

Why Do Central Banks Hold International Reserves?

An Application of Models for Homogeneous and Heterogeneous Panel Data

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January 2009

Abstract

The significant increase of central banks' international reserve holdings in the recent past is a puzzle for standard economic theory. This paper investigates empirically the determinants of reserve holdings for a large panel data set of developing and industrialized countries covering the period from 1975 to 2003.

It extends existing empirical studies on reserve holdings in several ways. First, the data set covers virtually all countries for which data on reserves are available. Second, the determinants of reserves are reconsidered and some new empirical measures for these determinants are proposed. Finally, and most importantly, the paper examines the extent to which conclusions of panel data studies on the determinants of international reserve holdings are robust to the inclusion of dynamics as well as to the consideration of heterogeneity across countries.

The results show that the neglect of dynamics and heterogeneity in country behaviour may lead to misleading inferences. Independent of the chosen estimation method, the findings suggest that both traditional variables of the buffer stock model and variables related to financial crises determine the level of reserves. Central banks take precautionary measures against the downside of the increasing international financial integration.

Keywords: International Reserves, Central Bank Behaviour, Panel Data Models
JEL Classification Codes: C23, E58, F31, F32

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1 Introduction

One puzzle of the international financial system is the enormous increase in foreign exchange holdings by central banks, particularly in developing and transition economies, since the demise of the Bretton Woods system. In contrast to general wisdom, the transformation to de-jure more flexible exchange rate regimes was not accompanied by a permanent reduction in the level of reserves. Between 1975, just after the demise of the Bretton Woods system, and 2006, the absolute value of worldwide official reserves increased by a factor of 17. More importantly, the increase is also observable in commonly used indicators of reserve adequacy, which consider the level of reserves in relation to a scaling variable like GDP or external debt. This development has not come to an end. Since the East Asian financial crisis the level of reserves has almost trebled (see figures 1 and 2 for a graphical representation of indicators of reserve adequacy).

These developments gave rise to a series of papers that – after economists had almost ignored the topic for two decades – analyse international reserve holdings, both theoretically and empirically. For a comprehensive survey of the literature of the 1960s and earlier see Grubel (1971); Bahmani-Oskooee and Brown (2002) provide a more recent review. A short, but well-balanced summary of the more recent lines of argumentation is given in an Occasional Paper of the European Central Bank (ECB 2006). The majority of empirical studies focuses on a small number of countries – often belonging to a certain region – or does not include the recent period of reserve accumulation. Pooling over countries and the application of static models of reserve determination is the standard method. To my knowledge, the possibility of heterogeneous behaviour across countries has not been considered so far.

The contribution of this paper to the literature is threefold. First, a larger data field is used that covers virtually all countries for which data on reserves are available and that extends to the recent period of reserve accumulation until 2003. This allows us to draw more general conclusions. Second, the determinants of reserves are reconsidered and some new empirical measures for these are proposed. Finally, the paper examines the extent to which conclusions of panel data studies on the determinants of international reserve holdings are robust to the inclusion of dynamics as well as the consideration of heterogeneity across countries.

The approach is positive in that it describes and explains the phenomenon of reserve accumulation without giving a value judgement. We use a panel data set of a maximum of 162 countries over the period 1975 – 2003 to identify the determinants of international reserve holdings. Questions of the optimality and adequacy of international reserve holdings are not touched.

The main findings of the paper can be summarized along two lines: first, with respect to the research question why central banks hold international reserves and, secondly, in a more general way concerning the effects of neglected dynamics and heterogeneity in panel data studies.

The findings suggest that countries that are more open or have a higher external debt burden, hold more reserves. This supports the idea that countries hold reserves as a cushion against external shocks and financial crises. Intermediate exchange rate regimes are associated with the highest level of reserves, which might hint at the desire for heavy exchange rate management. Whereas opportunity costs seem to play no role in a central bank's strategy, persistence of the reserve stocks is an important property.

The neglect of dynamics - independently of whether models for homogeneous or heterogeneous data are used - leads primarily to differences in the magnitude of the estimated coefficients. The difference between the estimates of homogeneous and heterogeneous models is more pronounced. They differ not only in the magnitude of the effects but reveal conflicting results concerning the significance of the effects. These results suggest that the pooling of cross-sectional data is not always a good idea. If the assumption of equal behaviour of all cross-sectional units is questionable, the loss of accuracy might outweigh the gain of efficiency provided by pooling. This is especially important in macroeconomic applications where countries are pooled. As long as one does not capture all country differences by control variables – which is almost impossible – the assumption that countries behave equally is heroic.

This paper is organized as follows. Section 2 describes the theoretical determinants of the level of reserves and their empirical counterparts. Section 3 discusses the question whether the data can be pooled and gives a description of the panel data estimators, which will be used in the empirical analysis. The empirical results are presented in Section 4. The final section concludes and summarizes the main findings.

2 International reserves and their determinants

Based on a review of theoretical models, this section identifies possible determinants of the level of international reserves and explains how they are measured in the empirical analysis.

2.1 Theoretical considerations

According to the cost-benefit approach to determine the optimal level of reserves (Heller 1966) central banks face a trade-off between the cost of holding reserves and the cost of an adjustment of a balance of payments deficit without the use of reserves. Reserves can be used to temporarily mitigate these adjustment costs and to allow for a smooth adjustment in the face of an external shock¹. Central banks demand reserves until their opportunity cost equals the marginal benefit.

These models ignore the implications of increasing financial integration for developing and emerging economies. With respect to reserve holdings one can distinguish two opposing effects of financial integration.

First, private sector access to international capital markets facilitates private financing of balance of payments imbalances. Loans from the international capital market can serve as a substitute for reserves in order to smooth absorption in the presence of trade shocks. Hence, the adjustment to trade shocks ceased to be a topic of great concern.

Second, open capital markets increase the exposure to external financial disturbances and speculative flows. The sources of risk move from the current account to the capital account. Therefore, the more recent literature views reserves as a precautionary cushion against the risks of capital account liberalization, namely sudden stops, reversals of capital flows and financial volatility (see as examples Aizenman and Lee (2007), Jeanne and Rancière (2006) or Li and Rajan (2005)).

This implies that open capital markets reduce the need for official reserve holdings in good times but increase the need for reserves in times of economic crisis.

The function of precautionary reserves includes both crisis prevention and crisis management. The former refers to the role of reserves in reducing the probability of a crisis. A high level of

¹ However, in the case that the balance of payments deficit is not temporary and the use of reserves only delays a necessary adjustment, the use of reserves might even exacerbate the crisis since the adjustment takes place under less attractive terms.

reserves may signal good fundamentals and prevent the outset of a speculative run which leads to a self-fulfilling crisis. Crisis management refers to the role reserves may take in a crisis. Reserves can reduce and smoothen the adjustment of the exchange rate and of output.

A series of empirical studies supports the idea that higher reserves reduce both the probability of a currency crisis (Berg and Pattillo 1999; Bussière and Mulder 1999; Chui 2002; García and Soto 2006) and its depth (De Gregorio and Lee 2004) if it materializes. Li and Rajan (2005) show in a theoretical model that high reserves can countervail the negative impact of moderately weak fundamentals.²

2.2 Determinants of reserves

The following part defines the dependent variable and presents possible determinants of reserves, their expected effect and their definition in the empirical analysis in more detail.

