Does the Accumulation of International Reserves Spur Inflation? A Panel Data Analysis

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Abstract

Central banks' international reserve holdings have increased significantly in the recent past. This paper assesses the consequences for monetary policy both on theoretical and empirical grounds.
According to the quantity theory of money, the accumulation of reserves might result in inflationary pressures if the resulting monetary expansion is not fully sterilized and exceeds the growth of money demand. This is especially likely for countries that operate under fixed exchange rates but may also affect countries with floating rates proportionate to their individual rate of reserve accumulation.
These hypotheses are tested in a panel data set of developing and industrial countries covering the period from 1970 to 2006. The evidence suggests that the accumulation of reserves increases inflation. Global reserve growth significantly raises the inflation rate with a lag of two years. This effect is especially strong for countries with fixed exchange rate regimes for which global reserve growth is found to Granger-cause inflation. A rate of global reserve growth of 1% causes an increase of the global price level of 0.25% over a period of two years. On the level of individual countries, the growth of domestic central banks assets is the major monetary determinant of inflation. The growth of reserves, however, causes inflation in a subsample including only moderate inflation rates. The degree of sterilization of the effects of reserve changes on the monetary base has changed considerably over time, with the 1970s and recent years since 2000 characterised by relatively low degrees of sterilization.

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1 Introduction

The current accumulation of international reserves by central banks is part of the vividly debated phenomenon of global imbalances. One possible consequence of the accumulation of reserves, however, has been disregarded so far: The effect of rising reserves on the price level. A rise in reserves increases the monetary base as long as it is not fully sterilized. The increased monetary base, in turn, leads through the functioning of the money multiplier to an expansion in the total amount of money. Finally, according to the quantity theory of money, the growth of money causes prices to rise after some delay. This argument is due to Heller (1976) and was confirmed by Khan (1979).

There is an additional argument: under fixed exchange rates monetary policy may be constrained by a lack of reserves. If all countries have more reserves, they may choose more expansionary policies.

Since these seminal papers, the relationship between reserves and inflation has not been reconsidered. Even though the risks of reserve accumulation for monetary policy have been recognized (see for example ECB 2006)[1], a deep theoretical and empirical study on the topic is missing. Moreover, since the studies of Heller and Khan, the international financial system has changed fundamentally and their conclusions of the Bretton Woods period might not be valid in a financial system with flexible exchange rates and a high degree of capital mobility. It is therefore warranted to reconsider whether the current accumulation of reserves creates inflationary pressures.

The uncertainty with respect to the inflationary consequences of the ongoing reserve accumulation is amplified by the fact that recent empirical studies disagree in the assessment of the extent of de-facto sterilization. Whereas Aizenman and Glick (2008) find that the extent of sterilization has risen after the Asian financial crisis, Reinhart and Reinhart (2008) show that recent years have been characterised by less sterilization.

If the accumulation of reserves were not fully sterilized, inflation rates in many emerging and developing countries would be expected to rise further in the near future. This might require a change in central banks' sterilization policy since their goals of maintaining price stability and

[1] The authors point out that the accumulation of reserves might challenge monetary policy: "Particularly in the presence of continuous net capital inflows, intervention on currency markets […] may lead to an excessive easing of domestic monetary conditions which could then threaten price stability." (ECB 2006, p.36)

preventing currency crises via reserve accumulation can only be attained simultaneously if the effects on the monetary base are sterilized. .

The article is organized as follows: The following section summarises the existing empirical findings on the relationship between reserve accumulation, global liquidity and inflation. Section 3 reviews the theoretical links between reserves, the monetary base and inflation. Section 4 investigates the relationship empirically in a panel data set that covers a large number of countries over the period 1970-2006. Static and dynamic panel data models are applied to test whether increasing reserves create inflation. The final section concludes.

2 Literature review

2.1 Reserves and inflation in fixed exchange rate regimes

The seminal paper exploring the links between changes in international reserves and inflation is due to Heller (1976). A regression analysis covering the period 1958-1975 (Heller 1979) shows that prices react with a mean lag of three years to changes in international reserves. This lag tends to be much shorter in developing than in industrial countries. A one per cent increase in reserves is estimated to result in a cumulative price increase of about 0.4 per cent. This effect is larger in developing than in industrial countries.

Khan (1979) challenges these results arguing that the empirical tests of Heller do not allow the conclusion that changes in international reserves caused inflation. One could as well argue in favour of a reversed causality argument, namely that nominal international reserves respond to inflation. However, Khan's causality tests confirm Heller's results for the whole period of observation (1957-77). Conversely, tests for the floating rate period (1973-77) show that the two series are independent and that the relationship between them is rather contemporaneous than causal.

Rabin and Pratt (1981) question the generality of Heller's results. They argue that his results are driven by a short episode of reserve accumulation and rising inflation in the 1970s and cannot be generalised.

2.2 Inflation as a global phenomenon

According to global monetarism, inflation is a global monetary phenomenon. Under floating exchange rates, however, the central bank can pursue an independent monetary policy such that the inflation rate is determined domestically. The question to which extent inflation is due to local and global factors has attracted increasing interest in recent years.

Neely and Rapach (2008) decompose a cross-section of inflation rates into their global, regional and country-specific components. They find that changes in global inflation explain a high proportion of domestic inflation variability, namely 34% of the total variability. This is especially true for developed and open economies with independent central banks.

Ciccarelli and Mojon (2005) consider inflation to be a global phenomenon in the sense that the international comovement of inflation rates is high. For 22 OECD countries changes of their average inflation explain 70% of the country-individual inflation variance. These common fluctuations are found to stem from commodity price changes and the international business cycle in the short run, and changes in the monetary policy regime and the tolerated inflation rate in the long run.

A related literature considers the inflationary consequences of global excess liquidity, defined as the amount of global liquidity that cannot be explained by a global money demand function including income and short-term interest rates. One possible source of global excess liquidity is the worldwide accumulation of international reserves. Rüffer and Stracca (2006) find that global excess liquidity conveys important information about future inflation at the global level.

The mentioned studies, however, disregard the accumulation of reserves as a possible source of excess liquidity. This study shall fill this gap and examine whether inflation can partly be attributed to the growth of international reserves.

3 Reserve accumulation and inflation: theoretical aspects

Since the inflationary consequences of the reserve accumulation may depend on the exchange rate arrangement, the theoretical section considers fixed and floating exchange rates separately.

