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RESEARCH ARTICLE

IMF Support and Inter-Regime Exchange Rate Volatility

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Abstract It is widely agreed that when moving from fixed to floating exchange rates the increase in exchange rate volatility is not matched by an equivalent rise in the volatility of fundamentals. We argue and demonstrate that in inter-regime comparisons one has to account for 'missing variables' that compensate for the fundamental variables' volatility under fixed exchange rates. Previous studies have often used foreign exchange reserves, but without much success. We argue why reserves are not a reliable measure, while IMF credit support is. Our empirical analysis identifies IMF support as a crucial and significant compensating variable.

Keywords Exchange rates · Exchange rate regimes · Excess volatility · IMF credit

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1 Introduction

The early proponents of flexible exchange rates (see, for example, Friedman 1953; Sohmen 1961 and Johnson 1958) viewed the fixed but adjustable Bretton Woods exchange rate arrangement as inherently unstable, because it failed to provide an effective adjustment mechanism. In contrast, a regime of flexible exchange rates was regarded as providing an automatic adjustment mechanism and flexible rates were therefore predicted to be inherently stable. However, the post-Bretton Woods and inter-war experiences with flexible exchange rates suggest that exchange rates when left to their own devices are inherently volatile. Of course, this does not mean that such rates are *excessively* volatile, since as Friedman recognized, if the underlying fundamentals are unstable then exchange rates are likely to be unstable as well:

> Instability of exchange rates is a symptom of instability in the underlying economic structure. Elimination of this symptom by administrative freezing of exchange rates cures none of the underlying difficulties and only makes adjustment to them more painful. (Friedman 1953)

However, the so-called exchange rate disconnect discussed in Obstfeld and Rogoff (2000) summarizes a widely held belief in the profession that exchange rates have indeed been excessively volatile with respect to traditional macroeconomic variables in the post-Bretton Woods period.[1] There are two aspects to this volatility disconnect in the literature, and we label these inter- and intra-regime volatility. *Inter-regime* volatility refers to the striking result that in moving from a system of fixed to floating exchange rates, the volatility of macroeconomic fundamentals, such as the money stock and income, does not change, but the volatility of the exchange rate does. The concept of *intra-regime* volatility refers to the view that in floating exchange rate regimes exchange rates appear to be excessively volatile with respect to the fundamentals. This paper focuses on the first issue of inter-regime volatility and leaves intra-regime volatility to one side.

The issue of inter-regime volatility has been studied in a number of papers. For example, Baxter and Stockman (1989) examine the variability of output, trade variables, private and government consumption and the real exchange rate and are: "… unable to find evidence that the cyclical behavior of real macroeconomic aggregates depends systematically on the exchange rate regime. The only exception is the well-known case of the real exchange rate." Flood and Rose (1995) use flexible price and sticky price variants of the monetary model to show that the volatility of their so-called 'traditional fundamentals' (money and income) remain roughly unchanged in the move from the Bretton Woods to the post-Bretton Woods regime, but that the volatility of virtual fundamentals (the exchange rate minus the interest rate differential) increases dramatically. Flood and Rose (1999) present a similar exercise in which they compare the volatility of fundamentals (including the interest differential) with exchange rate volatility per se for the Bretton Woods and

[1] The exchange rate disconnect also refers to the apparent difficulty in forecasting (the level of) exchange rates, although this is not uncontroversial; see, for example, MacDonald (2007).

the post- Bretton Woods period and again find that the volatility of the exchange rate dominates the volatility of the fundamentals.[2]

In this paper we propose to re-evaluate the inter-regime volatility issue. On the theory side we expand the monetary model of floating exchange rates to account for one of the 'missing variables' in the case of regulated markets. Since the Bretton Woods regime was characterized by fixed exchange rates combined with trade and capital market distortions, an analysis of this regime has to take account of such distortions.

A key novelty in our study lies in the examination of inter-regime volatility and, in particular, the behavior of an expanded set of fundamentals in the Bretton Woods and post-Bretton Woods periods. We shift the question from 'why do we not observe more exchange rate volatility in fixed rate regimes given that standard fundamentals have similar volatility under both regimes?' to 'which variables absorb the fundamental volatility under fixed rates?' We believe that asking the question in this way is insightful since there may be other fundamentals which absorbed the fundamentals' variability in these regimes. If exchange rates are fixed, or managed, then it should be variables like trade restrictions, capital controls, international reserves or balance of payments support which adjust rather than the exchange rate. Marston (1993) showed, for example, that the interest differentials between the onshore and offshore Eurocurrency market under Bretton Woods was as large as one hundred basis points on an annual basis. Moreover, these differentials were highly variable. Furthermore, in these regimes there are often other regulatory aspects which should be incorporated into any empirical evaluation of the volatility of exchange rate fundamentals. We demonstrate that the volatility in the fundamentals is at least partly absorbed by one of these missing variables.

Several studies have used official reserves as the key variable that absorbs the variability in the other fundamental variables in case the exchange rate is fixed or regulated. Theories of balance of payments crises heavily rely on this variable. Nevertheless, empirical results for this channel are weak. The main contribution of this paper is to argue and show that IMF credit support provides a cleaner measure for the absorption of exchange rate pressure. IMF credit and official reserves are related but distinct variables. The key difference is that official reserves can be kept artificially high in case of balance of payments problems with the help of IMF credit. Therefore the latter variable provides a better measure for the absorption of exchange rate pressure through fundamentals. Our empirical evidence shows that IMF credit has considerably higher explanatory power. In the current euro-crisis it is intra EMU credit, e.g. via the target system, that substitutes for currency adjustment rather than official reserves.

[2] Duarte (2003) examines the effects of the exchange rate regime in the context of a dynamic general equilibrium model with nominal goods prices set in the buyer's currency and incomplete asset markets. Her model predicts a sharp increase in the volatility of the real exchange rate when moving from fixed to flexible exchange rates. This pattern is not observed for other variables. Reinhart and Rogoff (2002) argue that at least part of the inter-regime volatility puzzle may be explained by using an inappropriate classification of the exchange rate regime. In particular, they show that in moving from the IMF's classification of an exchange rate regime (as used in the studies of Baxter and Stockman (1989) and Flood and Rose (1995, 1999)) to one based on the factual properties of the regime, there was in fact much more flexibility of exchange rates during Bretton Woods and much more rigidity during the post-Bretton Woods period.

