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Discussion paper [or working paper, etc.]

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ABSTRACT We develop an econometric model of the demand for M2 in Tanzania, using quarterly data from 1998 to the present. The continuous decline in velocity since the late 1990s is associated with a transformation of economic activity that has cumulatively increased the monetary intensity of GDP. Portfolio behavior also responds to expected inflation and to exchange rate depreciation, with weaker effects from interest rates. The components of M2 respond to opportunity costs as expected, with currency more sensitive to expected inflation and deposits more sensitive to the interest rate on government securities. We discuss the policy implications of our results, including their relevance to the velocity-forecasting exercise that plays a key role in the Central Bank of Tanzania‟s policy framework.

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1. Introduction

The Bank of Tanzania (BoT) uses a monetary aggregate as its intermediate target for monetary policy, on the grounds that portfolio equilibrium induces a reasonably predictable relationship between money and prices in Tanzania. The fulcrum of this relationship is the private sector‟s demand for money. If this is a stable function of observable variables, then a policy that targets the growth of nominal money has some prospect of stabilizing inflation at desired levels and at reasonable cost in terms of other variables. But if the demand for money is subject to large and unpredictable shifts, an approach that places less emphasis on money growth may produce superior macroeconomic outcomes. Instability of money demand is widely viewed as having contributed to the demise of money-targeting frameworks among the industrial and emerging-market economies and their replacement since the early 1990s with variants of inflation targeting (Freedman and Laxton 2009).

While the demand for money has been the subject of considerable research within Tanzania, data constraints are severe and the published literature is relatively small. Econometric models currently do not play as prominent a role in policy formation as the Bank desires. Forecasts of nominal money demand are required to determine program targets for money base growth, but these generally come down to judgmental extrapolations of trends in velocity.

We pose a simple question in this paper: does a stable money demand function exist in Tanzania? Given its prominence in Tanzania‟s monetary framework we focus primarily on broad money (M2). Currency is an unusually large proportion of M2 in Tanzania, however, and recent data suggest that fewer than 10 percent of rural households have a member with a bank account. We therefore disaggregate M2 and present results separately for currency and deposits. Further work is a high priority, including an investigation of M3, which includes foreign-currency deposits, the fastest-growing component of bank liabilities since the mid-1990s.

We begin the paper by summarizing some of the key features of portfolio behavior in Tanzania. Section 3 reviews existing econometric work on money demand. In

Sections 4 and 5 we present our empirical work, focusing in turn on long-run relationships and short-run dynamics. Section 6 discusses the relevance of our results to the velocity forecasts that underpin the BoT's reserve-money program. We conclude in Section 7 with a summary of findings and policy implications.

2. The Tanzanian setting

Denoting the log of real M2 by m_t, a conventional demand for money function takes the form

$$m_t = f(y_t, \boldsymbol{i}_t^{ALT}, \boldsymbol{i}_t^{OWN}, E\pi_{t+1}, E\varepsilon_{t+1}, \boldsymbol{z}_t), \tag{1}$$

where y_t is a scale variable, typically the log of real GDP, $\boldsymbol{i}^{ALT}$ and $\boldsymbol{i}^{OWN}$ are row vectors of interest rates on alternative assets and the components of *M2*, E[.] is the expected value operator, π_t is the inflation rate, ε_t is the rate of nominal depreciation, and $\boldsymbol{z}$ is a vector of other determinants (Ericsson 1998).[2]

As alternative scale variables, we consider real GDP and gross national expenditure (GNE); both serve as proxies for the transactions demand for money.[3] The two variables behave similarly over time, but differences due to aid, terms of trade effects, and private capital flows can sometimes be substantial. In the end our empirical results favor real GDP.

The menu of alternative assets includes claims denominated in foreign currency, domestic government securities, and inventories of goods. Foreign currency was widely traded during the exchange-control period and has been legal since the early 1990s. Foreign-currency deposits were introduced in the early 1990s and now account for nearly a third of total M3. Capital controls continue to prohibit the accumulation of offshore assets, but the effectiveness of these controls is uncertain and there may well be substantial dollar balances abroad. We use expected depreciation as our main measure of the return on assets denominated in foreign currency. Domestic government securities are

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[2] The theory underlying this specification is discussed in more detail in Appendix 2.

[3] Theory suggests a role for financial wealth as well, and recent work on South Africa confirms its potential importance (Hall *et al* 2009), but wealth data are unavailable.

limited to short-maturity Treasury bills, introduced in 1994. To capture the return on inventories of goods, we use the expected inflation rate, a variable that features prominently in money demand work on developing countries (Siram 2001).

Our econometric work focuses primarily on the period since 1998. While the brevity of the sample is a serious limitation, there is a tradeoff between the benefits of longer runs of data and the misspecification that can arise in fitting empirical models across very different economic regimes (Juselius 2006). As outlined in Appendix I, the decade that preceded 1998 was one of intensive economic reforms. While many of these were in place by 1994 – including interest rate liberalization, exchange rate unification, the removal of price controls, the licensing of foreign exchange bureaus, the introduction of foreign currency deposits and treasury-bills, and the opening of the banking sector to competition – the transformation of the public sector took longer, and occupied much of the 1990s. The near-monopoly National Bank of Commerce (NBC), for example, was restructured repeatedly during the first half of the 1990s, and in 1997 was relieved of most of its rural branch network in a split that created the new National Microfinance Bank. The new NBC was finally privatized only in 2000, and the NMB in 2005 (Cull and Spreng 2010). Other public enterprises continued to be privatized throughout the 1990s, with the first 115 divested between 1992 and 1994 and another 168 between 1995 and 1998 (PSRC 2000; Waigama 2008).

Trends in velocity

Figure 1 shows the ratio of real GDP to real money balances – the velocity of money[4] – for the four main monetary aggregates in Tanzania, from the late 1980s to the present. The sharp increase in 1995 coincides with the adoption of a cash budget by the public sector, a move Ndulu (1997) credits with validating a disinflation strategy that was based on restricting growth in the monetary aggregates (at that time M3 was the main target). However, while the initial increase in velocity is a plausible effect of tight money, its persistence through most of the second half of the 1990s is puzzling. None of the standard determinants of money demand deteriorated during this period: real GDP was rising (in

[4] Velocity is usually measured as the ratio of nominal GDP to the nominal money stock. Here we measure it as the ratio of real GDP to the real money stock. This is necessitated by our choice to interpolate real GDP from annual to quarterly frequency: we do not have a reliable quarterly nominal GDP series. The two measures differ by the ratio of the GDP deflator to the consumer price index.

contrast to the more typical contraction in a money-based stabilization), inflation was falling, nominal depreciation remained modest, and interest rates fell rapidly from their initially high levels.

Problems in the banking sector may have played some role in dampening money demand during the mid to late 1990s. The restructuring process, in particular, appears to have restricted the access of households to financial services, particularly in rural areas (Cihak and Podpiera 2008). In 1994 alone, the NBC retrenched 2,800 employees and closed 23 branches. Successive household budget surveys show a sharp decrease during the 1990s in the proportion of households reporting a bank account – this number falls from 18.0 percent in the 1991/92 survey to 6.4 percent in 2000/01, before recovering to 10.0 percent in the 2007 survey.[5] Confidence in the banking system may also have been shaken by the collapse of Meridien-BIAO and Tanzania Housing Bank in the mid-1990s, though these failures do not appear to have systemically endangered the banking system.

The trend of financial shallowing reverses itself around 1999/2000, and financial deepening continues strongly throughout the ensuing decade. The ratio of M2 to GDP exceeds 20% for the first time in 2008 – very low by international standards, but a typical value for low-income Africa (Honohan and Beck 2007). Below we show that a variety of measures of structural change reverse course during the second half of the 1990s, consistent with a fundamental reorientation of the economy towards trade, investment, and private sector activity.

Composition of the aggregates

M3 is defined in Tanzania as M2 plus foreign currency deposits. The composition of M3 (Figure 2) brings out two main observations. The first is the continued prominence of currency – at 20 percent of M3 in 2008 – despite its gradual replacement by bank deposits. Currency remains the dominant means of exchange in much of Tanzania, especially in rural

[5] It is likely that the proportion bottomed out in the mid- to late-1990s, as NBC was being restructured and new banks had not yet established a substantial foothold. Reductions in rural access may well have lasted longer, however. The National Microfinance Bank, which succeeded NBC and acquired most of NBC‟s rural branch network, remained in state hands until 2005, operating for most of the 1997-2005 period under a private consulting contract that focused on enhancing profitability, not on expansion of reach or services. See Cull and Spreng (2008).

areas.[6] Figure 3 provides some evidence of the links between currency and rural economic activity in Tanzania. The seasonal pattern of real currency holdings is very strongly correlated with the seasonal in the monthly real price of food, where the latter is defined as the food CPI deflated by the non-food CPI. Nyella (2005) suggests that these co-movements are driven by the crop cycle, with currency holdings peaking at the time of harvest (he also cites an end-of-year holiday spending effect).

The second feature of M3 is the growing importance of foreign-currency deposits (FCDs), which peaked in 2006 at just above one third of the total. Kessy (2008) finds that the share of FCDs in total deposits is an increasing function of expected depreciation and the share of trade in GDP. Figure 4 compares the *ex post* yield on 12-month foreign currency deposits with the interest rate on comparable domestic deposits over the past decade. For most of the period FCD have constituted a favorable medium-term store of value for households prepared to tolerate the volatility in their return.

Key features

Our discussion has emphasized a set of potentially important features of the Tanzanian case since the mid-1990s. These include

- a large share of currency in the higher monetary aggregates;
- a small share of the public with bank accounts, particularly in rural areas where the economy remains largely cash-based;
- the coexistence of deposit dollarization with capital controls, potentially allowing a higher degree of exchange-rate-based portfolio substitution within M3 than between domestic and foreign bonds;
- the introduction of Treasury Bills in 1994, offering a high-yielding alternative to bank deposits;
- significant structural change in the economy stemming from macroeconomic and supply-side reforms which shifted economic activity towards more monetary-intensive activities and;

[6] While 10 percent of Tanzanian households reported a member with a bank account in 2007, this proportion was nearly 25 percent in Dar es Salaam. The figure for rural areas must therefore be well below 10 percent.

- the transformation of the banking sector after 1992, which improved the quality of bank services while potentially restricting access to banking services at least initially.

The reforms of 1988-94 changed the menu of financial assets and the character of the banking sector. In our view, these reforms were fundamental enough that an investigation of contemporary portfolio behavior should start in 1994 at the earliest. We also noted, however, that velocity behaves very differently during the second half of the 1990s than subsequently. In principle, the sharp change in money supply behavior starting in 1995 should assist in the econometric identification of the money demand equation. As we have stressed, however, the disinflation period as a whole remains something of a puzzle. Real money balances fell sharply and persistently, despite the absence of commensurate movements in the conventional determinants of demand. Below we identify components of the $\boldsymbol{z_t}$ vector that perform strongly in the post-1998 sample while providing at least a partial account of the collapse in real money demand during the second half of the 1990s.

3. Existing work on money demand in Tanzania

We briefly review the Tanzanian literature, beginning with work that preceded the first application of modern time series methods by Randa (1999).

The early literature features a set of partial adjustment models applied to annual data (Gerdes 1990, Maje 1992, Kihuale 1994, Mgonya 1997). Estimation samples start in 1967 and end in 1995 or earlier. These models incorporate a lagged dependent variable but otherwise have very sparse dynamics, if any. They use expected inflation as the opportunity cost of money, reflecting the undeveloped nature of the financial system and the absence of interest-bearing alternatives to money. In the earliest study, Gerdes (1990) introduces the key empirical themes of this literature: high income elasticities, even by the standards of low-income countries; conventional but weak portfolio responses to expected inflation; and controversies over the empirical stability of the estimated relationships.

These early contributions uniformly employed real GDP as the scale variable. Using data from 1967 to 1985, Gerdes (1990) reported long-run income elasticities of close to 2.0 for M1 and M2, against a benchmark of 0.5 from the Baumol-Tobin transactions demand model and 1.0 from the quantity theory of money. In line with the literature on low-income countries, he attributed these high elasticities to ongoing monetization of the economy and the persistence of limitations on the menu of alternative financial assets. Similar long run income elasticities were found in subsequent applications, including prominently that of Maje (1992), who incorporated the number of branches of the monopoly National Bank of Commerce (NBC) as a direct proxy for the pace of monetization. The sign on this variable was positive, as expected, but was not statistically significant.

The coefficients on expected inflation varied across applications, but they tended to be small and were in most cases statistically insignificant. Starting with Maje (1992) the time deposit rate was often included as a measure of the return to alternative assets (M1) or as part of the own return on money (M2); point estimates were often appropriately signed, but were uniformly small and imprecisely estimated. It was not possible in this early literature to reject the hypothesis of a perfectly inelastic response of money demand to interest rates.