3.1 Fixed exchange rates: Global monetarism

Standard monetarist theory states that inflation is a monetary phenomenon. Inflation can be explained by the rate of change of domestic money supply. This theory is formalised by the quantity equation of money:

$$M^S \cdot V = P \cdot Y$$

where M^S is the nominal money supply, V the velocity of money, P the price level and Y real output. After taking natural logarithms and differentiating with respect to time this can be expressed in rates of change as:

$$\hat{P} = \hat{M}^S + \hat{V} - \hat{Y}$$

where a hat on a variable denotes its rate of change. If one assumes that the velocity of money is constant and real output growth is constant[2], changes of the price level depend on the supply of money.

Global monetarism states that under fixed exchange rates this relation also holds at the global level: The worldwide inflation rate is determined by changes in the global supply of money.

Under fixed exchange rates the relative value of national currencies is stable and the world money supply, defined as the sum of domestic money supplies converted into a numeraire, is a meaningful concept. The balance of payments mechanism distributes the world money supply across countries such that the monetary market is in equilibrium in each country. If a country creates an excess supply of domestic money, its balance of payments turns into

[2] The effect of money on the price level is a long-run effect. Over this period, output is not constant, but output growth may be close to constant.

deficit: It looses reserves until the relative supply of domestic to foreign currency is again compatible with the value of the fixed exchange rate. As a result, the world money supply increases unless the foreign country sterilizes the increase in its monetary base.

If – as stated by global monetarism – global money supply determines global inflation, small open economies cannot control their inflation rate. Inflation may be generated by equal rates of money growth across countries or by the monetary policy of one single country.

The link between the money supply and the accumulation of international reserves can be illustrated by the money supply process. Money supply depends on two major factors: the money multiplier (m) and the monetary base (B):

$$M^S = m \cdot B$$

The monetary base equals a central bank's liabilities, namely the sum of currency (C) and deposits of commercial banks at the central bank (R). Alternatively, it can be defined by the assets of the central bank's balance sheet as the sum of net domestic assets (NDA) and net foreign assets (NFA):

$$M^S = m \cdot (C + R) = m \cdot (NDA + NFA) \tag{1}$$

Hence, the rate of change of money supply can be expressed as

$$\hat{M}^S = \hat{m} + \frac{NDA}{B} \cdot N\hat{D}A + \frac{NFA}{B} \cdot N\hat{F}A \tag{2}$$

Combining this specification of the money supply process with the quantity theory of money and assuming a constant velocity of money results in

$$\hat{P} = \hat{m} + \frac{NDA}{B} \cdot N\hat{D}A + \frac{NFA}{B} \cdot N\hat{F}A - \hat{Y} \tag{3}$$

This equation highlights the links between changes in international reserves and the price level. One can distinguish two extreme cases: If the central bank accumulates international reserves and fully sterilizes the effects on the monetary base through an open-market operation reducing its holdings of domestic bonds in exchange for money, $\frac{NDA}{B} \cdot N\hat{D}A = -\frac{NFA}{B} \cdot N\hat{F}A$, the price level is unaffected. If, however, the central bank does not sterilize, the increase in international reserves directly translates into an increase of the price level.

This argument holds for any individual country. If the assumptions of global monetarism are fulfilled – a world under a system of fixed exchange rates without sterilization ($\Delta NDA = 0$) – this equation also holds for world aggregates:

$$\hat{P}^{W} = \hat{m}^{W} + \frac{NFA^{W}}{B} N\hat{F}A^{W} - \hat{Y}^{W}$$

where the superscript w denotes world variables. If the world money multiplier is constant, world inflation equals the weighted rate of net foreign asset creation minus the growth rate of world output.

3.2 Floating exchange rates: National monetarism

Under floating exchange rates, the central bank can pursue an independent monetary policy such that the inflation rate may vary substantially between countries. There are no monetary restrictions that make domestic inflation rates interdependent. Differences in the growth rate of the monetary base can be maintained permanently as the resulting differences in inflation rates are accommodated via changes in the exchange rate. Hence, inflation is a national phenomenon under floating exchange rates. This, however, does not foreclose that inflation rates show some co-movement due to common non-monetary factors.

With inflation rates being independent, the concept of a worldwide inflation rate determined by world money supply is no longer meaningful. Consequently, the implications of the quantity theory of money cannot be applied to the world as an aggregate. In the words of Niehans (1976, p. 179) under floating exchange rates “international reserves have lost their

significance for inflation or deflation in the world economy, each country now controlling its own price trend." However, for each individual country, the quantity theory still applies.

Given the above reasoning (see equation (3)), the effect of an accumulation of international reserves on the inflation rate depends on the degree of sterilization. If countries do not offset the expansionary effect of accumulating international reserves, this might raise the domestic inflation rate. If, on the contrary, they fully sterilize, the accumulation of reserves has no impact on money supply and is not inflationary. To be more precise, only the direct monetary effects of the reserve accumulation are not inflationary in this case. There are, however, political economy reasons why sterilized purchases of foreign exchange might raise inflation. Since a sterilization operation expands the stock of domestic debt, policymakers might be tempted to reduce the nominal value of the debt through a surprise inflation. Hence, increasing domestic debt aggravates the commitment problem of the central bank and inflation expectations might rise. (see Calvo 1991)

4 Empirical analysis

The empirical analysis tests two hypotheses: 1. global reserve growth drives global inflation, and 2. reserve accumulation is inflationary within each country. The latter hypothesis is based on fewer assumptions since it does not require a fixed exchange rate regime.

4.1 Data

The empirical analysis is carried out on the basis of a pooled data set of cross-country and time-series observations. It contains annual data from 1970 to 2006. Data for international reserves are available for 191 countries. After dropping small countries (population smaller than 3 millions in the year 2000), the sample contains 126 countries, which are listed in appendix A. Since data for several explanatory variables are missing for some countries, the number of countries used in the econometric analysis depends on the particular specification and is indicated in the respective tables. It ranges from 66 to 118 countries. 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 their data sources can be found in appendix B.

In line with equation (2) the growth rates of reserves and domestic central bank assets are weighted by their fraction in the total monetary base.

4.2 Statistical evidence

This section presents statistical evidence with respect to the correlation between the growth rate of reserves and monetary variables.

Figure 1 plots the relationship between the growth rate of world reserves and the world inflation rate. Each data point relates to a specific year between 1975 and 2006. The world inflation rate is calculated as the weighted mean of individual countries' inflation rates where a country's fraction of world GDP is used as its weight. Weights are calculated for each year individually such that changes in the relative size of an economy are accounted for. This is a test of global monetarism.