The outline of the remainder of this paper is as follows. In the next section we present an extension of the monetary model. This model is designed to motivate the kind of traditional fundamentals used in exchange rate studies and the incorporation of the distortion variables or wedges. The extended model shows how volatility of the traditional fundamentals is absorbed by the wedges rather than the exchange rate. In Section 3 we empirically investigate the inter-regime volatility. The last section concludes.

2 Theoretical Background

We adapt the standard flexible price monetary model to illustrate the relationship between fundamentals and the exchange rate. The incorporation of distortions drives a wedge between the exchange rate and the standard fundamentals. We go on to show how these may pick up the volatility in the fundamentals. We start with a modified version of absolute PPP:

$$P = \Omega S P^{*}. \tag{2.1}$$

Here the domestic (traded goods) price deflator P equals the price of the consumption bundle in foreign (traded goods) prices P^{*} times the distortion Ω and the exchange rate S. The distortion is responsible for the absence of absolute PPP (see Obstfeld and Rogoff 2000) and signifies anything that drives or sustains a wedge between the domestic and foreign price levels. This includes tariff levies, export subsidies, transportation costs and the tariff equivalent of any quotas that drive a wedge between the foreign and domestic price levels. It also includes balance of payments support that is used to sustain current account deficits and postpone adjustment.

A more elaborate exchange rate model including standard macro variables is obtained by combining the PPP relation (2.1) with the domestic and foreign quantity theory based equations for money demand respectively:

$$M \exp(\lambda R) = P Y^{\phi} \text{ and } M^{*} \exp\left(\lambda R^{*}\right) = P^{*}\left(Y^{*}\right)^{\phi}. \tag{2.2}$$

Taking the logarithm of (2.1) and substituting the home and foreign log transformed money demand functions gives the monetary model of the exchange rate:

$$s = m - \phi y + \lambda r - \omega. \tag{2.3}$$

Here $s=\log(S)$ is the log exchange rate, $m=\log(M/M^{*})$ is the relative money supply, $y=\log(Y/Y^{*})$ is relative income, $r=R-R^{*}$ is the interest rate differential and $\omega = \log(\Omega)$ is the log of the wedge. Apart from the distortion, ω, the derivation gives the standard monetary approach exchange rate equation. More elaborate derivations based on individual agent optimization, as in Stockman (1980) and Lucas (1982), yield a pricing kernel. After calibration, the kernel reduces to specifications that are similar to (2.3), see Mark (2001). The specification (2.3) without the distortion matches the specification of the macro-economic fundamentals as in Flood and Rose (1999, p. 663). Omitting λr-ω from (2.3) gives the so-called traditional fundamental from Flood and Rose (1995).

Note that the wedge in (2.3) enters with a negative sign, as in the case of relative incomes, since it keeps domestic prices artificially higher than the foreign prices thereby improving the terms of trade. If the wedge adjusts to counter the movements in the traditional fundamentals, it can compensate for the fluctuations in these other driving factors. How can we ensure that ω is chosen correctly? Some of the distortions to free trade, like the costs of transportation, can hardly react to changes in the fundamentals. But other distortions like the implicit price distortions induced by a quota or variable balance of payments support, and interest rate differentials, as the result of capital controls and official reserves or IMF credit, may be sufficiently flexible to absorb the fundamentals' movements and keep the spot rate constant. The case of Germany in the 1960's and more recently the case of China shows that massive reserve hoarding, in combination with inward capital controls, can for extended periods of time take away the pressure for appreciation. While more difficult in the other direction due to limited means, devaluation has been postponed by employing reserves or foreign credit. In the paper we focus on this channel for volatility absorption in particular. To make a link to the empirical section, we compute the variance on both sides of the exchange rate eq. 2.3:

$$\sigma_s^2 = \sigma_m^2 + \phi^2\sigma_y^2 + \lambda^2\sigma_r^2 + \sigma_\omega^2 - 2\phi\sigma_{m,y} + 2\lambda\sigma_{m,r} - 2\sigma_{m,\omega} - 2\phi\lambda\sigma_{y,r} + 2\phi\sigma_{y,\omega} - 2\lambda\sigma_{r,\omega}. \quad (2.4)$$

On the one hand, under a free float without movements in the wedge, the volatility equation reduces to:

$$\sigma_s^2 = \sigma_m^2 + \phi^2\sigma_y^2 + \lambda^2\sigma_r^2 - 2\phi\sigma_{m,y} + 2\lambda\sigma_{m,r} - 2\phi\lambda\sigma_{y,r}. \quad (2.5)$$

In a fixed exchange rate regime on the other hand, (2.4) becomes:

$$0 = \sigma_m^2 + \phi^2\sigma_y^2 + \lambda^2\sigma_r^2 + \sigma_\omega^2 - 2\phi\sigma_{m,y} + 2\lambda\sigma_{m,r} - 2\sigma_{m,\omega} - 2\phi\lambda\sigma_{y,r} + 2\phi\sigma_{y,\omega} - 2\lambda\sigma_{r,\omega}. \quad (2.6)$$

The received evidence is that there is little or no difference in the variability of the traditional fundamentals across regimes. If this is the case, eqs. 2.5 and 2.6 show that

$$\sigma_\omega^2 - 2\sigma_{m,\omega} + 2\phi\sigma_{y,\omega} - 2\lambda\sigma_{r,\omega}, \quad (2.7)$$

has to bear the brunt of foreign exchange rate stabilization. These variance and covariance terms related to the wedge need to compensate for the volatility in the fundamentals in such a way that the exchange rate variability, ${\sigma_s}^2$, is nil. Under a dirty float, all terms in (2.4) will in general be non-zero. The next section tries to identify part of the missing variances and covariance's in (2.7).

3 Inter-Regime Volatility

In this section we combine data from the Bretton Woods and post-Bretton Woods periods to address the issue of the importance of the wedge in explaining why traditional monetary fundamentals may not be enough to explain inter-regime

volatility. We focus on balance of payments support as an important factor in postponing exchange rate adjustment. More than any of the other distortions, like a tariff, this balance of payment support by the IMF is readily available and quite flexible.

