Final report

Modelling the impact of capital account restrictions on the exchange rate in Tanzania

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July 2017

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Modelling the impact of capital account restrictions on the exchange rate in Tanzania

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1. Introduction

This note describes the econometric approaches employed in the IGC presentation *Exchange Rate Dynamics in Tanzania: Capital Mobility and Implications for Intervention* made to the Economic Affairs Sub-Committee of the MAC in Zanzibar on 30 January 2017. The report is methodological in nature and eschews a detailed discussion of monetary and exchange rate policy in Tanzania.[1] It is fundamentally concerned with assessing the effectiveness of restrictions on capital account transactions as a complement to conventional monetary policy instruments in circumstances where the exchange rate is under pressure. The context is as follows. In August 1993, the official and parallel market exchange rates for the Tanzanian Shilling were unified; since then the Tanzanian shilling has maintained a *de jure* floating exchange rate regime, broadly similar to that of its neighbours, Kenya and Uganda.[2] Under this arrangement the central bank does not pursue any target value for the official exchange rate which is instead determined in the interbank foreign exchange market (IFEM). The Bank of Tanzania does, however, intervene in the foreign exchange market in order to pursue a limited number of objectives. Principally these include: securing adequate net official international reserves; meeting domestic liquidity management objectives, in the context where the Bank is a structural net seller of foreign exchange received as budget support from donors and the IFIs; and to avoid destabilizing short-run movements in the IFEM exchange rate.

As a result of exchange rate unification current account transactions are essentially unrestricted but Tanzania has moved gradually, and more slowly than its EAC neighbours, towards the removal of restrictions on capital account transactions (the purchase and sale of financial assets by Tanzanian

[1] Readers interested in the broader context for monetary policy in Tanzania should consult P.J.Kessy, J.Nyella and S.O'Connell "Monetary Policy in Tanzania" in C.Adam, P.Collier and B.Ndulu (eds) *Tanzania: The Path to Prosperity* Oxford University Press (2016).

[2] In the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions* for 2016, Kenya, Uganda and Tanzania are classified as *de facto* 'floating exchange rate regimes' with Tanzania classified as having a 'monetary aggregate target', Uganda an 'inflation targeting framework' and Kenya an 'Other' monetary anchor. Rwanda is classified under 'Other managed exchange rate arrangements' with a monetary aggregate target and Burundi a 'stabilized arrangement' with monetary aggregate.

residents and non-residents). At various times in recent years – particularly at times of exchange rate turbulence following the ramp-up in inflation in 2011 through the exchange rate volatility in 2015-- the Bank of Tanzania has implemented changes in the regulations concerning capital account transactions as adjunct measures to complement conventional monetary policy and intervention instruments.

The rationale for these complementary capital control measures is to put 'sand in the wheels' so as to limit the (short-run) rate of depreciation of the Shilling and/or reduce the volatility in exchange rate movements, consistent with the broader commitment to the exchange rate float.

In this note we examine two alternative approaches to assessing the efficacy of capital control measures on moderating the dynamic path of the nominal exchange rate. The first approach employs a structurally identified vector auto regression model (SVAR) designed to assess the extent to which private agents are able to unwind or 'offset' official monetary and/or exchange rate policy actions and whether these offset effects are moderated in the presence of capital control measures. The second approach employs an 'event study' approach in which we examine exchange rate movements following identified specific changes in capital controls. Here the idea is to estimate a conventional (reduced form) single equation model for the exchange rate and then measure the 'excess deviation' of the actual exchange rate from its counterfactual value following the implementation of policy changes. Sections 3 and 4 present these methods while Section 5 briefly summarizes the results. Before getting to methodological sections, we start by briefly describing the context for the analysis.

2. Exchange Rate Movements and Policy Responses

Figure 1 plots the nominal and real exchange rate between the Tanzanian Shilling and the US dollar from January 2002 to December 2016 where in both cases an upward movement in the plot indicates a depreciation of the exchange rate. The defining feature of this period is that following a steady depreciation in the nominal and real exchange rate through to 2007, the rate of nominal depreciation slowed markedly to the extent that the exchange rate was remarkably stable from mid-2011 to late 2014, before experiencing a sharp depreciation in the first quarter of 2015. Given that Tanzanian inflation over this period consistently exceeded that of the US, this period of relative stability of the nominal exchange rate was associated with a sharp appreciation in the bilateral real exchange rate, which registered a peak-to-trough appreciation of almost 40% between mid-2006 and early 2014.

Part of the explanation for this was the relatively tight monetary stance adopted by the Bank of Tanzania following the inflation spike of 2010-11. This is shown clearly in Figure 2 which plots the nominal exchange rate against the Tanzania-US short-run interest differential. The Bank's tight monetary position kept Shilling liquidity relatively scare driving up its price relative to dollar liquidity.

Figure 1

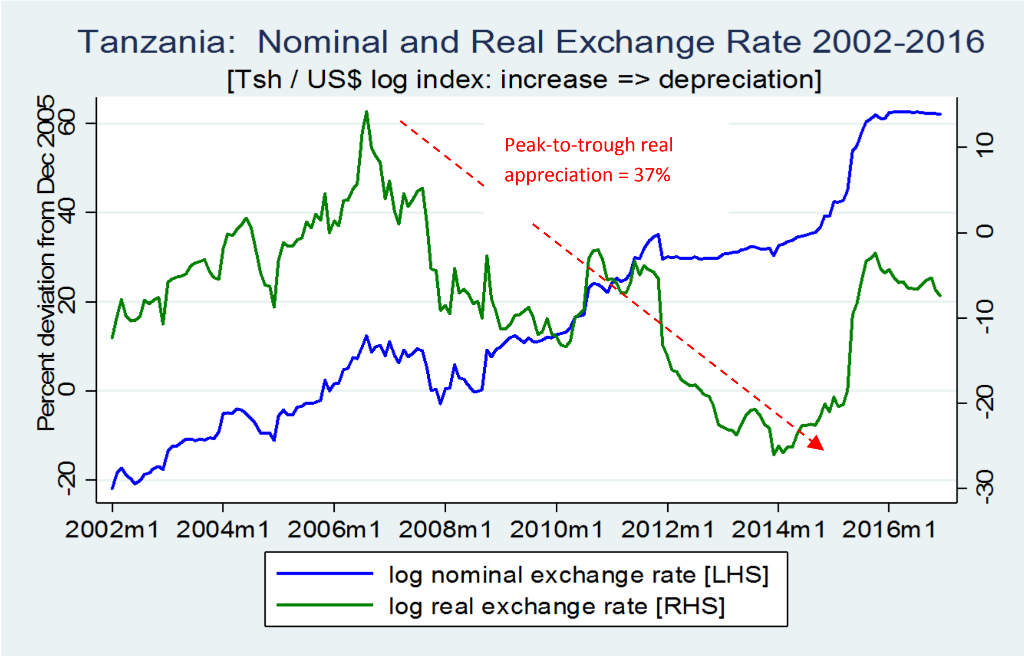
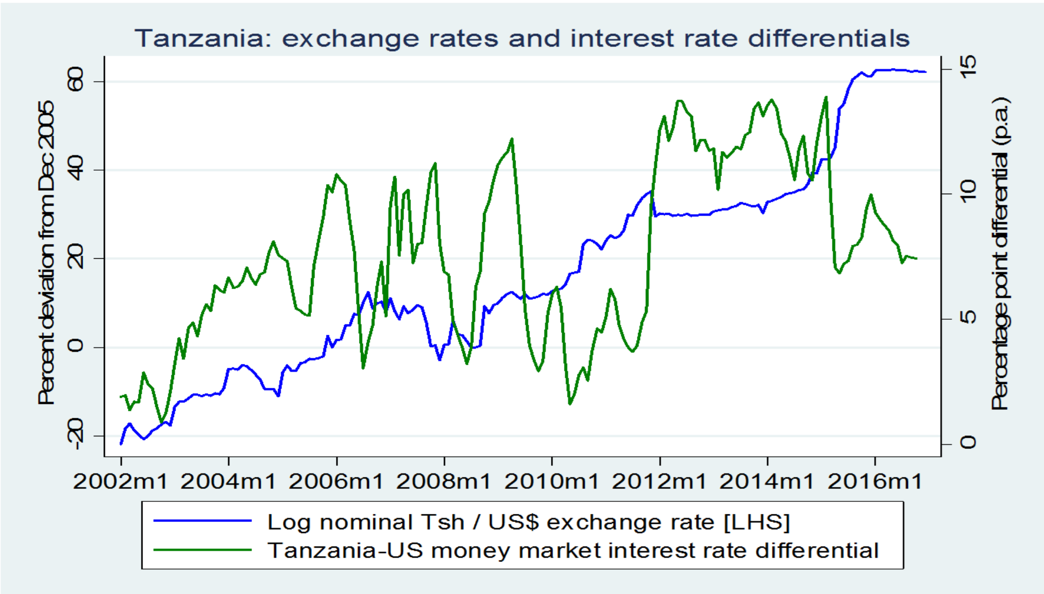


Figure 2



Source: Bank of Tanzania.