Gerdes (1992), Maje (1992) and Mgonya (1997) all implemented Chow tests to assess the stability of the money demand function, as did Kihuale (1994) who applied a broader battery of tests using data from 1967 to 1990. Results were mixed; Gerdes and Mgonya were unable to reject parameter stability, while Maje and Kihaule found evidence of instability. While the latter finding was perhaps more plausible in a highly controlled economy undergoing the stresses of financial repression, economic collapse, and structural adjustment, the sources of instability were not carefully diagnosed. A limitation of this early literature, moreover, is the difficulty of distinguishing genuine parameter instability from slow equilibrium correction when the variables have stochastic trends. More generally, conventional tests of significance can be misleading when the variables are non-stationary, as emphasized in the time-series literature following Engle and Granger (1987); a cointegration/error-correction framework is required to correctly identify short- and long-run relationships and support accurate inference (Enders 2007).

Randa (1999) established the standard for contemporary research by moving to quarterly data (1974q1-1996q4), incorporating a role for currency substitution, and applying modern time series methods. Randa focused on M0, M1 and M2; Nyella (1998) applied similar methods to M3, using quarterly data from 1986q1 to 1997q4. The hallmark of the modern time-series approach is two-fold: first, close attention to the stationarity properties of the data and the resulting distinction between long-run equilibrium relationships and short-run dynamics; and second, where feasible, the adoption of a system-based approach in which multiple long-run relationships may exist among the variables. We return to these themes in Section 4 below.

Moving to quarterly data requires interpolation of the scale variable, since the GDP accounts are available only annually. Randa uses quadratic interpolation, which does not require (or benefit from) the use of indicator variables available at quarterly frequency. Using similar interpolation methods, Nyella uses gross national disposable income (GNDI), which differs from GDP by the sum of net factor income and net transfers, a quantity dominated by large and variable amounts of foreign aid.

Randa"s second innovation was the incorporation of the rate of depreciation of the black market exchange rate as a measure of opportunity cost for households with access to assets denominated in foreign currency. Currency substitution was illegal until the early 1990s, and it is still illegal for Tanzanian residents to hold offshore assets. The foreign exchange black market was nonetheless active starting in the mid-1970s, and there is considerable evidence that portfolio influenced the behavior of the parallel premium during the 1970s and 80s (O"Connell 1992).

Randa"s specification omitted interest rates in favor of inflation and depreciation. The Johansen method confirmed the presence of a single cointegration vector relating real money balances, real GDP, inflation and depreciation. Interpreted as a money demand function, all coefficients had the expected signs and were statistically significant. Estimated income elasticities were higher for successively broader monetary aggregates, a finding also characteristic of the earlier literature. In all cases, however, they were markedly smaller than previous work had suggested (0.81, 0.96 and 1.11 for M0 M1 and M2 respectively) and more in line with estimates for other countries. The inflation elasticity of demand for money was negative, as expected (magnitudes 0.43, 1.08 and

1.16 for M0, M1 and M2, respectively), as was the elasticity with respect to expected depreciation.

Randa interprets stability in terms of existence of a cointegrated long-run money demand relationship. His conclusion is that a stable set of demand functions exists despite the economic and financial reforms that have taken place since late 1980s. Nyella (1998) reports a similar finding for real M3 (M2 plus foreign currency deposits), using quarterly data for 1986q1 to 1997q4. Nyella‟s specification incorporates a measure of the own return on money, in the form of the time deposit rate adjusted by the ratio of these deposits to M3. It also incorporates expected depreciation, which plays double duty as a component of the own return on foreign currency deposits and an opportunity cost for households with access to foreign currency and offshore deposits that are outside of M3.

Nyella (1998) innovates by incorporating a deterministic proxy for financial liberalizations undertaken in the early 1990s. This proxy goes from zero to 1 when foreign currency deposits are introduced in 1992, and from 1 to 2 when the government T-bill market is introduced in 1994. This variable is constrained to lie in the cointegration space, implying a sequence of two equal and permanent shifts in the long-run relationship.

As in Randa (1999), Nyella‟s analysis supports the presence of a cointegration vector with the characteristics of a long-run money demand function. At 0.58, however, the income elasticity is extremely low by the standards of previous research. The own rate of return has a positive and statistically significant impact as expected, and the coefficient is large, at −3.7. Depreciation has a positive (0.9) and significant coefficient, consistent with stronger substitution into domestic foreign currency deposits than into other foreign assets when expected depreciation rises. Short run elasticities from the error-correction representation of the money demand equation were plausibly signed in most cases.

4. The demand for M2

We estimate the demand for the M2 aggregate and its two sub-components, currency and deposits, using quarterly data on the variables identified in equation (1) above (see Appendix 3 for details). Quarterly data are available for all monetary aggregates, prices, interest rates and exchange rates. Data on the scale variables (real GDP and real GNE) are only available at an annual frequency. We interpolate these to a quarterly frequency using an augmented version of the „proportional Denton interpolation" method.[7]

The modern approach to money demand starts by interpreting equation (1) as a long-run equilibrium relationship. The deviation from this equilibrium should therefore be a stationary random variable with a zero mean. Denoting the vector of determinants by $\boldsymbol{x_t} = (y_t, \boldsymbol{i_t^{ALT}}, \boldsymbol{i_t^{OWN}}, \pi_t, e_t, \boldsymbol{z_t}')'$, and assuming linearity, this implies

$$m_t = \beta' \boldsymbol{x_t} + u_t, \tag{2}$$

where the „equilibrium error" u has a zero unconditional mean and constant unconditional variance and where the sub-vector $\boldsymbol{z}$ may include deterministic components (e.g., a constant, a linear trend, seasonal dummy variables). We verify below that *m* and the variables in $\boldsymbol{w}$ have unit roots (see Appendix 4). In this case the stationarity of u implies that the variables are cointegrated. The long-run money demand coefficients correspond to the cointegration vector $(1, -\beta')'$.

If there is only one long-run relationship between the variables in $(m_t, \boldsymbol{x}_t')'$, then the long-run coefficients can be estimated consistently in a variety of ways, including OLS as applied to equation (2). The short-run dynamics of the system can then be recovered by estimating an error-correction specification in which the change in money balances responds to current and lagged changes in the other variables as well as to the previous period"s estimated equilibrium error, $m_{t-1} - \beta' \boldsymbol{x_{t-1}}$:

$$\Delta m_t = \sum_{i=1}^{p} \gamma_i \Delta m_{t-i} - \alpha (m_{t-1} - \beta' \boldsymbol{x_{t-1}}) + \sum_{i=0}^{q} \delta_i' \Delta \boldsymbol{x_{t-i}} + \varepsilon_t. \tag{3}$$

[7] This method generates a smoothed interpolated quarterly series from annual data subject to the constraint that the sum over the year of the interpolated quarterly values for GDP equals the known annual total GDP. We augment this series by exploiting known quarterly movement in correlates of real GDP, such as trade flows and investment expenditure.

Cointegration implies that the adjustment speed $\square$ lies between −2 and 0. While OLS yields a consistent estimator of the adjustment speed, consistency of the other estimates relies on weak exogteneity of the right-hand-side variables (Enders 2006).

In large samples, a systems approach is likely to be preferable to the Engle-Granger two-step method we have just described. Starting with an unstructured vector autoregression involving the vector $\square_t = (\square_{\square}, \square_t')'$, the Johansen method allows joint estimation of the short- and long-run coefficients and provides an orderly approach to assessing exogeneity and identifying multiple cointegrating relationships among the variables (e.g., Juselius 2006). In the presence of a single cointegration vector, however, the Engle-Granger two-step method tends to produce smaller bias in very small samples. In what follows we rely on the two-step procedure, leaving systems estimation as a potential extension.

Incorporating structural change

As emphasized above, the money demand literature in Tanzania has tended to feature income elasticities that are both very high and sensitive to the sample. The standard explanation for high income elasticities in low-income countries is that increases in aggregate income are accompanied by structural changes that increase the use of currency and bank deposits in transactions. These changes can bias upwards the measured income elasticity by conflating it with the impact of structural change.

While the „monetary intensity‟ of economic activity cannot be measured directly, we can proxy it based on the set of measures depicted in Figure 5. Starting from the activity side, we define the *monetary-intensive share of GDP* as the share of mining and quarrying, manufacturing, electricity and water supply, trade, restaurants and hotels, transport and communications, and finance, insurance and real estate. We then include *investment as a share of GDP* and *imports as a share of GDP*, on the grounds that these components of expenditure are more transactions-intensive than other components of GDP. The *government wage bill as a share* of GDP is next; this has increased substantially in recent years, reflecting increases in both real wages and employment (including MDG-related spending). In contrast to much of the private sector, government wages and salaries are paid though the banking system. Finally, *credit to the private sector as a share of M3* provides a direct measure of banking sector intermediation.

These proxies tend to emphasize change in the demand for liquidity services. Other things equal, reductions in the effective cost of acquiring financial services would also serve to increase the monetary intensity of economic activity, and *vice versa.* To date, however, it has not been possible to compute measures of these supply-side changes, either directly in terms of the cost of access to financial services or indirectly through measures of the changing structure and operations of the financial system as a result of the reforms described in Appendix 1. We hope to develop such measures and incorporate these in our measure of structural change in subsequent work.

While each of these variables captures a distinct aspect of the changing monetary intensity of GDP, data limitations preclude our incorporating multiple proxies in our regressions. We can summarize the information content in these measures, however, by extracting their first principal component. Table 1 shows the results of this exercise. There is a very strong commonality across the movements of these variables, such that a more-or-less equally weighted average accounts for nearly three-quarters of their total covariance. We use this weighed average as our proxy for transactions intensity. As indicated in Figure 5, transactions intensity falls dramatically in the early stages of the 1995-99 disinflation, before stabilizing in the late 1990s and then rising sharply and cumulatively starting around 2002.

Long-run estimates

Table 2 shows our results for the long-run demand for M2, for samples beginning in 1994q1 and 1998q1. Note that in all specifications a Dickey-Fuller test rejects the hypothesis of a unit root in the residuals. Since the variables themselves are I(1), this is evidence of cointegration. Results are somewhat stronger for real GDP than for real GNE, and in subsequent tables we focus solely on specifications involving real GDP.

The results for the post-1998 sample appear in columns 3 and 4. The transactions intensity of GDP comes in very strongly, and with this dimension of structural change included in the regression, the expenditure and income elasticities – at 1.58 and 1.78 when transactions intensity is excluded – fall sharply. The scale elasticities are now insignificantly different from 1. Expected inflation and expected depreciation have the anticipated signs and reasonable magnitudes, with a 10 percent increase at an annual rate reducing real money demand by 0.8 and 2.2 percent, respectively. [8]

We noted earlier that an existing literature finds weak interest rate effects, based mainly on samples ending in the mid-1990s or earlier. Perhaps surprisingly, this effect persists after a decade of banking sector reforms. The spread between the T-bill rate and the rate on time deposits has a plausible sign and magnitude in column 3, but neither survives in column 4, and we cannot reject that the coefficient is zero in either case. At least one of the centred seasonal dummies, in contrast, has a large and statistically significant coefficient in each specification.

Figure 6 shows the cointegration relationship for the regression in column 4. While real money balances and their determinants move closely together, the mean squared error is substantial at 3.7 percentage points. Equilibrium errors are sizeable over the 2005-2007 period, with a persistent under-prediction starting in 2005 followed by over-prediction in 2007.

As shown in columns 1 and 2, cointegration survives but the fit deteriorates markedly when the sample is extended back to 1994. The root mean squared errors rise by roughly a third. Among the opportunity cost variables, only expected depreciation continues to perform strongly, its significance intact and its magnitude roughly doubling. The income elasticities are now significantly below unity.

Short-run dynamics

In Table 3, we estimate dynamic error-correction models (ECMs) using the estimated equilibrium errors from columns 2 and 4 of Table 2. Note that all variables in these specifications are stationary – the equilibrium errors by virtue of cointegration, and the remaining variables via differencing. Statistical tests suggest excluding the transactions intensity variable from the short-run dynamics, and so we proceed accordingly. We focus on the post-1998 sample (columns 2 and 3).

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[8] For all models we report heteroscedasticity-robust standard errors. Our interpolation of real GDP allows us to exploit a sample of approximately 40 observations. However, this masks the fact that we have only 11 independent observations on real GDP. To check that this does not seriously distort our interpolation, we also compute standard errors from a bootstrap routine. This slightly raises the estimated standard errors reported in the tables in this paper but not sufficiently to alter any inference we draw from the results.

Column 2 shows an unrestricted ECM that includes one lag of all variables, and in column 3 we reduce this to a parsimonious specification with stronger statistical properties.[9] The parsimonious specification generates a root mean squared error of 2.6 percentage points, by comparison with a standard deviation of the dependent variable of 3.6 percentage points per quarter. There is no evidence of serial correlation in the post-1998 sample.

Error correction is an implication of cointegration, and so the negative and statistically significant coefficient on the lagged equilibrium error is important corroboration of our cointegration result. The speed of error correction is considerable, at over 30 percent per quarter. At the same time the growth in real money balances displays considerable short-run inertia, with a lag coefficient of roughly 0.3. Real GDP has a smaller impact in the short run than it does over time, but the coefficient is strongly significant. Inflation and depreciation both come in strongly in the short run; and the interest-rate spread continues to be insignificantly different from zero. The seasonal dummies remain large and important.