We start by examining the role of IMF support in suppressing exchange rate variability during the Bretton Woods period. We then go on to combine IMF support with traditional fundamentals, like money and income, to address the volatility issue. The volatility comparisons will be done using both annual and monthly datasets. Both datasets span the Bretton Woods *and* post-Bretton Woods periods and for European currencies include the period in which the ERM operated. This variation in regimes within the dataset follows Flood and Rose (1995) and is essential for an empirical investigation of *inter-regime* volatility. Throughout the empirical analysis, two countries will be used as numeraire: the United States (1) and Germany (2). Although the US was clearly the dominant numeraire currency in the Bretton Woods period, Germany's importance increased in the post-Bretton Woods period, particularly after the formation of the ERM.

To the extent that central banks use foreign exchange reserves to stabilize the exchange rate, a tradeoff between exchange rate and reserve volatility would be expected. According to the monetary approach to the balance of payments, a divergence in the fundamentals (e.g. high domestic money growth) must be dissipated through a loss of reserves or the peg will have to be abandoned. Note, however, that we do not expect such a trade-off when the fundamentals do not diverge.

There appears to be little in the way of empirical evidence supporting a trade-off between exchange rate and reserve volatility. Intuitively, the abandonment of a peg would be expected to lead to a reduction in reserve holdings and their volatility. However, Flood and Rose (1995) find that the volatility of reserves is generally higher following the collapse of the Bretton Woods system. Thus Flood and Rose (1995) concluded that non-gold reserves were not an important source of fundamental volatility. We offer an explanation for this apparent absence of a trade-off. Our discussion suggests that it is not sufficient to rely on non-gold reserves, rather IMF credit or Fund holdings of currency should be taken into consideration.

A key reason why there is not a strong trade-off between reserves and exchange rate volatility, is that IMF credit facilities may distort the relationship. IMF credit can and has often been used to replenish a country's dwindling reserves. This enables a country that has pegged its exchange rate to maintain a sizable positive balance of foreign exchange reserves, even in times of severe balance of payments problems. IMF credit therefore can mask the visibility of balance of payments problems if one relies on reserves. We therefore argue that any analysis of the trade-off between exchange rate and reserve volatility needs to take into account the role of IMF credit in supporting weak currencies. One may then ask why IMF credit has not been recognized before as an important explanatory variable.[3] The reason is the asymmetric way in which IMF support is incorporated in the reserve statistics. A country's reserve position in the IMF is in fact incorporated in the reserves as long as

[3] We owe this question at a referee.

a country has not overdrawn its IMF quota. In the case that a country has used none or part of its quota, the difference between the full quota and its use of IMF credit is included in the official reserves (i.e. the non-gold reserves are the sum of the reserve position at the IMF and the foreign exchange reserves). Once a country's currency has exceeded the quota limit, the extra use of IMF credit above its quota limit is accounted for in the fund's holdings of that particular currency. But this may not show up in the foreign exchange reserves, as it could be spent on official intervention. Typically one sees that once a country comes under balance of payment pressure, it will borrow from the IMF in excess of its quota. The country then uses this extra foreign exchange to stabilize the exchange rate by intervention in the currency markets. This can even leave its reported official reserves more or less constant, perhaps in an effort to trying to hide the pressure on its balance of payments. But the fund's holdings of the country's currency will reflect the extra borrowing from the IMF. Due to this asymmetry, it may well be the case that IMF credit better reflects the absorption of foreign exchange pressure than official reserves that often did not move in tandem with this pressure, while IMF credit in excess of the quota did.

We first investigate whether the IMF support variable is quantitatively sufficiently important to be included in an analysis of the volatility tradeoff. Table 1 shows the IMF's holdings of a currency, that is IMF credit, as a percentage of non-gold reserves

Table 1 IMF currency holdings as % of non-gold reserves

	1960–1971	1972–1983	1984–1998
Australia	25	34	20
Austria	7	6	7
Belgium	33	11	25
Canada	26	37	44
Denmark	41	19	9
Finland	35	43	12
France	143	17	20
Germany	8	2	7
Greece	35	31	15
Ireland	11	7	7
Italy	12	54	9
Japan	19	5	5
Netherlands	36	9	13
Norway	21	8	3
Portugal	12	75	30
Spain	38	12	4
Sweden	21	14	11
United Kingdom	337	46	24
United States	211	116	33
Average	59	26	15

Source: IFS

for all countries during three sub periods. In general this percentage is highest during the Bretton Woods years and in the 1970s. With a few exceptions the percentage has declined from the 1980s onwards.[4] In the remainder of our analysis we look at the IMF holdings of a currency as a percentage of its IMF quota, to correct for the effect of quota increases. We thus opt for Fund holdings of currency as a percentage of Fund quota and refer to this as our IMF variable.

Figure 1 contains scatter plots of the change in the exchange rate (against the dollar, in dlog) versus, respectively, the change in our IMF variable (in dlog) in the top plot and the change in non-gold reserves (in dlog) in the bottom plot. The data are monthly and combine the experiences of 21 countries over the period 1960 to 1998 (see the Data appendix for a list of countries). Figures 2 and 3 report individual country experiences. The scatter-plot for the IMF variable is shaped in the form of a cross, implying a highly non-linear dependence between changes in the exchange rate and the IMF measure. Either exchange rates or the Fund holdings of a currency are adjusting, but not both. The two alternative mechanisms for adjustment are more or less orthogonal and do not appear in combination.

In comparison, the scatter-plot for non-gold reserves has much less observations along the two axes. The first quadrant suggests that the changes in the exchange rate and non-gold reserves can very well occur jointly. As we explained above, IMF credit was often used to maintain a sizeable balance of reserves, even as a country was on its way towards devaluation. Looking at all quadrants, the two variables appear to be more or less independent. Reserves are only an imperfect indicator for balance of payments problems and do not reflect necessary compensating flows. In contrast IMF credit was an almost perfect substitute for exchange rate movements.

Based on the magnitude of IMF support (especially in the Bretton Woods period) and the cross-shaped pattern in the top plot of Fig. 1, we have chosen the IMF variable as our candidate measure of the wedge ω. In the next two sections, we combine the IMF variable with traditional fundamentals to estimate (2.4).

3.1 Volatility Comparisons: Annual Data

As an initial pass at the issue of inter-regime volatility by means of eqs. 2.5–2.7 we present in Table 2 the variances of two traditional macroeconomic fundamentals, namely the annual inflation and income growth differentials, along with the variances in exchange rate changes and in the changes in our IMF variable across 19 countries (see Table 6 in the Data appendix for a listing of countries). The use of annual data has the advantage of reducing short-term noise in the macroeconomic data while preserving the underlying signal. As this comes at the cost of a reduction in the number of observations, an analysis of monthly data is added in the next subsection. In the empirical analysis we have chosen inflation instead of money supply growth as our monetary fundamental because of the limited availability of money growth data for several countries in the 1960s. This is an important consideration in view of the small sample size of our annual analysis. We will

[4] In Table 1, the high percentage for France during the first sub-period can be partly explained by the fact that France had chosen to hold most of its reserves in gold instead of foreign currency (dollars).

