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Monetary Policy Implementation and Volatility Transmission along the Yield Curve: The Case of Kenya

by C. Emre Alper, Armando Morales, and Fan Yang

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Monetary Policy Implementation and Volatility Transmission along the Yield Curve: The Case of Kenya[1]

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Abstract

This paper analyzes the degree to which volatility in interbank interest rates leads to volatility in financial instruments with longer maturities (e.g., T-bills) in Kenya since 2012, year in which the monetary policy framework switched to a forward-looking approach, relative to seven other inflation targeting (IT) countries (Ghana, Hungary, Poland, South Africa, Sweden, Thailand, and Uganda). Kenya shows strong volatility transmission and high persistence similar to other countries in transition to a more forward-looking monetary policy framework. These results emphasize the importance of a strong commitment to an interbank rate as an operational target and suggest that the central bank could reduce uncertainty in short-term yields significantly by smoothing out the overnight interest rates around the policy rate.

JEL Classification Numbers: E58, E43

Keywords: Monetary policy implementation, inflation targeting, volatility transmission

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I. INTRODUCTION

Modern central banks typically act to smooth overnight interbank rates at or close to the policy rate. By announcing a rate that it wishes to prevail in the overnight interbank market and ensuring its implementation through day-to-day liquidity operations, the central bank aims to influence and stabilize longer-term rates, important for overall level of prices and real economic activity. Likewise, the central bank's ability to reduce volatility of overnight interbank rates should matter for monetary policy because interbank market volatility may affect funding costs for longer-term financing. In fact, changes in the policy rate may not have the intended effect on funding costs for longer-term maturities, if accompanied by increased volatility of the overnight market interest rate, all else equal.[1]

Reliance on policy interest rates to signal the monetary policy stance is a relatively recent phenomenon for many developing countries, including Kenya, which until recently used to center their monetary policies on periodic quantitative targets for money aggregates. Similar to experiences of industrialized countries in the early 1980s, the move away from conventional monetary targeting in developing countries emerged as a result of weaker relationship between money and inflation, owing to decreases in inflation rates to single digits, rapid financial innovation, greater integration with the global economy, and deregulation of financial markets contributing to unstable money demands.[2] Coupled with higher exchange rate flexibility and lower fiscal financing requirements, several countries have switched to modern monetary frameworks by using interbank interest rates as the operational target to achieve the inflation objective. However, operational challenges in hitting the operational target consistently raise questions about the readiness of frontier economies to move more decisively to a full-fledge inflation targeting (IT) framework.[3]

This paper analyzes the transmission of changes in the policy rate to the interbank interest rate and assesses the degree to which volatility in overnight interbank rates affects volatility in other maturities in Kenya relative to a sample of seven IT countries, namely Ghana, Hungary, Poland, South Africa, Sweden, Thailand, and Uganda, in order to extract policy implications. Similar studies found support to the idea that central bank efforts to maintain reasonable stability of short-term interest rates are conducive to stabilizing long-term rates.

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[1] The effects of volatility in overnight interbank market on longer term maturities have been studied for advanced economies. Among others, see Ayuso et al. (1997), Cohen (1999), and Carpenter and Demiralp (2011).

[2] See IMF (2015a) for an overview of issues in evolving monetary policy regimes in the low -income countries and other developing countries.

[3] These issues are discussed in Maehle (2015) and IMF (2014).

Also, there is some evidence that reserve requirements and direct targeting of interbank rates help mitigate volatility along the yield curve.[4]

In line with the literature, the paper first estimates exponential generalized autoregressive conditional heteroskedasticity (E-GARCH) models to examine the daily volatility of interbank rates for Kenya and the seven selected IT countries. Next, it assesses, for each country, the effects of fitted variances of interbank rates on variances of longer-term interest rates.

The results suggest important differences between countries in transition (including Kenya) and more advanced IT countries. The findings suggest that volatility transmission, and its persistence and autocorrelation, are more likely in countries in transition to a more forward-looking monetary policy framework. They also suggest that central banks can influence short-term yields and their volatility through a more pro-active smoothing of interbank interest rates around the policy rate.

The remainder of the paper is organized as follows. The next section discusses the evolution of the monetary policy framework in Kenya in recent years. Section III describes the data and estimation techniques used, and presents results of the within- and across- country analyses. Section IV concludes.

II. EVOLUTION OF MONETARY POLICY FRAMEWORK IN KENYA

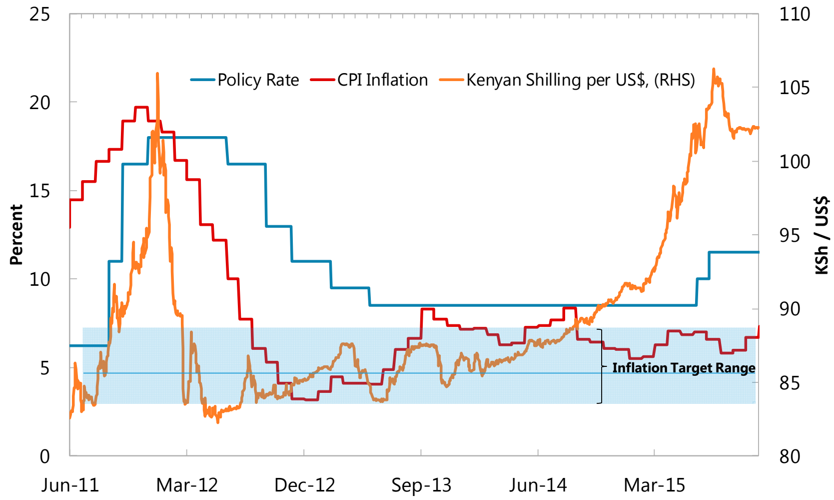
Overview[5]

Since the late 1990s, Kenya has pursued an inflation objective in the context of a managed float, with reserve money as the operational target, sought to be met through different instruments. Following frequent misses of monetary targets and the disconnect of these deviations from the actual inflation performance, since 2011 the Central Bank of Kenya (CBK) embarked on modernizing its framework to make monetary policy more forward looking by shifting its operational target away from reserve money.

[4] See Ayuso et al. (1997), Cohen (1999), and Carpenter and Demiralp (2011).

[5] See also IMF (2015b).

Figure 1. Kenya: Policy Rate, Exchange Rate, and Inflation



Source: CBK and authors' calculations.

Since October 2011, the CBK has taken steps to a more forward-looking monetary framework moving gradually towards an IT regime. Kenya gradually centered its monetary policy on the Central Bank Rate (CBR) which acted as a ceiling for repo (7-day maturity) and a floor for reverse repo (overnight) operations. The money market rates broadly converged to the CBR by end-2012. To facilitate fine-tuning monetary operations, longer maturity instruments were introduced in July 2012, namely term auction deposits (TAD) with 14-, 21-, and 28-day maturities, with the CBR acting as a ceiling in fixed volume auctions. Recently, the CBK raised the spread for TAD actions to 250 basis points above the CBR in May 2015, and introduced 3-day repos in June 2015.

Monetary policy environment

Mandate and accountability

The principal objective of the CBK is formulating and implementing monetary policy to achieving and maintaining price stability as well as fostering and maintaining a stable financial system (2010 Central Bank Act). Without prejudice to these two objectives, the CBK is also directed to support growth and employment. The Central Bank Act stipulates that the National Treasury in consultation with the CBK sets the inflation target at the beginning of every fiscal year.[6] The inflation target range has been 5±2.5 percent since July 2012. In case of deviations from the target range for three consecutive months, the CBK is required to provide the Treasury with its assessment of the underlying factors and the corrective measures needed to address those deviations.

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[6] In practice, so far, this has not created tensions between the National Treasury and the CBK.

The CBK has published a Monetary Policy Statement every six months since 1997 to communicate medium-term trends and monetary targets.[7] Under normal circumstances the CBK's Monetary Policy Committee (MPC) meets every other month and signals its monetary stance through the policy rate. The CBK's MPC communicates its decisions through its press releases published online, including its views on recent developments and the outlook in Kenya and the global economy, as well as its assessment of demand and supply pressures on inflation.

