Changes in the relationship between interest rates and housing prices in South Africa around the 2007 financial crisis

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CHANGES IN THE RELATIONSHIP BETWEEN INTEREST RATES AND HOUSING PRICES IN SOUTH AFRICA AROUND THE 2007 FINANCIAL CRISIS

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ABSTRACT: In this study we investigate the cointegration relationship between interest rates and housing prices in South Africa using the autoregressive distributive (ARDL) model applied to quarterly data covering the post inflation targeting period of 2002:Q1 and 2016:Q4. Our empirical consists of splitting the empirical data into two sub-periods, one corresponding to the pre-crisis period (i.e. 2002:Q1 – 2008:Q2) and the other corresponding to the post-crisis periods (i.e. 2008:Q3 – 2016:Q4). Indeed, our empirical results confirm changing dynamics of the interest rate-housing price relationship in light of the financial crisis with the Reserve Bank appearing to respond to changes in the housing price growth in the post-crisis period. This results reflect the strong macropudential stance which the Reserve Bank has recently assumed after the sub-prime crisis and such policy stance critically depends on monitoring asset prices such as housing and property prices as a means of assessing market conditions.

Keywords: Interest rates; Housing prices; Monetary policy; Cointegration; ARDL model; South Africa; Emerging economy.

JEL Classification Code: C22; C51; E31; E52.

1 INTRODUCTION

Within the macroeconomic paradigm, research developments are commonly fostered by prominent crises which force economics to challenge conventional ways of thinking and therefore influencing the formulation of macroeconomic policies. The most recent global financial crisis of 2007-2008 which emulated as a crash in the US housing market has rekindled a lively debate on the role of monetary policy in influencing asset prices such as property prices. Surely the effects of the sub-prime crisis were catastrophic as the US housing market crash promulgated its adverse effects to the US banking sector before finally resulting in a worldwide financial crisis which is infamously dubbed as the worst financial crisis since the Great Depression. In terms of global impact, it has been acclaimed that the financial crisis alone is responsible for the loss of 34 million jobs worldwide as well as declining global economic growth rates from 3 percent in 2008 to 0.3 percent by the end of 2009 (Estevao and Tsounta, 2011).

The highly expansionary monetary policy stance assumed by the US Federal Reserve Bank under the Alan Greenspan administration in the early 2000's, and in particularly the aggressive Federal Fund rate reduction following the September 11 attacks, is commonly cited as the key reason for the housing price bubble which burst during the financial crisis (Xu and Chen, 2012). Since then researchers and policymakers alike have become increasingly aware that monetary policies have far-reaching implications for the housing sector which tends to be more interest-rate sensitive than the economy as a whole and such sensitivities can vary though time (Wudud et. al., 2012). The main concern occupying the minds of policymakers is that a house price boom might be followed by a bust which would undermine bank safety and soundness (Shi et. al., 2014). Consequentially, through appropriate policy intervention, Central Banks may play a significant role in deflating a house price bubble before it erupts and precipitates extensive damage to the financial sector.

Nevertheless, a vast majority of Central Banks worldwide tend to be overly concerned with the attainment of a low and stable inflation environment with the asset prices of real estate not being taken directly into consideration in policy formulation. This is certainly of concern since conventional economic theory describing or underlying the monetary transmission mechanism dictates that interest rates exerts both direct effects (i.e. user cost, future expectations and hosing supply) and indirect (i.e. wealth effects, credit-channel effects and balance sheet effects) on the housing sector (Mishkin (2007) and Elbourne (2008)). In turn, the housing market would then influence macroeconomy activity via changes in disposable income and consumption levels (Jiang, 2012). Hence, at the crux of modern day monetary policy debate is the issue of whether or not Central Banks should directly target asset prices such as housing prices in their policy reaction functions.

Subsequent to the advent of the global financial crisis there has been a prolific empirical literature which has examined the effect of monetary policy on housing markets for both industrialized economies (Elbourne (2008), Vargas-Silva (2008), Bjornland and Jacobsen (2010), Gupta and Kabundi (2010), Yang et. al. (2010), Wudud et. al. (2012), Shi et. al. (2014), Tsai (2013), Costello et. al. (2015)) and developing or emerging countries (Gupta et. al. (2010), Gupta and Kasai (2011), Xu and Chen (2012)). And even with this absolute dearth of literature, what has certainly been ignored in the current literature thus far, is whether the global financial crisis affected the interest rate-housing market relationship, with the recent contribution of Tse et. al. (2014) serving as the sole study to do so for the UK. Indeed, the empirical results presented by Tse et. al. (2014) unveil a changing relationship between interest rates and the housing sector as caused by a structural shift owing to the global financial crisis. In our study, we follow in pursuit along this line of thought and investigate the possible changing relationship between interest rate and housing prices for the South African economy in light of the sub-prime crisis.

We consider the South African economy as a worthwhile case study for a couple of reasons. Firstly, South Africa is an important emerging economy representative for a number of prominent blocs such as BRICS, G20, South African Development Community (SADC), Sub Saharan Africa (SSA), Newly Industrialized Countries (NIC) etc. Secondly, the South African economy is more susceptible to external shocks, such as those transmitted from the global financial crisis owing to her well-developed financial system and high levels of openness. Thirdly, South Africa is one of the few African countries which has adopted the highly sophisticated inflation targeting regime as an official monetary policy framework. This hence renders the South African Reserve Bank (SARB) more vulnerable to aggressive interest rate manipulations in the interest of keeping inflation within it's designated target. Lastly, the South boasts one of the most developed real estate markets on the African continent hence increasing the scope for which house pricing shocks propagate towards the real economy in comparison to other African economies.

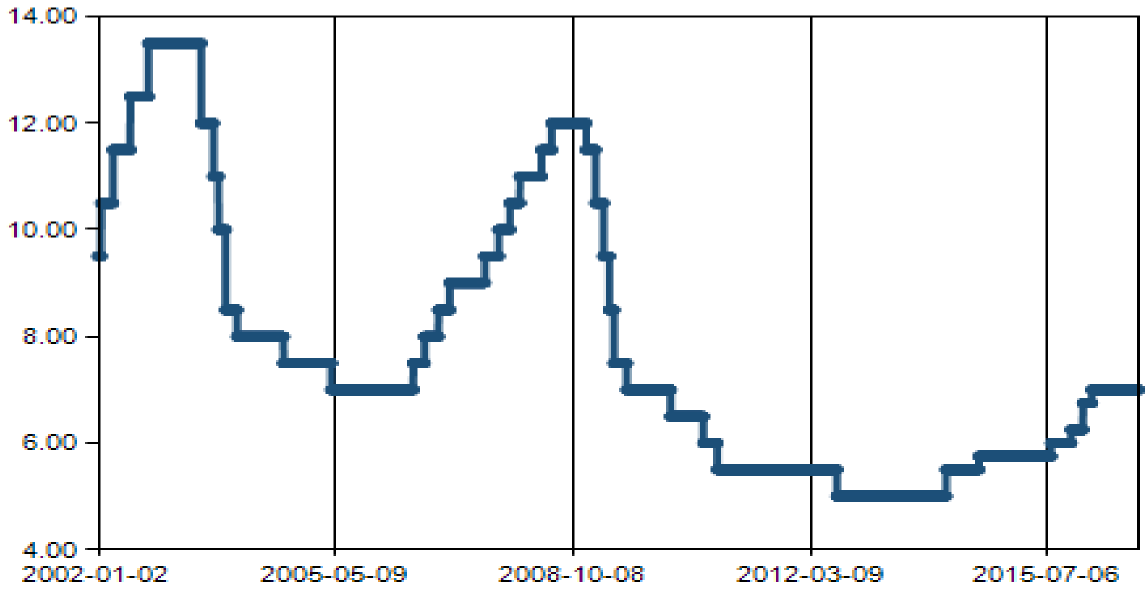
Methodologically, we rely on the autoregressive distributive (ARDL) model of Pesaran et. al. (2001) and we favour this econometric framework on the following accounts. Firstly, the ARDL mode fosters for cointegration between trend-stationary and difference-stationary time series, whereas other competing residual-based cointegration models such as the vector autoregressive (VAR) and vector error correction (VEC) models, which are widely used in the current literature, fail to do so. Secondly, the model performs exceptionally well even with small samples a feature which will prove to be particularly crucial in our analysis. Moreover, both the short-run and long-run coefficient estimates from the ARDL model are estimated simultaneously without the loss of any information. We apply the ARDL model to quarterly time series data collected for periods subsequent to the post-inflation target era and further segregate this data into two sub-sets, one corresponding to the pre-crisis periods (i.e. 2002:Q1 – 2008:Q2) and the other corresponding to the post-crisis period (i.e. 2008:Q3 – 2016:Q4). We consider our choice of time framework highly appropriate since the monetary policy shift associated with the adoption of the inflation targeting regime renders any attempts to study the effects of monetary policy action with pre-2002 time series data quite futile (Phiri, 2015).