The graph visualises two patterns: First, data points are not agglomerated in a data cloud but rather distributed over a large range of inflation rates and growth rates of reserves. This points to the fact that both rates varied considerably in the period under consideration. This variability might be due to factors not considered in the graph.

Second, the downward sloping line of fitted values suggests a negative relationship: Higher growth rates of reserves are correlated with lower inflation rates. This correlation, which is not in line with our hypothesis, is statistically insignificant. The missing correlation might stem from the fact that the scatter diagram only considers two variables. Hence, additional factors that affect one of the variables are implicitly assumed to be constant. In our case, inflation rates in many emerging and developing countries have fallen since the beginning of the 1990s while at the same time countries increasingly accumulated reserves. However, the fall in inflation is usually attributed to a trend for more prudent macroeconomic policies and increased central bank accountability. This might bias the scatter diagram. Therefore, relationship warrants a finer analysis by means of a regression analysis, which accounts for additional determinants of the inflation rate.

After this time-series analysis of world averages, figure 2 presents the relationship between the growth of reserves and the inflation rate in the cross section. Each data point represents an individual country displaying its average growth rate of reserves and its average inflation rate over the period 1970-2006. The left-hand side graph shows that both rates are positively

correlated. This supports the hypothesis that the accumulation of reserves is correlated with higher inflation rates. Since this relationship might be driven by some outliers with very high inflation rates and/or high growth rates of reserves, the right-hand side is based on a reduced sample after dropping countries with an average growth rate of reserves and/or inflation exceeding 50%. In this case, reserve growth and inflation are not correlated.

According to the theory developed in section 3, the link between the growth of reserves and inflation works through an indirect transmission channel. It is assumed that the growth of reserves increases the monetary base, which, in turn, leads to an increase in money supply (M1) ultimately causing the inflation rate to rise. Therefore, the correlation between reserve growth on the one hand and the growth rate of base money and M1 on the other is depicted in two additional graphs (figures 3 and 4). Each data point represents the average growth rates of both variables over the period from 1970-2006 for an individual country. Whereas the left-hand side graph is based on the full sample, the graph on the right hand displays the relationship for a reduced sample excluding outliers, namely countries with a growth rate of reserves and/or a growth rate of base money or M1, respectively, larger than 50%. All four graphs show that countries' growth rates of the monetary base and M1 are the higher, the higher their growth rate of international reserves is. All effects are significant at the 5%-level. This is first evidence that the inflationary impact of reserve accumulation works through an increase of domestic money supply.

4.3 Estimation results

4.3.1 Global monetarism

The regression analysis first replicates the analysis of Heller (1976, 1979). It investigates whether inflation is a global phenomenon in the sense that the growth of the stock of worldwide reserves causes inflation. Global inflation is calculated as the geometric mean of country-specific inflation rates, which are weighted by a country's fraction of world GDP. Whereas Heller regresses the inflation rate on current and lagged changes of reserves, I prefer to use a vector autoregression (VAR) of reserves and inflation that (1) includes also lagged values of the dependent variable, (2) does not a-priori assume variables to be endogenous or exogenous and (3) allows to test for the direction of causality. Thereby I can directly approach Khan's reversed causality argument. The VAR consists of the following two equations:

$$\pi^W = \alpha_1 + \sum_{j=1}^{p} \beta_j \cdot \pi^W_{t-j} + \sum_{j=1}^{p} \gamma_j \cdot \hat{R}^W_{t-j} + u_{1t}$$

$$\hat{R}^W = \alpha_2 + \sum_{j=1}^{p} \theta_j \cdot \pi^W_{t-j} + \sum_{j=1}^{p} \lambda_j \cdot \hat{R}^W_{t-j} + u_{2t}$$

where π^W and $\hat{R}^W$ denote world inflation and the growth rate of world reserves, respectively. p is the number of included lags. This model can be estimated by OLS.

The number of included lags is determined by the minimization of information criteria, namely the Akaike information criterion and the Schwarz-Bayes criterion. The preferred specification includes two lags.

Table 1 presents the estimation results. The growth of reserves significantly increases the inflation rate with a lag of two years. However, this effect is economically small and not comparable to the magnitude reported by Heller: An increase of world reserves by 10% raises inflation two years later by about 0.7%. To check the causality of this relationship, a Granger test is applied. The hypothesis that the growth of reserves does not cause inflation cannot be rejected at a the 10%-significance level (it can be rejected at at a level of significance of 11%).

The lower panel of the table tests for reversed causality: Inflation has no significant impact on reserve growth. Moreover, inflation does not Granger-cause reserves to growth.

Figure 5 shows the impulse-response function for an expansionary reserve growth shock. Reserve growth reduces inflation in the year following the shock, but has a positive impact on inflation two years later. This effect only decreases slowly over time. The negative impact in the first year is unexpected. It might be due to the fact that reserves are often replenished after a crisis has occurred (see chapter 3). Therefore, rising reserves might coincide with lower inflation rates due to the implementation of macro stabilization programmes.

As discussed in the theoretical section, the conclusion of global monetarism - global reserve growth causes world inflation - is based on the assumption of a world of fixed exchange rates. Therefore, I replicate the vector autoregressions of table 1 for a reduced sample. The subsample contains only those annual observations when a de jure fixed exchange rate was in place.[3] Based on these observations, world inflation and world reserve growth are calculated.

[3] This classification is flawed for our purposes and may be sharpened in future research: Global monetarism makes its statements for countries whose currencies are fixed with respect to one common currency. The empirical group of pegged exchange rates, however, consists of various blocs of fixed exchange rates with respect to different currencies, i.e. the Dollar, Euro or Yen.

Vector autoregresions examine the relationship between both variables. The results are presented in table 2. Reserve growth significantly reduces inflation after one year and significantly raises inflation with a lag of two years. The total effect is positive: If reserves grow by 1%, two years later inflation will increase by almost 0.25%. The Granger test supports the hypothesis that the growth of reserves causes inflation. Although the lags of inflation significantly affect the growth of reserves, the hypothesis of reversed causality can be rejected.

4.3.2 National monetarism

The following tables examine the hypothesis that inflation is rather a national than global phenomenon. To this end, the panel data set is analysed that contains individual country data for the period 1970-2006. It estimates the extent to which the foreign and domestic components of the monetary base determine the inflation rate independently of the evolution of global liquidity and the inflation rate in other countries.

