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Assessing the stability and predictability of the money multiplier in the EAC: the case of Tanzania

Discussion paper [or working paper, etc.]

Assessing the stability and predictability of the money multiplier in the EAC:

The Case of Tanzania

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This paper was commissioned by the Economic Affairs sub-committee of the East African Community Monetary Affairs Committee. The paper offers a template for Partner State central banks to employ in developing common operational and analytical approaches to understanding the evolution and behaviour of the money multiplier in the context of reserve money-based monetary programmes.

The paper is the outcome of research collaboration between staff of the Bank of Tanzania and the International Growth Centre. The views expressed in this paper are solely those of the authors and do not necessarily reflect the official views of the Bank of Tanzania or its management. We are grateful to members of the Sub-Committee for useful comments. All errors are those of the authors.

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1. Introduction

This paper discusses the stability and predictability of the money multiplier in the context of a reserve money anchor for inflation. The methods are illustrated throughout using data from Tanzania, but the discussion is relevant for the whole of the East African Community.

The money multiplier is a measure of the leverage of a country's banking system, in other words the extent to which fractional banking activities produce 'inside' money (i.e. the monetary liabilities of the banking system) from 'outside' or base money (i.e. the primary monetary liabilities of the central bank). Defined as the ratio of the money supply to base money, the multiplier plays a central role in the monetary policy frameworks in all the EAC members. All five countries seek to anchor inflation around a target rate by influencing the growth rate of (some measure of) broad money. This intermediate target is, in turn, pursued through policy actions designed to influence the path of reserve money. Successful targeting of broad money therefore depends on the existence of a stable relationship between it and base money. It follows there exists a different multiplier for each definition of the money supply. For the East African Community the two relevant multipliers are those relating M2 to base money and M3 to base money.[1]

The remainder of the paper proceeds as follows. In section 2 the multiplier is derived from first principles to highlight the relationship between the multiplier and underlying behaviour of the banking system and the non-bank private sector. Alternative notions of stability and predictability are also examined. Section 3 discusses the evolution and properties of the M2 money multiplier in Tanzania and Section 4 examines the accuracy of alternative forecasting models for the multiplier, comparing these against the predictions of the Tanzanian authorities and the IMF published in the regular sequence of IMF country reports. Section 5 concludes.

2. Defining the money multiplier

The M2 money multiplier, denoted m_2 , is defined as

$$m_2 = \frac{M2}{B} = \frac{D+C}{C+R} = \frac{1+c}{c+r} \tag{1}$$

where *B* is base or reserve money, consisting of cash in circulation (*C*) plus bank reserves with the central bank (*R*) and M2 is a broad money measure *excluding* foreign currency deposits. Here, M2 consists of domestic currency deposits, both demand and time and savings deposits, aggregated and denoted by *D*, and cash in circulation. Dividing through by *D*, as shown in the final expression in (1), the multiplier can be expressed in terms of two basic ratios

$c = \frac{C}{D}$ the cash ratio - defined as the ratio of currency in circulation to total deposits

$r = \frac{R}{D}$ the reserve ratio – defined as the ratio of eligible bank reserve to total deposits

[1] Kenya and Rwanda currently target M3 (which includes foreign currency deposits) while Tanzania, Uganda and Burundi target M2.

This simple manipulation expresses the identity in terms of two behavioural ratios, the cash ratio which reflects a portfolio choice of the non-bank private sector and the reserve ratio which reflects bank's asset allocation choices.

In practice, total reserves can be partitioned between required reserves, as defined by the central bank, and the excess held over this requirement. Expressed as a ratio of deposits, we define $r = \tau + x$ where τ is the statutory reserve requirement (as a percentage of deposits, *D*) and x is the excess reserve ratio, so that the M2 multiplier becomes

$$m_2 = \frac{1+c}{c+\tau+x} \tag{2}$$

The critical distinction in this case is that τ is a policy variable under the direct control of the authorities whereas *c* and *x* are now the relevant discretionary portfolio choices of the non-bank private sector and the banking sector respectively.

The M3 multiplier is defined in an analogous manner, except now $M3$ includes foreign currency deposits, $F = E.\tilde{F}$ where *E* is the nominal exchange rate and the tilde (~) denotes foreign currency values. In Tanzania, and elsewhere in the EAC, where banks' reserve requirements on foreign currency deposits are denominated in local currency, total reserve holdings can then be written as

$$R = \tau^D D + E\left(\tau^F \tilde{F}\right) + X \tag{3}$$

so that the multiplier can be expressed as

$$m_3 = \frac{M3}{B} = \frac{D+F+C}{C+\tau^D D+E(\tau^F \tilde{F})+X} = \frac{1+f+c}{c+\tau^D+\tau^F f+x} \tag{4}$$

where $f = \left(E.\tilde{F}\right)/D$ is ratio of foreign to domestic deposits, expressed in terms of local currency. If foreign and domestic deposits attract the same reserve requirement so that $\tau^D = \tau^F$, equation (4) simplifies to

$$m_3 = \frac{1+f+c}{c+\tau(1+f)+x} \tag{4'}$$

This extended definition now sees the multiplier determined by four factors. The first two, *c* and *f*, describe private sector portfolio behaviour, between cash and deposits and between foreign and domestic deposits respectively; τ is a policy measure; and x reflects the banks' discretionary portfolio behaviour.

In the case where banks are required to post reserves *in the currency of the deposit itself*, the relevant formula changes. In particular, this opens up the possibility that banks may hold excess foreign currency deposits so that banks' total foreign reserves consist of the statutory reserve ratio in terms of foreign currency, which we denote as τ^f, and and excess reserves relative to foreign currency deposits, denoted $x^f = \left(\tilde{X}/\tilde{F}\right)$. In such circumstances, the M3 money multiplier, m_3 , is defined as

$$m_3 = \frac{1+f+c}{c+\left(\tau^d+x^d\right)+f(\tau^f+x^f)} \tag{5}$$

Stability and predictability

Equations (2) and (5) hold by definition at every point in time but the multiplier and its components may vary over time. The relevant policy question is whether this variation is sufficiently predictable for policymakers to rely on. One way of assessing predictability is to focus on time-series properties of the multiplier and its component. Specifically, it requires analysing the behaviour of the mean and variance of these multiplier components over time, and whether these are stable around a trend. Absolute stability, in this sense, implies predictability, at least in the absence of large scale structural change. An alternative perspective on predictability recognizes that the multiplier and its components may not be stable unconditionally, but may be a stable function of other variables or of their own past values, or both. Here the relevant gauge is the ability of the authorities to predict with reasonable accuracy the evolution of the multiplier over some horizon. In the next two sections we examine the data on the multiplier and its components in Tanzania from both perspectives, starting with the former. In Section 4 we focus on the relative performance of a small set of alternative forecasting models, including the 'judgemental' forecast underpinning successive IMF programmes.

3. Tanzania: evidence and interpretation

In this section we present data on the M2 money multiplier as defined in equation (2), reflecting M2's role as the intermediate target for monetary policy in Tanzania, and discuss its properties. Any time series variable can be decomposed into three systematic components: the long-run trend; the cyclical movement around the trend; and the within-year movement relative to the trend and cycle, the so-called seasonal component. We start by looking at the trend characteristics of the multiplier and its components followed by an examination of the seasonal pattern. We conclude by looking at the short-run or cyclical pattern.

Trends in multiplier components

Figure 1 plots the log of M2 against the log of base money and the multiplier and Figure 2 decomposes the multiplier in terms of its three component ratios. The raw data behind these pictures are reported in Appendix I.

A number of key features emerge from these figures. First, from Figure 1, although there is significant month-to-month movement in the multiplier (which is examined in detail below), there is no decisive trend in the series over the period. This is confirmed in the first row of Table 1. The multiplier did drop sharply in August 2002 but returned to its (constant) mean almost immediately thereafter.[2]

[2] Reserve money jumped sharply between August and October 2002, principally as a result of substantial private capital inflows. These occurred at a time when the Bank of Tanzania temporarily lacked sufficient debt instruments with which to sterilize the inflow. As a result, reserve money and excess liquidity jumped sharply but this growth was rapidly sterilized in the final quarter of 2002 following the decision by government to securitize government debt liabilities for use by the Bank of Tanzania for liquidity management purposes (see Minister of Finance Letter of Intent to the IMF, July 2003).