Figure 7 shows the actual and fitted values from the parsimonious ECM (column 3). The short-run dynamics go some way towards resolving the large and persistent equilibrium errors in 2005-2007, with the exception of a single large outlier in the first quarter of 2005.

5. Currency and deposits

In Tables 4-6 we undertake a similar exercise for the two main components of M2, currency and domestic-currency bank deposits. Our aim here is to shed some light on compositional effects within M2. While these effects are present in any money demand exercise, they may be of particular interest in Tanzania. The dominance of currency in rural areas, the small proportion of the population with bank accounts, and the potentially even smaller proportion with interest in or awareness of the T-bill market, suggests that the relevant opportunity costs may differ sharply across the components of M2. The

[9] Where appropriate we accommodate higher lags in the parsimonious specification.

puzzle of largely-absent interest-rate effects, in particular, may in part be a result of aggregation, if markets are partly segmented and only a portion of M2 responds to interest rate differentials.

While the results should be considered preliminary, they suggest sharp and intuitively appealing differences within M2. As earlier we focus on the post-1998 results. In Table 4, long-run currency demand responds strongly to expected inflation and not at all to interest rates (we exclude them on statistical grounds). Perhaps surprisingly, expected depreciation also has a small and insignificant impact on currency demand. The demand for deposits, in contrast, responds very strongly to expected depreciation, consistent with substitution between domestic- and foreign-currency deposits within M3. The point estimate on the interest rate spread (we use the T-bill rate minus a weighted average of domestic-currency deposit rates), moreover, is considerably larger in the deposit equation than in the overall M2 regression, and much closer to statistical significance. The impact of expected inflation on deposits is small and statistically insignificant. A weak response to interest rates remains a feature of the short-run dynamics, however, and inflation appears to have at least as strong a short-run impact on domestic-currency deposits as it does on currency (Tables 5 and 6)

6. Forecasting velocity

Forecasts of velocity play a central role in the Bank of Tanzania‟s policy framework. Expressed in terms of growth rates, the definition of velocity ($V = P\square/\square$) implies that

$$\Delta\square_{\square+1} = \Delta\square_{\square+1} - \Delta\square_{\square+1}, \qquad (4)$$

where $\square$ is the log of velocity. The change in real money balances, in turn, is the difference between nominal money growth and inflation: $\Delta\square = \Delta log\square - \Delta\square\square\square P$. The Bank of Tanzania‟s reserve-money program combines an inflation target ($\Delta\square\square\square P_{\square+1} = \pi$) with a projection for real growth $\Delta\square_{\square+1} = \Delta\square$, to yield an inflation-consistent growth rate for nominal money:

$$\Delta m_{t+1} = \Delta y + \pi - \Delta v_{t+1}. \qquad (5)$$

The velocity forecast Δv_{t+1} therefore directly affects the programmed growth rate for M2.

Large forecast errors are potentially costly. Too high a projection for Δv implies a tighter policy stance than intended: failure to accommodate a higher-than-anticipated money demand may drive inflation below target, while serving as a brake on real economic activity. Too loose a projection may feed inflation or asset price bubbles, with delayed adverse effects on the economy.

The Bank of Tanzania"s current approach relies on extrapolation of recent trends in velocity. This approach makes sense when velocity appears to be subject to relatively slow-moving trends: as indicated in Figure 8, velocity has been falling at an average of 5.25 percent per year for almost a decade. There is substantial short-run volatility around this average, however – the standard deviation of the year-on-year change is 6.1 percent.

In this section we briefly compare the Bank"s trend-extrapolation methods with alternative approaches based on the time-series behavior of velocity, including a VAR incorporating the determinants of money demand. We end by discussing how information from an econometric money demand equation can be used in a velocity-forecasting exercise. We proceed in two steps, first looking at the within-sample performance of alternative models and then considering their out-of sample forecasting properties. The first of these steps is diagnostic: it allows us to assess and discuss the properties of alternative models against the background of full information about the data.

Within-sample performance

The BoT"s approach is an example of a broader class of univariate forecasts that rely only on the past behavior of velocity. In what follows we compare a set of univariate approaches with a multivariate approach based on the variables in our money demand equation. We begin with a pair of univariate models that assume a locally deterministic path for velocity. With some oversimplification, these represent alternative formalizations of what the BoT does in practice.

(i) A *rolling trend estimator* assumes that velocity will return, next quarter, to the seasonally-adjusted trend line it has followed over the recent past. For purposes of comparison, we use a 3-year window. The rolling trend estimator for period *t* is therefore the one-period-ahead extrapolation of a linear trend estimated over quarters *t*−13 to *t*−1, with seasonal dummy variables included.

(ii) A *moving average growth estimator* extrapolates the growth rate of velocity, rather than its level. A velocity forecast of this type features prominently in the „McCallum rule" for base money growth (McCallum 1988). Maintaining our 3-year window, we compute the moving average growth estimator for quarter *t* as the value of velocity in quarter *t*−4, plus the average year-on-year growth in velocity over quarters *t*−13 to *t*−1.

We also consider a pair of univariate models that treat the trend in velocity as stochastic.

(iii) A simple *random walk with drift* (and deterministic seasonal effects) takes the form

$$\Delta v_t = \alpha + \sum_{s=1}^{3} \beta_s D_s + \varepsilon_t. \qquad (6)$$

where the parameters are estimated over the full sample. This model has the well-known property that the best estimate of velocity next period is its value this period (after accounting for the estimated drift and seasonal determinants of velocity).

(iv) A random walk with drift is a special case of a more general set of I(1) models of which the stationary part may exhibit a combination of autoregressive and/or moving average components. The Box-Jenkins method provides a set of guidelines for identifying a *parsimonious ARIMA model* that „best" exploits the observed autocorrelations and partial autocorrelations of a given time series. Estimating over the period since 1998q1, we selected an ARIMA(1,1,2) model with deterministic seasonal factors. This model takes the form:

$$\Delta \square_{\square} = \square_0 + \square_1 \Delta \square_{\square-1} + \sum_{\square=1}^{3} \square_{\square} \square_{\square} + \square_{\square} + \theta_1 \square_{\square-1} + \theta_2 \square_{\square-2} . \qquad (7)$$

Univariate forecasting models employ only the history of velocity itself. Our money demand equation, however, suggests a natural multivariate alternative. Using ***r*** to denote the non-income determinants of the demand for money, equation (3) can be written as

$$\begin{aligned} \Delta \square_{\square} &= \square_0 + \square_1 \Delta \square_{\square-1} - \square \left(\square_{\square-1} - \square_1 \square_{\square-1} - \square_2 \boldsymbol{r}'_{t-1} \right) + \\ & \square_2 \Delta \square_{\square} + \square_3 \Delta \square_{\square-1} + \square_4 \Delta \boldsymbol{r}'_{t-1} + \square_5 \Delta \boldsymbol{r}'_{t-1} + \square(\square), \end{aligned} \qquad (8)$$

where for simplicity we have imposed a lag order of $p = 1$. Using the definition $\square_{\square} = \square_{\square} - \square_{\square}$, equation (8) implies the velocity equation

$$\begin{aligned} \Delta \square_{\square} &= -\square_0 + \square_1 \Delta \square_{\square-1} - \square \left(\square_{\square-1} - (1 - \square_1) \square_{\square-1} + \square_2 \boldsymbol{r}'_{t-1} \right) + \\ & (1 - \square_2) \Delta \square_{\square} - (\square_1 + \square_3) \Delta \square_{\square-1} - \square_4 \Delta \boldsymbol{r}'_{t-1} - \square_5 \Delta \boldsymbol{r}'_{t-1} - \square(\square) . \end{aligned} \qquad (9)$$

Equation (9) can in turn be rewritten as a distributed lag model in which the level of velocity depends on its own lags and on the current and lagged levels of the determinants of money demand In effect, we can think of (9) as the first row in the structural simultaneous equations system

$$\square \square_{\boldsymbol{t}} = \square(\square) \square_{\boldsymbol{t-1}} + \boldsymbol{\varphi}_{\boldsymbol{t}}, \qquad (10)$$

where the vector $\square_{\boldsymbol{t}} = (\square_{\square}, \square_{\square}, \boldsymbol{r}'_t)'$ includes velocity and the determinants of money demand discussed above, and $\boldsymbol{\varphi}$ is a vector of structural disturbances.

Equation (10) is a structural simultaneous equations model, but as long as *B* is invertible it will have a reduced-form VAR representation of the form

$$\Box_{t} = \Box \; \Box \; \Box_{t-1} + \boldsymbol{\vartheta}_{t}, \qquad (11)$$

where $\Box \; \Box \; = \Box^{-1}\Box(\Box)$ and $\vartheta_{\Box} = \Box^{-1}\varphi_{\Box}$. Equation (11) is stochastically balanced, and therefore can be estimated consistently in levels, as long as each I(1) variable in the VAR is cointegrated with at least one other I(1) variable in the VAR – a condition our cointegration analysis has established. The estimated VAR provides a basis for multivariate forecasting of velocity – or, for that matter, of any element of the vector $\Box_{t}$. It constitutes our final forecasting model.

Table 7 and Figures 9a and 9b compare the within-sample properties of the four univariate approaches and the VAR.[10] We report two standard measures, the root mean square error (RMSE) and the mean absolute error (MAE).[11] Amongst the univariate models, the time-series models systematically out-perform those that treat the trend as locally deterministic. All models will fail to predict turning points in the data, but short-lag time-series based models will „get back on track" more rapidly than deterministic-trend models (this difference will increase the longer the time-span used to estimate the local trend).

Figure 9b, which compares the goodness of fit of the preferred ARIMA model – the best-fitting univariate model of velocity – with that of the VAR model, clearly shows the substantial gains to conditioning the estimate of velocity on the full set of determinants of money demand. Prediction errors are generally smaller and shorter-lived. This increase in predictive accuracy is direct reflected in Table 7 where the root mean square error of the VAR forecast is less than half that of the rolling trend (from 5.3percent per quarter to 2.4 percent per quarter) and more than one percentage point per quarter lower than the „best fitting" univariate ARIMA model.

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[10] By construction, the rolling trend and McCallum rule forecasts differ from the time series model in one important sense. By construction, for the former the forecast at time *t* is based only on information up to time *t-1*. This contrasts with the time-series models where the predictive performance of the model at time *t* is conditional on data up to time *t-1* but the parameters of the models are estimated on data for the whole sample *t= 1...T.* This distinction disappears when we compare out-of-sample forecast performance.

[11] The RMSE is the most commonly used measure, having the property that it is measured in the same units as the dependent variable itself. The MAE is similarly measured. The RMSE is, however, more sensitive than the MAE to outlier errors: the squaring process gives disproportionate weight to very large errors. Hence if the cost of an error is roughly proportional to the size of the error, not the square of the error, then the MAE may be a more relevant criterion. Generally, however, these statistics will vary in unison.

Out-of-sample forecasting

Next we compare the out-of-sample forecast performance of the same set of models. We estimate each model over the sample period to 2006q4 and compute summary measures of forecast performance over the period from 2007q1 to 2008q4, reporting both one-step-ahead and, for the three time series models, dynamic 8-step-ahead forecasts for the period 2007q1 to 2008q4.[12]

Table 8 reports the forecast statistics which serve to reinforce the within-sample evidence. In terms of one-step-ahead forecast performance, the time-series models again dominate the deterministic-trend models while the velocity forecast from the VAR model again exhibits a substantially lower forecast error than any of the univariate measures. Conditioning on the determinants of money demand clearly and decisively enhances forecast performance. This is so for both the one-step and multistep forecast even though the latter are necessarily higher. Figure 10 illustrates the one-step-ahead forecast error for three representative measures (the rolling trend, the ARIMA and the VAR model). All three models initially under-predict velocity in the first two quarters of 2007 and over-predict throughout the remainder of 2007 and into 2008, although the VAR again shows lower deviation and more rapid error correction. Finally, Figures 11 plots the multi-step forecast for velocity, estimated from the VAR, against the actual path of velocity, illustrating the systematic over-prediction of velocity throughout late 2007 and 2008.

7. Conclusions and Implications for Monetary Policy

We have identified a well-behaved dynamic demand function for M2 in Tanzania for the period from 1998 to the present and have shown how this model can be used to enhance the forecasting of velocity. Real income growth and structural change continue to

[12] A one-step-ahead forecast is generated by estimating the model on data up to period t and forecasting the outcome for $t+1$ The estimate for $t+2$ is obtained by using the same model but computing the forecast conditional on the actual data up to $t+1$. By contrast, an h-period-ahead forecast computes each successive forecast period from $t+1$ to $t+8$ without updating the data beyond that available at time t. Thus, in this case, the estimate for $t+2$ is obtained using the data up to period t and the forecast *made at time t* of the value of the data at $t+1$. Forecast errors are therefore cumulated as the horizon is extended.

generate a strong underlying trend of financial deepening, and by separating these two effects our results shed light on the high and variable income elasticities that have been a feature of the Tanzanian literature. Conventional opportunity cost effects are present, but as in the earlier literature they appear to be dominated by substitution between domestic-currency and foreign–currency assets, and between money and inflation hedges. Disaggregating currency and deposits, we find that currency responds more strongly to expected inflation, and deposits to the interest-rate spread vis-à-vis T-bills, than does overall M2.

