WP/05/178

IMF Working Paper

How Useful Is Monetary Econometrics in Low-Income Countries? The Case of Money Demand and the Multipliers in Rwanda

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INTERNATIONAL MONETARY FUND

 WP/05/178

IMF Working Paper

African Department

How Useful Is Monetary Econometrics in Low-Income Countries? The Case of Money Demand and the Multipliers in Rwanda

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September 2005

Abstract

This paper revisits the usefulness of econometric monetary analysis in low-income countries in a case study on Rwanda, an interesting case given its floating exchange rate and reliance on indirect monetary policy instruments on the one hand, and its somewhat typical data and institutional shortcomings on the other hand. The findings are generally encouraging for the use of econometric models for monetary analysis in low-income countries. Notwithstanding substantial qualifications, time series and structural models of the money multiplier and money demand yield results that are statistically and economically reasonable enough to usefully inform policymaking.

JEL Classification Numbers: E41, E51

Keywords: Money demand, money multiplier, Rwanda

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[1] The authors are in the Fiscal Affairs Department and Policy Development and Review Department, respectively. The paper was written when they were in the African Department. Thanks are due to Rodolphe Blavy, Francesco Caramazza, Bernard Laurens, Rodolfo Maino, Kenneth K. Meyers, and Laurean W. Rutayisire for helpful suggestions. Of course, any remaining errors are the authors' responsibility.

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I. Introduction

Uncertainty about money demand and the money multiplier constitutes one of the main challenges to monetary policy design and implementation in most low-income countries. Therefore, it is widely recognized that monetary policy implementation in these countries would benefit greatly from an improvement in the underlying analytical framework.[2]

However, despite this apparent need for better analytical frameworks for monetary policy, the usefulness of econometric models is generally regarded as limited. Most often-cited reasons are shortcomings in the availability, frequency, and accuracy of data. Beyond that, fiscal dominance (limiting the central bank's control over the monetary base), and (usually quarterly) test dates under IMF conditionality, which concern most low-income countries, can imply erratic movements that are out of tune with underlying developments and thus affect the conclusiveness of statistical analysis.

This paper revisits the potential scope for econometric analysis in low-income countries, based on a case study for Rwanda. We examine the reliability of the results generated by simplified versions of common econometric models of money demand and the money multiplier. While earlier papers have studied the money demand functions for various low-income countries,[3] this study takes a more encompassing approach by jointly analyzing the demand and supply side. Rwanda is a particularly interesting case, given its floating exchange rate and reliance on indirect monetary policy instruments on the one hand, and its somewhat typical data and institutional shortcomings on the other hand.

The findings are generally encouraging for the use of econometric models for monetary analysis in Rwanda. Despite serious data limitations, common models yield results that are sufficiently reliable to usefully inform policymaking. Nevertheless, the judgment of policymakers will always remain the pivotal point of monetary policy implementation.

On the supply side, the multipliers can be forecast with reasonable reliability. For all multipliers and component ratios, it is possible to construct simple time series models that reduce the residuals to white noise. The aggregate approach to forecasting the multiplier yields somewhat better results than the components approach. Examining the component ratios from the structural side, we can establish for the reserve ratio (which reflects the behavior of the banks) the relationships usually found in this kind of study, but not for the ratios reflecting the behavior of the non-bank public.

On the demand side, the long-term money demand relationship can be characterized by a cointegrating vector, and for the short-term relationship, a Vector Error Correction Model (VECM) can be fitted well to the actual series (in levels). The long-term relationship includes the price level, real output, and the exchange rate as a proxy for the opportunity cost of

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[2] See, for example, International Monetary Fund (2004).

[3] For Rwanda, e.g., Nachega (2000) estimates the money demand function based on quarterly data.

holding nominal balances of domestic currency. However, some variables frequently used in long-term money demand models cannot be included due to data problems. The periods of excess money demand or supply resulting from this cointegrating equation can be shown to be intimately associated with discernable shocks. The short-term specification, in addition to the variables in the long-run specification, also includes structural and seasonal dummies.

There are a number of possible extensions to the analysis that are worth considering. It would be useful to distinguish between monetary and non-monetary GDP, to include a measure of "core" CPI, or a measure of exchange rate premium in parallel markets. Furthermore, alternative ways to identify the structural VAR associated with the money demand VECM deserve careful consideration.

In what follows, Section II discusses some constraints on econometric analysis in the Rwandese case, such as data and institutional limitations to the application of econometric models for monetary analysis. Section III investigates models of the money multipliers and Section IV models of money demand. Section V concludes with a number of policy implications.

II. Constraints on Econometric Analysis

This section briefly describes some of the limitations on econometric analysis of money demand and the multipliers in an environment such as Rwanda's.

Monetary statistics in Rwanda are broadly adequate for econometric analysis. The National Bank of Rwanda (NBR) publishes its balance sheet and data on its money and foreign exchange market operations, including exchange rates and interest rates, on a weekly basis, and the banking sector balance sheet on a monthly basis. Format and detail of the information provided conform mostly to generally accepted standards.

Nevertheless, some serious data limitations must be borne in mind in the economic interpretation of the statistical results presented below: (a) most series have several breaks, most importantly due to the war and genocide in 1994; (b) some series important for our analysis (e.g., borrowed reserves) are only available after 1995; (c) interest rate and exchange rate controls during some periods limited not only the variance of some variables, but also their economic interpretation;[4] (d) with regard to national accounts, only annual GDP statistics are available and those only for the production side;[5] (e) for prices, the GDP deflator shares the problems just mentioned, while the consumer price index (CPI) is constrained by its technical implementation and uneven regional coverage.

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[4] Unfortunately, collection of parallel exchange market data has started only recently.

[5] Agricultural production is estimated per season (approximately every six months) and the estimates are published by the ministry of agriculture. However, this series also has missing entries and some inconsistencies in the methodology used for its compilation.

Limitations on control over the monetary base by the central bank limit not only the effectiveness of monetary policy, but also the usefulness of monetary control models. In principle, the central bank can control three sources of the monetary base: net foreign assets, net credit to government, and credit to the private sector. The fourth source, other items net, contains assets and liabilities that are mostly outside the direct control of the central bank, such as the counterpart to valuation changes in its net foreign assets. However, net foreign assets are also largely outside the control of the central bank when foreign exchange inflows are uncertain, as in the case of substantial grant flows. The same applies to net credit to government in the case of fiscal dominance, particularly when coordination between the treasury and the central bank is lacking.