Figure 1: Money, Base Money and the Multiplier

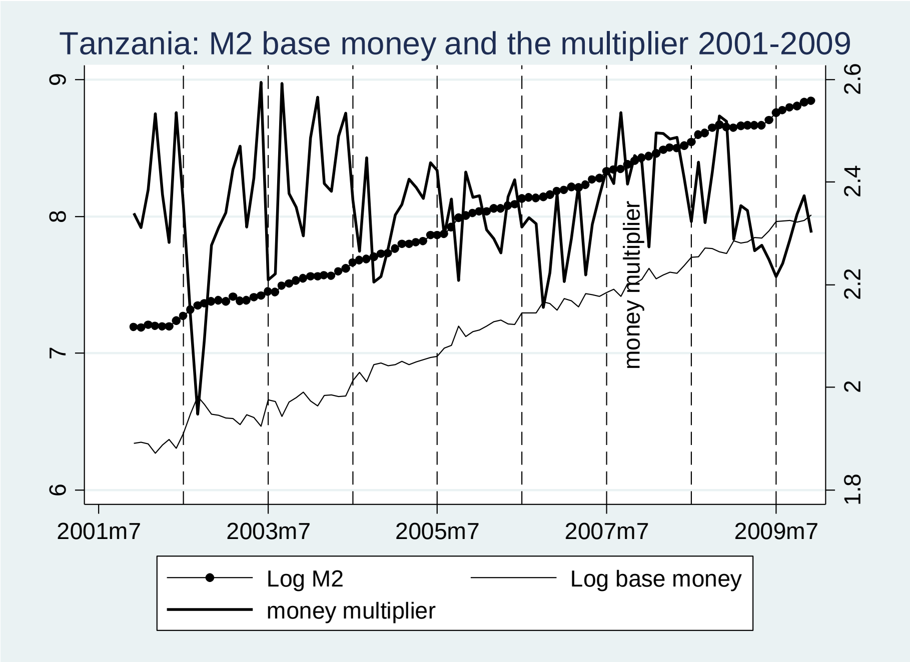


Figure 2: M2 multiplier components

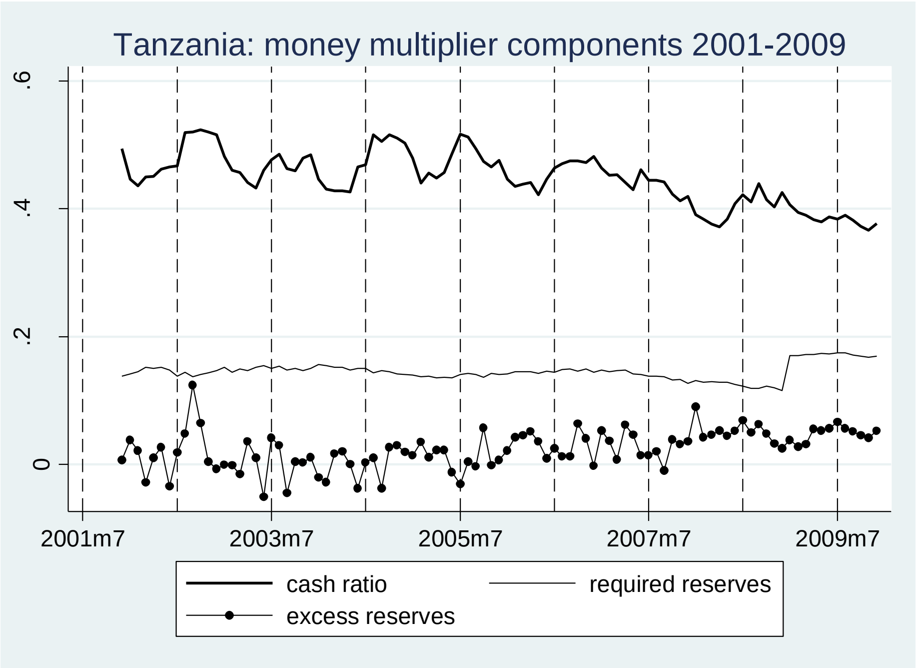


Table 1: estimated long-run trend in M2 multiplier and components December 2001 to December 2009.

Component	Trend per month	t-stat	Adjusted R-squared
M2 multiplier	0.01%	0.49	0.059
Cash Ratio	-0.25%	12.16	0.641
Bank Reserves	0.33%	5.50	0.286
Required Reserves	0.01%	0.34	0.028
Excess Reserves	1.37%	4.44	0.240

Notes: trend computed from OLS regression of log of multiplier (and components) on linear trend and seasonal dummy variables of the form $\ln(x) = \alpha + \beta . t + \sum_{i=1}^{11} \gamma_i \, S_i$ where *x* denotes the multiplier and its components, *t* the time trend and *S* monthly seasonal dummy variables.

But while there has been no statistically significant trend in the overall M2 multiplier since 2001, the underlying components themselves are moving in opposite directions, with a steady long-run trend decline in the cash ratio, of about one quarter of one percent per month, and an offsetting rise in the bank reserve ratio, driven principally by a rising excess reserve ratio. The excess reserve ratio has, however, been much more variable around its trend than has been the cash ratio around its (after controlling for seasonality).

The falling cash ratio, which as Figure 2 indicates seems to accelerate from around 2007, reflects a number of factors. Greater formalization of the economy, including the wider use of direct payment of salaries into bank accounts will drive down the cash ratio, as will technological innovation such as the roll-out of ATMs and, especially, mobile phone-based financial services, both of which allow for individuals to economize on cash holdings.[3] Given the speed of diffusion of both ATMs and mobile-phone banking across the economy, this downward trend in the cash ratio may be expected to accelerate in the future.

The evolution of excess reserves, on the other hand, is characterized by two distinct phases. From mid-2003 until the early part of 2008, banks' holdings of excess reserves rose steadily as a share of deposits (at an average rate of 2.25% per month); since then, however, the growth in excess reserves was less than 0.6% per month (and not statistically different from zero). This abrupt change in behaviour is consistent with important changes in the Bank of Tanzania's approach to liquidity management. During the middle of the decade, the Bank relied heavily on open market operations in the domestic debt market to hit its reserve money targets. This drove up short-term interest rates on Treasury Bills, creating an incentive for the banking sector to both hold excess claims on government and, importantly, to remain excessively liquid in anticipation of (predictable) actions by the Bank to mop up excess liquidity. In early 2008, however, the Bank began to rely more heavily on foreign exchange sales for sterilization purposes which contributed to an easing of domestic interest rates and a moderation of excess liquidity on the part of the banking system. This shift in emphasis was supported by a move to

[3] The cash ratio was substantially higher prior to the unification of the exchange rate in the early 1990s as households also held cash balances to participate in the parallel market for foreign exchange.

reduce the frequency of auctions for government securities in the hope that this would deepen the market, increase competition and ease the pressure on interest rates.

The onset of the global financial crisis in the second half of 2008 coincided with a sharp drop in the multiplier. As Figure 2 indicates however, this drop mainly reflected a step *increase* in the reserve requirement ratio in January 2009 rather than movements in the other components of the multiplier. Increasing reserve requirements at a time when the authorities were generally seeking to ease monetary conditions as part of the response to the global financial crisis may seem inconsistent. However, the jump was, in fact, the consequence of a policy of increasing the reserve requirement on government deposits held in the banking system, introduced in lieu of compulsory repatriation of government deposits to the central bank.[4] This policy had been promulgated mid-2008, at a time when there were concerns of overheating in Tanzania. By late 2008, the balance of risks in both the global and domestic economies had shifted, suggesting an easing of the monetary policy stance.

Setting this specific policy action aside, it is notable that unlike elsewhere in the world where the onset of the global financial crisis, particularly through rising economic uncertainty and the seizure of interbank markets was associated with very sharp increases in liquidity preference amongst banks and the non-bank private sector, the evidence from Tanzania suggests a much more modest and gradual response. The main changes occurred on the asset side of the banking sector's balance sheet. The growth in credit to the private sector slowed markedly as banks shifted their lending portfolios in favour of government securities and foreign assets.

Seasonal patterns

The multiplier itself does not exhibit strong seasonality but the two behavioural components, the cash ratio and the excess reserve ratio do. Figures 3a and 3b plot the mean percentage monthly deviation of the M2 multiplier and its components from their long-run trend.

The cash ratio exhibits a strong seasonal pattern through the year consistent with the central role of agriculture in the Tanzanian economy (Figure 3a). Cash holdings relative to deposits rise sharply in August and September as substantial liquidity is injected into the rural economy following harvest and crop purchase. From this high, the cash ratio then falls steadily throughout the year, with a small reversal around the festive season in December and January, and by the end of the growing season it is substantially below its full-year average.

[4] This policy serves as a progressive repatriation of government deposits thereby avoiding the disruption a one-time repatriation would cause to the banking system, and particularly to weak banks. As the reserve requirement is progressively increased, more of the deposits are in effect transferred back to the Bank of Tanzania: in the limit, a reserve requirement of 100% on government deposits is equivalent to consolidation of all such deposits with the central bank.