Column (1) of table 3 tests for the effect on the contemporaneous inflation rate. Both growth rates are weighted by their fraction in the total monetary base. While the growth rate of domestic central bank assets significantly increases the inflation rate, the effect of foreign assets (= international reserves) is insignificant.

According to the money market equilibrium condition, monetary expansion raises inflation only to the extent to which it exceeds the growth of money demand, e.g., real GDP growth. Column (2) shows that real GDP growth indeed significantly lowers inflation for a given monetary base. The effects of the two components of the monetary base are basically unchanged.

Economic theory suggests that inflation reacts with some time lag to increases in money supply. Existing evidence suggests that monetary factors feed into inflation with a lage of two to three years. Therefore, column (3) adds three lags of both the growth rate of reserves and the growth rate of domestic central banks assets. With respect to the growth of domestic central bank assets, the contemporaneous and the previous period's growth rate raise inflation. The growth of international reserves, however, feeds into inflation with a lag of three years. This effect is economically small (on average 0.02%).

The effect of monetary factors on inflation might be different during currency crises than in normal times. The expected deflationary impact of reserve losses during crises might be overcompensated by other factors like a devaluation of the currency. Therefore, column (4)

adds a dummy for currency crises that takes the value one in years where a currency crisis was identified by an exchange market pressure index. Its effect, however, is not significant.

The importance of monetary factors in the inflation process may depend on the level of inflation. A reduced sample that disregards high inflation periods might offer additional insights how moderate inflation rates are determined. To this end, table 4 replicates the estimations of table 3 for a reduced sample that disregards all observations with an inflation rate exceeding 50%.

Column (1) includes the growth rates of the domestic and foreign component of the monetary base and column (2) adds real GDP growth. Whereas domestic central bank assets do not significantly affect moderate inflation, the growth of international reserves significantly increases inflation and the growth of real GDP significantly decreases it. Column (3), which investigates if inflation reacts to monetary factors with some time lag, shows that the effect of the growth rate of international reserves lasts two years. With an average growth rate of the weighted nominal reserves of 16% in the whole sample, the inflation is expected to be on average 0.4% higher than without reserve growth. This marginal effect of reserve increases implicitly assumes that all other factors are constant, particularly that the reserve growth is not sterilized by the central bank.

In sum, reserve growth significantly raises moderate inflation rates. However, monetary factors do not explain moderate inflation rates well as the low levels of the coefficients of determination (R^2) indicate. This general result is in line with the findings of De Grauwe and Polan (2005).

4.3.3 Robustness

To test the robustness of the results, the effects of the growth rate of reserves on the inflation rate are investigated for different time periods. To this end, the sample is divided into three periods of equal size (twelve years). The results are presented in table 5. Columns (1) and (2) present the results for the first period from 1970 to 1982. Both the growth of domestic central bank assets and the growth of reserves have a positive and significant impact on inflation. Whereas the effect of domestic assets is distributed over three years, the effect of reserve growth is only contemporaneous. With an average weighted growth rate of nominal reserves

during 1970-1982 of 17%, reserve growth raises the inflation rate on average by 1.6% if the effect on the monetary base is not sterilized (marginal effect).

During 1983-1994 reserve growth significantly raise the inflation rate with a lag of three years. This effect is much smaller than in the previous period. The inflationary impact of domestic asset growth, in turn, is larger compared to 1970-1982. For the last period from 1995 to 2006 (columns (5) and (6)), reserve growth contemporaneously raises inflation. This effect, however, becomes insignificant when three lags are included.

Results differ between periods. This might be due to changes in the variability of the variables: Whereas the highest variability of inflation can be observed between 1983 and 1994, the variability of the growth rate of reserves in 1995-2006 is larger than in the other two periods. The variability of the growth rate of domestic central bank assets has declined over the three periods of consideration.

Table 6 replicates the analysis of temporal subsamples for the restricted sample of moderate inflation rates. Whereas the growth of domestic central bank assets is insignificant, reserve growth raises inflation in all three periods.

Table 7 tests whether the results are robust to the use of a different specification. It uses the between regressor, which is based on country averages over the whole period. It tests whether countries with higher growth rates of the components of the monetary base are on average associated with higher inflation rates. For the full sample (columns (1) and (2)) and the sample of moderate inflation rates (columns (3) and (4)) inflation is significantly higher, the higher the growth rate of domestic central bank assets. The growth rate of reserves, however, does not significantly affect the inflation rate.

Current inflation might not be time-independent but related to past inflation rates. This might be due to pricing policies and the formation of inflation expectations. If indexation mechanisms are in place such that prices like wages, tariffs and rents adjust automatically to past inflation rates, the current price level depends on the past inflation rate. Adaptive expectations imply that the expected future inflation rate is the higher, the higher the inflation in the past was. This theory can be tested in the form of a dynamic regression analysis that includes the lagged level of the inflation rate as one of its determinants. The results for moderate inflation rates are presented in table 8.

The lagged level of inflation is significant. Part of the previous period's inflation rate is passed to the next period. This inertia, however, is relatively small. The growth of domestic central bank assets raises the inflation rate whereas the current growth rate of reserves does not significantly affect inflation.

4.3.4 Sterilization policies

As pointed out in the theoretical section, the effect of an increase in international reserves on the inflation rate depends on the degree of sterilization of these purchases by the central bank. If the effect of the accumulation of international reserves on the monetary base is fully sterilized through the sale of domestic bonds, the inflationary impact of the accumulation of reserves, for which the previous tables offer weak evidence, is cushioned.

To measure the extent of sterilization, I estimate sterilization coefficients. Along the lines of Aizenmann and Glick (2008) I regress the growth rate of domestic central bank assets on the growth rate of reserves and the growth rate of nominal GDP. The sterilization coefficient is defined as the coefficient of reserve growth in this regression. A sterilization coefficient of minus one represents full sterilization while a coefficient of zero implies no sterilization. Nominal GDP growth is included to control for increases in nominal money demand. Hence, with full sterilization the central bank prevents an expansion of the monetary base due to changes in reserves, but domestic credit may grow due to other reasons, namely increases in money demand.

The results of a cross-section analysis are presented in table 9. It assumes by definition that the sterilization coefficient is constant over time and over all countries. It equals –0.26 (column (1)). This indicates that the effect of reserve growth on the monetary base was partially offset by the sale of domestic central bank assets. However, the coefficient is relatively small implying that sterilization is far from complete.