International reserves: Reserves consist of gold, convertible foreign exchange, unconditional drawing rights with the IMF (the country's reserve position in the Fund) and special drawing rights (SDRs). In the econometric analysis, the dependent variable is international reserves net of gold divided by GDP. GDP as a scaling variable is motivated by the idea that reserves depend on the size of an economy, which is linked to the volume of its international transactions.

As seen in the theoretical section, the traditional literature identifies a set of standard variables that is expected to determine the level of reserves. These are output per capita, trade openness, a volatility measure and the opportunity cost of holding reserves.

Development: On theoretical grounds, the expected impact of the stage of development on the level of reserves is ambiguous. On the one hand, less developed countries may wish to hold more reserves for two reasons. First, since their access to international capital markets is limited, the financing of balance of payments imbalances is more difficult. Reserves could be used, at least in the short-run, as a substitute for private foreign capital. Second, the probability that these countries are affected by a financial crisis is higher. On the other hand,

² More precisely they conclude that higher reserves may offset weak fundamentals within a certain range. However, in the case of very weak fundamentals, a crisis or adjustment is inevitable independently of the level of reserves.

less developed countries might not afford to hold the desired amount of reserves. Therefore, development can only be expected to have a positive impact on reserves if the observed amount of reserves equals its desired level.

In the empirical analysis output per capita is used to control for the level of development.

Trade openness: Trade openness is hypothesised to have a positive impact on the level of reserves. The more open the economy, the more vulnerable it is to external shocks.

The prevailing measure of openness used in the literature is nominal imports plus exports relative to nominal GDP. This measure, however, overestimates openness of poor countries because the relative price of nontradables to tradables is lower in less developed countries. According to the Balassa-Samuelson theory, the labour forces of poor countries are less productive than those of rich countries. This difference in productivity is especially pronounced in the tradables sector, whereas it is negligible in the nontradables sector. Since the law of one price forces prices of tradables to equal internationally, the wage level in the poor country will be lower. Hence the production costs and price of nontradables are lower in the poor country as well. This implies that a given national real GDP evaluated at national prices and then converted into dollars will be lower if it is produced in a poor country. The measure of openness is consequently biased upwards.

Therefore, I use an alternative measure of openness, called real openness. This measure was first proposed in the context of trade and productivity by Alcalá and Ciccone (2004). Real openness is defined as the sum of imports and exports in exchange rate US\$ divided by GDP in purchasing parity US\$. In other words, the national volume of production is multiplied by the corresponding prices in the United States. Using real openness instead of openness as a measure for the importance of trade for an economy eliminates distortions due to differences in the purchasing power of one dollar between countries.

External volatility: Volatility of external payments and receipts or volatility of the terms of trade may translate into large swings in the current account. It increases the probability to face balance of payments problems and to hit the lower bound of reserves. From a precautionary perspective, higher volatility is therefore expected to be associated with a higher level of reserves.

For the empirical investigation, however, a direct measure of the volatility of the balance of payments is not usable because of its endogeneity. The observed volatility is the outcome

after having used reserves or other adjustment policies to mitigate disturbances so that it does not reflect the volatility without intervention.

A standard proxy for external volatility, previously used in the literature on international reserves, is the standard deviation of the previous five years of the growth rate of exports. Since exports are measured in current dollars, both volume and price volatility are captured. I refer to this variable as volatility (nominal). From a current account perspective, however, exports are important because they generate foreign exchange income which, in turn, is used to finance imports. If export income is short of the import demand, reserves may be used to fill the gap. Therefore, it might be preferable to use the growth rate of exports as a capacity to import as the relevant variable and use its standard deviation of the previous five years as a proxy for volatility. This variable is called volatility (real).

Opportunity cost: International reserves are part of the total capital resources of a country. As such, they could be used alternatively to finance productive investment projects, to repay (external) government debt or to buy assets according to optimal portfolio considerations. The difference between these alternative investment options and the yield on liquid international reserves is the appropriate concept of opportunity cost. In the empirical analysis, the opportunity cost measure is calculated as the difference between the national lending rate to prime customers net of the national inflation rate and the US treasury bill rate less the US inflation rate.

The real opportunity cost measure is lagged by one period because of two considerations. First, it is assumed that central banks adjust their reserves to changes in the opportunity cost with some time lag. Second, there might be an endogeneity problem since an increase in reserves might reduce the sovereign risk premium and hence have a negative impact on the opportunity cost.

This real opportunity cost measure is superior to the opportunity cost measure used by the mainstream of the literature.³ It takes into account that the difference between real interest rates is the proper concept of opportunity cost. Since the exchange rate is expected to adjust to inflation differentials, large nominal interest payments in a high-inflation country are nullified as soon as the foreign currency is changed into national currency.

³ In the existing literature, the opportunity cost is either proxied by the differential of nominal interest rates or just by the level of the domestic interest rate. More importantly, after the opportunity cost was found to be mostly insignificant in the literature of the 1970s, many authors do not include it at all (see Bahmani-Oskooee and Brown 2002 and references cited there).

Exchange rate system: The need for central banks to intervene in the markets for foreign exchange depends substantially on the exchange rate system. The more flexible the exchange rate, the less reserves are needed for its management. In a fixed exchange rate system the central bank is committed to buy and sell foreign exchange at the fixed parity. If, however, the exchange rate is flexible, market forces determine the value of the exchange rate such that the balance of payments is in equilibrium. The exchange rate is used as adjustment mechanism and balance of payments imbalances cannot materialize.

On the basis of the de jure classification of exchange rate arrangements provided by the IMF three dummy variables of exchange rate flexibility are constructed for the empirical analysis: Fixed, intermediate, and flexible exchange rates.

So far the traditional determinants of reserves were discussed. The focus of the more recent literature that emerged after the series of financial crises during the 1990s shifted from the current account to the capital account. Reserves may be held as a self-protection against financial, currency and banking crises. As a result, new determinants of reserve demand were asserted. These are financial openness, total external debt and short-term external debt.

Financial openness: Whereas the inclusion of trade openness is motivated by the idea that reserves are held as a buffer against real shocks, reserve holdings might also depend on financial openness. Its effect is ambiguous. Financially open countries can – at least theoretically - finance a current account deficit by a capital account surplus, that is by credits of the international financial market. Thus, reserves and debt are substitutes and reserves are less needed to finance imbalances in the balance of payments or to smooth the adjustment process of the current account. On the other hand, integration in the international financial market also contains the risk of sudden stops and reversals of capital flows. The access to global capital markets is uncertain. Since financially open countries are more vulnerable to currency and financial crises they are expected to hold more reserves.

Total external debt: Reserves might be seen as a collateral for debt and enhance the foreign investors willingness to invest in the domestic economy. Moreover, empirical studies show that both a high level of external debt and a low level of reserves increase the probability of a financial crisis. Hence, reserves might offset the vulnerability induced by external debt.

Therefore, it is expected that countries with a high level of external debt hold more reserves for precautionary reasons.