Table 1. Sources of the Monetary Base
(Percentage change relative to the beginning-of-period monetary base)

Period	B	NFA	NCG	CPS	OIN
1995	39.4	89.1	-68.5	6.8	12.0
1996	23.7	19.8	11.8	-4.5	-3.4
1997	6.1	43.5	19.9	-7.6	-49.8
1998	-8.3	-26.6	-8.2	9.7	16.8
1999	15.8	-3.0	18.8	0.2	-0.2
2000	-9.0	27.3	-27.9	3.8	-12.1
2001	4.6	39.8	-11.2	-23.6	-0.5
2002	13.0	58.3	-56.8	16.9	-5.4
2003	15.2	-17.0	44.0	2.1	-13.8

Sources: National Bank of Rwanda; authors' calculations.
Notes: B…Monetary Base, NFA…Net Foreign Assets, NCG…Net Credit to Government (credit minus deposits, includes all public entities except for public enterprises), CPS…Credit to Private Sector (includes commercial banks, other financial institutions, and private and public enterprises), OIN...Other Items Net.

The NBR has obtained increasing, albeit still limited, control over the monetary base in recent years. Table 1 shows the annual growth rates of the monetary base from 1995 to 2003, and the respective contributions of the four sources of the base. On the back of higher grant inflows, a lessening of fiscal dominance occurred in 2000–2002, although the year 2003 marked a reversal here. While net credit to the private sector was a minor contributing factor to the growth in the monetary base up to the year 2000, it has gained considerably in importance during recent years.

III. Modeling the Money Multipliers

In this section, we examine the scope for modeling Rwanda's money multiplier and its components. First, we introduce the money multipliers and component ratios, including descriptive statistics. Second, we examine whether ARIMA models can forecast the money multipliers reasonably well. Third, we look at whether the component ratios obey the same well-established structural relationships in Rwanda as in many other countries.[6]

While the money multiplier approach has gone out of fashion in industrial countries, more interest has recently been devoted to it for developing countries. According to classic monetary theory (for example, Brunner, 1997), the multiplier reflects the behavior of the public and the banks, while the monetary base reflects actions of the central bank. However, most well-known studies of the multipliers in industrial countries date back to the 1970s and 1980s,[7] with the notable exceptions of Baghestani and Mott (1997) and Freeman and Kydland (2000). Central banks in industrial and middle-income countries have increasingly shifted from controlling the money stock through reserve aggregates to targeting credit market conditions through interest rates. However, in low-income countries, where financial markets are less developed, and the estimated interest rate elasticity of money demand is more uncertain, targeting of reserve aggregates remains prevalent.[8] In recent years, several papers have been devoted to the money multiplier in developing countries more recently, for example, Darbha (2002), Hasan (2001), and Zaki (1995).

A. Introducing the Money Multipliers and Component Ratios

We use the following concepts:[9] The monetary base (B) is currency held by non-banks (C) plus bank reserves (R). The adjusted monetary base (B_a) excludes borrowed reserves. Narrow money ($M1$) is currency held by nonbanks and demand deposits (D). Broad money ($M2$) is $M1$ plus time and savings deposits (T). Four multipliers relate the (adjusted) monetary base to narrow and broad money: $m1$, $m1_a$, $m2$, and $m2_a$. The components of the multipliers are the currency ratio ($c = C/D$), the deposit ratio ($t = T/D$), and the (adjusted) reserve ratio ($r = R/[D+T]$ or $r_a = R_a/[D+T]$). The multipliers and their components are related as follows (replace r by r_a, $m1$ by $m1_a$, and $m2$ by $m2_a$ for the multipliers based on adjusted bank reserves):

[6] We limit our analysis in this section to the post-1994 period owing to data limitations and because substantial interest rate controls limit the usefulness of interest rate data prior to 1995.

[7] E.g., Beenstock (1989), Frost (1977), Rasche and Johannes (1987), Garfinkel and Thornton (1991).

[8] Rasche and Johannes (1987) show that the expected utility loss from deviations of actual money around its targeted level in an interest rate regime versus a reserve aggregate regime mostly depends on the uncertainty of the estimated interest rate elasticity versus the variance of the multiplier forecasts.

[9] For the definitions of the monetary aggregates see the data section.

$$M1 = \frac{1+c}{c+r(1+t)} B = m1 * B \qquad (1)$$

$$M2 = \frac{1+c+t}{c+r(1+t)} B = m2 * B \qquad (2)$$

The monetary aggregates are defined as: The monetary base is currency in circulation outside banks plus bank reserves (including cash in banks) plus non-bank deposits in the NBR, as defined for the IMF-supported program.[10] The adjusted monetary base is the monetary base excluding borrowed reserves. M1 is currency in circulation plus demand deposits with commercial banks. M2 is M1 plus time and savings deposits with commercial banks. We do not adjust the monetary base for changes in the reserve requirement ratio. This allows all the effect of changes in the reserve requirement to appear in the r-ratio and, hence, as fluctuations in the multipliers. The multipliers rise when the reserve requirement ratio is lowered and fall when the reserve requirement ratio is raised.[11]

We use monthly observations from 1/1995 to 12/2003. Descriptive statistics of multipliers and components are in shown in Table A1 in the Appendix. During the period studied, the M2 multiplier rose by 83.7 percent, an increase entirely due to a 222.9 percent increase in the time deposit ratio. At the same time, the currency ratio declined by 9.3 percent and the reserve ratio declined by 65.4 percent. Obviously, adjusted multipliers that exclude borrowed reserves are more volatile than the unadjusted multipliers.

Plots of the multipliers and their components are shown in Figure 1. Both *m1* and *m2* have been trending upwards for most of the sample period (Figures 1a and 1b).[12] The residuals of *m1* and *m2* after detrending and seasonal adjustment (with Census X-12) were smaller in 1999 to 2003 than in 1995 to 1998. The currency ratio has remained relatively stable since 2001, after a precipituous decline from 1995 to 2000 (Figure 1c). The time deposit ratio trended upward during most of the sample period, but has stabilized somewhat since end-2001 (Figure 1d). The reserve ratio and the adjusted reserve ratio have trended downward over the sample period, due to the decline in the excess reserve ratio that arguably reflects both the development of better investment opportunities for the commercial banks (government and central bank bills) and the deteriorating solvency of the banking system during the sample period (Figures 1e and 1f).