In addition, however, during this period the Bank complemented its conventional monetary policy operations with discrete changes to the regulations governing capital account transactions, in each case seeking to reduce the ease with which private agents, either directly or through the banking sector, were able to undertake capital account transactions. The three principal events we focus on are:

- **Event 1: 18th October 2011.** Bank of Tanzania Circular FA56/240/01 introduced a range of capital market restrictions. Specifically the Circular established:
    - limits on non-residents' Tanzania Shilling capital account transactions (including trade in equity and money markets);
    - a prohibition on derivative products except when underpinned by specific activities; and
    - a reduction in banks' permitted net open (i.e. uncovered) foreign exchange position from 20% to 10% of core capital.

- **Event 2: 26th November 2012.** The BoT further reduced banks' permitted net open position from 10% to 7.5% of core capital.

- **Event 3: 29th April 2015** BoT announced a third reduction in banks' net open position from 7.5% to 5% of core capital.

The restrictions on non-resident participation in equity and money markets and the prohibition on derivative trading remained in place through Events 2 and 3 (and are still in force).

In what follows we discuss two approaches to examine the efficacy of these measures.

3. Short-Run Capital Mobility in Tanzania: A Structural VAR Approachl[3]

In this section we develop a set of structural VAR estimates to assess the degree of short-term capital mobility in Tanzania and, by extension, how this mobility is affected by capital control measures. We draw on an old tradition in empirical macroeconomics known as the 'offset coefficient approach' which entails modelling the dynamic relationships between exchange rate depreciation (ΔlnE), changes in net foreign assets (ΔNFA) and changes in net domestic assets (ΔNDA), where the latter is our measure of monetary policy actions by the authorities.

3.1 The offset coefficient approach

The essential argument is straightforward. We can think of the private sector as holding a portfolio of domestic and foreign financial assets. Monetary policy actions by the central bank – forex intervention and/or open market operations -- alter the relative supplies of the two assets and hence their market clearing price (which is either the exchange rate or interest rate depending on the exchange rate regime), *ceteris paribus.* The central issue here is how easily the private sector can respond to this incipient price signal in order to re-optimize its portfolio. The more easily it can, in other words the higher the elasticity of substitution between domestic and foreign assets, the less

[3]. This section is based on an earlier background note prepared for C. Adam, P. Kessy, C. Kombe and S. O'Connell (2012) "Exchange Rate Arrangements in the Transition to Monetary Union" Central Bank of Tanzania and International Growth Centre, February.

effective is monetary policy and *vice versa.*[4] This is what we mean by the 'offset' and it is at this juncture capital control measures may play a role by reducing the ease with which the private sector can alter its asset portfolio.

The mechanics of the offset are as follows, where it is useful for purposes of exposition to contrast the hypothetical cases where, first, the exchange rate is fixed or very heavily managed and then where it is freely floating. This then allows us to consider the empirical reality of Tanzania where there is some exchange rate intervention by the central bank. The key point is that under a fixed exchange rate regime all external 'adjustment' occurs through changes in NFA (while the exchange rate is fixed) whereas in a pure float adjustment occurs through changes in the exchange rate only and NFA are constant.

To fix ideas we start with a simplified representation of the central bank's balance sheet which takes the form

$$H = NFA + NDA, \tag{1}$$

where *H* denotes reserve money (the liabilities of the central bank), *NFA* net foreign assets and *NDA* net domestic assets, consisting of domestic credit (overwhelmingly to government)[5] and, with a minus sign, the bank's net worth:

$$H = NFA + DC - NW.$$

Expressed as changes over time, the balance sheet implies

$$\Delta H = \Delta\$NFA + Rev + \Delta DC - \Delta NW, \tag{2}$$

where we have decomposed the change in net foreign assets into the central bank's net acquisition of foreign assets *in foreign currency terms* and the net revaluation effect arising from movements in the exchange rate.

Under heavily managed exchange rates (a fixed exchange rate or periodic adjustment), a common approach to assessing the degree of short-term capital mobility is to measure the degree to which a policy-induced expansion in domestic liquidity – i.e., in the monetary base through increased DC – is offset by an endogenous decline in liquidity due to reduced net foreign assets. The latter effect occurs through capital outflows, as portfolio holders respond to lower domestic interest rates by substituting in favour of foreign assets. To implement this approach, we need a measure of policy-induced changes in net domestic assets, as well as a domestic-currency measure of the net

[4] See J.Ostry *et al* (2012) "Two Target, Two Instruments: Monetary and Exchange Rate Policies in Emerging Market Economies" *IMF Staff Discussion Note 12/01* for a discussion of how central banks can and should use foreign exchange intervention within an inflation-focused monetary policy framework when the capital account is not fully integrated with world markets.

[5] Outside of QE arrangements, central banks typically do not lend to the private sector except in their lender-of-last-resort role where it lends to (distressed) private sector banks. The analysis in this note assumes domestic credit to the private sector from the central bank is zero.

acquisition of international reserves. In other words the VAR would be defined in terms of $\Delta \$NFA$ and ΔNDA (since, by definition $\Delta lnE = 0$ in a fixed exchange rate).

Under a purely floating exchange rate, the *desired* capital outflow associated with a monetary expansion affects the exchange rate rather than reserves and the VAR in this case would be in terms of ΔNDA and ΔlnE (since, by definition $\Delta \$NFA = 0$ in a pure float).

Under a managed float, such as prevails in Tanzania, the same desired outflow (at initial exchange rates) may affect either the exchange rate or reserves, or some combination of the two. We can therefore extend the traditional offset coefficient literature to the case of a managed float by adding exchange rate depreciation to the two existing variables. We therefore estimate three-variable VARs in $[\Delta \ln E_t\,,\ \Delta \$NFA_t,\ \Delta NDA_t]$ and assess offset behavior by examining the impulse responses of both depreciation and reserve accumulation to 'adjusted' changes in domestic credit.

3.2 Defining variables for the analysis

To get to this point we need to be able to define the variables correctly. In other words we need a measure of the *purposive* change in net foreign assets and net domestic assets (i.e. we need to get rid of the changes due to movements in the exchange rate or due to non-monetary policy actions). Appendix I explains how we purge the data of exchange rate revaluation effects.

Measuring policy-induced changes in domestic liquidity is a little more complicated. The developed-country literature sometimes uses the change in domestic credit, but for low-income countries this approach may be compromised by transactions that take place entirely within the public sector and do not constitute any change in monetary policy. The two main examples are government transactions in foreign exchange with the central bank, typically arising from the management of aid flows for budget support, and central bank payments of dividends to government. These transactions alter domestic credit but have no direct impact on the monetary base. We will therefore work with an 'adjusted' measure of the change in NDA.

Consider first foreign aid transactions. An aid inflow to the government will typically involve the government swapping the aid dollars for domestic-currency deposits at the central bank and then spending a portion of these dollars in due course on imports. As each of these transactions occurs, the change in net domestic credit is offset by an equal change in international reserves ($\Delta DC = -\Delta \$NFA$ in equation 2), leaving the monetary base unchanged. Dividend payments also change domestic credit without altering the state of liquidity, because the reduction in net domestic credit is offset by a reduction in net worth ($\Delta DC = \Delta NW$). We want to make sure that these changes in domestic credit do not get mis-interpreted as purposive monetary-policy changes in domestic credit.

What we do in this paper is to generate an 'adjusted' measure that isolates the monetary policy component of the change in net domestic assets. Specifically, we first subtract the change in net worth, net of exchange-rate valuation effects, from the change in domestic credit:

$$Adjusted\ \Delta NDA_t = \Delta DC_t - [\Delta NW - Rev_t] = \Delta H - \Delta \$NFA_t. \qquad (3)$$

The adjustment for net worth purges domestic credit of changes that are automatically offset by changes to the central bank's equity and reserve accounts. The addition of exchange rate valuation changes then purges the resulting measure of distortions from exchange-rate changes.

The intent is to isolate movements in domestic credit that are potentially associated with the central bank's use of domestic assets to manage liquidity. As is apparent from the second equality in (3), the adjusted change in domestic credit can be simply measured as the change in the monetary base minus the domestic-currency value of the central bank's net acquisition of foreign exchange.

A problem of spurious inference remains, however, if there are substantial transactions in foreign exchange between the government and the central bank. These transactions produce equal and offsetting changes in domestic credit and foreign exchange holdings at the central bank. They therefore 'look like' rapid capital movements in response to changes in domestic interest rates, even though the stance of monetary policy is unchanged. Failure to control for these transactions would significantly *overstate* the offset coefficient. In our econometric specification, we handle this issue by interpreting any offsetting movements in domestic credit and international reserves that occur within the space of a month (the frequency of our data) as transactions in foreign exchange between the central bank and the rest of the public sector.

This 'identifying restriction', which we discuss below, means that our assessment of short-term capital mobility is restricted to behaviour that we can identify econometrically as being 'additional' to these internal transactions. Notice, however, that if there is substantial within month private offset activity, this will be interpreted as public sector activity and hence our measured offset will be biased downwards. Our strategy will therefore give us a lower-bound on the offset although, as we shall see below, we are nonetheless able to identify the impact of changes in capital control measures.

