The Determinants of Real Exchange Rate Volatility in South Africa*

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Abstract

This paper investigates the determinants of medium to long-run real exchange rate volatility in South Africa over the period 1986-2015. Employing the Autoregressive Distributed Lag (ARDL) cointegration approach and using a variety of specifications and robustness tests, results show that trade openness has a significant positive impact on real exchange rate volatility. The interaction term of trade openness and the dummy variable for capital account libelisation, leads to a significant negative impact on real exchange rate volatility. Furthermore, findings indicate that volatility of output, commodity prices, money supply, and government consumption, and the exchange rate regime significantly influence rand volatility.

Keywords: Real Exchange Rate Volatility, Economic openness, ARDL cointegration, South Africa

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1 Introduction

Increasing financial liberalisation since the collapse of the Bretton Woods system in the 1970s has rendered exchange rates volatile in both developed

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and developing countries. As a result, the causes and effects of exchange rate volatility have become of particular interest to both researchers and policymakers. This paper focuses on the causes of medium to long-run real exchange rate volatility for South Africa's currency (the rand). This kind of study is important because medium to long-run real exchange rate volatility raises the risks associated with investment in the tradable sector, and is detrimental to long-term economic growth. For instance, there is evidence in South Africa of exchange rate volatility having significant effect on macroeconomic factors such as employment and trade (Todani and Munyama, 2005; Mpofu, 2013; Aye, Gupta, Moyo and Pillay, 2014). Therefore finding the sources of real exchange rate volatility is relevant to researchers and policymakers to assist them in investigating how to tackle some of the adverse effects of exchange rate volatility.

Given the above, the question that follows is, when did financial liberalisation occur in South Africa? The answer is, it occurred in March 1995 when the South African economy abolished the dual exchange rate system which had been in place since the mid-1980s. With this, figure 1 shows that both exports and imports as a percent of GDP, had a downward trend between 1986 to mid-1990s. However, from mid-1990s, there is a significant increase in the share of trade following the loosening of exchange rate controls. This motivates us to find the impact of trade openness on rand volatility. This follows the conflicting results offered by empirical studies. Some researchers find that trade openness reduces exchange rate volatility (Hau, 2002; Calderón, 2004; Bleaney, 2008; Amor and Sarkar, 2008; Caporale, Amor and Rault, 2009), while others find the opposite or no relationship (Stancık, 2006; Stancık, 2007; Grydaki and Fountas, 2010; Chipili, 2012; Jabeen and Khan, 2014). This suggests that the relationship between exchange rate volatility and trade openness depends on specific institutional characteristics of a country, which can only be shown using an empirical analysis.

In addition, studies like Hau (2002) and Calderón (2004) attempt to find the sources of exchange rate volatility in South Africa[1]. However, these studies use cross-country data and find aggregate results which do not isolate country specific effects. Besides, Hau (2002) states that the theoretical linkage between trade openness and real exchange rate volatility depends on the magnitude of the monetary and real shocks of each country. This suggests that analysing the sources of exchange rate volatility at a country level will likely be better for formulation of the correct type of policy response(s).

To the best of our knowledge, there is one study by Arezki, Dumitrescu,

[1] This follows the fact that South Africa is included in their sample of countries analysed.

Freytag and Quintyn (2014) for South Africa that examine the determinants of medium to long-run rand volatility. As such, this study contributes to the literature in two ways. First, we differ with Arezki, Dumitrescu, Freytag and Quintyn (2014) that examine the relationship between rand volatility and gold price volatility by focusing on the sources of real exchange rate volatility using output volatility, money supply volatility, commodity price volatility, ratio of general government consumption expenditure to GDP volatility, trade openness, and exchange rate regime dummy, as explanatory variables. This is because many empirical studies in South Africa have mostly focused on analysing the determinants of the level of the exchange rate. That is, estimating the long-run equilibrium exchange rate level and the extent of its misalignment (Aron, Elbadawi and Kahn, 1997; MacDonald and Ricci, 2004; Frankel, 2007; Saayman, 2007; Faulkner and Makrelov, 2008). Second, the study also uses a variable that has not been included in previous studies, which is the interaction term of trade openness and exchange rate regime dummy, to capture how trade openness and real exchange rate volatility relationship depends on monetary policy stance.

This study employs an Autoregressive Distributed Lag (ARDL) cointegration method for the period 1986-2015 and uses various specifications and robustness tests. We use two measures (the moving standard deviation over a one-year window and over a four-year window) for the volatility of real effective exchange rate (REER) and the volatility of REER fundamentals. The findings show that trade openness is associated with a significant and robust positive effect on real effective exchange rate. The interaction term of trade openness and exchange rate regime dummy, a variable that has not been used in previous studies, has a significant and robust negative effect on real effective exchange rate volatility. Furthermore, the results show that volatility of output, commodity prices, money supply, and the ratio of general government consumption expenditure to GDP, as well as the exchange rate regime significantly influence rand volatility.

The structure of the paper is as follows: section 2 presents the literature review. Section 3 reports the data and methodology. Section 4 reports the results and section 5 concludes.

2 Literature Review

There is no general consensus on the macroeconomic determinants of exchange rate volatility in the literature. This is due to different approaches used based on different theoretical models of exchange rate level determination. Examples include: First are the monetary models of exchange rate level determination, which emphasise that monetary variables are the main determinants of exchange rate volatility (see e.g., Morana, 2009; Grydaki and Fountas, 2009; Grydaki and Fountas, 2010). Second are the Optimum Currency Area models which put emphasis on trade linkages; asymmetry or similarity of economic shocks to output, country size and geographic factors, as the determinants of exchange rate volatility (see e.g., Bayoumi and Eichengreen, 1998; Devereux and Lane, 2003). Third are the New Open Economy Macroeconomics models which stress that monetary and non-monetary variables are important in explaining exchange rate volatility (see e.g., Hau, 2002; Calderón, 2004; Amor and Sarkar, 2008; Caporale, Amor and Rault, 2009).

However, other studies investigate the determinants of exchange rate volatility not based on a specific theoretical model but based on variables considered important in explaining exchange rate movements in the countries of their studies. Such studies include Chipili (2012) and Jabeen and Khan (2014) to mention a few. Nevertheless, other studies find no link between macroeconomic fundamentals and exchange rate volatility (Flood and Rose, 1995). Such studies support the role of non-macroeconomic determinants of exchange rate volatility.

