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Modelling the Dynamics, Structural Breaks and the Determinants of the Real Exchange Rate of Australia

Abstract

This paper examines the dynamics, structural breaks and determinants of the real exchange rate (RER) of Australia derived from an inter-temporal general equilibrium model. Autoregressive Distributed Lag (ARDL) modelling results show that a one per cent increase in: (1) terms of trade appreciates the RER by 0.96 to 1.05 per cent in the long-run; (2) government expenditure appreciates the RER by 0.53 to 0.46 per cent in the long-run; (3) net foreign liabilities appreciates the RER by 0.18 to 0.22 per cent in the long-run; (4) interest rate differential depreciates the RER by 0.007 to 0.01 per cent in the long-run; (5) openness in trade depreciates the RER by 1.15 to 1.31 per cent in the long-run; and (6) per-worker labour productivity depreciates the RER by 0.38 to 0.55 per cent in the long-run. The two endogenously determined structural breaks are positive but are statistically insignificant. The speed of adjustment towards equilibrium is high with short-run disequilibrium correcting by nearly 39 to 47 per cent per quarter. These results add new insights to the literature on the determinants of RER in Australia. Apart from the terms of trade, the effects of other determinants of RER are contrary to the results obtained in previous studies.

JEL Classification: F13, F31, F41.

Key words: Determinants of RER; Endogenous Structural Breaks; Unit-root; ARDL.

Modelling the Dynamics, Structural Breaks and the Determinants of the Real Exchange Rate of Australia

1. Introduction

The recent appreciation in the Australian nominal exchange rate (NER) and in the real exchange rate (RER) has prompted questions about the sustainable value of the exchange rate and its long-run impacts. After falling briefly below US50c in the early 2000s, the NER quickly began to appreciate, later triggering speculation that it may reach parity with the US dollar. By July 2008, when Australia was experiencing the global financial crisis (GFC), the dollar had surged to US98c. However, Australia was soon caught up in the midst of a collapsing world economy, and the NER fell to US64c in March 2009. Unpredictably, the Australian dollar made a rapid recovery; within seven months it had risen again to US90c and ultimately touching US110c in July 2011. Australia's RER, measured by trade weighted index (TWI), has followed similar patterns. While there was a sudden and precipitous drop at the time of the GFC, both (NER and RER) have now exceeded their pre-GFC levels.

During the crisis, the Australian stock market lost 59 per cent and unemployment peaked at 5.7 per cent, but relatively speaking Australia had a free pass. Australia was the only developed country to avoid a technical recession. The stock market has bounced back since mid-July 2010 and house prices are higher now than in 2007. The Reserve Bank of Australia (RBA) has incrementally increased its cash rate by 1.75 per cent since October 2010 to its current level of 4.75 per cent. This is a clear indication that the danger in Australia is over[1]. In contrast, a key global structural imbalance has emerged by China pegging its currency with the US dollar at an undervalued rate. The peg poses a "double threat" during the GFC. The "threats" are

[1] Broadly speaking, the recovery from the GFC can be attributed to four main factors: (1) A mining boom generated by China; (2) A fiscal stimulus combined with an accommodating monetary policy; (3) Resilience of Australian banks during the crisis because of their limited exposure to toxic debt compared to other nation's financial institutions; (4) A steady increase in population, fuelled mainly by migration, prevented the housing market from collapsing.

described by Ferguson and Schularick (2009: 4) in the following words: "First, it limits U.S. recovery by overvaluing the dollar in key Asian markets. Secondly, as the dollar weakens against other developed world currencies—notably the euro and the yen — the burden of adjustment falls disproportionately on Europe and Japan, since dollar depreciation translates automatically into renminbi depreciation, through the action of the peg. This is a recipe for protectionist responses and new distortions."

Against this backdrop, we emphasise that RER plays a pivotal role in macroeconomic adjustment because RER is a *price* that ensures internal and external equilibrium. RER also measures the degree of external competitiveness of a country and its misalignment can have adverse welfare and efficiency costs[2] on small, open economies like Australia. Therefore, it is imperative to understand how RER reacts to changes in its economic fundamentals. A desirable level of RER can be achieved through influencing the RER determinants.

Research on the determinants of RER in Australia was pioneered by RBA researchers (Blundell-Wignall et al., 1993; Gruen and Wilkinson, 1994; Gruen and Kortian, 1996; Tarditi, 1996 and Beechey et al., 2000). In evaluating the RBA studies, Aruman and Dungey (2003: 67) observe that: "The RBA research represented in these studies can be interpreted as an attempt to fit the stylised empirical facts of a strong relationship between the Australian dollar exchange rate and the terms of trade into a cohesive theoretical framework." Subsequently, a handful of academics (Chand, 2001; Aruman and Dungey[3], 2003; Bagchi et al., 2004) estimated RBA-type single-equation structural models. The 'structural models' have numerous weaknesses including forecasting failures in periods of major macroeconomic disruptions.

[2] Chile, Uganda and Mauritius in the 1980s and India and China in the 1990s have all benefited from competitive RER. In contrast, most Latin American and African economies have suffered due to exchange rate overvaluation.(Mexico, Brazil and Argentina in the 1990s are good examples). Gala (2008) provides additional theoretical analysis and empirical evidence of channels through which RER can influence economic development.

[3] This paper provides empirical analysis of each of the RBA models, over both the original periods of estimation and an updated dataset.

The forecasting failures coupled with the inability to accommodate the role of forward-looking behaviour of agents raise concerns about the validity of these models. Aruman and Dungey (2003: 57) rightly point out: “The results illustrate the evolution of research in exchange rate determination in the Bank, notably through several theoretical approaches. The extensions show why those particular models have (or should have) been abandoned in the ensuing years.” Research on this topic seems to have ceased and no studies have been published since 2004.