Having provided a background to the study, we structure the remainder of the manuscript as follows. The following section of the paper provides an overview of interest rate movements in South Africa subsequent to the adoption of the inflation targeting regime framework. The third section of the paper gives an overview of interest rates movements in the post inflation targeting era. The econometric methodology is outlined in the fourth section whereas the empirical data and the empirical results are presented in the fifth section of the paper. The sixth section concludes the paper in the form of policy implications and recommendations.

2 REPO RATE MOVEMENTS IN SOUTH AFRICA: A POST INFLATION TARGETING PERSPECTIVE

Since the implementation of the inflation targeting regime by the SARB in 2002, the repurchase or 'repo' rate currently serves as the Reserve Bank's short term policy instrument and the monetary policy committee (MPC) has been designated the necessary authority to carry out all policy-related obligations (Phiri, 2017). In a nutshell, the inflation targeting framework stipulates that the Reserve Bank should contain CPI inflation within a width-band of 3 to 6 percent. In the event that inflation exceeds the upper 6 percent limit, then the Central Bank raises the repo rate, which then causes other market rates to increase hence contracting the real economy which eventually lowers the inflation rate. Conversely, when the inflation rate breaches the lower 3 percent margin, then the Reserve Bank implements expansionary monetary policy by lowering the repo rate as means of stimulating the economy and hence increasing the inflation rate. Figure 2 below presents a time series plot pertaining to the repo rate movements since the adoption of the inflation targeting framework over the period 2002-2016.

Figure 1: Repo rate movements in the post-inflation targeting era



Source: South African Reserve Bank (SARB) website

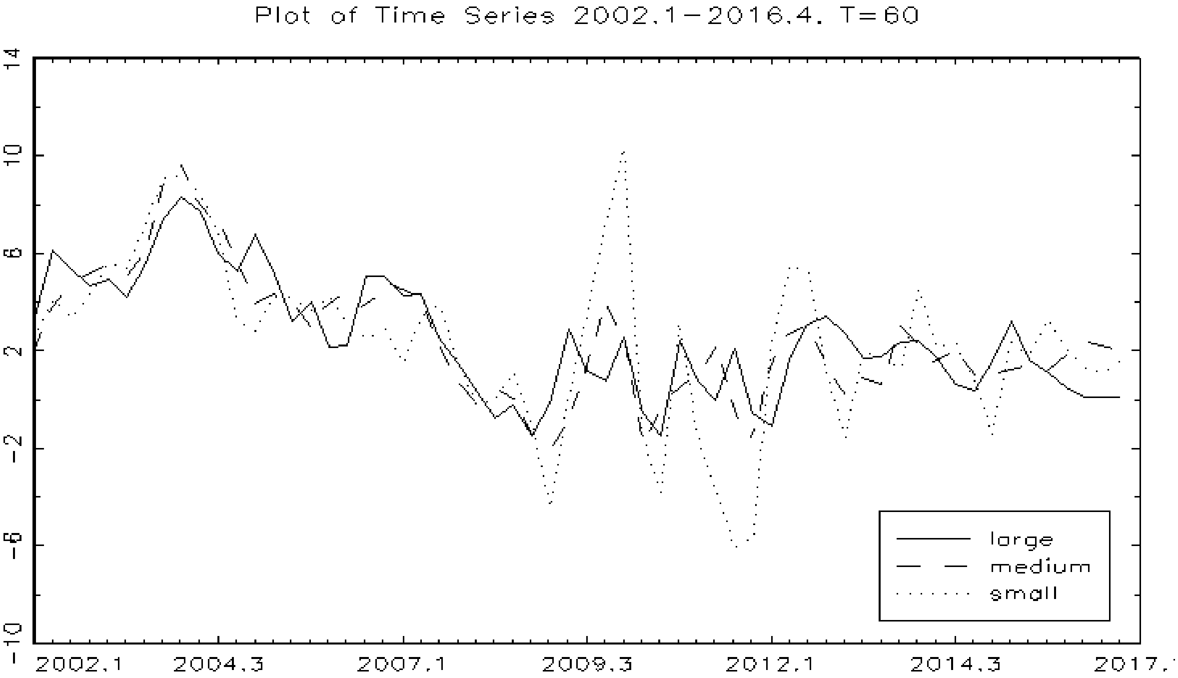
It should be noted that the adoption of the inflation targeting regime coincides with the period at which the US monetary authorities drastically decreased the Federal Fund rate from 6.1 percent in 2001 to 1 percent between 2003 and 2004 in response to the September 11 terrorist attacks and the wave of US corporate accounting scandals. The US Federal actions were accompanied by a sudden burst of short-term capital flow in South Africa which resulted in a depreciation of the Rand as well as sharp increases in domestic and imported prices which were aggravated by increasing world oil prices. (Phiri, 2012). The SARB was hence forced to implement a series of interest rate hikes in the repo rate from 10.50 percent in the first quarter of 2002 to 13.50 percent in the first quarter of 2003. Following the resounding declining of inflation to relatively low levels, the Reserve Bank began to engage in what appears to be expansionary monetary policy which involved decreasing the repo rate from 13.50 percent in the second quarter of 2003 to 7 percent in the first quarter of 2006. However, the relaxation of interest rates was short lived following another episode of sharp depreciation of the local currency experienced from 2006 to 2009 fuelled by strong global demand and rising inflation rates which were transmitted through increased import prices (Phiri, 2016). In response to global pressures, the SARB hiked interest rates from 7.50 percent in the second quarter to 12 percent by the end of the third quarter of 2008.

Subsequent to the filling of Chapter 11 bankruptcy by the Lehman Brothers in September 2007 and the resulting global financial crisis of 2007-2008, the US released the Emergency Economic Stabilizing Act (EESA) of 2008 which permitted the Federal Reserve to engage in a bailout of the US financial system. This was achieved in the form of a three-stage quantitative easing (QE) programme which saw the Federal Reserve buy distressed financial assets and bonds from the banking sector as a means of lowering the yields of these assets and hence reducing the Federal Fund rate to its targeted 'zero lower bound level' (Phiri, 2016). The first round of the QE process implemented between November 2008 and June 2010, the sound round between November 2010 and June 2011 and the third between November 2012 and June 2013. The resulting decrease of the Federal Fund rate to 0.09 percent between 2012 and 2014 was accompanied by a corresponding drop of the repo rate from 12 percent in the third quarter of 2008 to 5 percent between the third quarter 2012 and the first quarter of 2014. Following the decision by the Federal Reserve to completely phase out the quantitative easing monetary policy programme in mid-2014, the Federal Reserve announced two interest rate hikes in December 2015 and another in December 2016. The SARB followed in close pursuit of the US Federal Reserve by gradually hiking up the repo rate form 5.50 percent in the second quarter of 2014 to 7 percent in the fourth quarter of 2016.

3 AN OVERVIEW OF THE HOUSING MARKET IN SOUTH AFRICA BETWEEN 2002 AND 2016

As previously mentioned, South Africa boasts one of the most prestigious property markets on the African continent with a major portion of this market being attributed to the housing sector. For convenience sake, the South African residential market can be categorized into three housing segments namely, luxury (R3.1 million to R11.5 million), middle segment (R430 000 to R3.1 million) and affordable (below R430 000). Nevertheless, time series data is only available for the middle segment which is further segregated into three size classes, namely, small houses (80-140 square metres), medium houses (141-220 square metres) and large houses (221-400 square metres). Figure 2 provides a comprehensive time series plot of the movement in the price growth in all three classes of housing groups and at face value, it can be visually observed that the growth in small house prices is more volatile in comparison to the growth in both medium and large houses over the entire sample period.

Figure 1: Price growth of house prices for small, medium and large houses



Source: Authors own plot.