This paper is related to a range of studies that specifically analyse the role of economic openness on exchange rate volatility. Most studies define economic openness in two different ways namely: trade openness and financial openness. Hau (2002) employs cross-sectional analysis on 48 countries over the period 1980-1998 and provides evidence that more trade openness leads to less exchange rate volatility. Hau (2002) uses real effective exchange rate (REER) volatility measured as the moving sample standard deviation of REER percentage changes over three-year period as well as control variables like per capita GDP, dummies for revolutions and coups, central bank independence, and exchange rate commitments. Using a GMM method on 77 industrial and developing countries over the period 1974-2003, and measuring real exchange rate volatility as the standard deviation of changes in the REER over a five year period, Calderón (2004) also finds a negative relationship between trade openness and real exchange rate volatility. Similar results are found by studies like Amor and Sarkar (2008) for ten South and South East Asia economies, Bleaney (2008), and Caporale, Amor and Rault (2009) for 39 developing countries. However, using monthly data and GARCH methods, Chipili (2012) finds insignificant results when GARCH(1,1) and TARCH(1,1) methods are used between trade openness and exchange rate volatility. Using an EGARCH(1,1), he finds positive and significant results between exchange rate volatility for Zambian kwacha and 19 other currencies, except for Zambian kwacha/Zimbabwean dollar which is negative and significant over the period 1964-2006. Jabeen and Khan (2014) use trade restrictions measured by the reciprocal of trade openness and find positive and insignificant relationship with exchange rate volatility. Stancık (2006) and Stancık (2007) uses daily bilateral real exchange rate volatility measured using the TARCH model between the euro/U.S dollar for six Central and Eastern European countries. The final model is estimated using OLS and the results show a negative and significant relationship between exchange rate volatility and trade openness for four countries only while the other two are insignificant[2].

For the relationship between financial openness and exchange rate volatility, Calderón (2004) finds a weak negative relationship. Amor and Sarkar (2008) find a positive relationship between exchange rate volatility and financial openness. Caporale, Amor and Rault (2009) also find a positive relationship for 39 developing countries. Separating the 39 countries into three regions, Caporale, Amor and Rault (2009) find a positive relationship between real exchange rate volatility and financial openness for 20 Latin American countries and ten Asian countries while for nine MENA countries[3], they find a negative relationship.

Empirical studies on the relationship between economic openness and real exchange rate volatility offer conflicting results as shown above. This suggests that the relationship depends on specific institutional characteristics of a country. As such, this study differs from Hau (2002), Calderón (2004), Amor and Sarkar (2008), and Caporale, Amor and Rault (2009), by focusing on a single country, South Africa. South Africa provides a context for analysing the impact of economic openness on exchange rate volatility. In 1994, South Africa became a multi-racial democracy after nearly four decades of state sanctioned racial segregation. Arising out of this were major institutional and policy changes to South Africa's monetary operations (see e.g., Du Plessis, 2002; Aron and Muellbauer, 2007; Ndikumana, 2008) for full details. In March 1995, the South African financial system opened up to the rest of the world. Prior to March 1995, South Africa followed a dual exchange rate system which was in place between September 1985 and February 1995. During this period, the financial rand system of capital controls was imposed on non-resident portfolio investors while the commercial rand system was not imposed. This was the result of the increased volatility of the rand during the period 1982-1985 because of political pressure from the international commu-

[2]The countries involved are Poland (with 31% trade openness), Latvia (50%), Slovenia (50%), Czech Republic (61%), Hungary (61%) and Slovakia (70%). Negative and significant results are for Poland, Latvia, Slovenia, and Slovakia only.

[3]The countries in the MENA region include: Algeria, Egypt, Iran, Israel, Jordan, Morocco, Syria, Tunisia, and Turkey.

nity, which imposed trade sanctions because of apartheid. The unification of the financial and commercial rand systems of capital controls in March 1995 allow us to investigate the impact of such a change in institutional settings on the relationship between exchange rate volatility and its fundamentals. In addition, South Africa's monetary policy adopted informal inflation targeting system between 1998 and early 2000, and eventually adopted formal inflation targeting system in February 2000.

Subsequent studies in South Africa that examine the determinants of exchange rate volatility are as follows: Arezki, Dumitrescu, Freytag and Quintyn (2014) employ a Vector Error Correction Model (VECM) to examine the relationship between the volatility of the South African real effective exchange rate and the volatility of commodity prices (proxied by gold price) for the period 1980-2010. Measuring volatility by the 12-month rolling window of the standard deviation of gold price index and real exchange rate, they find that gold price volatility is significant in explaining the excessive exchange rate volatility of the rand mostly after the liberalisation of capital controls in 1995. Other studies like Farrell (2001) and Mpofu (2016) use monthly data to find the sources of rand volatility, which is inconsistent with the theoretical predictions of the relationship between economic openness and real exchange rate volatility as argued by Hau (2002). Likewise, Fedderke and Flamand (2005), Farrell, Hassan and Viegi (2012), Hassan (2015), and Mpofu and Peters (2016) explain rand volatility using very high frequency data (intraday and daily data), whereby macroeconomic fundamentals are really not important.

This paper complements the analyses on studies that investigates the determinants of exchange rate volatility using macroeconomic fundamentals. We differ from Arezki, Dumitrescu, Freytag and Quintyn (2014) by focusing on economic openness and exchange rate volatility relationship as well as using more variables as determinants of South African rand volatility. In addition, this paper contributes to the debate about exchange rates in South Africa by focusing on the determinants of exchange rate volatility (i.e. the second moment of the relationship between the exchange rate and its determinants) given that most studies in South Africa have analysed the determinants of the level of the exchange rate (i.e. the first moment of the relationship between the exchange rate and its determinants) (see e.g., Aron, Elbadawi and Kahn, 1997; MacDonald and Ricci, 2004; Frankel, 2007; Saayman, 2007; Faulkner and Makrelov, 2008).

Given that different models examine the determinants of real exchange rate volatility and the fact that it is not practical to include all fundamental variables in an empirical model, the question that follows is, what variables in addition to trade openness are we going to use and why? This study chooses variables based on the variables that have been used in South African studies that analyse the determinants of exchange rate level and the variables that are consistently significant in driving real exchange rate volatility. One such variable is output volatility. Friedman (1953) states that exchange rate instability may be due to macroeconomic instability and establishes that there is a positive relationship between exchange rate volatility and macroeconomic volatility. Several studies (see e.g., Hau, 2002; Calderón, 2004; Amor and Sarkar, 2008; Caporale, Amor and Rault, 2009) find the positive and significant relationship between output volatility and real exchange rate volatility.