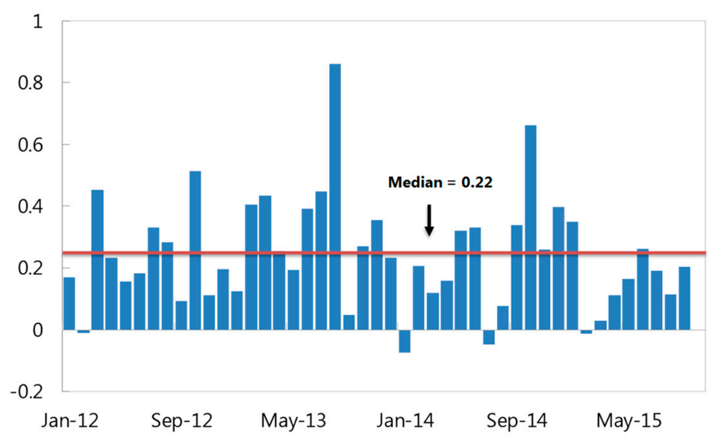
Macro-financial building block

Since mid-2000s, Kenya has maintained a flexible exchange rate regime, with CBK interventions largely to mitigating excessive volatility in the foreign exchange market. The CBK, at opportune times, acquires foreign exchange in the market to build up international reserves and meet reserve cover targets consistent with the East African Monetary Union convergence criterion of 4.5 months of import cover.

Financial markets are generally well functioning, and interbank and government securities markets are relatively deep compared to countries at the same level of development. Kenya's commercial banks do not show persistent and high levels of excess bank liquidity compared to other Sub-Saharan (SSA) countries.[8]

Figure 2. Kenya: Commercial Bank Excess Reserves

(monthly averages, as percent of total deposits, 2012-2015)



Source: CBK and authors' calculations.

The Central Bank Act allows the National Treasury to access an overdraft facility at the CBK, up to a ceiling of 5 percent of the most recent audited revenues of the central government (about 1 percent of GDP), which is lower than the limits granted by the other

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[7] While broad and reserve money targets are specified in the Monetary Policy Statements, since October 2011 these are used only for forecasting purposes as the interbank rates gradually replaced the reserve money as the operational target.

[8] In accordance with the CBK Act, the reserve requirement ratio is currently 5.25 percent of total of commercial bank's domestic and foreign currency liabilities. The maintenance period is 30 days and commercial bank reserves are required not to fall below 3 percent of total liabilities on a daily basis. Saxegaard (2006) reported that on average, countries in SSA had excess reserves amounting to 13.2 percent of total deposits with a median value of 8.3 percent.

regional central banks.[9] While fiscal dominance has not been a concern, weaknesses in cash and debt management operations have complicated monetary policy implementation at times.

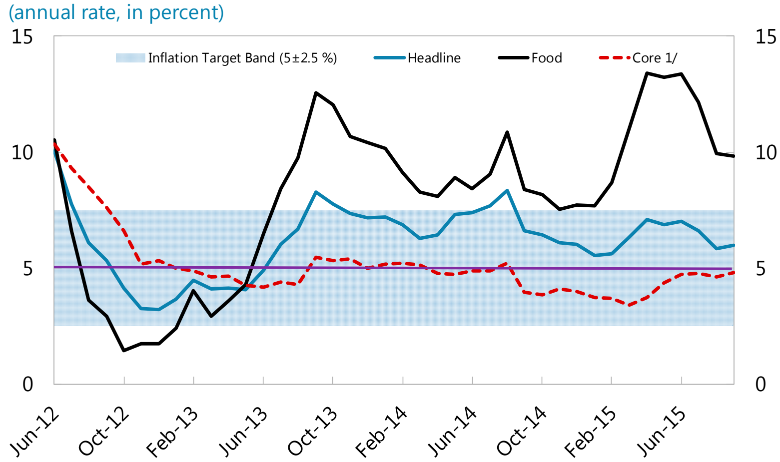
Data and analytical capacity

Monthly inflation rates are released by the Kenya National Bureau of Statistics at the end of each month, and the CBK conducts end-year inflation expectations survey every other month (not published) which are used in its forward-looking inflation assessments. In 2013, the CBK created a Monetary Policy Analysis Unit within the CBK's Research Department to provide the MPC with projections and analyses using an in-house forecasting and policy analysis system (FPAS), which was re-designed into an inflation modeling and forecasting unit in March 2015.

Key challenges moving forward and lessons

Reflecting frequent adverse food and energy price shocks, headline inflation has typically remained within the upper half of the target range (5±2.5 percent) since mid-2013. Headline inflation stayed above the official target in 28 of the last 37 months, and it has not been below the mid-point of the target range since June 2013. Average non-food non-oil inflation during the same period was slightly above 5 percent.

Figure 3. Kenya: Recent Inflation Developments, 2012-2015
(annual rate, in percent)

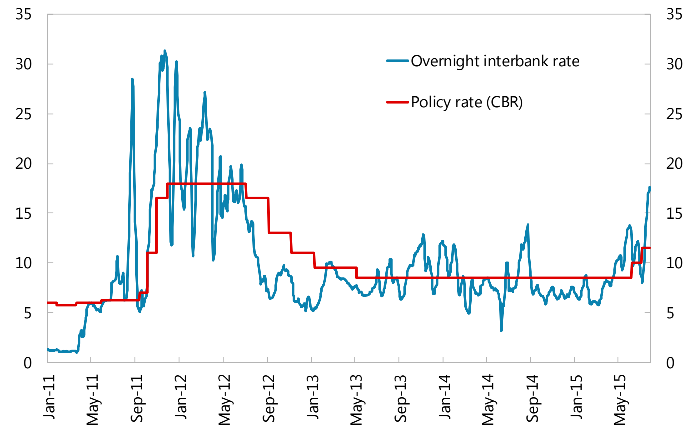


Sources: Kenyan authorities and authors' calculations.
1/ Core inflation excludes, food, energy, and transportation.

[9] See Jacome and others (2012) for legal limits on central bank credit to government. For example, government overdraft access as ratio of previous year's revenues is 12.5 percent in Tanzania, 18 percent in Uganda and 15 percent in Zambia.

Kenya has experienced large and persistent deviations of the overnight interbank rate from the policy rate that are often accompanied by higher volatility compared to IT countries. While the interbank rate mostly fluctuated within a +/-250 basis points range, at times the deviations have exceeded 1,500 basis points. The median absolute deviation of the overnight rate from the policy rate is about 185 basis points since October 2011, 210 basis points for the first nine months of 2015.

Figure 4. Kenya: Central Bank Rate and Overnight Interbank Rate (in percent)

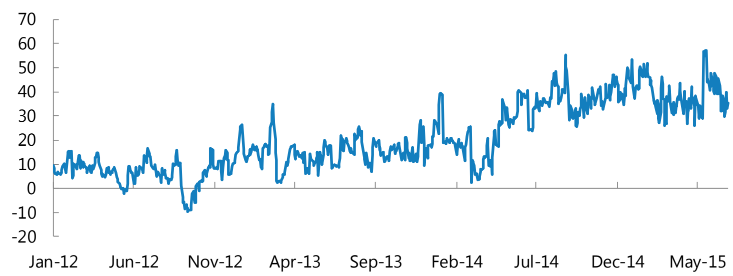


Source: Central Bank of Kenya.

Main contributors to persistent deviations of the overnight interbank rates from the central bank policy rate are largely associated with fiscal pressures and foreign exchange interventions of the CBK. The former includes large and unpredictable fiscal flows, narrow room for short-term financing to the government as the use of the overdraft facility is frequently at the ceiling, and weak coordination between fiscal and monetary authorities in their interaction with financial markets. In addition, the central bank has introduced ad-hoc measures at times in response to exchange rate pressures, in order to reverse expectations quickly.[10] While foreign exchange pressures have so far not been persistent, Kenya's increasing integration into global financial markets could result in an increased frequency of such episodes and may challenge the CBK to choose between higher volatility in interest rates or exchange rates during such episodes.

Figure 5. Net Government Deposits at the CBK 1/

(2012-2015, daily, in percent of reserve money)



1/ Government deposits at the CBK less overdraft credit extended to the government.
Sources: CBK, authors calculations.

[10] Such ad-hoc measures included suspension of reverse-repo liquidity injection to banks and the restrictions to banks' access to the overnight discount window.

III. Assessing Interest Rate Volatility: An E-GARCH Model of Volatility Transmission

How have deviations of interbank market rates with respect to the policy rate translated into higher interest rate volatility of instruments with higher maturities? In this section we analyze empirically the extent of interbank interest rate volatility in Kenya and its implications for other short-term interest rates, in particular for Treasury bills.

