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Interest rate pass-through to bank mortgage and participation bond rates in South Africa: Evidence from ARDL and FMLS models

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This paper examines the degree of pass-through and the adjustment speed of the bank rate and partB rate in response to changes in the repo and treasury bill rates in South Africa for the period 1998M4 to 2011M1. The repo rate is the policy rate while the treasury bill rate (TBR) represents money market rates. We employ the ARDL and FMLS estimators to test for co-integration over the whole sample period 1998M4 to 2011M1. From the ARDL model, long-run repo rates pass-through to bank rates range from 0.83 to 1.21. Estimates higher than unity indicate the overshooting of bank rates. Long-run TBR pass-through to participation mortgage bond rates lie between 1.00 and 1.29. A striking result is that both repo rates and TBR show overshooting in bankrates and partB rates. This phenomenon is akin to overshooting in exchange rates due to price increases. Our repo results to bankrates are similar to Aziakpono et al. (2007) and De Angelis et al. (2005). To the author's knowledge, there are no studies that have examined repo and TBR pass-through to participation mortgage bond rates in South Africa¹.

Key words: Interest rate pass-through, monetary policy, incomplete pass-through, ARDL, FMLS, bankrates, partB rates, overshooting, TBR, repo rates.

INTRODUCTION

The objective of this paper is to provide interest rate pass-through estimates (long and short run) via ARDL, a single equation error correction model, and long-run estimates from the FMLS model. It is generally accepted that monetary policy actions influence economic activity with a time lag that ranges from 4 months to 2 years

(Romer and Romer, 1989). There are six identifiable channels of monetary policy transmission to economic activity: (1) the interest rate channel, (2) the bank lending channel, (3) the balance sheet channel, (4) the asset price channel, (5) the exchange rate channel and (6) the expectation channel. Of these, the interest rate channel

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¹The Autoregressive Distributed Lag (ARDL) approach provides estimates of a single cointegrating relation on the basis an ARDL model selected by means of model selection procedures such as Akaike, Schwarz, Hannan and Quinn information criteria. Phillips-Hansen's fully modified FMLS provides single-estimates of the cointegration relations in an efficient and consistent way and also corrects the estimation for serial autocorrelation and endogeneity. A participation bond (partbond) is a collective investment scheme under which

investor money is pooled to provide loans to property developers or a mortgage bond over immovable property. The Bankrate is the loan rate charged by banks for residential mortgages. For commercial, industrial, and retail structures, the participation rate (or partB) is the loan rate. The repurchase (repo) rate is the rate at which the Reserve Bank lends money to the country's commercial banks, which in turn lend money to corporate and individual consumers at a higher rate - the repo rate plus 3.5% - known as the prime interest rate.

is often viewed as the most important since all other channels are related to changes in it. De Bondt (2002, 2005) describes the interest rate channel of monetary policy as reliant on the central bank's dominant influence on money market conditions, and thus on money market interest rates. However, changes in money market rates affect long-term market rates such as bond and mortgage rates. According to Hofmann and Mizen (2004), if monetary policy actions are to matter and be influential, the changes in the policy rate must completely pass-through to market rates and retail rates over a short horizon. However, in practice, differentials may persist for a time if banks and building societies (savings and loans) adjust their margins accordingly or if they face sizable costs of adjustments to changing rates.

We check the stability of the estimates by rolling and recursive regression methods. We do so by relating the repo and the 91-day Treasury bill (TBR) rates to the bank rate and the partB rate using monthly data for the 1998M4 – 2011M1.² Specifically, the paper addresses three empirical questions. First, are changes in the repo and TBR rates transmitted to the Bankrate and the partB rate? Second, is there complete repo and TBR pass-through to the Bankrate and partB loan rates? Finally, do the repo and TBR pass-through differ across two estimators (the autoregressive distributed lag model (ARDL) and the Fully-Modified Least Squares (FMLS)?

Greenwood-Nimmo et al. (2010) suggest that there are two strands of empirical literature that address the linkage between money market rates and longer-term rates depending on whether the financial system is "bank-based" or "market-based." In South Africa and Europe where the financial system is traditionally bank-based (central banks and other authorities), the analysis of pass-through is from policy rates (the repo rate) and short-term rates (91-day Treasury bill rate) to long-term commercial bank interest rates (the Bankrate (loan) rate and the PB or Part B rate). On the other hand, in the U.S. and other countries with market-based systems, the focus is on the relationship between short-term interest rates and long-term bond yields (the term structure of interest rates). Walsh (2009) suggests that without a clear understanding of the monetary transmission from policy rates to lending rates (in our case, mortgage rates), macroeconomic models in which the interest rate is viewed as a single decisive influence on aggregate demand may be of limited use. In South Africa, loans for residential houses account for about 73% of all outstanding loans by commercial banks, building societies (savings and loans) and other non-bank players in the residential market. For this segment of the economy, the Bankrate is the loan rate charged by banks in mortgages. For commercial, industrial and retail

structures, the participation rate (or partB) is the loan rate. Thus, for South Africa, it is important to understand the interest rate pass-through from the policy rate (the repo) to the Bankrate and the PartB rate, and the short-term money market (91-day Treasury bill) to the Bankrate and PartB rate. Given the importance of residential housing, commercial, industrial and retail structures in the South African economy, it is important to obtain estimates of interest rate pass-through to mortgage rates within the interest channel of monetary policy transmission.

REVIEW OF LITERATURE

The interest rate pass-through is not restricted to monetary policy only. In industrial organization literature, it is used to explain how costs are passed through to prices in oligopolistic markets. In international economics, Dornbusch (1987), Krugman (1987) and Dixit (1989) investigated how costs are passed through internationally for aggregate imports or specific imported goods. Clearly, the interest rate pass-through has parallels in industrial organization. The repo rate is a major determinant of the cost of deposits on the liability side of a bank's balance sheet while the retail rate (mortgage rate and other loan rate) is the price of loans on the asset side of a bank's balance sheet. Mann (1986), Feenstra et al. (1996) and Athukurola and Menon (1994) have examined how changes in exchange rates are fed into domestic imported goods, a phenomenon known as the exchange rate pass-through. With specific reference to mortgages in the U.K., Heffernan (1997) found that there was complete interest rate pass-through for repayment mortgages but incomplete pass-through for savings and checking accounts in the long-run for U.K. banks and building societies (Hofmann and Mizen, 2004). Evidence from an increasing number of interest rate pass-through studies are mixed; some studies find no interest rate pass-through, some find incomplete and complete pass-through, and some studies report asymmetries and non-linear pass-through.³

Aziakpono et al. (2007)'s and de Angelis et al. (2005)'s studies are the only studies that have estimated interest pass-through for various interest rates in South Africa. They found that the long-run pass-through of policy rates to lending and deposit rates ranged from 0.93 to 1.04 and 0.44 to 1.20 respectively. The short-run rate pass-through to lending and deposit rates were 0.40 to 0.92 and -0.01 to 0.80 respectively. De Angelis et al. (2005) focused only on the period, 1998 and 2004 and their results are lower than those in Aziakpono et al. (2007). Egert et al. (2007) suggest macroeconomic conditions like rapid growth, and higher inflation often encourages banks to

²PartB are participation mortgage bond rates that exclusively apply to commercial, industrial, and retail structures. Note that PartB and PB are used interchangeably in the paper.