Another variable is the terms of trade (TOT) volatility. Unlike other studies that use TOT volatility, this study uses commodity price volatility. This follows the finding by other researchers (see e.g., Cashin, Cespedes and Sahay, 2002; MacDonald and Ricci, 2004; Frankel, 2007) that TOT tends not to be significant in most countries that are commodity exporters as one of the determinant of exchange rate, whilst commodity prices tend to be significant. MacDonald and Ricci (2004) assert two reasons for this. First, commodity prices are more accurate in terms of measurements, unlike TOT, which are based on arbitrary construction of country-specific export and import deflators. Second, commodity prices data are frequently available for analysis. Likewise, monetary policy volatility is another variable. Most studies use money supply to proxy this variable and find positive and significant relationship. This is likely to be as a result of nominal depreciations or increases in prices. Calderón (2004), Morana (2009), Caporale, Amor and Rault (2009), and Chipili (2012) provide evidence of this. The volatility of the ratio of government consumption expenditure to GDP is another variable used. Exchange rate literature show that the effect of government consumption on real exchange rate is ambiguous (MacDonald and Ricci, 2004). For example, if the decline in government spending falls on nontraded goods, this leads to a depreciation of the real exchange rate while if spending effect is via aggregate demand whereby both the demand for traded and non-traded goods increases, this induces an appreciation of the real exchange rate. Finally, dummy variables for institutional changes are found to significantly influence real exchange rate volatility. The next section defines these variables.

3 Data and Methodology

This paper uses quarterly time series data for South Africa from 1986-2015 obtained from the South African Reserve Bank (SARB) and Datastream. All the variables are seasonally adjusted using TRAMO/SEATS[4] ARIMA tools. This is done to remove cyclical seasonal movements that are common in time series data observed at monthly and quarterly frequency. The variables are defined as follows:

The dependent variable, the volatility of real effective exchange rate *(reerv)*, is measured as the 4-quarter moving standard deviation of the first difference of log real effective exchange rate. Real effective exchange rate (REER) is the trade weighted real exchange rate for the 20 trading partners of South Africa based on manufacturing goods. The formula for calculating volatility is as follows:

$$Vol_i = \left[\frac{1}{n} \sum_{i=1}^{n} (x_{t+i-1} - x_{t+i-2})^2 \right]^{1/2} \tag{1}$$

where n is the number of periods encompassed by the moving standard deviation. This study uses two numbers for n. First is n = 4 (i.e. the moving standard deviation over a one-year window) and second, n = 16 (the moving standard deviation over a four-year window), which we use for robustness test later. x is the variable in question. For this study, x = REER, output, money supply, commodity prices and the ratio of general government consumption expenditure to GDP.

Independent variables are defined as follows. First, volatility of output *(rgdpv)* is measured as the 4-quarter moving standard deviation of real GDP at 2010 constant prices. Second, volatility of money supply *(moneyv)* is measured as the 4-quarter moving standard deviation of M1. Third, volatility of commodity prices *(goldpv)* is measured as the 4-quarter moving standard deviation of the gold price in domestic currency based on the pricing in London. Gold price is used to proxy commodity prices because gold is the commodity mostly exported given that South Africa is the second largest producer of gold and earns more on gold exports relative to other commodities (see e.g., Arezki et al. 2014). Fourth, volatility of government spending *(gvtcv)* is measured as the 4-quarter moving standard deviation of the ratio of general government consumption expenditure to GDP. Fifth is trade openness *(topen)* which is measured as the ratio of real exports and imports to real GDP. Sixth, are the dummy variables. The exchange rate regime dummy *(exrated)* takes the value of one from 1995Q2 onwards and zero otherwise. This follows the capital account liberalisation in March 1995. We use two monetary policy dummies, informal inflation targeting regime *(iitd)* which

[4] TRAMO stands for Time Series Regression with ARIMA noise, missing values and outliers. SEATS stands for Signal Extration in ARIMA Time Series.

takes the value of one from 1998Q2 to 2000Q1 and zero otherwise, and formal inflation targeting regime *(itd)* which takes the value of one from 2000Q2 onwards and zero otherwise.

3.1 Descriptive Statistics

Estimating empirical models using time series data requires the variables be stationary, implying unit root tests should be conducted before carrying out any analysis. Accordingly, we apply the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to find the order of integration of the variables. The results for the unit root tests are shown in table 1, with panel A showing the ADF test and panel B showing the PP test. Panel A shows that four variables are integrated of order one and two variables are integrated of order zero, while panel B shows that five variables are integrated of order one and one variable is integrated of order zero.

[Insert Table 1 Here]

After finding the stationarity properties of all the variables, we find the summary statistics of all the variables to show some key stylised facts. Table 2 shows that some of the variables exhibit similarities with the behaviour of financial time series data. That is, having excess kurtosis, and not following a normal distribution. For example, the volatility of real exchange rate, gold price and government spending show excess kurtosis. The kurtosis of the standard normal distribution is three. The skewness of the variables is not equal to zero, which implies the variables do not follow a standard normal distribution. Using the Jarque-Bera statistic, table 2 shows that all the variables are not normally distributed, given that they have significant coefficients.

[Insert Table 2 Here]

Table 3 shows the correlation matrix for exchange rate volatility, trade openness, and volatility of exchange rate fundamentals. The table shows that real effective exchange rate volatility is positively correlated with the volatility of output, money supply and gold price, while it is negatively correlated with the volatility of government consumption. The association between REER volatility and gold price volatility is the strongest. The correlation between REER volatility and trade openness is positive. This suggests that the higher the degree of openness to international trade in goods and services, the higher the volatility of the REER. This is contrary to the hypothesis mentioned in section 1 and 2 earlier.