Figure 3a: Seasonal Patterns in M2 multiplier and cash ratio

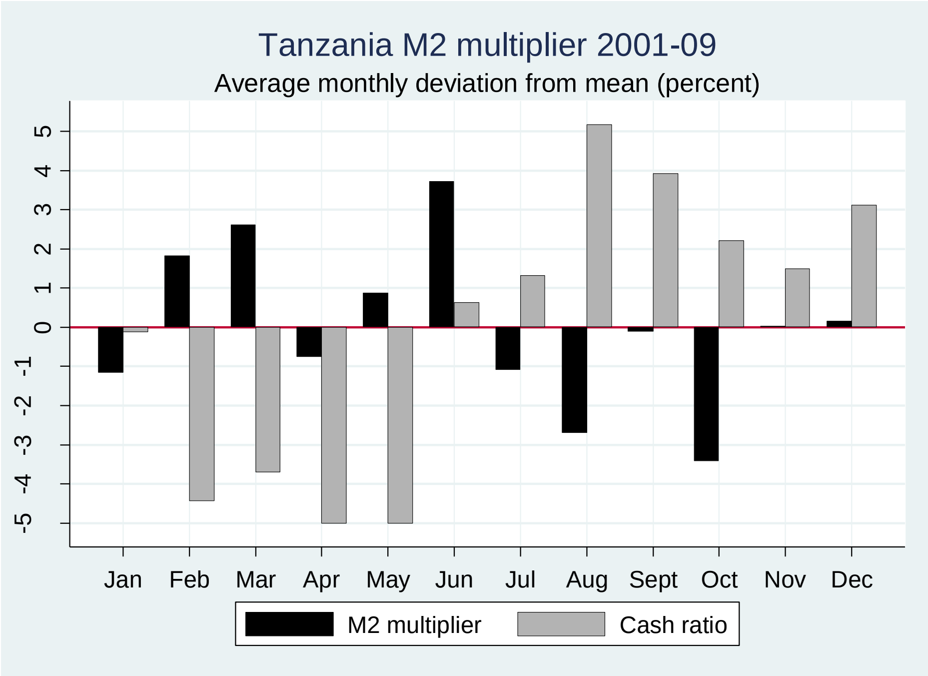
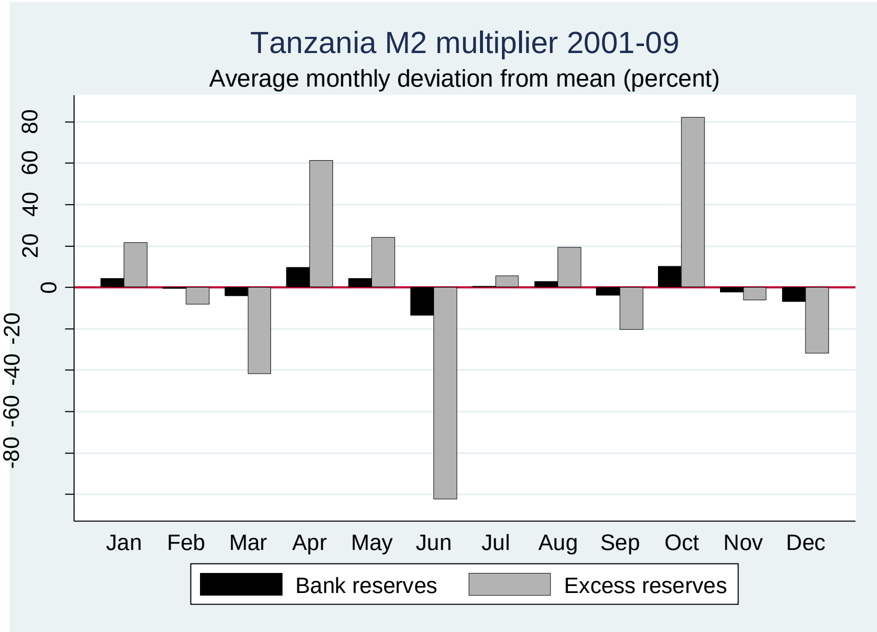


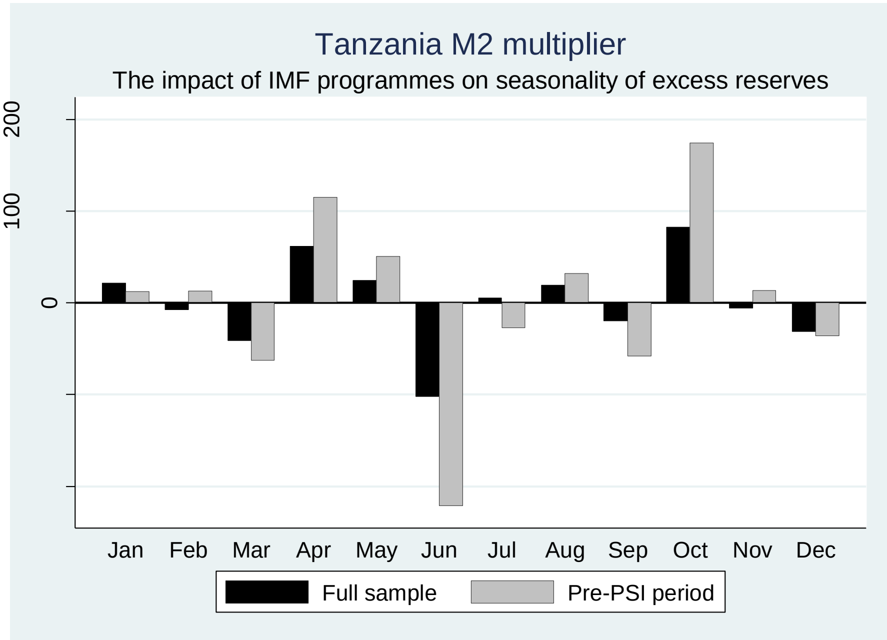
Figure 3b: Seasonal Patterns in reserve requirements and excess reserves



This smooth seasonal pattern does not repeat with the other components of the multiplier. Required reserves are essentially not seasonal, but there is a distinct pattern in the behaviour of excess reserves which fall sharply in March, June, September and December and tend to rebound in the subsequent month. This pattern appears to reflect the authorities' behaviour as they approach IMF programme benchmark dates (which have typically been the end-quarter). As these dates approach, the Bank aggressively attempted to mop up excess liquidity, with these operations being reversed immediately the benchmark date has passed.

To test this hypothesis we re-compute the seasonal pattern in excess reserves over the period up to July 2007, when Tanzania graduated from a conventional PRGF arrangement, under which hitting programme benchmarks was a necessary condition for release of funds, to a no-funds Policy Support Instrument (PSI) where the programme benchmarks were indicative rather than binding. As Figure 3c indicates, the seasonality in excess reserves was much more marked in the earlier period when programme benchmarks figured much more prominently in the conduct of monetary policy.[5]

Figure 3c: The impact of IMF programme benchmarks on excess reserves



Money growth and the multiplier in the short- and long-run

From equation (1), and denoting the percentage growth of a variable by a hat (^), the period-to-period growth in M_2 can be written as $\widehat{M}_2 = \widehat{m}_2 + \widehat{B}$. Table 2 reports summary statistics for the money aggregates and the multiplier over the full period from 2001 to 2009 as well as four sub-periods.

[5] It should be acknowledged that some of the reduction in the seasonality in excess reserves post 2007 may also reflect changes in the Bank of Tanzania's operating procedures which saw it shift more of the burden of sterilization towards the foreign exchange market.

Table 2: The stability of the M2 money multiplier, Jan 2002 to Dec 2009

	Average monthly growth rates			Average monthly variances and covariances			
	$\widehat{M}_2$	$\widehat{B}$	$\widehat{m}_2$	$Var(\widehat{M}_2)$	$Var(\widehat{B})$	$Var(\widehat{m}_2)$	$Cov(\widehat{m}_2, \widehat{B})$
Jan02 to Dec09	1.72%	1.74%	-0.02%	0.03	0.31	0.28	-0.28
Jan 02 to Dec 02	1.63%	1.73%	-0.10%	0.04	0.57	0.48	-0.50
Jan 03 to Dec 04	1.42%	1.50%	-0.07%	0.03	0.49	0.46	-0.46
Jan 05 to Dec07	1.95%	1.75%	0.20%	0.03	0.21	0.17	-0.17
Jan 08 to Dec 09	1.72%	1.96%	-0.24%	0.03	0.15	0.16	-0.14

Consistent with the graphical evidence in Figures 1 and 2, the left hand block of Table 2 confirms that the average month-to-month percentage change in the multiplier is approximately zero. On average, over the long-run, the growth in M2 is determined principally by the growth in base money.

This long-run relationship can be verified more formally by testing for cointegration between broad money and the monetary base (see Table 3).

Table 3: The long-run relationship between base money and M2[1].

Johansen Rank Test[2]				Cointegrating Vector[3]		
Ho: Rank	Trace-stat	1% CV				
r=0	36.48	20.04	**	Ln(M2)	1.00	
r=1	0.271	6.65		Ln(H)	-1.004	0.0147
r=2	-			Cons	-0.802	

Notes: [1] All calculations based on monthly data from December 2001 to December 2009, with monthly seasonal dummy variables; [2] Johansen Rank test for cointegration against cumulative null that r≥n where n=0,1,2; [3] Cointegrating vector allows for constant in long-run relationship.

This cointegration evidence offers very strong support for the existence of a stable long-run relationship between the money base and M2. Moreover, the cointegrating vector suggests this relationship exhibits exact long-run proportionality between the money base and broad money. By implication, the multiplier in Tanzania is constant over the long-run.

But this robust long-run relationship masks a more complicated set of short-run interactions. These are investigated in the right-hand panel of Table 2. Most notably, in the short-run, the path of M2 appears to be much more stable around its mean growth than is base money. This can be seen if we compute the variance of the growth in M2, which, from above, is defined as

$$Var(\widehat{M}_2) = Var(\widehat{m}_2) + Var(\widehat{B}) + 2Cov(\widehat{m}_2, \widehat{B})$$

As seen in Table 2, the month-to-month growth in reserve money and the multiplier are substantially more volatile than the money supply, but to a very substantial degree, this volatility cancels out: the covariance between base money and the multiplier is approximately the same order of magnitude as the individual variances, implying a correlation coefficient between base money and the multiplier of approximately -1.

A correlation of -1 is not inevitable. In fact, if the bank and non-bank private sectors were optimizing their portfolios relative to some target value of the cash and reserve ratios and that they could adjust their portfolios with little or no cost, then the component parts of the multiplier, and the multiplier itself, would be constant and orthogonal to changes in base money. In those circumstances, changes in base money would pass directly through to changes in broad money and the volatility of broad money would mirror that of base money. The correlation between base money and the multiplier would be zero. A correlation coefficient of -1 suggests that, on the contrary, the multiplier accommodates changes in base money.

To understand how this might come about, we decompose the overall movement in the multiplier to identify the contribution of its individual components. First, note that differentiation of the multiplier yields the following partial derivatives with respect to the core ratios:

$$\frac{\partial m_2}{\partial c} = \frac{(\tau+x-1)}{(\tau+x+c)^2} < 1$$

and

$$\frac{\partial m_2}{\partial \tau} = \frac{\partial m_2}{\partial x} = \frac{(c-1)}{(\tau+x+c)^2} < 1$$

An increase in the cash ratio or bank reserves, whether required or excess, will reduce the multiplier, *ceteris paribus*, with the size of the response depending on relative size of the cash ratio and the reserve ratio.