³This paper focuses on cointegration and linear correction models only. Hannan and Berger (1991), Mester and Saunders (1995), and Hofmann and Mizen (2004) have modeled asymmetries and other non-linearities in interest rate adjustments when policy rates change

easily pass on changes in the interest rate to the prime rate and then to their lending and deposit rates. This reasoning might explain how South African banks were able to raise the loan rates as the prime rate rose to 9.6% in October 2010. Kapwil and Scharler (2006) presented results that show that the pass-through rate in the euro area is below 0.55 in all cases. In some cases, there are instances when the prime and loan rates overshoot in response to a change in the policy rate. Overshooting occurs when the pass-through coefficient is more than one. This phenomenon can be explained by the over-reaction of creditors to rising interest rates as they hedge their credit risks in the face of uncertainty.

According to West (2008), the repurchase rate (hereafter, repo) is the rate that is used for borrowing and lending between the South African Reserve Bank (hereafter, SARB) and commercial banks (Absa, FNB, Nedbank, Standard Bank and other banks). By changing the supply of available funds, the SARB can affect short-term interest rates that are determined by demand and supply market forces. The short-term rate in turn affects the yield curve which is often used as a predictor of economic growth especially in market-based economies. The repo rate is indirectly set by the Monetary Policy Committee (MPC) of the SARB which meets every two months. During the period leading to an announcement by the SARB, financial markets engage in speculation and positioning in terms of whether the MPC will change the repo (if so, by how much) or leave it unchanged.⁴ This has been the practice before 2000 when a rate called the SAREP1 (which varied daily) played the role of repo rate.

Bank loans (mortgages) and the bankrate (mortgage rate)

Until recently, the prime rate was often considered to be the best borrowing rate granted to bank customers.⁵ The creditworthiness of bank customers was usually indicated by the margin paid above the prime rate and no customers could obtain loans for rates less than the prime rate. Thus, for simple loan products with the prime rate as a benchmark, SARB's monetary policy had a direct impact on bank borrowers for residential housing, and on investors who participated in supplying funds to managers who in turn loaned these funds for commercial, industrial, and retail buildings. In other words, the SARB could directly affect credit demand. However, over time the direct link to the prime rate has lost its relevance given that a substantial part of the asset side of banks is not based on prime rates. On the liability side of bank balance sheets, the prime rate does not have a major impact except in few cases related to the preference share market, an instrument used for raising bank

capital. In mortgage lending, banks often use their own home loan rate which does not always track the policy rate (the repo), and their own home loan rate often does not equal the prime rate. In the paper, this rate is the *Bankrate*. Since the link between the repo rate and the prime rate was well-understood by customers and banks, the banks influenced the prime rate and banks did not have to renegotiate loan and deposit rates anytime the prime rate changed, due to the wide usage of the variable rate mortgage available from all banks.

Over the years, South African banks have encountered four challenges that have squeezed bank overall yields on assets (excluding the costs of funds).⁶ First, banks have been forced to increase loan rate concessions (the *Bankrate* is an average rate) to customers due to increased competition within the banking industry by both local and foreign banks. Second, there is an increase in the number of retailers, motor manufacturing, and some agricultural firms that provide credit to consumers, thus bypassing the banks. Third, the residential home market has seen an entry of mortgage originators providing direct loans to buyers, thus increasing competition for banks. Finally, there has been an increasing reliance on wholesale funding for retail assets.

Participation mortgage bonds and part B rate (loan rate)

The Participation Bonds Act 55 of 1981 was designed to enable financial institutions (the "manager" of the fund) to offer to investors (those who may wish to invest small sums) the opportunity of participating with other investors in an investment secured by a registered mortgage bond over immovable property (commercial, industrial and retail buildings) and yielding a competitive rate. In this paper, the rate is termed *partB (PB)*. Under the Act, the financial institution (the "manager") has to find a borrower and a number of investors who are prepared to advance sums of money which will match collectively the sum that is required by the borrower. More often, the manager cannot achieve such a perfect match. In the event that the manager has enough money from investors in a participation mortgage bond but has no borrower, the manager must return the money to investors within 60 days. If the manager has a borrower but not enough investors, the manager can participate by providing the shortfall. However, in cases where the required funds are loaned to the borrower (at rate *partB* in this paper) a participation mortgage bond must be registered in the deeds registry. The manager is required to keep a register with the names of participants (investors), the extent of their participation (how much they contributed), as well as all amounts repaid to participants in the form of interest income.

⁴Gidlow (1998) has a detailed account of the SARB's monetary policy.

⁵An address by SARB Governor at the 81st ordinary meeting of shareholders, August 28 2001.

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The payment of interest to the Participation Bond Fund (manager) is distributed as income to investors who may be individuals, pension funds and trusts. The interest rate paid by borrowers is usually a couple of percentage points below the prime rate but *higher* than interest rates offered by most money market funds. Like the Bankrate, the interest rate tends to fluctuate. Managers of participation mortgage bonds are bound by law to insure properties in their portfolio (to eliminate risk for investors). Besides this attraction, there are three additional benefits. First, monthly interest income for investors is better than that obtainable in money market. Second, mortgage bonds are on a variety of commercial, industrial, and retail properties within the portfolio held by investors as security (Candy, 2006). Finally, according to the Collective Investment Schemes Control Act (CISCA), partbond companies (managers) can lend only up to a maximum of 75% of the value of each property. Since the property serves as security against the loan, the managers of the fund can repossess if the borrower fails to make payments.

The rates that drive both the Bankrate and the PartB rate are the repo rate- a policy rate and the Treasury Bill rate (TBR) – a money market rate. Treasury bills are short-term debt obligations which are in bearer form with a term not exceeding twelve months. Tender bills, with tenure of 91, 182 and 273 days, are allocated by the South African Reserve Bank on behalf of the government at a weekly tender on Fridays, for settlement the following week. The weekly Treasury bill tender rate (*TBR* in this paper refers to the bill with 91 days of maturity) is a prime indicator of money-market conditions. Special tender bills are issued on any day of the week for varying periods of no longer than one year. The Bankrate is the interest rate charged by the bank for residential loans. For example, Standard Bank has traditional home loans with a term of 30 years. However, mortgage repayments require a compulsory debit order from one's bank account. ABSA Home Loans is the largest mortgage lender in South Africa, with up to 30% share of the home loans market. The bank offers a wide range of home finance options to suit different customers' needs, including 110% home loans. In this paper, the *Bankrate* refers to the average loans rates across all major banks in South that include ABSA, Standard Bank, Nedbank and the FNB.⁷

The repo rate (repurchase rate) is the interest at which commercial banks (such ABSA, Standard Bank, FNB, and Nedbank) borrow from SARB.⁸ To make profit banks

lend this money to bank customers at a higher prime rate. Thus, the repo rate, a short-term money market rate, is a crucial determinant of commercial bank funding costs. Thus, sustained movements in the repo will always end up in a compensating move in bank's prime lending and deposit rates. Each day, the SARB makes available a certain amount of funding to commercial banks through repo (repurchase) transactions which involves banks selling securities to the SARB in return for funds. The funds are made available against the obligation to purchase back the securities at an agreed price at a future date. Since the repo rate is variable, the banks essentially determine the rate at which they submit bids since the final repo rate is the average of the rates attached to all successful bids.⁹ In order to avoid borrowing at the punitive rate, banks often increase the rate at which they bid for repo funds, pushing the repo rate upwards.