Sterilization policies of central banks might change over time. They depend on the primary objectives of central bank policy, economic circumstances and the policies of other central banks. To investigate the stability of the relationship over time, I estimate the regression for different time periods. The sample is divided into three time periods of equal size. Columns (2) to (4) of table 9 present the results. The sterilization coefficient amounts to –0.43 in the 1970s, decreases (in absolute terms) first to –0.22 between 1983 and 1994 and falls further to

–0.15 between 1995 and 2006. This indicates that the sterilization of the effect of reserve changes on the monetary base has decreased over time.

Given this instability of sterilization coefficients, it might be appropriate to focus on shorter time periods. To this end, I use a rolling regression over a period of five years. The first regression covers the period from 1970 to 1974, the second from 1971 to 1975 and the last uses data between 2002 and 2006. Figure 5 plots the sterilization coefficients. Sterilization is relatively small in the first half of the 1970s but increases after the end of the Bretton Woods System. The effect of reserve changes on the monetary base are at least cut by half. Until the late 1980s sterilization further increases but then falls abruptly to very low levels. During the 2000s sterilization remains low, both in absolute terms and in comparison with other periods.

An explanation for the decreasing sterilization efforts of central banks might be given by the increase of capital mobility. Private capital flows may render central banks' sterilization policies ineffective. If a central bank sterilizes its accumulation of reserves, the interest rate is higher than without sterilization. Hence, foreign capital flows might continue and challenge the central bank to further accumulate reserves, thereby offsetting its sterilization policies.

5 Conclusions

This paper examines the inflationary consequences of reserve accumulation, both at the global and the country level.

Global reserve growth significantly raises the inflation rate with a lag of two years. This effect is especially strong for countries with fixed exchange rate regimes. In a world of fixed exchange rates, reserve growth is found to Granger-cause inflation. A rate of reserve growth of 1% causes an increase of the price level of 0.25% over a period of two years.
On the level of individual countries, the growth of domestic central banks assets is the major monetary determinant of inflation. If domestic central bank assets increase by 1%, inflation rises during the current and subsequent year by more than 0.5%. Changes in international reserves do not significantly affect inflation. These effects are reversed if only moderate inflations are to be explained. The growth of international reserves then significantly contributes to higher moderate inflation rates.

Further results suggest that the growth of reserves contributed to higher inflation rates during the 1970s and between 1995-2006, but was insignificant during the 1980s. Hence, the results of Heller (1976) that the accumulation of reserves has inflationary effects can be confirmed for the 1970s.

The estimation of sterilization coefficients shows that the degree of the sterilization of the effects of reserve growth on the monetary base varies considerably over time. The observation that sterilization is relatively low during the 2000s allows two concluding remarks. First, sterilization policies of central banks might be increasingly offset by private capital flows in a financially integrated world. Second, since the recent accumulation of reserves is less sterilised than in previous periods, its inflationary impact in the future might be larger.

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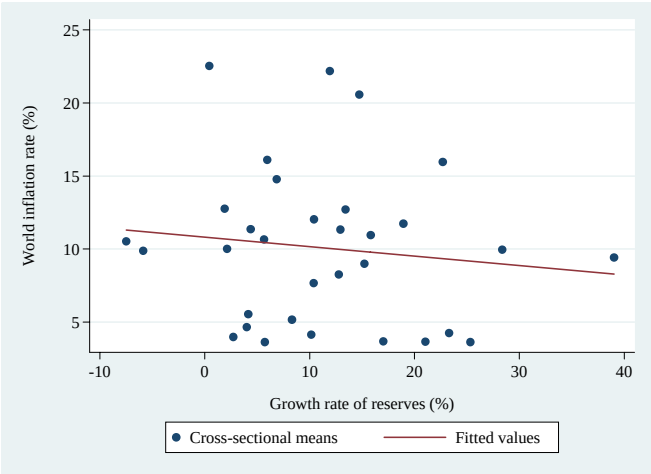
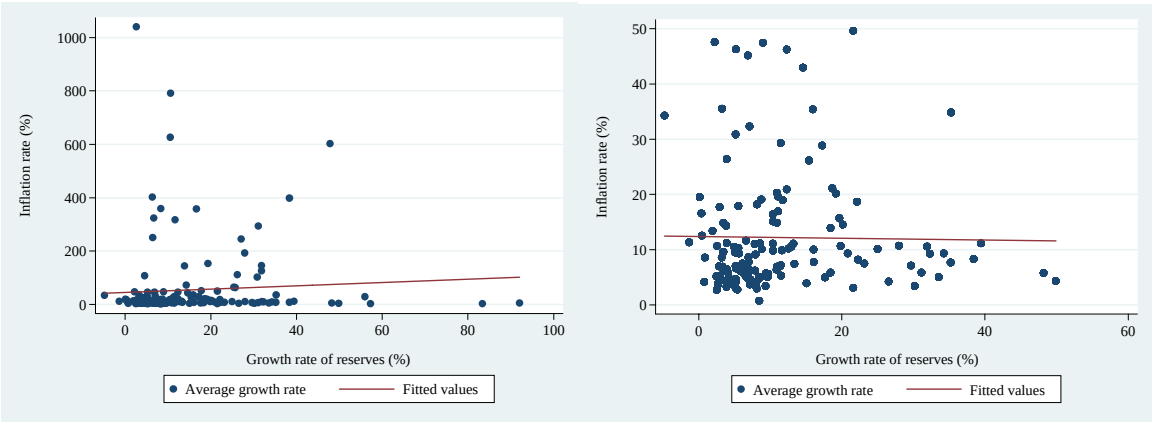
Figure 1: World inflation and growth of world reserves (1975-2006)