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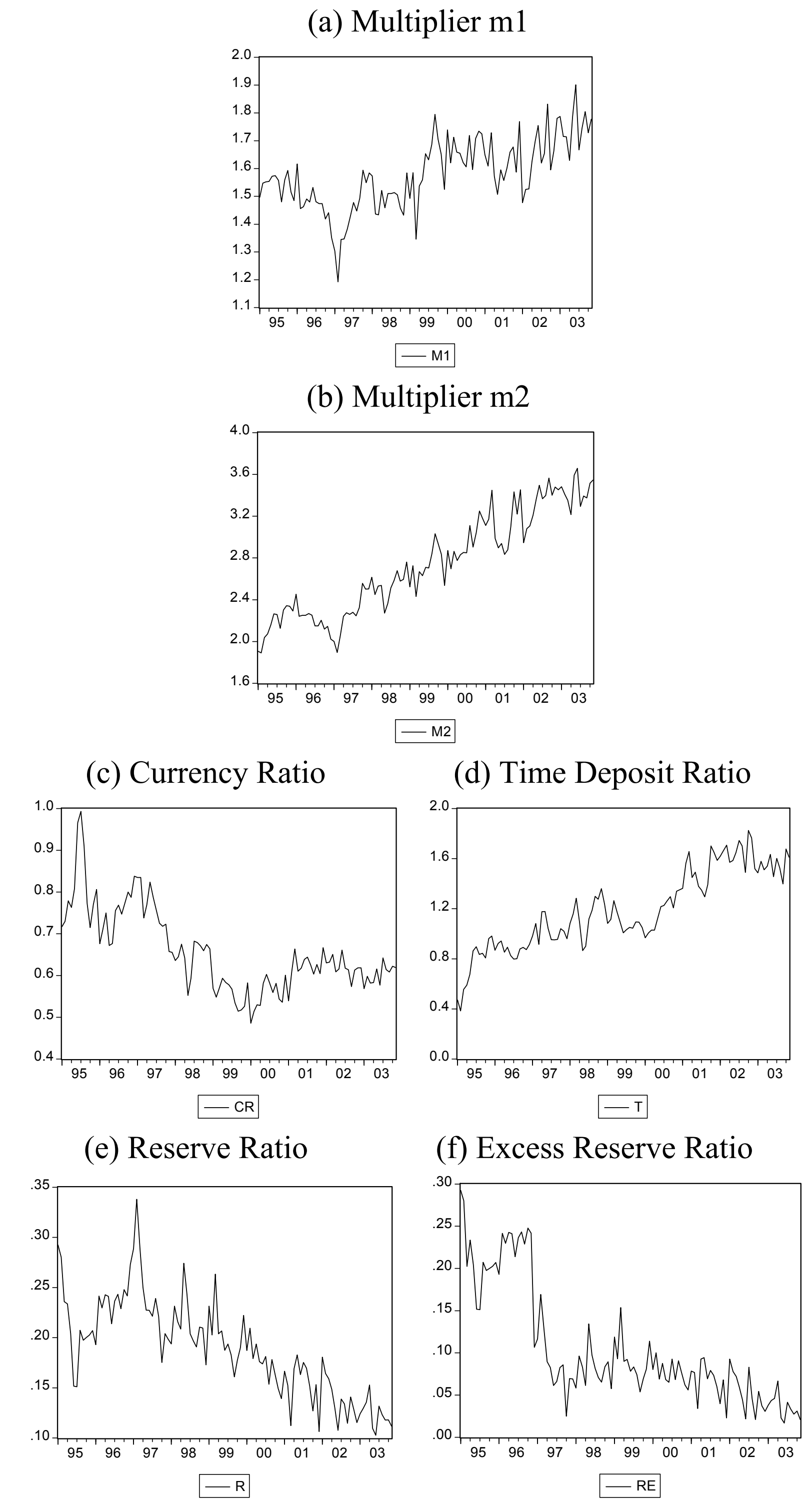
[10] While non-bank deposits in the central bank do not, strictly speaking, constitute high-powered money, a large part of “non-bank deposits” are deposits by (money-creating) non-bank financial institutions, most importantly the *Union des Banques Populaires Rwandaises* (UBPR).

[11] An alternative approach would have been to use the *reserve adjustment magnitude* (RAM) developed by Brunner and Meltzer (see, for example, in Burger and Rasche, 1977, and Frost, 1977). We regard RAM as overly sophisticated for the present context, because the NBR only very rarely changed the reserve requirement in past years, and our concern here is mostly the short-run predictability of the multipliers. Ex post, the ARIMA results below support this decision, as the longest lag in the preferred model for the r-ratio is an MA(1) term.

[12] The downward spike in early 1997 reflects an extremely abrupt expansion in the monetary base (through net credit to government and net foreign assets at the same time) during that period.

Figure 1. The Multipliers and Their Components



Sources: National Bank of Rwanda; authors' calculations.

Regressing the multipliers on their components individually (Table 2) suggests that the reserve ratio causes most of the volatility in the multipliers. This crude measure (serial correlation in the residuals is ignored) also shows that volatility in the deposit ratio *t* accounts for some of the volatility in the *m1* multiplier, but is insignificant for the *m2* multiplier. All significant coefficients have the expected signs.

Table 2. Sources of Volatility in the Multipliers

	m1	$M1_a$	*m2*	$m2_a$
c	-0.35 [R^2=0.03]	-0.22 [R^2=0.00]	0.06 [R^2=0.01]	0.32 [R^2=0.00]
	(1.79)	(0.74)	(0.17)	(0.59)
t	-0.33 [R^2=0.15]	-0.36 [R^2=0.08]	0.21 [R^2=0.01]	0.20 [R^2=0.00]
	(4.40)	(2.98)	(1.53)	(0.88)
r	-2.83 [R^2=0.66]	-3.80 [R^2=0.53]	-5.11 [R^2=0.77]	-6.90 [R^2=0.54]
	(14.43)	(10.78)	(18.74)	(6.07)
r_a	-2.18 [R^2=0.61]	-3.66 [R^2=0.75]	-3.93 [R^2=0.70]	-6.74 [R^2=0.79]
	(12.87)	(17.95)	(15.86)	(19.93)

Source: Authors' calculations. Note: Absolute values of t-statistics are in brackets.

The high contribution of (excess) bank reserves to the volatility of the multiplier has important policy implications. Because excess reserves (required reserves are proportional to total deposits and thus rather stable) are at least partly determined by the central bank's policy stance through open market operations, the multipliers cannot be regarded as exogenous with respect to the NBR's policy stance. Thus, policymakers must also predict the effect of their actions on the multiplier when pursuing the multiplier approach to money stock control.[13] Against this background, the central bank should (a) aim to predict the effects of their policy actions on excess reserves and thus on the multiplier, and (b) promote structural measures to reduce the volatility in excess reserves.[14]

B. ARIMA Forecasts of the Money Multipliers

We assess the forecast power of ARIMA models of the multipliers and the component ratios based on the aggregrate (forecast the multipliers directly) versus the components approach (calculate the multipliers from the forecasts of the components). All the series we examine in this section are integrated of order I(1). As Rasche and Johannes (1987), we do not seasonally adjust the series in order to avoid the introduction of spurious autocorrelation from the standard seasonal adjustment techniques. As yearly seasonal patterns in the multipliers can be observed, we followed Box and Jenkins (1976) by including 12-month seasonal autoregressive (AR) and moving average (MA) terms in all models; results, however, were inferior to those of other models.