The widespread use of adjustable rate mortgages (Bankrate and PartB rates) in South Africa alters the monetary transmission in two ways (Payne, 2007). First, monetary changes in policy and market rates are transmitted quickly to retail rates. Second, changes in market rates affect the payments on existing mortgages and participation bonds which have an impact on household discretionary incomes. Thus, we expect repo rate and TBR changes should be completed pass through within a short period. Whether this happens in South Africa is an empirical matter that is examined in the next section. The official interest rate is the repo rate. It is the rate at which central banks lend or discount eligible paper for deposit money banks, typically shown on an end-of-period basis.

METHODOLOGY

Although there are several methods for conducting the cointegration test, this paper uses the autoregressive distributed lag (ARDL) modeling approach and the Fully Modified Least Squares (FMLS) estimator for comparison.¹⁰ The FMLS estimator is only available for long-run analysis. We discuss two estimators that are used to determine the extent to which changes in mortgage rates (Bankrate and PARTB) follow changes in repo and the TBR rates, and to determine how fast the adjustment occurs.

⁷The residential sector addressed does not capture low to moderate housing where over 75% of the population resides. This housing is strictly occupied by mainly Africans and to a lesser extent, Indians and Coloureds. The Financial Sector Charter (FSC) was established to provide previously disadvantaged people with different ways of buying residential property. The FSC programs apply to those who earn less \$2,000 per month.

⁸South Africa's repo rate is analogous (not identical) to the federal funds rate in the US. The interest rate that the borrowing bank pays to the lending bank to borrow the funds is negotiated between two banks, and the weighting average of this rate across all such transactions is the federal funds effective rate.

⁹In the event that commercial banks are not able to borrow adequate funding from the repo tender, they can use the marginal lending facility. The problem with using this facility is that it increases the cost of funds for the bank since the marginal lending rate is always punitive --- well above the repo rate and the TBR.

¹⁰The widely used estimators include the residual-based Engle and Granger (1987) test, maximum likelihood-based Johansen (1988, 1991, 1995), the Johansen and Juselius (1990), and the Phillips and Loretan (1991) tests. For more details, see Shrestha (2005). We note that the FMLS estimator requires knowledge of integration properties of the data. We tested the variables used in the model by the Dickey-Fuller (ADF) and the Phillips and Perron (PP) (1988) tests. Results show variables to I(1) in levels but I(0) when differenced once. Thus, all variables are stationary in their first differences

Table 1. Bounds testing for cointegration.

Dependent variable	Number of variables	F-Statistics @ 95% (Case II: Intercept and no trend)	
		Lower critical value	Upper critical value ¹¹
		3.793	4.855
$F_{RP}(RP BR)$	2	F(2,114)=1.40	
$F_{BR}(BR RP)$	2	F(2,114)= 4.89	
$F_{BR}(BR TBR)$	2	F(2, 114)= 5.10	
$FT_{BR}(TBR BR)$	2	F(2,114)=1.66	
$FT_{PB}(PB RP)$	2	F(2,114)= 5.75	
$FT_{RP}(RP PB)$	2	F(2,114)=1.20	
$FT_{TBR}(TBR PB)$	2	F(2,114)=2.71	
$FT_{PB}(PB TBR)$	2	F(2,114)= 5.87	

ARDL modeling or bounds testing procedure

The ARDL modeling was popularized by Pesaran and Pesaran (1997), Pesaran et al. (2001), Pesaran and Smith (1998) and Pesaran and Shin (1999). The main advantage of the ARDL is that it can be employed even if the variables are I(0) or I(1) and this dispenses with the need to carry out unit root tests. Another advantage is that it can accommodate a sufficient number of lags to ensure validity of the data generating process in a general-to-specific modeling approach. If the variables are cointegrated, this means that there exists an error-correction model (ECM) that integrates short-run dynamics with long-run, ensuring that there is no loss of long-run information. Finally, in using the ARDL, one avoids problems associated with non-stationary data.

In Table 1, *RP* is the repo rate, *TBR* is the Treasury bill rate, *BR* is the Bankrate, and *PB* represents Participation mortgage bond rates. The ARDL modeling is carried out in three steps. First, the ARDL testing procedure begins by conducting the bounds test (or F test) for the null of no cointegration. The calculated F-statistic is compared to critical values tabulated in Pesaran et al. (2001) or Pesaran and Pesaran (1997). If the calculated F-statistic is larger than the tabulated upper critical value, the null of no cointegration is rejected regardless of whether variables are I(0) or I(1). However, if the calculated F-statistic is smaller than the tabulated lower critical value, the null of no cointegration is not rejected. Finally, if the calculated F-statistic is between the lower and upper critical value, the result is inconclusive without additional information.

The results in the table confirm the existence of an equilibrium relationship at the 5% level of significance if the Bankrate (*BR*) is the dependent variable and the repo rate (*RP*) is the independent or ‘forcing variable.’ The F-statistic is 4.89, which is above the upper critical value of 4.855. Since there are four variables, we are bound to test all of them. We test $F_{RP}(RP | BR)$ for cointegration and the result is 1.40 which lies below 3.793. The result means that there is no cointegration when the repo is the dependent variable and *BR* is the independent variable. When *BR* is the dependent

variable with *TBR* as the independent variable, that is, $F_{BR}(BR | TBR)$, the F-statistic equals 5.10 which indicates cointegration since 5.10 is greater than the upper critical value of 4.855. The same holds in $F_{PB}(PB | RP)$ and $F_{PB}(PB | TBR)$. Table 1 also points to the existence of four cointegration vectors, which means that there are four error-correction models obtained in equation (2). The ARDL estimator estimates $(p + 1)^k$ number of regressors per equation in order to obtain an optimal lag for each variable, where *k* is the number of variables (two in our case) and *p* is the maximum number of lags that removes serial correlation. Selection criteria such as AIC and SBC are used to determine optimal lags (SBC tends to choose the smallest possible lag to produce a parsimonious model).

The second step involves estimating long-run estimates using the ARDL. If the long-run holds, it means that there exists an error-correction representation. Third, the error-correction model is estimated to obtain the speed of adjustment to a long-run equilibrium following a shock to the system. As part of output, the ARDL model yields both diagnostic tests and stability tests. The diagnostic tests check for serial correlation, normality, functional form and heteroscedasticity. Stability tests are examined by displaying two graphs: the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ).¹² Finally, the best fitting model can be examined by looking at the difference between actual and forecast values: the smaller the differences, the better the fit of the ARDL model to data.

The objective is to establish whether the repo rate and the TBR and the BR and PB are cointegrated by employing the ARDL approach. The long-run model is given as:

$$ARM^i_t = \beta_0 + \beta_1 R^j_t + e_t, \quad i = BR, PB, \quad j = TBR, RP \quad (1)$$

where ARM^i represents the *Bankrate (BR)* and *Part B (PB)*

¹¹The critical values are taken from Pesaran and Pesaran (1997).