However, there might be exceptions from this expected behaviour: Highly indebted countries might not be able to acquire the desired level of reserves. Therefore, there might exist a discrepancy between the desired and affordable level of reserves.

Short-term external debt: Reserves that cover short-term debt enable a country to repay its external obligations as scheduled even if capital inflows stop suddenly. Hence, the negative repercussions of capital flight can be mitigated. More importantly, the negative long-term effects of credit loss by foreigners in terms of lost access to international capital markets can at best be averted. Short-term external debt is defined as external debt with a remaining maturity of one year or less.

Persistence: The level of reserves is a stock variable that, if the central bank were totally passive (freely floating exchange rate) would be constant over time. The initial stock of reserves is not zero, but when a central bank determines the level of reserves, it always starts from the existing level of the previous period. Therefore, the determination of the level of reserves is a natural candidate for a dynamic specification that includes the lagged level of reserves as one of its determinants.

Analytically, the inclusion of the lagged dependent variable can be motivated by a partial adjustment or habit-persistence model. A central bank might only partially adjust the level of reserves to its desired level when the adjustment is costly and when an optimising behaviour is assumed, trading off the costs of making the adjustment and the costs of not having the desired level of reserves. In addition, the lagged dependent variable might be interpreted as a measure of inertia or historical persistence. A central bank that evaluates the past level of reserves as adequate will be inclined to stick to this level, even if the determinants of reserve holdings call for a reduction. Bordo and Eichengreen (2001) show that inertia is at least present for gold holdings of central banks.

Regardless of these considerations, the standard approach of the literature on the determinants of international reserves uses static models. There are only two exceptions (Bordo and Eichengreen 2001 and Dreher and Vaubel 2005).

3 Empirical strategy

3.1 Data

The empirical analysis is carried out using annual data from 1975 to 2003. The beginning of this period is motivated by the previous breakdown of the Breton Woods system. This institutional change probably led to a structural break in the time-series of foreign exchange holdings from which we would like to abstain in this study.

The database extends to a maximum of 181 countries. These are all countries – industrial, emerging as well as developing countries – for which data on official reserve holdings for the period from 1975 to 2003 are available in the International Financial Statistics. A list of the countries included in the sample can be found in appendix A. Since data for some of the explanatory variables are not available for all countries, the econometric analysis makes use of a maximum of 162 countries. Moreover, since some of the data is not available for all years, the panel data set is unbalanced. With a few exceptions data are taken from the International Financial Statistics of the IMF and the World Development Indicators of the World Bank. A detailed description of the variables and data sources can be found in the appendix B.

3.2 Econometric methodology

The standard model to analyse panel data is the unobserved effects model. Observations are pooled over time and units of observation, with or without individual-specific effects. These effects can be fixed (fixed effects model) or random (random effects model). Analytically, in its dynamic version it can be written as

$$y_{it} = \delta y_{i,t-1} + x_{it}\beta + c_i + \varepsilon_{it} \quad (1)$$

where y is the level of reserves and x represents a set of variables that potentially affect the level of international reserves. c represents the country specific effect and u is the error term. i denotes a specific country and t stands for time. In total, we observe N countries over T time periods.

Homogeneous versus heterogeneous parameters

Panel data models with unobserved effects allow for some country heterogeneity but, at the same time, assume that this heterogeneity can be captured by an individual effect – random or fixed. That is to say the heterogeneity is time-constant and independent of the explanatory variables. Concerning the slope coefficients, it is assumed that they are constant over time and over all cross sections. Hence, one assumes that the postulated economic relationship is constant over time and that the effect of the explanatory variables is equal over all units of observations.

Heterogeneity between countries, however, might not be solely due to fixed effects, but also to different responses with respect to changes in the explanatory variables. For example, the effect of openness – trade as well as financial openness – of a country on the level of reserves might depend on the country-specific experiences with openness. To be more precise, if a country had been hit by a balance of payments crisis in the past, it might evaluate the risk of openness differently than a country without this experience. In addition, if reserves had been used in the past to cushion the negative effects of openness, economic agents would expect the central bank to do so in the future, too. This creates moral hazard in the sense that economic agents do not evaluate risks properly. The central bank might simply respond to these expectations. Moreover, the effect of a given degree of openness might depend on the history of this variable. Countries that opened their current and capital account just recently might behave differently than countries that have a long history of openness.

Since the majority of empirical studies on the determinants of international reserve holdings rely on fixed-effects estimation of static panel data models, the question arises whether the results are robust to possibly neglected dynamics and heterogeneity across countries.

Theoretically, the estimators from a pooled model are more efficient than those based on individual models if the conditions for pooling are fulfilled. Pooled estimators are consistent as long as all regressors are strictly exogenous and all parameters are random and distributed independently of the regressors. Pooling presumes that there are similarities or linkages in the data generating processes of the different units of observation. They are assumed to belong to one population.

In practice, however, the strong assumption of common slopes might be violated. Countries behave differently and the results for one country are not completely transferable to other countries. The following section illustrates the consequences of neglecting parameter heterogeneity.

Country behaviour might be modelled according to the following heterogeneous specification, which allows for country-specific parameters β and δ , indicated by the index i :

$$y_{it} = \delta_i y_{i,t-1} + x_{it} \beta_i + c_i + v_{it} \quad (2)$$

where v is the error term and δ is set equal to zero in the static case. Let us assume that the coefficients β_i and δ_i vary across countries but are fixed over time. They consist of a component that is common for all countries and a country-specific random deviation:

$$\begin{aligned} \delta_i &= \delta + \eta_i \\ \beta_i &= \beta + \alpha_i \end{aligned}$$

η_i and α_i are identically independently distributed, independent of x_{it} and u_{it} and have a zero mean and a constant variance. If this heterogeneity is neglected and estimation based on a restricted homogeneous model specified by (1), the heterogeneity terms become part of the error term:

$$u_{it} = v_{it} + \eta_i y_{i,t-1} + x_{it} \alpha_i \quad (3)$$

Given the assumptions that all regressors x_{it} are strictly exogenous and that all parameters are random and distributed independently from the regressors x_{it} , v_{it} and $\alpha_i x_{it}$ are independent of x_{it} . Therefore, in the static case ($\delta_i = \alpha_i = 0 \forall i$) the composite error term u_{it} is independent of the regressors and the fixed effects estimator is consistent.⁴ This result originates from Zellner (1969). However, the error u_{it} is heteroskedastic and serially correlated if x_{it} is serially correlated. This makes the estimates inefficient but does not affect their consistency.

⁴ Wooldridge (2004) shows that for consistency of the static fixed effects estimator it suffices that β_i is independent of the time-demeaned explanatory variables x_{it} . In particular, β_i may depend on the time averages of x_{it} .

These results for static cases, however, do not apply to dynamic models. Since y_{it} is serially correlated, the composite error term is serially correlated as well and not independent of the lagged dependent variable. Therefore, in the dynamic case, pooling gives inconsistent estimates of the coefficients. The bias persists regardless of the size of N , T and of any choice of instruments. This inconsistency was first noted by Robertson and Symons (1992) and examined more rigorously by Pesaran and Smith (1995).