[Insert Table 3 Here]

3.2 Econometric Approach

Based on the unit root tests, which show that the variables in question are I(0) and I(1), motivate us to use the Autoregressive Distributed Lag (ARDL) cointegration method. Unlike other cointegration methods of Engle and Granger (1987), Johansen (1988), Stock and Watson (1993), and Johansen (1995) which concentrate on cases in which the underlying variables are I(1) only, the ARDL approach can be applied regardless of whether the regressors are I(0) only or I(1) only or a mixture of both (Pesaran, Shin and Smith, 2001). However, the regressors should not be I(2). The other advantage of the ARDL approach is that it performs better in small samples (Pesaran and Shin, 1999). In addition, this approach is also dynamic in that it allows the derivation of a dynamic error correction model (ECM) which integrates short-run dynamics and the long-run equilibrium. Lastly, Pesaran, Shin and Smith (2001) state that as long as the ARDL model is appropriately augmented to allow for contemporaneous correlation, valid asymptotic inference can be made under least squares estimates. Therefore, the ARDL is applicable even when some explanatory variables are endogenous.

To find the sources of real exchange rate volatility, we follow Hau (2002) with some modifications to test the hypothesis that more trade openness reduces real exchange rate volatility. We differ with Hau (2002) in two ways. First, we use more explanatory variables following the New Open Economy Macroeconomics models that argue that both monetary and non-monetary variables are important in explaining real exchange rate volatility. Second, we explicitly test the implications of the New Open Economy Macroeconomics models that trade openness helps attenuate the effects of the volatility of fundamentals. We achieve this by using the interaction terms of trade openness with the volatility of fundamentals as done by Calderón (2004) and Pakravan, Vash and Ghaffari (2015). However, we contribute to the literature by adding an interaction term between trade openness and the exchange rate regime dummy to see how this relationship depends on the monetary policy stance. Our regression equation is as follows:

$$\begin{aligned} reerv_t &= \alpha_0 + \alpha_1 rgdpv_t + \alpha_2 moneyv_t + \alpha_3 goldpv_t + \alpha_4 gvtcv_t \\ &\quad + \alpha_5 topen_t + \alpha_6 dummy_t + \alpha_7 v_t + \varepsilon_t \end{aligned} \tag{2}$$

where $reerv_t$ is the real effective exchange rate volatility, $rgdpv_t$ is the volatility of output, $moneyv_t$ is the volatility of money supply, $goldpv_t$ is the volatility of gold price which proxy commodity prices, $gvtcv_t$ is the volatility of government consumption expenditure, $topen_t$ is trade openness, $dummy_t$ represents the dummy variables we use which include exchange rate regime (exrated), informal inflation targeting (iitd) and formal inflation targeting (itd), v_t stands for the interaction terms we use which are torgdpv (trade openness*rgdpv), tomoneyv (trade openness*moneyv), togoldpv (trade openness*goldpv), togvtcv (trade openness*gvtcv) and openexd (trade openness*exchange rate regime dummy). $\alpha_{0,\ldots,7}$ are parameters and ε_t is the error term.

4 Results

In estimating equation 2, we take two factors into consideration. First, the most appropriate lag specification is required. This paper uses the Akaike Information Criterion (AIC) to establish the appropriate lag specification. The findings from the regression analysis are in tables 4 and 5[5], which show the long-run estimates and the error correction model (ECM) respectively using alternative specifications (columns 1-10). For columns 1-6, we set the maximum lag order at five to estimate the ARDL models while in columns 7-10, we set the maximum lag order at four. We use different lag specifications to mitigate the residual serial correlation problem which is the second factor taken into consideration. We use the LM test to test for serial correlation, and the results in table 5 show that there is no serial correlation given insignificant probabilities.

[Insert Tables 4 and 5 Here]

The results in table 5 show the dynamic nature of the ARDL models. As such, we first interpret the coefficients of lagged exchange rate volatility. These results show that lagged exchange rate volatility coefficients are statistically significant with positive values mostly for dreerv1 and dreerv3 for all specifications, and dreerv4 for columns 1-6 but with negative coefficients. The positive and significant coefficients indicate a high degree of persistence in exchange rate volatility. These results compare favourably to other studies like Caporale, Amor and Rault (2009) and Cevik, Harris and Yilmaz (2015) that also analyse emerging market economies like we do in this study. The negative and significant values suggest mean reverting in exchange rate volatility.

In column 1 of tables 4 and 5, we investigate whether trade openness on its own might be a source of real exchange rate volatility. The estimated coefficients are positive and significant at 1 percent level. This suggests that

[5]The results are based on the time period of 1987Q1-2015Q2 due to end point problem of using the method of moving standard deviation for calculating the volatility of the variables in question.

increasing trade openness is associated with an increase in real exchange rate volatility. However, the poor goodness of fit (adjusted R^2 of 0.392 as shown in table 5) suggest that trade openness only explains a very small fraction of the volatility of the real exchange rate. As such, in columns 2-10, we include more variables as sources of real exchange rate volatility. The adjusted R^2 increases to the range of 0.593-0.653, while the positive coefficient for trade openness remains significant at the 10 percent level (columns 3 and 10) and 5 percent (column 5) for the long-run estimates. For the ECM estimates, we also find positive and significant values in columns 2-7, and 10. This result is contrary to what other studies find (see e.g., Hau, 2002; Calderón, 2004; Caporale, Amor and Rault, 2009; Cevik, Harris and Yilmaz, 2015; Pakravan, Vash and Ghaffari, 2015). However, institutional changes in March 1995 changes the relationship between trade openness and real exchange rate volatility. Using the interaction term of trade openness and exchange rate regime dummy, tables 4 and 5 show negative and significant coefficients. This suggests that trade openness reduces real exchange rate volatility via flexible exchange rate regime, a channel which was not analysed by previous studies.

We find that the higher the volatility of gold price (used to proxy commodity prices), the higher the real exchange rate volatility. The estimated coefficients are positive and statistically significant at 1 percent level (columns 2-8, and 10). An increase of 1 percent in gold price volatility increases real exchange rate volatility in the range of 0.39-0.66 percent in table 4 and in the range of 0.48-0.56 percent in the short-run as shown in table 5. This result is not surprising given the high volatility of the world commodity prices and that South Africa is a commodity exporting country. The positive effect of gold price volatility on real exchange rate volatility is similar to studies that employ terms of trade but using different methodology to ours (see e.g., Calderón, 2004; Caporale, Amor and Rault, 2009). However, in column 9, the coefficient is negative and significant for gold price volatility while the interaction term of trade openness and gold price volatility is positive and significant with higher magnitudes of 3.64 and 1.84 for long-run and short-run estimates respectively. This suggests that the more trade openness is, the larger the impact of gold price volatility on real exchange rate volatility.