Data

Daily and weekly data on the policy rate, the domestic interbank overnight rate, 3-, 6-, and 12-month maturity T-bill[11] rates were compiled using official data sources for Kenya and seven IT countries: Ghana, Hungary, Poland, South Africa, Sweden, Thailand, and Uganda. For all countries, domestic-currency denominated securities are used for the analysis. In the case of SSA countries in our sample (Kenya, Ghana, South Africa, and Uganda), lack of daily secondary market data on the T-Bill rates restricts the analysis to weekly/bi-weekly auction yields.[12] For all other countries, we use daily data. To minimize measurement problems resulting from sharp movements in the interbank rates, where necessary, we followed Cohen (1999) by resizing 5% of the extreme values to the 95th percentile. Details on the data coverage and treatment of outliers are summarized along with some summary statistics in Annex II.

Unit root tests (ADF and KPSS) on all rates indicate integration of maximum order 1 for all countries. Therefore, the ensuing analysis is done using yields in first differences. Time varying volatility clustering is evident from a visual inspection of the differenced interbank interest rates as well as the descriptive statistics of differenced series provided in Annex II. The differenced rate series for all countries exhibit excess kurtosis in the data (all values are greater than 3, the kurtosis of a univariate normal distribution). Indeed, not unlike other financial series, we observe episodes of high volatility followed by low volatility, and vice versa, and infrequent transition between these episodes. We capture these features using the family of autoregressive conditional heteroskedasticity models.

Kenya's 3-, 6-, and 12-month T-bill rates appear much less volatile when compared to the weekly averages of daily overnight interest rates.

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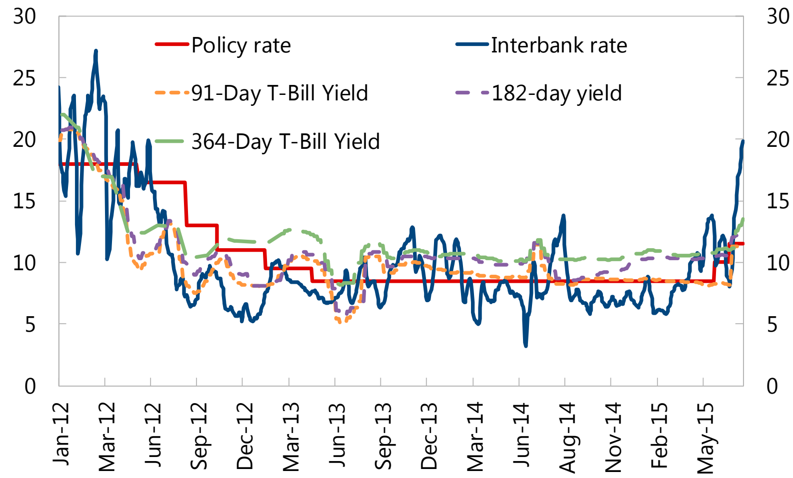
[11] We used treasury-bill auction yields published by treasury and central bank websites. For Sweden and Poland, we used interbank rates for 3-, 6-, and 12-month maturities. See Annex I.

[12] Weekly auction yields for 3- and 6-month T-bill auction yields are available in Kenya since 2012. T-Bills with 12-month maturity were auctioned once a month until March 2013. Regular weekly auctions have been conducted since then. In Uganda, T-Bill auctions are conducted bi-weekly. For Ghana, Kenya, South Africa, and Uganda, we used daily interbank rate data to estimate the conditional volatility and then calculated weekly/bi-weekly averages to analyze volatility transmission.

Figure 6. Kenya: Policy Rate and T-bill Auction Yields (2012-2015)
(in percent, weekly)



Sources: CBK and authors' calculations.

We observe differences among interbank rate profiles for each of the eight countries. Among the SSA countries, Kenya and Ghana's overnight rates seem to deviate from the policy rate more persistently compared to Uganda and especially South Africa (Figure 7a-b).[1] Ghana shows infrequent reversals of the overnight rate to the policy rate, with large deviations prevailing most of the time. Uganda's 7-day rate remained close to the policy rate for much of the sample but there were instances of significant yet short-lived deviations during 2012 and 2015. Among the other four IT countries, Thai interbank rates appear to be the most stable and responsive to policy rate changes. Sweden, Hungary, and Poland seem to fall in between Kenya and Thailand in terms of overall deviation, persistence, and responsiveness. We note that these observations are robust to inclusion of data prior to the 2008 financial crisis.

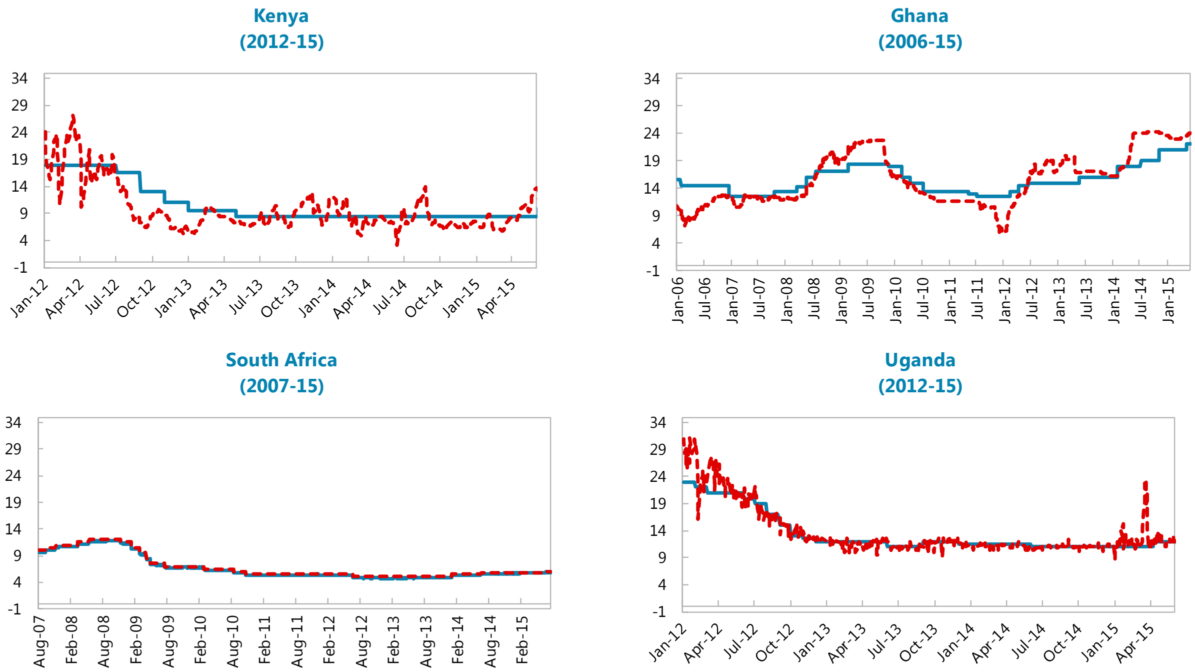
Descriptive statistics of the differenced rates on various instruments up to one-year maturity (Annex II)[2] suggest that (i) Uganda has the highest variance in interbank, 3-, 6-, 12-month rates followed by Kenya and Ghana; (ii) median absolute interbank rate spread from the policy rate is the highest in Ghana and Kenya (185 and 174 basis points, respectively) and less than 35 basis points in remaining IT countries; and (iii) all countries exhibit excess kurtosis, common in financial data.

Our econometric methodology allows for the incorporation of all of these features in the estimation of the conditional variance of the overnight interest rate.

[1] Figure A1.1 in Annex I provides the same text figure with differing vertical scales for each country. Interbank rate for Uganda refers to the 7-day rate.