Interestingly enough the aggressive policy stance undertaken by the SARB in 2002, was accompanied by an appreciation in the house price growth experienced in all three house classes, even reaching 30 year record high levels by the end of 2003. Similarly, the decrease in the repo rate experienced from 2004 to 2006 was accompanied by a similar decrease in the growth of housing prices. Notably, both aforementioned time episodes contradicts conventional economic theory which speculates on a negative relationship between the interest rates and the growth in the housing sector (Mishkin, 2007). However, from 2006 to 2008, when the Reserve Bank raised it's repo rate in response to inflationary pressures, the growth in housing prices began to drastically decline, more significantly so for small houses. Also worth noting are the negative growth rates in housing prices experienced during the event of the 2008-2008 global financial crisis.

Since the sub-prime crisis, the movement of the growth in housing prices has fluctuated unprecedentedly. For instance, between the second quarter of 2009 and the first quarter of 2010, the growth rate in house prices appeared to recuperate from the financial crisis as all three classes of house sizes recorded positive growth levels, averaging 5.28 percent for small houses, 1.75 percent for medium houses and 1.84 percent for large house and these coincide with a decline in repo rate. However, in a turn of events, there were low growth rates experienced in housing prices between the second quarter of 2010 and the first quarter of 2012, recording averages of -2.12 percent for small houses, 0.11 percent for medium houses and 0.19 percent for large houses and at this time the SARB was still engaging in expansionary monetary policy in the form of declining repo rates. Again this seemingly observed positive movement between the repo rate and house price growth contradicts conventional economic theory. Between 2012 and 2014, the SARB kept the repo rate untampered at 5 percent resulted in a declining trend of growth in house prices although these growth rates never breached into negative figures with a 1.72 percent, 1.70 percent and 2.29 percent for small, medium and large houses respectively. However, flowing the repo rate hikes from 2014 to 2016, has been accompanied by declining performance of the growth in housing prices (i.e. averages of 1.53 percent for small houses, 1.67 percent for medium houses and 1.13 percent for large houses), an observation which more-or-less concurs with economic theory.

4 DATA AND EMPIRICAL MODEL

4.1 Empirical data

As previously noted, the South African housing market can be formally categorized into luxury (R3.1 million to R11.5 million), middle segment (R430 000 to R3.1 million) and affordable (below R430 000). However, concerning the housing price variables as an empirical measure, we observe that the large-middle (i.e. $221m^2$ – $400m^2$), the medium middle (i.e.

$221m^2 – 400m^2$) and small-middle (i.e. $221m^2 – 400m^2$) of the middle-segment of the three price segments are the most commonly used time series variables due to their data availability (see Das et. al. (2011), Ncube and Ndou (2011) and Simo-Kengne et. al. (2013)). We follow in pursuit of the aforementioned authors and use these three measures of hosing prices (which have been renamed house1, house 2 and house3, respectively) and this housing pricing data is collected from the Amalgamated Bank of South Africa (ABSA) provides the seasonally adjusted house price index. In line with Das et. al. (2011), we convert the housing time series data into real house price growth by dividing the nominal house price by CPI inflation and converting the series into growth rates.

As a measure of interest rate, we employ the SARB repo rate as an empirical measure and we find it the most convenient since the repo rate is the Reserve Bank's official short-term policy instrument. However, since the repo data is available in daily frequencies, from the SARB online database, we apply interpolation techniques to convert this data into quarterly frequencies to ensure consistency with remaining time series variables used in the empirical study. Other commonly used variables employed in the interest-housing relationship as control variables include the inflation rate (Anari and Kolari (2002), Iacoviello (2004) and Giuliodori (2005)) as well as disposable income (Gallin (2006), Fraser et. al. (2012), Barrell et. al. (2015) and Caporale and Gil-Alana (2015)). Both these time series variables are included as control variables in our study and these variables are easily accessible from the SARB online database.

Therefore, collectively speaking, the empirical data used in our study comprises of four time series, namely, the SARB repo rate (*repo*), ABSA housing prices (*house*), CPI inflation rate (π) and disposable income (*income*), of which the hosing data is further segregated into three sub-categories namely, the large (house1), medium (house2) and small (house3) housing sizes. Our time series data is employed on a quarterly basis between the periods 2002:Q1 and 2016:Q4 and is further segregated into two sub-periods, one corresponding to the pre-crisis era (2002:Q1 – 2008:Q2) and the other corresponding to the post-crisis era (2008:Q3 – 2016:Q4).

4.2 Empirical model

Having presented our empirical, we proceed to specify our empirical models. We particularly rely on the autoregressive distributive lag (ARDL) model of Pesaran et. al. (2001) to model the cointegration relationship between housing prices, the repo rate and inflation for South African data. Our baseline empirical model specifications take the following form:

$$\Delta Inhouse_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta Inhouse_{t-i} + \sum_{i=1}^{p} \alpha_{2i}\, \Delta Inrepo_{t-i} + \sum_{i=1}^{p} \alpha_{3i}\, \Delta In\pi_{t-i} + + \sum_{i=1}^{p} \alpha_{4i}\, \Delta logincome_{t-i} + \beta_{1i} Inhouse_{t-i} + \beta_{2i} Inrepo_{t-i} + \beta_{3i} In\pi_{t-i} + \beta_{4i} Inconsumption_{t-i} + e_t \quad (1)$$

$$\Delta Inrepo_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta Inhouse_{t-i} + \sum_{i=1}^{p} \alpha_{2i}\, \Delta Inrepo_{t-i} + \sum_{i=1}^{p} \alpha_{3i}\, \Delta In\pi_{t-i} + + \sum_{i=1}^{p} \alpha_{4i}\, \Delta Inincome_{t-i} + \beta_{1i} Inhouse_{t-i} + \beta_{2i} Inrepo_{t-i} + \beta_{3i} In\pi_{t-i} + \beta_{4i} Inincome_{t-i} + e_t \quad (2)$$

$$\Delta In\pi_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta Inhouse_{t-i} + \sum_{i=1}^{p} \alpha_{2i}\, \Delta Inrepo_{t-i} + \sum_{i=1}^{p} \alpha_{3i}\, \Delta In\pi_{t-i} + + \sum_{i=1}^{p} \alpha_{4i}\, \Delta Inincome_{t-i} + \beta_{1i} Inhouse_{t-i} + \beta_{2i} Inrepo_{t-i} + \beta_{3i} In\pi_{t-i} + \beta_{4i} Inincome_{t-i} + e_t \quad (3)$$

$$\Delta Inincome_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta Inhouse_{t-i} + \sum_{i=1}^{p} \alpha_{2i}\, \Delta Inrepo_{t-i} + \sum_{i=1}^{p} \alpha_{3i}\, \Delta In\pi_{t-i} + + \sum_{i=1}^{p} \alpha_{4i}\, \Delta Inincome_{t-i} + \beta_{1i} Inhouse_{t-i} + \beta_{2i} Inrepo_{t-i} + \beta_{3i} In\pi_{t-i} + \beta_{4i} Inincome_{t-i} + e_t \quad (4)$$

Where δ_0 is the intercept term, the parameters $\alpha_1, \ldots, \alpha_4$ and $\beta_1, \ldots, \beta_4$ are the short-run and long-run elasticities, respectively, and e_t is a well-behaved error term. The first step in the empirical process, is to test the time series variables for their integration properties. By rule, the ARDL model can only be used when the time series are found to be integrated of order I(0) or I(1). Once it is verified that the time series are not integrated of order I(2) or higher, then one can proceed to test for cointegration effects among the time series. This is achieved by testing the null hypothesis of no cointegration (i.e. $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$) which is tested against the alternative of cointegration effects (i.e. $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$).