For output volatility, we find that an increase in output volatility leads to a decrease in real exchange rate volatility in the long-run as shown in columns 3 and 9 of table 4. However, in the short-run, table 5 shows that an increase in output volatility is associated with an increase in real exchange rate volatility. The positive and significant effect follows the perspective of Friedman (1953) that exchange rate volatility might be caused by macroeconomic instability. These results are similar to other studies (see e.g., Calderón, 2004; Amor and Sarkar, 2008; Caporale, Amor and Rault, 2009; Cevik, Harris and Yilmaz, 2015; Pakravan, Vash and Ghaffari, 2015). The long-run results are also similar to arguments presented by Friedman (1953) that it is possible to have high output volatility leading to lower exchange rate volatility. This suggests that there are some traders who are not concerned about instability in a country and are interested in investing in such countries, as long as they will ultimately benefit. This phenomenon is widely seen in countries with many natural resources like gold or diamonds or oil. The interaction term of trade openness and output volatility is insignificant in both the short-and long-run.

The results also show that the higher the volatility of money supply, the higher the volatility of real exchange rate. An increase of 1 percent in the volatility of money supply, increases real exchange rate volatility by 0.86 percent (column 6) in the long-run. In the short-run, an increase in the volatility of money supply leads to a reduction in real exchange rate volatility as shown in column 6 of table 5. This result is similar to Morana (2009) who finds a negative value in one country analysed and Grydaki and Fountas (2010) who find negative money supply volatility for Argentina and Chile. However, column 8 in tables 4 and 5 include an interaction term between trade openness and money supply volatility. Both tables show that an increase in money supply volatility is associated with a decrease in real exchange rate volatility. But the more trade openness is in South Africa, the higher the impact of money supply volatility on real exchange rate volatility, given the positive and significant interaction coefficients with higher magnitudes of 5.501 and 3.020 for long-run and short-run estimates respectively.

For government consumption expenditure volatility, we find that in the long-run, a 1 percent increase in the volatility of government consumption expenditure is associated with a reduction in real exchange rate volatility of 0.53 percent (column 3) and 0.98 percent (column 6). This result is similar to studies by Calderón (2004) and Pakravan, Vash and Ghaffari (2015). However, in the short-run, we find positive and significant relationship. The interaction term between trade openness and government consumption volatility is negative and insignificant.

The results show that the exchange rate regime dummy is positive and significant. This means that switching to a floating exchange rate system leads to more exchange rate volatility, which is consistent with most findings in the literature (see e.g., Canales-Kriljenko and Habermeier, 2004; Calderón, 2004; Stancık, 2007; Chipili, 2012). The dummy variables for informal and formal inflation targeting regimes are negative and significant. This suggest that having independent central bank leads to the reduction of real exchange rate volatility. This result is similar to the finding by Hau (2002) who uses an index for the central bank independence. Table 5 shows that in all ten specifications, the estimated error correction coefficients {ECM(-1)} have the expected negative signs which are significant at 1 percent level in the range of -0.253 to -0.549. The correct sign for the ECM(-1) term confirms the existence of a long-run relationship between real exchange rate volatility and the various explanatory variables[6].

4.1 Robustness Tests

Studies like Froot and Rogoff (1995) find that the upper bound for standard estimates of the real exchange rate half-life is four years. This time period also coincides with the average length of the business cycle in South Africa (Hassan, 2015). As such, the robustness test we employ is to explore how the use of volatility of real exchange rate and its fundamentals over the average of four years affect the results. To that end, we measure the volatility of real exchange rate, output, money supply, gold price and government consumption expenditure as a 16-quarter moving standard deviation. And include other variables like trade openness, exchange rate regime dummy and the dummies for informal and formal inflation targeting regime in the regression analysis. The results for robustness checks are shown in tables 6 and 7[7]. Similar to the results in table 5, real exchange rate volatility measured using the average of four years shows a high degree of persistence given the positive and significant coefficients of the lagged terms of real exchange rate volatility as shown in table 7.

[Insert Tables 6 and 7 Here]

Likewise, we find that trade openness is still associated with an increase in real exchange rate volatility. The results in tables 6 and 7 also show that the interaction term of trade openness and exchange rate regime dummy has a negative and significant relationship with real exchange rate volatility, similar to the results in tables 4 and 5. Furthermore, we still find that an increase in gold price volatility is associated with an increase in real exchange rate volatility both in the long-and short-run. Accordingly, an increase of 1 percent in gold price volatility increases real exchange rate volatility in the long-run in the range of 0.24-0.51 percent as shown in table 6. In column 8 of

[6] This result is also confirmed by the bounds testing approach. Testing for the existence of a level relationship among all the variables in the ARDL model, the computed F-statistics, not shown here but available upon request, are found to be higher than the upper bound of the critical values of Pesaran et al. (2001).

[7] The results are based on the time period of 1987Q1-2012Q4 due to end point problem of using the method of moving standard deviation for calculating the volatility of the variables in question.

both tables, the coefficient of gold price volatility is negative and significant while the interaction term of trade openness and gold price volatility is positive and significant with higher magnitudes of 4.17 and 1.67 for long-run and short-run estimates respectively. This means that the more trade openness is, the larger the impact of gold price volatility in increasing real exchange rate volatility.

The long-run results in table 6 show similar results of negative relationship between output volatility and real exchange rate volatility as shown in table 4 but with more significant coefficients and larger magnitudes. For example, now a 1 percent increase in output volatility reduces real exchange rate volatility in the range of 2.80-5.94 percent versus the range of 2.15-4.22 percent. The same results of negative relationship between output volatility and real exchange rate volatility are found in the short-run (see column 3 and 7 in table 7. But the lagged output volatility in the short-run show a positive and significant impact. The interaction term of trade openness and output volatility still shows insignificant results both in the short-and long-run.

The findings for money supply volatility show more significant coefficients for this variable with the expected sign of positive relationship with real exchange rate volatility. Accordingly, an increase of 1 percent in money supply volatility, increases real exchange rate volatility in the range of 0.31-0.77 percent. We find similar sign results in the short-run. However, the lagged money supply volatility coefficients have a negative and significant values in the short-run. The interaction term of trade openness and money supply volatility shows insignificant coefficients.