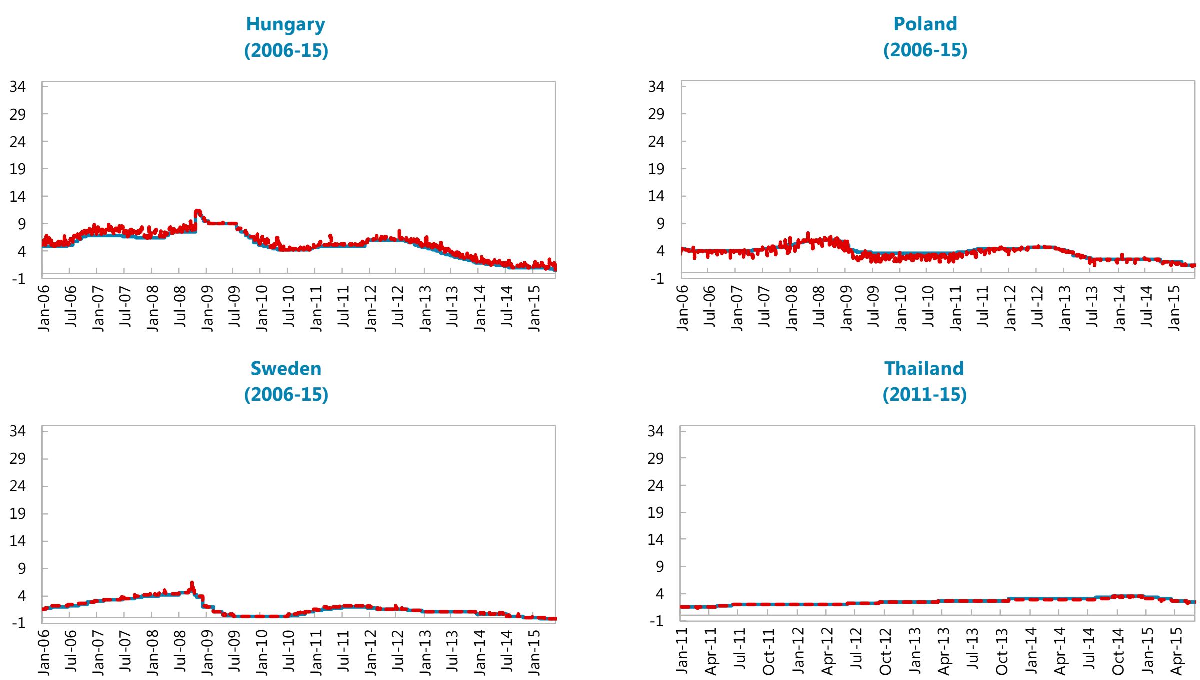
[2] Ghana's 1-year note yields have been constant from March 21, 2014 to October 30, 2015 at 22.5 percent. This rules out estimation at this maturity and hence we do not report descriptive statistics for this maturity.

Figure 7a. Policy And Interbank Rates In Kenya And IT Economies in SSA, 2006-2015 (identical scales In vertical axes)†



†See Annex I, Figure A1.1 for the same panel with country-specific scales in vertical axis. Data sources are in Table A1.1

Figure 7b. Policy And Interbank Rates In Selected IT Economies, 2006-2015 (identical scales in vertical axes)†



†See Annex I, Figure A1.2 for the same panel with country-specific scales in vertical axis. Data sources are in Table A1.1

Methodology

We follow Ayuso et al. (1997) to model the overnight interbank rate volatility and its transmission onto volatility of higher maturity yields. More specifically, in this paper we use the E-GARCH specification, which allows for asymmetric positive and negative deviations of rates.

Two-stage estimation approach

We assess the transmission of volatility along the yield curve by conducting a two-stage analysis. We first model the interbank volatility whereby we specify the mean equation with an error correction mechanism. Through an iterative selection process, we jointly estimate a mean and variance equation, which consequently allows us to generate an estimated conditional variance series for the interbank rate.

To model the interbank interest rate, we specify the mean equation with the form of an AR(m) model as follows:

$$\Delta r_t = \alpha_0 + \alpha_1 (r - p)_{t-1} + \sum_{i=1}^{m} \beta_i \Delta r_{t-i} + \sum_{i=0}^{n} \gamma_i \Delta p_{t-i} + X_t + \varepsilon_t,$$

where *r* is the interbank rate, *p* the official policy rate, and *X* is the effect of other potential explanatory variables. The lagged interbank-policy rate spread (with coefficient α_1) represents the error correction and allows for a long term mean-reversion process between the policy and overnight rate. Lastly, X_t may include a set of control variables including dummy variables and the Chicago Board Options Exchange volatility index, VIX. Depending on the data frequency, we include daily, weekly or bi-weekly dummy variables to account for recurrent factors including the impact of the bank reserves' maintenance period and the timing of tax payments.[1] VIX is included to control for global liquidity conditions.

We do not impose limits on the number of lags *m* and *n*, but find that the optimal lag length is less than 5 for most cases. Our modeling strategy is general to specific; to minimize over-fitting and variance inflation, insignificant variables (at the 10% level) are typically excluded.

Among alternatives, the chosen E-GARCH specification allows for a conditional variance of process with asymmetrical responses to positive and negative shocks. The log-linear form also has the additional advantage that there is no need to restrict the coefficients in the

[1] There are differences across countries in our sample in maintenance periods. The bank reserves' maintenance period in Kenya is from 15th of each month to 14th of next month and commercial bank reserves are required not to fall below 3 percent of total liabilities on a daily basis. In Thailand, Commercial banks are required to maintain a minimum reserve on average over a fortnightly period (starting on a Wednesday and ending on a second Tuesday thereafter), with carry-over provisions, equaled to a specified percentage of the previous period's average.

conditional variance specification to ensure a non-negative variance. Specifically, we estimate:

$$\ln \sigma_t^2 = \boldsymbol{\alpha_2} + \sum_{i=1}^{p} \boldsymbol{\omega_i} \ln \sigma_{t-i}^2 + \sum_{i=1}^{s} \boldsymbol{\delta_i} \frac{\varepsilon_{t-i}}{\sigma_{t-i}} + \sum_{i=1}^{q} \boldsymbol{\varphi_i} \left| \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right| + Y_t,$$

Similar to the mean equation, we allow for additional control variables represented by Y_t. The ε_{t-i}^2 term comes from the mean equation, and is the deviation of the expected value of the interest rate conditional on all past information:

$$\varepsilon_t = E_{t-1}[\Delta r_t] - \Delta r_t = \sigma_t^2 z_t$$

for some standardized random variable *z*.

After obtaining the estimated conditional variance of the interbank rate series, we then proceed to model the volatilities of the 3-, 6-, and 12-month rates. The process is identical to that of the interbank model, with two exceptions. First, the error correction term $(r - p)_{t-1}$is not included in the mean equation. Secondly, we include the estimated conditional variance of interbank rate (in natural logarithm) into the log-linear form of the variance equation. The coefficient of this term would be interpreted as the proportion of overnight volatility transmitted to the longer-maturity rate (Ayuso et al. 1997).

Main findings

We find in all cases that an E-GARCH(1,1) specification was appropriate to estimate the conditional variance. We find leptokurtosis in residuals, and so opt to estimate the model with a student's t-distribution.[2] All diagnostics tests point to a well specified and stable model; the correlograms (residuals in level and squared) suggest that all autoregressive effects have been captured. The estimation results are summarized for each country in Annex III, Table A1-A8.[3]

Interbank market

Second column of Table 1 presents the mean-variance model for Kenya's overnight interbank interest rates estimated for January 2012-June 2015. Consistent with Figure 2a, in the mean model, a change in the official rate has an insignificant impact on Kenya's overnight rate. Moreover, the difference between official and overnight rates narrows very

[2] While not reported in tables, the student t-distribution degrees of freedoms are statistically significant in E-GARCH estimations for all countries.

[3] The estimation results are for different periods for all countries. The results are qualitatively robust to restricting the sample to 2012-2015 for all countries.

gradually, at the rate 0.004 percent (the error correction model). This suggests that the policy rate has had a weak impact on the interbank rates during 2012-2015 in Kenya.

Results for all other countries are presented in the second columns of country-specific tables in Annex III. In Uganda, from January 2012 to July 2015, the impact of a 100 percentage point official rate change on the 7-day interbank rate is 21 percentage points. Thereafter the decay rate is 28 percent per period. Both parameters are highly significant, and are consistent with reasonably rapid convergence—as evident from Figure 2a—of 7-day interbank rates toward the official rates. Eighty percent of the adjustment of overnight rates is complete after as quickly as 4 days. Among other IT countries in the sample, estimated mean equations suggest that 80 percent of adjustment is complete more rapidly in Hungary (2 days) and Thailand (7 days) and less rapidly in Poland (23 days).[4] The reported results obtained for Hungary, Poland, Thailand, and Uganda are similar to those reported by Ayuso et al. (1997) for United Kingdom, Spain, and France for the period 1988-1993. Ghana stands out because not only the interbank rate does not respond significantly to the policy rate changes but also the error-correcting term is insignificant suggesting that the interbank rates behave not differently from a "random walk" around the policy rate.