While our results go some way towards resolving the puzzle of persistently declining velocity during the disinflation of 1995-99, our empirical models deteriorate markedly when the four years 1994q1-1997q4 are included in the sample. Further work may well improve our account of this period, but for operational purposes our view is that the BoT should base its statistical work on the later period.

A variety of extensions are of high priority. The first is to complement – or replace – our single-equation analysis with a multivariate approach that allows an orderly treatment of exogeneity issues and multiple long-run relationships. It remains to be seen whether our short sample will support such an approach, but some of the most important policy questions have to do with system-wide dynamics. For example, we have shown clearly that expected inflation affects money demand; for policy purposes, the urgent question is whether monetary disequilibrium affects future inflation. An integrated treatment of money and inflation dynamics would be of considerable value.

A second extension is to apply the methods of this paper to M3. Kessy (2008) finds considerable evidence of substitution within M3, and our results are consistent with this. Understanding the behavior of overall M3 may be of considerable value, particularly in advance of capital account is liberalization.

Velocity forecasts play a central role in the BoT"s monetary policy framework, as they do throughout much of Sub-Saharan Africa. We have shown, not surprisingly, that a vector auto-regression model, based on our structural money demand equation, substantially out-performs a variety of univariate approaches, both within-sample and over a short out-of-sample horizon. Thus, for short-term forecasting purposes, the existence of a stable cointegrating relationship between real money balances – or velocity

-and the determinants of money demand suggests that VAR-based forecasts, based on the most up-to-date data, may have substantial value in program formulation, as a complement to judgment and a check on simple univariate extrapolation.

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Tables and Figures

Table 1. Principal components analysis, 1994q1-2008q4
Number of observations: 59
Number of components: 5

1. Principal components

Component	*Eigenvalue*	*Difference*	*Proportion*	*Cumulative*
Comp1	3.6546	2.8040	0.7309	0.7309
Comp2	0.8505	0.4151	0.1701	0.9010
Comp3	0.4354	0.4026	0.0871	0.9881
Comp4	0.0329	0.0063	0.0066	0.9947
Comp5	0.0266	.	0.0053	1.0000

2. Weights in first principal component, and descriptive statistics

Variable	*Weights*	*Mean*	*Std. Dev.*	*Min*	*Max*
gwssh	0.4233	0.0398	0.0060	0.0342	0.0562
ytishr	0.4096	0.3778	0.0186	0.3480	0.4123
dcpm3	0.4738	0.3541	0.1118	0.1482	0.5802
gfcfgdp_di	0.5002	0.1927	0.0317	0.1492	0.2516
impgdp_di	0.4224	0.2759	0.0629	0.2065	0.3826

Notes: "Weights" is the eigenvector that constitutes the first principal component. See Appendix 3 for definitions and sources of variables.

Table 2. Long-run static regressions, M2
Dependent variable: l_m2r

Variable	1994q1-2008q4		1998q1-2008q4	
	(1)	(2)	(3)	(4)
l_rgne	0.6809		1.1111	
	7.53		7.49	
l_rgdp		0.863		1.0169
		12.14		8.22
spreada	0.0641	0.1194	-0.2734	0.0176
	0.31	0.61	-1.01	0.08
l_infq	-0.1543	0.2516	-0.783	-0.3383
	-0.24	0.46	-1.67	-0.92
l_depfa	-0.5252	-0.4707	-0.2415	-0.2713
	-4.55	-4.14	-2.14	-3.23
struc_pc1	0.0957	0.0896	0.0607	0.0841
	7.61	10.06	3.66	6.68
sq1	-0.0269	-0.0155	0.0015	0.0066
	-1.29	-0.91	0.06	0.38
sq2	-0.0357	-0.0064	-0.0446	-0.0084
	-1.48	-0.32	-1.99	-0.46
sq3	0.0018	0.0402	-0.0009	0.0274
	0.06	1.90	-0.04	2.15
N	59	59	44	44
rmse	0.06199	0.05062	0.047	0.03727
aic	-152.5	-176.4	-136.3	-156.7
bic	-133.8	-157.7	-120.2	-140.6
ll	85.23	97.18	77.13	87.35
DF t-stat	-3.961	-5.08	-4.198	-3.944
5% crit. val	-3.43	-3.43	-3.43	-3.43

Notes: Robust t-statistics are below estimated coefficients. See Appendix 3 for definitions and sources of variables.

Table 3. Dynamic ECM regressions, M2
Dependent variable: D.l_m2r

Variable	94q1-08q4	1998q1-2008q4	
	(1)	(2)	(3)
L.equi_err	-0.3405	-0.3324	-0.3294
	-2.88	-2.52	-3.28
LD.l_m2r	0.3398	0.3103	0.3039
	2.82	1.58	1.70
D.l_rgdp	0.126	0.4317	0.4355
	1.03	2.29	3.00
LD.l_rgdp	-0.1616	-0.0084	
	-1.33	-0.08	
D.spreada	0.0631	-0.0719	
	0.64	-0.27	
LD.spreada	-0.0047	0.1086	
	-0.04	0.51	
D2.spreada			-0.0862
			-0.58
D.l_infq	-0.3235	-0.5002	-0.5087
	-1.2	-1.84	-2.71
LD.l_infq	0.0818	0.0191	
	0.37	0.10	
D.l_depfa	-0.0533	-0.0862	-0.0847
	-0.83	-1.66	-1.87
LD.l_depfa	0.1836	0.0084	
	1.93	0.06	
sq1	-0.0322	-0.0145	-0.0147
	-2.22	-0.86	-1.06
sq2	0.018	0.0102	0.0095
	1.32	0.46	0.50
sq3	0.0322	0.0432	0.0424
	2.12	2.4	2.62
N	58	42	42
Rmse	0.02895	0.02525	0.02364
Aic	-234.3	-178.9	-186.8
Bic	-205.5	-154.5	-169.4
Ll	131.2	103.4	103.4
P-values			
Res normality	0.05	0.001	0.001
BP Het	0.038	0.008	0.009
BG Auto lag1	0.45	0.878	0.997
lag2	0.016	0.281	0.367
lag3	0.014	0.106	0.166
lag4	0.009	0.181	0.271

Note: l.equi_err is the lagged equilibrium error from the static regression in column 2 or 4 of Table 2.

Table 4. Long-run static regressions, Currency and Deposits
Dependent variable: l_cur or _depr

	Currency		Deposits	
Variable	94q1-08q4	98q1-08q4	94q1-08q4	98q1-08q4
	(1)	(2)	(3)	(4)
l_rgdp	0.5247	0.5636	0.9734	1.2427
	7.03	3.57	13.15	9.45
spreada			-0.0789	-0.3198
			-0.43	-1.23
l_infq	-0.3122	-0.9283	0.4406	-0.1385
	-0.47	-2.39	0.77	-0.32
l_depfa	-0.4778	-0.096	-0.4193	-0.3028
	-3.15	-0.76	-3.47	-2.94
struc_pc1	0.0831	0.0935	0.1008	0.0822
	9.46	5.81	11.25	6.44
sq1	-0.0893	-0.0688	0.0192	0.043
	-4.36	-3.29	0.95	1.98
sq2	-0.0714	-0.0606	0.0184	0.0137
	-2.79	-2.67	0.88	0.66
sq3	-0.0063	-0.0124	0.0594	0.0465
	-0.23	-0.54	2.64	2.84
N	59	44	59	44
rmse	0.06168	0.04703	0.05536	0.04333
aic	-153.9	-137	-165.8	-143.4
bic	-137.3	-122.7	-147.1	-127.4
ll	84.94	76.49	91.9	80.71
DF t-stat	-4.049	-3.995	-5.245	-4.274
5% crit. val	-3.43	-3.43	-3.43	-3.43

Notes: Robust t-statistics are below estimated coefficients. See Appendix 3 for definitions and sources of variables.

Table 5. Dynamic ECM regressions, Currency
Dependent variable: D.l_cur

Variable	94q1-08q4	1998q1-2008q4	
	(1)	(2)	(3)
L.equi_err	-0.3942	-0.4971	-0.5196
	-3.31	-2.71	-3.12
LD.l_cur	0.1872	0.2184	0.2192
	1.37	1.11	1.43
D.l_rgdp	0.2399	0.4336	0.4432
	2.06	1.71	1.76
LD.l_rgdp	-0.1359	0.0676	
	-1.31	0.35	
D.l_ifwd2a	-2.1789	-7.5882	-5.5459
	-1.87	-1.78	-1.82
LD.l_ifwd2a	2.0943	3.1821	
	1.48	0.77	
D.l_infq	-0.6995	-0.97	-0.8423
	-2.06	-2.46	-2.88
LD.l_infq	-0.1824	-0.198	
	-0.57	-0.56	
D.l_depfa	-0.1246	-0.1309	
	-1.44	-1.14	
LD.l_depfa	0.3162	0.2672	
	2.00	1.07	
D2.l_depfa			-0.1956
			-1.59
sq1	-0.1029	-0.0856	-0.0848
	-5.92	-2.88	-3.07
sq2	0.0153	0.0202	0.0267
	0.48	0.57	0.77
sq3	0.0403	0.026	0.0367
	2.13	1.00	1.78
N	58	42	42
Rmse	0.03878	0.0409	0.03898
Aic	-200.4	-138.3	-144.8
Bic	-171.6	-114	-127.4
Ll	114.2	83.17	82.39
P-values			
Res normality	0.576	0.516	0.647
BP Het	0.811	0.955	0.766
BG Auto lag1	0.096	0.131	0.25
lag2	0.233	0.071	0.06
lag3	0.391	0.135	0.124
lag4	0.091	0.196	0.201

Note: l.equi_err is the lagged equilibrium error from the static regression in column 1 or 2 of Table 3.

Table 6. Dynamic ECM regressions, Deposits
Dependent variable: D.l_depr

Variable	94q1-08q4 (1)	1998q1-2008q4 (2)	(3)
L.equi_err	-0.3343	-0.2714	-0.3196
	-2.59	-2.20	-3.55
LD.l_depsr	0.4298	0.2856	0.3074
	3.86	1.98	2.31
D.l_rgdp	0.0948	0.3906	0.4168
	0.70	2.21	3.26
LD.l_rgdp	-0.1463	0.0235	
	-1.09	0.15	
D.spreada	-0.0391	-0.2947	-0.2747
	-0.34	-1.02	-1.32
LD.spreada	0.0695	0.2656	
	0.56	1.69	
D.l_infq	-0.2924	-0.4104	-0.4302
	-1.13	-1.50	-2.07
LD.l_infq	0.0192	0.0073	
	0.09	0.04	
D.l_depfa	-0.0322	-0.0713	-0.0718
	-0.41	-1.12	-1.14
LD.l_depfa	0.1338	-0.0892	
	1.08	-0.53	
sq1	0.0092	0.0158	0.019
	0.61	1.11	1.49
sq2	0.0067	-0.0057	-0.0099
	0.53	-0.33	-0.79
sq3	0.0308	0.0417	0.0382
	1.95	2.49	2.62
N	58	42	42
Rmse	0.03289	0.02746	0.0263
Aic	-219.5	-171.8	-177.8
Bic	-190.7	-147.5	-160.5
Ll	123.8	99.91	98.92
P-values			
Res normality	0.027	0.001	0.001
BP Het	0.765	0.977	0.929
BG Auto lag1	0.817	0.19	0.768
lag2	0.028	0.222	0.142
lag3	0.016	0.084	0.083
lag4	0.009	0.109	0.139

Note: l.equi_err is the lagged equilibrium error from the static regression in column 3 or 4 of Table 3.