The large sample bias of δ will be positive if the serial correlation of x_{it} is larger than zero.⁵ The estimator of β will be downward biased. The size of the bias increases with the degree of parameter heterogeneity (i.e. the variance of β_i).

If the explanatory variables x_{it} are serially correlated – which is the empirically relevant case – the bias persists even if the only source of heterogeneity comes from variations in β_i across groups whereas the adjustment parameter δ_i is the same across all countries.

Monte Carlo studies presented in Pesaran, Smith and Im (1996) investigate the small sample properties of various estimators in heterogeneous panels. They indicate that the mean group estimator generally outperforms pooled estimators (fixed effects estimator, Anderson-Hsiao estimator) by far. A comparative study of the bias of the GMM-type estimators and the mean group estimator, however, remains a task for future research.

Since our data set spans over a sufficiently large period, separate regressions for each country can be estimated. In this case, it is natural to consider heterogeneous panel data models. For each country equation (2) is estimated individually. Rather than assuming equal parameters for all countries, one can estimate individual parameters and then test the hypothesis that the parameters are equal.

3.3 Tests for poolability of the data

The poolability over countries can be tested by a Chow test that is extended to N linear regressions. Like a standard Chow test, it compares the residual sum of squares of a restricted model with that of an unrestricted model. The restricted model is the pooled model with the same parameters for all countries and over all periods except a country-specific intercept (fixed effects model). The unrestricted model consists of the same behavioural equation,

⁵ Since in dynamic fixed effects estimations based on pooled OLS δ is biased upwards due to the presence of the lagged dependent variable, the two biases attenuate each other.

which is, however, estimated individually for each country, thereby allowing for different parameters across countries. Intuitively, the Chow test rejects the hypothesis of poolability if the reduction in the residual sum of squares is relatively large when individual parameters are allowed for.

The standard Chow test is only valid for disturbances that meet the twin assumption of homoskedasticity and no serial correlation. A modified test statistic that allows for both heteroskedasticity and serial correlation of the errors is available. It is a special application of the Roy-Zellner test for aggregation bias in a set of seemingly unrelated regressions.

However, there is a problem with the standard F test in large samples: As the sample size grows, classical testing at a fixed level of significance increasingly favours the alternative hypothesis. When the sample size increases, the probability of accepting a false hypothesis (type II error) converges to zero whereas the probability of rejecting a true hypothesis (type I error) remains at its predefined level. If one is willing to reduce the two types of errors simultaneously, the critical value should be an increasing function of the sample size.⁶ Leamer (1978) proposes such a correction to the critical value of the F statistic, which will be presented as an alternative to the standard Chow test.

These tests evaluate exclusively the validity of the hypothesis of common parameters across countries. They do not take into account that pooling data has the advantage that the variance-covariance matrix of the pooled model always has smaller entries than in the unrestricted model. The restricted model might hence be preferred if one accepts some bias in trade for a gain in precision. This trade-off between bias and variance is captured by the mean square error (MSE)⁷ criteria for poolability, which were proposed by Toro-Vizcarrondo and Wallace (1968) and Wallace (1972). Strictly speaking, the MSE criteria do not test the hypothesis of equal parameters across countries, but allow to choose between two estimators pragmatically trading off bias and variance.

The results of the poolability tests are presented in table 1. The evidence is mixed. For our data set, three out of the four described tests reject the hypothesis of poolability. Only the Chow test with the corrected F statistic according to Leamer's formula accepts the hypothesis of common parameters across countries.

⁶ This idea is in line with the Bayesian viewpoint that the critical value is an increasing function of the sample size.

⁷ The mean square error of an estimator is defined as its variance plus the square of its bias.

Table 1: Poolability tests across countries

	Large sample (93 countries)	Small sample (72 countries)
Observed F statistic	15.36	14.99
Chow test		
a) Generalized (Roy-Zellner) ¹ H ₀ of same slope coefficients across countries	F _{crit} = 1.11 rejected	F _{crit} = 1.13 rejected
b) Leamer critical values ² H ₀ of same slope coefficients across countries	F _{crit} = 20.00 accepted	F _{crit} = 15.72 accepted
Mean square error criteria		
a) strong MSE criterion Pooling better?	F _{crit} = 1.15 rejected	F _{crit} = 1.15 rejected
b) 2 nd weak MSE criterion Pooling better?	F _{crit} = 2.34 rejected	F _{crit} = 2.34 rejected

Notes:

The large sample of 93 countries includes all those countries of the benchmark regression (table 2, equation (2)) for which data for at least 10 years are available. The small sample consists of the same countries but requires at least data over 20 years. Since regression (2) of table 2 also includes countries with data over fewer years, the samples are smaller. This restriction is necessary since the calculation of the test statistic is based on the estimation of the behavioural equation individually for each country. So it is guaranteed that the estimation country by country is based on at least 10 or 20 data points, respectively.

All critical values of the F statistic are based on a level of significance of 5%.

¹ The generalized Chow tests allows for both heteroskedasticity and serial correlation of the errors.

² The critical values are calculated according to the following formula which is given in Leamer (1978, p.114):

$$F_{crit} = \frac{N(T-K-1)}{(N-1)K} \cdot \left((NT)^{(N-1)K/NT} - 1 \right)$$

where N is the number of countries, T the number of time periods and K the number of estimated parameters excluding the intercept.

This result, however, comes as no surprise. Previous studies found that the hypothesis of common slope parameters is very often rejected (see for example Pesaran and Smith 1995). This tendency of overrejection in finite samples was also attested by Monte Carlo studies conducted by Bun (2004). Nevertheless, it indicates that heterogeneity in international reserve determination among individual central banks is considerable. As described in the previous section, while static models are still unbiased, the neglect of heterogeneity may lead to misleading results in dynamic models.

Nevertheless, following the literature, the results of pooled models will be presented despite the presence of country heterogeneity. The purpose of this paper is precisely to present the results of pooled as well as individual models and to highlight the differences.

3.4 Static models

This section presents different estimators for static models of panel data, which will be used for estimation. It summarises their characteristics and possible shortcomings.

Fixed effects model: The standard model for the analysis of macroeconomic panel data is the fixed effects model, which takes into account individual country effects. However, the fixed effects estimator (also known as the within estimator) is only efficient if the errors are homoskedastic and serially uncorrelated. These assumptions are likely to be violated in a panel data context. Since countries differ considerably in their absolute level of international reserves, they may also exhibit different variation in their reserve level and hence be subject to country-specific heteroskedasticity. Serial correlation – temporal dependence of the error terms – is also likely since unobserved shocks might affect the relationship over various periods. Therefore, a robust variance matrix is estimated, which allows for general forms of heteroskedasticity and serial correlation. This was suggested by Arellano (1987) and is equivalent to a White-corrected variance matrix.

Random coefficient model: A model that allows for additional parameter heterogeneity is the random coefficient model. Rather than just the intercept varying across groups, all coefficients and the intercept vary randomly across groups but share a common mean and the same variance-covariance matrix. It can be interpreted as an extension of the random effects model where not only the intercept but also the slope parameters are random.

In our sample of countries where the differences between countries are not random but rather systematic, the random model seems to be inappropriate. Despite these caveats, the random coefficient model will be included in the econometric analysis because interest centres on the effect of permitted heterogeneity.