The significance of this paper lies in the urgent need to analyse the determinants of RER of Australia because of the shortage of in-depth studies. Previous attempts at modelling equilibrium RER have not proved particularly useful which will be evident from the discussion in section 2. Therefore, the objective of this paper is twofold: (1) to develop a dynamic model of RER; and (2) to estimate the determinants of RER for the Australian economy. The behaviour of RER and its responses to nominal and real shocks as a part of the macroeconomic adjustment process has great relevance for policy making in Australia. In December 1983, the exchange rate policy shifted from a managed float to flexible exchange rate. Besides changes in the exchange rate regime, trade and financial liberalisation, and easing of restrictions on capital flows during the past three decades have reduced many distortions. These structural changes may facilitate the RER to converge rapidly towards the long-run equilibrium.

This paper adds new insights to the literature on the determinants of RER in Australia and differs from the previous studies in several ways: First, we estimate an inter-temporal general equilibrium model where long-run movements in the RER reflect developments in financial, goods and factor markets. Previous studies estimated structural equation models where the Australian terms of trade and the real interest differential played a role in determining the RER. This study is a comprehensive analysis of the *fundamentals* in relation to RER determination. Second, we utilise the post-float data from 1984:1 till 2011:1, while previous studies have used small samples that were a hybrid of different exchange rate regimes. Third, we conduct unit-root tests in the presence of two endogenous structural breaks which was not attempted before. Further, the breaks are embedded in the model to capture the potential non-linearity in the model. Fourth, we model RER in Australia by applying the Autoregressive Distributed Lag (ARDL) methodology which is flexible and robust. This is also unique to this study.

The plan of this paper is as follows. We motivate the issue with a critical literature review in section 2. The analytical framework of the paper is outlined in section 3. Section 4 presents the data and its sources. This section also tests the time series properties of the variables utilising a battery of unit-root tests. In section 5 we apply the ARDL methodology of Pesaran and Shin (1999) to examine the determinants and dynamics of RER. Section 6 contains the summary of the findings.

2. Literature Review

The modelling of Australia's RER was pioneered by Blundell-Wignall et al. (1993). The modelling was based on a balance of payments approach which postulates that the equilibrium exchange rate is a function of the state of excess demand for domestic goods and net foreign liabilities, and there will be some adjustment path towards that exchange rate. They found a long-run relationship between Australia's RER and its terms of trade, long-term real interest differential and net foreign liabilities. The authors report two sets of results: the first result is based on a long sample period (1973:2 to 1992:3); while the second result is based on the post-float data (1984:1 to 1992:3). The results show *instability* because one of the parameters *switches* sign (for example, the coefficient of interest rate differential) in the two samples. Moreover, the long sample consisted of two overlapping exchange rate regimes where the dynamics of exchange rate adjustments are likely to be different. These differential effects are not captured in their long sample.

Gruen and Wilkinson (1994) adopted a prototype of the small, commodity-exporting open economy model of Blundell-Wignall and Gregory (1990) and found *weak* evidence of a stable long-run relationship of the Australian RER and its terms of trade. They found some evidence that the terms of trade and long-term real interest rate differential explain the RER since the float of the currency and the deregulation of financial markets. The results were obtained, with quarterly data from 1969 to 1990, by using three different cointegration techniques: (1) the Engle-Granger procedure (EG), (2) the Fully Modified OLS (FMOLS) procedure and (3) the Johansen procedure (1988, 1991, 1995) (JP). However, this study "lacks a coherent theoretical background, pulling rather on components of existing work to justify what are essentially observed empirical relationships (Aruman and Dungey, 2001: 58).

Tarditi (1996) pointed out omitted-variable bias in Blundell-Wignall et al.'s (1993) results. Tarditi, therefore, augmented their model with additional variables like the cumulated current account deficit, relative slopes of domestic and foreign yield curves and a fiscal variable. Tarditi estimated the model over two sample periods: (1) 1973:4 to 1995:2 and (2) 1985:1 to 1995:2 (post-float). The effects of the cumulated current account deficit and the yield gap were insignificant in both samples. Results indicate that only in the post-float era did the exchange rate play a role in channelling changes in real interest rates through to the broader economy.

It is noteworthy that the RBA models' estimation results are *not* consistent with those in the original publications for a longer post-float data set (Aruman and Dungey, 2001: 58). The key to resolving this inconsistency lies in understanding the forces that determine the equilibrium RER. Two additional studies followed the RBA research. Chand (2001) used quarterly data from 1981:3 to 2000:4 to quantify the extent of misalignment of the Australian RER by its terms of trade, resource balance and openness of the economy. The econometric results remain suspect. Results reported in Table 1 (page 19) show that all the variables are, in fact, *nonstationary*. Therefore, the OLS and Instrumental Variable results are unreliable.

Finally, in a cross country study of 12 small, open, developed economies, Bagchi et al. (2004) found that the terms of trade and long-term real interest rate differentials significantly affect the RER of Australia between 1973:1 and 1995:3. The core weakness here is the *robustness* of the results. Bagchi et al. (2004: 84) clearly admit: "The countries in our sample have not operated under a pure float throughout the sample periods. The relationship between the real exchange rate and its determinants may display different properties under different exchange rate regimes."

The discussion above clearly exposes the weaknesses in the existing literature. There are four common elements in the cited works: (1) estimation of single-equation, behavioural models of exchange rate determination; (2) inclusion of hybrid exchange rate regimes in samples; (3) application of the Johansen cointegration procedure utilising small samples with the exception of Tarditi (1996) and Chand (2001); and (4) exclusion of structural breaks. This study contributes to the literature by overcoming its weaknesses via robust econometric modelling.