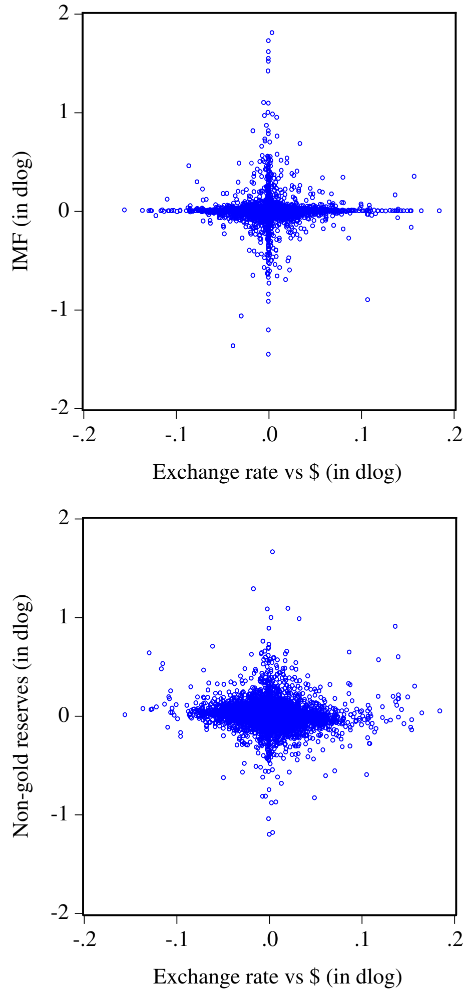

Fig. 1 The cross (1960–1998)

redress this in the monthly analysis below, which includes money growth. The variances in Table 2 have the US and Germany as their numeraire countries and are calculated for three sub periods of comparable length (a Bretton Woods period, from 1961 to 1971, and two post-Bretton Woods periods, respectively from 1972 to 1983 and from 1984 to 1998). Not only are these periods of comparable length, but they also cover more or less the three regimes that prevailed: fixed exchange rates with adjustable peg supported by current and capital account restrictions and IMF credit, floating exchange rates but retaining balance of payment restrictions, capital controls and IMF support, and a complete free float.

The first point to note from Table 2 is that they confirm the point made by a number of other researchers that in moving from Bretton Woods to the post-Bretton Woods period the volatility of standard fundamentals is very similar but the volatility of the exchange rate increases substantially. Note, however, that in the floating periods exchange rate volatility vis-à-vis the dollar is almost twice the volatility vis-

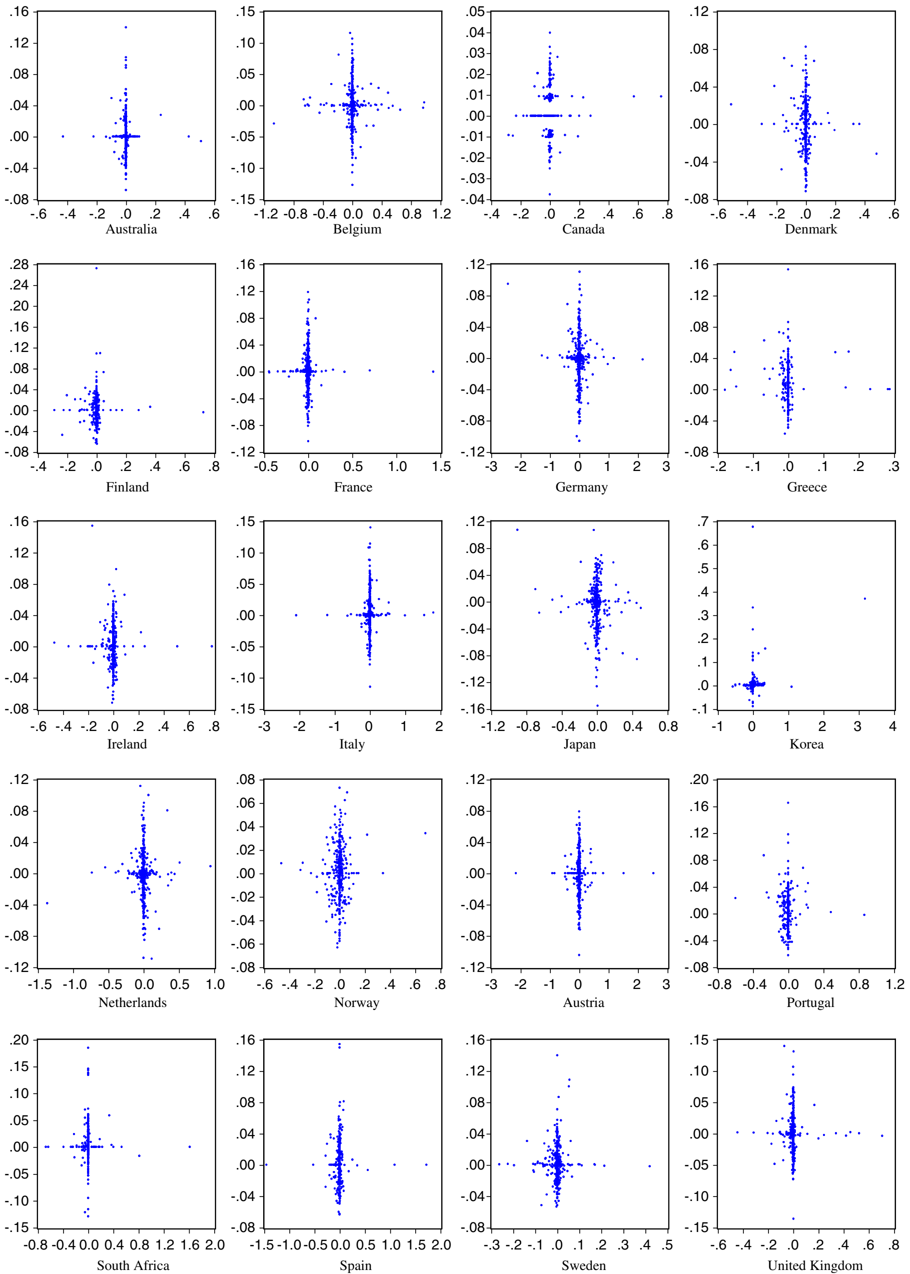

Fig. 2 % Change in IMF holdings of currency (hor. axis) vs % change in dollar exchange rate (vert. axis), 1960–1998

à-vis the DM. This suggests that the volatility issue might at least partly be a dollar issue. We will return to this theme below.