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[13] See Garfinkel and Thornton (1991).

[14] Potential measures include closing the commercial bank accounts at the central bank later in the day, and promoting the interbank market by reducing credit risk through more transparency (for example, an automated book-entry system).

Table 3. Preferred Models for Multipliers and Components

y	p,d,q		Q(24)	S.E.
m1	9,1,1	$y_t = 0.2849\ y_{t-9} - 0.5313\ \varepsilon_{t-1} + \varepsilon_t$ (0.1041) (0.0864)	23.7	0.0814
$m1_a$	9,1,1	$y_t = 0.4345\ y_{t-9} - 0.5839\ \varepsilon_{t-1} + \varepsilon_t$ (0.1017) (0.0834)	25.3	0.1126
m2	0,1,1	$y_t = -0.4263\ \varepsilon_{t-1} + \varepsilon_t$ (0.0884)	22.9	0.1469
$m2_a$	9,1,1	$y_t = 0.4817\ y_{t-9} - 0.5801\ \varepsilon_{t-1} + \varepsilon_t$ (0.1003) (0.0834)	18.4	0.2068
c	0,1,2	$y_t = -0.3611\ \varepsilon_{t-2} + \varepsilon_t$ (0.0906)	20.4	0.0434
t	0,1,2	$y_t = -0.3782\ \varepsilon_{t-2} + \varepsilon_t$ (0.0903)	20.3	0.1056
r	0,1,1	$y_t = -0.3932\ \varepsilon_{t-1} + \varepsilon_t$ (0.0903)	21.6	0.0255
r_a	0,1,1	$y_t = -0.5001\ \varepsilon_{t-1} + \varepsilon_t$ (0.0829)	21.9	0.0305

Source: Authors' calculations.
Notes: Standard errors of coefficients in parentheses. Q(24) is the Ljung-Box statistic at lag 24. S.E. is the standard error of the regression.

For all the multipliers and components, it is possible to construct a simple ARIMA model that reduces the residuals to white noise.[15] The preferred models are shown in Table 3. The models for *m1*, $m1_a$ and $m2_a$, in addition to the error, each consist of an AR(9) and an MA(1) term. The models for *m2*, *r* and r_a, each consist of only an MA(1) term. The models for *c* and *t* each consist of only an MA(2) term.

The aggregate approach yields better results than the components approach. Comparing their forecasting power in a static (one-step-ahead) forecasting framework,[16] all diagnostic indicators (Table 4) consistently support this finding for all four multipliers defined here.

Three combinations of the two approaches improve the forecast power relative to the aggregate approach only for *m1*, due to the weak power of the component approach. Three standard methods were used to combine the forecasts: First, the unweighted mean; second, weighting by the coefficients from a regression under the restriction that the coefficients must sum to unity; and third, weighting by the coefficients from an unrestricted regression.[17]

[15] We tried several models and kept those (i) whose coefficients were all significant at the 1 percent level, and (ii) for which the LM and Ljung-Box tests did not reject the null hypothesis of no serial correlation in the residuals. Among the short-listed models, we used the Akaike and Schwarz criterions to guide the selection of the most parsimonious model.

[16] See Hafer and Hein (1984) and Rasche and Johannes (1987) for more elaborate discussions of this approach.

[17] The equations of the restricted and unrestricted regressions are $y_t = \alpha_1 f^a + (1\text{-}\alpha_1) f^c$ and $y_t = \alpha_1 + \alpha_2 f^a + \alpha_3 f^c$, respectively, where f^a and f^c are the aggregate and component forecasts, respectively.

However, as Table 4 shows, only for *m1* the combined forecasts add value, and here only with the weightings from the unrestricted regressions. For the other three multipliers treated here, the combination of forecasts does not add value: This is due to the very weak forecast power of the components approach, which effectively adds more noise than usueful information.[18]

Table 4. Multiplier Forecast Diagnostics

	RMSE	MAE	MAPE	TIC	BP	VP	CP
Aggregate approach							
m1	0.0805	0.0672	4.2869	0.0254	0.0013	0.0305	0.9683
$m1_a$	**0.1114**	**0.0885**	5.4191	**0.0341**	**0.0007**	**0.0299**	0.9694
m2	**0.1462**	**0.1121**	**4.0798**	**0.0264**	0.0320	**0.0034**	0.9646
$m2_a$	**0.2047**	**0.1556**	**5.3406**	**0.0348**	**0.0030**	**0.0110**	0.9860
Components approach							
c	0.0431	0.0322	4.9412	0.0324	0.0014	0.0037	0.9949
t	0.1051	0.0821	7.0173	0.0428	0.0237	0.0012	0.9751
r	0.0254	0.0199	11.0202	0.0652	0.0112	0.0064	0.9824
r_a	0.0304	0.0234	16.6710	0.0806	0.0120	0.0123	0.9757
m1	0.0895	0.0729	4.6090	0.0282	0.0035	**0.0176**	0.9893
$m1_a$	0.1263	0.0924	5.5351	0.0387	0.0059	0.0389	0.9656
m2	0.1507	0.1160	4.1138	0.0266	**0.0233**	0.0083	0.9786
$m2_a$	0.3175	0.1974	6.2477	0.0551	0.1238	0.1075	0.7778
Combination of aggregate and components forecasts: unweighted average							
m1	0.0831	0.0693	4.4000	0.0262	0.0024	0.0300	0.9780
$m1_a$	0.1216	0.0885	**5.2567**	0.0375	0.0580	0.1512	0.8005
m2	0.6612	0.6221	21.6007	0.1313	0.8853	0.0804	0.0355
$m2_a$	0.7942	0.7108	23.4363	0.1545	0.8008	0.1292	0.0720
Combination of aggregate and components forecasts: restricted regression							
m1	0.0805	0.0670	4.2758	0.0254	0.0011	0.0297	0.9796
$m1_a$	0.1302	0.0926	5.4524	0.0404	0.1406	0.2317	0.6367
m2	1.2784	1.2219	42.6043	0.2890	0.9137	0.0742	**0.0130**
$m2_a$	1.3951	1.3095	43.8703	0.3080	0.8810	0.1040	**0.0162**
Combination of aggregate and components forecasts: unrestricted regression							
m1	**0.0794**	**0.0649**	**4.1370**	**0.0250**	**0.0000**	0.1140	**0.8964**
$m1_a$	0.1299	0.0918	5.4030	0.0402	0.0980	0.3505	**0.5610**
m2	1.2361	1.1772	40.9499	0.2767	0.9069	0.0804	0.0137
$m2_a$	1.3104	1.2163	40.4688	0.2835	0.8616	0.1226	0.0172

Source: Authors' calculations.
Notes: RMSE is the root mean squared error. MAE is the mean absolute error. MAPE is the mean absolute percent error. TIC is the Theil inequality coefficient, and BP, VP and CP are its bias, variance and covariance proportions, respectively. Best results for each multiplier is bolded.