3. Analytical Framework

3.1 Theory, Variables and RER fundamentals

The theoretical framework for this study is adapted from Edwards' (1988, 1989) model of RER determination. It is an intertemporal general equilibrium model of a small, open economy consisting of optimising consumers and producers, and a government. This model captures the stylised features of a small, open economy like Australia, which produces and consumes two goods: tradables (T) and nontradables (NT). The government sector consumes both tradables and nontradables, and finances its expenditures by non-distortionary taxes and domestic credit creation. The country holds both domestic money (M) and foreign money (FM). The model also assumes that there is a tariff on imports. Finally, there is no uncertainty, and agents have perfect foresight. The model consists of five sectors: (1) portfolio composition, (2) demand side, (3) supply side, (4) government sector and (5) external sector, within which the equilibrium exchange rate is determined.

The essence of Edwards' (1989) model is summarised by Edwards (1988: 6–7) as follows: "Although there are many such variables, in analytical discussions we can distinguish between two broad categories of fundamentals: external fundamentals and domestic fundamentals. The external RER fundamentals include (a) international prices (that is, international terms of trade), (b) international transfers, including flows of foreign aid, and (c) world real interest rates. The domestic RER fundamentals can be divided into those variables that are directly affected by policy decisions and those that are independent of them. Among the more important policy-related RER fundamentals are (a) import tariffs, import quotas, and export taxes, (b) exchange and capital controls, (c) other taxes and subsidies, and (d) the composition of government expenditure. Among the domestic nonpolicy fundamentals, technological progress is the most important." By incorporating Edwards' "external and domestic fundamentals", the long-run model of RER in natural logarithmic form is given in equation (1).

$$LnRER_t = \alpha + \beta LnTOT_t + \gamma LnGEX_t + \delta LnNFL_t + \varphi IRD_t + \theta LnOPEN_t + \phi LnTEP_t + v_t \qquad (1)$$

where, RER = real exchange rate index. An appreciation is recorded as an increase in the RER; TOT = terms of trade; GEX = government expenditure; NFL = net foreign liabilities; IRD = interest rate differential between Australia and the world; OPEN = openness as a proxy for trade restrictions; and TEP = technological and productivity improvement.

The most important external fundamentals to affect RER in the long-run include the international terms of trade, international transfers and world real interest rates. Domestic RER fundamentals can be classified into policy-related and non-policy related fundamentals. The policy-related domestic fundamentals include government consumption expenditure and import restrictions, export taxes or subsidies and exchange and capital controls. Among the domestic non-policy fundamentals of RER, technical progress and productivity gains are important. We shall discuss the role of these fundamentals below.

Terms of trade (TOT) effect: The literature on the effects of TOT shocks on exchange rates is vast to review here, but a particularly useful and general analysis is discussed by Neary (1988). TOT is postulated as a determinant of RER, because foreign price shocks account for large fluctuations in RER in both developed and developing countries. However, economic theory cannot unambiguously specify the effect of a TOT movement on RER. Edwards (1989) demonstrates that changes in TOT generate substitution and income effects, and the final outcome depends on the relative strength of these two effects. The income effect results from an increase in export prices or a fall in import prices, which tends to raise the income of an economy and increases the demand for and price of nontradables. This tends to increase the relative price of nontradables to tradables and appreciates the RER.

The substitution effect, on the other hand, is due to the relative cheapness of nontradables. If the increase in TOT is due to an export price increase, improvement in TOT tends to depreciate the RER, assuming that the nominal exchange rate and the price of nontradables remain constant. However, if the improvement in TOT is brought about by a fall in the price of imports alone, then the increase in income due to an improvement in the current account balance would increase the aggregate price of nontradables and cause an appreciation of RER. Hence, the income effect would be more prominent in this case. Thus, the final effect of a TOT shock on RER is ambiguous.

Government expenditure (GEX): GEX is another fundamental variable that affects RER. Increases in GEX will increase the demand for nontradables if the bulk of GEX is spent on nontradable goods and services. This increase in demand bids up the price of nontradables and causes a RER appreciation — the traditional Mundell-Fleming effect of fiscal expansion. However, RER depreciation will occur if the larger share of GEX is spent on the tradable sector, rather than on the consumption of nontradables. Second, fiscal action influences the exchange rate through a risk premium (Tarditi, 1996: 16). Fiscal expansion may be penalised by investors who perceive an increased probability of default or expect higher inflation in the future, because they believe that the incentive exists for the government to "inflate" away its debt. In order to hold domestic assets, they demand a risk premium on domestic interest rates. Higher government budget deficits are often associated with negative sentiments about the exchange rate, because they imply lower national savings in the longer-run. The negative sentiment depreciates the exchange rate. Therefore, the impact of GEX on RER is also ambiguous.

Net foreign liabilities (NFL): Persistent large current account deficits leading to NFL have an impact on RER. An increase in NFL warrants larger trade balance surpluses to restore external balance, achievable via a depreciation of RER to attract resources into the tradables sector. Alternatively, trade restrictions can be used to combat the situation. If trade restrictions improves the current account position and increases the price of nontradables, RER appreciates. In this instance, the increase in the price of nontradables due to trade restrictions is higher than the increase in the composite price of tradables. Thus, easing trade barriers can often lead to a current account deficit and burgeoning NFL over time.