For government consumption expenditure volatility, we also find more significant coefficients. In the long-run, a 1 percent increase in volatility of government consumption expenditure is associated with a reduction in real exchange rate volatility in the range of 0.27-2.14 percent. The same negative relationship is found in the short-run. However, the lagged values in the short-run have a positive and significant coefficients only in column 2 (see table 7). The interaction term of trade openness and government consumption expenditure volatility is positive and significant in both the short-and long-run with bigger magnitudes of 1.03 and 3.46 respectively.

Finally, the results show that the exchange rate regime dummy is positive and significant in columns 3, 7,and 8 but negative with smaller magnitudes in columns 1 and 2 in the long-run. We find similar results in the short-run. Table 7 shows that in all nine specifications, the estimated error correction coefficients [ECM(-1)] have the expected negative signs which are highly significant in the range of -0.209 to -0.400. The correct sign for the ECM(-1) result confirms the existence of a long-run relationship. This table, further, shows that all the results do not suffer from the problem of serial correlation given insignificant probabilities.

5 Conclusion

This paper investigates the determinants of real effective exchange rate volatility over the period 1986-2015 for South Africa. The study applies the ARDL cointegration approach and uses a 4-quarter and a 16-quarter moving standard deviation to measure the volatility of real exchange rate, output, money supply, commodity prices, and the ratio of government consumption expenditure to GDP. Other explanatory variables included are trade openness (to test the hypothesis that real exchange rate fluctuations are less volatile in more open countries), exchange rate regime dummy and the dummies for monetary policy regimes.

We find that real exchange rate volatility is higher in flexible exchange rate regime. The findings also suggest that an increase in the volatility of gold price and money supply generates more volatility of real effective exchange rate. However, an increase in the volatility of output and government consumption is associated with a reduction in real exchange rate volatility. In addition, we find that the impact of volatile shocks to gold price, money supply and government consumption fluctuations on the volatility of real effective exchange rate is larger if the economy is more open to international trade. These results are in contrast with the findings by Calderón (2004).

Furthermore, the results show a significant and robust positive relationship between real exchange rate volatility and trade openness. This result is contrary to the findings by other studies (see e.g., Hau, 2002; Calderón, 2004; Caporale, Amor and Rault, 2009; Cevik, Harris and Yilmaz, 2015; Pakravan, Vash and Ghaffari, 2015). However, we find that institutional changes in March 1995 changes the relationship between trade openness and real exchange rate volatility. Using an interaction term of trade openness and exchange rate regime dummy, we find a significant and robust negative relationship between this variable and real exchange rate volatility.

Exchange rate volatility might cause uncertainty amongst investors. This is likely to lead to delays in investment decisions and thus hurt the economy through adverse effects on employment growth and trade. As such, finding the sources of real exchange rate volatility is important to policymakers to assist them in coming up with economic policies to minimise this volatility. One variable that stands out as one of the main drivers of real exchange rate volatility is the commodity price volatility (proxied by gold price volatility). Given that South Africa cannot control commodity price volatility, the policy recommendation here is for South Africa to strengthen its buffers, for example, international reserves as well as reducing external vulnerabilities which should reduce the susceptibility to real exchange rate volatility. In addition, increasing international trade together with maintaining a flexible exchange rate regime would be beneficial in the long-run in reducing real exchange rate volatility.

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6 Appendix

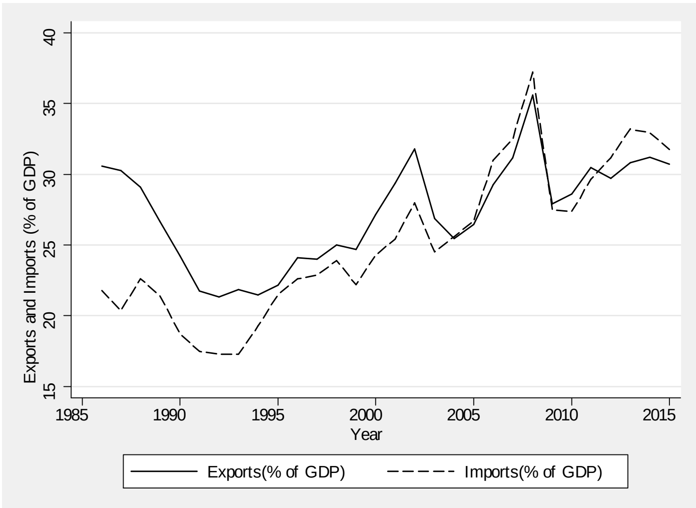

Figure 1: The share of exports and imports in GDP (1986-2015)

Table 1: Unit Root Tests

Panel A(i): ADF-level				
Variable	t-Stat	1%CV	5%CV	10%CV
reerv	-2.864	-4.044	-3.452	-3.151
rgdpv	-2.745	-4.045	-3.452	-3.151
moneyv	-3.592**	-4.044	-3.452	-3.151
goldpv	-3.413*	-4.045	-3.452	-3.151
gvtcv	-3.965**	-4.042	-3.450	-3.151
topen	-2.017	-4.041	-3.450	-3.150
Panel A(ii): ADF-first difference				
reerv	-8.379***	-2.586	-1.944	-1.615
rgdpv	-10.310***	-2.586	-1.944	-1.615
goldpv	-4.916***	-2.587	-1.944	-1.615
topen	-9.904***	-2.586	-1.944	-1.615
Panel B(i): PP-level				
reerv	-2.815	-4.041	-3.450	-3.150
rgdpv	-3.398*	-4.041	-3.450	-3.150
moneyv	-3.067	-4.041	-3.450	-3.150
goldpv	-2.916	-4.041	-3.450	-3.150
gvtcv	-4.628***	-4.041	-3.450	-3.150
topen	-2.017	-4.041	-3.450	-3.150
Panel B(ii): PP-first difference				
reerv	-8.694***	-2.586	-1.944	-1.615
rgdpv	-16.819***	-2.586	-1.944	-1.615
moneyv	-15.178***	-2.586	-1.944	-1.615
goldpv	-10.813***	-2.586	-1.944	-1.615
topen	-9.904***	-2.586	-1.944	-1.615

Notes: ADF denotes the Augmented Dickey-Fuller unit root test. PP represents the Phillips-Perron unit root test. The null hypothesis: Series has a unit root (*MacKinnon 1996 one-sided p-values). ***,**,* denotes rejection of null hypothesis at the 1%, 5% and 10% respectively. CV stands for critical values. Variables are defined in section 3.