[18] Many of the coefficients on the components approach forecasts are not significant at the 10 percent level, another indicator of the weak power of the components approach.

In sum, the aggregate approach permits to forecast the multipliers with considerable reliability, particularly for a relatively unsophisticated monetary system. The diagnostic indicators for the aggregate approach are all at acceptable levels. Theil inequality coefficents of about 0.3 are arguably even surprisingly good given the volatile economic environment; and most of the forecasting error can be explained by the covariance proportion, as should be the case.[19] Among the component ratios, not surprisingly, the t ratio (which contains also the foreign-currency deposits) and the r and r_a ratios prove to be most difficult to forecast. The forecasts of the adjusted multipliers are consistently less robust than those of the unadjusted multipliers. This is not surprising, given the intrinsicly higher volatility of the adjusted multipliers (which exclude borrowed reserves).

Two additional factors give us confidence in our results. First, the differences in the forecast diagnostics between the two approaches are small. This shows that the multipliers in Rwanda's case are no "black boxes" that could potentially hide large unexplainable variations in the multiplier components when analyzed with the aggregate approach. Second, the robustness of the forecasts for Rwanda compares favorably to that found for other other low-income countries (for example, Zaki 1995).

While the multiplier forecast diagnostics are ambiguous about whether M1 or M2 can be controlled with greater precision, Chow tests point to M2 in this regard. While the mean absolute percent error is better for M1, the other scale-invariable indicator, the Theil inequality coefficient, is about the same for M1 and M2. However, applying Chow tests for potential structural breaks sequentially (as the position of a potential breakpoint is unknown) suggests that the forecasts of the M2 multipliers are preferable: for the M2 multiplier, the null hypothesis of no structural break cannot be rejected at the 5 percent level at any interval, while results are more ambiguous for the M1 multiplier.

C. Explaining the M2 Component Ratios by Structural Models

This section presents structural analysis of the M2 component ratios in Rwanda. Again, some data limitations come to bear. There is, for instance, no reliable measure of velocity to include as an independent variable, as we only have annual observations of GDP.

The currency ratio and the time deposit ratio do not seem to behave in line with relationships well established in other (more advanced) economies. Usually, the currency ratio (time deposit ratio) can be shown to be decreasing (increasing) in income and in the deposit rate. However, for Rwanda we cannot establish this relationship in regressions of the currency ratio and the time deposit ratio on GDP and the three-month deposit rate, which reflects the opportunity cost of holding currency versus time deposit balances (demand deposits are typically unremunerated in Rwanda), and between demand deposits and time deposits, respectively. That is, consumers seem to choose between currency versus demand deposits

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[19] The variance proportion indicates how far the variation of the forecast is from the variation of the actual series, while the bias proportion indicates how far the mean of the forecast is from the mean of the actual series.

and demand deposits versus time deposits independently of income and of the opportunity cost of holding currency and (usually unremunerated) demand deposits versus time deposits.

The reserve ratio behaves well in line with the results found for other countries. The demand for excess reserves (determined by the banks) is likely to increase with the mean and the variance of the frequency distribution of withdrawals. It is thus expected to vary inversely with the *t*-ratio, that is, with the share of time deposits in total deposits, because withdrawals from time deposits require advance notification (unless a penalty is paid) and the variance of time deposits is therefore usually lower. The tightness of the NBR's money market policy is likely to affect the demand for reserves. If the central bank assisted the market through its "front window," that is, at market rather than penalty rates, the banks' demand for reserves would tend to fall.[20] To capture this effect, we use Howard's (1982) variable PEN, defined by

$$PEN = discount\ rate \bullet \frac{outstanding\ discount\ window\ borrowing\ from\ the\ NBR}{cash\ reserves\ of\ the\ banking\ system}. \qquad (3)$$

However, as in Howard (1982), we do not find PEN to be significant. As an alternative (and arguably more parsimonious) indicator for the NBR's money market policy stance, we include the discount rate in the model and find it to be highly significant. Since r is naturally constrained between zero and unity, we estimate the model:

$$\underset{}{\ln[r/(1-r)]_t} = \underset{(-2.26)}{-0.90} + \underset{(2.40)}{0.32}\ln[r/(1-r)]_{t-1} + \underset{(2.29)}{0.22}\ln[r/(1-r)]_{t-2} \underset{(-3.40)}{-0.72}t_t + \underset{(2.29)}{0.05}R_{dis,t}, \qquad R^2=0.70 \qquad (4)$$

where t is the deposit ratio and R_{dis} is the discount rate; *t*-statistics are in parentheses. The reserve ratio behaves well in line with the results generally found for advanced economies. As expected, a higher t-ratio reduces demand for reserves, while a higher discount rate increases demand. All coefficients are significant at the 1 or 5 percent level.

In sum, structural models can characterize only the reserve ratio with reasonable reliability. Forecasting the multiplier by structural equations is unlikely to yield reliable results given the apparent independence of the currency ratio and the time deposit ratio of variables suggested by theory and empirical studies on many other countries. However, there is a statistically sound basis for forecasting the reserve ratio r by a structural model such as the one suggested by equation (4), combined with the model for the time deposit ratio t in Table 3.

[20] For a more detailed exposition of the preceding argument, see Beenstock (1989).

IV. Modeling Money Demand

In this section, we examine the scope for modeling Rwanda's money demand both for the long and short terms. For the long-run, we identify a money market equilibrium condition by a cointegrating vector of real money balances, output and the exchange rate. For the short run, money demand is estimated by a vector error correction model. We use quarterly data for the years 1980 to 2003. We limit the analysis in this section to M1, since M2 (a) is composed of assets reacting differently to changes in the interest rate, and (b) includes dollar-denominated deposits depending highly on foreign investment projects.