¹²CUSUM and CUSUMSQ graphs are not reported here in order to preserve space. These are available from the author.

rate at time t , R_t^j represents the TBR and the Repo rate (RP) at time t , and e_t is an error term. In (1), β_0 represents an immediate pass-through or a constant loan intermediation margin (Payne, 2007). It gives the reaction of the Bankrate or Participation bond rate to a change in the repo or TBR rate within the same period (one month in this case). In other words, it is the percentage point difference between the Bankrate and PartB and the base rate (repo and TBR). If $\beta_1 = 1$, there is a complete interest rate pass-through while if $\beta_1 < 1$, this indicates an incomplete pass-through. It is possible for $\beta_1 > 1$ in which case the retail rates, Bankrate and the partB rate are more than passes through repo and TBR rates. That is, they respond more than the policy or money market rates in the *long-run*. The overshooting in the short-run has economic explanation similar to the overshooting of the exchange rate, following a price increase (Dornbusch, 1987). Finally, if $\beta_1 = 0$, it indicates that there is zero repo rate pass-through to prime interest rates. This result is unlikely in the presence of monetary policy that targets inflation via changes in the policy rate. From (1), the error-correction version of the ARDL model is given by:

$$\Delta ARM_t = \alpha + \sum_{k=1}^n \phi_k \Delta ARM_{t-k} + \sum_{k=0}^n \lambda_k \Delta R_{t-k} + \delta_1 ARM_{t-1} + \delta_2 R_{t-1} + \varepsilon_t \tag{2}$$

with variables defined as in (1).

In (2), ϕ s and λ s represent short-run dynamics of the model whereas δ_1 and δ_2 represent a long-run relationship. The null hypothesis of no cointegration is $\delta_1 = \delta_2 = 0$. This test is necessary to establish whether the repo rate and the TBR rate are cointegrated with the Bankrate and the PartB. The monthly data on the repo, TBR, Bankrate, and PartB were obtained from the SARB database. It covers the period 1998M4 to 2011M1. The choice of 1998M4 as the starting date is related to various attempts by the SARB to initiate steps towards adopting the repo rate as a monetary policy rate. The ARDL method was applied to the period, 1998M4 to 2011M1.

The fully-modified least squares (FMLS) approach

Following Panopoulou (2005) and Phillips and Hansen (1990), let z_t and u_t be two bivariate processes, with $z_t = [y_t, x_t]^T$ and $u_t = [u_{1t}, u_{2t}]^T$. Furthermore, assume that u_t is a VAR (1) process that is driven by $e_t = [e_{1t}, e_{2t}]^T$, and the data generating mechanism for y_t is given as follows,

$$y_t = \theta x_t + u_{1t} \tag{3}$$

$$\Delta x_t = u_{2t} \tag{4}$$

$$\begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} u_{1t-1} \\ u_{2t-1} \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix} \tag{5}$$

$$\begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix} \square NIID \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix} \begin{pmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{pmatrix} \right] \text{ for all } t=1,2, \dots,T \tag{6}$$

In order for y_t and x_t to be I (1) variables and the cointegration error to be an I(0) process, the eigenvalues of the matrix $A = [a_{ij}], i, j = 1, 2$ are assumed to be less than one. The long-run covariance matrix Ω and the one-sided covariance matrix Δ are required to define asymptotic nuisance parameters, given by the following equations. In (7)-(9), I is an identity matrix,

$$\Omega = (I - A)^{-1} \Sigma (I - A^T)^{-1} \tag{7}$$

$$\Delta = G(I - A^T)^{-1} \tag{8}$$

where Σ is the innovation covariance matrix of the VAR and G is the unconditional covariance matrix of u_t given by

$$vecG = (I - A \otimes A)^{-1} vec\Sigma \tag{9}$$

The estimation of (4) and (5) can be accomplished by an OLS estimator which is consistent with the larger sample size. However, (a) 'long-run correlation' and (b) 'endogeneity' problems usually referred to as 'second-order effects' remain when one conducts any statistical inference on the cointegrating vector. Phillips and Hansen (1990) employ semi-parametric corrections for (a) and (b) which modifies the OLS estimate of θ in (3) and its standard error to give rise to the FMLS method via a consistent estimation of Ω and Δ in (8) and (9) respectively. The method suggested requires two procedures; the selection of a kernel estimator and the choice of bandwidth. Thus, in (3), the dependent variables are the Bankrate (BR) and the participation mortgage bond rate (PB) that are regressed on an I(1) regressors (the repo rate and the TBR) without intercepts or a time trend.¹³The selection of the lag window (Bartlet, Tukey, equal weight, and Parzen) is available from *Microfit*.¹⁴ With the lag window chosen, the next task is to specify the length of the lag window.¹⁵ For this paper, the lag window chosen is the Parzen window, and 12 is chosen as the length of the lag window. The Parzen window ensures positive standard errors while the length of the window takes the frequency of data. Other lengths were tried but the length of 12 produced the best results. The FMLS results are presented in Table 2 (Panels B, D, F, and H).

RESULTS AND DISCUSSION

All results are presented in Tables 2 and 3 in the Appendix A. The long-run results from ARDL and FMLS methods are presented in Panels A to H in Table 2. Panels A, C, E, and G show long-run estimates of the interest rate pass-through from the ARDL models with the

¹³The repo rate, the TBR rate, Bankrate, and partB are I(1) while the same variables in first differences are I(0).

¹⁴All estimates were carried out using the Microfit package, Version 4.0

¹⁵For more details on the lag window and the length of the lag window, see Newey and West (1987, 1994).

repo rate and the TBR as independent variables and the Bankrate and PartB as dependent variables. We report similar results in Panels B, D, F, and H for the FMLS approach. With the repo rate as the independent variable and BR as the dependent variable, the ARDL and FMLS show that the repo pass-through to the BR rate is complete as the estimates are 0.96 and 0.83 respectively, close to unity (Panels A and B). The ARDL and FMLS estimates of the TBR rate pass-through to BR are 1.21 and 1.04 respectively. In other words, there is overshooting of BR and PB rates when there is a change in the money market rates, as investors and banks expect further adjustments to the repo which is closely associated with the TBR rate. In Figures 1b and 1c (Appendix B), the correlation between the repo and the TBR is 0.99, a very close relationship under any definition. When TBR is the independent variable and PB the dependent variable the TBR pass-through estimates are 1.29 and 1.00 for the ARDL and FMLS models respectively.

Above all, there are three noteworthy results in Table 2. First, the repo rate pass-through to the Bankrate in the ARDL model is 0.96 while the TBR rate pass-through to the Bankrate in the FMLS model is 0.83 (Panels A and B). This means that the long-run repo rate pass-through to bank loans is complete since $\beta_1 \approx 1$. Second, the TBR pass-through to bank loan rates overshoots in both models (Panels C and D). This is important in that money market rates are usually the last stage in the pass-through mechanism; the first stage is repo changes to money market rates, followed by money market adjustment to retail rates. Finally, the TBR pass-through to participation mortgage rates (PB) also indicates overshooting in Panels E and unity in Panel F. However, the repo rate pass-through to PB in Panel G indicates overshooting (1.05) whereas the FMLS result in Panel H presents incomplete pass-through. All results in Panels A to H show the estimates of repo rate and TBR pass-through to be positive and significant at the 5% level of significance. Overall, Panels C, E, and G show that all the ARDL estimates indicate overshooting. However, overshooting is not restricted to ARDL models since Panels D and F show FMLS estimates that are either close or above unity. In Panel E, diagnostic tests show that the model passes the tests for functional, serial correlation, normality and heteroscedasticity. However, models in Panels A, C, and G fail the normality test. The normality assumption is important in small samples but it is not generally required when the sample is large as in our case (Pesaran and Pesaran, 1997).