This aforementioned cointegration test is evaluated via an F-test and the critical values of this test are reported in Pesaran et al. (2001). The null hypothesis of no cointegration can only be rejected if the computed F-statistic exceeds the upper bound of the critical level whereas the null hypothesis cannot be rejected the F-statistics fall below the lower bound of the critical level. However, if the F-statistic falls between the lower and upper bounds of the critical levels then the cointegration test is considered inconclusive. Once cointegration effects are validated, then the following unrestricted error correction model (UECM) representation of the ARDL regression (2) can be modelled as follows:

$$\Delta lnhouse_t = \delta_0 + \sum_{i=1}^{p} \delta_{1i}\, \Delta lnhouse_{t-i} + \sum_{i=1}^{p} \delta_{2i}\, \Delta lnrepo_{t-i} + \sum_{i=1}^{p} \delta_{3i}\, \Delta ln\pi_{t-i} + \sum_{i=1}^{p} \delta_{4i}\, \Delta lnincome_{t-i} + \eta\, ect_{t-i} + \xi_t \quad (5)$$

$$\Delta lnrepo_t = \delta_0 + \sum_{i=1}^{p} \delta_{1i}\, \Delta lnhouse_{t-i} + \sum_{i=1}^{p} \delta_{2i}\, \Delta lnrepo_{t-i} + \sum_{i=1}^{p} \delta_{3i}\, \Delta ln\pi_{t-i} + \sum_{i=1}^{p} \delta_{4i}\, \Delta lnincome_{t-i} + \eta\, ect_{t-i} + \xi_t \quad (6)$$

$$\Delta ln\pi_t = \delta_0 + \sum_{i=1}^{p} \delta_{1i}\, \Delta lnhouse_{t-i} + \sum_{i=1}^{p} \delta_{2i}\, \Delta lnrepo_{t-i} + \sum_{i=1}^{p} \delta_{3i}\, \Delta ln\pi_{t-i} + \sum_{i=1}^{p} \delta_{4i}\, \Delta lnincome_{t-i} + \eta\, ect_{t-i} + \xi_t \quad (7)$$

$$\Delta lnincome_t = \delta_0 + \sum_{i=1}^{p} \delta_{1i} \Delta lnhouse_{t-i} + \sum_{i=1}^{p} \delta_{2i} \Delta lnrepo_{t-i} + \sum_{i=1}^{p} \delta_{3i} \Delta ln\pi_{t-i} + \sum_{i=1}^{p} \delta_{4i} \Delta lnincome_{t-i} + \eta \, ect_{t-i} + \xi_t \quad (8)$$

Where ect_{t-1} is the error correction term which measures the speed of adjustment of towards steady-state equilibrium in the face of disequilibrium. Pragmatically, the error correction term should be significantly negative and must be bound between 0 and -1. Moreover, a significant and negative error correction estimate is indicative of long-run causality between the time series variables.

5 EMPIRICAL RESULTS

7.1 Unit root test results

As previously mentioned, one of the major advantages of the ARDL modelling system is that the procedure allows for modelling of time series variables whose integration properties are either I(0) or I(1). Unfortunately, the modelling procedure cannot be applied to time series variables integrated of order I(2) or higher and hence it is imperative that the time series are tested for unit root properties before the variables can be estimated by the ARDL model. Therefore, as a first step in our empirical process, we test for the integration properties of the time series variables using three unit root testing procedures, namely, ADF and DF-GLS unit root testing procedures. The unit root tests are performed inclusive of both a drift and a trend, with the results of the empirical exercise are reported in Table 1 below.

As can be observed from our results, we find when the ADF test is applied to the time series, there results are mixed. For instance, in the pre-crisis period the ADF test statistic points to the 'repo' and 'income' variables being I(1) variables, the 'house1', house2' and 'house3' and inflation variables are all integrated of an order higher than I(1). For the post-crisis periods, the ADF test statistics point to the variables being I(1) with the exception of the 'house 2' variable which is observed to be levels stationary. However, when the DF-GLs test is performed on the variables, we find that the variables are mutually I(1) variables whilst in the post-crisis periods, the house1, house2 and house3 variables are I(0) whilst the remaining variables are I(1). Therefore, in light of this empirical evidence presented, we consider the results of the DF-GLS tests as being more plausible since these test are generally more powerful at detecting unit root tests. Hence, we conclude that none of the time series variables being integrated of an order higher than I(1) and proceed to apply the bounds test of cointegration and estimating the ARDL model in the following sub-section of the paper.

Table 1: Unit root tests results

	Time series	ADF		DF-GLS	
		level	1st difference	level	1st difference
Pre-crisis	house1	-0.40	-1.40	-1.68	-4.79***
	house2	-0.44	-1.55	-1.65	-4.87***
	house3	-0.52	-1.57	-1.68	-4.83***
	repo	-2.61	-10.49***	-1.59	-5.32***
	π	-2.02	-4.89	-1.97	-5.07**
	income	-2.62	-8.11***	-1.79	-4.85***
Post-crisis	house1	-2.48	-4.30***	-3.57**	-5.52***
	house2	-3.15*	-7.70***	-3.97***	-5.07***
	house3	-1.15	-5.75***	-1.39	-6.67***
	repo	-2.85	-3.84**	-1.98	-3.91
	π	-2.62	-8.22***	-1.99	-3.56
	income	-2.44	-5.77***	-2.49	-3.24

Notes: '***', '**','*' represent the 1%, 5% and 10% significance levels, respectively.

7.2 Cointegration tests and ARDL model estimates

Having confirmed that the time series variables are combinations of I(0) and I(1) variables, we proceed to test for cointegration effects amongst the time series variables for the following ARDL regression functions which are summarized below in Table 2.

Table 2: ARDL specifications

dependent variable	ARDL function
house	*f*(*house1* | *repo*, π, income) *f*(*house2* | *repo*, π, income) *f*(*house3* | *repo*, π, income)
repo	*f*(*repo* | *house1*, π, *income*) *f*(*repo* | *house2*, π, *income*) *f*(*repo* | *house3*, π, *income*)
inflation	*f*(π | *repo*, *house1*, *income*) *f*(π | *repo*, *house1*, *income*) *f*(π | *repo*, *house1*, *income*)
disposable income	*f*(*income* | *repo*, π, *house1*) *f* (*income* | *repo*, π, *house2*) *f* (*income* | *repo*, π, *house3*)

Note that the lag lengths of the aforementioned regression functions are selected using the Schwarz-Bayesian Criteria (SBC) information criterion and the regressions are performed for the two sample periods namely i) the pre-crisis period and ii) the post-crisis period. Further note that each regression is further performed using three measure of the housing prices, namely i) large-sized houses (house1), ii) medium-sized houses (house2) and iii) small-sized houses (house3). The results of the cointegration tests are reported in Table 3 below, with Panel A presenting the results for the pre-crisis period whereas those for the post-crisis period are presented in Panel B.

Table 3: Bounds tests results for cointegration

Panel A: Pre-crisis results			Panel B: Post-crisis results		
Function form	ARDL specification	F-statistic	Function form	ARDL specification	F-statistic
f(house1|repo, *π*, income)	(1,0,0,0)	0.84	*f(house1|repo*, *π*, income)	(0,1,0,0)	1.52
f(house2|repo, *π*, income)	(1,0,0,0)	0.58	*f(house2|repo*, *π*, income)	(1,0,0,0)	2.78
f(house3|repo, *π*, income)	(1,0,0,0)	1.45	*f(house3|repo*, *π*, income)	(1,0,0,0)	3.46*
f(repo|house1, π, *income*)	(1,0,0,0)	3.49*	*f(repo|house1*, π, *income*)	(1,0,0,0)	4.93***
f(repo|house2, π, *income*)	(1,0,0,0)	3.56*	*f(repo|house2*, π, *income*)	(1,0,0,0)	5.62***
f(repo|house3, π, *income*)	(1,0,0,0)	3.82*	*f(repo|house3*, π, *income*)	(1,0,0,0)	4.94**
f(π|*repo, house1*, *income*)	(1,1,0,0)	7.33***	*f*(π|*repo, house1*, *income*)	(1,0,1,1)	2.65
f(π|*repo, house2*, *income*)	(0,1,0,0)	1.26	*f*(π|*repo, house2*, *income*)	(1,0,0,1)	2.31
f(π|*repo, house3*, *income*)	(0,1,0,0)	1.49	*f*(π|*repo, house3*, *income*)	(1,0,0,1)	1.24
f(income|repo, π, *house1*)	(1,0,1,1)	4.27**	*f(income|repo,* π, *house1*)	(1,0,0,1)	2.81
f(income|repo, π, *house2*)	(1,0,0,1)	4.24**	*f(income|repo,* π, *house2*)	(1,0,0,1)	2.27
f(income|repo, π, *house3*)	(1,0,0,1)	3.65*	*f(income|repo,* π, *house3*)	(1,0,0,0)	2.04

Notes: '***', '**','*' represent the 1%, 5% and 10% significance levels, respectively. P-values reported in parentheses ().

When house 1, 2 and 3 are the dependent variable (i.e. *f(house1* | *repo*, *π*, income), *f(house2* | *repo*, *π*, income) and *f(house3* | *repo*, *π*, income)), the F-statistics produced are 0.84, 0.58 and 1.45, respectively for the pre-crisis and all these statistics are lower than the lower bound of the 10 percent critical level. On the other hand, the F-statistics for these same regression functions for the post-crisis period are 1.52, 2.78 and 3.46, respectively with only the last statistic being significant at a 10 percent critical level. Concerning the repo functions (i.e. *f(repo* |*house1*, *π*, income), *f(repo* |*house2*, *π*, income) and *f(repo* |*house3*, *π*, income)) we obtain F-statistics of 3.49, 3.56 and 3.82, respectively for the pre-crisis period and 4.93, 5.62

and 4.94, respectively, for the post-crisis period. Note that all F-statistics reported for both pre and post crisis periods are significant at a 10 percent significance level.