The results in Table 2 also indicate that there is a lot of volatility stemming from the IMF variable in the Bretton Woods period and, interestingly, that the average

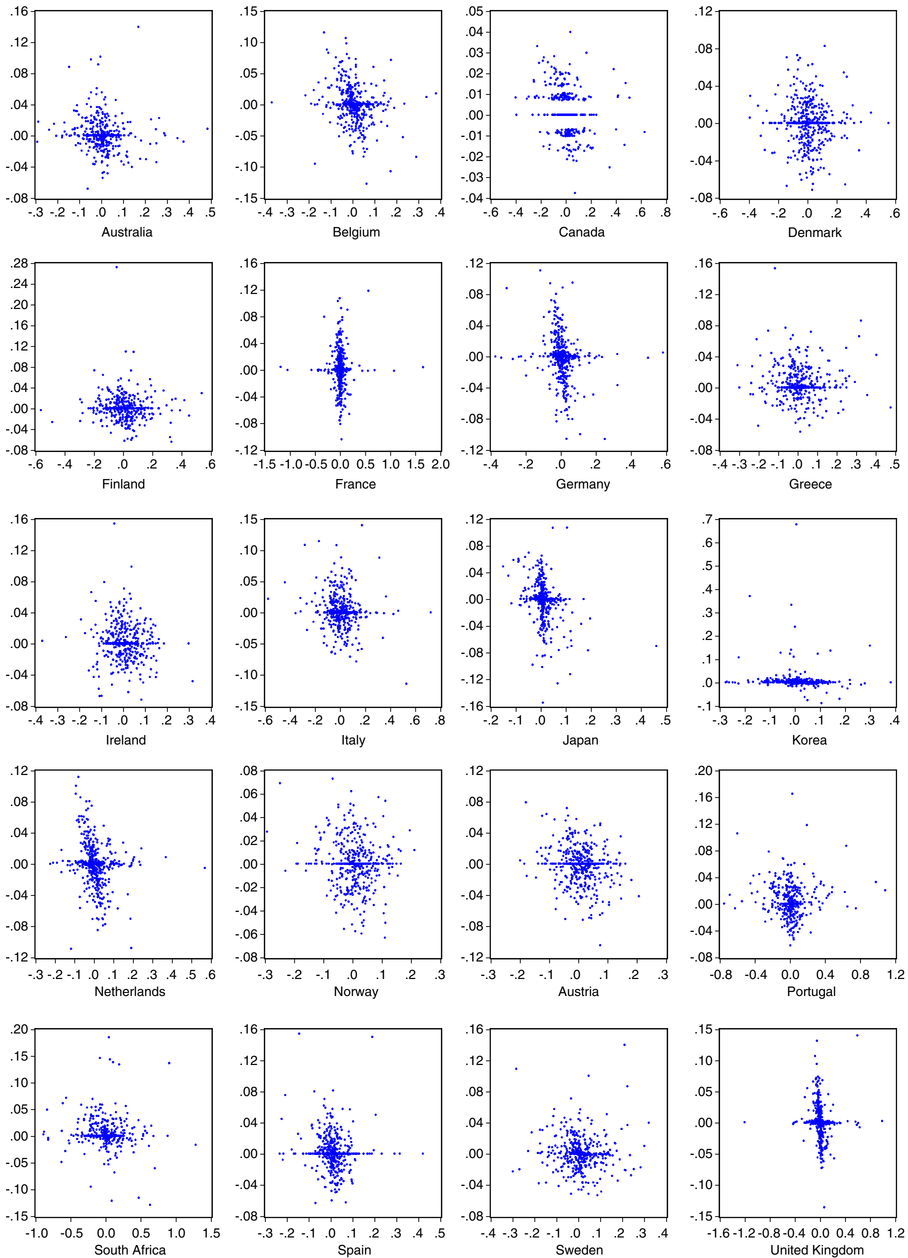

Fig. 3 % Change in non-gold reserves (hor. axis) vs % change in dollar exchange rate (vert. axis), 1960–1998

volatility of this variable decreases as we move into the first post-Bretton Woods period and decreases again substantially in the period when capital controls were finally relaxed (1984–1998). There thus appears to be a clear trade-off between exchange rate volatility and volatility in IMF support as one moves between the

Table 2 Volatility comparisons (average variances for 19 countries)

	BW 1961–1971	Post-BW I 1972–1983	Post BW II 1984–1998
var(ΔIMF) (/100)	35.1	19.3	2.4
var(ΔRES) (/100)	14.2	11.0	7.1
$ numeraire			
var(Δp)	4.6	10.6	5.9
var(Δy)	8.5	8.4	4.7
var(Δs)	8.1	111.7	117.6
DM numeraire			
var(Δp)	5.2	11.5	8.0
var(Δy)	6.3	5.4	6.4
var(Δs)	11.7	56.0	59.3

Data source: annual data from the European Commision and IFS. Variances are computed from 100*dlog x, where x is the variable under consideration

regimes. In contrast, the cross-regime differences in the volatility of non-gold reserves are much less pronounced.

To explicate the inter-regime volatility we run regressions of exchange rate volatility on fundamental volatility as specified in eq. 2.4. As we noted, under a fixed regime (2.4) collapses to (2.6) while in an undistorted free float (2.4) reduces to (2.5). The parameters on the fundamental variables excluding the wedge are identical across the fix, dirty float and pure float specifications; the regime differences are reflected by whether a certain variable is zero or non-zero. This enables us to combine the observations from all three regimes in a single regression.