Interest rate differentials (IRD): The impact of monetary policy on RER is substantial. First, the gap between short and long nominal interest rates may be thought of as a proxy for the stance of monetary policy. Second, it is also a measure of real interest rate differential. Under both interpretations, IRD captures short-run exchange rate dynamics. A fall in world real interest rates or a rise in international transfers also affects the equilibrium RER in the same way as net capital inflow. A major share of international transfers is generally spent on nontradables, which pushes up the price of nontradables and tends to appreciate the RER. Relaxation of capital controls increase capital inflow, leading to an expansion in the monetary base, which, in turn, raises current expenditure and increases the demand for and the price of nontradables. This results in an appreciation of the equilibrium RER. However, within a flexible-price monetarist model, a rise in domestic interest rate leads to a fall in domestic demand for money, which then reduces the demand for and price of nontradables leading to a depreciation of the RER. Thus, a policy-induced IRD can also yield ambiguous results.

Trade openness (OPEN): Trade restrictions, in the form of tariffs, quotas, etc., lead to an appreciation of RER. Openness in the trade regime tends to depreciate RER by reducing the price of nontradables to tradables. In the case of tariffs, Edwards (1989) shows that the effects are ambiguous. If tariffs improve the current account position and increase the price of nontradables, RER appreciates. However, if tariffs lead to a worsening of the current account deficit and reduce the demand for and the price of nontradables, then there will be RER depreciation. So the overall effect of openness is ambiguous.

Technological and productivity improvement (TEP): This non-policy domestic fundamental impacts the efficiency and productivity of the tradable sector and is likely to produce ambiguous effects. Technology-induced higher productivity augments factor availability. By reducing the cost and price of tradables, increased productivity tends to depreciate RER. Here, the supply effects of technological progress offset the demand effects according to the Rybczynski principle (Edwards, 1989: 48). However, if the technological improvement increases the income of a country, which increases the demand for and price of nontradables, a real appreciation will occur. Thus, the demand effects of technological progress dominate the supply effects, and it is referred to as the Ricardo-Pigou-Balassa-Samuelson effect (Edwards, 1989: 47).

Next we turn to the empirical testing of this model.

4. Time-series Properties in the Presence of Structural Breaks

4.1 Data Sources

The sample period considered here is the post-float period of the Australian dollar from 1984:1 to 2011:1. The sources of data for the variables are:

RER: Trade-weighted RER index (RER) was extracted from RBA Table F.15 Real Exchange Rates Measures;

TOT: Terms of trade (TOT) was extracted from RBA Table G.04: Other Price Indicators;

GEX: Government expenditure (GEX) was taken from Australian Bureau of Statistics (ABS) Table 5206:38: General Government Income Account: Seasonally Adjusted;

NFL: Net Foreign Liabilities (NFL) was taken from RBA Table H.05: Australia’s Net Foreign Liabilities;

TEP: Technological and productivity improvement (TEP), proxied by real GDP per hour worked, was taken from ABS Table 5206.02: Key National Accounts Aggregate: Seasonally adjusted;

IRD: Interest rate differential (IRD) between Australia and the world proxied by the US rate, was taken from OECD Main Economic Indicators; and

OPEN: Openness (OPEN) is measured by [(Exports + Imports)/GDP]. The exports and imports figures are taken from RBA's Balance of Payments Table H.01.

4.2 Unit-root tests in the presence of structural breaks

We applied the ADF unit-root test as a *benchmark.* ADF test has very low power against I(0) alternatives that are close to being I(1). For maximum power against very persistent alternatives we have also used the efficient unit-root tests suggested by Elliot et al. (1996) and Ng and Perron (2001) complemented by the Kwiatkowski et al. (1992) (KPSS) unit-root test[4]. A summary of the unit-root test results is given in Table 1.

[Insert Table 1 here]

ADF test show an uniform failure to reject the null hypothesis for all variables except *IRDL* and *LnTEP* (refer to Table 1). Turning attention to the generalised least squares (GLS) detrended class of unit-root tests the evidence is unequivocal. The GLS test proposed by Elliot et al. (1996) and M− test suggested by Ng and Perron (2001) reject the null of a unit-root for all the variables. However, based on the KPSS test we reject the null hypothesis of stationarity for all the variables except IRDL and LnOPEN. On balance, the evidence in Table 1 is inconclusive.

Here we highlight the time-series property of the Australian RER – a key variable in this study. Evidence regarding the time-series properties of RER is mixed. In earlier studies, the Australian RER was characterised as a unit-root process (Blundell-Wignall and Gregory, 1990; Blundell-Wignall et al., 1993; Gruen and Wilkinson, 1994; Bagchi et al., 2004). However, Gruen and Kortian (1996: 10) found "ambiguous results" in the post-float period. Tests on a longer sample of Australia's trade-weighted RER suggest it is stationary, possibly around a trend (Gruen and Shuetrim 1994: 353). This result is also confirmed by Tarditi (1996). However, these studies ignored the presence of structural breaks while testing for unit-root. Perron

[4] This was suggested by an anonymous reviewer for checking the robustness of the results.

(1989) and Zivot and Andrews (1992) henceforth ZA, inter alia, argue that unit-root tests are biased towards the null in the presence of structural breaks.

Subsequently, Henry and Olekalns (2002) used unit-root tests by ZA and Perron (1997) and failed to find evidence of mean reversion in RER of Australia between 1973:1 and 1999:1. In contrast, Chowdhury (2007) employed a bevy of unit-root tests and found that the Australian trade-weighted RER index, the export-weighted index and the import-weighted index are *stationary*; while the G7-GDP weighted index is *nonstationary*. Both Chowdhury (2007) and Henry and Olekalns (2002) report the single structural break date without reporting its statistical significance. This issue is important and will be addressed here.