It follows that if changes in base money induce changes in the core ratios, *c*, τ and *x*, at least in the short-run, the multiplier will not be exogenous with respect to the central bank policy stance. Table 4 summarizes the empirical evidence on these relationships for Tanzania. The correlation between movements in the components and the multiplier are all negative and the relative sizes of the contributions to movements in the multiplier are exactly as the algebra predicts. Importantly, as the pair-wise correlations indicate, required and excess reserves are *positively* correlated, suggesting that attempts to eliminate the latter by raising the former may be counterproductive, at least in the short run.

As noted above, these short-run changes may reflect error-correction effects between the current value of the behavioural ratios and their long-run target. For example, an increase in reserve money resulting from central bank open-market operations may lead to a temporary accumulation of excess reserves by banks before these resources can be lent on to the non-bank private sector, with the effect that the multiplier falls in the short run, relative to its mean, before rising again to its long-run value. In other words there is an incomplete short-run pass-through from base money to the intermediate money.

Table 4: the contribution of components to movements in the M2 multiplier
Dec 2001 to Dec 2009

	Levels		Contribution of components[1]		Pair-wise correlations			
	mean	std	Coeff (t-stat)	R-sq	*m*	*c*	τ	*x*
m	2.355	0.111			1.000			
c	0.447	0.041	-0.674 (2.42)	0.231	-0.289*	1.000		
τ	0.145	0.013	-2.299 (2.86)	0.250	-0.242*	-0.203*	1.000	
x	0.024	0.030	-2.294 (7.62)	0.513	-0.666*	-0.384*	0.531	1.000

Notes: **[1]** coefficients derived from a linear pairwise regression of the multiplier on the relevant ratio, controlling for a constant and 11 monthly seasonal dummy variables. Conventional t-statistics in parenthesis.

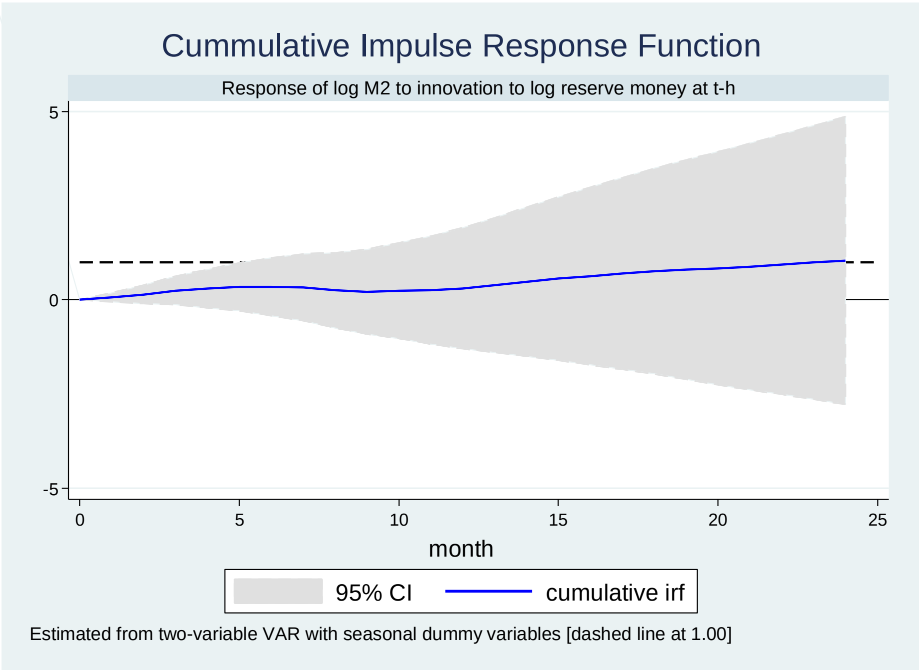
Figure 4 and Table 5 indicate the speed of the pass through as measured by the cumulative impulse response function of broad money for a one percent shock to reserve money. This response function is estimated from a two variable vector auto-regression in log M2 and log H with a full set of seasonal dummy variables, estimated for the full sample period with up to 12 lags in the VAR.

Table 5: Cumulative pass- through from reserve money to M2 growth

lag	Cumulative response of log M2
t=1	0.069
t=3	0.248
t=6	0.348
t=12	0.307
t=18	0.762
t=24	0.991

Together the table and plot suggest that after one quarter around 25 percent of the shock to base money is transmitted to broad money and that it takes just less than 24 months for the full effect of the shock to filter through.

Figure 4: The pass-through from base money to broad money



4. Forecast performance

In this final substantive section we examine the ability of alternative models to forecast the short-run evolution of the M2 multiplier and its components. We focus on mechanistic, univariate forecasting models rather than structural models of the behavioural components of the model. Specifically we examine simple trend-extrapolation methods and ARIMA-based models, although we compare these with the judgemental forecasts published in the IMF's PRGF and PSI programme review document.

The suite of models is estimated on actual data from December 2001 to December 2005. We then compare the forecast performance of each model over the period from January 2006 to the end of 2009. In each case we examine the comparative performance of one-step-ahead forecast accuracy (although this comparison could be extended to *h*-step ahead forecasts as well) using standard root mean square forecast error (RMFSE) and mean absolute forecast error (MAFE) indicators. Models are estimated in terms of the natural log of the multiplier and its components so that forecast error measures are in percentage points per month. An *EViews* programme providing the code for running each of these models is provided at Appendix II.

The models

Model 1:A Benchmark: the 'pure' random walk

The simplest benchmark model takes the form

$$\Delta m_t = \varepsilon_t \qquad (6)$$

or, equivalently,

$$m_t = m_{t-1} + \varepsilon_t \tag{6'}$$

This, of course, has the forecasting property that the best guess of velocity tomorrow is the actual velocity today. This 'random walk' model is a useful benchmark in that it provides an estimate of the average unconditional forecast error for the month-to-month change in the multiplier.

In practice, however, any month-to-month forecast of the multiplier or its components should also take into account the strong seasonality in the process. The models we run against the pure random walk therefore all contain a full set of seasonal dummy variables. Thus the forecast of the month-on-month change in the multiplier or its components in period *t+1* is conditional on information up to and including *t* plus the estimated seasonal component for month *t+1.*

Model 2: random walk with seasonal dummy variables

This model simply augments the pure random walk by conditioning the random walk on a vector of deterministic seasonal dummy variables

$$\Delta m_t = \alpha + \sum_{i=1}^{11} \gamma_i S_i + \varepsilon_t \tag{7}$$

Where *S* is a vector of seasonal dummy variables.

Model 3: local linear trend

Our first alternative model is of the form

$$m_t = \alpha + \beta . t + \sum_{i=1}^{11} \gamma_i S_i + \varepsilon_t \tag{8}$$

This model, which closely follows the practice adopted by Bank of Tanzania, is estimated on a rolling 12- 24- or 36-month window. Thus the one-period ahead forecast (for *t+1*) is computed from a model estimated over the data for the previous one- two- or three years, up to and including time t. As with equation (7) this forecast is conditional on a vector of estimated seasonal dummy variables.

Models 4 and 5: ARIMA and Seasonal ARIMA models

The random-walk model is a special case of a more general class of autoregressive integrated moving average, or ARIMA, models. The general form of these models is

$$\Delta^d m_t = \alpha + \sum_{i=1}^{p} \mu_i \Delta^d m_{t-i} + \varepsilon_t + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} + \sum_{i=1}^{11} \gamma_i S_i \tag{9}$$

where *d* denotes the degree of integration (i.e. the number of unit roots in the time series), *p* the degree of autocorrelation and *q* the moving average order of the error term. In terms of notation, equation (9) is described as an ARIMA(p,d,q) specification. We can write (9) using the lag operator, *L*, as

$$\Delta^d m_t (1 - \mu_1 L - \mu_2 L^2 - \cdots - \mu_p L^p) = \alpha + \varepsilon_t (1 + \theta_1 L + \theta_2 L^2 + \cdots + \theta_p L^q) + \sum_{i=1}^{11} \gamma_i S_i \tag{9'}$$

where $L^n x_t = x_{t-n}$.

Equation (9) and (9') allow for a deterministic set of seasonal dummy variables. An alternative approach involves directly estimating the seasonal effects in the data using a Seasonal ARIMA model of the form

$$\Delta^d m_t(1 - \mu_1 L - \cdots - \mu_p L^p)(1 - \varphi L^{12}) = \alpha + \varepsilon_t(1 + \theta_1 L + \theta_2 L^2 + \cdots + \theta_p L^q)(1 - \omega L^{12}) \quad (10)$$

where $(1 - \varphi L^{12})$ and $(1 - \omega L^{12})$ are the seasonal differences for the AR and MA components of the process. These terms serve to purge the underlying ARMA model of any purely seasonal variation in the data.