Table 7. Velocity: within-sample predictive performance
Sample 2002q1 to 2008q4

Model (dependent variable log velocity)	RMSE (% per quarter)	MAE (% per quarter)
Rolling Trend	5.26	4.47
Seasonal Moving Average	6.66	5.16
Random walk with seasonals	4.09	3.13
SARIMA (1,1,2,4)	3.61	2.92
VAR (2)	2.42	1.70

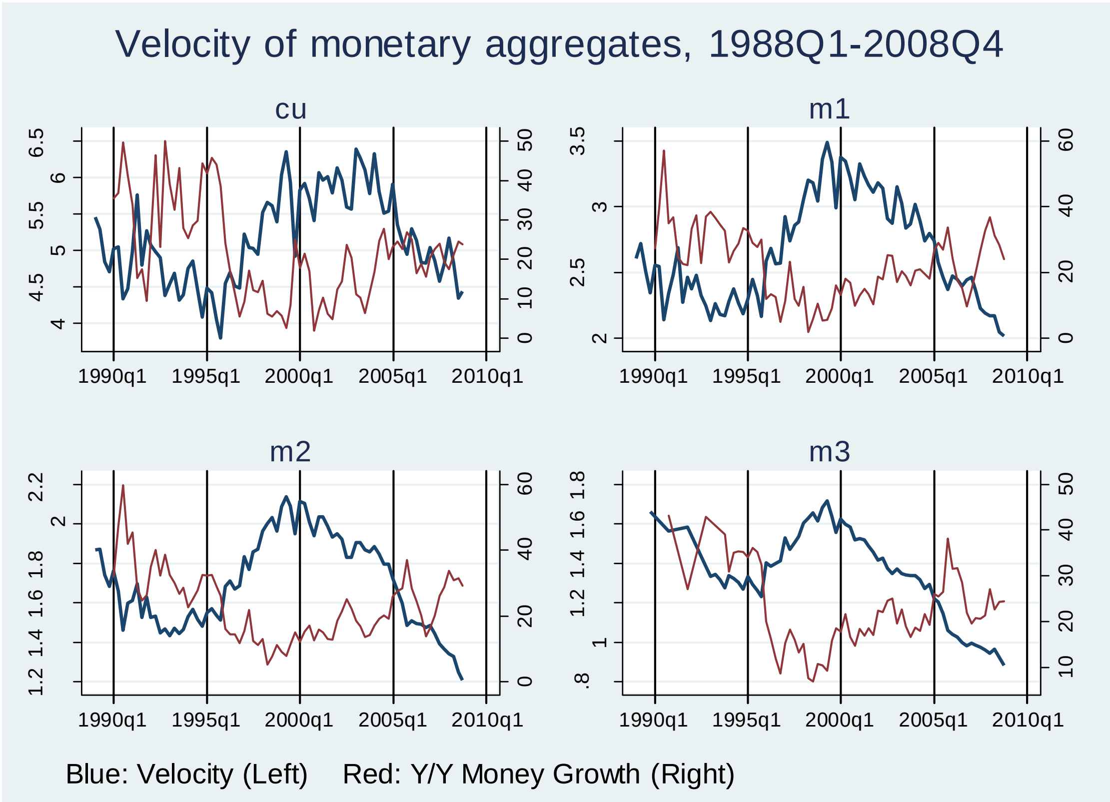
Notes: Measures indicate the accuracy of the within-sample predictive power of the model, where for each model the prediction error is □ □ = [□ □ − □(□)]. RMSE is the root mean square error; MAE the mean absolute error. SARIMA denotes seasonal autoregressive integrated moving average of order p=1, d=1, q=2 and s=4 where *p* denotes the autoregressive order, *d* the order of integration, *q* the moving average error order and *s* the number of deterministic seasonal dummy variables. VAR(2) denotes vector auto-regression with two lags on each variable (plus deterministic seasonal dummy variables).

Table 8. Velocity: out-of-sample forecast performance
Estimation Sample 1998q1 to 2006q4
Forecast Sample 2007q1 to 2008q4

Model (dependent variable log velocity)	1-step-ahead forecast (% per quarter)		8-step-ahead forecast (% per quarter)	
	RMSE	MAE	RMSE	MAE
Rolling Trend	6.04	5.61	-	-
Seasonal Moving Average	7.67	6.99	-	-
Random walk w/ seasonals	3.76	3.20	7.45	6.95
SARIMA (1,1,2,4)	4.05	3.05	7.31	6.86
VAR (2)	2.51	2.11	5.13	4.54

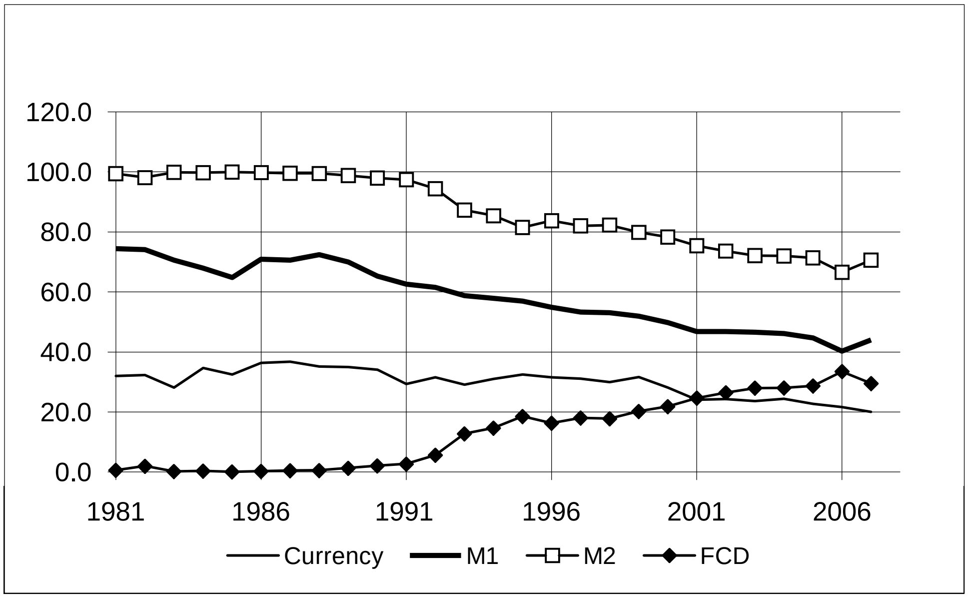
Notes: See Table 7 and text.

Figure 1. Velocity of monetary aggregates, 1988q1-2008q4



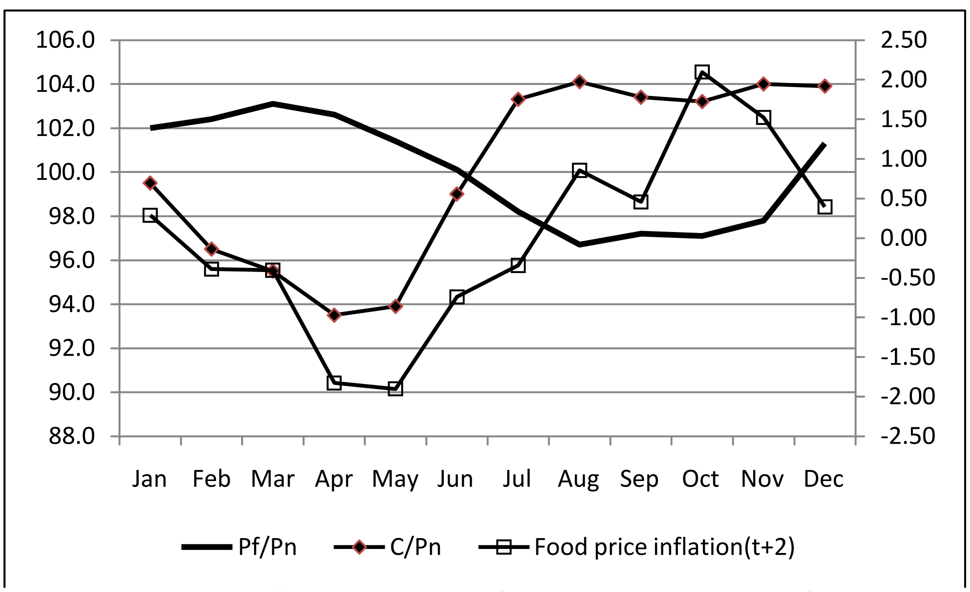
Source: Bank of Tanzania

Figure 2. Composition of M3



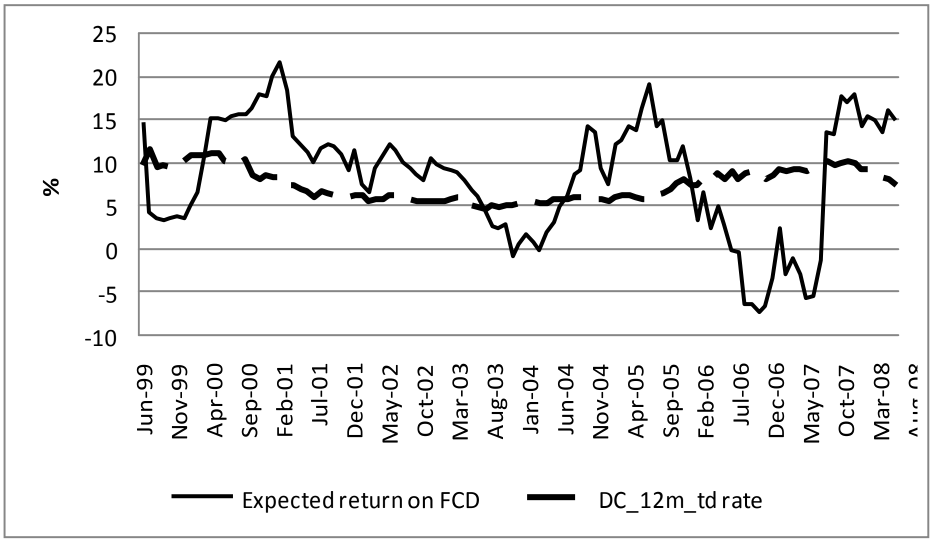
Source: Bank of Tanzania

Figure 3. Currency and food price seasonals



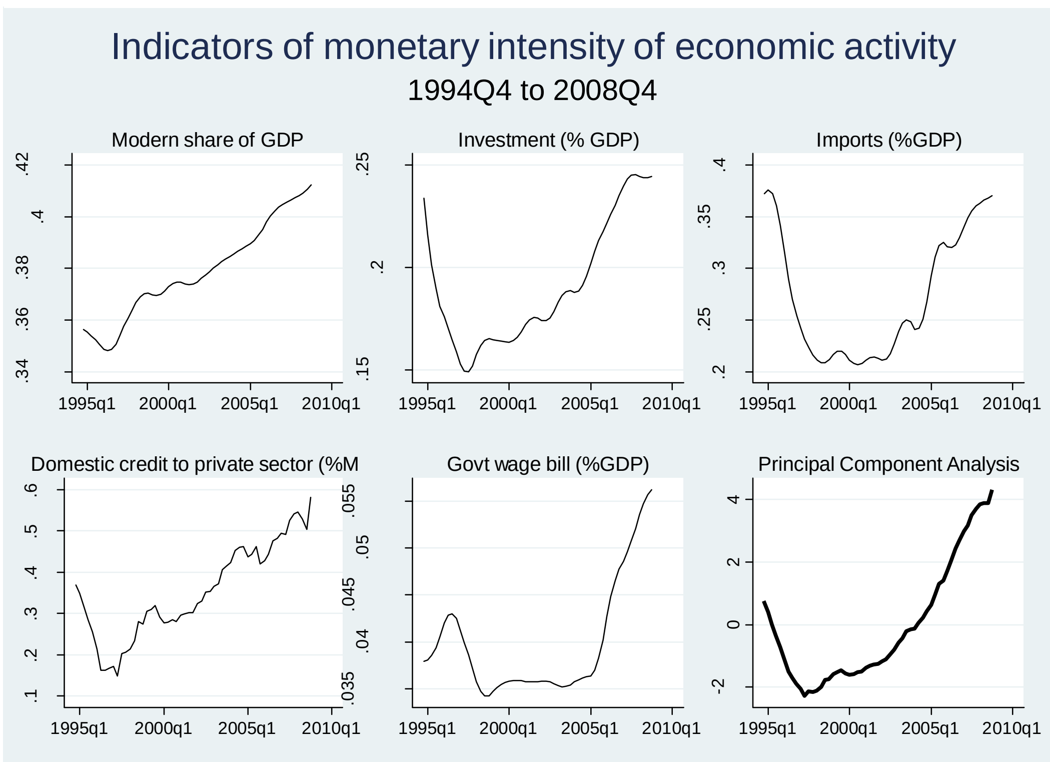
Source: NBS and Bank of Tanzania. Data are from 2001m1 to 2008m12. Pf and Pn are the food and non-food consumer price indexes, and C is currency held outside the banking system. Seasonal factors are multiplicative for C/Pf and Pf/Pn and additive moving-average for food price inflation.