The unit-root tests in the above studies, which either do not allow for a break under the null such as ZA or model the break as an Innovational Outlier (IO) as Perron (1997)[5], suffer from severe spurious rejections in finite samples when a break is present under the null hypothesis (Lee and Starzicich, 2001, 2003). Because the spurious rejections are not present in the case of a known break point, Lee and Starzicich (2001) identify the inaccurate estimation of the break date as a source of the spurious rejections. Lee and Starzicich (2001) also found that the asymptotic null distributions of the DF-type endogenous break test statistics are affected by nuisance parameters. Therefore, in this paper the null hypothesis is examined by using a minimum Lagrange Multiplier unit-root test that allows for breaks in level and trend.

Lee and Strazicich (2003) Unit-Root Test, henceforth LS,

Consider the DGP as follows:

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + u_t$$

[5] ZA and Perron (1997) unit-root tests are derived from Perron (1989) test where the ADF regression is augmented with dummy variables accounting for the break.

where, $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t\tilde{\delta}$ (t = 2,…T) and Z_t is a vector of exogenous variables defined by the data generating process; $\tilde{\delta}$ is the vector of coefficients in the regression of Δy_t on ΔZ_t respectively with Δ the difference operator; and $\hat{\psi}_x = y_1 - Z_1\tilde{\delta}$, with y_1 and Z_1 the first observations of y_t and Z_t respectively.

The unit-root null hypothesis is described by ϕ = 0 and the LM *t*-test is given by $\tilde{\tau}$, where $\tilde{\tau}$ = *t*-statistic for the null hypothesis ϕ = 0. The augmented terms $\Delta\tilde{S}_{t-j}$, j = 1,...*k*, terms were included to correct for serial correlation. The value of *k* is determined by the general-to-specific search procedure. To endogenously determine the location of the break (T_B), the LM unit-root searches for all possible break points for the minimum (the most negative) unit-root *t* -test statistic, as follows:

$Inf\ \tilde{\tau}(\tilde{\lambda}) = Inf_{\lambda}\tilde{\tau}(\lambda)$; where $\lambda = T_B / T$.

The two-break LM unit-root test statistic can be estimated analogously according to the LM (score) principle. The critical values of the endogenous two-break LM unit-root test is reported in Table 3 of LS.

LS conclude on page 1087:

> “In summary, the two-break minimum LM unit-root test provides a remedy for a limitation of the two-break minimum LP test that includes the possibility of a unit-root with break(s) in the alternative hypothesis. Using the two-break minimum LM unit-root test, rejection of the null hypothesis unambiguously implies trend stationarity”.

LS Model C captures the change that is *gradual* whereas LS Model A picks up the change that is *rapid*. We have reported the results of Model C in Table 1. Model A’s results can be obtained upon request. On the basis of the LS1 unit-root test, we found that all variables are also nonstationary except LnGEX. Given a loss of power from ignoring one structural break, it is logical to expect a similar loss of power from ignoring two breaks in the one-break test. Therefore, we applied the LS2 unit-root test and we found that the majority of the variables are stationary with the exception of LnRER, LnTOT and LnNFL.

4.3. Endogenously determined structural break dates

The corresponding break dates for the variables are: LnRER (1988:2 and 2002:4); LnTOT (2000:3 and 2006:3); LnGEX (1988:1 and 2005:3); LnNFL (1989:2 and 2001:3); LnTEP (1990:1 and 2001:2); LnIRDS, (1989:1 and 1995:2); LnIRDL (1987:4 and 1997:3) and LnOPEN (1987:3 and 2002:4) respectively. The structural break dates are *statistically significant* for all variables except one of the break dates is not statistically significant for LnTOT.

The first break date of LnRER coincided with the abandonment of the "*check-list*" approach in favour of a "*discretionary*" approach to monetary policy[6] by the RBA in 1988:2. The second break date is determined around 2002:4. Between January 2002 and July 2008 the Australian dollar appreciated sharply from US51c to US97c which was largely driven by increased demand for Australian exports. The behaviour of the RER shows periods of instability, for example, one such period was centred on June 1986; and the other occurred between March 1998 and June 1999. After a sustained period of depreciation, appreciations of the RER occurred during 1986–1989, so that the first break date for the RER was picked up in 1988:2, followed by the meltdown in 2001 and a recovery in early 2002. The endogenously determined break dates for other variables are plausible, given the events that occurred in the Australian economy and elsewhere during the sample period. Discussion on these break dates is omitted to conserve space.

[6] Macfarlane (1999) provides an excellent commentary on the stance of monetary policy in Australia.

5. Empirical Findings

5.1. Econometric methodology

We shall use the ARDL modelling for cointegration analysis developed by Pesaran and Shin (1999) and extended by Pesaran et al. (2001). ARDL modelling is flexible and it can be applied "irrespective of whether the regressors are purely I(0), purely I(1) or mutually cointegrated" (Pesaran et al., 2001: 289–290). ARDL also takes sufficient numbers of lags to capture the DGP in a general-to-specific modelling framework (Laurenceson and Chai, 2003: 28). Moreover, a dynamic error-correction model can be derived from the ARDL through a simple linear transformation (Banerjee et al., 1993: 51). ARDL typically outperforms alternative approaches to cointegration (such as FMOLS) when the sample size is small. This is particularly true of the size-power performance of the tests on the long-run parameter. Finally, ARDL modelling is robust against autocorrelation and simultaneous equation bias, provided the orders of the ARDL model are adequately selected on the basis of any model selection criterion.