Estimation of ARIMA models

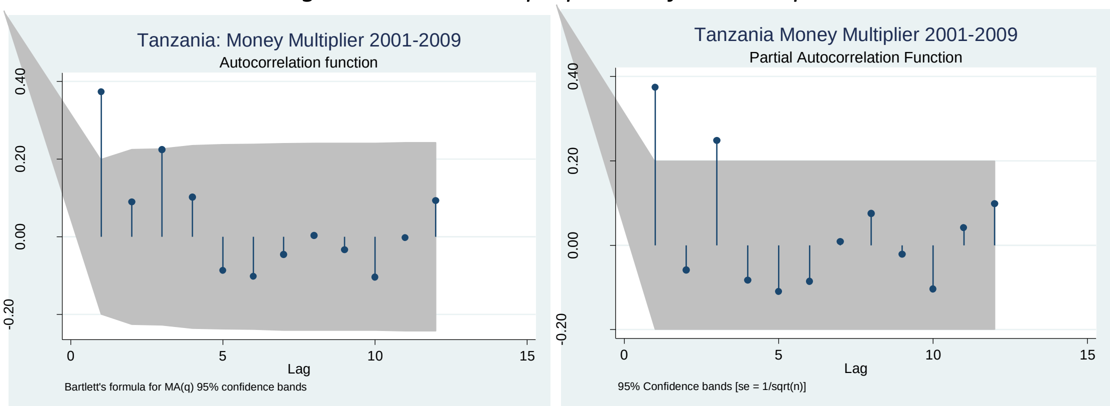
It is notoriously difficult to select the optimal ARIMA structure (i.e. the 'best fitting' combination of the order of integration, *d*, and the AR and MA components, *p* and *q*) for any given time series and sample period. Moreover, there is no guarantee that the optimal model form for the multiplier itself corresponds to the optimal form for any of the individual components.

The first step typically entails the order of integration. As we noted above, the multiplier is strongly stationary which allows us to set *d=0.* To select the AR and MA components we proceed in two steps. We first examine the autocorrelation function (ACF) and partial autocorrelation functions (PACF) for the multiplier to identify the *maximum* AR and MA lengths. Then, we estimate all possible combinations within these limits and use standard selection criteria to identify the 'best' ARMA specification.[6]

The ACF and PACF have the convenient property that for an AR(*p*) process the PACF goes to zero after lag *p* while for an MA(*q*) process the ACF goes to zero after *q* lags. Hence by examining the two functions together we can make an informed guess as to the maximum ARMA structure in the data.

Figure 5 illustrates the ACF and PACF for the M2 multiplier over the 2001 to 2009 period.

Figure 5: time series properties of M2 multiplier



[6] This search procedure is often referred to as Box-Jenkins methods. See Enders (2004).

The shaded areas in the two panels demarcate the 95% confidence interval around the null that each (partial) autocorrelation is equal to zero. Hence 'spikes' which broach this boundary indicate significant (partial) autocorrelation. On this basis the PACF plot suggests that the autoregressive order for the multiplier is certainly 1 and most likely 3; likewise the evidence from the ACF plot suggests a first order moving average but again there may be an MA process of order 3.

This gives us a starting point. To search within these limits, we next estimate all possible combinations and use standard goodness-of-fit information criteria to select the best-fitting model. In this case we conduct the selection using versions of equation (9') where seasonality is modelled using deterministic dummy variables. We are looking for the ARMA order that minimizes the relevant information criteria.

Table 6: ARMA Selection

ARMA order	Akaike	Schwarz	Hannan-Quinn
0,0	-1.548097	-1.132843	-1.385355
0,1	-1.741912	-1.292053	-1.565608
0,2	-1.710886	-1.226423	-1.521021
0,3	-1.690982	-1.171914	-1.487554
1,0	-1.628185	-1.174410	-1.450689
1,1	-1.689688	-1.201007	-1.498538
1,2	-1.656366	-1.132779	-1.451562
1,3	-1.624487	-1.065995	-1.406030
2,0	-1.647256	-1.154281	-1.454819
2,1	-1.651265	-1.123077	-1.445082
2,2	-1.842614	-1.279214	-1.622686
2,3	-1.952978	-1.354366	-1.719304
3,0	-1.696742	-1.163869	-1.489177
3,1	-1.670770	-1.102372	-1.449367
3,2	*-1.971496	*-1.367573	*-1.736256
3,3	-1.937078	-1.297630	-1.688000

* indicates best model

The results are decisive, suggesting that an ARIMA(3,0,2) specification offers the best fitting specification. We are dealing with a relatively short time series so that degrees of freedom are limited. In what follows, therefore, we also estimate a more parsimonious ARIMA(1,0,1) model. In both cases we also estimate the corresponding SARIMA(3,2) and SARIMA(1,1) representations.

Judgemental forecasts

Tanzania's regular engagement with the IMF also generates a sequence of agreed projections for the money multiplier.[7] These are typically negotiated and represent the outcome of extensive discussion between the Bank of Tanzania, the IMF mission and resident representative and are typically set and revised during the IMF's regular PSI (formerly PRGF) and Article IV missions.

[7] These are typically implicit programme targets and projections. The multiplier is not in itself a programme benchmark but targets and projections can be derived from programme values for the relevant money aggregates.

Using the Board-approved reports for all such missions since December 2001, we construct a real-time database consisting of the full set of programme targets and projections for the M2 (and M3) multiplier for each quarter from March 2002 to June 2011. For most quarters during this period there will be both preliminary and revised targets and projections, allowing us to consider how these projections are revised with time.

Figures 6a and 6b plot the actual value of the end-of-quarter multiplier for M3 and M2 respectively against the revised programme target for that period and 'most recent' projected values as reported in IMF reports pre-dating the relevant quarter. The IMF will typically produce projections for up to 8-12 quarters ahead (and occasionally longer) so that for many quarters there will be multiple projections of different vintages: in Figure 6, however, we plot only the final revised forecast for immediately preceding the relevant end-quarter dates (March, June, September and December). These final revised forecasts necessarily cast the IMF/BoT judgemental forecasts in the best possible light: below we examine the power of forecasts over extended forecast horizons.

A number of features emerge from these figures. First, the revised targets and projections are reasonably close to the actual value of the multiplier: the average (final) forecast error is approximately -1.9% for the M3 mutliplier and -1.6% for the M2 mutliplier. The deviations of the actual multipliers from programme targets are of the same magnitude. This latter deviation must, however, be treated with some caution since the target itself is, to some degree, revised in the light of actual outcomes: this pattern of convergence between forecasts and the actual outcome and between actual and programmed values is, therefore, not entirely surprising.

Second, despite this good average performance, the authorities and the Fund appeared to consistently under-predict the rise in the multiplier through most of the decade but may have taken too optimistic a perspective when the global crisis hit from late 2008 onwards, assuming that credit creation by the banking sector would not contract by as much as it appears to have done. Though the differences are small, this pattern is more pronounced for the M3 multiplier, possibly underlining the difficulty in accurately predicting household's demand for broad money components, particularly foreign currency demand.