To summarize, therefore, our focus in this exercise is on the impulse-response functions from a structural VAR defined over exchange rate depreciation (ΔlnE), changes in the dollar value of net foreign assets ($\Delta\$NFA$) and changes in 'adjusted' net domestic assets ($\Delta NDAa$). Our primary interest is on the 'offset' which is inferred from the response of the exchange rate and net foreign assets to impulses in adjusted net domestic assets. In addition, however, we can interpret other impulse responses generated by the VAR. First, the response of $\Delta NDAa$ to shocks in $\Delta\$NFA$ provides evidence on the degree of sterilization of foreign-exchange transactions; and second, the responses of $\Delta NDAa$ and $\Delta\$NFA$ to shocks to the exchange rate provide evidence on the degree to which balance of payments shocks constrain monetary policy. We do not focus on these latter impulse responses in this note.

3.3 Structural identification of the VAR.

As is standard when working with VAR models we need a strategy to authoritatively identify structural impulses in particular in this case the monetary policy shock. One standard option would be to adopt a recursive ordering or Choleski factorization which seeks to order the variables from the 'most exogenous' to the least. In the case being considered here the most obvious ordering for the three-variable VAR would be $[\Delta NDAa, \Delta\$NFA, \Delta lnE]'$ or $[\Delta\$NFA, \Delta NDAa, \Delta lnE]'$ which allow for either innovations in adjusted net domestic assets or dollar-valued net foreign assets to be the driving shocks in the system with the exchange rate able to respond contemporaneously to all variables.

We do not report the results under these recursive orderings here but both are easy to run from the Eviews program in Appendix I. Instead we impose some explicit restrictions on the VAR to produce a structural identification as follows.

First, defining the vector of variables as $y_t = [\Delta NDAa, \Delta\$NFA, \Delta lnE]'_t$ we write the structural VAR is

$$By_t = Ay_{t-1} + \varepsilon_t \quad (4)$$

where B and A are 3x3 parameter vectors describing the contemporaneous and lagged interactions between the element of y_t. The reduced-form representation to be estimated from the data takes the form

$$y_t = \Pi y_{t-1} + u_t \quad (5)$$

where $\Pi = B^{-1}A$. We know from econometric theory that the reduced form and structural shocks are related by $u_t = B^{-1}\varepsilon_t$ and in order to exactly identify the structural shocks in this model we need at least $\frac{n^2-n}{2} = 3$ restrictions on the estimated B^{-1} covariance matrix. Identification in this context means that we can give the estimates errors of the VAR (the $\hat{u}_t$ sequences) a structural or economic interpretation.

Our strategy is as follows. Let $u = [u_D, u_R, u_E]'$ be the vector of reduced-form innovations from the three-variable VAR in $[\Delta NDAa, \Delta\$NFA, \Delta lnE]'$. Let $\varepsilon = [\varepsilon_D, \varepsilon_A, \varepsilon_B]'$ be the vector of mutually-exclusive structural shocks where ε_D demotes the domestic credit or 'monetary policy' shock; ε_A the *contemporaneous* shock to net foreign assets which we associate with aid or aid-financed domestic spending shocks; and ε_B non-aid balance of payments shocks.

What we are trying to do is define a set of theory-informed restrictions on the contemporary covariance matrix below. To keep the notation simple we re-label B^{-1} as C.

$$u = B^{-1}\varepsilon = C\varepsilon => \begin{bmatrix} u_D \\ u_R \\ u_E \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_D \\ \varepsilon_A \\ \varepsilon_B \end{bmatrix} \quad (6)$$

We proceed as follows:

<u>First</u>, following from the previous paragraphs, we will assume that when aid arrives it is transferred to the central bank (an increase in NFA) and simultaneously the government account is credited (so there is an equal and opposite reduction in NDA). This gives us our first identifying restriction

$$u_D = \varepsilon_D - \varepsilon_A$$

which translates into the restriction on the **C** matrix of $c_{12} = -c_{11}$.

Second, reflecting our earlier comments on the managed nature of the exchange rate in Tanzania we allow for balance of payments shocks (ε_B) to impact both movements in reserves and the exchange rate contemporaneously. Thus an adverse balance of payments shock would see a decline in reserves ($u_R < 0$) and a depreciation in the exchange rate ($u_E > 0$). We reflect the distribution by the weights β and $(1-\beta)$ where we let the data determine the size of β. For example, in a pure float $\beta \rightarrow 0$ and vice versa for fixed exchange rate. Noting the opposite signs on u_R and u_E we reflect this with the restriction on the **C** matrix of the form $c_{23} = -(1-c_{33})$. Noting that for a positive shock ε_B we expect c_{33}<0 which allows us to re-write this restriction as $c_{23} = (1+c_{33})$.

Third, if aid shocks are fully sterilized contemporaneously by offsetting movements in net domestic assets as per our first identifying restriction, this implies a further restriction on **C** such that $c_{32} = 0$.

Finally, we assume that 'non-aid' balance of payments shocks do not contemporaneously affect adjusted net domestic assets so that $c_{13} = 0$. Strictly, therefore, we end up with an over-identified covariance matrix; it is trivial to relax the final identifying restriction so that the matrix is 'just-identified

This final restriction is a strong one because it implies that non-aid balance of payments shocks are allowed to feed through to the monetary base contemporaneously (because there is no offset via reductions in domestic credit). This may seem unreasonable under a money-targeting regime but one possible interpretation of this is that the MPC's policy decisions are not made contemporaneously but are based on information available at the beginning of the period so that policy choices are set before balance of payments shocks are realized and hence the policy response to these shocks is lagged by one period. Given that the system is over-identified with four restrictions It may be worth exploring whether this restriction could be dropped. In the case of the results presented below, dropping this additional restriction does not alter the results.

All other coefficients in the **C** matrix are unrestricted. Putting this together we get the following restricted covariance matrix

$$u = C\varepsilon => \begin{bmatrix} u_D \\ u_R \\ u_E \end{bmatrix} = \begin{bmatrix} c_{11} & -c_{11} & 0 \\ c_{21} & c_{22} & 1+c_{33} \\ c_{31} & 0 & c_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_D \\ \varepsilon_A \\ \varepsilon_B \end{bmatrix} \quad (7)$$

The parameters of the structural VAR can now be recovered, where the diagonal of the ***C*** matrix indicate the variances of the underlying orthogonal shocks.

3.4 Incorporating capital control measures

In order to evaluate the effect of capital control measures we can augment the SVAR in equation (4) with a vector of strictly exogenous variables capturing the successive tightening of capital controls. The augmented SVAR takes the form

$$By_t = Ay_{t-1} + Dz_t + \varepsilon_t \quad (8)$$

where y_t is as before and the vector $z_t = [z_t^1, z_t^2, z_t^3]'$ consists of three 1-0 dummy variables corresponding to the three events described in Section 2 above, and D is a 3x3 vector of parameters. If we assume the vector of capital control measure dummies is strictly exogenous, augmenting the SVAR in this manner does not alter the identification of the structural shocks. This is a strong assumption to which we return below in the discussion of these methods.

3.5 Results and interpretation

There are a number of ways in which we can present the SVAR results. Table 1 provides a summary of core SVAR coefficient estimates. The SVAR is estimated with four lags on each of the endogenous variables but for ease of presentation we report the sum of the coefficients on the lagged values.[6] The VAR is estimated on monthly data from June 2002 to July 2016 and includes a full set of monthly dummy variables to absorb any systematic seasonality in the data.

Of particular interest in this paper is the first column which constitutes the equation for the depreciation of the exchange rate, conditional on the lagged values of the change in NFA and NDA and the vector of capital controls. What we see is that there is strong persistence in the depreciation of the exchange rate (the sum of the lagged dependent variable is 0.94) and that (purposive) changes in net domestic assets are positively and significantly associated with the depreciation of the exchange rate. Hence an increase in domestic credit to government, *ceteris paribus*, is associated with a deprecation in the exchange rate. [Note here that the coefficient measures the semi-elasticity of the rate of depreciation (in percent, where 1=100%) to a Tsh 1bn change in adjusted NDA.]

More interesting, though, are the results on the capital control measures which suggest that Event 1 (in October 2011) have a significant impact on the rate of depreciation of the exchange rate. Other things equal, the capital control measures led to a weakly-significant *appreciation* of the nominal exchange rate. The marginal impact of Event 2 was about have a strong in magnitude but not statistically significant, while Event 3 also had no significant impact on the exchange rate but here the sign on the coefficient is reversed.

It is conventional to examine these effects through the lens of impulse response functions (IRFs) which summarize the dynamic response of each of the endogenous variables in the VAR to each of the structural shocks (in our case monetary policy shocks, aid shocks and non-aid balance of payments shocks). Since we treat the capital control dummy variables as strictly exogenous we cannot generate impulse response functions in the conventional manner. But what we can do is generate IRFs from the SVAR in Equation (4) where we do not control for capital control measures and for the SVAR in Equation (8) where we do. The difference between the two sets of IRFs give use a measure of the contribution of capital control measures to the dynamic properties of the model. So, for example, comparing the difference in the IRFs for the exchange rate in response to a monetary policy shock from the two SVARs response of the exchange rate to monetary policy shocks tells us by how much, and over what period, the capital control measures moderate exchange rate dynamics.