Mean group estimator: The mean group estimator (MG), which was proposed by Pesaran and Smith (1995), allows for slope heterogeneity between groups. For each country, it estimates an individual regression by OLS and averages the coefficients over groups.

This estimator leads to consistent estimates of the coefficients if N and T tend to infinity. For small T , however, there is the small-sample downward bias (Nickell bias) in the coefficient of the lagged dependent variable. Since each of the country estimates are subject to this bias, it will not be reduced by averaging across groups. The magnitude of the bias depends on $1/T$ and is less of concern if T and N are of the same order of magnitude. Hence, if one estimates a dynamic model for heterogeneous data, one has the choice between two biased estimators: an instrumental variables estimator à la Arellano-Bond which is biased because of the neglect of slope heterogeneity and the mean group estimator which is subject to the Nickell bias.

3.5 Dynamic models

In dynamic specifications, the lagged dependent variable enters as an explanatory variable. In this setting, the assumption of strict exogeneity is violated since the lagged dependent variable is correlated with the error term by construction. Previously discussed fixed effects estimators are biased and inconsistent for $N \rightarrow \infty$ and fixed T .⁸

The literature proposes two different solutions: a correction for the bias or, alternatively, estimation by the Generalized Method of Moments (GMM).

Bias-corrected fixed effects estimator: For dynamic panel data models with serially uncorrelated errors and strongly exogenous regressors, Kiviet (1995) derives an approximation for the bias of the fixed effects estimator. He proposes a corrected fixed effects estimator that subtracts a consistent estimate of this bias from the standard fixed effects estimator. In Kiviet (1999), a more accurate bias approximation is derived. Bun and Kiviet (2003) reformulate the approximation with simpler formulae for each term. Bruno (2005) extends these results to unbalanced panels. Simulation studies, which are included in the articles on bias approximation cited in this paragraph, show that this correction is an efficient method and can even be more efficient in finite samples than instrumental variables estimators.

⁸ For $N \rightarrow \infty$ and $T \rightarrow \infty$ the estimator would be consistent. However, a Monte Carlo study, conducted by Judson and Owen (1999), reveals that even for a relatively large time dimension ($T=30$) the bias may be equal to as much as 20% of the true value of the coefficient of interest.

Instrumental variables estimators are proposed as an alternative solution. This class of estimators eliminates the country-specific effects by first differencing. It then applies instrumental variables to the transformed equation.

Difference GMM estimator: Arellano and Bond (1991) propose a GMM estimator that uses all feasible lagged values of the dependent variable as instruments. More precisely, beginning with $y_{i,t-2}$ all lagged levels of y until $y_{i,0}$ can be used as instruments. Hence, the number of instruments varies with t since with each forward period an extra instrument is added.

A shortcoming of the Arellano-Bond estimator – just as of the fixed effects estimator – consists in the fact that it makes use only of the time variation within each cross section, whereas the cross-sectional variation is not used for estimation. However, we are not only interested in the time-series relationship between the level of reserves and its determinants, but also in their cross-country relationship.

System GMM estimator: This loss of information is avoided by an alternative estimator that combines, in a system, the regression in differences with the regression in levels. The regression in differences, the first part of the system, and its instruments are the same as those of the Arellano-Bond estimator. For the regression in levels, the second part of the system, lagged first-differences of the corresponding variables are used as instruments. For consistency of this estimator, an additional stationarity assumption on the initial value of the level of reserves is required. If one can assume that the same process has generated the series for a long time, the condition will hold automatically.

Hence, the system estimator basically extends the Arellano-Bond estimator by adding the regression in levels.

The consistency of the GMM estimator depends on the validity of the instruments. To address this issue, two specification tests are used: The Sargan test of overidentifying restrictions evaluates the overall validity of the instruments. The Arellano-Bond test for autocorrelation in the residuals assesses the assumption that the residuals are uncorrelated over time. It tests the null hypothesis that second-order serially correlation is absent. This implies that the original residuals are uncorrelated, too. The results of both tests are reported at the bottom of the output tables.

4 Estimation results

4.1 Static models

Table 2 presents the results of the estimation of a static fixed effects model. The dependent variable is reserves over GDP. Column 1 only includes the traditional, current account based determinants of reserves. It is a test of the classical buffer stock model.

Real GDP per capita has no significant impact on reserves. More open economies are associated with higher ratios of reserves to GDP, and this effect is statistically significant at the 1% level. This result is in line with the hypothesis that countries use reserves to protect the economy from external shocks.

An increase in the external volatility significantly lowers the level of reserves. This effect is inconsistent with our theoretical considerations. It also persists the robustness check: if nominal volatility is replaced by real volatility (see column 4), the effect is still negative and significant. Apparently, countries do not behave as hypothesized by the theoretical models. One explanation could be that countries with high external volatility deviate from the desired or “recommended” level of reserves. So far, it was assumed that changes in the amount of international reserves reflect a movement towards their desired level. This is the idea of the partial adjustment model. Countries, however, might deviate deliberately from the desired level of reserves because they cannot afford these reserves. This might be especially true for countries affected by high external volatility. The negative correlation between volatility and GDP per capita (-0.11) supports this explanation.

In this context it might be helpful to go further into the question why some countries are exposed to higher external volatility than others. The reasons might be local – economic crisis, political instability, changing law and order, natural disasters – or global – terms of trade shocks and volatile prices of natural resources in economies whose export sector is not well diversified. Hence, both low reserves and high volatility might be the outcome of poor macroeconomic management (common cause dependence).

Concerning the exchange rate system, a de jure fixed exchange rate significantly lowers the level of reserves. Although this is also contrary to our expectations, it is in line with the findings of similar studies (Lane and Burke 2001). The category of fixed exchange rates includes currency unions, dollarized economies as well as currency boards. Under these exchange rate systems, reserves are held for intervention purposes, but less to resist speculative attacks. An explanation for the lower reserves under a fixed exchange rate might

be that the precautionary motive – prevalent under flexible exchange rate systems – is associated with a larger reserve demand than the intervention motive. Interestingly, even intermediate exchange rate systems hold fewer reserves than flexible ones, although the difference is not statistically significant.

In column 2 capital account-based explanatory variables are added: Total external debt (in per cent of GDP) increases the level of reserves, whereas short-term debt (as per cent of GDP) decreases reserves. Both effects are significant at the 1% level. This is in line with the hypothesis that reserves are considered as a means to protect the economy from negative repercussions associated with a sudden withdrawal of foreign capital. However, since capital flight primarily concerns short-term debt, one would expect that reserves increase even more if the share of short-term debt in total external debt rises. An explanation for the observed negative effect might lie in the fact that a high level of short-term debt implies that the country received large capital inflows in the recent past. The central bank might sell part of its reserves in order to satisfy the domestic credit demand, thereby substituting external by internal financing.

The sign and significance of the traditional variables remain unchanged, with two exceptions. Real GDP per capita has now a significant positive effect, and the sign of the intermediate exchange rate system changed from negative to positive.