In Table 3 we report estimates of eq. 2.4 using the annual dataset by means of generalized least squares on the panel of 19 countries and for the 3 sub periods identified above (using EViews6). This yields a total of 57 observations. Interest rates have been omitted from the regressions due to lack of data. Below, we will include interest rates in a smaller sample of monthly data. From Table 3 we see that the explanatory power of the DM regressions is high in comparison to the results for the dollar. Whereas fundamentals explain over 50% of the variance of the exchange rate vis-à-vis the German currency, the explanatory power versus the dollar is only about 25%. The dollar is thus the most difficult currency to explain.[5]

Table 3 also includes regressions where the variance and covariance's involving the IMF variable are replaced by non-gold reserves (*RES*). The explanatory power then drops from 0.27 to 0.15 for the dollar specification and from 0.63 to 0.41 for the DM specification. The IMF variable based specification has considerably higher explanatory power as it provides a cleaner measure of the absorption of exchange rate pressure.

The second observation relates to the sign and significance of the traditional fundamentals. For the German numeraire, the variances of inflation and income

[5] A similar finding holds for forward premium regressions. Perhaps that the role of the dollar as the key currency is part of the explanation. But we do not have a variable for this phenomenon.

Table 3 Panel regressions on annual data

	Var(Δs)			
	vs $	vs $	vs DM	vs DM
constant	71.38** (2.49)	73.14** (3.33)	9.53** (2.31)	8.00** (2.83)
var(Δp)	4.47* (1.87)	4.36** (2.14)	3.06** (7.31)	2.76** (6.72)
var(Δy)	−1.43** (2.42)	−1.76 (1.00)	0.58* (1.67)	0.37 (0.60)
var(ΔIMF)	−0.005** (4.30)		−0.001 (1.25)	
var(ΔRES)		−0.009** (3.45)		0.001 (9.87)
covar(Δp, Δy)	7.01** (2.85)	5.40** (2.83)	2.85** (4.22)	2.07** (2.78)
covar(Δp, ΔIMF)	−0.42** (12.24)		−0.036 (0.24)	
covar(Δy, ΔIMF)	−0.08 (0.45)		−0.031 (0.35)	
covar(Δp, ΔRES)		0.07 (0.79)		0.19** (4.38)
covar(Δy, ΔRES)		−0.26** (5.98)		−0.07 (0.43)
# observations	57	57	57	57
weighted adj. R^2	0.27	0.15	0.61	0.43

GLS estimation with cross-section weights, t-stats in parentheses are calculated using white cross-section standard errors (Eviews 6.0). Balanced panel of 19 countries; variances and covariance's calculated using annual data for three sub-periods (1961–1971; 1972–1983; 1984–1998); the * and ** indicate significance at respectively 10% and 5% levels

growth are positively and significantly related to the variance of the exchange rate, as one would expect from the monetary model. Inflation and income growth do much worse in the dollar regressions, where the variance of inflation is barely significant and the variance of income has the wrong sign.

Turning to the variance and covariance's involving the IMF variable, we observe that these are highly significant in the dollar regression, but not so in the DM regression; but see Table 4 where this variable has a significantly positive coefficient.[6] The variance of the IMF variable has a negative sign, perhaps due to an omitted variable bias, since not all variables of the monetary model are included; but see below in Table 5. The reserve variable also has the wrong sign in the dollar regression. Inflation and income may inadequately capture fundamental volatility. The significant negative sign for var(ΔIMF), or var(ΔRES) for that matter, may then pick up the covariance's between IMF support and other missing fundamental variables. The negative sign, though, corresponds to the visual impression from Fig. 1, which illustrated the negative cross-shaped dependence between the exchange rate and IMF support, and also makes intuitive sense, as fluctuations in IMF support might serve to stabilize the currency.

According to (2.4), volatility in IMF support should increase exchange rate volatility, *ceteris paribus* the volatility in other fundamental variables. It is only by co-varying with the traditional fundamentals that IMF support should result in lower

[6] A referee has suggested that this may be due to the fact that snake and EMS arrangements provisioned for intervention by other members in case of exchange rate pressure for one of the participants. To investigate this explanation, we ran the DM regression exclusively for the EMS countries on the data from the Bretton Woods era. But we did not find a significant coefficient for the IMF variable either.

Table 4 Panel regressions on monthly data (full sample)

	Var(Δs)			
	vs $	vs $	vs DM	vs DM
constant	0.0004** (13.15)	0.0004** (12.56)	0.0004** (10.08)	0.0005** (11.48)
var(Δm)	9.11** (8.30)	8.24** (7.93)	14.86** (10.45)	12.13** (9.81)
var(Δy)	0.004 (0.80)	0.005 (0.91)	0.002 (0.36)	0.007 (1.24)
var(ΔIMF)	−0.0003* (1.80)		0.001** (2.40)	
var(ΔRES)		0.0007** (2.09)		0.002** (3.95)
covar(Δm,Δy)	0.886* (1.79)	0.193 (0.42)	1.186** (2.00)	0.686 (1.42)
covar(Δm,ΔIMF)	−1.392** (8.66)		−1.985** (10.25)	
covar(Δy,ΔIMF)	−0.01 (1.37)		−0.004 (0.47)	
covar(Δm,ΔRES)		0.210 (1.58)		0.020 (0.16)
covar(Δy,ΔRES)		0.025 (3.56)		0.037** (4.86)
# observations	680	680	672	672
weighted adj. R^2	0.159	0.083	0.230	0.157

Cross-section SUR estimation, t-stats in parentheses are calculated using white cross-section standard errors (Eviews 6.0). Unbalanced panel of 20 countries; annual variances and covariance's calculated using monthly data from 1960.01 to 1998.12; the * and ** indicate significance at respectively 10% and 5% levels

exchange rate volatility. A good example of how this works is the negative and significant coefficient of covar(Δp, ΔIMF) in the dollar specification. The interpretation is that inflationary policies in the Bretton Woods period could be sustained longer without the need for an exchange rate adjustment when IMF support was made available. A positive covariance between Δp and ΔIMF thus reduces var(Δs). Per contrast, for the DM based regression we find that the covar (Δp,ΔRES) is positive and significant (and is positive in the dollar regression as well). This can be explained by the observation that in times of exchange rate pressure, which often goes hand in hand with domestic inflation, the pressure was masked by an increase in reserves through IMF credit. In other words, IMF credit served two purposes, relief of exchange rate pressure and hiding imminent balance of payments problems by increasing official reserves.

Summarizing our annual results, we conclude that the extent to which the volatility issue is a puzzle seems to depend partly on the choice of numeraire. The IMF credit variable gives the specification considerably higher explanatory power than the reserve variable. We will now investigate whether these results are upheld using a monthly dataset.