[6] The underlying SVAR results can easily be recovered by running the Eviews programme in Appendix II.

Table 1

Vector Autoregression Estimates

Sample: June 2002 to July 2016

	Dependent Variable					
	Δs(t)		**ΔNFA(t)**		**ΔNDA(t)**	
Sum Δs(t)	0.94	*	3.59	*	11.76	**
Sum ΔNFA(t)	-0.0021		-0.68	***	-0.09	*
Sum ΔNDA(t)	0.004	**	-0.38	***	-0.3	**
z(Oct 2011)	-1.05	*	-202.8	*	165.1	*
z(Nov 2012)	-0.61		-344.5	**	531.6	**
z(Apr 2015)	0.29		-300.7	**	47.8	
R-squared	0.270		0.314		0.342	
Mean dependent	0.484		19.115		17.299	
S.D. dependent	1.895		189.195		231.139	

Notes: VAR estimated with 4-lags on each variable and includes a full vector on monthly dummy variables; NFA and NDA purged of exchange rate valuation effects; */**/*** denotes 10%/5%/1% significance.

To show this we first report the full set of full set of accumulated IRFs for the structural VAR with capital controls as reported above. These are produced directly from EViews and are shown in Figure 3. Next, to focus on the exchange rate, we overlay the three exchange rate IRFs for the case where we do not control for the capital account measures (Figure 4) and finally in Figure 5 we plot the difference between these IRFs and those generated from the mode in Equation (8) where we do control for capital account restrictions.

The first row of Figure 3 (re-produced for ease of reading in Figure 4) shows a conventional pattern of responses with an aid inflow tending to appreciate the nominal exchange rate and an expansionary monetary policy (NDA) shock tending to depreciate the nominal exchange rate. The way we have defined the identifying restrictions means that a shock to the non-aid balance of payments is a *deterioration* in the incipient external position which also leads to a depreciation in the exchange rate.

Figure 5 is the interesting plot. What this shows is that when we control for capital account restrictions, the exchange rate response is *more appreciated* when the economy is hit by a monetary policy shock or an (adverse) external balance of payments shock and *more depreciated* when hit by an aid shock. In other words, the capital controls appear to work exactly as theory work predict. However, it is instructive to examine the scale of the differential effects as shown in Figure 5: they are extremely small relative to the overall impulse response shown in Figure 4.

Figure 3

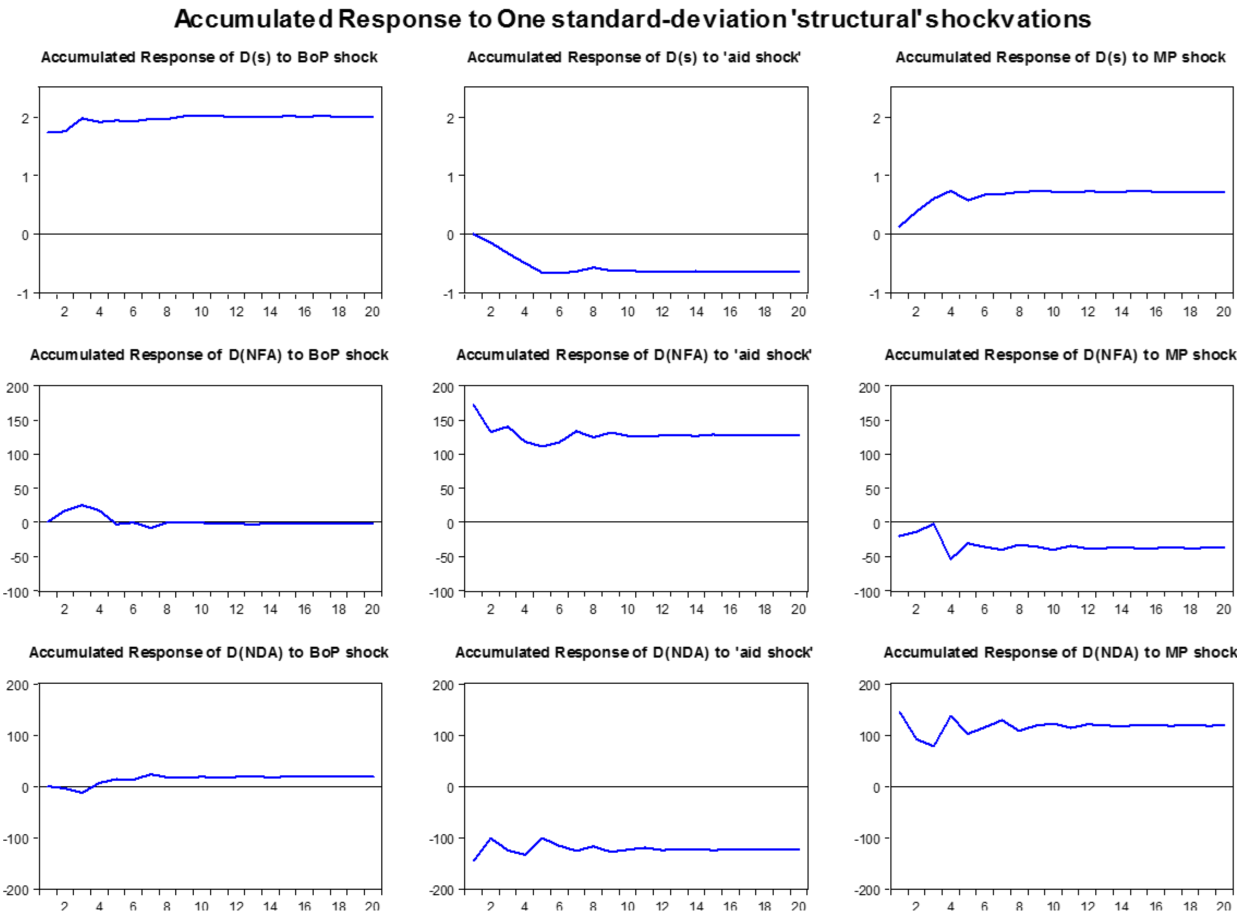


Figure 4

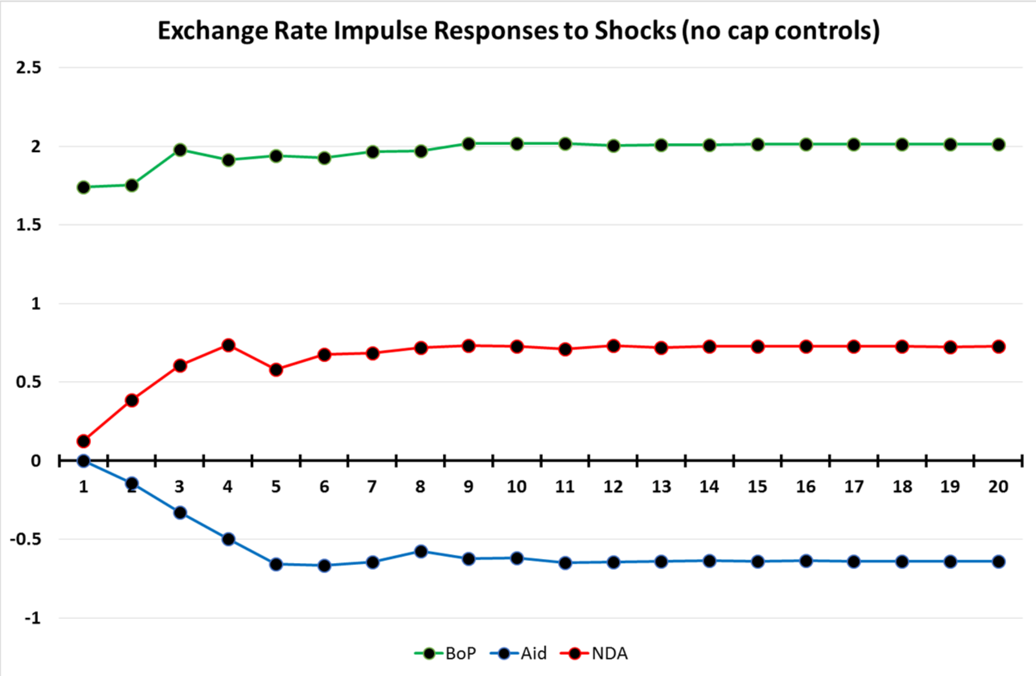
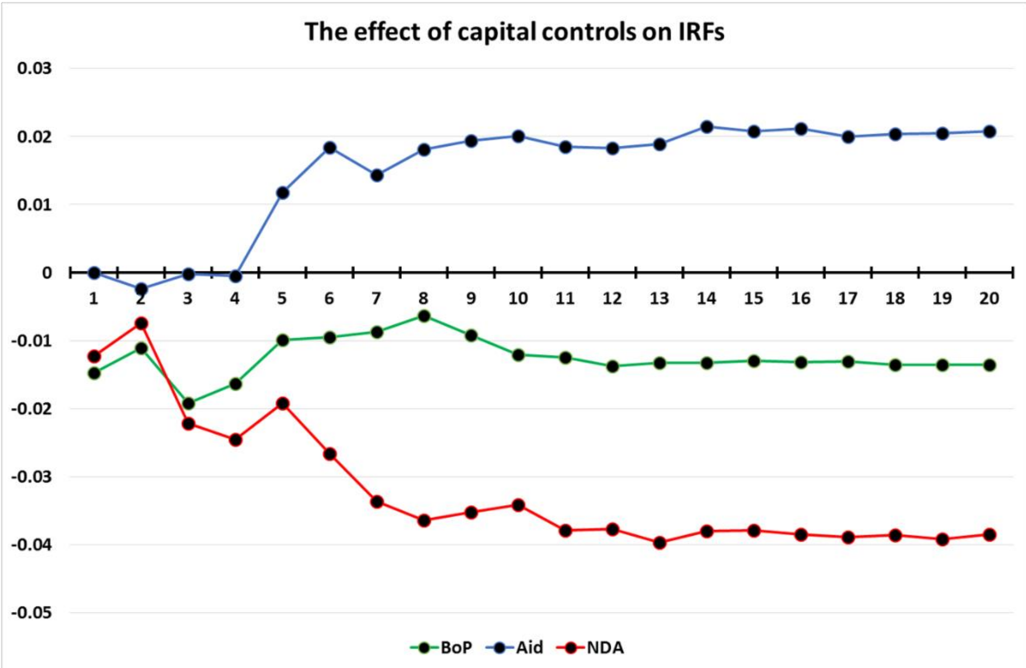