There are no short-run dynamics from the FMLS approach. The short run dynamics are shown in Table 3 in Panels A to C representing various ARDL models from ARDL (2,5), ARDL (2,4), ARDL (1,4) and ARDL (1, 2) in Appendix A. In Panel A (ARDL; 2,5), the short-run repo rate pass-through is 0.4 but insignificant. Similarly, the

first and second lagged estimates of the repo are negative and insignificant. The third and fourth lagged repo rates are positive and significant. Figure 1d in Appendix B shows the recursive estimates of the repo rate pass-through initial falling before they rise again. More importantly, the ECM has the correct sign and shows that 16% of any deviation from equilibrium (complete pass-through) is corrected within a month. In Panel B (ARDL; 2, 4), the coefficients of the first and second TBR are negative and significant while the third lagged TBR value is positive and significant. Figure 1c shows initial declining TBR pass-through followed by positive values in that pass-through. The coefficient of the error-correction term is -0.51 and significant at 5% level of significance. When $\Delta PartB$ is the dependent variable, the model ARDL (1, 4) shows the first to the third lagged values of the TBR to be negative and significant (Panel C). In Panel D (ARDL; 1, 2), the short-run repo pass-through coefficient is -0.02 and significant. Whereas a one-lagged repo estimate is -0.24 and significant at the 5% level of significance. In both C and D, the coefficient of the error-correction term is negative and significant. Overall, short-run repo pass-through estimates are smaller than long-run estimates.

Stability tests

We employ two stability tests: the Recursive Least Squares graph and the Rolling Least Squares estimation. They augment the CUSUM and CUSUMSQ available from the ARDL single equation model.¹⁶

Recursive least squares

This option allows one to estimate a linear regression equation recursively by the OLS method. The estimated regression coefficients together with their standard errors are shown graphically in Figures 1d to 1g in Appendix B. One option in *Microfit* allows for the plotting of the recursive coefficients and their standard error bands, computed as the recursive coefficients plus or minus twice their standard errors. Figure 1d shows the impact of repo changes on changes in mortgage rate (Bankrate). It shows that the repo pass-through estimated coefficients initially decline before they remain constant for the rest of the period. The repo interest pass-through is close to unity as reported in Table 2 (Panel A). In Figure 1e, the impact of repo changes on participation bond rates (PartB) initially exhibits a decrease followed by a rise around 1999M5. For the rest of the period, the interest rate pass-through is closer to unity. Figure 1f shows the

¹⁶CUSUM and CUSUMSQ graphs are not reported here in order to preserve space. These are available from the author.

impact of changes in the TBR on participation bonds (PartB). It shows the pass-through coefficient to be rising almost beyond unity beginning around 2004M5. Similarly, Figure 1g shows the value of the TBR pass-through to BR increasing from 1999M12 with temporary dip in 2003M5. This figure compares well to Panel E in Table 2.

Rolling window tests

This option allows one to plot rolling coefficients and their standard error bands, computed as the rolling coefficients plus or minus twice their standard errors. The size of the window is 12.¹⁷ The rolling estimation graph (Figure 1k) shows that the impact of repo changes on changes in the bank loan rate (Bankrate) shows great volatility of pass-through rates around zero for the whole period. Figure 1j shows the impact of changes in TBR on participation mortgage bonds. It shows gradually increasing interest rate pass-through over unity. The figure is close to Table 2 (Panel E) which shows a long-run pass-through coefficient of 1.29. Figure 1j shows that TBR changes tend to be reflected in higher pass-through rates in PartB or participation mortgage bond rates. Figure 1h shows TBR changes on bankrates. It is similar to Figure 1k. Finally, Figure 1j shows repo changes to participation mortgage bond rates. The graph is almost identical to Figure 1k. This means that TBR and repo changes on participation mortgage bond rates are almost identical. All recursive and rolling regression coefficients lie within plus or minus twice their standard errors. The results point to the stability of the coefficients presented in Tables 2 and 3. These graphs are supported by CUSUM and CUSUMSQ graphs.

Conclusion

The paper examined three questions concerning the relationship between bankrates, participation mortgage rates and the repo and TBR rates over the period 1998M4 to 2011M1. In Table 1, we established that repo and TBR rates cause changes in bankrates and participation mortgage bond rates. From Table 2, it is clear that it is changes in the repo and TBR rates that lead to changes in the Bankrate and participation mortgage bond rates. In other words, the repo and TBR rates are the 'forcing variables' in equation (1). There is complete interest repo pass-through to the participation mortgage bond rates in Table 2(Panel G) and overshooting in Panel E. The TBR pass-through to the Bankrate overshoots in Panels C. In Table 3, the short-run repo rate pass-through estimates to the Bankrate are only significant for third and fourth lagged repo rates. The

short-run repo rate pass-through estimates to the participation mortgage bond rates are only significant for one-lagged repo rate. In Table 2, long-run rate pass-through is 0.79 to 1.29. In both ARDL and FMLS models, there is overshooting of bankrates and partB rates in response to changes in the repo and TBR rates. Our repo results of bankrates are similar to that of Aziakpono et al. (2007) and De Angelis et al. (2005).

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¹⁷The window size of 12 yielded the best results. The choice of an optimal window size is more of art than science.

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Appendix A

Table 1. Long-run results: Dependent variable: PARTB.