Recalling equation (1) from section 3.1

$$LnRER_t = \alpha + \beta LnTOT_t + \gamma LnGEX_t + \delta LnNFL_t + \varphi IRD_t + \theta LnOPEN_t + \phi LnTEP_t + \nu_t \qquad (1)$$

The error correction specification of the ARDL model pertaining to equation (1) is given in equation (2) below:

$$\Delta LnRER_t = \alpha_0 + \delta_1 LnTOT_{t-1} + \delta_2 LnGEX_{t-1} + \delta_3 LnNFL_{t-1} + \delta_4 IRD_{t-1} + \delta_5 OPEN_{t-1} + \delta_6 LnTEP_{t-1} + \\ + \sum_{i=1}^{m} a_i \Delta LnTOT_{t-i} + \sum_{i=1}^{n} b_i \Delta LnGEX_{t-i} + \sum_{i=1}^{p} c_i \Delta LnNFL_{t-i} + \sum_{i=1}^{q} d_i \Delta IRD_{t-i} \sum_{i=1}^{r} e_i \Delta OPEN_{t-i} \sum_{i=1}^{s} f_i \Delta LnTEP_{t-i} + \varepsilon_t \qquad (2)$$

where, Δ denotes the first difference operator, ν_t and ε_t represent the residuals. Following Pesaran et al. (2001:307) two dummy variables, *D1* and *D2*, are included in equations (1) and (2) for the statistically significant structural breaks in 1988:2 and 2002:4 respectively for *LnRER*. This gives us the estimable equations (3) and (4).

$$LnRER_t = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \beta LnTOT_t + \gamma LnGEX_t + \delta LnNFL_t + \varphi IRD_t + \theta LnOPEN_t + \phi LnTEP_t + \nu_t \tag{3}$$

$$\begin{aligned}\Delta LnRER_t = {} & \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \delta_1 LnTOT_{t-1} + \delta_2 LnGEX_{t-1} + \delta_3 LnNFL_{t-1} + \delta_4 IRD_{t-1} + \delta_5 OPEN_{t-1} + \delta_6 LnTEP_{t-1} + \\ & + \sum_{i=1}^{m} a_i \Delta LnTOT_{t-i} + \sum_{i=1}^{n} b_i \Delta LnGEX_{t-i} + \sum_{i=1}^{p} c_i \Delta LnNFL_{t-i} + \sum_{i=1}^{q} d_i \Delta IRD_{t-i} \sum_{i=1}^{r} e_i \Delta OPEN_{t-i} \sum_{i=1}^{s} f_i \Delta LnTEP_{t-i} + \varepsilon_t\end{aligned} \tag{4}$$

where the dummy variable *D1* = 1, over the period 1988:2–2002:3, and 0 elsewhere; *D2* = 1, over the period 2002:4–2011:1. Pesaran et al. (2001: 307) emphatically write that "The asymptotic theory developed in the paper is *not affected* by the *inclusion* of such 'one-off' dummy variables."

The parameter δ_i, i =1, 2, 3, 4, 5 and 6 are the long-run multipliers. The parameters a_i, b_i, c_i, d_i, e_i and f_i are the short-run multipliers. ν_t and ε_t represent the residuals. The model above is ARDL *(m, n, p, q, r, s)*, where *m, n, p, q, r* and *s*, represent the lag length. In equation (4), the terms with the summation signs represent the error correction dynamics while the first part (terms with δ_i) corresponds to the long-run relationship.

The ARDL procedure involves two stages of tests. First, we test the null of no cointegration (H_0*: all* $\delta_i = 0$); against the alternative of an existence of cointegration. Secondly, we estimate the coefficients of the long-run relations along with the error correction term (ECM_{t-1}). The ARDL procedure estimates $(l+1)^k$ number of regressions to obtain the optimal lags for each variable, where l represents the maximum number of lags used and *k* is the number of variables in the model. Four lags are selected as the maximum lag (*l*) following Pesaran and Pesaran (2009). The model specification we used is the unrestricted intercept with no trend (Case III in Pesaran et al., 2001: 296).

We estimated equation (4) and the optimal ARDL model, based on the Akaike Information Criterion (AIC), is reported in Table 4. Judge et al. (1985: 869) clearly show how the most common model selection criteria are variations of one another and are asymptotically equivalent whilst Maddala (2001: 484–491) shows how they are all flawed to varying degrees.

5.2. Estimation of long-run coefficients

The long-run relationship of equation (4) was tested with the *bounds procedure* of Pesaran et al. (2001). The null hypothesis of the bounds procedure tests the joint significance of $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$ in equation (4) with an *F*-test. This *F*-test has a nonstandard distribution. Pesaran et al. (2001) computes two sets of asymptotic critical values which classify regressors into pure I(1), I(0) and mutually cointegrated categories. If the computed *F*-statistic is greater than the upper critical bound (UCB), the regressors are I(1); if the *F*-statistic is less than the lower critical bound (LCB), the regressors are I(0); and if the *F*-statistic falls within the interval of LCB and UCB, "inference is inconclusive and order of integration between the underlying variables are required for a conclusive inference" (Pesaran et al., 2001: 290).

[Insert Tables 2a and 2b here]

We experimented with short and long-term interest rates as alternative measures of real interest rate differentials. The computed *F*-statistic is 3.97 (Model 1) and 4.11 (Model 2) in Tables 2a and 2b exceed the upper critical bound (UCB*)* at the 5 per cent significance level. Hence, we have conclusive evidence of a long-run relationship between the RER and the relevant macroeconomic variables (TOT, GEX, NFL, OPEN, IRDS or IRDL and TEP). Since, the variables are cointegrated in the long-run, there exists an error correction mechanism which brings together the long-run relationship with its short-run dynamic adjustments. The long-run results are given in Table 3.