Figure 5



3.6 Interim conclusions

The offset analysis provides the following interim conclusions. First, capital account control measures appear to exert theoretically plausible but weak impact on exchange rate dynamics. Specifically, we find that in the presence of capital account restrictions we find that the exchange rate adjusts *less* to external shocks (whether there is partial sterilization or not) and to purposive NDA (monetary policy) measures. In other words, they limit the extent of the private sector's 'offset capacity' and therefore increase the efficacy of domestic monetary policy to lean against incipient exchange rate movements. Second, however, the scale of these effects is very small and, as the results in Table 1 suggest, these effects diminish with repeated application of such measures.

We will discuss the implications of these results in Section 5 below but before this we turn to an alternative 'Event Study' approach to exploring the same phenomenon.

4. Event Study

In this section we repeat the same analysis but instead use an event study approach. This methodology is widely used in the financial econometric literature to analyze the impact of specific events such as changes in regulations or in dividend or profit announcements (see for example MacKinlay, 1997). Similar methods have been used to study foreign exchange markets (see Neely, 2005). In our case the 'events' comprise the three capital account restriction announcements discussed above, and the behaviour of the exchange rate is analyzed during the days surrounding each event.

We pay particular attention to the direction and magnitude of ex-post abnormal returns, which represent the deviation of the observed exchange rate returns from an appropriately defined counterfactual. Significant abnormal returns, indicate the presence of event-induced price deviations, in other words offer evidence of the effectiveness of the restrictions. Generating appropriate counterfactuals is crucial, as this allows for the cleaner identification of the impact of each event.

As with the offset analysis, we find that restrictions on capital account transactions were initially effective, but that subsequent tightening of limits on banks' net open foreign exchange position were progressively less effective. This results is consistent with the international evidence on historical experiments with capital outflow controls (see for example Magud et al. (2011) which suggest that anticipation and innovation by the markets in response to the controls tends to undermine their effectiveness.

4.1 Econometric Approach

In this approach the impact of specific 'events' is assessed by examining the change in the behaviour of exchange rate 'returns' (i.e. the depreciation of the exchange rate or its volatility) around the event. In the language of event studies we focus on 'abnormal returns' defined as the difference between the actual return (or exchange rate depreciation) and that predicted by our counterfactual model (the so-called 'normal return'). In contrast to the offset analysis we exploit high-frequency daily data to conduct the event study.

The events in this case are as described above. Around each event, we define 'pre-event' and 'post-event' windows, where the former is used to estimate the 'normal returns' model and the latter the period over which we compute the 'abnormal returns'. Working with daily data, we set the pre-event window to be six weeks (although for sensitivity analysis we consider a window of up to 10 weeks). The post-event window is varied between one and four weeks. The shorter the window the less likely the 'abnormal returns' are confounded by factors other than the capital account restrictions but at the same time, the shorter the window the harder it is to allow for gradual market adjustments, which may be important in thinly traded financial markets such as the IFEM in Tanzania, where information acquisition is costly. Hence the need for some sensitivity analysis.

We analyze the ex-post cumulative abnormal returns (CARs), as these quantities indicate the direction as well as the magnitude of the event's impact. The cumulative abnormal return over the period from $t = t_1$ to $t = t_2$ where t_1 and t_2 lie in the post-event window are defined as

$$CAR(t_1, t_2) = \sum_{t=t_1}^{t_2} AR_t \quad (9)$$

where the abnormal return for each period t is $AR_t = R_t - NR_t$, and and R_t and NR_t are respectively the observed and normal returns. The framework used to generate normal returns in the case of the Tanzanian monetary policy framework and foreign exchange rate market is developed further in Section 4.2

We assess the effectiveness of our capital control measures by assessing the sign and significance of the CARs. In our case a negative and significant CAR over the post-event window indicates that exchange rate appreciated relative to the counterfactual. Parametric *t-test*s and a non-parametric Wilcoxon (1945) sign-rank test are employed, where the latter is computed by ranking the observed differences between the cumulative abnormal returns and zero, the latter of which would imply that the event had no impact. Under the null hypothesis that each *CAR=0* there would be a similar number of positive and negative ranks. The Wilcoxon null hypothesis assumes a standard normal distribution.

For the t-test, MacKinlay (1997) shows that under the null that the cumulative abnormal returns are zero $CAR(t_1, t_2) \sim N(0, \sigma_t^2)$ where $\sigma_t^2 = (t_2 - t_1 + 1)\sigma_{et}^2$ and σ_{et}^2 is the sample variance of the abnormal returns over the post-estimation window.

4.2 Estimating normal returns

Normal returns are derived as forecasts from a model of the exchange rate depreciation fitted in the pre-event window. Here we draw on the standard literature on exchange rate forecasting (reviewed in detail in Frankel and Rose, 1995, Engel et al., 2007, Rossi, 2013) but seeks to account for the fact both that the Bank of Tanzania is transitioning from money to inflation targeting, and that it frequently engages in foreign exchange rate intervention.

An important feature of this literature (see Meese and Rogoff, 1983) is that it is often difficult to forecast better than a random walk model of the exchange rate which implies the best one-period ahead forecast of the exchange rate is the current value (a so-called 'no change forecast'). To engage with this feature of the data we develop a set of short-run models consisting of VAR models and single-equation ARIMA models. In both cases we assess the forecast power of each model against the no-change forecast from the random walk.

The basic VAR model is defined in terms of five core variables $y_t = [\Delta s_t, i'_t, \Delta m_t, \chi_t, \omega_t]'$ where the elements are: Δs_t the daily change in the log of the official Tsh-US$ exchange rate (which itself is the weighted average rate established on the previous day's trade on the interbank foreign exchange market (IFEM); i'_t, daily interest rate spread between the Tanzanian and US overnight rates; Δm_t the day-on-day change in reserve money; χ_t the BoT's planned net sales of foreign exchange into the IFEM; and ω_t the difference between daily actual and planned foreign exchange interventions.

Given the acknowledged weakness of exchange rate forecasting models and the fact that the monetary policy regime in Tanzania is in transition we compare the full set of 12 permutations around this core model. These are described in Table 2.

Table 2: Model permutations

Model	**Description**
$y_{At} = [\Delta s_t, i'_t]'$	Exchange rate and interest differential (simple UIP)
$y_{Bt} = [\Delta s_t, i'_t, \omega_t]'$	UIP with idiosyncratic BoT intervention
$y_{Ct} = [\Delta s_t, i'_t, \chi_t]'$	UIP with BoT planned net intervention
$y_{Dt} = [\Delta s_t, i'_t, \chi_t, \omega_t]'$	UIP with BoT planned and idiosyncratic net intervention
$y_{Et} = [\Delta s_t, \Delta m_t]'$	Exchange rate with reserve money (monetary model)
$y_{Ft} = [\Delta s_t, \Delta m_t, \omega_t]'$	Monetary model with idiosyncratic BoT intervention
$y_{Gt} = [\Delta s_t, \Delta m_t, \chi_t]'$	Monetary model with BoT planned net intervention
$y_{Ht} = [\Delta s_t, \Delta m_t, \chi_t, \omega_t]'$	Monetary model with BoT planned and idiosyncratic net intervention
$y_{It} = [\Delta s_t, i'_t, \Delta m_t]'$	Exchange rate with interest rate differential and reserve money (hybrid model)
$y_{Jt} = [\Delta s_t, i'_t, \Delta m_t, \omega_t]'$	Hybrid model with idiosyncratic BoT intervention
$y_{Kt} = [\Delta s_t, i'_t, \Delta m_t, \chi_t]'$	Hybrid model with BoT planned net intervention
$y_{Lt} = [\Delta s_t, i'_t, \Delta m_t, \chi_t, \omega_t]'$	Hybrid model with BoT planned and idiosyncratic net intervention

Note: all models include daily dummy variables (to control for day-of-the-week trading effects); the VIX index to reflect global market volatility; and spot and future oil price measures to reflect external terms of trade uncertainty.