Figure 6a

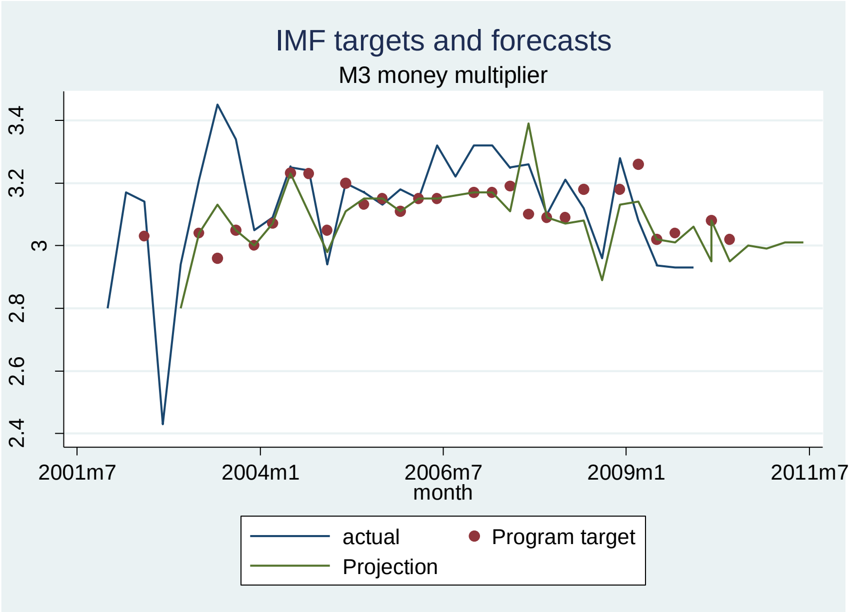


Figure 6b

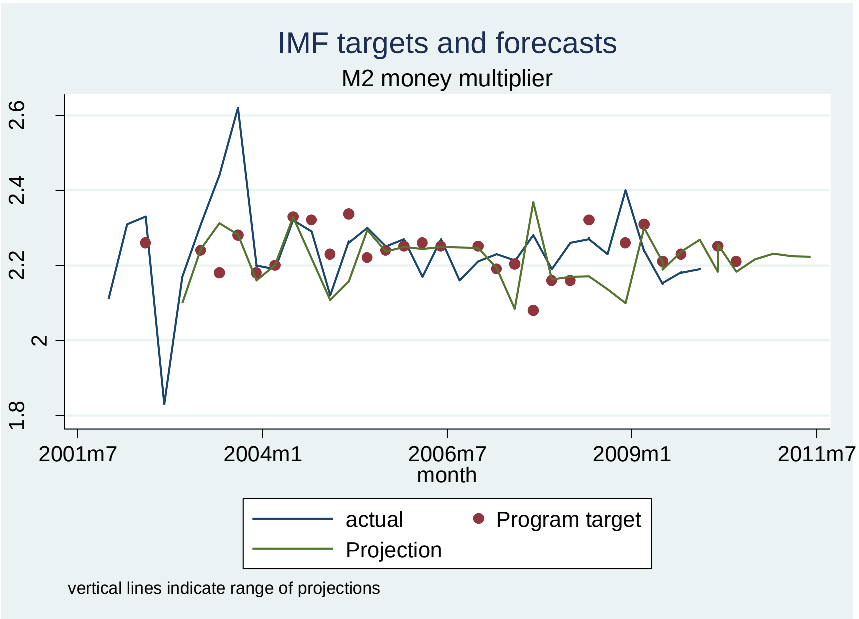
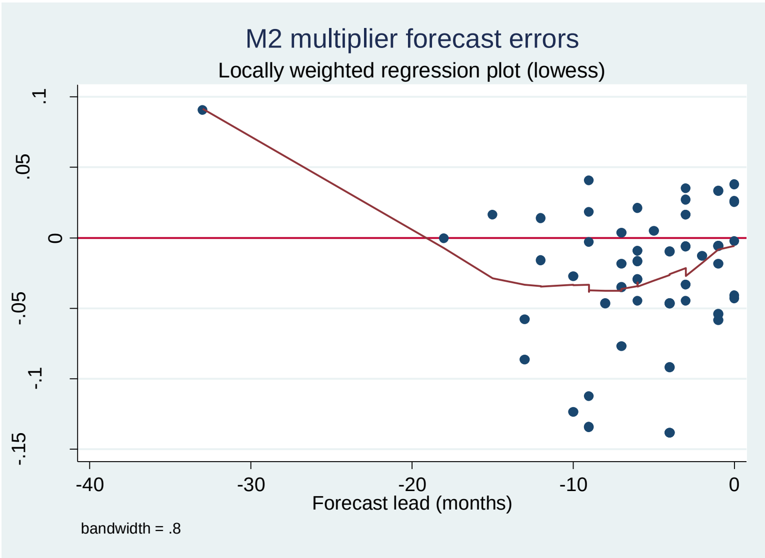


Figure 7 and Table 7 re-examine the BoT/IMF forecast performance in more detail by reporting forecast errors at different horizons. As expected, the forecast error diminishes sharply as the horizon shortens but does so in a non-monotonic manner. Figure 7 plots the mean forecast error over different horizons and overlays these with a flexible locally-weighted regression line (a ‘lowess’ fit). Over the decade, the authorities’ forecasts have been reasonably balanced. There is no strong bias in either direction, although there is a slight tendency to under-predict velocity for longer horizons. We can ignore the single long-range forecast in the sample which was optimistic (i.e. over-estimating the multiplier). Focussing on those forecasts over horizons of less than two years we not that forecasts have tended to under-predict the true value of the multiplier, but the forecast errors become more symmetric as the forecast horizon reduces. Nonetheless, the forecast errors are relatively small, around 5% as the forecast horizon dips below six months.

Figure 7: M2 multiplier, percentage forecast errors at different horizons



Summary

Table 7 pulls together the comparative forecast performance of all five statistical models along with the IMF 'judgemental' forecasts. The accuracy of the forecasts are evaluated using two standard measures.

The model is estimated up to some period *t* and forecast one period ahead (i.e. a forecast is generated for *t+1* for the model estimated to *t*. This one-step ahead forecast is defined as $\hat{x}_j$ and the corresponding forecast error is $(\hat{x}_j - x_j)$ where x_j denotes the actual value in *t+1.* The sample period is extended by one period, the model is re-estimated and the next one-step forecast error is computed. This is repeated *n* times. The 'root mean squared forecast error' (RMSFE) summarizes this sequence of *n* one-step ahead forecast errors and is defined as

$$RMSFE = \sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(\hat{x}_j - x_j\right)^2}$$

The 'mean absolute forecast error' is computed in an analogous manner except in this case we compute the average of the absolute forecast errors thus

$$MAFE = \frac{1}{n}\sum_{j=1}^{n}\left|\hat{x}_j - x_j\right|$$

Though not reported here, the same principles apply in assessing multi-step forecasts in which the sequence of forecast errors are computed over progressively increasing horizons. Thus the estimation period is kept fixed at *t=1...t* and the sequence of forecast errors runs from *j=t+1, t+2...t+n.*

A number of patterns emerge quite clearly. First, there are very substantial gains, in terms of forecast error reduction, from using ARIMA models relative to simple linear trend extrapolations. Given the absence of any long-run trend in the data, extrapolation of linear projections proves to be relatively uninformed. In particular this model does not adequately reflect the mean-reverting properties of the multiplier over the short-run. Second, within the class of ARIMA models there are clear gains from allowing for a more complex set of dynamics. The ARIMA (1,0,1) model dominates the random walk (an ARIMA(1,0,0)) while the ARIMA(3,0,2) dominates both. Third, it would appear for Tanzania, there is little to choose between modelling the seasonal variation in the data using a set of additive linear seasonal dummy variables or modelling the seasonal pattern directly using a seasonal ARIMA model. Finally, over horizons longer than six months, mechanistic ARIMA models generate predictions that are no less accurate than those generated by the Bank of Tanzania and IMF. However, when the forecast horizon shortens, the capacity to draw on a richer set of information allows judgemental forecasts to dominate mechanistic ones, presumably because such forecasts are able to augment the baseline offered by mechanistic forecasts.

Table 7: Comparative Forecast Performance

Model No. and description		M2 multiplier		Cash Ratio		Excess reserve ratio	
		RMSFE	MAFE	RMSFE	MAFE	RMSFE	MAFE
		% per month		*% per month*		*% per month*	
1.	Pure Random Walk	4.795	4.433	3.990	3.243	20.479	13.781
2	Random Walk with seasonal	4.425	3.522	2.816	2.109	17.688	13.196
3a	Local Linear Trend [12 month window]	8.633	6.604	9.852	8.183	35.652	27.367
3b	Local Linear Trend [24 month window]	5.484	4.359	8.473	7.295	25.137	20.600
3c	Local Linear Trend [36 month window]	6.049	5.065	5.798	4.902	19.143	16.224
4a	ARIMA(1,0,1) with seasonal dummies	4.052	3.397	2.787	2.214	16.785	13.222
4b	SARIMA(1,0,1,12)	4.130	3.413	3.039	2.381	17.682	13.982
5a	ARIMA(3,0,2) with seasonal dummies	3.832	3.176	2.536	2.019	15.919	12.825
5b	SARIMA(3,0,2,12)	3.990	3.243	2.834	2.237	16.697	12.778
6	IMF Forecast errors[1]						
	Less than 6 month horizon	4.567	3.338				
	Less than 3 month horizon	3.101	2.650				

Notes: See text for description of models; dependent variable log M2 multiplier, log cash ratio and log excess reserve ratio respectively; all models estimated over 2001m12 to 2005m12; forecast error statistics based on one-step-ahead forecasts; [1] See text above for explanation.

5. Summary and conclusion

Our objective in this paper was twofold. The first was to lay out for EAC member countries, elements of a common approach to analyzing the evolution of the money multiplier. We propose a two part analysis. First we systematically examine the historical evidence on multiplier and its principal components in terms of three frequencies: the long-run trend; the within-year seasonal pattern; and the short-run or cyclical pattern. This provides the basis for understanding how key structural developments in the economy have influenced the central policy link between the authorities' intermediate monetary policy target, the broad money supply and its operational target, reserve money. The second component consists of developing a framework for the systematic analysis of alternative models for forecasting the multiplier.[8]

[8] Programme files implementing the key elements of this methodology and written for STATA and Eviews are available from the authors.

The second objective of the paper was to apply this methodology to the M2 multiplier in Tanzania over the period from 2001 to the present, up to an including the period of the global financial crisis. Four main messages emerge from this analysis. First, there is strong evidence that the M2 multiplier is stable over the long run so that on average broad money has grown one-for-one with reserve money. Taken together with the evidence on the relationship between broad money growth and prices in recent decades (see Adam *et al,* 2010), this helps explain why the Tanzanian authorities' efforts to anchor inflation by means of a reserve money programme have been well-founded and have helped stabilize prices over the last decade. However, the stability of the multiplier itself masks offsetting trends in the principal components. The cash ratio has exhibited a steady downward trend over time but this has been offset by a rise in banks' excess reserve ratio. That these two components have offset each other over the period from 2001 to 2009 is, to some degree, coincidental. It is likely that while the cash ratio will continue to decline in the future, reflecting long-run structural and technological developments, the deepening of financial markets will limit growth in banks' excess reserves ratio. The net effect, therefore, will be an upward trend in the multiplier. Second, it takes time for this exact proportionality to emerge. Over the short run, the multiplier is not constant but responds inversely to movements in reserve money. This negative correlation between base money and the multiplier attenuates the impact of (policy-induced) changes in base money on broad money; our evidence suggests full pass-through takes around 24 months. Third, whilst the multiplier itself is not strongly seasonal, its key components are. The strong within-year movements in the cash ratio reflects the seasonality of demand in the rural economy, while movements in banks' excess reserve ratio appears to have been driven by the Bank of Tanzania's approach to conducting monetary policy in the context of conventional IMF lending programmes. As the latter has been replaced by the less conditional Policy Support Instrument, and as the Bank has progressively balanced its sterilization activities between foreign exchange and domestic money markets, this particular seasonal component has moderated. Finally, we have shown how standard models can be employed to develop a reasonably accurate forecast of the future path of the multiplier and its components. In particular we have shown that a modest investment in developing robust ARIMA forecasting models can generate significant returns in terms of policy formulation. Our work on forecasting, however, remains a work in progress. We have restricted our attention to evaluating the performance of alternative models over a fixed period (January 2006 to December 2009) and over a one-period-ahead forecast horizon. Further work is required to analyze the forecast performance of alternative models over different samples and longer forecast horizons.

References

Adam, C., P. Kessy, J. Nyella, and S. O'Connell (2010) "The Demand for Money in Tanzania" *Bank of Tanzania and IGC Working Paper No.2.*

Enders, W. (2004) *Applied Econometric Time Series Analysis* (Norton).