A. Cointegration Analysis of Long-Run Money Demand

We assume a standard functional form for real money demand. Thus, real money demand is assumed to be a function of output, y (as a proxy for expenditure), a vector including variables that proxy the opportunity cost of holding money balances, ψ, and a vector that includes other variables that influence the demand for real balances, ζ. In the long-run, the money market equilibrium condition can be expressed as

$$\mathrm{M1} / \mathrm{P} = f(y,\psi,\zeta) \tag{5}$$

We specify the following variables (see Table A1): Real money balances are the difference between the logs of M1 in nominal terms, *lm1*, and either the GDP deflator (*lgdpdef)*, or the CPI (*lcpi)*, while expenditures are proxied by the log of real GDP (*lgdpr*). The vector ψ is proxied by the inflation rate, measured either as the log first difference of the GDP deflator (*dlgdpdef*) or the CPI (*dlipc*) and the depreciation of the exchange rate (*dlerya*). In addition, we include structural dummies, one for the period of war (*dumg*, 4/1993–1/1995), and another to capture periods of particularly rapid exchange rate depreciation (*dumer*, 4/1990–1/1991; 1/1995–3/1995). Seasonal dummies are also included (*dumq2*, *dumq3*, *dumq4*).

Figure 2 shows the evolution (in natural logs) of the variables used in the estimation. The discrete changes in output and exchange rates are apparent during periods of political conflict or when there are significant changes in policies. Regarding nominal money balances, note how limited the response was during moments of political turmoil. This seems to hint that the adjustment to desired real money balances most likely occurred through inflation and exchange rate depreciation, the latter particularly in the second sample half.[21]

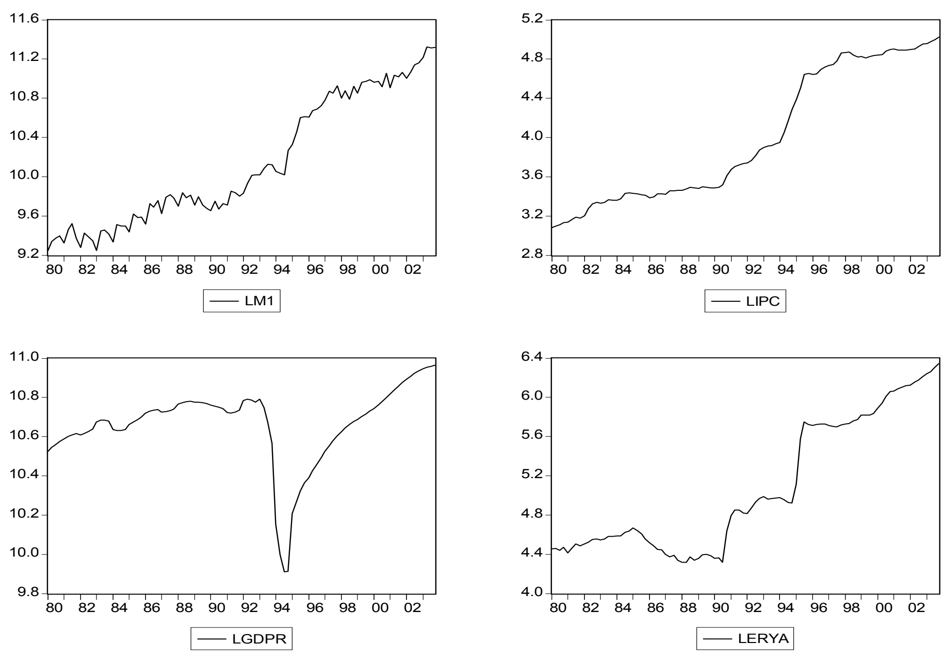
As we cannot use some variables commonly found in long-run money demand functions, we estimate the disequilibrium in the market for real money balances in period t by

$$\mathrm{E}_t = lm1 - \beta_2\, lcpi - \beta_3\, lgdpr + \beta_4\, lerya, \tag{6}$$

[21] This also seems to indicate difficulties to convert domestic currency into foreign currency as a form to adjust to excess money supply; in these cases, the adjustment seemed to have been through exchange rate movements.

where the coefficient on *lm1*, β_1, is normalized to unity. Some papers on money demand (Celasun and Goswami, 2002, among others), include the inflation rate and/or the depreciation of the exchange rate and the interest rate in their formulation of the long-run equilibrium. In the case of Rwanda, this is not possible as these variables are all I(1) in levels. (This holds even considering different subsamples.[22]) Furthermore, since the only interest rate (*irate*) available for most of the period studied, the three-month deposit rate, was under the control of the monetary authorities during an extended period of time, it cannot be used as a genuine measure of the opportunity cost of holding money.

Figure 2. The Main Variables of the Money Demand Function



Source: Authors' calculations.

The Johansen trace statistic suggests one cointegrating relationship of long-term money demand at the 1 percent significance level and with the expected signs:

$$lm1 - 1.13\ lcpi = 6.06 + 1.27\ lgdpr - 0.38\ lerya. \tag{7}$$[23]

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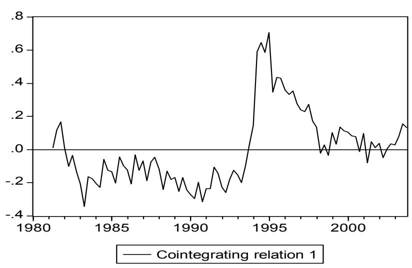
[22] The null that the first log difference of the GDP deflator (*dlgdpdef*) has a unit root cannot be rejected at usual significance levels. Building on that, several models using *dlgdpdef* as a measure of opportunity cost in the cointegrating relationship were tested, some of them with positive results with regard to the economic significance of the coefficients found. However, the goodness of fit was less impressive, in particular for the period after 1998.

[23] Unit-root tests indicate that all the variables considered are I(1). Alternative models combined some of the variables included in equation (7) with various other variables, including end-of-period instead of quarterly

(continued…)

The coefficient of the price level is not significantly different from unity, nor is the coefficient on output at usual confidence levels; this is consistent with a constant velocity in the long run. Note that there is a negative association in the long run between real money balances and the level of the exchange rate. There could be two mutually related reasons for this: (a) the CPI seems to be a good proxy for the prices of non-tradable goods and the price of food staples; (b) the prices of some goods are fully dollarized, regardless of whether they are quoted in domestic currency. As a consequence, it seems the presence of the exchange rate in the cointegrating equation behaves like a shadow price index for tradable goods.

Figure 3. The Disequilibrium in the Market for Nominal Money Balances



Source: Authors' calculations.

The disequilibrium in the market for nominal money balances, $E_{t,}$ (Figure 3) shows excess demand for most of the 1980s and a monetary overhang following the civil war. From equation (6) it is clear that if $E_t<0$, there is an excess demand for real money balances. Equilibrium could be restored either through the adjustment of endogenous variables (the price level, the exchange rate level or the level of real income), or through increases in the money supply. (Conversely, if $E_t >0$, there is an excess supply of real money balances.) Under deteriorating political and economic conditions, the market turned to excess supply for 1994–95 and returned to equilibrium only at the end of the 1990s; since then it has fluctuated around equilibrium. However, the figure shows some monetary overhang at the end of 2003.