In turning to the inflation functions (i.e. *f(*π*| repo*, *house1*, income), *f(*π*| repo*, *house2*, income) and *f(*π *| repo*, *house3*, income)), we obtain F-statistics of 7.33, 1.26 and 1.49, respectively for the pre-crisis period, of which the F-statistic for the *f(*π*| repo*, *house1*, income) function being the only significant cointegration regression at a 10 percent critical level. Conversely, for the post-crisis period none of the F-statistics of 2.65, 2.31 and 1.24 for the inflation functions, respectively, are all insignificant. Lastly, for the three income functions (i.e. *f(income | repo*, π, *house1*), *f(income | repo*, π, *house2*) and *f(income | repo*, π, *house3*)), we find highly significant F-statistics of 4.27, 4.24 and 3.65, respectively whilst for the post-crisis period the F-statistics of 2.81, 2.27 and 2.64, respectively, are all insignificant at all critical levels.

In summary, we find seven significant ARDL function for the post-crisis periods, namely i) *f(repo |house1*, π, income) ii) *f(repo |house2*, π, income) iii) *f(repo |house3*, π, income) iv) *f(*π*| repo*, *house1*, income) v) *f(income | repo*, π, *house1*) vi) *f(income | repo*, π, *house2*) vii) *f(income | repo*, π, *house3*), whereas we find only four significant functions for the post-crisis periods i.e. i) *f(repo | house1*, π, income) ii) *f(repo | house2*, π, income) iii) *f(repo | house3*, π, income) iv) *f(house3 | repo*, π, income).

Table 4: ARDL estimates for pre-crisis period

Long-run estimates	**repo**	**repo**	**repo**	**π**	**income**	**income**	**income**
house1	-0.03 (0.49)	-	-	0.06 (0.79)	-0.29 (0.33)	-	-
house1(-1)	-	-	-	-	0.47 (0.11)	-	-
house2	-	-0.02 (0.60)	-	-	-	0.17 (0.40)	-
house3	-		-0.03 (0.52)	-	-	-	0.08 (0.70)
repo	-	-	-	4.42 (0.00)***	0.21 (0.09)*	0.19 (0.18)	0.23 (0.16)
repo(-1)	0.93 (0.00)***	0.93 (0.00)***	0.93 (0.00)***	-4.07 (0.00)***	-	-	-
π	0.14 (0.00)***	0.14 (0.00)***	0.14 (0.00)***	-	0.12 (0.92)	0.03 (0.81)	0.01 (0.92)
π(-1)	-	-	-	0.28 (0.08)*	-0.29 (0.02)**	-0.26 (0.05)*	-0.28 (0.05)*
income	0.07 (0.02)**	0.07 (0.04)*	0.07 (0.03)*	-0.22 (0.29)	-	-	-
income(-1)	-	-	-	-	0.58 (0.00)***	0.60 (0.00)***	0.63 (0.00)***
Short-run estimates	**Δrepo**	**Δrepo**	**Δrepo**	**Δπ**	**Δincome**	**Δincome**	**Δincome**
Δhouse1	-0.03 (0.49)	-	-	0.06 (0.79)	-0.29 (0.33)	-	-
Δhouse2	-	-0.02 (0.60)	-	-	-	0.17 (0.40)	-
Δhouse3	-	-	-0.03 (0.57)	-	-	-	0.01 (0.92)
Δrepo	-	-	-	4.42 (0.00)***	0.21 (0.09)*	0.19 (0.18)	0.23 (0.16)
Δπ	0.14 (0.00)***	0.14 (0.00)***	0.13 (0.00)***	-	0.12 (0.92)	0.03 (0.81)	0.11 (0.92)
Δincome	0.07 (0.03)**	0.07 (0.03)**	0.07 (0.03)**	-0.22 (0.28)	-	-	-
ect(-1)	-0.07 (0.00)***	-0.07 (0.00)***	-0.07 (0.00)***	-0.72 (0.00)***	-0.42 (0.00)***	-0.40 (0.00)**	-0.37 (0.00)***

Notes: '***', '**','*' represent the 1%, 5% and 10% significance levels, respectively. P-values reported in parentheses ().

Based on the empirical results for the pre-crisis period reported in Table 4, we report the following findings. Firstly, we note that for the repo functions (i.e. *f(repo |house1*, π, income), *f(repo |house2*, π, income) and *f(repo |house3*, π, income)), the regression estimates produce negative yet insignificant coefficients on the house1 (-0.03), house2 (-0.02) and house3 (-0.03) variables. This results imply that during the pre-crisis periods the SARB was unresponsive towards house prices and notably this result differs from conventional theory which hypothesizes on significant relationship between the two variables. On the other hand, inflation and disposable income variables both produce highly significant coefficient estimates of 0.14 and 0.07, respectively, across all estimated regressions. We consider this result encouraging since it adheres to economic theory and is further concurrent with the results established in the previous studies of Mitchell-Innes et. al. (2007) and Phiri and Lusanga (2011) for similar South African time series data.

Similarly for the inflation function (i.e. *f(*π | *repo*, *house1*, income)), we observe that an insignificant coefficient estimates of 0.06 and -0.22 for the housing and disposable income variables, respectively. Note that the later result is particularly in alignment with conventional growth theory and is also reiterated in the studies of Anari and Kolari (2002) and Gallin (2006), respectively, albeit for different economies/more advanced economies. However, for the same function, we are able to obtain a positive and significant coefficient of 4.42 for the repo rate whilst we obtain a significantly negative coefficient of -4.07 for the lag of the repo rate. This later results implies that inflation initially has a positive relationship with an increase in the repo rate which then turns negative after one quarter period. Mitchell-Innes et. al. (2007) argue that the changes in the repo rate as induced by the SARB take between 12 and 24 months to fully reflect on inflation rate.

Concerning the income functions (i.e. *f(income* | *repo*, π, *house1*), *f(income* | *repo*, π, *house2*) and *f(income* | *repo*, π, *house3*)), we find insignificant coefficient estimates of -0.29 for and 0.47 for the house(1) and lag of house(1) variables, respectively, whereas we obtain insignificant estimates of 0.17 and 0.08 for the house(2) and house(3), respectively. For the same income functions, the inflation variable produces insignificant estimates of 0.12, 0.03 and 0.01, respectively, whereas the lag inflation variable produces significant estimates of -0.29, -0.26 and -0.28, respectively. Also note that, concerning the *f(income* | *repo*, π, *house1*) function, we find a positive coefficient of 0.21 for the repo variable whereas for the same variable we obtain insignificant coefficient estimates of 0.19 and 0.23 for the *f(income* | *repo*, π, *house2*) and *f(income* | *repo*, π, *house3*) functions.

In diverting our attention to error correction estimates reported in panel B of Table 4, we note that the all error correction estimates produce the correct negative and significant estimates of -0.07 for all three housing functions, -0.72 for the repo functions and between -0.37 and -0.42 across all three income functions. These results imply that between 7 and 42 percent of deviations from equilibrium are corrected in each quarter and further indicates long-run causality between the time series variables.

Table 5: ARDL estimates for post-crisis period

Long-run estimates	**repo**	**repo**	**repo**	**house3**
house1	-0.09 (0.04)*	-	-	-
house2	-	0.11 (0.79)	-	-
house3	-	-	-0.01 (0.68)	0.47 (0.00)***
repo	-	-	-	-0.07 (0.86)
repo(-1)	0.80 (0.00)***	0.84 (0.00)***	0.84 (0.00)***	-
π	0.22 (0.00)***	0.16 (0.00)***	0.16 (0.00)***	0.21 (0.67)
income	0.41 (0.04)*	0.03 (0.12)	0.04 (0.09)*	-0.07 (0.73)
Short-run estimates	**repo**	**repo**	**repo**	**house3**
Δhouse1	-0.09 (0.04)*	-	-	-
Δhouse2	-	0.01 (0.79)	-	-
Δhouse3	-	-	-0.01 (0.68)	-
Δrepo	-	-	-	-0.07 (0.68)
Δπ	0.22 (0.00)***	0.16 (0.00)***	0.16 (0.00)***	0.16 (0.00)***
Δincome	0.04 (0.04)*	0.04 (0.09)*	0.04 (0.09)*	0.04 (0.09)*
ect(-1)	-0.20 (0.00)***	-0.16 (0.00)***	-0.16 (0.00)***	-0.16 (0.00)***

Notes: '***', '**','*' represent the 1%, 5% and 10% significance levels, respectively. P-values reported in parentheses ().