Table 1. Estimation Results for Kenya (2012-2015)

Mean Equation	ON (d)	3-month T-Bills (w)	6-month T-Bills (w)	12-month T-Bills (w)
α_0	-0.009	-0.005	0.000	-0.003
$\sum\beta$	**0.718**	**0.633**	**0.528**	**0.402**
$\sum\gamma$	-0.081	-0.018	0.050	**0.203**
α_1	**-0.004**	-	-	-
Variance Equation				
α_2	**-1.303**	-0.392	0.299	-0.830
ω	**0.730**	**1.057**	**0.999**	1.634
δ	0.018	-0.116	-0.261	0.234
φ	**0.882**	**0.821**	**0.899**	**0.727**
Ω	-	**0.171**	**0.189**	0.164
Mean GARCH	0.103	0.271	0.628	0.241
Sample	2012-15	2012-15	2012-15	2013-15
Error Dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.
N	884	180	185	123

Notes: Bold values indicate significance at 10 percent. Other control variables in mean and variance equations (not reported in the table) may include VIX, garch-in-mean term, and dummy variables to account for maintanence period.

[4] The convergence of the interbank rate to the policy rate for South Africa and Sweden is extremely low but volatility of the interbank rate is also low. Ayuso et al. (1997) also reported relatively sluggish response of overnight rates to policy rates in Germany from 1988 to 1993.

With the exception of Thailand, the variance equations for overnight models all have highly significant first order ARCH and GARCH effects, indicating autocorrelation and persistence in conditional volatility as expected.[5] We do not find any evidence of asymmetrical effects in the conditional variance equations for Kenya and for other SSA countries; meaning that positive and negative (lagged) shocks in the money markets have symmetric effects on volatility.

3-, 6-, and 12-month maturities

Next, we present our analysis of the mean-variance behavior in the 3-, 6-, and 12-month treasury auction yields of Kenya and make cross-country comparisons. For almost all countries and maturities, we were able to find admissible E-GARCH models with no significant autocorrelation at the 5 percent confidence level. As discussed earlier, we include estimated conditional volatility of interbank rates in natural logarithms into log-linear variance terms of higher maturity instruments and consider potential volatility transfer onto longer-maturity rates. We find evidence of volatility transmission from the interbank rate to higher maturities in Kenya, Ghana, Hungary, Thailand, and Uganda.

Columns 3-5 in Table 1 presents mean-variance model estimates for Kenya. The mean equations for Kenya's Treasury bill rates show similar results. Autoregressive coefficients are significant and range from 0.4 to 0.6 indicating persistence, which seems to decrease slightly at longer maturities. Yields do not seem to respond significantly to policy rate changes with the exception of the 12-month maturity which responds by 20 percentage points for each 100 percentage point change in the official policy rate.

For all countries, we find the presence of ARCH effects at all maturities and GARCH effects for some of the maturities. The ARCH term is the contribution from the absolute residuals in the mean equation; and its lack of significance means that the observed volatility of the last period provides no additional information when the last period forecasted volatility is taken into account. The GARCH term corresponds to the previous period's estimated conditional variance; and its significance implies volatility clustering. We do not find significant asymmetric GARCH effects for Kenya, Ghana, Poland, and South Africa. We find presence of asymmetric effects in Uganda (6- and 12-month), Hungary (6-month), Sweden, and Thailand (the latter two in all maturities).

In terms of volatility transmission along the yield curve, we find significant spillovers of volatility from the overnight interbank rates onto longer-maturity T-bill auction yields in Kenya. The immediate impact of volatility transmission, lies between 17 to 19 percent for 3- and 6-month maturities and 16 percent for the 12-month maturity, although not statistically significant in the latter case. In Uganda the range of immediate volatility transmission is from

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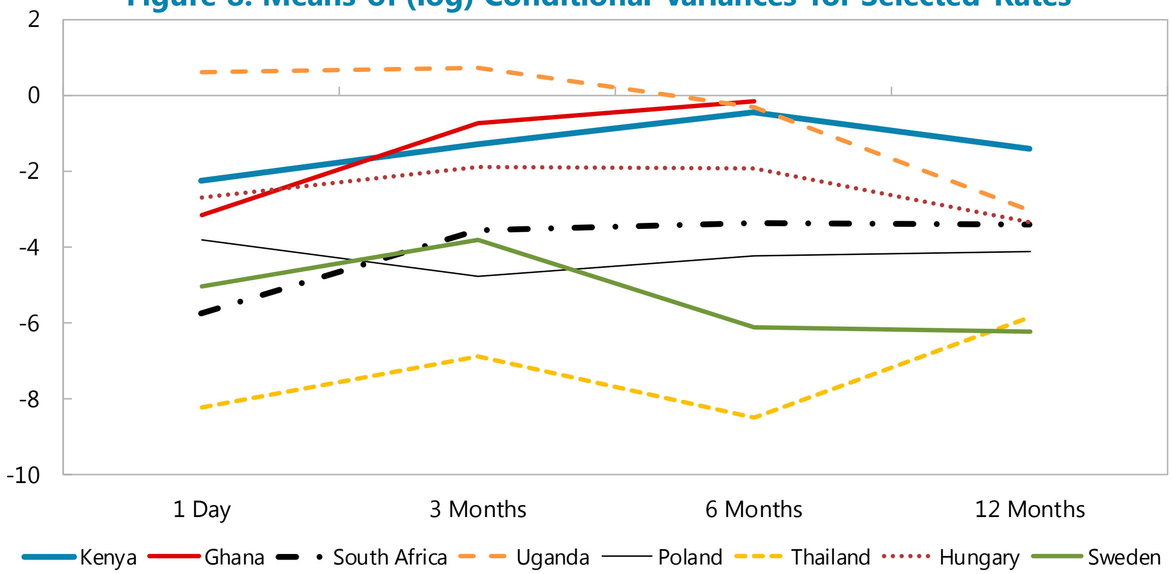
[5] We use the squared residuals of the LS model as the overnight volatility variable for Thailand and insert these into the conditional variance equations of the 3-, 6-, and 12-month maturities in the next section.

7 to 38 percent from the 7-day interbank rate. We also find significant volatility transmission from the overnight onto the 6-month maturity for Ghana 11 percent. We find no volatility transmission in South Africa, Poland, and Sweden and negligible volatility transmission in Thailand (3-5 percent) and in Hungary (only for 6-month maturity). The absence of volatility transmission in these IT countries does not come as a surprise and most likely reflect the direct consequence of monetary policy regime that emphasizes smoothing interbank rate volatility (Figure 7a-b and Figure A1.1-2). Similar results were found in the literature for Germany, France, and Japan (Cohen, 1999, and Ayuso at al., 1997).

We next present the entire set of estimated E-GARCH volatilities by maturity in this paper. Within countries we see that there is a general pattern of volatility along the yield curve. With the exception of Hungary and Uganda, interbank conditional volatilities (overnight for all countries with the exception of Uganda's 7-day maturity) are larger than for other maturities. Uganda, Kenya, Hungary, and Ghana show the largest estimated conditional volatilities among the eight IT countries. In this context, the mitigation of volatility transmission deserve consideration for policy decisions in these countries.

Figure 8. Means of (log) Conditional Variances for Selected Rates



The average widths (Jan. 2012- Jun. 2015) of overnight standing facilities corridors are +/-250 bps for Kenya (informal); +/-190 bps for Ghana; +/-100 bps for South Africa; +/-200 bps for Uganda; +/-100 bps for Hungary: +/-140 bps for Poland; +/-75 bps for Sweden; and +/-50 bps for Thailand.

IV. CONCLUDING REMARKS

We presented the mean-variance profiles of Kenya's overnight interbank rates, as well as 3-, 6-, and 12-month T-bill yields and compared them to seven other IT countries. First, we provide evidence that Kenya's overnight (and also T-bill) interest rate movements have a relatively slow response rate to changes in the policy rate. Second, we provide evidence that volatility transmission occurs in Kenya from the overnight to the 3- and 6- month T-bill rates. The extent of immediate transmission is around 18 percent suggesting non-trivial spillover effects.