Figure 4. *Ex post* yields on domestic and foreign currency deposits



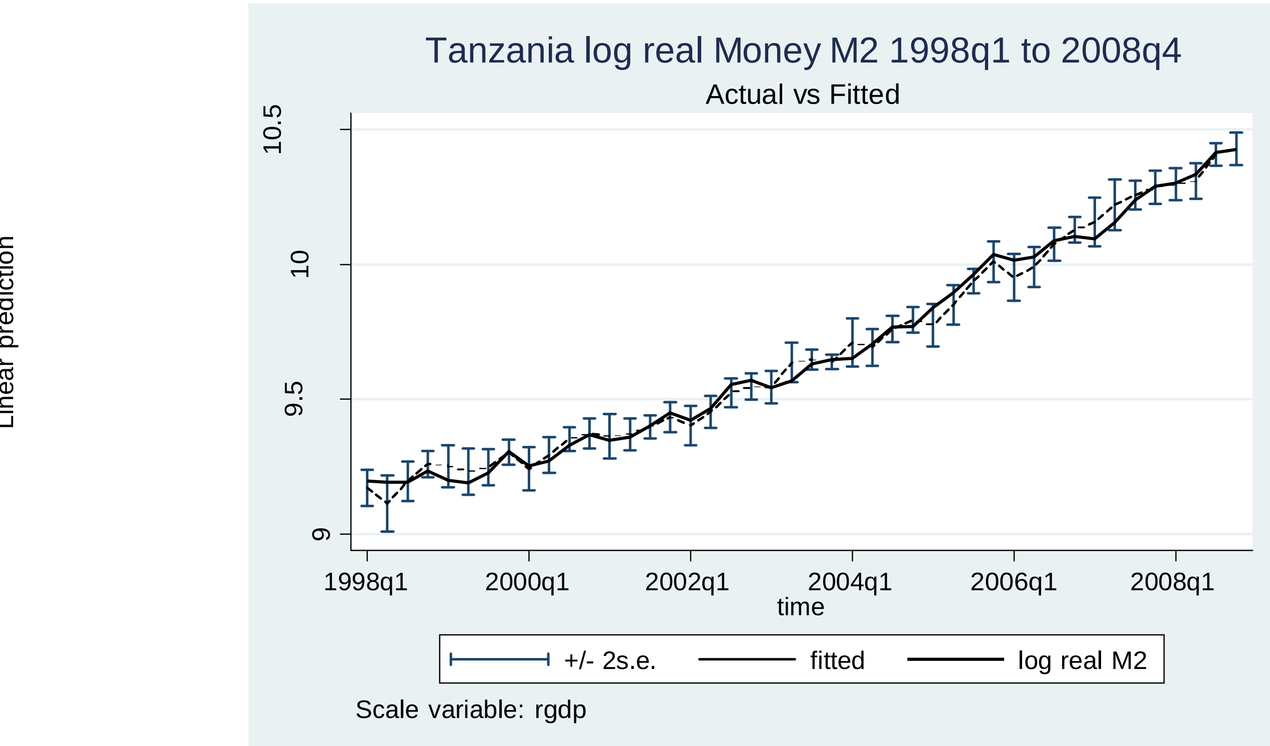
Source: Bank of Tanzania

Figure 5. Structural Change and the Monetary Intensity of Economic Activity.



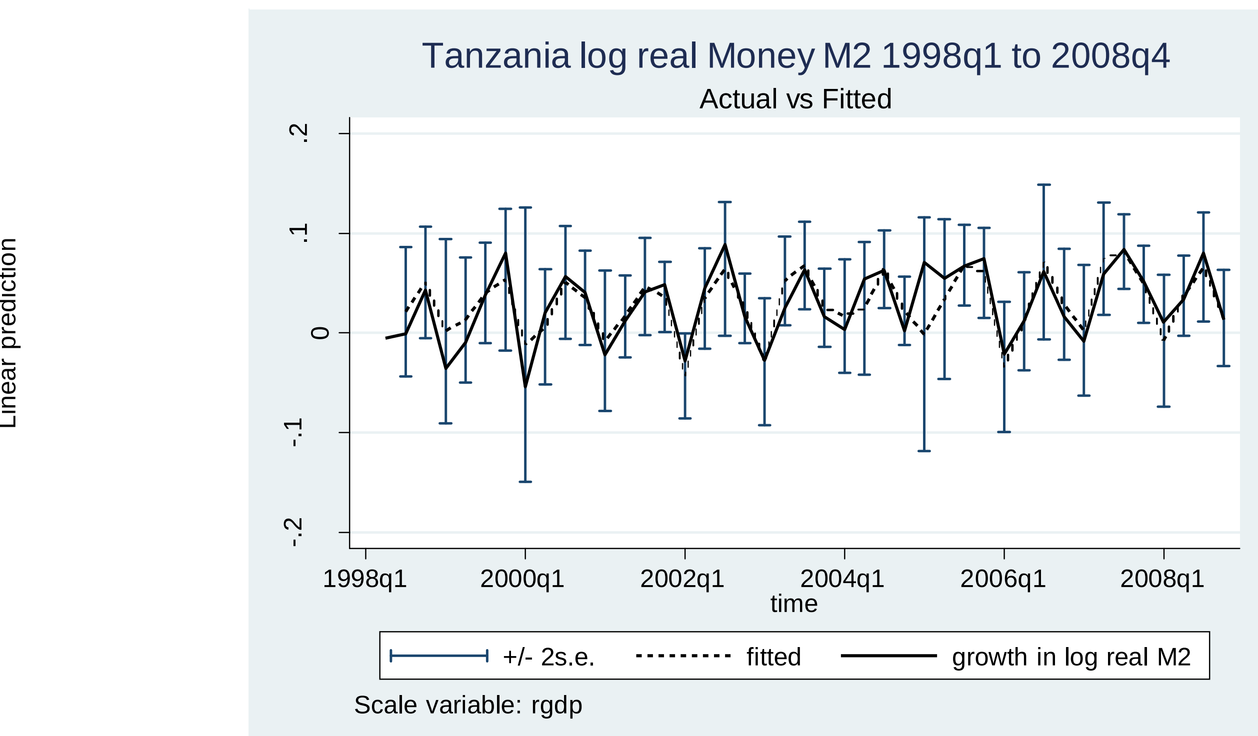
Note: See Table 1 for details on the principal components calculation.

Figure 6. Long-run equilibrium: actual and fitted values



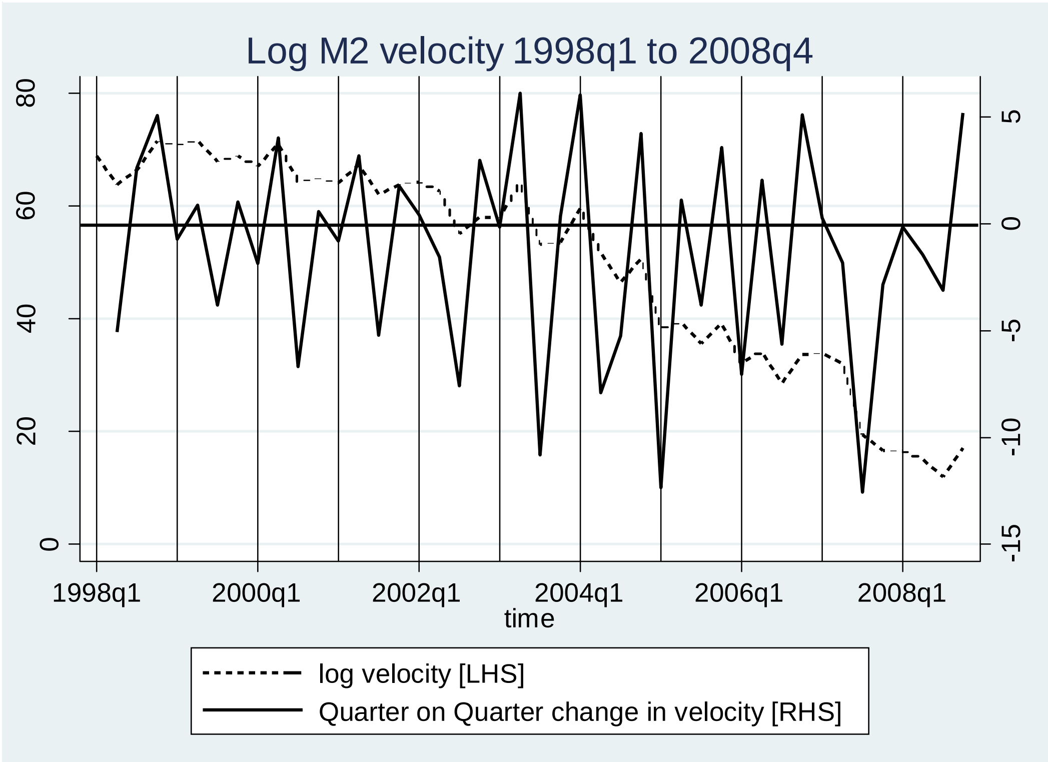
Source: Column 4 of Table 2.

Figure 7. Short-run dynamics: actual and fitted values



Source: Column 3 of Table 3.

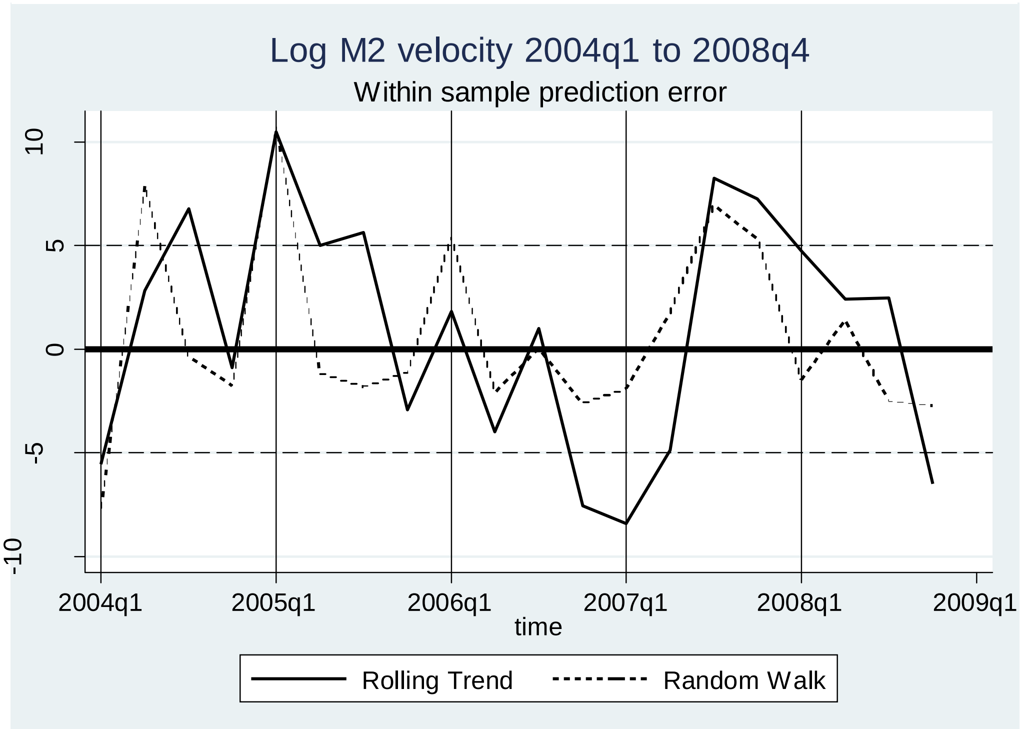
Figure 8. Time-series forecasts of M2 velocity



Source: Bank of Tanzania.