B. Short-Run Money Demand and VECM

There are different approaches to model the demand for real money balances in the short run. One is to integrate the long-run equilibrium condition obtained from the Johansen methodology as one of the terms into a short-run demand in first differences. A more comprehensive approach is to recognize the mutual interaction of the variables in money demand, and integrate short-run demand into a more general macroeconometric model as

$$\Delta X_t = \Pi_0 + \Pi\ X_{t-1} + \Pi_1\ \Delta X_{t-1} + \Pi_2\ \Delta X_{t-2} + ...+ \Pi_p\ \Delta X_{t-p} + \Gamma\ Z_t + \varepsilon_t. \qquad (8)$$

average exchange rates, interest rates, a dummy to account for differences in interest rates regimes, and the consideration of the real money demand as a unique variable forcing the coefficient on the price level to unity.

Here, ΔX_t is a 4x1 vector of log first differences of the endogenous variables, Π_0 is a 4x1 vector of constants, Π is a 4x4 matrix including the coefficients (*betas*) and adjustment coefficient (*alphas*) of the cointegrating relation, X_{t-1} is a 4x1 vector of the endogenous variables in levels for the period *t-1,* while the rest is composed by lags of ΔX_t and their respective matrices of coefficients. Finally, Z_t is a vector of exogenous variables and ε_t is a 4x1 vector of disturbances that are such that ε_{it} may be correlated with ε_{jt}.

We model a VECM in the first differences of the variables considered in the estimation of the cointegration equation, plus structural and seasonal dummies. Based on the Akaike information criterion and Cholesky decomposition, we proceed to estimate a model with *lerya*, *lgdpr*, *lcpi*, *lm1*, and four lags (reducing the sample to 91 observations from 2/1981 to 4/2003).[24] We use the log first difference of real GDP as the second equation in the VECM because it is often affected by weather-related shocks to the agricultural sector.

The coefficients of the lagged portion of the short-run money demand are generally in line with economic theory (Table 5). Output is positively associated with money demand. Price increases precipitate an initial increase of the demand of nominal balances, but a subsequent decrease associated with the need to economize money balances to avoid the inflation tax. In addition, money demand is negatively associated with exchange rate depreciation, which also is the reflection of a higher opportunity cost of holding money.

Table 5. Lagged Coefficients of Estimated (Short-Term) Money Demand

Lag	1	2	3	4
d(lerya)	-0.15	0.07	0.32	-0.14
std	-0.14	-0.15	-0.14	-0.12
t	-1.03	0.49	2.30	-1.14
d(lgdpr)	0.39	0.52	-0.46	-0.20
std	-0.16	-0.17	-0.17	-0.17
t	2.41	3.05	-2.76	-1.17
d(lipc)	0.60	-0.29	-0.60	0.25
std	-0.35	-0.38	-0.38	-0.32
t	1.71	-0.76	-1.57	0.80
d(lm1)	-0.30	-0.12	0.03	0.29
std	-0.12	-0.12	-0.12	-0.12
t	-2.47	-1.02	0.28	2.47

Source: Authors' calculations.

The size and signs found for the seasonal and structural dummies (Table 6) seem to adequately reflect Rwanda's seasonality and economic circumstances. Money demand is

[24] Structural innovations in *lerya* are assumed to simultaneously affect the innovations in the other variables, while structural innovations in *lm1*, do not. This ordering seems reasonable as the exchange rate remained fixed during a significant part of the sample period, and, central bank interventions continued after its liberalization.

stronger in the second quarter than in the third and fourth quarters (agricultural crop cycle), and decreases in the first quarter compared with the fourth. The structural dummies for episodes of rapid depreciation (DUMER) and the genocide period (DUMG) are both positive, reflecting discrete reductions in nominal money demand responding to these shocks.

Table 6. Structural Coefficients of Estimated (Short-Run) Money Demand

	DUMER	DUMG	DUMQ2	DUMQ3	DUMQ4
Coefficient	0.02	0.08	0.11	0.05	0.05
std	-0.04	-0.06	-0.03	-0.02	-0.03
t	-0.60	1.38	4.19	2.91	1.90

Source: Authors' calculations.

Regarding the long-run equilibrium condition, the associated adjustment coefficients (*alphas*, Table 7) have signs consistent with economic intuition. If $E_t > 0$, nominal money decreases, while the price level, the exchange rate and real GDP increase to restore equilibrium in the market for real money balances. The *alpha* for the equation concerning the log first difference of nominal money (the first equation of the VECM) implies that the demand for nominal money balances in the short run will be partially explained by the adjustment towards equilibrium, provided there was disequilibrium in the previous period. Although this adjustment seems small, it was already suggested by the evolution of nominal money balances in Figure 4.[25] The *alpha* for consumer prices implies that approximately 2 percent per year of the disequilibrium in the market for money is translated into changes in the price level, that is, into positive inflation rates provided there is excess supply in the market for real money balances. The *alpha* for the exchange rate implies that part of a depreciation occurring in a given year will be partially explained by the adjustment in the market for money. Real output adjusts more to disequilibria in the money market, with approximately 8 percent of the disequilibrium per year being transmitted to this variable.[26]

Table 7. Long-Term Equilibrium Condition for Money Demand

	d(lerya)	D(lgdpr)	d(lipc)	d(lm1)
Coefficient	0.003	0.018	0.004	-0.002
std	-0.004	-0.004	-0.002	-0.006
t	-0.721	5.045	2.295	-0.289

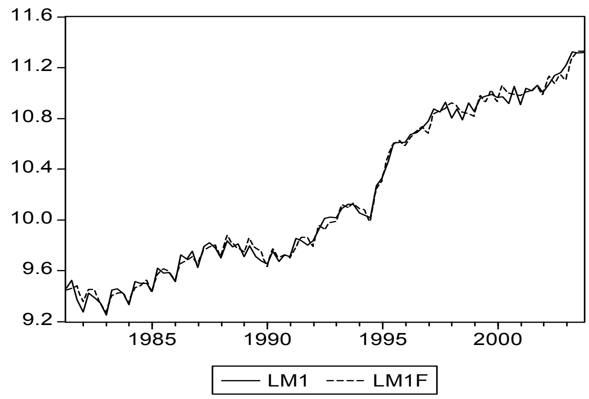
Source: Authors' calculations.

[25] In the particular case of Rwanda, the failure of nominal money balances to adjust to disequilibrium in the market for real balances could also be related to the existence of dormant accounts in the wake of the genocide.