Perhaps not so surprisingly, we also show that the width of the standing facility corridors in each IT country in general correlates with volatility of overnight interbank rates. In our sample, Kenya, Uganda and Ghana show wider interbank rate corridors and the largest conditional volatility along the yield curve. These results are robust to the inclusion of pre-quantitative easing observations for IT economies including Hungary, South Africa, and Sweden.

The results suggest important differences between countries in transition and more advanced IT countries. The findings suggest that volatility transmission, and its persistence and autocorrelation, are more likely in countries in transition to a more forward-looking monetary policy framework. One hypothesis could be that once expectations fully incorporate the implicit "reaction function" of central banks into their decisions, markets will not react immediately to episodes of volatility spikes in money markets at all maturities.

Although not the subject of this paper, other alternative hypotheses are worth exploring further: Is the slow response of overnight interest rates observed in Kenya an endogenous response to the significant deviations of the overnight interest rates from the policy rate? Is faster response only possible with a larger central bank presence in the markets in countries in transition (as suggested by Uganda's higher-than-normal volatility transmission)?

We conclude by emphasizing the importance of a strong commitment to the interbank rate as an operational target. Creating a narrower corridor would force a faster rate of convergence in overnight rates, reduce persistence in volatility, and mitigate absolute volatility along the yield curve. This effort should be supported by other policies such as and enhancing coordination between fiscal and monetary operations and improving the market infrastructure. Significant volatility transmission in transition economies suggests that central bank policies can contain volatility rapidly by significantly by smoothing out the overnight interest rates around the policy rate thereby making monetary policy more effective.

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ANNEX I. DATA AND SOURCES

Table A1.1. Data description

Country	Source	Policy rate	Interbank rate	3-, 6-, 12-month rates	Date IT adopted[1]
Kenya	Central bank website	Central Bank Rate; daily; Central Bank of Kenya (CBK)	Overnight interbank weighted average; daily; CBK	Treasury bill bid rates; weekly; CBK	Transitioning since 2011
Ghana	Central bank website and Bloomberg	Monetary Policy Rate, daily, Bank of Ghana (BOG)	Overnight interbank weighted average; daily; BOG	91-, 182-day discount rates, 1-year fixed rate note; weekly; Bloomberg	Informally in 2002, formally from May 2007
Hungary	Central bank website and DataStream	Central Bank Base Rate; daily; National Bank of Hungary	HUFONIA; daily; National Bank of Hungary	Treasury bill rates; daily; DataStream	June 2001
Poland	Central bank website and DataStream	Reference Rate; daily; National Bank of Poland	POLONIA; daily; National Bank of Poland.	WIBOR; daily; DataStream	1998
South Africa	Central bank website and Bloomberg	Repo rate; daily; South African Reserve Bank	SABOR; daily; South African Reserve Bank	Treasury bill bid rates; weekly; Bloomberg	February 2000
Sweden	Central bank website	Repo Rate; daily; Sveriges Riksbank	Sweden interbank tomorrow/next; daily; Sveriges Riksbank	STIBOR, daily, Sveriges Riksbank	Announced in January 1993 and applied as of 1995
Thailand	Central bank website	Bank of Thailand 1-day repo rate; daily; Bank of Thailand	Weighted average interbank overnight; daily; Bank of Thailand	BIBOR; daily; Bank of Thailand	May 2000
Uganda	Central bank website and Bloomberg.	Central Bank Rate; daily; Bank of Uganda	7-day interbank weighted average; daily; Bank of Uganda	Treasury bill bid rates; biweekly; Bloomberg	Informally in July 2011, formally from June 2014

[1] See Hammond (2012)

Fig. A1.1 Policy and interbank rates in Kenya and IT economies in SSA, 2006-2015 (country-specific scales in vertical axes)

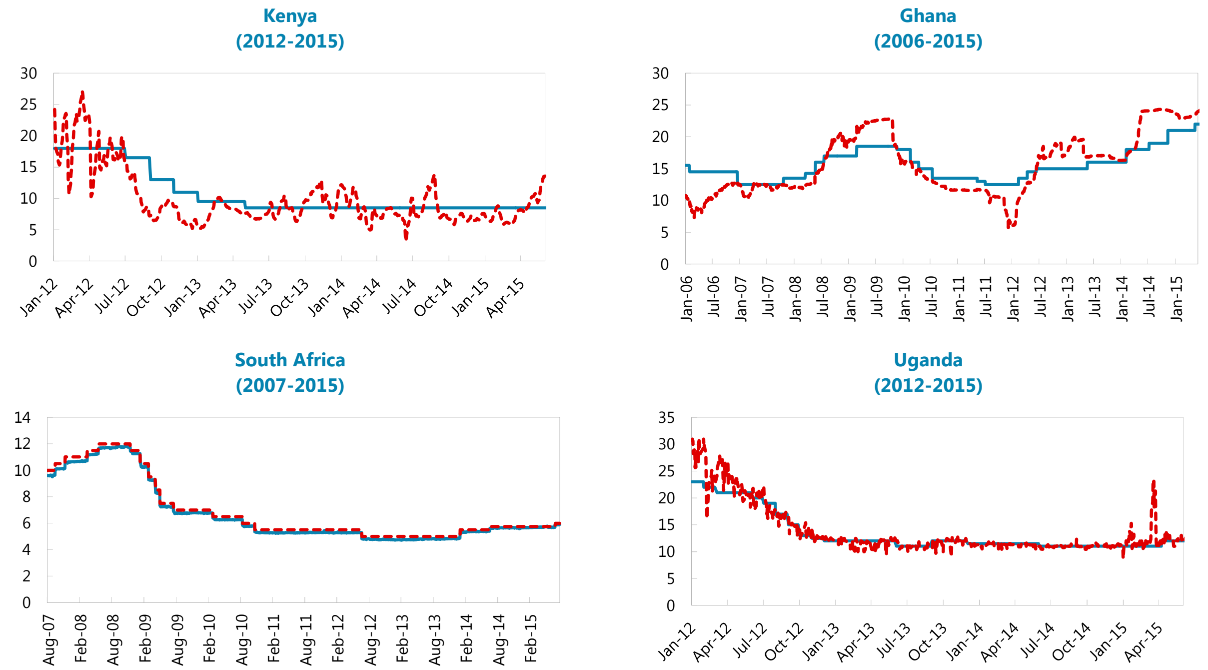
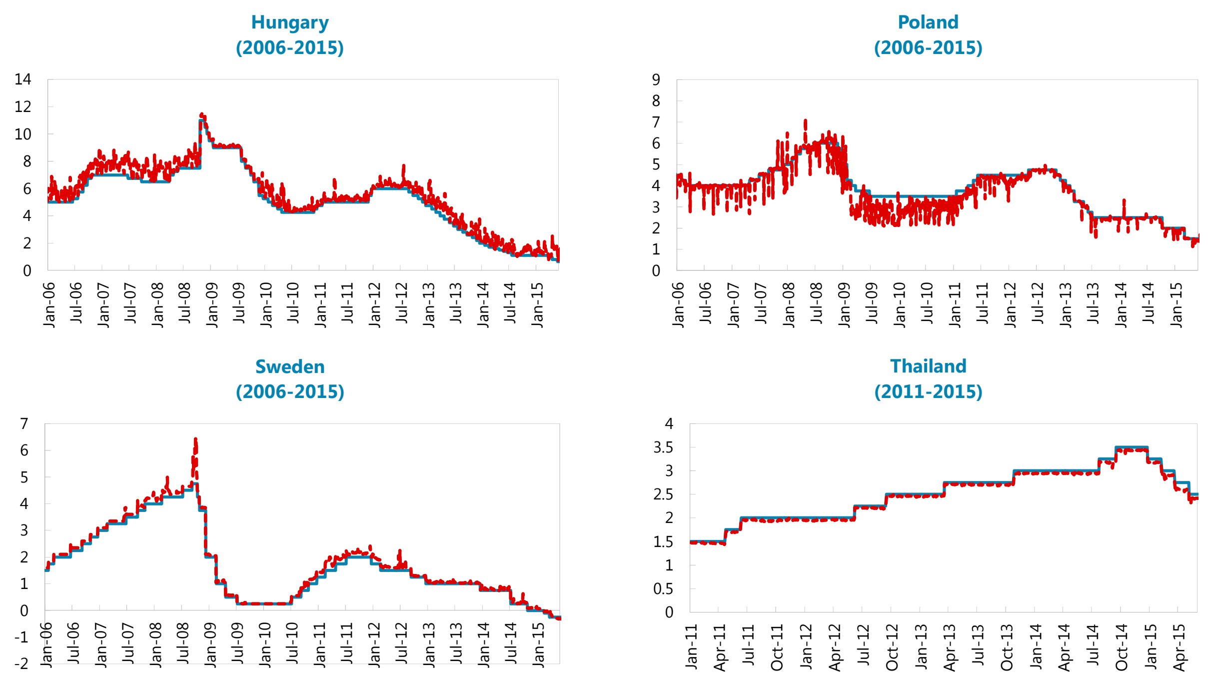