[Insert Table 3 here]

In the long-run, a one per cent increase in the terms of trade leads to 1.05 per cent increase (appreciation) in RER in Model 1 and 0.96 per cent increase in RER in Model 2. The estimated coefficients are positive and are highly significant. The terms of trade has a powerful impact on the equilibrium level of RER. These findings conform to the findings of earlier studies (Blundell-Wignall and Gregory, 1990; Blundell-Wignall et al., 1993; Gruen and Wilkinson, 1994; Tarditi, 1996; Bagchi et al., 2004). Our elasticity coefficients are higher compared to 0.8 and 0.9 per cent reported by Blundell-Wignall et al. (1993) and Tarditi (1996) respectively, but they are lower than 1.3 per cent reported by Bagchi et al. (2004).

Historically, Australia has faced declining and highly volatile TOT. However, since the trough in 1986, the TOT has been less volatile, with a slightly upward trend. Several factors are responsible for a more stable and relatively strong TOT: (1) Australia’s exports are now more diversified across both products and markets and (2) significant reduction in the prices of Australia’s imports, especially for information and communications technology (ICT) goods. This diversification notwithstanding, the prices of Australia’s exports (particularly minerals) have increased; and prices of imports have generally trended down over the past decade. However, the trend decline in import prices has been more pronounced, reflecting rapid price falls for ICT goods. Thus, the income effect and substitution effect due to terms of trade improvement reinforced each other, leading to RER appreciation for Australia (Treasury, 2002–03: 47–48).

Government expenditure (GEX) has an appreciating effect on the RER in both the models. The estimated coefficient of GEX is 0.53 and 0.46 per cent in Models 1 and 2 respectively and they are statistically significant. These findings are consistent with the traditional appreciating Mundell-Fleming effect of fiscal policy. Business cycle models predict that government spending raises the relative price of domestic goods reflecting an increase in relative demand of domestic goods. The results are consistent with the result obtained by Tarditi (1996: 22) for Australia. Ravn et al. (2007), however, find that government spending depreciates the RER in a panel of four industrialised countries (Australia, Canada, the UK and the US) from 1975 to 2005. This result has been explained by the "deep-habit mechanism". Likewise, Enders et al. (2010), Kim and Roubini (2008), inter alia, find depreciation of the US RER in response to expansionary government spending.

Net foreign liabilities (NFL) exert a positive influence on the Australian RER. NFL is defined as Australia's gross foreign liabilities less gross foreign assets. A one per cent increase in NFL appreciates the RER by nearly 0.18 to 0.22 per cent in the long-run. The answer to this counter-intuitive result is given by Tarditi (1996: 12, with emphasis added):

> Increasing net foreign liabilities, as a share of wealth, require larger balance of trade surpluses to restore equilibrium. Similar to the macro-model mechanism of maintaining external balance, this may require a depreciation of the real exchange rate to attract resources into the tradeables sector. (*Of course, if the real return on investment is high, the higher trade surpluses may be achieved without a real depreciation*.)"

The various managed exchange rate regimes prior to December 1983 were accompanied by capital controls and widespread regulations in the domestic financial system. When the Australian dollar was floated on 12 December 1983, foreign exchange controls were dismantled virtually overnight (Blundell-Wignall et al., 1993: 38). Since then, Australia's NFL as a share of GDP has been growing steadily. Changes in NFL as a share of GDP are influenced by differences in the rates of return on gross foreign assets and liabilities. Australia has benefited over time from higher rates of return on their gross foreign assets compared to returns on their gross foreign liabilities. This has been partly because Australia's gross foreign assets include a higher share of equities (with a higher average rate of return than debt) than their foreign liabilities (Garton, 2007: 101). Garton observes that: "Over the longer term,… Australia have benefited from rates of return on foreign assets exceeding those on foreign liabilities, with much of this coming from proportionately higher valuation gains on foreign assets" (Garton, 2007: 116).

Technological and productivity (TEP) improvement has a depreciating effect on RER of Australia. A one per cent increase in TEP depreciates RER by 0.38 to 0.55 per cent in the long-run in Models 1 and 2 respectively. The TEP coefficients are marginally significant at the 10 per cent level. A plausible explanation for this is because of uneven productivity growth in the tradable and nontradable sectors. If productivity in the nontradable sector grows relatively more rapidly than in the tradable sector, RER will tend to depreciate, other factors remaining unchanged. Over the 1990s there was relatively rapid productivity growth in Australia's nontradable sector, particularly in industries such as wholesale trade, finance and insurance, utilities and construction, as a result of increased domestic competition (Treasury, 2002–03: 52). In this situation, the supply effects of productivity improvement offset the demand effects according to the Rybczynski effect. Therefore, the dynamic productivity effect (Harrod-Pigou-Balassa-Samuelson effect) is not evidenced for the Australian economy. In contrast, Chowdhury (2011) finds a strong evidence of the Balassa-Samuelson effect in Australia in a bivariate model. Enders et al. (2010) also find an appreciation of the US RER in response to positive technology shocks.

