Standard errors are given in parentheses and are corrected for heteroskedasticity using the Newey-West consistent covariances.
*denotes significance at the 5% level.
The regression´s constant is not shown. See Appendix A2 for definition of the variables.