When the real opportunity cost is added (column 3), the effects of the other explanatory variables are qualitatively unchanged. Real opportunity cost itself is not significant. This finding was also prevalent in the early literature and led to the disregard of the opportunity cost variable in many empirical studies (see Lane and Burke 2001). The interest elasticity of the demand for reserves seems to be low. A central banks might simply not bother about opportunity costs since it is blamed for not having sufficient reserves in times of crisis but is not accused of paying a too high opportunity cost in good times when reserves are not needed.

The results are also robust to the replacement of the standard volatility measure (nominal volatility) by the standard deviation of export growth as a capacity to import (real volatility). As well as the original volatility measure, this variable has the wrong sign.

Table 3 reports the regression results using alternative estimators, which allow determining whether the results are robust to the inclusion of parameter heterogeneity. Since the mean

group estimator is based on individual regressions for each country, the sample is restricted to countries for which at least 20 observations for each variable are available. This reduces the sample to 63 countries. As explanatory variables the core variables, which turned out to be significant in Table 2, are included. For comparison, column 1 contains the fixed effects estimation of the reduced sample. Significance and sign of the parameters mostly correspond to those found in Table 2. Exceptions are real volatility, which is no longer significant, and the intermediate exchange rate dummy, which changes its sign. Column 2 presents the results of the mean group estimator. Significance and sign of the variables are very similar to those of the fixed-effects estimator. However, quantitatively, the effects vary considerably, with the coefficients of volatility and short-term debt more than twice as large as those reported by the fixed effects estimates. Moreover, the two debt variables are no longer significant. The findings of the random coefficient model (column 3) once again confirm the sign of the effects. Nevertheless, only the effects of openness and a fixed exchange rate are significant.

As a test for robustness, the exercises of Table 2 and Table 3 were replicated for a different specification where the dependent variable is not reserves over GDP but reserves over base money. By and large, the previous findings are confirmed.⁹

4.2 Dynamic models

In this section the results from the dynamic specifications are presented. As expected, the lagged level of reserves is highly significant in all specifications and for all applied estimators.

Table 4 compares the different estimators for homogeneous panel data. The differences are striking: The coefficient of the lagged endogenous variable ranges from 0.76 to 0.96. The quantitative effects for the other explanatory variables also vary considerably. Concerning the qualitative results, the estimates are more homogeneous. Independently of the estimator, the coefficients of openness and external debt are positive and significant. This is in line with the findings from the static models. Moreover, the effect of short-term debt is significant and negative for all estimators which is again in line with the results from the static models.

The three tests of consistency of the GMM estimators – the Sargan, Hansen and Arellano-Bond test - clearly accept the specification.

⁹ The results are available on request from the author.

Analogously to table 3, table 5 compares the restricted models characterized by homogeneous slope parameters with the mean group estimator. Again the sample is restricted to countries for which at least 20 observations for each variable are available. This reduces the sample to 70 countries. The findings in column 1 to 3, which replicate the estimation of columns 1, 3 and 4 from table 4 for the reduced sample, are similar to those described before. However, the results of the mean group estimator differ considerably from the homogeneous parameter methods: The coefficients of total external debt and short-term debt are no longer significant. The effect of the lagged endogenous variable is much smaller, whereas openness has a much larger effect. The coefficient of volatility, until now mostly insignificant, becomes significant at the 10 per cent level. Concerning the exchange rate dummies, at least the sign and significance do not change.

5 Conclusions

The results suggest that the neglect of dynamics and heterogeneity in country behaviour may lead to misleading inferences. Dynamic and heterogeneous regression results differ from their static and homogeneous counterparts with respect to magnitude and significance of the effects. Whereas the differences between the static and dynamic models for homogeneous data regard primarily the estimated magnitude of the effects, the comparison of the estimates of homogeneous versus heterogeneous models reveals conflicting results concerning the significance of the effects. These inconsistencies are especially pronounced in the dynamic specification. The results confirm the theoretical finding that the neglect of heterogeneity affects inferences in dynamic models.

Since the tests for poolability reject the hypothesis of common slope parameters, the mean group estimator is expected to lead to the most reliable results. The findings suggest that both traditional variables of the buffer stock model and variables related to financial crises determine the level of reserves. Central banks take precautionary measures against the risks of the increasing international financial integration, which were highlighted by the series of financial crises in the second half of the 1990s.

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Figure 1: Indicators of reserve adequacy – traditional view

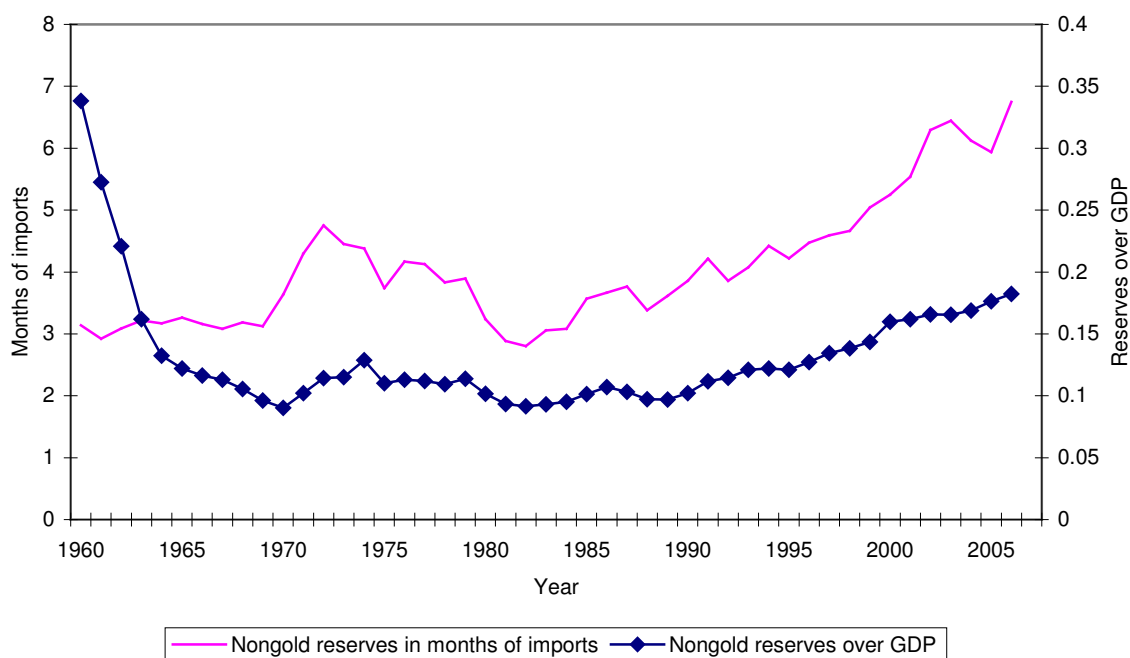
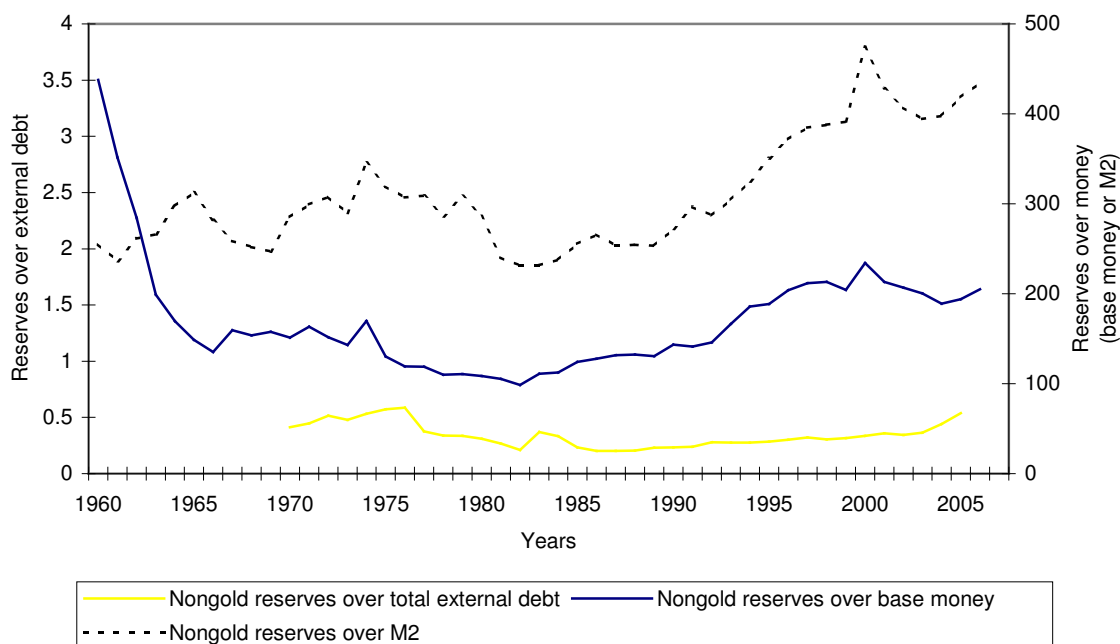