[26] It is possible that the *alphas* of the CPI, the exchange rate and M1 are underestimated, as the one of GDP may be overestimated for two reasons. First, a significant part of the variance observed in the GDP series is related to weather-related shocks that are, initially, non-monetary in nature; second, the strong recovery in both real money balances and GDP after the genocide in 1994 may have biased the results.

It is possible to construct a VECM of money demand in levels that fits the actual series well, in particular up to 1997 (Figure 4).[27] Reasons for the larger residuals in the later part of the sample could include more frequent shocks and more alternatives to money offered by the banks. (Table A3 shows the nominal money demand in levels resulting from the reduced form of the VECM in levels, blending both short- and long-term estimated portions.)

Figure 4. Actual and Fitted Money Demand



Source: Authors' calculations.

C. Possible Extensions

A number of potential extensions could be envisaged: First, it would be useful to distinguish between monetary and non-monetary GDP. A significant portion of Rwanda's GDP is generated by the agricultural sector, and part of it does not enter the market or is bartered. Although estimates of non-monetary GDP exist, it would require a great deal of discretion to use them to determine quarterly changes in monetary GDP. Second, it would be interesting to pursue further the effects of weather-related shocks on real money balances: When positive shocks occur, the share of the monetized sector of the economy could rise (since more households achieve a level of production beyond subsistence), giving rise to real money demand pressures. In contrast, negative shocks could imply that the monetized portion of the economy decreases, entailing an excess supply of real money balances.

Second, the consideration of a "core CPI" in measuring real money balances and associated core inflation in modeling its demand could be interesting, not the least because of the possibility of core inflation being a unit root process. Particularly through food, a significant part of the variance in the CPI is weather-related. Therefore, the cyclical variations observed in the index are mostly the consequence of cyclical changes in food prices generated by a stationary "weather process."

[27] The same model was estimated using different subsamples (excluding the last year and the last two years of the main sample). The parameters obtained for the cointegrating equation are not statistically different from those in (7) at usual confidence levels. Thus, out of sample forecasts resemble those shown in Figure 4 above.

Third, the compilation of a series for exchange rate premia in parallel markets could improve the estimation, as exchange rate developments in official markets do not sometimes adequately reflect the relative price of foreign exchange, that is, black market premia are significant. Thus, both the potential future availability of an alternative measure of *lerya*, or of a measure of opportunity cost in the cointegrating equation (only if the new compiled time series in parallel markets is I(2)) could open new estimation possibilities.

Fourth, a different approach could be attempted regarding the identification methodology applied in modeling the VECM. Instead of assuming the, relatively simple, Cholesky approach to identification, a structural VECM could be estimated imposing theory-motivated identification conditions.

V. Conclusions and Policy Recommendations

Overall, the application of econometric monetary analysis to Rwandan data yields results statistically and economically reasonable enough to inform policymaking. However, the judgment of experienced policy-makers will always have to supersede the findings of econometric models.

While the statistical properties of the models are worse than for more advanced economies, some aspects of monetary analysis work better for Rwanda than others. With regard to the multiplier, non-theoretical (time series) models work better than structural models because data limitations permit only a relatively low share of the variation to be explained. Regarding money demand, short-term VECM work better than long-term cointegration relationships due to frequent shocks that destabilize the long-term relationships.

The main policy implications of the findings of this paper are:

- First, public sector operations should be coordinated more closely to reduce the volatility in the multipliers. Most of the volatility in the multipliers comes from the reserve ratio as opposed to the currency ratio. Thus, the volatility of the multipliers mainly reflects the monetary policy operations of the National Bank of Rwanda. This underlines the need coordinate public sector operations more closely given their effect on liquidity and to analyze the use of different monetary policy instruments.

- Second, the NBR should promote measures that could stabilize excess reserves. Measures could include closing the commercial bank accounts at the central bank later in the day and promoting the interbank market by reducing credit risk through more transparency (for example, an automated book-entry system).

- Third, the NBR's monetary programming could benefit from attributing a higher weight to the specification of money demand. The analysis in this paper shows that, despite political and economic volatility, and extensive controls, money demand, both in the short and long terms, reacts in a way consistent with economic fundamentals. Taking this into account when planning interventions in the foreign exchange and money markets (both through changes in discount interest rates and open market operations) could help the NBR to avoid monetary overhangs and exchange rate volatility, or bursts in the core inflation rate.

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APPENDIX TABLES

Table A1. Descriptive Statistics of the Multipliers and Components

	$M1$	$M1_a$	$M2$	$m2_a$	c	t	r	r_a
Mean	1.58	1.62	2.74	2.82	0.66	1.19	0.19	0.18
Median	1.57	1.61	2.71	2.71	0.63	1.12	0.19	0.19
Maximum	1.90	2.17	3.66	4.24	0.99	1.83	0.34	0.34
Minimum	1.19	1.19	1.89	1.89	0.49	0.38	0.10	0.04
Std. Dev.	0.13	0.17	0.49	0.59	0.10	0.32	0.05	0.06

Source: Authors' calculations.

Table A2. Variable Specifications

Variable	Definition	Source
erya	quarterly average of the official exchange rate	Rwandese authorities and IFS
erye	end-of period (quarterly) official exchange rate	Rwandese authorities and IFS
eryem	end-of period (quarterly) official exchange rate	Rwandese authorities and IFS
gdpr	quarterly real GDP, resulting from smoothing the annual series using a quadratic approximation	Rwandese authorities and authors' calculations
gdpn	quarterly nominal GDP, resulting from smoothing the annual series using a quadratic approximation	Rwandese authorities and authors' calculations
gdpdef	implicit quarterly deflator from *gdpr* and *gdpn*	Rwandese authorities and authors' calculations
ipc	end-of period (quarterly) consumer price index	Rwandese authorities and IFS
irate	three-month deposit rate in RF	Rwandese authorities and IFS
m1	M1 in nominal terms	Rwandese authorities and IFS
m1p	M1 in real terms deflated by the CPI	Rwandese authorities and IFS
ci1	currency outside banks in nominal terms	Rwandese authorities and IFS
ci1p	currency outside banks in real terms deflated by the CPI	Rwandese authorities and IFS

Source: Authors.

Table A3. VECM of Money Demand

Lag		1	2	3	4	5
Constant	-0.11					
DUMER	0.03					
DUMG	0.08					
DUMQ2	0.11					
DUMQ3	0.05					
DUMQ4	0.05					
lerya		-0.15	0.22	0.25	-0.46	0.14
lgdpr		0.41	0.13	-0.98	0.26	0.20
lipc		0.61	-0.89	-0.31	0.85	-0.25
lm1		0.69	0.18	0.15	0.26	-0.29

Source: Authors' calculations.