Figure 9. Velocity forecasting models: within-sample performance

(a) Rolling trend forecaster vs random walk



(b) ARIMA versus VAR

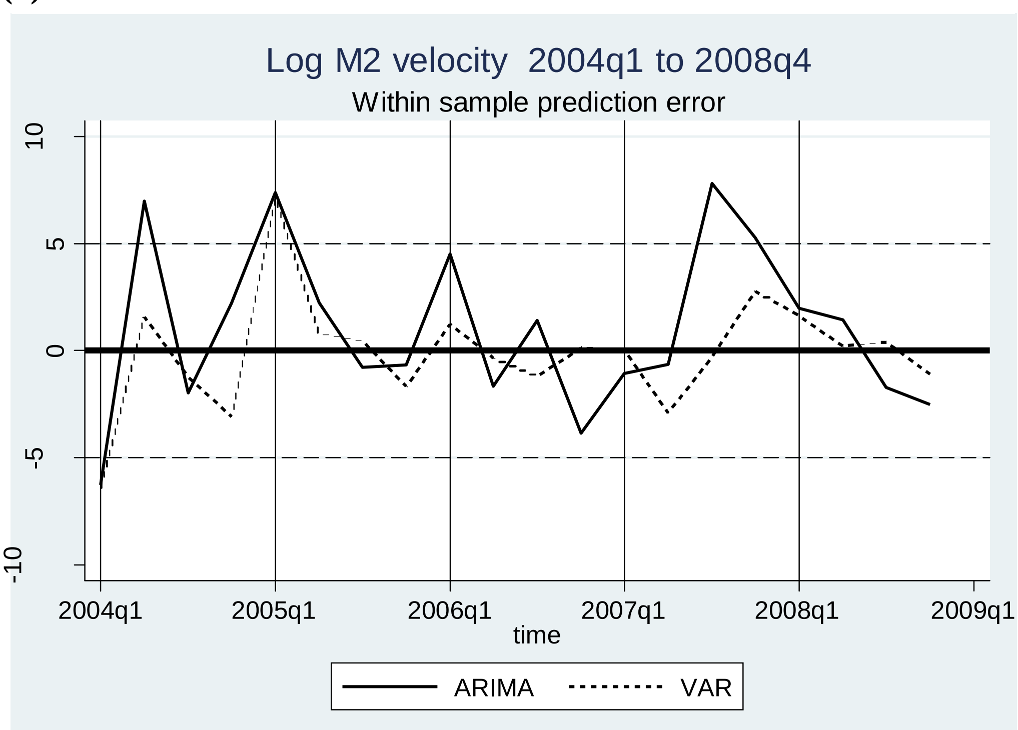


Figure 10. One-step-ahead forecast error from alternative forecast models

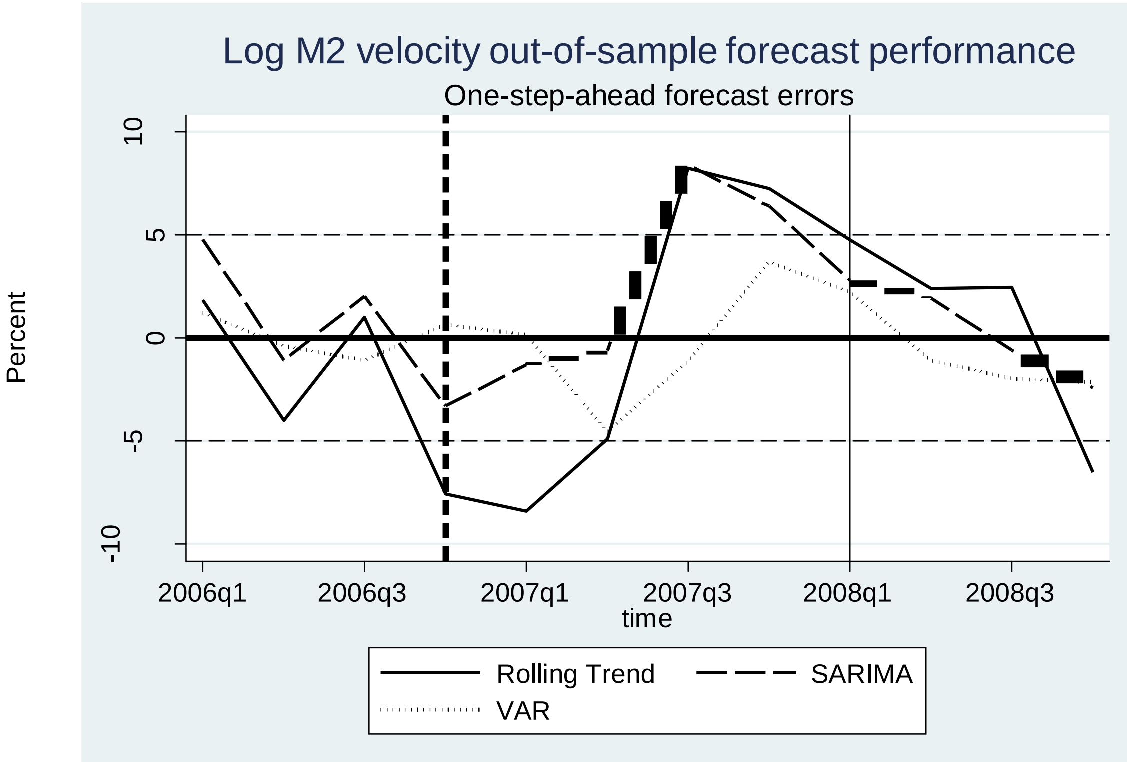
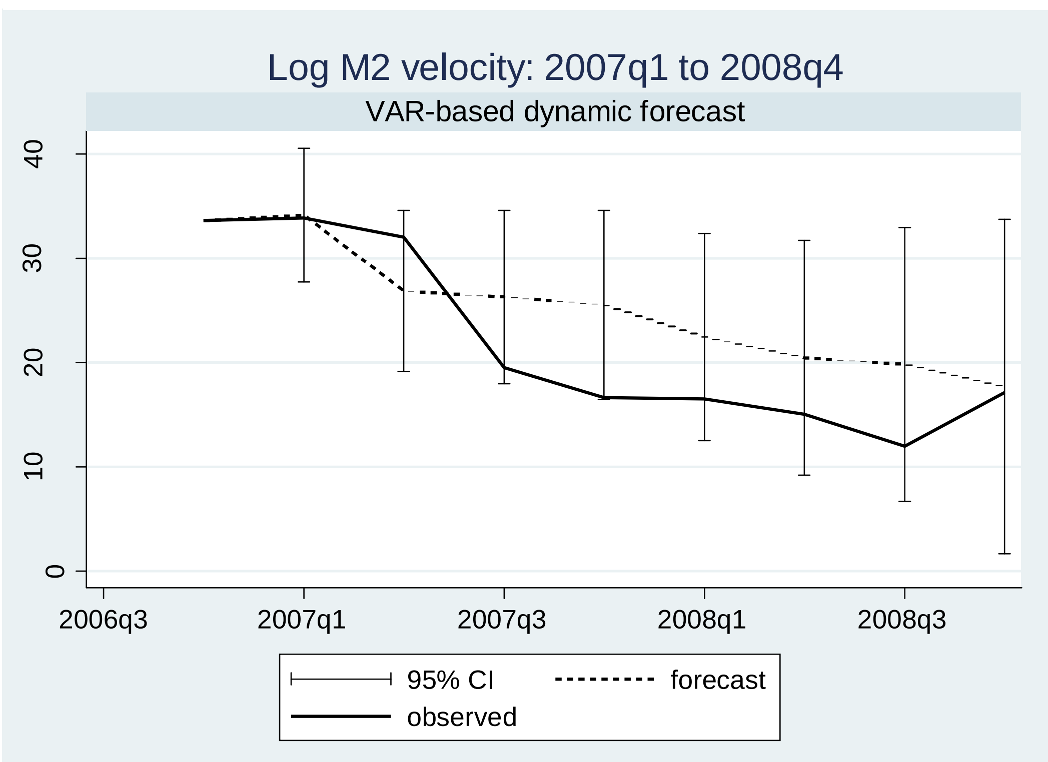


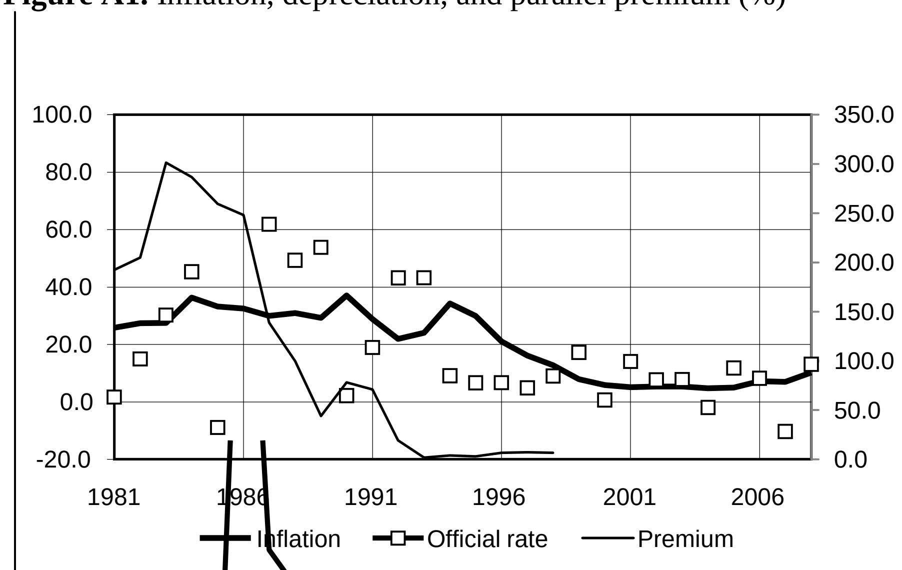
Figure 11. Actual velocity versus 8-step ahead VAR-based forecast



Appendix 1. Macroeconomic Developments, 1966-95

The Tanzanian shilling was introduced in 1966 in the context of a fixed exchange rate regime. With the Arusha Declaration in 1967, Tanzania embarked on a socialist path that gave the National Bank of Commerce, a state-owned enterprise, a near-monopoly over the commercial banking sector and produced rapid growth in other parts of the public sector. In a context of emerging macroeconomic imbalances and inflationary pressures, the first oil shock (1973/74) produced a balance of payments crisis. Reluctant to devalue the exchange rate, the BOT responded by tightening exchange controls, which led to the emergence of a substantial parallel market for foreign exchange (Figure A1). As inflationary pressures continued during the 1970s the government responded with administrative measures, imposing a broadening array of price controls on widely-consumed items.

Figure A1. Inflation, depreciation, and parallel premium (%)



The 1976/77 coffee boom provided temporary relief from macroeconomic imbalances, but at the end of the 1970s a set of macroeconomic shocks – the end of the coffee boom, the onset of the second global oil crisis (1978/79), and the financing of a war with Uganda – produced a loss of fiscal control and a renewed balance of payments crisis. Fiscal imbalances were monetized – broad money grew by 38 percent in 1979 alone – and excess demand pressures led to a further tightening of controls on foreign exchange allocation and domestic prices. The combination proved unsustainable, more so following the global debt crisis of 1982 and a souring of relations between the government of Tanzania and its major donors. Economic growth virtually stopped in the late 1970s, averaging 0.8 percent between 1977 and 1983 and turning sharply negative in per-capita terms, amid a general deterioration of social services.[13]

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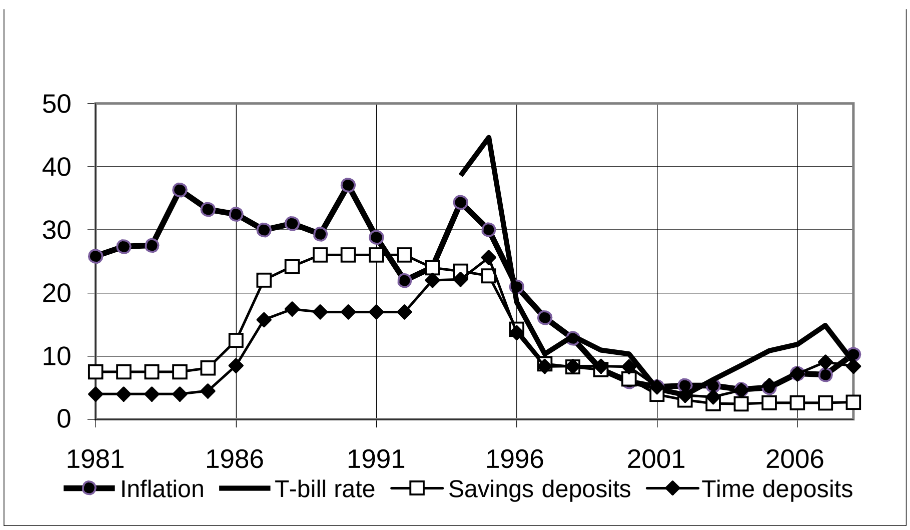
[13] The official economy shrank rapidly during the early 1980s as economic agents responded to scarcity by diverting dwindling supplies of goods and foreign exchange onto parallel markets. The macroeconomics of the control period 1967-1985 have been studied extensively, including the implosion of the official

A maxi-devaluation in 1983, undertaken in the midst of deep macroeconomic difficulties, marked the beginning of what ultimately proved a decisive transition from direct controls to price-based mechanisms of macroeconomic adjustment in Tanzania. President Nyerere resigned in 1985, and in the following year the country embarked on a sequence of 3-year Economic Recovery Programmes (ERP I, 1986-89, and ERP II, 1989-92) with IMF and World Bank support. These were designed to convert an administratively controlled economy into one with market-determined prices and private ownership and control. Over the course of a decade, these reforms transformed the banking sector and the menu of financial assets available to Tanzanian households.

Financial Sector Reforms[14]

Financial sector reforms began in 1987 with interest-rate adjustments designed to move real interest rates into positive territory (Figure 1). The banking system nonetheless remained heavily repressed until the early 1990s. All financial institutions were fully owned by the government, and entry of private and foreign banks was prohibited. As late as 1993, there were only 3 banks in operation, one of which operated in Zanzibar; the National Bank of Commerce accounted for over 90 percent of deposits.[15] The government controlled interest rates and the exchange rate, and and allocated credit and foreign exchange administratively. The burden of non-performing loans reached 60 percent in 1992, reflecting poor accountability and an absence of prudential norms.

Figure A2. Inflation and interest rates



economy after 1980 due to shortages, rationing, and a monetary overhang. See Bevan *et al.* 1993 and O"Connell 1997.

[14] See Nyella (2003).

[15] National Bank of Commerce (NBC), Cooperative and Rural Development Bank (CRDB) and the People"s Bank of Zanzibar (PBZ). In July 1997, the NBC was split into two banks, the NBC and the National Microfinance Bank (NMB).

Following the Nyirabu Commission‟s report in 1990, the government undertook a sequence of reforms that transformed an insolvent nationalized monopoly banking system into an increasingly competitive sector dominated by foreign-owned banks (Cull and Spreng 2008). The process began with the entry of the first private foreign banks in 1992 and 1993 (they began operations in 1994) and the privatization of the Cooperative and Rural Development Bank (CRDB) in 1996. The dominant National Bank of Commerce (NBC) was recapitalized in successive efforts during the early and mid-1990s, and in 1997 the Government divided it into the new NBC, which inherited the bank‟s urban branches and its traditional urban- and trade-based lending business, and the National Microfinance Bank (NMB) which inherited the old NBC‟s network of rural branches and its mandate to provide banking services to rural populations. The new NBC was privatized in 2000, and the NMB went 0 to 49% private participation in 2005.