Figure 2: Indicators of reserve adequacy – focus on capital flight



Source: Author's calculations based on International Monetary Fund (2008) and World Bank (2007).
 Note: For each year, the data refer to unweighted country averages.

Table 2: Static models: Fixed effects estimation

Dependent variable: Reserves/GDP

	(1)	(2)	(3)	(4)
Real GDP per capita	0.0001 (-0.19)	0.03 (8.21***)	0.04 (6.83***)	0.03 (6.31***)
Openness	0.1022 (8.97***)	0.0644 (4.70***)	0.0713 (4.15***)	0.0734 (4.45***)
Volatility (nominal)	-0.0269 (-5.96***)	-0.0167 (-4.06***)	-0.0205 (-4.18***)	
Volatility (real)				-0.0096 (-3.27***)
Total external debt (per cent of GDP)		0.0363 (7.18***)	0.342 (5.50***)	0.0378 (6.87***)
Short-term debt (lagged) (per cent of GDP)		-0.1838 (-8.57***)	-0.1813 (-7.80***)	-0.1905 (-8.22***)
Real opportunity cost (lagged)			0.0000 (-0.37)	
Fixed exchange rates, dummy	-0.0242 (-6.47***)	-0.0092 (-1.95*)	-0.0130 (-2.27**)	-0.0082 (-1.63)
Intermediate exchange rates, dummy	-0.0011 (-0.28)	0.0056 (1.33)	0.0025 (0.48)	0.0070 (1.54)
Number of countries	162	125	117	119
Number of observations	3411	2518	1694	2221
Method of estimation	OLS	OLS	OLS	OLS
R ² (overall)	0.17	0.09	0.12	0.12

Notes:

t-statistics (in brackets) computed with heteroskedasticity-consistent standard errors.
*, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 3: Static models: Alternative estimators allowing for parameter heterogeneity

Dependent variable: Reserves/GDP

	(1)	(2)	(3)
Real GDP per capita	0.0329 (5.92***)	0.0360 (1.66*)	0.0286 (1.26)
Openness	0.0535 (2.67***)	0.0929 (3.54***)	0.1058 (3.63***)
Volatility (real)	-0.0144 (-0.64)	-0.0629 (-1.15)	-0.0292 (-0.50)
Total external debt (per cent of GDP)	0.0409 (6.66***)	0.0311 (1.07)	0.0084 (0.28)
Short-term debt (lagged) (per cent of GDP)	-0.1983 (-8.04***)	-0.5262 (-1.65*)	-0.2937 (-0.90)
Fixed exchange rates, dummy	-0.0145 (-2.82***)	-0.0262 (-3.80***)	-0.0216 (-2.93**)
Intermediate exchange rates, Dummy	0.0069 (1.37)	0.0024 (0.49)	0.0019 (0.36)
Number of countries	63	63	63
Number of observations	1743	1743	1743
Method of estimation	OLS	MG	RC
R ² (overall)	0.10		

Notes:

t-statistics (in brackets) computed with heteroskedasticity-consistent standard errors.

*, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

OLS: pooled OLS including fixed country effects

MG: mean group estimator

RC: random coefficient estimator

Table 4: Dynamic models: Homogeneous parameters

Dependent variable: Reserves/GDP

	(1)	(2)	(3)	(4)
Lagged endogenous variable	0.7605 (16.52***)	0.7846 (16.52***)	0.9639 (47.22***)	0.9316 (69.29***)
Real GDP per capita	-0.0064 (-2.29**)	-0.0066 (-2.37**)	0.0004 (1.39)	-0.0013 (-1.10)
Openness	0.0495 (3.60***)	0.0491 (3.52***)	0.0124 (5.45***)	0.0314 (5.74***)
Volatility (nominal)	-0.0053 (-1.29)		-0.0026 (-2.70***)	-0.0041 (-1.89*)
Volatility (real)		-0.0039 (-1.27)		
Total external debt (per cent of GDP)	0.0145 (4.55***)	0.0177 (4.35***)	0.0105 (4.26***)	0.0136 (6.20***)
Short-term debt (lagged) (per cent of GDP)	-0.0580 (-2.67***)	-0.0705 (-2.62***)	-0.0371 (-3.51***)	-0.0361 (-3.52***)
Fixed exchange rates, dummy	-0.0115 (-2.36**)	-0.0105 (-2.37**)	-0.0054 (-2.39**)	-0.0016 (-0.58)
Intermediate exchange rates, dummy	0.0048 (1.14)	0.0052 (0.96)	0.0009 (0.39)	0.0011 (0.40)
Number of countries	125	118	125	
Number of observations	2317	2036	2446	
Method of estimation	Difference GMM (two step)	Difference GMM (two step)	System GMM (two step)	LSDV (corrected)
Sargan Test (p-level)	1.0	1.0		
Hansen Test (p-level)			1.0	
Arellano-Bond-Test (p-level)	0.95	0.93	0.90	

Notes:

t-statistics (in brackets) computed with heteroskedasticity-consistent standard errors.
 *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.
 LSDV: least-squares dummy variable estimator (=fixed effects estimator)

Table 5: Dynamic models: Alternative estimators allowing for parameter heterogeneity