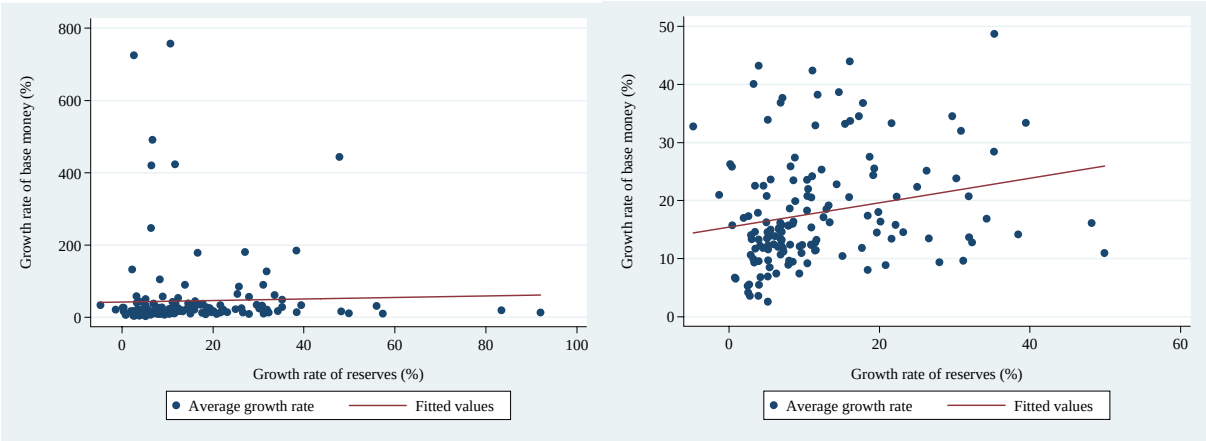
Note: The graph displays annual combinations of the growth rate of world reserves and world inflation calculated as a weighted average of individual country's inflation rates.

Figure 2: Growth of reserves and inflation (country averages)



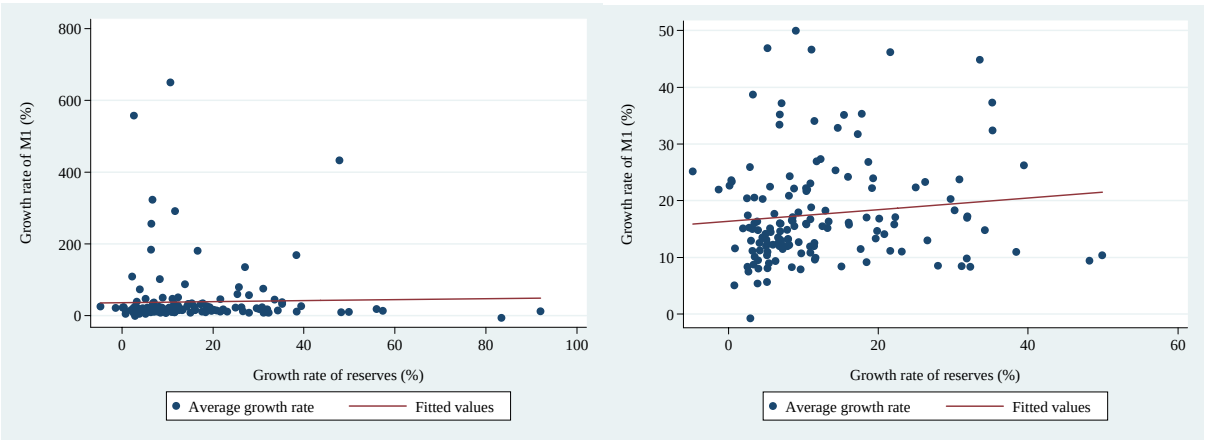
Note: Each data point displays the average growth rate of reserves and the average inflation rate over the period 1970-2006 for an individual country. The left-hand side graph includes all countries for which data are available with the exception of three extreme outliers. The right-hand side graph is based on a reduced sample after with an average inflation rate and/or growth rate of reserves exceeding 50% have been dropped.

Figure 3: Reserves and monetary base



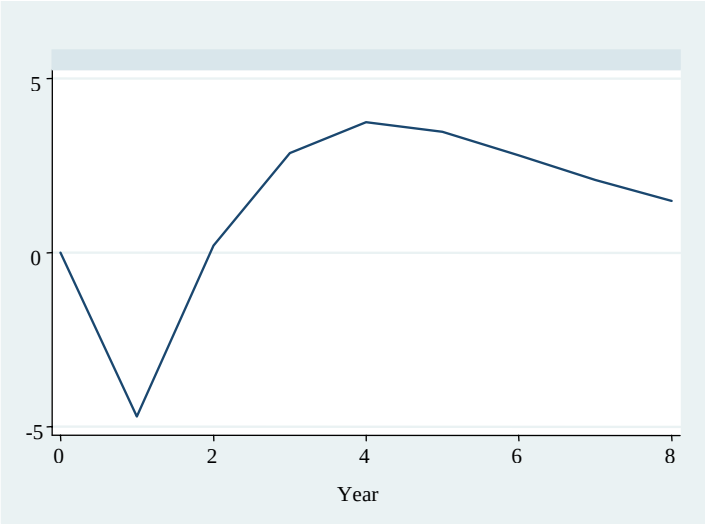
Note: Whereas the left-hand side graph is based on the full sample, the graph on the right hand displays the relationship for a reduced sample excluding outliers, namely countries with a growth rate of reserves and/or a growth rate of base money larger than 50%.

Figure 4: Reserves and money (M1)



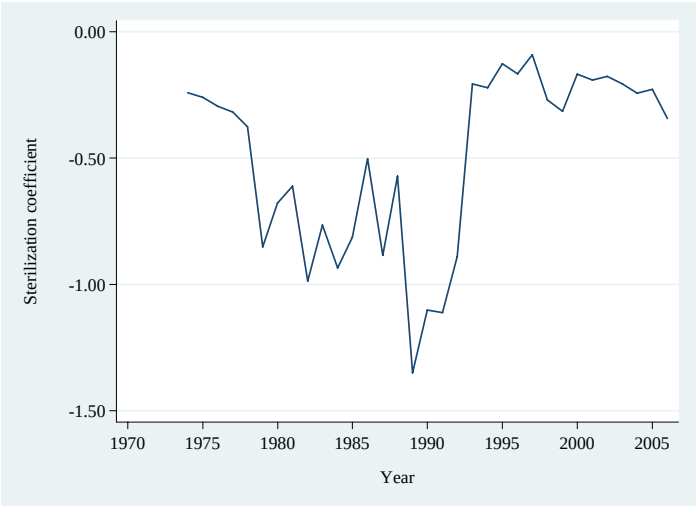
Note: Whereas the left-hand side graph is based on the full sample, the graph on the right hand displays the relationship for a reduced sample excluding outliers, namely countries with a growth rate of reserves and/or a growth rate of money (M1) larger than 50%.

Figure 5: Impluse-response function for expansionary reserve growth shock



Note: The graph displays the time path of the response of the inflation rate to reserve growth.