Exchange rate forecasts from this suite of VAR models are compared to the exchange rate forecast from a random walk model: $\Delta s_t = 0$ where the h-step ahead forecast error for each model is computed as

$$\hat{\varepsilon}_{t+h|t} = \hat{s}_{t+h} - s_{t+h}$$

To complement the multivariate analysis, we also check the forecasting properties of univariate models of the exchange rate. Univariate, or *ARIMA(p*, *d*, *q)*, models seek to describe the data generating process behind a particular time series by specifying its order of integration (*d*), as well as its appropriate autoregressive (*p*) and moving-average terms (*q*) components. As the exchange rate is typically integrated of order one in the data, we work with *ARIMA(p*,1, *q)* models and use the Box-Jenkins procedure for selecting the optimal *ARIMA(p*, *d*, *q)* model.

4.3 Forecast evaluation

We evaluate each model's predictive ability by estimating the model over the first three quarters of the pre-event window and retaining the final quarter of the same to validate the forecast performance of the model. We also conduct sensitivity analysis by varying the breakpoint, *K*. Forecast accuracy is evaluated using the root mean squared forecast error (RMSFE) and the Diebold and Mariano (2002) test of predictive accuracy relative to the no-change forecast from the random walk model. The null hypothesis of the Diebold and Mariano (2002) test is that two models have equal predictive accuracy. For a model to beat the random walk, we first require that the RMSFE of that model is lower than that of a random walk or, equivalently, that the *relative* root mean squared forecast error (RRMSFE) is less than one. It is important to note that our focus here is on forecast accuracy: it is possible that one model fits better than another over the estimation window but performs less well out-of-sample. Given the nature of the exercise, we focus on their abilities to generate good out-of-sample forecasts. Models with good in-sample fit but poor forecasting accuracy are not useful for our purposes. That said, we still require models to satisfy certain in-sample criteria before venturing to assess their predictive abilities. In particular, we require that the estimated models have white noise residuals (i.e. not heteroskedastic nor serially correlated), and also, in the multivariate case, be dynamically stable.

4.4 Model performance

Table 3 summarizes the estimation and forecasting results for Event 1 (similar results, available on request are generated for Events 2 and 3). We find that for Event 1, Model L, the hybrid model with BoT intervention dominates optimal. This hybrid model passes the pre-event window criteria of stability and white noise residuals, also has jointly significant lags, forecasts significantly differently than the random walk at the 5% significance level, and has the lowest RRMFE among all the models of 0.66.

Amongst the single equation ARIMA models the one with the highest predictive accuracy is an *ARIMA*(2,1,0) on the exchange rate, with a relative root mean square forecast error of 0.78, significantly higher than our preferred VAR-based models.

We do not report the details here but for Events 2 and 3, however, the predictive accuracy of the univariate and multivariate models is not significantly different than that of a random walk. For the sake of consistency as well as to control for the effects of conventional monetary policy, we use the hybrid model L to generate normal returns for all three events.

We now turn to the results of the event study.

Table 3: Event 1 Forecast Model Selection Criteria

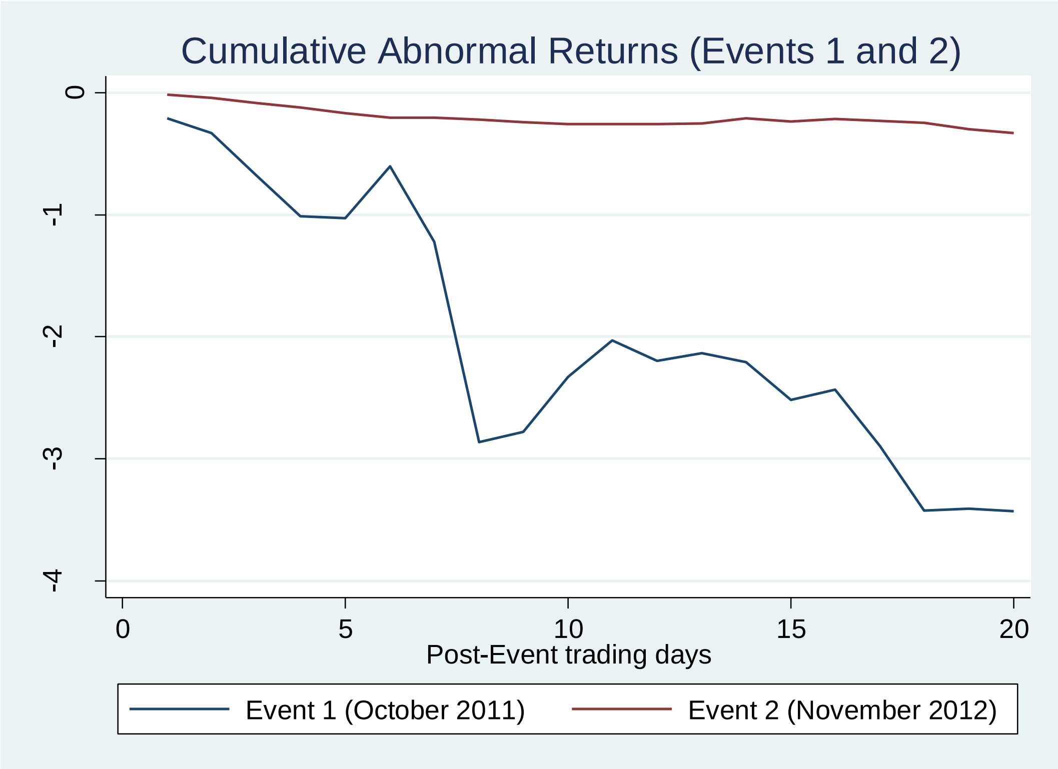
Model	y_A	y_B	y_C	y_D	y_E	y_F	y_G	y_H	y_I	y_J	y_K	y_L
Model adequacy												
WN(p-value)	0.22	0.30	0.20	0.33	0.27	0.14	0.62	0.40	0.64	0.10	0.28	0.17
Wald (p-value)	0.01	0.10	0.24	0.17	0.00	0.02	0.46	0.05	0.00	0.00	0.00	0.00
Stability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Forecast performance												
DM (p-value)	0.05	0.05	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.06	0.05	0.05
Relative RMSFE	0.86	0.86	0.87	0.87	0.75	0.75	0.79	0.76	0.66	0.67	0.68	0.66

Notes: WN (p-value) refers to the significance level of a Portmanteau white noise test with *H0* : Residuals are white noise; Stability refers to whether the eigenvalues of the VAR lie inside the unit circle; Wald (p-value) refers to the significance level of the Wald lag exclusion test with *H0* : Endogenous variables at a given lag are jointly zero; DM (p-value) refers to the significance level of the Diebold-Mariano test with *H0* : VAR forecast is no different than a NCF from a random walk; Relative RMSFE compares the RMSFEs of the VAR and a random walk. A RRMSFE<1 implies that the VAR forecast is better than a NCF.

4.5 Event study results

Finally we generates the CARs. To recap, the preferred model is estimated over the 6-week pre-event window and then forecast over the post-event window to generate the counterfactual normal returns, from which the CARs are generated. We use windows of one up to four weeks. To test whether the capital account restrictions had purchase, we evaluate the impact of each event using parametric t and non-parametric Wilcoxon sign rank tests. Figure 6 shows how the CARs evolved over the four-week horizon after each Event 1 (October 2011) and Event 2 (November 2012). We do not plot the results for Event 3 at this stage. Table 4 provides the values of the cumulative abnormal returns for 20 days after each event as well as the p-values on the t and Wilcoxon test statistics. There are several interesting results.

Figure 6: Evolution of the CARs for Capital Restrictions.



The first finding is that the first implementation of the capital restrictions (Event 1) had an immediate and significant impact on the excess movement in the exchange rates, and this was only slightly delayed in Event 2 (reduction in the NOP from 10% to 7.5% on 26th November, 2012). The cumulative abnormal returns are generally significant, with the Wilcoxon test p-values corroborating those from the t-test, despite the lower power of the former non-parametric test. Second, the effectiveness of capital controls appears to have deteriorated over time. Event 1 led to a 1% appreciation of the TNZ-USD exchange rate over the first week relative to the counterfactual. This increased to 3.5% by the end of the fourth week. Event 2 had much less leverage but did lead to a slight strengthening of the exchange rate relative to the counterfactual from 0.17% by the end of the first week to 0.32% by the end of the fourth week. By contrast, as shown in Table Event 3, however, was counterproductive. The exchange rate actually depreciated by 6.5% relative to the counterfactual by the end of the fourth week. The empirical evidence indicates that attempts by the Bank of Tanzania to reverse the pre-event depreciation trends that had emerged in the first quarter of 2015 were progressively more ineffective.