Table 2: Descriptive Statistics

	reerv	rgdpv	moneyv	goldpv	gvtcv	topen
Mean	0.0525	0.0054	0.0336	0.0667	0.0190	0.5777
Median	0.0436	0.0052	0.0321	0.0588	0.0122	0.5963
Maximum	0.1383	0.0108	0.0675	0.1796	0.0933	0.7165
Minimum	0.0086	0.0013	0.0025	0.0108	0.0018	0.3920
Std.Dev	0.0337	0.0024	0.0165	0.0370	0.0181	0.0874
Skewness	1.0156	0.4943	0.1635	1.1383	2.2615	-0.6634
Kurtosis	3.2878	2.6759	1.8246	3.9387	8.1582	2.2857
Jacque-Bera	19.9914	5.1415	7.0706	28.8044	223.5616	10.7856
Probability	0.0000	0.0765	0.0292	0.0000	0.0000	0.0045
Sum	5.9870	0.6171	3.8255	7.6080	2.1631	65.8578
Sum Sq.Dev	0.1284	0.0006	0.0309	0.1544	0.0369	0.8632
Observations	114	114	114	114	114	114

Notes: See section 3 for the definition of the variables.

Table 3: Correlation matrix for all the variables

	reerv	rgdpv	moneyv	goldpv	gvtcv	topen
reerv	1					
rgdpv	0.157	1				
moneyv	0.297	0.082	1			
goldpv	0.588	0.051	0.416	1		
gvtcv	-0.065	0.016	-0.104	-0.084	1	
topen	0.185	0.041	-0.035	-0.088	0.038	1

Notes: All the variables are stationary.

Table 4: Long-run estimates of the ARDL models

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
topen	0.235***	-0.019	0.201*	0.219	0.410**	-0.247	0.167	0.134	0.086	0.271*
	(0.066)	(0.135)	(0.110)	(0.196)	(0.187)	(0.279)	(0.150)	(0.125)	(0.139)	(0.155)
goldpv		0.477***	0.516***	0.514***	0.394***	0.667***	0.516***	0.321***	-1.884***	0.509***
		(0.165)	(0.130)	(0.157)	(0.123)	(0.180)	(0.114)	(0.080)	(0.712)	(0.112)
rgdpv		-0.206	-4.218**	0.552	-1.334	-2.637	-12.784	-1.245	-2.149*	0.113
		(2.032)	(2.048)	(1.831)	(1.735)	(2.134)	(7.764)	(1.127)	(1.243)	(1.269)
moneyv		0.116	0.104	0.103	-0.104	0.861**	0.009	-3.129***	-0.012	0.057
		(0.291)	(0.285)	(0.268)	(0.302)	(0.432)	(0.198)	(1.002)	(0.177)	(0.187)
gvtcv		-0.406	-0.526*	0.078	0.128	-0.980*	0.131	0.075	-0.025	1.171
		(0.292)	(0.270)	(0.252)	(0.234)	(0.532)	(0.187)	(0.151)	(0.175)	(0.871)
exrated		0.018	-0.004	0.210*	0.214*	-0.166	0.286***	0.198***	0.263***	0.243***
		(0.024)	(0.020)	(0.120)	(0.110)	(0.198)	(0.095)	(0.072)	(0.082)	(0.088)
iitd			-0.051**			-0.042**				
			(0.020)			(0.020)				
itd			-0.030**		-0.013					
			(0.014)		(0.010)					
openexd				-0.356	-0.401*	0.331	-0.502***	-0.365**	-0.454***	-0.413**
				(0.230)	(0.216)	(0.370)	(0.182)	(0.140)	(0.158)	(0.170)
torgdpv							20.709			
							(13.158)			
tomoneyv								5.501***		
								(1.707)		
togoldpv									3.638***	
									(1.130)	
togvtcv										-2.112
										(1.632)
constant	-0.084**	0.020	-0.047	-0.110	-0.170*	0.124	-0.059	-0.019	0.011	-0.133*
	(0.039)	(0.062)	(0.049)	(0.093)	(0.087)	(0.135)	(0.072)	(0.062)	(0.071)	(0.074)

Notes:***,**,* indicate significance at 1%, 5%, and 10% level respectively. The variables are defined in section 3. Values in () represent the standard error.

Table 5: Error Correction representation of the ARDL models

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
dreerv1	0.365***	0.252***	0.266***	0.268***	0.302***	0.186**	0.304***	0.317***	0.318***	0.319***
dreerv2	0.132	0.118	0.134*	0.127	0.150*	0.119	0.174**	0.206***	0.191***	0.201***
dreerv3	0.201**	0.228***	0.245***	0.254***	0.269***	0.248***	0.281***	0.300***	0.265***	0.274***
dreerv4	-0.318***	-0.220***	-0.227***	-0.207**	-0.204**	-0.145*				
dtopen	0.060***	0.155**	0.072**	0.228***	0.150**	0.102	0.231***	0.073	0.043	0.313***
dtopen1		0.100		0.107		0.184**	0.135*			0.138*
dtopen2		0.134*		0.132*		0.214***	0.152*			0.162**
dgoldpv		0.527***	0.476***	0.541***	0.501***	0.559***	0.550***	0.488***	-0.621*	0.583***
drgdpv		-0.062	0.346	0.185	0.920	-0.835	-4.816	1.240	0.351	0.054
drgdpv1			1.263		1.161		1.327	1.825**	1.759**	
dmoneyv		0.035	0.037	0.034	-0.040	-0.022	0.004	-1.717***	-0.006	0.027
dmoneyv3						-0.260**				
dmoneyv4						-0.391***				
dgvtcv		-0.029	-0.083	0.026	0.047	-0.175	0.061	0.041	0.204	0.562
dgvtcv1		0.312*	0.349**			0.444**				
dgvtcv3			0.316*			0.421**				
dexrated		0.005	-0.001	0.070	0.078*	-0.053	0.133***	0.109***	0.133***	0.117***
diitd			-0.018***			-0.013***				
ditd			-0.011**		-0.005					
dopenexd				-0.119	-0.147*	0.105	-0.233***	-0.200***	-0.230***	-0.198**
dtorgdpv							9.621			
dtomoneyv								3.020***		
dtogoldpv									1.844***	
dtogvtcv										-1.014
constant	0.084	-0.020	0.047	0.110	0.170	-0.124	0.059	0.019	-0.012	0.133
ECM(-1)	-0.253***	-0.299***	-0.358***	-0.335***	-0.365***	-0.317***	-0.465***	-0.549***	-0.507***	-0.480***
Serial corr	5.952[.203]	6.606[.158]	3.295[.510]	4.641[.326]	3.803[.433]	4.978[.290]	7.607[.107]	3.764[.439]	6.646[.156]	7.883[.096
Adj R^2	0.392	0.620	0.642	0.613	0.611	0.653	0.601	0.618	0.622	0.593

Notes:***,**,* indicate significance at 1%, 5%, and 10% level respectively. The term d denotes taking first difference, i.e. dreerv1=reerv(-1)-reerv(-2) or dtopen=topen-topen(-1). corr stands for correlation.