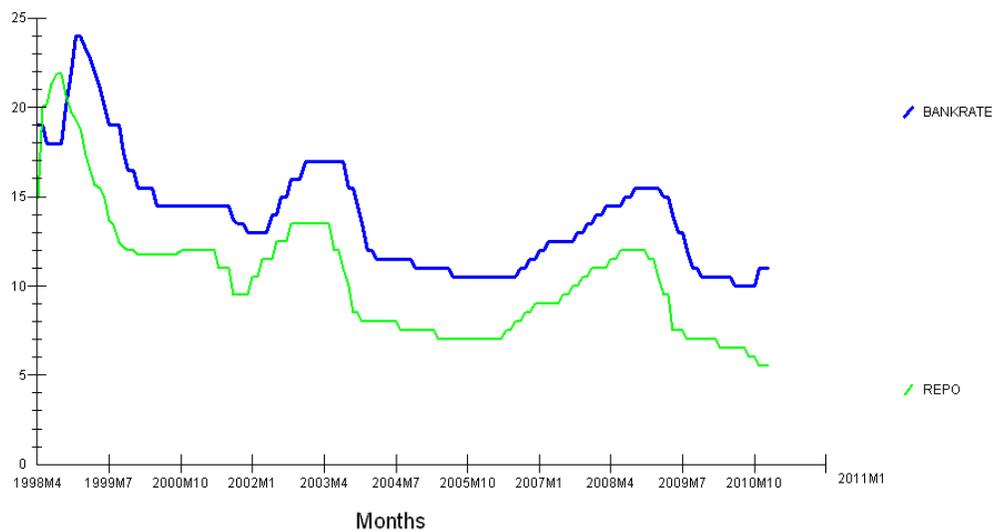
ARDL (1,4) Model Sample(1998M4-2011M1) <u>Panel E</u>	C TBR	0.89 1.29	0.37 0.04	2.39[0.00] 33.31[0.00]
Diagnostic test statistics Serial Correlation, $\chi^2(1) = 8.770[0.728]$, Functional Form, $\chi^2(1) = 2.99[0.08]$ Normality, $\chi^2(2) = 6.00[0.07]$, Heteroscedasticity, $\chi^2(1) = 10.62[0.056]$, $R^2 = 0.986$, Durbin-Watson Statistic = 1.93, F(6, 11) = 636.37[0.000]				
Fully Modified Least Squares (FMLS) (Parzen Weights, Lag=4, trended case): Sample(1998M4-2011M1) <u>Panel F</u>	C TBR	3.61 1.00	0.89 0.86	4.06[0.000] 11.62[0.00]
ARDL (1,2) Model Sample(1998M4-2011M1) <u>Panel G</u>	C Repo	2.35 1.05	0.49 0.05	4.77[0.00] 22.01[0.00]
Diagnostic test statistics Serial Correlation, $\chi^2(1) = 11.09[0.728]$, Functional Form, $\chi^2(1) = 0.78[0.376]$ Normality, $\chi^2(2) = 7.35[0.03]$, Heteroscedasticity, $\chi^2(1) = 8.67[0.561]$, $R^2 = 0.983$, Durbin-Watson Statistic = 1.90, F(4, 123) = 1827.8[0.000]				
Fully Modified Least Squares (FMLS) (Parzen Weights, Lag=4, trended case): Sample(1998M4-2011M1) <u>Panel H</u>	C Repo	5.18 0.79	0.67 0.06	7.74[0.000] 13.42[0.00]

Table 2. Dependent variable.

Long-run results: BANKRATE				
Estimator and sample period	Regressor	Coefficient	Standard error	t-Ratio
ARDL (2,5) Model Sample(1998M4-2011M1) Panel A	C	3.72	0.52	7.20
	Repo	0.96	0.05	19.40
Diagnostic Test Statistics				
Serial Correlation, $\chi^2(12) = 28.74[0.113]$, Functional Form, $\chi^2(1) = 0.23[0.63]$				
Normality, $\chi^2(2) = 58.16[0.000]$, Heteroscedasticity, $\chi^2(1) = 4.77[0.130]$, $R^2 = 0.993$, Durbin-Watson Statistic = 2.09, F(8, 120) = 2119.5[0.000]				
Fully Modified Least Squares (FMLS) (Parzen Weights, Lag=12, trended case) Sample(1998M4-2011M1) Panel B	C	5.24	0.47	11.11
	Repo	0.83	0.04	20.08
Diagnostic Test Statistics				
Serial Correlation, $\chi^2(1) = 12.40[0.414]$, Functional Form, $\chi^2(1) = 0.05[0.850]$				
Normality, $\chi^2(2) = 11.60[0.003]$, Heteroscedasticity, $\chi^2(1) = 4.07[0.441]$, $R^2 = 0.993$, Durbin-Watson Statistic = 2.07, F(6, 11) = 636.31.7[0.000]				
ARDL (2,4) Model Sample(1998M4-2000M1) Panel C	C	3.40	0.24	14.31[0.00]
	TBR	1.21	0.02	59.06[0.00]
Diagnostic Test Statistics				
Serial Correlation, $\chi^2(1) = 12.40[0.414]$, Functional Form, $\chi^2(1) = 0.05[0.850]$				
Normality, $\chi^2(2) = 11.60[0.003]$, Heteroscedasticity, $\chi^2(1) = 4.07[0.441]$, $R^2 = 0.993$, Durbin-Watson Statistic = 2.07, F(6, 11) = 636.31.7[0.000]				
Fully Modified Least Squares (FMLS) (Parzen Weights, Lag=12, trended case): Sample(1998M4-2011M1) Panel D	C	3.82	0.57	6.65[0.00]
	TBR	1.04	0.06	18.67[0.000]
Short-run results: Δ PARTB.				
ARDL (1,4) Model Sample(1998M4-2011M1) Panel C	dC	0.35	0.16	0.78[0.436]
	dTBR	0.07	0.09	44.15[0.030]
	dTBR1	-0.43	0.11	-3.72[0.000]
	dTBR2	-0.18	0.11	-1.63[0.106]
	dTBR3	-0.34	0.11	-3.07[0.003]
	ECM(-1)	-0.40	0.04	-9.20[0.000]
ARDL(1,2) Sample (1998M4-2011M1) Panel D	dC	0.67	0.17	3.89[0.000]
	dRepo	-0.02	0.07	-0.22[0.829]
	dRepo1	-0.24	0.09	-2.72[0.007]
	ECM(-1)	-0.28	0.03	-9.19[0.000]

Table 3. Short-run results: Dependent variable: Δ BANKRATE.

	Regressor	Coefficient	Standard Error	t-Ratio
ARDL (2,5) Model Sample(1998M4-2011M1) Panel A	dC	0.58	0.24	2.44[0.016]
	dBANKRATE1	-0.36	0.08	-4.70[0.000]
	dRepo	0.4	0.05	0.62[0.538]
	dREPO1	-0.1	0.08	-1.36[0.175]
	dREPO2	-0.14	0.08	-1.80[0.074]
	dREPO3	0.55	0.074	7.36[0.000]
	dREPO4	0.47	0.074	6.31[0.000]
	ECM(-1)	-0.16	0.06	-2.72[0.007]
ARDL (2,4) Model Sample(1998M4-2011M1) Panel B	dC	1.13	0.19	6.01[0.000]
	dBANKRATE1	-0.17	0.05	-3.52[0.001]
	dTBR	0.04	0.06	0.56[0.577]
	dTBR1	-0.41	0.11	-3.91[0.000]
	dTBR2	-0.58	0.1	-6.03[0.000]
	dTBR3	0.3	0.11	2.87[0.005]
	ECM(-1)	-0.51	0.06	-7.87[0.000]

Appendix B**Figure 1a.** The Repo and Bankrate Interest Rates, 1998M4-2011M1.

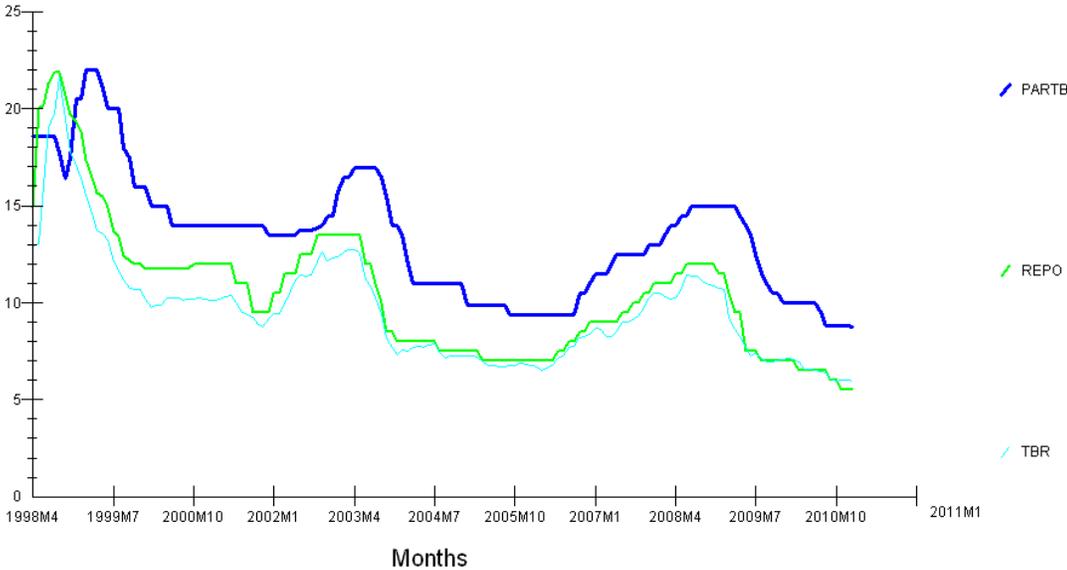


Figure 1b. The Repo, the TBR and PARTB, 1998M4–2011M1.