The introduction of competition transformed the quality, price, and availability of banking services in Tanzania, with potentially large impacts on the demand for bank liabilities. The evidence suggests substantial increases in bank profitability and efficiency. The restructuring process also appears to have restricted the access of households to financial services, however, at least initially and particularly in rural areas; the NBC retrenched 2,800 employees and closed 23 branches in 1994 alone. Successive household budget surveys show a sharp decrease during the 1990s in the proportion of households reporting a bank account – this number falls from 18.0 percent in the 1991/92 survey to 6.4 percent in 2000/01, before recovering to 10.0 percent in the 2007 survey.[16] But the Banking and Financial Institutions Act of 1991 authorized the entry of private and foreign banks, and in 1994 the first two (Standard Chartered and Meridien–BIAO, both foreign-owned) began operations. By the end of 2001, the total number of banks had reached 17; this number doubled again by 2009, with the majority of Tanzania‟s 34 banks foreign-owned., along with a possible reduction in access to financial services in rural areas, for example through the closure of branches when NBC was split (Cihak and Podpiera 2005). The rapid introduction of mobile banking and other technological innovations over the past 5 years or so has further transformed the menu of banking services available in Tanzania.

A set of contemporaneous reforms during the early 1990s converted a system of exchange controls and multiple exchange rates into one in which private residents were allowed to hold foreign currency and domestic foreign-currency deposits and exchange rates were determined in an inter-bank market. The Foreign Exchange Act of 1992 introduced privately-owned foreign exchange shops and allowed residents to hold foreign currency deposits for the first time. A weekly foreign exchange auction system was introduced by the BOT in 1993, with the official exchange rate determined by the marginal market clearing bid; as intended, this was replaced in June 1994 by the Inter-bank Foreign Exchange Market (IFEM).

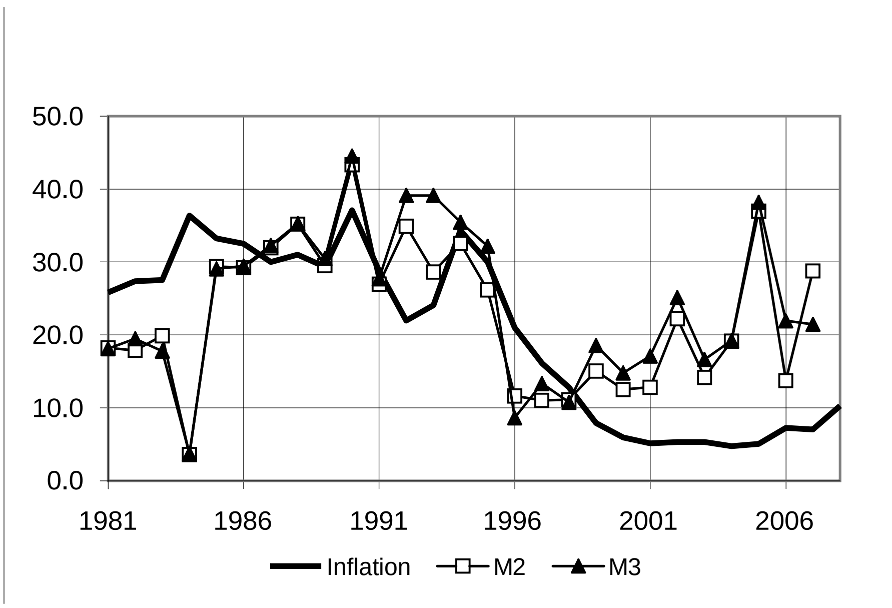
[16] It is likely that the proportion bottomed out in the mid- to late-1990s, as NBC was being restructured and new banks had not yet established a substantial foothold. Reductions in rural access may well have lasted longer, however. The National Microfinance Bank, which succeeded NBC and acquired most of NBC‟s rural branch network, remained in state hands until 2005, operating for most of the 1997-2005 period under a private consulting contract that focused on enhancing profitability, not on expansion of reach or services. See Cull and Spreng 2008.

Monetary and fiscal developments

The early 1990s saw a gradual shift from direct to indirect instruments of monetary control, facilitated by interest rate liberalization and the introduction of Treasury bill auctions in 1993. The ERPs emphasized macroeconomic stabilization and introduced annual money-growth targets as a means of inflation control. Inflation remained persistently high, however, as fiscal pressures drove money growth rates well above program targets (Figure 1). Thus M2 growth averaged 32.4 percent during the reform period, as against the target range of 10 to 17 percent, the difference largely reflecting government borrowing to finance crop authorities and cooperative unions (Ndanshau 1996).

Monetary accommodation continued over the five-year period following the 1990 general elections. In a context of expansionary fiscal policy, the growth rate of extended broad money averaged 36.3 percent and inflation averaged nearly 30 percent (Figure 2). By 1994/95, sharply rising interest costs had convinced the policy authorities that fiscal adjustment was essential for macroeconomic stabilization (Rashidi, 1997).

Figure A3. Inflation and money growth



The conduct of monetary and fiscal policy changed abruptly in 1995. The Bank of Tanzania Act placed price stability first among the objectives of monetary policy and granted the BOT the independence required to carry out its role and functions. The government adopted a cash budget, accepting a virtually complete denial of monetary finance. As the cash budget and reserve money programs gained traction, the growth rate of extended broad money fell sharply, averaging 13.2 percent for the five year period ending 2000. Disinflation was rapid; inflation fell from 30% in 1995 to 16% in 1997 and below 10% in 1999 (Figure A3).

Appendix 2. Motivating the demand for money

The demand for any monetary aggregate can be motivated by reference to the portfolio problem of the household sector (e.g., Walsh 2010).

The end-of-period financial wealth of the private non-bank sector is given by

$$C_t + E_t C_t^{\$} + D_t + E_t D_t^{\$} + B_t + E_t B_t^{\$}, \tag{A2.1}$$

where *C* and *D* refer to cash and bank deposits, *E* is the exchange rate in Tanzanian shillings per US dollar, *$* denotes holdings in foreign currency, and *B* denotes bonds, which on the domestic side are restricted to government securities and on the foreign side are illegal for Tanzanian citizens. More generally, the private sector"s overall wealth *W* also includes real assets, including inventories of goods.

Measuring wealth in real terms as *w*, the private sector"s budget constraint in terms of domestic goods can be written

$$\Delta w_t + c_t = y_t + r_t^{c} c_{t-1} + r_t^{c\$} c_{t-1}^{\$} + r_t^{d} d_{t-1} + r_t^{d\$} d_{t-1}^{\$} + r_t^{b} b_{t-1} + r_t^{b\$} b_{t-1}^{\$} + r_t^{k} k_{t-1}, \tag{A2.2}$$

where lower-case letters refer to quantities measured in real terms and r^j denotes a real return to asset *j*. The opportunity cost of holding wealth as domestic money varies across the components of money and the alternative assets that can be held. For domestic asset *m* and alternative asset *x*, therefore,

Opportunity cost of *m* in terms of *x* =

$$\left.\frac{\partial(\Delta w_t + c_t)}{\partial m_{t-1}}\right|_{dx_{t-1} = -dm_{t-1}} = r_t^{m} - r_t^{x}. \tag{A2.3}$$

The opportunity cost of currency or non-interest-bearing bank deposits in terms of domestic bonds, for example, is $r_t^{b} - r_t^{c} = i_{t-1}/(1+\pi_t)$ where π_t is the inflation rate; as long as π is small, this is approximately the nominal interest rate i_{t-1}. The opportunity cost of domestic currency in terms of foreign currency is $r_t^{c\$} - r_t^{c} = [(1+i_{t-1}^{\$})(1+e_t) - 1]/(1+\pi_t)$; if π is small this is approximately $i_{t-1}^{\$} + e_t$, the sum of the foreign interest rate and the rate of exchange rate depreciation. Interest-bearing deposits pay an „own return", and this reduces their opportunity cost in terms of other assets; the opportunity cost of time deposits in terms of government bonds, for example, is approximately $i_t - i_t^{d}$.

Note that although nominal interest rates are generally known at the time portfolio decisions are made, the only real returns known in advance are those on assets that are explicitly indexed to domestic inflation. Assets denominated in foreign currency are subject to exchange risk, and interest-bearing assets are subject to inflation risk (and, for long-term bonds, risk of capital gain or loss due to interest rate changes). Narrowlydefined real assets are subject to capital gains or losses when relative prices change, but the average capital gain on a diversified basket of goods is zero. An inventory of goods can therefore serve as an effective hedge against inflation if storage costs are low.

Except for currency, the monetary aggregates include a mixture of assets with different own returns. There is therefore no single opportunity cost of M2 in terms of any other asset. Since the opportunity costs can be approximately reduced to linear combinations of known or expected nominal yields, the standard empirical approach is to allow the demand for each aggregate to depend on the full set of expected nominal yields on own and alternative assets.

Since opportunity costs are typically positive, some other features of domestic money must motivate its being held. Primary among these is the convenience of using money for transactions. The demand for money therefore also depends on the anticipated volume of transactions, which we proxy using real GDP or real expenditure. Real wealth is an important additional variable in most treatments of money demand, but it is not observable in Tanzania and so we omit it.

Appendix 3. Definitions and sources of variables

Variable name	*Definition*	*Details and source*
l_cur	log(Currency Outside Banks/CPI)	End-of-quarter Currency Ouside Banks (BOT); Quarterly average CPI (NBS)
l_depr	log(Domestic Currency Deposits/CPI)	End-of-quarter Domestic Currency Deposits (BOT)
l_m2r	log(M2/CPI)	End-of-quarter M2 (BOT)
l_rgdp	log(Real GDP)	NBS and interpolated to quarterly frequency by authors.
l_rgne	log(Real Gross National Expenditure)	NBS and interpolated to quarterly frequency by authors.
l_ifwd2a	$\log(1 + i_{WD} /100)$	i_{WD} is the weighted interest rate on domestic-currency deposits (weights correspond to weights of saving and time deposits in total deposits). Quarterly average interest rates (BOT)
l_infq	$\log(1+\pi 100)$	π is the CPI inflation rate between quarters t and t-1
l_depfa	log(1+x/100)	x is the rate of depreciation for average end of quarter exchange rate TZS/ USD (BOT)
spreada	$\log(1 + i_{TB}/100) - \ln(1 + i_{WD}/100)$	i_{TB} is the 3-month treasury bill interest rate (BOT)
struc_pc1		First principal component of the following 5 transactions intensity indicators:
gwssh		Government wages and salaries as a share of GDP (BOT)
ytishr		Share of mining and quarrying; manufacturing; electricity and water supply; trade, restaurants and hotels; transport and communications; and finance, insurance and real estate, in GDP (NBS).
dcpm3		Domestic credit to the private sector as a share of M3 (BOT)
gfcfgdp_di		Gross fixed capital formation as a share of GDP (NBS)
impgdp_di		Imports as a share of GDP (NBS)

Appendix 4. Phillips-Perron Unit root tests

	b_tr	t_tr	p(z)_tr	p(z)_dr
l_m2r	0.002	2.733	0.912	1.000
D.l_m2r	0.001	3.555	0.000	0.000
l_cur	0.003	2.259	0.904	0.998
D.l_cur	0.001	1.193	0.000	0.000
l_depsr	0.002	3.992	0.622	1.000
D.l_depsr	0.001	4.754	0.000	0.000
l_rgne	0.010	5.028	0.000	0.995
D.l_rgne	0.001	1.740	0.000	0.000
l_rgdp	0.012	6.282	0.000	0.996
D.l_rgdp	0.001	1.350	0.000	0.000
l_ifsda	0.000	0.232	0.918	0.205
D.l_ifsda	0.000	2.026	0.000	0.000
l_iftda	0.000	0.358	0.876	0.408
D.l_iftda	0.000	1.384	0.000	0.000
l_infa	0.000	0.089	0.956	0.564
D.l_infa	0.000	1.731	0.000	0.000
l_depfa	-0.000	-0.791	0.007	0.001
D.l_depfa	0.000	1.165	0.000	0.000
l_e	0.004	2.420	0.351	0.611
D.l_e	-0.000	-0.737	0.000	0.000
l_infq	-0.000	-2.823	0.000	0.001
D.l_infq	0.000	0.869	0.000	0.000
Spreada	-0.000	-0.093	0.021	0.002
D.spreada	0.000	0.214	0.000	0.000
struc_pc1	0.014	11.817	0.018	0.993
D.struc_pc1	0.005	3.302	0.008	0.477

Notes: The columns of the table show the results of Phillips-Perrron unit root tests applied to variables on the rows (the null hypothesis is a unit root). The first 3 columns refer to PP tests with a trend term included: b_tr and t_tr are the estimated coefficient on the trend term and its t-statistic, and p(z)_tr is the MacKinnon approximate p value for the z(t) statistic. The final column is the MacKinnon approximate p value for tests with a constant but no trend term. For any chosen significance value α, values of p(z) less than α imply rejection of a unit root at the significance level α.
Key: l_x and D.l_x refer to the level and first difference of the log of variable *x*.