In turning our attention to the post-crisis results reported in Table 5, we firstly note that for the repo functions, the house(1) variable produces a significant coefficient of -0.09 whereas the coefficients on the house(2) and house(3) produce insignificant estimates of 0.11 and -0.01, respectively. In making a comparison to the results obtained for the pre-crisis periods, we note that during the post-crisis periods the SARB has significantly responded to house price movements, well at least for the 'house1' variable (i.e. large housing).

In similarity to the results obtained for the pre-crisis periods, we find inflation is positive and significant at all critical levels across all three repo functions, with a coefficient of 0.80 for *f(repo |house1*, π, income), 0.84 for both *f(repo |house1*, π, income) and *f(repo |house1*, π, income) functions. Pertaining to the disposable income coefficient for the repo functions, we obtain positive and significant estimates of 0.41 and 0.04 for the *f(repo |house1*, π, income) and *f(repo |house3*, π, income) functions whereas we find an insignificant estimate of 0.03 for the *f(repo |house2*, π, income) function. On the other hand, for the house3 function (i.e. *f(house3 | repo*, π, income)), we obtain insignificant parameters estimates of -0.07 for the repo variable, 0.21 for the inflation variable and -0.07 for the disposable income variable.

Note that the error correction terms for the three repo functions are -0.30, -0.16 and -0.16 and these estimates are significant at all critical levels. This implies that between 16 and 30 percent of deviations from equilibrium are corrected in each quarter when a shock is induced through the repo rate. On the other hand, the error correction term associated with the hosue3 function produces a highly statistically significant estimate of -0.16 which implies that 16 percent of disequilibriums from the steady state are corrected in each period when a shock is induced to the hosue3 variable. Also note that these significant error correction estimates indicate long-run causality between the time series.

5.3 Diagnostic and stability tests

A battery of diagnostic tests are performed for the estimated model functions and results of these diagnostic tests are reported in Table 6. These tests are particularly performed for serial correlation, functional form, normality and heteroscedasticity and the reported test results indicate that all estimated regressions are devoid of residual-based misspecifications. Moreover, the stability tests based on the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of residual (CUSUMSQ) for the seven pre-crisis estimated functions as plotted in Figure 3, whereas the CUSUM and CUSUMSQ plots for the post-crisis periods as plotted in Figure 4, indicate that the parameters in the each of the estimated models are stable at 5 percent significance level in both sample sub-periods. These diagrams are presented at the Appendix of the manuscript.

Table 6: Diagnostic test results

	ARDL specifications	Diagnostic tests (p-value)			
		Serial correlation	Function form	Normality	Heteroscedasticity
Pre-crisis period	*f(income* | *repo*, *π*, *house1*)	0.80	0.63	0.89	0.20
	f(income | *repo*, *π*, *house2*)	0.78	0.61	0.89	0.22
	f(income | *repo*, *π*, *house3*)	0.40	0.33	0.60	0.30
	f(π | *repo*, *house1*, income)	0.20	0.18	0.32	0.37
	f(income | *repo*, *π*, *house1*)	0.13	0.34	0.69	0.13
	f(income | *repo*, *π*, *house2*)	0.47	0.50	0.76	0.19
	f(income | *repo*, *π*, *house3*)	0.66	0.19	0.69	0.60
Post-crisis period	*f(repo* | *house1*, *π*, income)	0.29	0.35	0.51	0.42
	f(repo | *house2*, *π*, income)	0.28	0.37	0.52	0.43
	f(repo | *house3*, *π*, income)	0.31	0.39	0.48	0.44
	f(house3 | *repo*, *π*, income).	0.42	0.46	0.82	0.54

6 CONLCUSSIONS

Since the global financial crisis much academic attention has been given to the cointegration relationship between interest rates and the housing sector. Nonetheless, these previous studies tend to ignore the possibility of a changing relationship between the two variables as caused by a structural break attributed to the global financial crisis. In light of this empirical hiatus we contribute to the current literature by examining the possibility of a switching interest rate-housing prices relationship for South Africa, which arguably boasts the most prestigious housing market among all SSA countries. Because of the relative small sample of our quarterly empirical data as well as the mixture of I(0) and I(1) variables identified in our dataset, we consider the ARDL model as the most appropriate econometric framework for conducting our empirical analysis. Surely, our results indicate a significant changing relationship between interest rates and the growth in housing price with the Reserve Bank being more responsive to house price movements in the post crisis period. We attribute our findings to the macropudential framework adopted by the SARB which particularly focuses on reducing excessive growth in asset prices such as housing and property prices and uses these property prices to assess market conditions.

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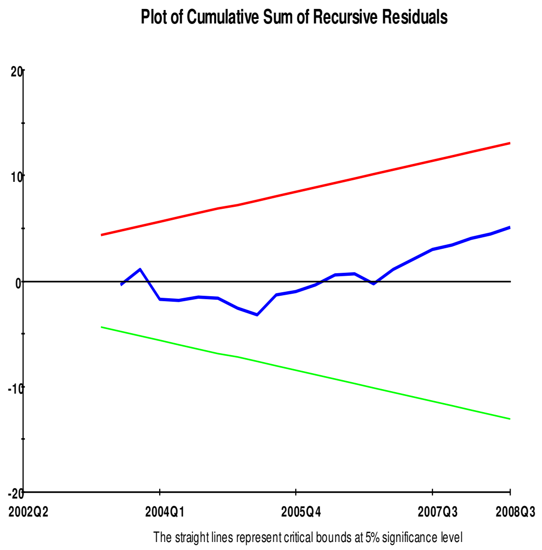
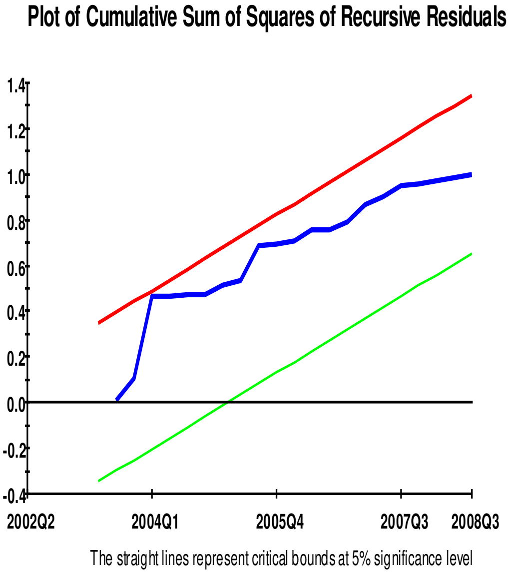
APPENDIX

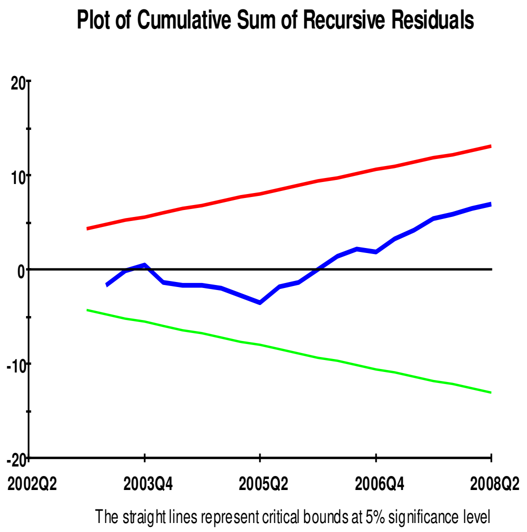
Figure 1: Plot to CUSUM and CUSUMSQ for pre-crisis periods

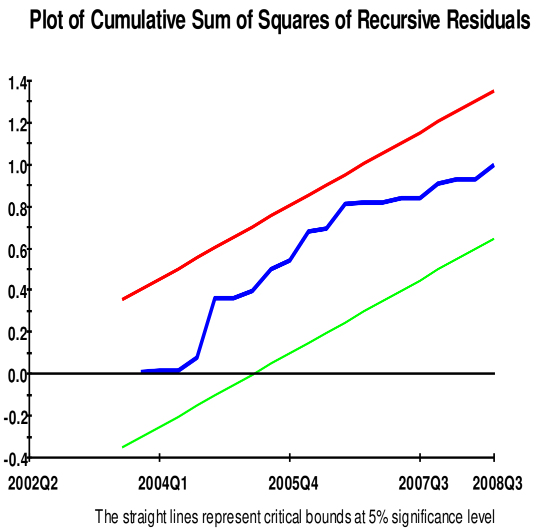
Model function: *f(repo |house1*, π, income)