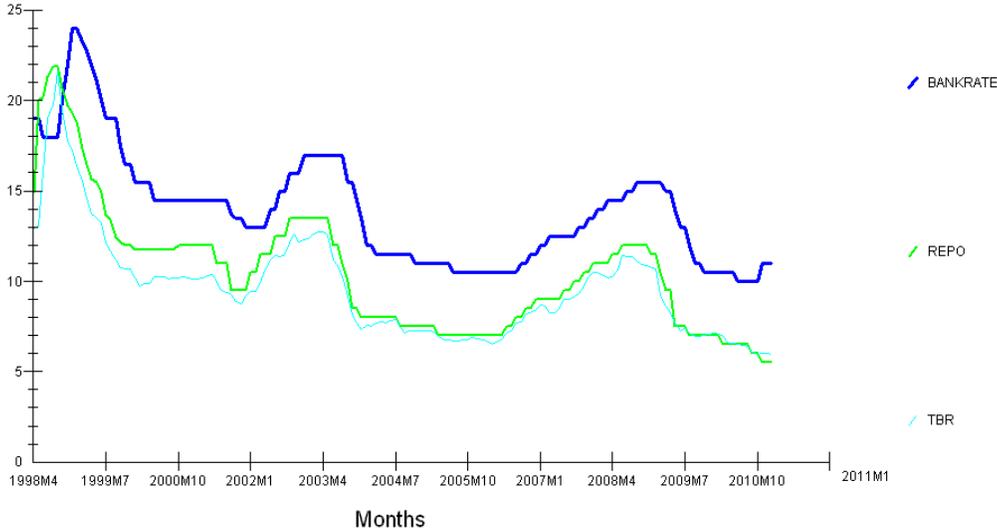


Figure 1c. The Bankrate, Repo and the TBR Rates, 1998M4-2011M1.

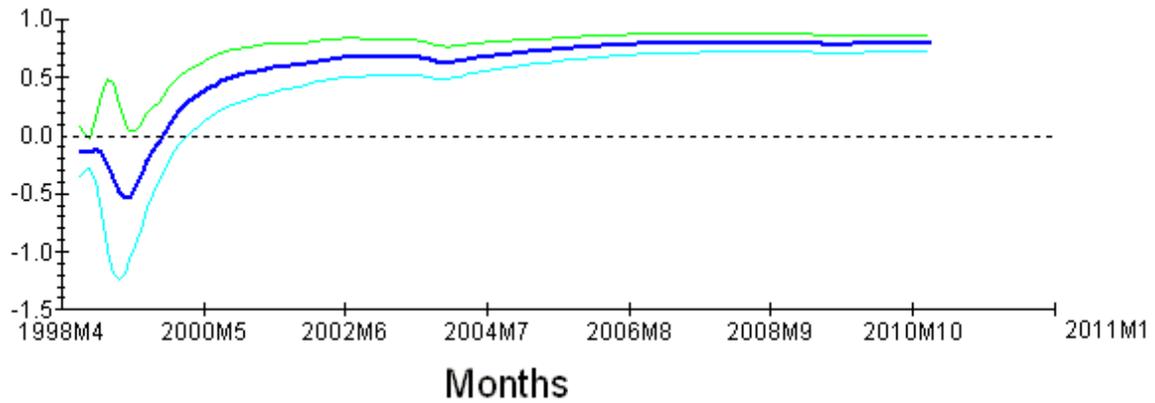


Figure 1d. Bankrate: Coefficients of Repo and its two S.E. bonds based on recursive OLS.

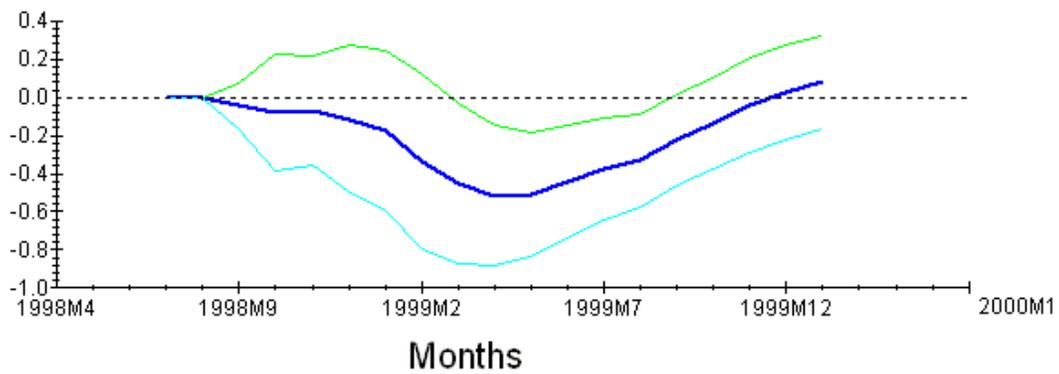


Figure 1e. PARTB: Coefficient of REPO and its two*S.E. bands based on recursive OLS.

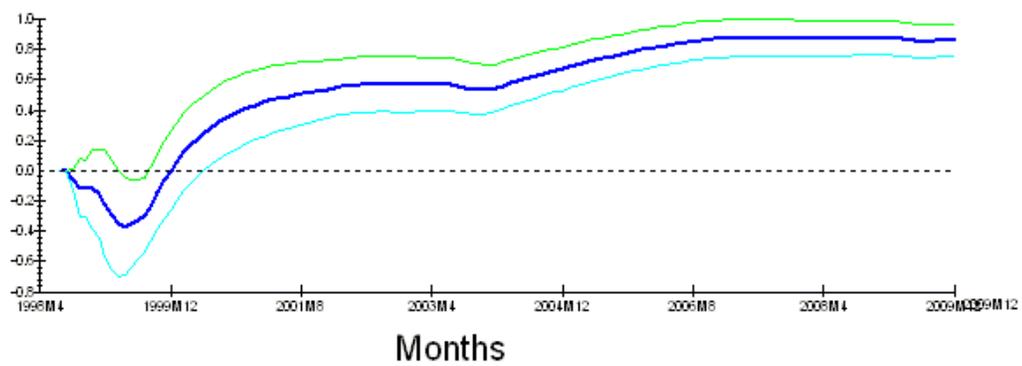


Figure 1f. PARTB: Coefficient of TBR and its two*S.E. bands based on recursive OLS.