Figure 6: Sterilization coefficients



Note: This graph is based on rolling regressions of the rate of growth of domestic central bank assets on the growth rates of international reserves. A total of 33 regressions is estimated, each covering 5 years. The graph plots the resulting coefficients attributed to international reserve growth. The year on the x-coordinate marks the last year of the respective regression, e.g. the coefficient in 1975 is based on the regression over 1971-1975.

Table 1: World reserves and world inflation (1970-2006)

Estimation method: Vector autoregression

Dependent variable: World inflation (%)

	Lags	1	2
World inflation		1.1480 (7.44***)	-0.3136 (-2.00**)
World reserves (growth rate)		-0.0471 (-1.05)	0.0668 (2.06**)
H_0: World reserve growth does not cause world inflation.		p-value: 0.11	

Dependent variable: World reserve growth (%)

	Lags	1	2
World inflation		-0.4436 (-0.74)	0.3144 (0.52)
World reserves (growth rate)		0.2287 (1.32)	0.0073 (0.06)
H_0: World inflation does not cause world reserves to growth.		p-value: 0.75	

Table 2: World reserves and world inflation under fixed exchange rate regimes

Estimation method: Vector autoregression

Dependent variable: Inflation (%)

Lags	1	2
Inflation	0.3268 (2.59***)	0.3861 (3.04***)
Reserves (growth rate)	-0.325989 (-2.38**)	0.556833 (4.80***)
H_0: Reserve growth does not cause inflation.	p-value: = 0.00	

Dependent variable: Reserve growth (%)

Lags	1	2
Inflation	0.1427 (1.04)	-0.1560 (-1.12)
Reserves (growth rate)	0.3480 (2.33**)	-0.2468 (-1.95*)
H_0: Inflation does not cause reserves to growth.	p-value: = 0.47	

Table 3: Determinants of inflation

Dependent variable: Inflation (%)
Estimation method: Fixed effects estimator

	(1)	(2)	(3)	(4)
Domestic central bank assets (weighted growth rate)	0.5285 (3.13***)	0.5271 (3.13***)	0.8507 (4.62***)	0.4152 (1.78*)
- lagged by one year			0.1200 (2.59***)	0.3310 (2.03**)
- lagged by two years			0.0403 (0.57)	0.1005 (1.39)
- lagged by three years			0.0233 (1.03)	0.0902 (1.21)
International reserves (weighted growth rate)	0.0022 (1.33)	0.0021 (1.35)	0.0018 (1.62)	0.1127 (1.82*)
- lagged by one year			-0.0002 (0.62)	-0.0006 (-0.20)
- lagged by two years			0.0004 (1.26)	-0.0033 (-1.17)
- lagged by three years			0.0006 (1.71*)	-0.0016 (-0.57)
Real GDP (growth rate)		-3.8150 (-2.44**)	-1.1426 (-1.02)	-0.9509 (-1.34)
Currency crisis, dummy				-0.4343 (-0.04)
Number of countries	116	115	115	100
Number of observations	3145	3118	2762	1356
Adjusted R^2 (overall)	0.30	0.30	0.32	0.54

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

Table 4: Determinants of moderate inflation

Dependent variable: Inflation (%)
Estimation method: Fixed effects estimator

	(1)	(2)	(3)	(4)
Domestic central bank assets (weighted growth rate)	0.0063 (1.29)	0.0058 (1.28)	0.0042 (1.27)	0.0032 (2.54***)
- lagged by one year			0.0047 (1.06)	0.0032 (1.66*)
- lagged by two years			0.0022 (0.51)	0.0005 (0.35)
- lagged by three years			0.0008 (0.28)	0.0005 (0.46)
International reserves (weighted growth rate)	0.0062 (4.77***)	0.0061 (4.81***)	0.0261 (3.01***)	0.0226 (2.11**)
- lagged by one year			0.0008 (1.75*)	0.0009 (1.82*)
- lagged by two years			0.0000 (0.11)	0.0001 (0.20)
- lagged by three years			0.0001 (0.34)	0.0002 (1.34)
Real GDP (growth rate)		-0.1222 (-4.02***)	-0.1517 (-4.69***)	-0.0914 (-1.83*)
Currency crisis, dummy				2.4711 (3.82***)
Number of countries	116	115	113	97
Number of observations	2912	2889	2383	1235
Adjusted R^2 (overall)	0.02	0.02	0.04	0.04

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

Table 5: Determinants of inflation (temporal subsamples)

Dependent variable: Inflation (%)
Estimation method: Fixed effects estimator

	(1)	(2)	(3)	(4)	(5)	(6)
	1970-1982		1983-1994		1995-2006	
Domestic central bank assets (weighted growth rate)	0.2291 (2.73***)	0.2133 (2.82***)	0.4880 (2.78***)	0.8725 (4.47***)	0.3681 (1.03)	0.3764 (1.06)
- lagged by one year		0.2176 (1.79*)		0.1287 (2.58***)		0.0360 (0.95)
- lagged by two years		0.1126 (3.43***)		0.0713 (0.74)		0.0172 (0.55)
- lagged by three years		0.1603 (2.60***)		0.0606 (1.21)		-0.0099 (-0.34)
International reserves (weighted growth rate)	0.1041 (3.44***)	0.0915 (4.59***)	0.0015 (1.10)	0.0012 (1.33)	0.2951 (2.79***)	0.1397 (1.25)
- lagged by one year		0.0206 (1.18)		-0.0012 (-1.43)		-0.0018 (-0.77)
- lagged by two years		0.0024 (0.17)		0.0004 (1.32)		-0.0013 (-0.55)
- lagged by three years		0.0050 (0.39)		0.0005 (1.67*)		0.0004 (0.37)
Real GDP (growth rate)	-0.1103 (-5.47***)	0.0755 (0.50)	-9.3253 (-2.18**)	-5.0961 (-1.81*)	0.4019 (0.21)	0.8904 (0.45)
Number of countries	78	78	103	88	113	113
Number of observations	892	814	996	935	1230	1167
Adjusted R^2 (overall)	0.30	0.46	0.31	0.33	0.10	0.20

Notes:

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

Table 6: Determinants of moderate inflation (temporal subsamples)