Hauner, D. and G. Di Bella (2005) "How useful is monetary econometrics in low income countries? The case of money demand and the multipliers in Rwanda." *IMF Working Paper* WP/05/178

Appendix I: Data

Date	M2	M3	Deposits LC D	Reserve money B	Currency in circulation C	Required Reserves RR	Excess Reserves XR	Multiplier M3	Multiplier M2
Dec-01	1327.53	1876.11	888.27	567.43	439.26	122.11	6.06	3.30635	2.33956
Jan-02	1322.02	1888.99	914.10	571.97	407.92	129.25	34.79	3.30262	2.31135
Feb-02	1347.49	1965.31	938.24	564.80	409.25	135.61	19.94	3.47966	2.38580
Mar-02	1335.89	1979.21	921.51	527.36	414.38	139.64	-26.66	3.75303	2.53314
Apr-02	1331.73	1975.19	918.30	560.48	413.44	137.76	9.28	3.52410	2.37605
May-02	1333.92	1984.94	912.56	584.34	421.36	138.44	24.55	3.39686	2.28276
Jun-02	1390.52	2016.91	948.80	548.32	441.71	139.62	-33.01	3.67834	2.53596
Jul-02	1435.34	2055.21	978.58	609.41	456.77	135.21	17.43	3.37247	2.35531
Aug-02	1508.66	2162.14	993.13	705.93	515.53	142.92	47.48	3.06281	2.13712
Sep-02	1554.43	2180.14	1022.79	798.17	531.65	139.96	126.56	2.73142	1.94750
Oct-02	1577.75	2239.04	1035.49	754.44	542.26	145.54	66.64	2.96784	2.09130
Nov-02	1602.98	2277.81	1054.58	703.89	548.40	151.23	4.26	3.23602	2.27731
Dec-02	1613.84	2355.57	1064.66	698.27	549.18	156.49	-7.40	3.37344	2.31120
Jan-03	1599.68	2381.62	1079.57	683.40	520.11	164.08	-0.78	3.48495	2.34076
Feb-03	1652.23	2418.50	1131.66	681.29	520.57	162.94	-2.22	3.54987	2.42514
Mar-03	1610.93	2407.69	1105.83	652.06	505.11	164.73	-17.78	3.69243	2.47052
Apr-03	1616.38	2406.08	1121.51	698.82	494.87	164.24	39.70	3.44308	2.31302
May-03	1648.41	2475.56	1150.61	684.56	497.80	175.08	11.67	3.61630	2.40800
Jun-03	1667.22	2505.55	1141.76	642.56	525.46	175.94	-58.84	3.89934	2.59466
Jul-03	1723.12	2560.53	1166.91	779.82	556.21	175.41	48.20	3.28348	2.20963
Aug-03	1714.42	2564.74	1153.95	771.88	560.47	177.25	34.15	3.32273	2.22110
Sep-03	1792.24	2629.61	1225.18	691.35	567.06	180.29	-56.00	3.80358	2.59237
Oct-03	1824.79	2714.48	1250.32	767.22	574.47	187.14	5.61	3.53805	2.37844
Nov-03	1866.19	2736.59	1261.33	793.69	604.86	185.36	3.47	3.44795	2.35129
Dec-03	1895.82	2778.84	1276.78	825.79	619.04	192.06	14.70	3.36506	2.29576
Jan-04	1921.58	2890.68	1328.52	772.79	593.06	207.25	-27.52	3.74058	2.48655
Feb-04	1916.75	2922.30	1340.15	746.98	576.60	207.48	-37.11	3.91216	2.56600
Mar-04	1931.96	2895.06	1352.59	805.90	579.37	204.79	21.73	3.59235	2.39728
Apr-04	1925.32	2878.56	1348.13	808.01	577.18	204.23	26.60	3.56252	2.38278
May-04	1989.95	2939.89	1395.49	799.36	594.46	205.73	-0.83	3.67782	2.48945
Jun-04	2037.14	2968.88	1389.81	803.72	647.33	208.64	-52.25	3.69391	2.53463
Jul-04	2126.56	3117.38	1447.51	899.03	679.05	217.08	2.90	3.46748	2.36539
Aug-04	2162.54	3056.20	1426.41	954.69	736.14	204.13	14.42	3.20125	2.26518
Sep-04	2182.71	3123.99	1449.61	891.64	733.10	213.07	-54.53	3.50365	2.44798
Oct-04	2222.50	3149.56	1466.48	1007.88	756.02	212.13	39.73	3.12493	2.20513
Nov-04	2264.82	3185.02	1499.12	1021.77	765.70	212.42	43.65	3.11717	2.21657
Dec-04	2271.16	3153.78	1511.16	999.99	759.99	211.87	28.12	3.15383	2.27119
Jan-05	2361.86	3325.89	1596.22	1010.76	765.65	223.03	22.09	3.29047	2.33671
Feb-05	2437.77	3394.78	1693.08	1034.66	744.69	231.45	58.51	3.28106	2.35611
Mar-05	2432.30	3422.31	1670.35	1010.87	761.95	230.99	17.94	3.38550	2.40613
Apr-05	2461.62	3378.71	1700.14	1030.12	761.48	230.05	38.59	3.27992	2.38964
May-05	2482.88	3414.07	1704.72	1048.15	778.16	231.83	38.16	3.25722	2.36881
Jun-05	2594.84	3552.01	1745.89	1064.40	848.95	236.66	-21.22	3.33710	2.43785
Jul-05	2597.84	3643.23	1712.49	1072.14	885.35	241.06	-54.27	3.39810	2.42304
Aug-05	2612.84	3702.84	1727.38	1137.63	885.46	245.50	6.67	3.25488	2.29674
Sep-05	2754.94	3851.76	1843.64	1163.72	911.30	258.45	-6.03	3.30988	2.36736
Oct-05	2949.80	4068.25	2000.92	1335.70	948.88	272.96	113.85	3.04579	2.20844
Nov-05	2997.11	4238.75	2045.42	1238.30	951.69	290.75	-4.14	3.42303	2.42034
Dec-05	3045.43	4250.73	2064.01	1284.69	981.42	289.59	13.68	3.30877	2.37057
Jan-06	3082.08	4359.74	2131.22	1298.15	950.86	301.80	45.50	3.35842	2.37420
Feb-06	3088.47	4404.99	2152.35	1338.67	936.12	311.27	91.28	3.29058	2.30712
Mar-06	3165.94	4480.58	2200.78	1382.37	965.15	318.27	98.95	3.24123	2.29022
Apr-06	3161.58	4481.22	2193.25	1397.56	968.33	317.80	111.43	3.20646	2.26221
May-06	3221.45	4541.00	2265.96	1358.65	955.50	322.14	81.01	3.34229	2.37107
Jun-06	3257.40	4662.80	2251.84	1354.44	1005.57	327.57	21.30	3.44261	2.40499
Jul-06	3399.19	4852.70	2322.05	1469.58	1077.14	334.89	57.55	3.30209	2.31303
Aug-06	3430.10	4978.59	2331.90	1471.90	1098.20	346.21	27.48	3.38243	2.33040
Sep-06	3413.20	4952.26	2314.53	1471.62	1098.67	344.85	28.09	3.36518	2.31936
Oct-06	3436.99	4976.86	2330.73	1594.44	1106.26	340.35	147.83	3.12139	2.15562
Nov-06	3502.47	5115.42	2378.38	1575.10	1124.09	355.09	95.91	3.24769	2.22365
Dec-06	3576.89	5164.46	2414.01	1504.12	1162.88	347.95	-6.70	3.43353	2.37805
Jan-07	3609.60	5250.77	2466.49	1635.82	1143.10	362.95	129.76	3.20987	2.20660
Feb-07	3691.78	5337.89	2541.69	1611.88	1150.08	368.79	93.01	3.31159	2.29035
Mar-07	3681.98	5330.55	2534.17	1538.20	1147.80	371.28	19.12	3.46544	2.39368