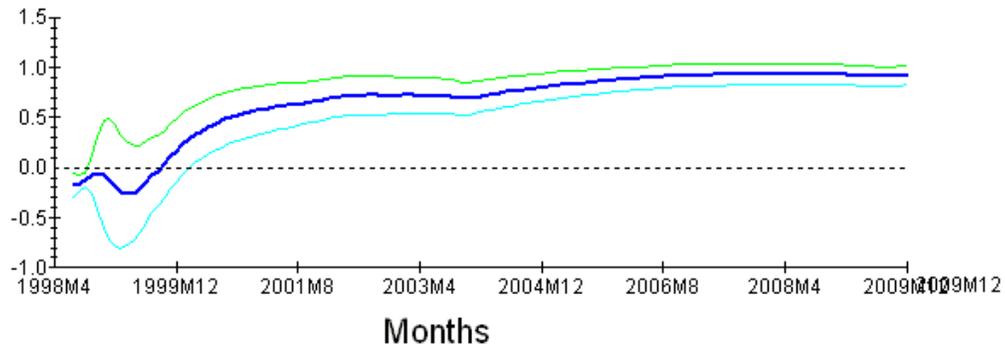


Figure 1g. BANKRATE: Coefficient of TBR and its two*S.E. bands based on recursive OLS.

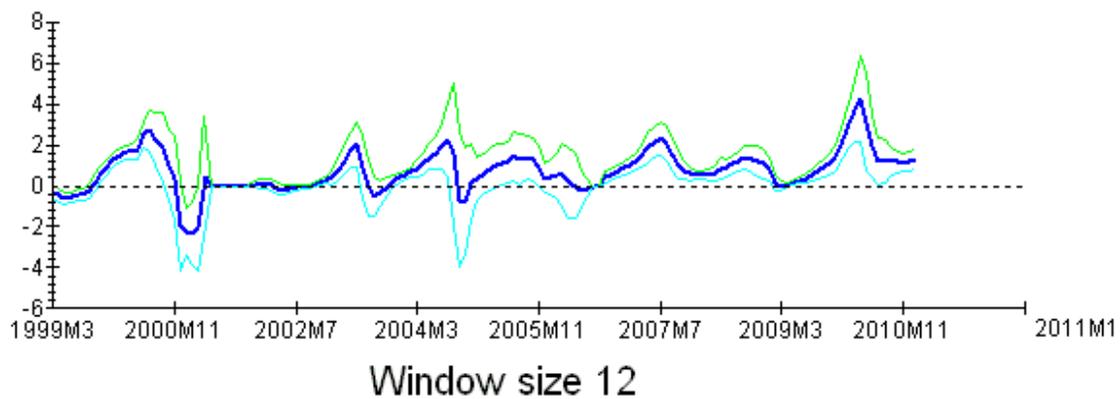


Figure 1h. BANKRATE: Coefficient of TBR and its two*S.E. bands based on rolling OLS.

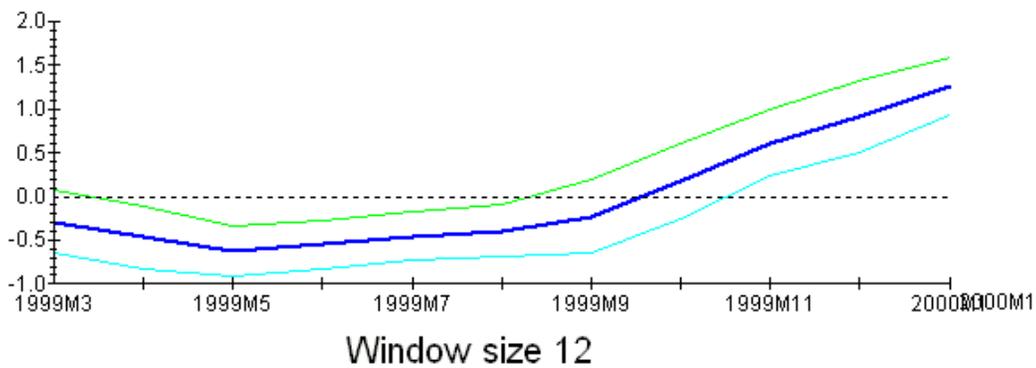


Figure 1j. PARTB: Coefficient of TBR and its two*S.E. bands based on rolling OLS.

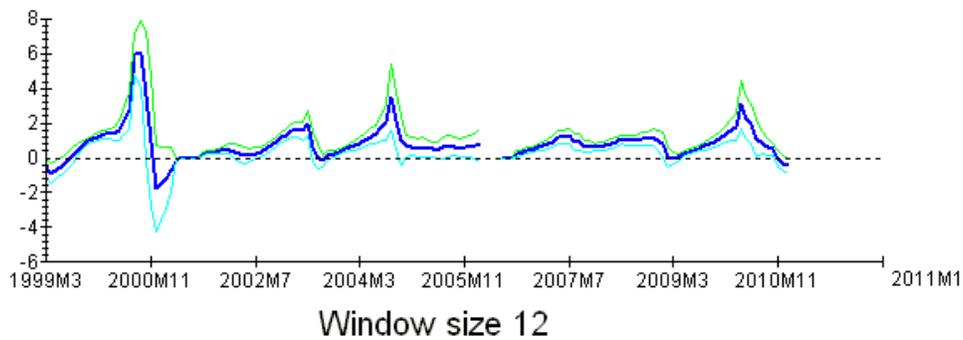


Figure 1k. Bankrate: Coefficient of REPO and its two*S.E. bands based on rolling OLS.

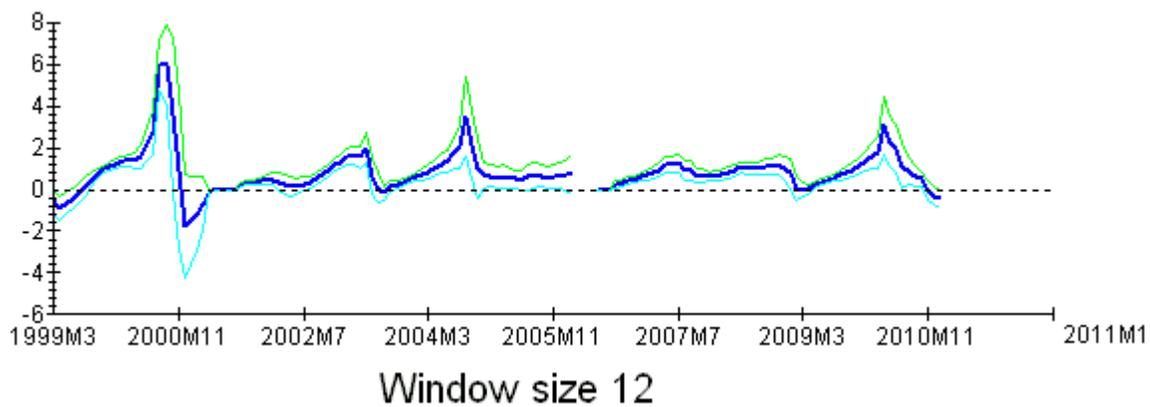


Figure 1l. PARTB: Coefficient of REPO and its two*S.E. bands based on rolling OLS.