Figure A1.2 Policy and interbank rates in selected IT economies, 2006-2015 (country-specific scales in vertical axes)



Annex II Descriptive Statistics

A. Sub-Saharan Africa Countries

Table A2.1. Kenya: Summary statistics of (differenced) rates

	Overnight[1]	|Spread|	3-month[1]	6-month	12-month
Mean	0.012	2.290	-0.039	-0.034	0.009
Median	0.027	1.738	-0.016	0.000	0.000
Maximum	0.998	9.296	1.414	2.987	1.395
Minimum	-1.189	0.001	-1.298	-1.848	-1.045
Std. Dev.	0.412	1.855	0.456	0.488	0.302
Skewness	-0.395	1.257	-0.036	0.457	0.499
Kurtosis	5	4	6	13	9
Observations	887	887	189	189	126

[1] For differenced overnight and 3-month rates, the top 5% most extreme values are resized to equal the 95th percentile. For overnight rates, the standard deviation of the original data is 0.564 and in the resized data it is 0.412. For 3-month rates, the standard deviation of the original data is 0.545 and in the resized data it is 0.456.

Table A2.2. Ghana: Summary statistics of (differenced) rates

	Overnight[1]	|Spread|	3-month	6-month	12-month
Mean	0.019	2.242	0.082	0.084	-
Median	0.000	1.850	0.013	0.007	-
Maximum	0.250	6.750	1.999	3.532	-
Minimum	-0.250	0.000	-1.637	-0.914	-
Std. Dev.	0.082	1.625	0.361	0.445	-
Skewness	0.162	1.022	2.037	4.657	-
Kurtosis	6	3	16	33	-
Observations	847	847	176	176	-

[1] For the differenced overnight rates, the top 5% most extreme values are resized to equal the 95th percentile. The standard deviation of the original data is 0.159 and in the resized data it is 0.082.

Table A2.3. South Africa: Summary statistics of (differenced) rates

	Overnight	|Spread|	3-month	6-month	12-month
Mean	-0.002	0.202	-0.009	-0.008	-0.001
Median	0.000	0.210	0.000	0.000	0.000
Maximum	0.420	0.660	1.060	0.730	1.030
Minimum	-0.930	0.000	-0.790	-0.690	-0.580
Std. Dev.	0.051	0.082	0.121	0.117	0.126
Skewness	-9.133	0.119	-0.312	-0.647	1.880
Kurtosis	173	4	28	16	21
Observations	2174	2174	413	410	363

Table A2.4. Uganda: Summary statistics of (differenced) rates

	7-day interbank	|Spread|	3-month	6-month	12-month
Mean	-0.022	0.902	0.001	0.001	0.005
Median	0.000	0.310	0.050	0.060	0.083
Maximum	4.836	12.110	4.005	4.003	4.642
Minimum	-4.836	0.000	-3.929	-5.609	-5.571
Std. Dev.	0.962	1.572	1.052	1.068	1.168
Skewness	-0.209	3.522	-0.953	-0.725	-0.210
Kurtosis	9	18	8	12	11
Observations	749	749	103	103	103

B. Remaining IT Countries in the Sample

Table A2.5. Hungary: Summary statistics of (differenced) rates

	Overnight	|Spread|	3-month[1]	6-month	12-month
Mean	-0.003	0.524	-0.003	-0.003	-0.003
Median	-0.007	0.348	0.000	0.000	0.000
Maximum	2.280	2.160	0.200	0.770	0.920
Minimum	-1.730	0.000	-0.200	-0.680	-0.710
Std. Dev.	0.234	0.451	0.055	0.077	0.088
Skewness	0.469	1.113	0.079	0.825	1.228
Kurtosis	14	4	7	28	28
Observations	2746	2746	2746	2746	2746

[1] For the differenced 3-month rates, the top 5% most extreme values are resized to equal the 95th percentile. The standard deviation of the original data is 0.074 and in the resized data it is 0.055.

Table A2.6. Poland: Summary statistics of (differenced) rates

	Overnight	|Spread|	3-month	6-month	12-month[1]
Mean	-0.003	0.161	-0.003	-0.003	-0.003
Median	0.000	0.080	0.000	0.000	0.000
Maximum	1.430	1.380	0.400	0.610	0.300
Minimum	-1.190	0.000	-0.350	-0.520	-0.300
Std. Dev.	0.193	0.206	0.101	0.128	0.119
Skewness	1.646	2.515	0.028	0.067	-0.022
Kurtosis	17	11	5	6	4
Observations	1006	1006	1006	1006	1006

[1] For the differenced 12-month rates, the top 5% most extreme values are resized to equal the 95th percentile. The standard deviation of the original data is 0.133 and in the resized data it is 0.119.

Table A2.7. Sweden: Summary statistics of (differenced) rates

	Overnight	|Spread|	3-month	6-month	24-month
Mean	-0.001	0.116	-0.001	-0.001	-0.001
Median	0.000	0.100	0.000	0.000	-0.001
Maximum	0.780	1.725	0.248	0.290	1.340
Minimum	-1.751	0.000	-0.639	-0.465	-0.248
Std. Dev.	0.071	0.131	0.037	0.037	0.051
Skewness	-7.621	5.634	-3.432	-1.529	8.015
Kurtosis	213	55	55	29	218
Observations	2322	2322	2322	2322	2322

Table A2.8. Thailand: Summary statistics of (differenced) rates

	Overnight[1]	|Spread|	3-month	6-month	12-month
Mean	0.000	0.055	0.000	-0.001	-0.001
Median	0.000	0.050	0.000	0.000	0.000
Maximum	0.100	0.234	0.079	0.083	0.075
Minimum	-0.100	0.004	-0.247	-0.260	-0.231
Std. Dev.	0.018	0.024	0.016	0.016	0.017
Skewness	-0.475	2.295	-7.041	-6.719	-5.095
Kurtosis	17	11	107	98	69
Observations	1127	1127	1127	1127	1127

[1] For the differenced overnight rates, the top 5% most extreme values are resized to equal the 95th percentile. The standard deviation of the original data is 0.030 and in the resized data it is 0.018.

ANNEX III. ESTIMATION RESULTS

The symbols in the tables represent:

$\sum \boldsymbol{\beta}$**:** the sum of coefficients of autoregressive lagged interest rates. Significance corresponds to most significant lag.

$\sum \gamma$: the sum of coefficients of current and possible lags of policy rate changes. Significance corresponds to most significant lag.

$\boldsymbol{\alpha_1}$**:** the coefficient of spread, defined as the interbank less the policy rate.

$\boldsymbol{\omega}$**:** the coefficient on the GARCH effect.

δ: the asymmetric volatility effect arising from idiosyncratic disturbances.

$\boldsymbol{\varphi}$**:** the coefficient of the ARCH effect.

Ω: Coefficient of the natural logarithm of the conditional volatility of the relevant interbank rate. A positive and significant value implies volatility transmission from interbank rate to longer maturity instrument.

C. Sub-Saharan Africa Countries

Table A3.1. Kenya: E-GARCH model Estimation Results (2012-15, daily/weekly)

Mean Equation	ON (d)	3-month T-Bills (w)	6-month T-Bills (w)	12-month T-Bills (w)
α_0	-0.009	-0.005	0.000	-0.003
$\sum\beta$	**0.718**	**0.633**	**0.528**	**0.402**
$\sum\gamma$	-0.081	-0.018	0.050	**0.203**
α_1	**-0.004**	-	-	-
Variance Equation				
α_2	**-1.303**	-0.392	0.299	-0.830
ω	**0.730**	**1.057**	**0.999**	1.634
δ	0.018	-0.116	-0.261	0.234
φ	**0.882**	**0.821**	**0.899**	**0.727**
Ω	-	**0.171**	**0.189**	0.164
Mean GARCH	0.103	0.271	0.628	0.241
Sample	2012-15	2012-15	2012-15	2013-15
Error Dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.
N	884	180	185	123

Notes: Bold values indicate significance at 10 percent. Other control variables in mean and variance equations (not reported in the table) may include VIX, garch-in-mean term, and dummy variables to account for maintanence period.