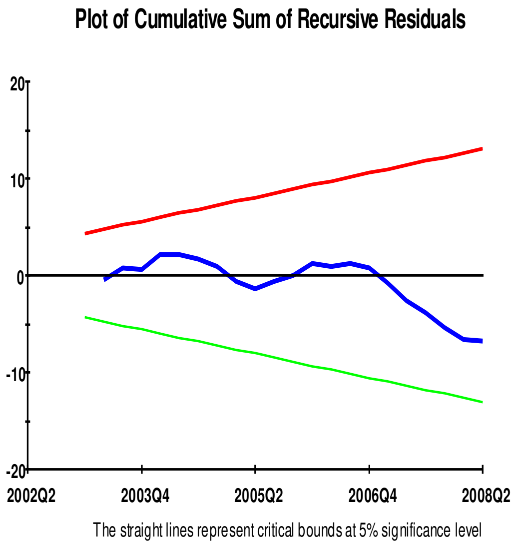


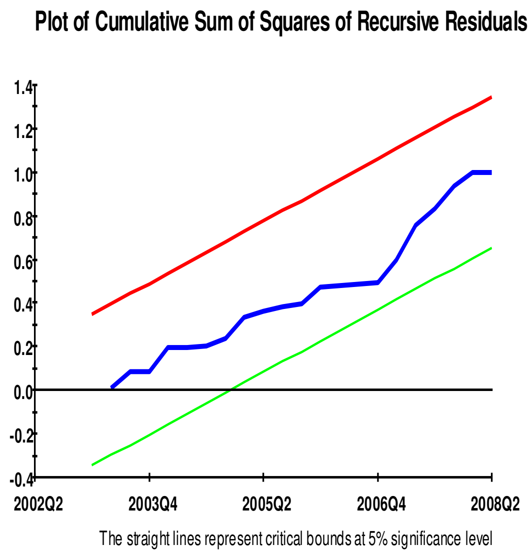
Model function: *f(repo |house2*, π, income)



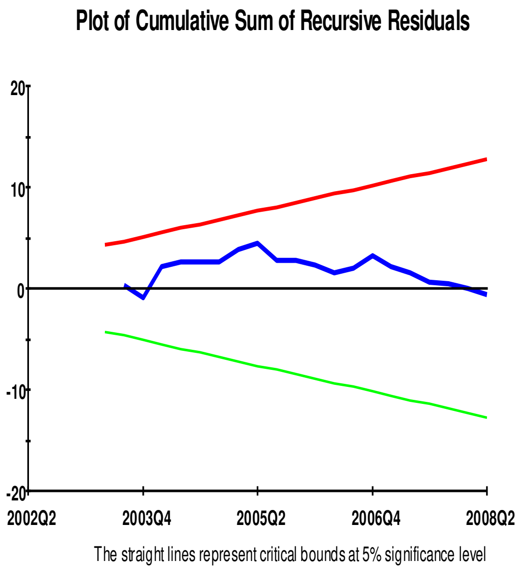


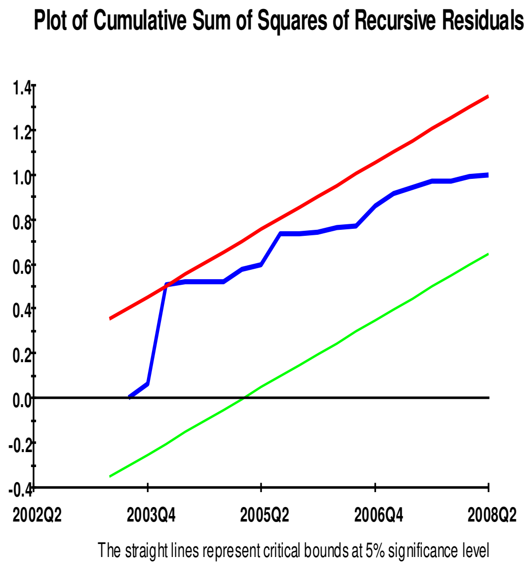
Model function: $f(repo \mid house3, \pi, \text{income})$





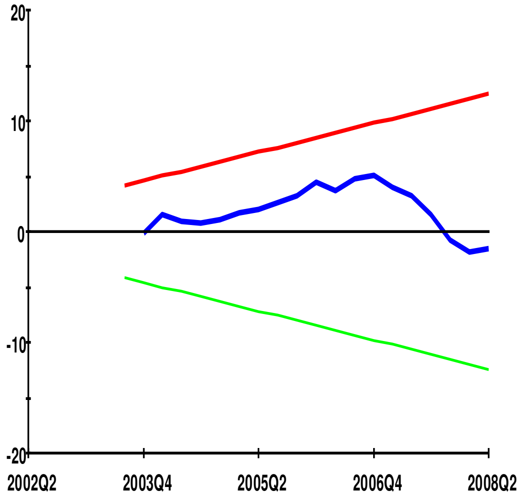
Model function: $f(\pi \mid repo, house1, \text{income})$





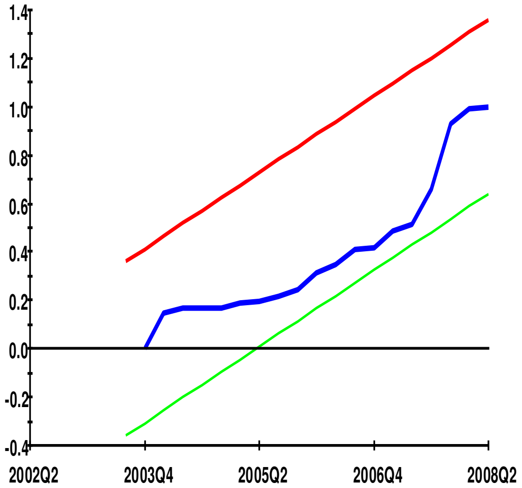
Model function: *f(income | repo, π, house1)*

Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

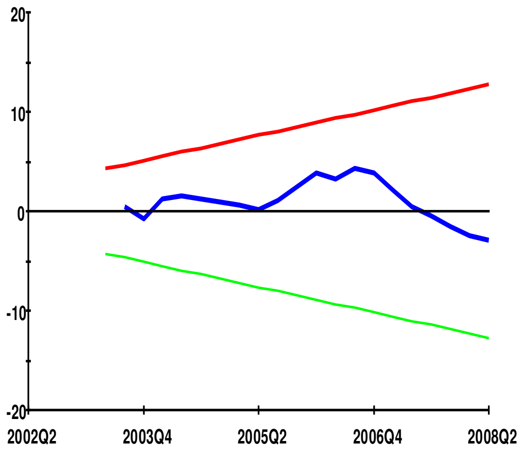
Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

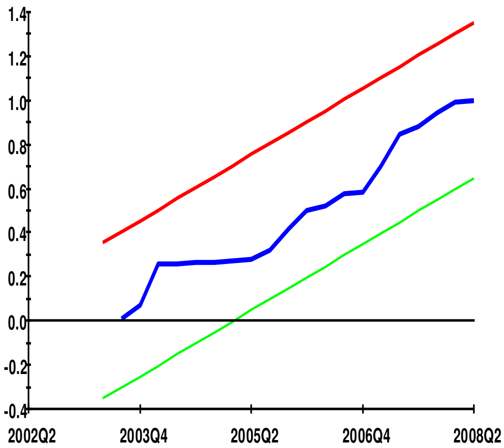
Model function: *f(income | repo, π, house2)*

Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Model function: *f(income | repo, π, house3)*