Table 4: Cumulative Abnormal Returns for all capital restriction events

Days	Event 1 (Oct 2011)			Event 2 (Nov 2012)			Event 3 (April 2015)		
	CAR(%)	pval-t	DM	CAR(%)	pval-t	DM	CAR(%)	pval-t	DM
1	-0.212	0.003	0.180	-0.018	0.126	0.655	1.448	0.000	0.623
2	-0.331	0.001	0.109	-0.040	0.026	0.285	2.430	0.000	0.214
3	-0.679	0.000	0.068	-0.084	0.000	0.144	3.280	0.000	0.139
4	-1.010	0.000	0.043	-0.120	0.000	0.080	4.179	0.000	0.060
5	-1.028	0.000	0.028	-0.170	0.000	0.046	4.276	0.000	0.046
6	-0.603	0.001	0.018	-0.202	0.000	0.028	4.617	0.000	0.024
7	-1.222	0.000	0.012	-0.204	0.000	0.017	4.826	0.000	0.015
8	-2.864	0.000	0.008	-0.222	0.000	0.011	4.966	0.000	0.012
9	-2.780	0.000	0.005	-0.240	0.000	0.007	5.040	0.000	0.007
10	-2.328	0.000	0.003	-0.258	0.000	0.004	4.935	0.000	0.004
11	-2.032	0.000	0.002	-0.259	0.000	0.002	4.905	0.000	0.003
12	-2.198	0.000	0.001	-0.257	0.000	0.002	4.872	0.000	0.002
13	-2.134	0.000	0.001	-0.250	0.000	0.001	4.824	0.000	0.001
14	-2.210	0.000	0.001	-0.209	0.000	0.001	4.729	0.000	0.000
15	-2.517	0.000	0.000	-0.234	0.000	0.000	5.018	0.000	0.000
16	-2.433	0.000	0.000	-0.215	0.000	0.000	5.308	0.000	0.000
17	-2.896	0.000	0.000	-0.231	0.000	0.000	5.750	0.000	0.000
18	-3.423	0.000	0.000	-0.245	0.000	0.000	6.200	0.000	0.000
19	-3.411	0.000	0.000	-0.301	0.000	0.000	6.126	0.000	0.000
20	-3.428	0.000	0.000	-0.332	0.000	0.000	6.448	0.000	0.000

Notes: CAR (%) is the cumulative abnormal depreciation rate; p-t is the p-value for the t-test; and DM the p-value for the Diebold Mariano test.

These results have been subject to extensive sensitivity analysis. We vary the pre-event window length, from 6 weeks to 10 weeks; we allow for the lagged effects of news and as well as information leakages by adjusting the post-event window accordingly; and we check the CAR results against alternative models for the normal returns. We find that the baseline results hold robust to all of these modifications.

5. Discussion, Caveats and Conclusions

Our analysis suggests that while restrictions on capital account transactions had some initial traction on the nominal exchange rate, their efficacy was relative modest and short-lived. Their effectiveness weakened between the first and second time the net open position was restricted, but the evidence on the third episode is less conclusive. These results are not surprising but might suggest further investigation.

It would appear that the events of October 2011 did take the markets by surprise and had a decisive effect on the exchange rate. The repetition a year later and then again in April 2015 may, however, have been anticipated as policy responses by the Bank of Tanzania to worsening economic conditions and as such may have been 'priced in' to the markets behaviour. Second and relatedly, the private sector, through their banks may have begun to innovate so that the change in capital account restrictions become less binding on their behaviour. The literature suggests that anticipation and circumvention played no small role in undermining the effectiveness of capital controls across time in countries such as Brazil, Columbia, and Thailand (for example, Habermeier et al., 2011). One popular interpretation offered in the literature is that firms were able to innovate through sophisticated derivatives markets, but this is more plausible in financially-developed countries such as Brazil, although in Tanzania it is plausible that firms may be increasingly using cross-EAC intra-firm relationships to circumvent Tanzania-specific restrictions on asset acquisition.

Both these approaches are subject to a number of caveats. First, the analysis presented here has focused narrowly on the impact of capital control measures on the *level* and depreciation of the nominal exchange rate. In practice, however, the purpose of such measures may be to lean against the *volatility* of the exchange rate. In principle, it is straightforward to adapt the same techniques –and in particular the event study approach -- to examine the impact of control on exchange rate volatility. The main challenges in doing so are in generating robust models of 'normal' volatility and of getting an accurate measure of actual exchange rate volatility over a relative short post-event window. This is not a problem in markets where there is deep intra-day trading of foreign exchange but in Tanzania with only one usable observation per day on the rate, this become difficult.

The second major caveat concerns the working assumption that these changes to capital account restrictions are in some sense exogenous to the exchange rate. Clearly this is not the case: restrictions are not introduced or tightened at random but in response to evolving circumstances. To do justice to this would require us to model the central bank's policy reaction function at a level of sophistication that cannot be sustained by the data. What is more plausible and is the assumption underpinning the analysis here is that the exact timing and magnitude of these events are exogenous shocks to the market. This seems a plausible working assumption. Finally, any work with asset markets has to grapple with the challenge that asset prices, including for foreign exchange, are driven not just by spot market conditions but fundamentally by expectations. In much of the developed-country literature we are able to back out exchange rate expectations from survey data, derivatives, forward contracts and so forth and are thus able to condition our forecasting models appropriates. In the data-scarce environment in Tanzania this is not yet possible. Being able to measure expectations with some degree of accuracy woul significantly enhance the quality of this work.

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Appendix 1
Adjusting Central Bank Balance Sheet Data for Exchange-Rate Valuation Effects

Accounting in theory
Net foreign assets at the end of period t are given by

$$NFA_t = E_t \cdot R_t^{\$} \tag{A1}$$

Where E_t is the end-of-period exchange rate in local currency per US dollar and $R_t^{\$}$ is the end-of-period value of net foreign assets in US dollars. The following two identities hold:

$$\Delta NFA_{t+1} = NFA_{t+1} - NFA_t = E_{t+1} \cdot \Delta R_{t+1}^{\$} + \Delta E_{t+1} \cdot R_t^{\$} = E_t \cdot \Delta R_{t+1}^{\$} + \Delta E_{t+1} \cdot R_{t+1}^{\$}$$

These identities give us two alternative decompositions of the change in net foreign assets into an acquisition component and a valuation component. The first decomposition is exact if all transactions in foreign exchange take place at end-of-period exchange rates; the second is exact if they all take place at beginning-of-period exchange rates. In reality, of course, transactions and exchange-rate changes can occur throughout the month.

If we think of foreign-exchange transactions as occurring in continuous time, the overall change in net foreign assets from this period to the next is therefore given by

$$\Delta NFA_{t+1} \equiv NFA_{t+1} - NFA_t = \int_t^{t+1} \left[\frac{d(E_s \cdot R_s^{\$})}{ds}\right] ds = \int_t^{t+1} \left[E_s \cdot \frac{dR_s^{\$}}{ds}\right] ds + \int_t^{t+1} \left[R_s^{\$} \cdot \frac{dE_s}{ds}\right] ds. \tag{A2}$$

The two parts of ΔNFA_{t+1} (i.e. the two final integrals) reflect net purchases or sales of foreign assets, on the one hand, and valuation changes, on the other. <u>Only the first of these affects the monetary base</u>.

To approximate this first term, we make two assumptions about how net foreign assets (in dollars) and the exchange rate evolve over the interval from t to $t+1$. First, we assume that reserves display a linear trend within the month so that

$$dR_t^{\$}/ds = \alpha \text{ for } s \,\epsilon\, [t, t+1] \text{ where } \alpha = R_{t+1}^{\$} - R_t^{\$}. \tag{A3a}$$

Second, we assume that the exchange rate depreciation is at a constant rate within the month

$$d\log(E_s)/ds = \beta \text{ for } s \,\epsilon\, [t, t+1] \text{ where } \beta = \log(\mathrm{E_{t+1}}/\mathrm{E_t}). \tag{A3b}$$

The second of these implies that for $s \,\epsilon\, [t, t+1]$ the exchange rate follows the process

$$E_s = E_t \cdot e^{\beta(s-t)}. \tag{A4}$$

The change in the monetary base due to reserve transactions is therefore given by

$$\int_t^{t+1} \left[E_s \cdot \frac{dR_s^{\$}}{ds}\right] ds = \alpha E_t \int_t^{t+1} e^{\beta(s-t)} ds = \alpha E_t \int_0^1 e^{\beta s} ds. \tag{A5}$$

The final integral equals $\beta^{-1}(e^{\beta} - 1)$, which in turn equals $z_{t+1}/\log(1 + z_{t+1})$ where z_{t+1} is the observed rate of depreciation between periods t and $t+1$.

Using (A3a) and (A3b), the change in the monetary base due to net foreign exchange transactions can therefore be approximated by

$$\int_t^{t+1} \left[E_s \cdot \frac{dR_s^\$}{ds}\right] ds = E_t \Delta R_{t+1}^\$ \frac{z_{t+1}}{\log(1+z_{t+1})}. \qquad \text{(A6)}$$

The correction term $z_{t+1}/\log(1+z_{t+1})$ is above 1 when z_{t+1} is positive and below 1 when z_{t+1} is negative. To calculate (A6) we only need to know the change in dollar net foreign assets and the cumulative percentage depreciation over the period.