3.2 Volatility Comparisons: Monthly Data

We use monthly data to derive annual standard deviations (based on 12 non-overlapping monthly observations) as our volatility measures. These are calculated only for complete years (i.e. years for which we have 12 monthly observations). In principle, this yields 39 (years) times 21 (countries)=819 observations, but in

Table 5 Panel regressions on monthly data (small sample)

	Var(Δ*s*)			
	vs $	vs $	vs DM	vs DM
constant	0.0003** (7.18)	0.0003** (7.00)	0.0004** (5.95)	0.0004** (6.32)
var(Δ*m*)	5.26 (1.39)	5.25 (1.32)	15.16** (3.91)	14.04** (3.49)
var(Δ*y*)	−0.006 (0.14)	0.020 (0.46)	0.029 (0.57)	0.008 (0.23)
var(Δ*il*)	1.19 (1.10)	0.84 (1.12)	2.35 (1.25)	3.51 (1.59)
var(Δ*IMF*)	0.001* (1.72)		−0.001 (0.78)	
var(Δ*RES*)		0.000 (0.56)		0.000 (0.46)
covar(Δ*m*,Δ*y*)	8.87** (3.13)	9.19** (3.27)	2.73 (1.24)	0.64 (0.29)
covar(Δ*m*,Δ*il*)	−6.10 (0.59)	−7.18 (0.61)	19.25** (1.98)	28.04** (2.52)
covar(Δ*y*,Δ*il*)	−2.217 (1.60)	−1.984 (1.41)	2.99* (1.95)	3.74** (2.34)
covar(Δ*m*,Δ*IMF*)	−0.58* (1.67)		−1.27** (2.75)	
covar(Δ*y*,Δ*IMF*)	0.017 (0.48)		−0.023 (0.51)	
covar(Δ*il*,Δ*IMF*)	−0.510 (1.55)		−0.680 (1.03)	
covar(Δ*m*,Δ*RES*)		0.34 (0.72)		0.61 (1.30)
covar(Δ*y*,Δ*RES*)		0.009 (0.24)		0.009 (0.43)
covar(Δ*il*,Δ*RES*)		−0.219 (1.24)		0.227* (1.79)
# observations	216	216	216	216
weighted adj. R^2	0.06	0.04	0.12	0.07

Cross-section SUR estimation with cross-section weights, t-stats in parentheses are calculated using white cross-section standard errors (Eviews 6.0). Balanced panel of 6 countries (Canada, France, Italy, UK, Australia and either the US or Germany); annual variances and covariance's calculated using monthly data from 1963.01 to 1998.12; the * and ** indicate significance at respectively 10% and 5% levels

practice limited data availability reduced this number, see the bottom line of Table 4. For all variables, except IMF support and the reserve variable**,** we take the first differences of the logs relative to the numeraire. See the Data appendix for full details.

Table 4 reports regression results for a large sample including all countries except Switzerland (for which the IMF measure was unavailable for most of the sample period). Due to the limited data availability for many countries, this regression again excludes interest rate volatility, but we can now use money growth instead of inflation. The increase in observations enables us to replace the weighted GLS method by SUR.

The regressions containing the IMF support variable have again higher explanatory power than the regressions with the reserve variable. But the explanatory power for the monthly data is lower than for the yearly data. The reason is as follows. For the yearly data the volatilities are computed over the time span of about a decade. With monthly data, the volatilities are computed per year. In the latter data set the exchange rate volatility is more prone to outliers such as devaluations. These are smoothed out in a decade by compensating movements in the fundamentals, since the latter take more time to adjust. This concurs with the received wisdom that the monetary model reflects the long term equilibrium.

Similar to the annual results, the volatility connection holds up better versus Germany than versus the US, both in terms of significance and explanatory power. Turning to the individual coefficients, Table 4 shows that the variance of money growth is significantly related to exchange rate volatility in all specifications. Income volatility is unrelated to exchange rate volatility in all regressions, which is perhaps not so surprising for monthly data. For both numeraires, the coefficient of covar(Δm, ΔIMF) is significantly negative, implying that IMF support can reduce or postpone the spill-over of a relatively high money growth into exchange rate volatility. This result resembles the negative sign on the covar(Δp, ΔIMF) variable in the annual dollar regressions. It supports our interpretation of IMF support as driving a wedge between the volatility in traditional fundamentals and exchange rate volatility. In addition to the covariance term, var(ΔIMF) is significantly positive in the DM regression, as it should in theory. The dollar based regression, though, caries a negative sign for this variable. The rerun of these regressions in which IMF support is replaced by non-gold reserves yields significant *positive* coefficients on the variances and covariance's involving reserves, confirming the original Flood and Rose (1995) finding of an absence of a trade-off between exchange rate and reserves volatility.

In order to ensure that our regression results do not depend on the inclusion of small high-inflation countries, Table 5 reports the results of a balanced panel regression for six large industrialized countries (Canada, France, Italy, Australia, the UK and either the US or Germany). Note that the number of observations is much lower than in the complete monthly dataset. This set of results shows the starkest contrast between the two numeraires. While the dollar regression basically fails to establish a link between fundamental volatility and exchange rate volatility (except for the covariance term between money and income growth), the DM regression does have some explanatory power. The variance var(Δm) is significantly related to var(Δs); the variance of the long-term interest rate var(Δil) is only marginally important.[7] In the DM specification, the coefficient of covar(Δm, ΔIMF) is again significantly negative, implying that IMF support dampens the spill-over of high money growth into exchange rate volatility. The covar(Δm, ΔRES) is again positive but insignificant in the companion regression. In total three out of six covariance terms are significant at the 10% significance level in the DM regression. Given the self-imposed constraint of a cross-section limited to just six countries, this is a strong result. Replacing IMF credit by reserves reduces the explanatory power; none of the (co)variances involving reserves is significant at a 5% level.

We conclude that the monthly data confirm the annual results. The fundamental connection is strongest in regressions that take the DM as the numeraire currency. In the majority of the regressions, there also appears to be a role for IMF support in explaining the wedge between fundamental and exchange rate volatility. Official reserves appear to go hand in hand with money growth as exchange rate volatility rises, while IMF support seems a counteracting force. The IMF variable carries higher explanatory power than the reserve variable. That said, the explanation of currency volatility vis-à-vis the dollar remains a challenge, although on the basis of

[7] The long-term interest rate did somewhat better in these regressions than the short-term interest rate. We only report regressions based on the long term rate.

our discussion in Section 2, access to a broader range of distortionary variables would likely help in explaining this volatility.