Apr-07	3762.48	5499.64	2611.66	1695.74	1150.83	384.61	160.31	3.24320	2.21878
May-07	3891.02	5554.83	2721.22	1678.92	1169.80	384.78	124.34	3.30858	2.31758
Jun-07	3945.04	5599.21	2700.75	1662.01	1244.29	380.08	37.65	3.36894	2.37365
Jul-07	4142.28	5811.42	2867.24	1708.22	1275.04	394.87	38.30	3.40203	2.42491
Aug-07	4197.94	5855.53	2906.31	1751.13	1291.62	401.92	57.59	3.34386	2.39727
Sep-07	4209.39	5850.93	2918.96	1660.33	1290.43	399.26	-29.37	3.52395	2.53527
Oct-07	4366.90	5989.02	3069.70	1821.97	1297.21	405.18	119.59	3.28711	2.39680
Nov-07	4467.60	6132.17	3163.78	1821.96	1303.82	419.30	98.83	3.36571	2.45209
Dec-07	4583.36	6223.59	3228.76	1879.05	1354.60	409.69	114.75	3.31210	2.43919
Jan-08	4641.44	6319.86	3337.53	2040.90	1303.91	435.65	301.34	3.09660	2.27421
Feb-08	4720.03	6377.58	3411.95	1891.34	1308.08	438.35	144.92	3.37199	2.49560
Mar-08	4850.87	6674.91	3525.03	1943.95	1325.84	456.89	161.22	3.43369	2.49537
Apr-08	4929.77	6663.80	3595.33	1984.49	1334.44	460.24	189.80	3.35795	2.48415
May-08	4896.02	6598.21	3537.29	1968.01	1358.73	453.16	156.13	3.35273	2.48780
Jun-08	5008.63	6612.15	3557.15	2079.54	1451.47	442.82	185.24	3.17962	2.40853
Jul-08	5129.41	6769.42	3607.92	2208.19	1521.49	440.56	246.14	3.06559	2.32290
Aug-08	5421.17	6994.47	3843.80	2222.90	1577.37	456.84	188.69	3.14655	2.43878
Sep-08	5485.40	7092.97	3811.33	2363.56	1674.07	451.55	237.94	3.00097	2.32082
Oct-08	5696.02	7474.58	4027.43	2354.81	1668.59	493.30	192.92	3.17418	2.41889
Nov-08	5822.80	7523.82	4149.47	2302.41	1673.34	496.03	133.05	3.26781	2.52901
Dec-08	5733.76	7458.78	4023.60	2276.44	1710.16	465.53	100.75	3.27651	2.51874
Jan-09	5698.84	7435.73	4053.26	2489.46	1645.58	690.13	153.75	2.98689	2.28919
Feb-09	5771.92	7553.01	4141.01	2451.44	1630.91	705.86	114.66	3.08105	2.35450
Mar-09	5810.45	7633.51	4180.73	2478.54	1629.72	719.33	129.49	3.07984	2.34430
Apr-09	5799.96	7627.40	4195.30	2558.64	1604.66	721.18	232.80	2.98104	2.26681
May-09	5806.56	7610.92	4210.04	2550.16	1596.51	730.13	223.51	2.98449	2.27694
Jun-09	6026.78	7866.03	4344.05	2678.96	1682.73	751.44	244.79	2.93623	2.24967
Jul-09	6371.45	8261.24	4605.91	2874.56	1765.54	804.91	304.11	2.87391	2.21649
Aug-09	6473.43	8350.86	4658.95	2887.30	1814.47	811.55	261.28	2.89227	2.24203
Sep-09	6614.56	8476.17	4786.93	2890.68	1827.64	820.13	242.91	2.93225	2.28824
Oct-09	6688.93	8564.15	4874.13	2861.45	1814.80	826.01	220.64	2.99294	2.33760
Nov-09	6872.02	8732.35	5029.75	2895.47	1842.27	842.40	210.80	3.01587	2.37337
Dec-09	6928.69	8831.77	5031.28	3009.96	1897.41	851.54	261.02	2.93418	2.30192

Source: Bank of Tanzania

Appendix II

An Eviews programme for running alternative forecast models.

The code presented here can be copied and pasted into an EViews *.prg programme. The data presented in Appendix I is called in Section 1 of the programme.

```
'FILENAME: mult_arma_8_8_10.prg
'Univariate multiplier modeling and forecasting for Tanzania m2 multiplier
'See EViews UGII Chapter 26 Time Series Analysis

'0. Directory to be set to user's own settings.

cd "C:\IGC\money multiplier\"

'1. Open monthly dataset (see Appendix I)
wfopen(type=eviews) mm2data.wf1

spool univariate1
univariate1.options margins titles comments displaynames

subroutine dispname(spool y, string %display_name)
  'must be used immediately after append command
  !spoolsize = y.@count
  if !spoolsize < 10 then
    y.displayname untitled0{!spoolsize} %display_name
  else
    y.displayname untitled{!spoolsize} %display_name
  endif
endsub

'2. Graph multipliers for full period 2001m12 to 2009m12
smpl 2001m12 2009m12
graph grmm2.line(x) multm2
grmm2.draw(line, l) 2.375
grmm2.addtext(t) "M2 multiplier"
freeze grmm2
univariate1.append grmm2

graph grmm3.line(x) multm3
grmm3.draw(line, l) 3.312
grmm3.addtext(t) "M3 multiplier"
freeze grmm3
univariate1.append grmm3

'3. Run alternative ARMA models on sample to2006m12
smpl 2001m12  2006m12
'
'4. look at correlograms of resids (xtra commands needed to name the objects)
for %y multm2 multm3
  univariate1.append {%y}.correl(24)
next

'5.use canned subroutine to compare all armas up to p,q. sub_arma.prg appended at end of this
programme

include sub_arma.prg
group x
x.add c m01 m02 m03 m04 m05 m06 m07 m08 m09 m10 m11
call arma(multm2, x, 4, 4, "multm2_out")
delete tab_*
call arma(multm3, x, 4, 4, "multm3_out")
delete tab_*


'Add arma output to spool
for %y multm2 multm3
  univariate1.append {%y}_out
  %dname = %y + "_arma_output"
  call dispname(univariate1,%dname)
next

'univariate1.display

'Run the preferred specs against some parsimonious alternatives
```

```
equation a1.ls multm2     c time m01 m02 m03 m04 m05 m06 m07 m08 m09 m10 m11  'linear trend M2
equation a2.ls d(multm2) c m01 m02 m03 m04 m05 m06 m07 m08 m09 m10 m11  'RW M2
equation a3.ls multm2      c m01 m02 m03 m04 m05 m06 m07 m08 m09 m10 m11  ar(1)  ma(1)
'ARMA(1,1) M2
equation a4.ls multm2      c   ar(1)  sar(12) ma(1) sma(12) 'SARMA(1,1,12) M2
equation a5.ls multm2      c   ar(1) ar(2) ar(3) ma(1) ma(2)  m01 m02 m03 m04 m05 m06 m07 m08
m09 m10 m11 'ARMA(3,2) with dummies
equation a6.ls multm2      c   ar(1)  ar(2) ar(3)  sar(12) ma(1) ma(2) sma(12) 'SARMA(3,2,12)
M3

'Add equation output to spool
for !i = 1 to 6
  univariate1.append a{!i}
  %dname = "a" + @str(!i) + "_ARMAestimates"
  call dispname(univariate1,%dname)
next

'univariate1.display

'univariate1.display

smpl 2001m12 2006m12
equation f1.ls multm2     c time m01 m02 m03 m04 m05 m06 m07 m08 m09 m10 m11  'linear trend M2
smpl 2007m1 2009m12
fi.forecast(f=na) f1fc f1err

stop
```

****Sub-routine sub_arma.prg

```
' subroutine that estimates all arma models up to specified lags
'
' usage: call arma(ser1, group1, scalar_ar, scalar_ma, tab_name)
'
' where
'
'      ser1: name of dependent variable series
'    group1: name of group of exogenous regressors (should include constant, if desired)
' scalar_ar: integer for highest AR order
' scalar_ma: integer for highest MA order
'  tab_name: name for stored table
'
' the program stores the AIC, SC, and HQ information criteria in a table named {%tabname}

subroutine arma(series y, group x, scalar ar_order, scalar ma_order, string %tabname)

        ' set upper limit lags
        !pmax=ar_order
        !qmax=ma_order

        ' declare test equation
        equation eq_test

        ' declare table to store information criteria
        table((!pmax+1)*(!qmax+1)+2,4) {%tabname}
        setcolwidth({%tabname},1,11)
        setcolwidth({%tabname},2,15)
        setcolwidth({%tabname},3,15)
        setcolwidth({%tabname},4,15)
        {%tabname}(1,1) = "ARMA order"
        {%tabname}(1,2) = "Akaike"
        {%tabname}(1,3) = "Schwarz"
        {%tabname}(1,4) = "Hannan-Quinn"
        setline({%tabname},2)

        ' loop through every combination of arma lags
        !row = 3
        for !p=0 to !pmax
                for !q=0 to !qmax
                        ' build up ar terms
                        if !p=0 then
                                %1 = " "
                        else
                                for !i=1 to !p
```

```
                        %1 = %1 + "ar(" + @str(!i) + ") "
                next
        endif
        ' build up ma terms
        if !q=0 then
                %1 = %1 + " "
        else
                for !i=1 to !q
                        %1 = %1 + "ma(" + @str(!i) + ") "
                next
        endif
        ' estimate model
        eq_test.ls(m=500,c=1e-5) y x {%1}
        ' store output in table
        freeze(tab_{!p}{!q}) eq_test.output
        %order = @str(!p) + "," + @str(!q)
        {%tabname}(!row,1) = %order
        {%tabname}(!row,2) = eq_test.@aic
        {%tabname}(!row,3) = eq_test.@sc
        {%tabname}(!row,4) = eq_test.@hq

        ' test for mininum noise model
        if !row=3 then
                !min_aic = eq_test.@aic
                !min_sc = eq_test.@sc
                !min_hq = eq_test.@hq
                !order_aic = !row
                !order_sc = !row
                !order_hq = !row
        else
                if eq_test.@aic < !min_aic then
                        !min_aic = eq_test.@aic
                        !order_aic = !row
                endif
                if eq_test.@sc < !min_sc then
                        !min_sc = eq_test.@sc
                        !order_sc = !row
                endif
                if eq_test.@hq < !min_hq then
                        !min_hq = eq_test.@hq
                        !order_hq = !row
                endif
        endif

        ' clear string
        %1 = " "
        %order = " "
        !row = !row+1

        ' delete table if not necessary
'       delete tab_{!p}{!q}
        next
next

' indicate best model in table
%aic = "*" + {%tabname}(!order_aic,2)
{%tabname}(!order_aic,2) = %aic
%sc = "*" + {%tabname}(!order_sc,3)
{%tabname}(!order_sc,3) = %sc
%hq = "*" + {%tabname}(!order_hq,4)
{%tabname}(!order_hq,4) = %hq

setline({%tabname},(!pmax+1)*(!qmax+1)+3)
{%tabname}((!pmax+1)*(!qmax+1)+4,1) = "    * indicates best model"

endsub
```