Table 6: Long-run estimates of the ARDL models (2)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
topen	0.204***	0.011	0.306***	0.176***	0.263***	0.531*	0.464**	0.103	0.191*
	(0.071)	(0.052)	(0.060)	(0.066)	(0.071)	(0.292)	(0.202)	(0.075)	(0.097)
goldpv	0.237*	0.507***	0.451***	0.395***	0.368***	0.374***	0.506***	-2.223***	0.402***
	(0.131)	(0.089)	(0.093)	(0.082)	(0.105)	(0.140)	(0.122)	(0.771)	(0.094)
rgdpv	-5.281***	-5.732***	-2.801***	-5.936***	-4.754***	12.116	-3.751**	-5.120***	-5.495***
	(1.530)	(1.070)	(0.964)	(1.277)	(1.408)	(18.442)	(1.555)	(0.954)	(1.514)
moneyv	0.517*	0.729***	0.645***	0.767***	0.590***	0.637*	2.569	0.309*	0.482**
	(0.286)	(0.161)	(0.172)	(0.165)	(0.203)	(0.358)	(2.306)	(0.177)	(0.210)
gvtcv	-0.356*	-0.720***	-0.126	-0.396***	-0.270*	-0.141	-0.062	-0.291***	-2.142**
	(0.209)	(0.151)	(0.116)	(0.143)	(0.158)	(0.207)	(0.148)	(0.110)	(0.914)
exrated	-0.026*	-0.018***	0.147***	0.033	0.066	0.091	0.168***	0.233***	0.035
	(0.014)	(0.007)	(0.042)	(0.046)	(0.052)	(0.068)	(0.053)	(0.050)	(0.061)
iitd		0.002			-0.006				
		(0.004)			(0.005)				
itd		0.018***		0.012***					
		(0.005)		(0.004)					
openexd			-0.289***	-0.101	-0.160*	-0.221*	-0.333***	-0.439***	-0.117
			(0.078)	(0.081)	(0.094)	(0.125)	(0.101)	(0.090)	(0.108)
torgdpv						-27.621			
						(32.702)			
tomoneyv							-3.350		
							(4.006)		
togoldpv								4.170***	
								(1.234)	
togvtcv									3.463**
									(1.663)
constant	-0.039	0.040	-0.131***	-0.043	-0.084*	-0.241	-0.219*	0.032	-0.034
	(0.038)	(0.027)	(0.035)	(0.040)	(0.044)	(0.151)	(0.112)	(0.052)	(0.601)

Notes:***,**,* indicate significance at 1%, 5%, and 10% level respectively. The variables are defined in section 3. Values in () represent the standard error.

Table 7: Error Correction representation of the ARDL models (2)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
dreerv1	0.309***	0.353***	0.402***	0.393***	0.362***	0.332***	0.377***	0.348***	0.296***
dreerv3	0.194*	0.240**	0.259***	0.241**	0.228**	0.243**	0.252***	0.263**	
dtopen	0.077***	0.064***	0.140***	0.100***	0.110***	0.141***	0.184***	0.041	0.057*
dtopen1		0.042*	0.035*				0.038*		
dgoldpv	0.309***	0.377***	0.313***	0.325***	0.292***	0.341***	0.334***	-0.695**	0.340***
dgoldpv1	-0.052	-0.079	-0.155**	-0.091	-0.102	-0.122	-0.137*	-0.069	-0.070
dgoldpv2	0.176**	0.194**		0.162**	0.148*	0.196**		0.185**	0.083
dgoldpv3	0.191**	0.219***		0.209***	0.173**	0.176**		0.193**	0.155***
drgdpv	-0.133	-1.349	-0.925**	-1.103	-0.335	3.637	-1.135**	-0.288	-0.620
drgdpv1	2.618***	2.022***		2.513***	2.646***	1.923**		2.559***	1.504*
drgdpv2	1.816**	1.700*		1.939**	2.166**	1.657*		2.255**	1.447*
dmoneyv	0.003	0.086	0.213***	0.046	0.051	0.077	0.777	0.112	0.143*
dmoneyv2	-0.391**	-0.436**		-0.422**	-0.395**	-0.444**		-0.337**	
dmoneyv3	-0.526***	-0.488***		-0.516***	-0.507***	-0.448***		-0.416**	
dgvtcv	-0.074*	-0.220	-0.042	-0.141***	-0.079*	-0.029	-0.019	-0.117***	-0.635**
dgvtcv1		0.336*							
dgvtcv3		0.297**							
dexrated	-0.005**	-0.007***	0.049***	0.012	0.019	0.019	0.051***	0.093***	0.010
diitd		0.745			-0.002				
ditd		0.007***		0.004***					
dopenexd			-0.095***	-0.036	-0.047	-0.046	-0.101***	-0.176***	-0.035
dtorgdpv						-5.786			
dtomoneyv							-1.014		
dtogoldpv								1.670***	
dtogvtcv									1.026**
constant	-0.039	0.040	-0.131	-0.043	-0.084	-0.241	-0.219	0.032	-0.034
ECM(-1)	-0.209***	-0.370***	-0.330***	-0.355***	-0.292***	-0.209**	-0.303***	-0.400***	-0.296***
Serial corr	4.384[.357]	3.142[.534]	2.324[.676]	3.667[.453]	2.286[.683]	6.529[.163]	0.927[.921]	4.226[.376]	5.263[.261]
Adj R^2	0.585	0.636	0.571	0.624	0.594	0.624	0.571	0.633	0.584

Notes are similar to table 5.