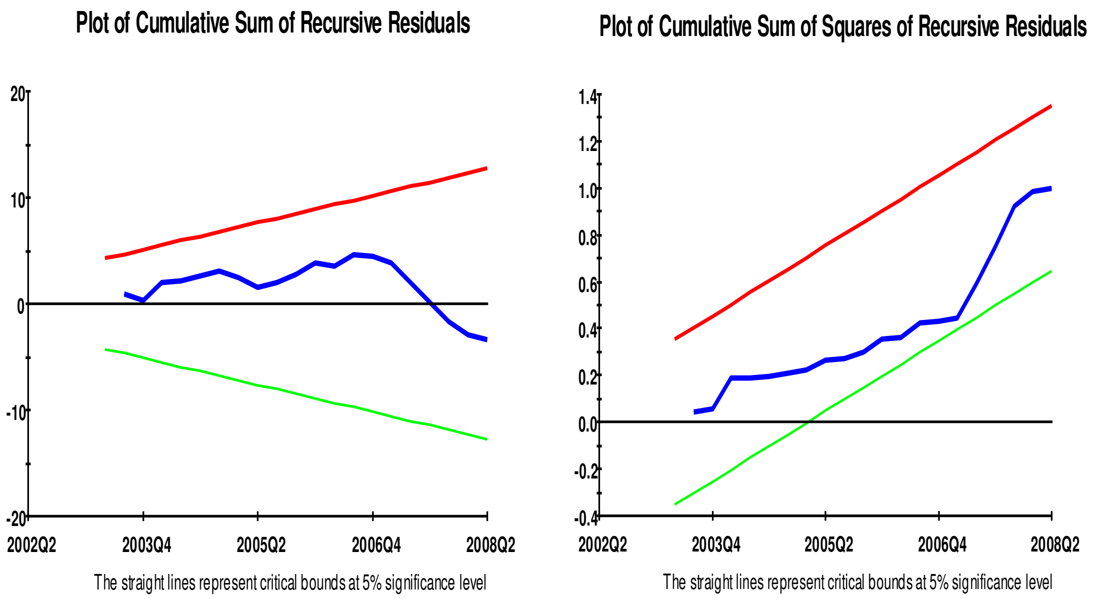
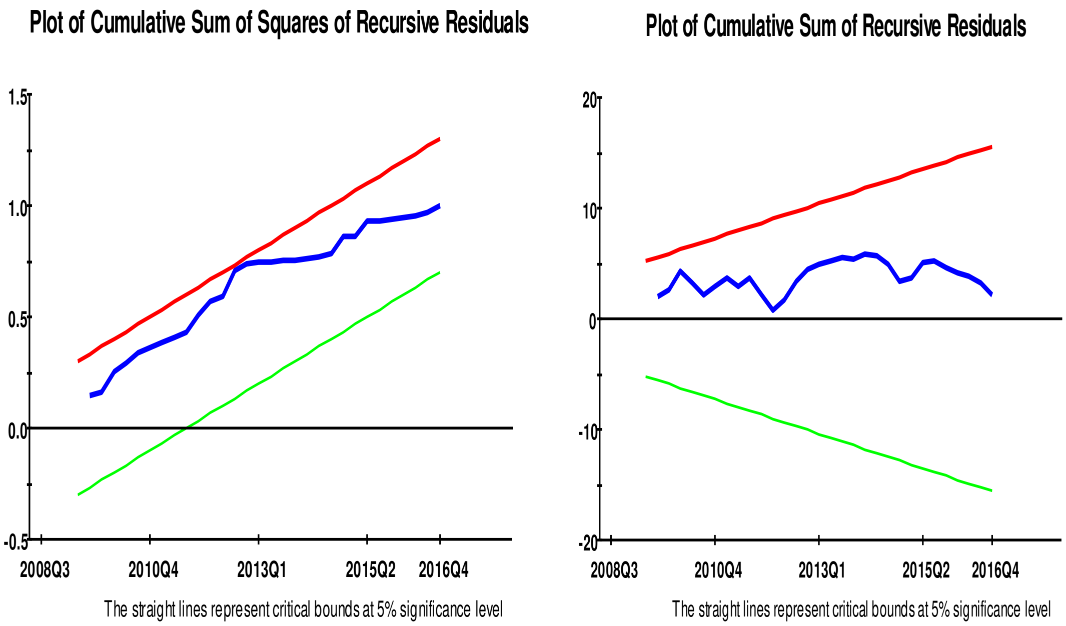
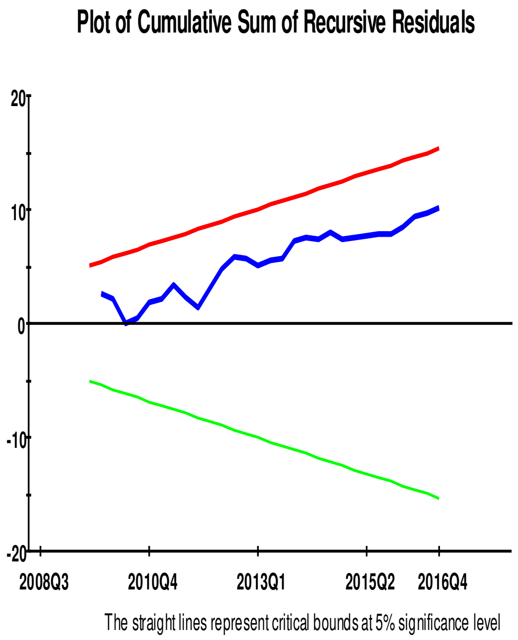


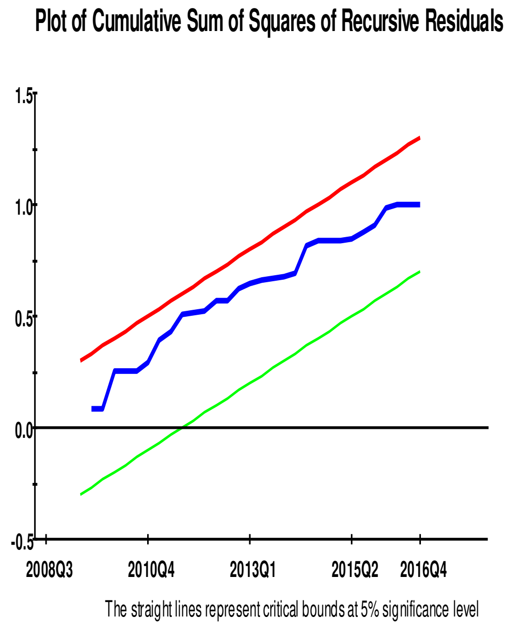
Figure 2: Plot to CUSUM and CUSUMSQ for post-crisis periods

Model function: *f(repo |house1, π,* income)

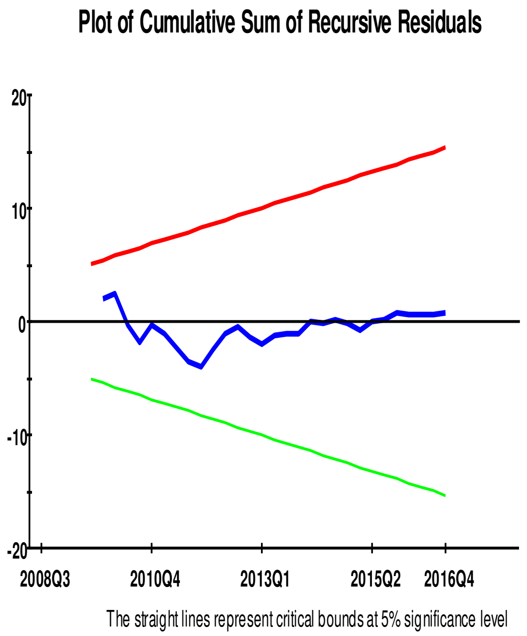


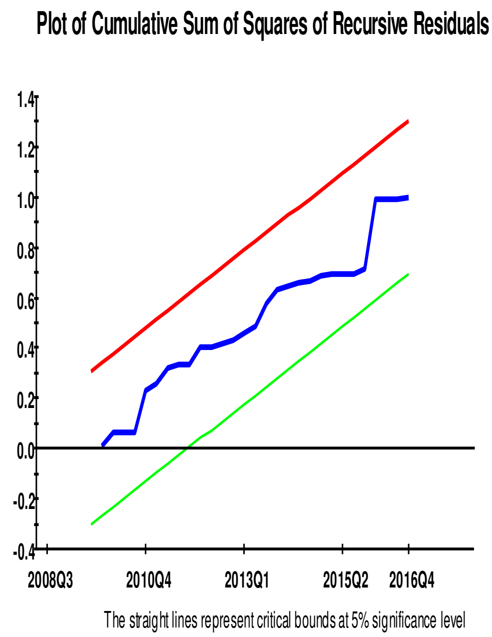
Model function: *f(repo |house2*, π, income)





Model function: *f(repo |house3*, π, income)





Model function: *f(house3 | repo*, π, income)