4 Conclusions

There exists a widely held notion that freely floating exchange rates become excessively volatile when moving from fixed to floating exchange rates. This paper reexamines the issue of inter-regime volatility. We confirm the findings of a number of other researchers that in moving from fixed to floating exchange rates the variability of the standard macroeconomic fundamentals stays roughly unchanged, but that the volatility of the exchange rate changes considerably, suggesting an apparent mismatch. Using a simple extended version of the monetary model, we demonstrated the potential importance of distortions in explaining this mismatch and, specifically, how the volatility of standard fundamentals is absorbed in fixed exchange rate regimes.

Previous studies have often focused on the role of foreign exchange reserves in suppressing exchange rate volatility. But these studies failed to find much evidence for a volatility trade-off between official reserves and exchange rates. This paper argues that IMF support renders reserves an unreliable measure. IMF support has enabled countries to replenish their reserves in times of currency unrest; as a result the effect of severe balance of payment problems on reserves was masked. We identify IMF credit support as a superior compensating variable and show that a country's position at the IMF is an important source of compensating volatility, i.e. helps in suppressing exchange rate volatility. The empirical evidence shows that IMF credit has considerably higher explanatory power than official reserves. Moreover, with an eye towards the current euro-crisis, credit through agencies like ECB, NCB's and EFSF rather than the official reserves are stabilizers. The target system imbalances, for example, reflect the considerable intra EMU trade credit and show how BOP imbalances are maintained that would otherwise lead to exchange rate adjustments.

Other distortions are also likely to be important in this regard, although unfortunately empirical data on these is limited or non-existent. In sum, we argue, and indeed demonstrate, that in cross-regime comparisons one has to account for the missing variables that compensate for the fundamental variables' volatility under fixed rates. Moreover, we find that the volatility issue may be partly a dollar issue, as the link between fundamental volatility and exchange rate volatility improves markedly if we switch the numeraire from the dollar to the DM.

Data Appendix

The annual macro-economic data have been taken from the European Commission AMECO database, except the data on IMF support, which have been derived using data from the IFS cd-rom (see below). The following countries are included: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, United Kingdom and the USA.

The monthly macro-economic data have been taken from the IFS cd-rom. The data are monthly and start in January 1960. Due to the introduction of the euro in January 1999, the sample period ends in December 1998. The following countries are included: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Netherlands, Norway, Portugal, South-Africa, Spain, Sweden, Switzerland, United Kingdom and the USA. Our exchange rate measure is the bilateral period-average price of the US\ dollar (IFS line rf). We choose M1 (IFS line 34 or national definition) as our monetary aggregate. Where M1 was not available, we have chosen either a narrower (currency, IFS line 34A) or a broader aggregate (IFS line 35 M or the national definition). To control for seasonality, we filter the money series by applying a one-sided moving average of the current observation and 12-lagged values. The seasonally adjusted industrial production index (IFS line 66) is used for output; the CPI (IFS line 64) for

Table 6 Data availability, monthly dataset

	M		Y	P	il
Australia	60:1–98:12	M1	60:1–98:12	60:2–98:12[3]	60:1–98:12
Austria	60:1–98:10	M1	60:1–98:12	60:1–98:12	71:1–98:12
Belgium	64:1–98:12	M1[1]	60:1–98:12	60:1–98:12	63:9–98:12
Canada	60:1–98:12	M1	60:1–98:12	60:1–98:12	60:1–98:12
Denmark	60:1–98:12	M1	74:1–98:12	67:1–98:12	60:1–98:12
Finland	69:1–98:12	Currency	60:1–98:12	60:1–98:12	92:11–98:12
France	60:1–98:12	M1	60:1–98:12	60:1–98:12	60:1–98:12
Germany	61:1–98:12	M1	60:1–98:12	60:1–98:12	60:1–98:12
Greece	68:12–98:12	Currency	60:1–98:12	60:1–98:12	86:5–88:12
					97:5–98:12
Ireland	67:1–98:12	Currency	60:1–98:12	60:2–98:12[3]	64:1–98:12
Italy	62:1–98:12	M1	60:1–98:12	60:1–98:12	60:1–98:12
Japan	63:1–98:12	M1	60:1–98:12	60:1–98:12	66:11–98:12
Korea	60:1–98:12	M1	60:1–98:12	70:1–98:12	73:5–98:12
Netherlands	60:1–97:12	M1	60:1–98:12	60:1–98:12	64:11–98:12
Norway	60:1–98:12	Broad M	60:1–98:12	60:1–98:12	61:9–80:7
					80:10–98:12
Portugal	76:1–98:12	Currency	60:1–98:12	60:1–98:12	60:1–64:4
					76:1–98:12
South-Africa	60:1–91:6	M1	61:1–98:12	60:1–98:12	60:1–98:12
	92:1–98:12				
Spain	62:1–98:12	M1	61:1–98:12	60:1–98:12	78:3–98:12
Sweden	61:1–98:12	Broad M	60:1–98:12	60:1–98:12	60:1–95:12
Switzerland	60:1–98:12	M1	63:2–98:12	60:1–98:12	64:1–98:12
UK	60:1–98:12	M0[2]	60:1–98:12	60:1–98:12	60:1–98:12
US	60:1–98:12	M1	60:1–98:12	60:1–98:12	60:1–98:12

[1] Currency (line 34a) until 79:12, thereafter M1. Ratio-spliced. [2] Broad money (line 35 L) until 75:5, thereafter M0. Ratio-spliced. [3] Interpolated from quarterly data

prices. We use both long-term (IFS line 61) and short-term interest rates (IFS lines 60b/60c). Off-shore interest rates are available for only a few countries. Regarding reserves, we use non-gold reserves (IFS line 1 L) and Fund holdings of domestic currency as a percentage of quota (IFS line 2 F). The latter measure - denoted IMF - indicates the extent to which a country draws upon the IMF. Data on the exchange rate and non-gold reserves are available for all countries over the complete sample period. The same applies to the IMF measure, with the exception of Portugal (1962:7–1998:12) and Switzerland (1992:2–1998:12). The availability of other series is indicated in Table 6. All data have been checked and corrected for errors. With the exception of interest rates, the data are transformed by natural logarithms. Interest rates are measured as nominal rates divided by 1200.

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