Table A3.2 Ghana: E-GARCH model Estimation Results (2012-15, daily/weekly)

Mean Equation	ON (d)	3-month T-Bills (w)	6-month T-Bills (w)	12-month T-Bills (w)
α_0	0.000	-0.005	-0.005	-
$\sum\beta$	**0.665**	**0.426**	0.040	-
$\sum\gamma$	0.049	**0.056**	-0.012	-
α_1	0.000	-	-	-
Variance Equation				-
α_2	**-0.588**	**-0.643**	-0.156	-
ω	**1.831**	0.927	2.071	-
δ	-	-	-0.155	-
φ	**0.978**	**0.878**	**0.837**	-
Ω	-	-0.026	**0.113**	-
				-
Mean GARCH	0.043	0.481	0.847	-
Sample	2012-15	2012-15	2012-15	-
Error Dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.	-
N	842	173	174	-

Notes: Bold values indicate significance at 10 percent. Other control variables in mean and variance equations (not reported in the table) may include VIX, garch-in-mean term, and dummy variables to account for maintanence period.

Ghana's 1-year note yields have been constant during March 21, 2014 - October 30, 2015 at 22.5 percent. This rules out estimation at this maturity.

Table A3.3 South Africa: E-GARCH model Estimation Results (2007-15, daily/weekly)

Mean Equation	ON (d)	3-month T-Bills (w)	6-month T-Bills (w)	12-month T-Bills (w)
α_0	-0.001	0.000	0.001	**0.021**
$\sum\beta$	**-0.237**	**0.088**	**0.223**	**0.146**
$\sum\gamma$	**0.208**	**0.497**	**0.307**	**-0.168**
α_1	-0.017	-	-	-
Variance Equation				
α_2	**-1.453**	**-0.890**	**-0.306**	**-1.967**
ω	**0.342**	**0.423**	**0.852**	0.856
δ	0.050	-	0.020	-0.157
φ	**0.801**	**0.957**	**0.777**	**0.795**
Ω	-	-0.051	0.192	-0.047
Mean GARCH	0.003	0.028	0.034	0.033
Sample	2007-15	2008-15	2008-15	2009-15
Error Dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.
N	2156	412	389	352

Notes: Bold values indicate significance at 10 percent. Other control variables in mean and variance equations (not reported in the table) may include VIX, garch-in-mean term, and dummy variables to account for maintanence period.

Table A3.4. Uganda: E-GARCH model Estimation Results (2012-15, daily/bi-weekly)

Mean Equation	7-day (d)	3-month T-Bills (bi-m)	6-month T-Bills (bi-m)	12-month T-Bills (bi-m)
α_0	-0.020	-0.404	**-0.411**	**-0.238**
$\sum\beta$	**-0.363**	**0.306**	**0.400**	**0.371**
$\sum\gamma$	**0.212**	**0.230**	**0.235**	**0.298**
α_1	**-0.281**	-	-	-
Variance Equation				
α_2	**-0.228**	0.455	0.003	-0.986
ω	**0.353**	0.238	**-0.480**	**-1.593**
δ	0.047	1.024	**-0.281**	**-0.887**
φ	**0.989**	-0.046	**0.839**	0.247
Ω	-	**0.181**	**0.073**	**0.377**
Sample	2012-15	2012-15	2012-15	2013-15
Error Dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.
N	746	91	91	64

Notes: Bold values indicate significance at 10 percent. Other control variables in mean and variance equations (not reported in the table) may include VIX, garch-in-mean term, and dummy variables to account for maintanence period.

D. Remaining IT Countries in the Sample

Table A3.5. Hungary: E-GARCH model Estimation Results (2009-15, daily)

Mean Equation	ON (d)	3-month T-Bills (d)	6-month T-Bills (d)	12-month T-Bills (d)
α_0	**0.013**	-0.001	0.000	**-0.003**
$\sum\beta$	0.097	0.009	**-0.036**	0.004
$\sum\gamma$	**0.767**	**0.022**	**0.075**	**0.081**
α_1	**-0.115**	-	-	-
Variance Equation				
α_2	**-0.414**	**-0.447**	**-0.432**	**-0.773**
ω	**0.126**	3.417	**2.828**	**1.000**
δ	**0.519**	0.875	**-0.134**	-0.074
φ	**0.917**	**0.950**	**0.954**	**0.925**
Ω	-	0.014	**0.077**	-0.008
Sample	2009-15	2009-15	2009-15	2009-15
Error Dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.
N	1658	1658	1495	1495

Notes: Bold values indicate significance at 10 percent. Other control variables in mean and variance equations (not reported in the table) may include VIX, garch-in-mean term, and dummy variables to account for maintanence period.

Table A3.6. Poland: E-GARCH model Estimation Results (2012-15, daily)

Mean Equation	ON (d)	3-month WIBOR (d)	6-month WIBOR (d)	12-month WIBOR (d)
α_0	**-0.034**	**-0.077**	**-0.105**	**-0.027**
$\sum\beta$	-0.098	**-1.740**	**-2.072**	**-1.122**
$\sum\gamma$	-0.070	0.018	**0.111**	**0.172**
α_1	**-0.068**	-	-	-
Variance Equation				
α_2	**-3.163**	**-0.222**	**-0.621**	**-1.064**
ω	**0.654**	**0.232**	**0.451**	**0.576**
δ	**-0.278**	-0.009	-0.073	0.050
φ	**0.712**	**0.978**	**0.939**	**0.835**
Ω	-	0.012	-0.012	0.004
Sample	2012-15	2012-15	2012-15	2012-15
Error Dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.
N	912	912	912	912

Notes: Bold values indicate significance at 10 percent. Other control variables in mean and variance equations (not reported in the table) may include VIX, garch-in-mean term, and dummy variables to account for maintanence period.

Table A3.7. Sweden: E-GARCH model Estimation Results (2006-15, daily)

Mean Equation	ON (d)	3-month STIBOR (d)	6-month STIBOR (d)	2-year STIBOR (d)
α_0	**2.213**	**0.000**	**1.713**	**0.006**
$\sum\beta$	**0.048**	-0.004	**-0.167**	-0.006
$\sum\gamma$	0.001	0.015	-0.001	0.018
α_1	**-0.019**	-	-	-
Variance Equation				
α_2	**-5.344**	-0.027	**-1.050**	**-0.535**
ω	**0.186**	**0.672**	**0.559**	**0.157**
δ	**0.131**	**0.128**	**-0.071**	**-0.045**
φ	**0.298**	**0.998**	**0.860**	**0.937**
Ω	-	0.011	0.042	0.007
Sample	2006-15	2006-15	2006-15	2006-15
Error Dist.	G.E.D.	Stu. t-dist.	Stu. t-dist.	G.E.D.
N	2322	2322	2322	2322

Notes: Bold values indicate significance at 10 percent. Other control variables in mean and variance equations (not reported in the table) may include VIX, garch-in-mean term, and dummy variables to account for maintanence period.

Table A3.8. Thailand: E-GARCH model Estimation Results (2011-15, daily)

Mean Equation	ON (d)	3-month BIBOR (d)	6-month BIBOR (d)	12-month BIBOR (d)
α_0	**-0.008**	0.000	0.000	0.000
$\sum\beta$	**-0.488**	**0.233**	**0.316**	**0.269**
$\sum\gamma$	**0.414**	**0.058**	**0.176**	**0.033**
α_1	**-0.137**	-	**-**	**-**
Variance Equation				
α_2	**-**	**0.206**	-0.096	-0.003
ω	**-**	**0.330**	**0.271**	**0.905**
δ	**-**	**0.222**	**0.116**	**0.491**
φ	**-**	**0.988**	**0.959**	**0.964**
Ω	**-**	**0.057**	**0.051**	**0.031**
Sample	2011-15	2011-15	2011-15	2011-15
Error Dist.	**-**	Stu. t-dist.	Stu. t-dist.	Stu. t-dist.
N	1127	1127	1121	1127

Notes: Bold values indicate significance at 10 percent. Other control variables in mean and variance equations (not reported in the table) may include VIX, garch-in-mean term, and dummy variables to account for maintanence period.