Dependent variable: Reserves/GDP

	(1)	(2)	(3)	(4)
Lagged endogenous variable	0.7946 (20.84***)	0.9678 (40.59***)	0.9314 (71.88***)	0.5449 (14.09***)
Real GDP per capita	-0.0041 (-1.28)	0.0001 (0.42)	-0.0014 (-1.05)	0.0106 (0.84)
Openness	0.0485 (3.64***)	0.0121 (3.80***)	0.0301 (4.85***)	0.0800 (4.90***)
Volatility (nominal)	-0.0021 (-0.21)	-0.0052 (-0.85)	-0.0060 (-0.80)	-0.0421 (-1.90*)
Total external debt (per cent of GDP)	0.0140 (3.67***)	0.0088 (3.28***)	0.0129 (5.10***)	0.0205 (1.25)
Short-term debt (lagged) (per cent of GDP)	-0.0567 (-2.23**)	-0.0332 (-3.00***)	-0.0324 (-3.24***)	-0.0599 (-0.65)
Fixed exchange rates, dummy	-0.0115 (-3.04***)	-0.0060 (-2.47**)	-0.0050 (-1.70*)	-0.0123 (-3.72***)
Intermediate exchange rates, dummy	0.0014 (0.70)	0.0011 (0.40)	0.0001 (0.05)	0.0040 (0.54)
Number of countries	70	70	70	70
Number of observations	1824	1896		
Method of estimation	Difference GMM (two step)	System GMM (two step)	LSDV (corrected)	MG
Sargan Test (p-level)	1.0			
Hansen Test (p-level)		1.0		
Arellano-Bond-Test (p-level)	0.92	0.95		

Notes:

t-statistics (in brackets) computed with heteroskedasticity-consistent standard errors.

*, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

LSDV: least-squares dummy variable estimator (=fixed effects estimator)

MG: mean group estimator

Appendix A: Country list

Afghanistan	Dominica	Libya	Senegal
Albania	Dominican	Lithuania	Seychelles
Algeria	Republic	Luxembourg	Sierra Leone
Angola	Ecuador	Macao, China	Singapore
Antigua and Barbuda	Egypt, Arab Rep.	Macedonia, FYR	Slovak Republic
Argentina	El Salvador	Madagascar	Slovenia
Armenia	Equatorial Guinea	Malawi	Solomon Islands
Aruba	Eritrea	Malaysia	Somalia
Australia	Estonia	Maldives	South Africa
Austria	Ethiopia	Mali	Spain
Azerbaijan	Fiji	Malta	Sri Lanka
Bahamas, The	Finland	Mauritania	St. Kitts and Nevis
Bahrain	France	Mauritius	St. Lucia
Bangladesh	Gabon	Mexico	St. Vincent and the Grenadines
Barbados	Gambia, The	Micronesia, Fed. Sts.	Sudan
Belarus	Georgia	Moldova	Suriname
Belgium	Germany	Mongolia	Swaziland
Belize	Ghana	Morocco	Sweden
Benin	Greece	Mozambique	Switzerland
Bhutan	Grenada	Myanmar	Syrian Arab Republic
Bolivia	Guatemala	Namibia	Tajikistan
Bosnia and Herzegovina	Guinea	Nepal	Tanzania
Botswana	Guinea-Bissau	Netherlands	Thailand
Brazil	Guyana	Netherlands Antilles	Togo
Bulgaria	Haiti	New Zealand	Tonga
Burkina Faso	Honduras	Nicaragua	Trinidad and Tobago
Burundi	Hong Kong, China	Niger	Tunisia
Cambodia	Hungary	Nigeria	Turkey
Cameroon	Iceland	Norway	Turkmenistan
Canada	India	Oman	Uganda
Cape Verde	Indonesia	Pakistan	Ukraine
Central African Republic	Iran, Islamic Rep.	Panama	United Arab Emirates
Chad	Iraq	Papua New Guinea	United Kingdom
Chile	Ireland	Paraguay	United States
China	Israel	Peru	Uruguay
Colombia	Italy	Philippines	Vanuatu
Comoros	Jamaica	Poland	Venezuela, RB
Congo, Dem. Rep.	Jordan	Portugal	Vietnam
Congo, Rep.	Kazakhstan	Qatar	Yemen, Rep.
Costa Rica	Kenya	Romania	Zambia
Cote d'Ivoire	Korea, Rep.	Russian Federation	Zimbabwe
Croatia	Kuwait	Rwanda	
Cyprus	Kyrgyz Republic	Samoa	
Czech Republic	Lao PDR	San Marino	
Denmark	Latvia	Sao Tome and Principe	
Djibouti	Lebanon	Saudi Arabia	
	Lesotho		
	Liberia		

Appendix B
List of variables and data sources

Variable	Source	Description
Reserves	World Bank (2005a)	Net international reserves comprise special drawing rights, reserves of IMF members held by the IMF, and holdings of foreign exchange under the control of monetary authorities. Gold holdings are excluded. Data are in current U.S. dollars.
Real GDP per capita	World Bank (2005a)	GDP is measured as gross domestic product in constant international dollars with the year 2000 as base. An international dollar has the same purchasing power over GDP as the U.S. dollar has in the United States. This measure of GDP is divided by the population which counts all residents regardless of legal status or citizenship.
Openness	World Bank (2005a)	Openness is defined as the sum of exports and imports divided by GDP. Data are expressed in per cent.
Volatility (nominal)	World Bank (2005a)	Volatility is measured as the standard deviation of the previous five years of the growth rate of exports.
Volatility (real)	World Bank (2005a)	The alternative proxy for volatility uses exports measured as a capacity to import as its base variable. Exports as a capacity to import equal the current price value of exports of goods and services deflated by the import price index. Data are in constant local currency. Volatility is then calculated as the standard deviation of the previous five years of the growth rate of this measure of exports .
Total external debt (divided by GDP)	World Bank (2005a)	Total external debt is the sum of public, publicly guaranteed, and private nonguaranteed long-term debt, use of IMF credit, and short-term debt. Data are in current U.S. dollars divided by GDP.
Short-term debt (divided by GDP)	World Bank (2005b)	Short-term external debt includes all debt that has an original maturity of one year or less. Data are in current U.S. dollars divided by GDP.

Appendix B (continued)

Variable	Source	Description
Real opportunity cost		Real opportunity cost is defined as the national real interest rate minus the real return of U.S. treasury bills.
• Real interest rate	World Bank (2005a)	The national real interest rate is calculated as the difference between the lending interest rate charged by banks on loans to prime customers and the inflation rate measured by the annual growth rate of the GDP implicit deflator which shows the rate of price change in the economy as a whole. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency.
• Real return of U.S. treasury bills	World Bank (2005a), IMF (2005)	The real return of US treasury bills is calculated as the difference of the rate of return of U.S. treasury bills (IFS line 60c) and the U.S. inflation rate measured by the annual growth rate of the GDP implicit deflator.
Fixed exchange rates, dummy	Ghosh, Gulde and Wolf (2002) and own update based on AREAER	Equals one if one of the following finer categories applies: dollarized, currency board, monetary union, single currency peg, published basket peg and secret basket peg.
Intermediate exchange rates, dummy	Ghosh, Gulde and Wolf (2002) and own update based on AREAER	Equals one if one of the following finer categories applies: cooperative system, crawling peg, target zone, unclassified rule-based intervention, managed float with heavy intervention, unclassified managed float and other floats.