Accounting in practice
A central bank balance sheet looks like this:

Assets	**Liabilities**
Net foreign assets	*Monetary Base*
Domestic credit	Currency outside banks
To government	Bank reserves
To banks	Vault cash
To private sector	Bank deposits
	Government Deposits
	Own Securities Outstanding
	Net Worth
	Capital and Reserves
	Other items net

Since the identity

Monetary Base = Net Foreign Assets + Net Domestic Asset (A7)

holds, net domestic assets are defined implicitly as

NDA = DC – Government Deposits – Own Securities Outstanding – NW. (A8)

Valuation changes in net foreign assets are absorbed on the right-hand side of (A7) via equal and opposite changes in NFA and Net Worth.

For purposes of studying central bank behaviour, we need to purge both NFA and NDA of valuation changes. From (A6), the change from one period to the next in the modified value of net foreign assets is

$$\Delta NFAa_{t+1} = E_t \Delta R_{t+1}^\$ \frac{z_{t+1}}{\log(1+z_{t+1})}. \qquad \text{(A9)}$$

which can be calculated directly if we have data on the US dollar value of net foreign assets. Finally, the change in modified net domestic assets can then be calculated as a residual:

$$\Delta NDAa_{t+1} = \Delta MB_{t+1} - \Delta \$NFA_{t+1}. \qquad \text{(A10)}$$

Appendix II

EViews Program for Offset Coefficient

Note: *the following programme and data sets are available as* *<u>tz_offset_prog_22_jan_2017.prg</u>* *and* *<u>BoT_Balance_Sheet_Dec01-Jul16.xls</u>*

```
'FILENAME: tz_offset_prog_22_jan_2017.prg
cd "D:\active\igc\igc-exchange_rates\mac-2017-presentation"

'Note: change cd instruction to user's own path!!

'1. Open monthly dataset in Excel
' Note 1: excel filename and range will need to be changed each time we update the data.
' Note 2: range currently extends to 2016m07. Change excel range to expand.
' Note 3: Excel file should be saved as Excel 97-2003 Worksheet format
' Note 4: This version includes dummy variables for nop in 2011, 2012 and 2015
'Note 5: ***!!! Reversed Structural Form Restrictions (relative to paper)!!!***

wfopen(type=excel) BoT_Balance_Sheet_Dec01-Jul16 range=TZvar_data!$A$1:$j$176

'2. Set sample, transform data for estimation, define groups and set up spool

smpl 2002m2 2016m07

'Work with 100 x natural log of exchange rate

    frml ler   =   100*log(er)

'generate monthly seasonal dummy variables

for %x 1 2 3 4 5 6 7 8 9 10 11
    frml m{%x} = @seas({%x})
next

'groups
group seas m1 m2 m3 m4 m5 m6 m7 m8 m9 m10 m11
close seas
group allvars ler d(ler)  mb d(mb) nda d(nda) ndap d(ndap) nir d(nir) nirp d(nirp)
close allvars
group basic   ler mb nda nir
close basic
group reval    ler mb ndap nir
close reval

'open spool to hold output
spool offset_22a_jan2017

'3. Key graphs

''Exchange Rate
graph g_ler.line er
g_ler.addtext(t) "Nominal Exchange Rate"
g_ler.options linepat
g_ler.setelem(1) lcolor(blue)  lpat(solid) legend("TZ Shillings per US$")
g_ler.draw(shade, bottom) 2011m10 2011m11
g_ler.axis(all)  grid
offset_22a_jan2017.append g_ler

''Balance Sheet
graph g_bs.line mb nir nda
g_bs.addtext(t) "BoT Balance Sheet - w/o adjustment for revaluation (Tz bn)"
g_bs.options linepat
g_bs.legend columns(3)
g_bs.setelem(1) lcolor(blue)    lpat(solid) legend("Money Base")
```

```
g_bs.setelem(2) lcolor(red)      lpat(solid) legend("NIR")
g_bs.setelem(3) lcolor(green) lpat(solid) legend("NDA")
g_bs.axis(all)  grid
offset_22a_jan2017.append g_bs

'NIR
graph g_nir.line nir nirp
g_nir.addtext(t) "Revaluation Effects on NIR"
g_nir.options linepat
g_nir.legend columns(2)
g_nir.setelem(1) lcolor(blue)    lpat(solid) legend("NIR")
g_nir.setelem(2) lcolor(red)      lpat(solid) legend("NIR purged")
g_nir.axis(all)  grid
offset_22a_jan2017.append g_nir

'NDA
graph g_nda.line nda ndap
g_nda.addtext(t) "Revaluation Effects on NDA"
g_nda.options linepat
g_nda.legend columns(2)
g_nda.setelem(1) lcolor(blue)    lpat(solid) legend("NDA")
g_nda.setelem(2) lcolor(red)      lpat(solid) legend("NDA purged")
g_nda.axis(all)  grid
offset_22a_jan2017.append g_nda

''Balance Sheet - purged
graph g_bsp.line mb nirp ndap
g_bsp.addtext(t) "BoT Balance Sheet - purged of revaluation (Tz bn)"
g_bsp.options linepat
g_bsp.legend columns(3)
g_bsp.setelem(1) lcolor(blue)    lpat(solid) legend("Money Base")
g_bsp.setelem(2) lcolor(red)      lpat(solid) legend("NIR")
g_bsp.setelem(3) lcolor(green) lpat(solid) legend("NDA")
g_bsp.axis(all)  grid
offset_22a_jan2017.append g_bsp


'4. Descriptive statistics (all variables)

offset_22a_jan2017.append allvars.stats

close allvars

'5. Unit root tests
'Loop over variables for unit roots

for %x ler mb nda ndap nir nirp

   offset_22a_jan2017.append {%x}.uroot(lag=4)
   offset_22a_jan2017.append {%x}.uroot(dif=1, lag=4)
   offset_22a_jan2017.append {%x}.uroot(pp)
   offset_22a_jan2017.append {%x}.uroot(dif=1,pp)
   offset_22a_jan2017.append {%x}.uroot(kpss)
   offset_22a_jan2017.append {%x}.uroot(dif=1,kpss)

next

'6.  Estimating VARs
'-------------------------------------------------------------------------------------------------------
'For each specification we estimate the VAR, do the diagnostics, and then
'compute impulse responses and variance decomposition.  We run two
'identification rules: (i) Cholesky; and (ii) structural.  Standard
'errors, where relevant, are computed by monte carlo using 1000, reps.
'We report IRFs is standard and accumulated form over a 20 quarter horizon.
'------------------------------------------------------------------------------------------------------

'***** Full sample
```

```
smpl 2002m2 2016m07

'A.: First difference estimation (with control for revaluation adjustments - no controls for capital control events)

 var var_A.ls 1 4 d(ler)  d(nirp)  d(ndap) @ c seas

offset_22a_jan2017.append var_A.svarout
offset_22a_jan2017.append var_A.arroots
offset_22a_jan2017.append var_A.testexog
offset_22a_jan2017.append var_A.testlags
offset_22a_jan2017.append var_A.laglen(6)
offset_22a_jan2017.append var_A.qstats(6)
offset_22a_jan2017.append var_A.arlm(6)
offset_22a_jan2017.append var_A.jbera
offset_22a_jan2017.append var_A.white


'Impulse responses and variance decomposition

'Structural identification
var var_As.ls 1 4 d(ler)  d(nirp)  d(ndap) @ c seas


var_As.append(svar) @e1=      c(1)*@u1                   +c(2)*@u3
var_As.append(svar) @e2=-(1-c(1))*@u1+c(3)*@u2+c(4)*@u3
var_As.append(svar) @e3=                       - c(5)*@u2+c(5)*@u3

var_As.svar(rtype=text, f0=c)
offset_22a_jan2017.append var_As.impulse(20,a,    imp=struct)
offset_22a_jan2017.append var_As.impulse(20,a, t, imp=struct)

offset_22a_jan2017.append var_As.decomp(20, t,     imp=struct)

'B.: First difference estimation (with control for revaluation adjustments - contorls for capital control events)

 var var_B.ls 1 4 d(ler)  d(nirp)  d(ndap) @ c seas d(nop2011) d(nop2012) d(nop2015)

offset_22a_jan2017.append var_B.svarout
offset_22a_jan2017.append var_B.arroots
offset_22a_jan2017.append var_B.testexog
offset_22a_jan2017.append var_B.testlags
offset_22a_jan2017.append var_B.laglen(6)
offset_22a_jan2017.append var_B.qstats(6)
offset_22a_jan2017.append var_B.arlm(6)
offset_22a_jan2017.append var_B.jbera
offset_22a_jan2017.append var_B.white


'Impulse responses and variance decomposition

'Structural identification
var var_Bs.ls 1 4 d(ler)  d(nirp)  d(ndap) @ c seas d(nop2011) d(nop2012) d(nop2015)


var_Bs.append(svar) @e1=      c(1)*@u1                   +c(2)*@u3
var_Bs.append(svar) @e2=-(1-c(1))*@u1+c(3)*@u2+c(4)*@u3
var_Bs.append(svar) @e3=                       - c(5)*@u2+c(5)*@u3

var_Bs.svar(rtype=text, f0=c)
offset_22a_jan2017.append var_Bs.impulse(20,a,    imp=struct)
offset_22a_jan2017.append var_Bs.impulse(20,a, t, imp=struct)

offset_22a_jan2017.append var_Bs.decomp(20, t,     imp=struct)
```

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