Dependent variable: Inflation (%)
Estimation method: Fixed effects estimator

	(1)	(2)	(3)	(4)	(5)	(6)
	1970-1982		1983-1994		1995-2006	
Domestic central bank assets (weighted growth rate)	0.0108	-0.0003	0.0061	-0.0002	0.0015	0.0010
	(1.15)	(-0.06)	(0.81)	(-0.03)	(1.04)	(0.65)
- lagged by one year		0.0019		0.0130		0.0016
		(0.14)		(1.22)		(0.70)
- lagged by two years		0.0097		0.0066		-0.0016
		(1.47)		(0.44)		(-1.02)
- lagged by three years		-0.0010		0.0099		-0.0017
		(-0.13)		(1.05)		(-1.09)
International reserves (weighted growth rate)	0.0292	0.0402	0.0056	0.0346	0.0220	0.0213
	(3.55***)	(5.45***)	(7.66***)	(5.87***)	(1.74*)	(1.66*)
- lagged by one year		0.0168		0.0007		0.0009
		(2.78***)		(0.07)		(2.28**)
- lagged by two years		-0.0010		-0.0029		0.0002
		(-0.16)		(-0.38)		(0.62)
- lagged by three years		-0.0006		-0.0056		0.0001
		(-0.13)		(-0.76)		(0.62)
Real GDP (growth rate)	0.0744	-0.0363	-0.0763	-0.0727	-0.1647	-0.1044
	(1.29)	(-0.61)	(-1.20)	(-1.04)	(-3.56***)	(-1.94*)
Number of countries	78	73	93	78	112	111
Number of observations	835	572	876	771	1178	1040
Adjusted R^2 (overall)	0.02	0.05	0.02	0.03	0.02	0.02

Notes:

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

Table 7: Determinants of inflation: cross-country analysis

Dependent variable: Inflation (%)
Estimation method: Between regression (country averages)

	(1)	(2)	(3)	(4)
	whole sample		moderate inflation	
Domestic central bank assets (weighted growth rate)	1.6406 (11.62***)	1.6342 (11.44***)	0.1442 (4.06***)	0.1473 (4.21***)
International reserves (weighted growth rate)	0.0087 (0.20)	0.0132 (0.29)	-0.0008 (-0.08)	-0.0015 (-0.15)
Real GDP (growth rate)		-3.3556 (-0.60)		0.5650 (2.32**)
Number of countries	92	91	92	91
Number of observations	2502	2475	2311	2288
Adjusted R^2 (overall)	0.60	0.60	0.16	0.20

Notes: Columns (1) and (2) are based on the whole sample, whereas columns (3) and (4) disregard episodes of inflation rates exceeding 50%.

Table 8: Determinants of inflation: dynamic model

Dependent variable: Inflation (%)
Estimation method: Arellano-Bond estimator (GMM)

	(1)
Lagged inflation	0.1410 (2.16**)
Domestic central bank assets (weighted growth rate)	0.0018 (3.08***)
International reserves (weighted growth rate)	0.0216 (1.61)
Real GDP (growth rate)	-0.1083 (-1.56)
Currency crisis, dummy	2.4264 (4.27***)
Number of countries	118
Number of observations	1003
Sargan Test (p-level)	1.0
Arellano-Bond-Test (p-level)	0.50

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

Table 9: Sterilization

Dependent variable: Growth rate of domestic central bank assets (%)
Estimation method: Cross-section analysis (between regression)

	(1) 1970-2006	(2) 1970-1982	(3) 1983-1994	(4) 1995-2006
Growth rate of international reserves	-0.2558 (-3.28***)	-0.4285 (-4.97***)	-0.2160 (-1.81*)	-0.1529 (-1.73*)
Nominal GDP (growth rate)	0.0369 (6.91***)	0.4155 (11.69***)	0.0317 (6.03***)	0.0571 (5.37***)
Number of countries	94	66	83	90
Number of observations	2510	754	809	947
Adjusted R^2	0.39	0.72	0.34	0.27

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

Appendix A: Country list

Albania
Algeria
Angola
Argentina
Armenia
Australia
Austria
Azerbaijan
Bangladesh
Belarus
Belgium
Benin
Bolivia
Bosnia and Herzegovina
Brazil
Bulgaria
Burkina Faso
Burundi
Cambodia
Cameroon
Canada
Central African Republic
Chad
Chile
China
Colombia
Congo, Dem. Rep.
Congo, Rep.
Costa Rica
Cote d'Ivoire
Croatia
Czech Republic
Denmark
Dominican Republic
Ecuador
Egypt, Arab Rep.
El Salvador
Eritrea
Ethiopia
Finland
France
Georgia
Germany
Ghana
Greece
Guatemala
Guinea
Haiti
Honduras
Hong Kong, China
Hungary
India
Indonesia
Iran, Islamic Rep.
Ireland
Israel
Italy
Japan
Jordan
Kazakhstan
Kenya
Korea, Rep.
Kyrgyz Republic
Lao PDR
Lebanon
Liberia
Libya
Lithuania
Madagascar
Malawi
Malaysia
Mali
Mexico
Moldova
Morocco
Mozambique
Myanmar
Netherlands
New Zealand
Nicaragua
Niger
Nigeria
Norway
Pakistan
Papua New Guinea
Paraguay
Peru
Philippines
Poland
Portugal
Romania
Russian Federation
Rwanda
Saudi Arabia
Senegal
Serbia
Sierra Leone
Singapore
Slovak Republic
South Africa
Spain
Sri Lanka
Sudan
Sweden
Switzerland
Syrian Arab Republic
Tajikistan
Tanzania
Thailand
Togo
Trinidad and Tobago
Tunisia
Turkey
Turkmenistan
Uganda
Ukraine
United Arab Emirates
United Kingdom
United States
Uruguay
Uzbekistan
Venezuela, RB
Vietnam
Yemen, Rep.
Zambia
Zimbabwe

Appendix B: List of variables and data sources

Variable	Source	Description
Reserves	World Bank (2008)	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.
Inflation	World Bank (2008)	Inflation is measured as the growth rate of the GDP implicit deflator which is defined as the ratio of GDP in current local currency to GDP in constant local currency.
De jure 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.
Domestic central bank assets	IMF (2008)	Domestic central banks assets are defined as the sum of the following items: claims on central government, claims on deposit money banks, claims on state and local governments, claims on nonfinancial public enterprises, claims on the private sector, claims on other banking institutions and claims on nonbank financial institutions. Since the majority of countries only reports data for the first two categories, central banks assets are narrowly defined as the sum of these two categories. The variable central bank assets (all), however, is the sum of all seven categories.
GDP	World Bank (2008)	
Currency crisis, dummy	Own calculations (see chapter 3)	The identification of a currency crisis is based on the exchange market pressure index described in chapter 3. A currency crisis is defined to occur if the index exceeds its mean plus two standard deviations. The dummy takes the value one in years with a currency crisis.