Here we experimented with alternative measures of short and long-term interest rate differential as a determinant of RER. We also experimented with the slope of the yield curve[7] as a regressor with disappointing results. Long-term interest differential (IRDL) is often justified on the grounds that shocks to the RER can persist for long periods and this slow reversion towards equilibrium is more appropriately matched by a correspondingly long-term interest rate. In contrast, the real short-term interest rate (IRDS) differential reflects the prevailing stance of domestic, relative to foreign,

[7] The slope of the yield curve contains information about the current and expected future stance of monetary policy.

monetary policy. The coefficients of IRDS in Model 1 and IRDL in Model 2, measuring real short and long-term interest rate differentials between Australia and the world, are negative and statistically significant. A one per cent interest rate differential depreciates the Australian RER by 0.007 and 0.011 per cent in the long-run in Models 1 and 2 respectively. This, too, is a non-conventional result[8]. Tarditi (1996) also failed to find a statistically significant effect of yield curve on RER over the full sample period. Tarditi (1996: 22) writes, "As expected, it is only after the floating of the Australian dollar that the exchange rate has played a role in channelling changes in real interest rates through to the broader economy." The results contradict the findings of earlier studies (Blundell-Wignall et al., 1993; Gruen and Wilkinson, 1994; and Bagchi et al., 2004). Our results conform to the flexible-price monetary model of exchange rate determination where a rise in domestic interest rate relative to foreign interest rate causes a depreciation of the domestic currency, because the interest rate differential can be interpreted as the expected rate of depreciation (Frankel, 1979: 610).

The openness index (OPEN), proxying exchange and trade controls, has a big depreciating effect on the RER of Australia. A one per cent increase in trade openness depreciates the Australian RER by 1.31 and 1.15 per cent in model 1 and 2 respectively. It indicates that after the float, a relaxation of the extent of impediments to international trade resulted in RER depreciation. Edwards (1989: 36-37) provides an elegant theoretical justification for this result. Lastly, both the structural break dummy variables are found to be positive, but they are statistically insignificant; indicating the stability of the model over the study period.

Table 3 shows that the goodness of fit of the estimated models is high, with $R^2 = 0.968$ and $R^2 = 0.966$ in model 1 and 2 respectively. The regressors are jointly

[8] MacDonald (1998: 133-134) finds that an increase in interest rate differential in the "home" country appreciates the real exchange rates of Germany, Japan and the US.
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significant at the one per cent level. Tests for serial correlation, heteroskedasticity, normality of residuals and model adequacy (RESET), reported in Table 3, indicate that the specified models pass all the diagnostic tests.

5.3. Short-run dynamics

Having estimated a stable long-run RER equation, we now proceed to estimate the dynamic (short-run) model. The short-run dynamics for the estimated ARDL model is given in Table 4. Short-run dynamics in the model are captured by the lagged differences of the variables and, for example, we can trace out the effects of a one-unit shock in $\Delta LnTOT_t$ on the long-run RER. The short-run coefficient of terms of trade ($\Delta LnTOT_t$) is statistically significant for the current and the subsequent three lags. The sign of the coefficient on the current ($\Delta LnTOT_t$) is positive while the signs of its first and second quarter lags ($\Delta LnTOT_{t-1}$ and $\Delta LnTOT_{t-2}$) change to negative before becoming positive in the next quarter. The negative (positive) sign indicates that if TOT improves then RER depreciates (appreciates) in that period (short-run). In subsequent periods, RER adjusts by the speed of adjustment given by the coefficient of the error correction term. The long-run parameters, shown in Table 3, capture the effects after all adjustments have been realised. The short-run effects of other variables in the model can be explained in an analogous way.

[Insert Table 4]

The short-run adjustment process is measured by the magnitude of the error correction term (ECM_{t-1}) in Table 4. Kremers et al. (1992) assert that the significance of the error correction term is an efficient and a useful alternative of establishing cointegration. The estimates of ECM_{t-1} are -0.471 and -0.389 in model 1 and model 2 respectively. The coefficients are correctly signed (negative for stability) and highly significant, indicating that the deviation from the long-run equilibrium path is corrected by nearly 47 per cent (model 1) and by 39 per cent (model 2) over the following quarter.

By comparison, Tarditi (1996) found the speed of adjustment to be even higher at 51 per cent per quarter in the post-float sample while the speed of adjustment was a mere 25 per cent per quarter during the full sample period.

6. Summary and Conclusion

This paper has analysed the dynamics and the determinants of the RER of Australia based on an inter-temporal general equilibrium model. Results show that the RER of Australia is appreciated in the long-run by increases in the terms of trade, government expenditures and net foreign liabilities. By contrast, the RER is depreciated by increases in the interest rates differential, openness in trade, and technological and productivity improvements in the long-run. The explanations of the above findings are given in the paper. The endogenously determined structural breaks are statistically insignificant. The speed of adjustment towards equilibrium is high, with short-run disequilibrium correcting by approximately 39 per cent (Model 1) to 47 per cent (Model 2) per quarter.

Apart from the terms of trade, the effects of other determinants on RER are contrary to the results obtained in previous studies[9]. The answer to this puzzle can be found in Aruman and Dungey's (2003: 62) assertion on one of the earlier RBA models: "It seems that the estimations are sensitive to small changes in data, and hence *replication* of this particular piece of work was extremely difficult, even with the original dataset." In contrast, our modelling is comprehensive and estimation exercises are robust in producing significant long-run relationships for the Australian RER and its fundamentals.

[9] MacDonald (1998: 118) argues that econometric methods used, and also the model specification, can have a crucial bearing on the findings of "significant and sensible long-run relationships".

The results of this study have important policy implications for the future. Australia is entering a “new danger zone”[10]. The problems in the Euro zone are acute since the processes of dealing with sovereign debt and competitiveness shortfalls have not been fully addressed. The recovery in the US is fragile while Japan is still in recession. China, Australia’s leading trading partner, is the only economy that is still growing. RER undervaluation[11] in China can account for some of the recent increase in its growth. Australia’s future prosperity is inextricably linked to its productivity growth and to the performance of its economy. Policy makers must focus on prudent macroeconomic management[12] (namely, fiscal and monetary policy; labour market participation and regulation; education and training; business regulation; and industry and trade policy, etc.) that reduces inflationary pressures and maintain the international competitiveness of export and import competing sectors of the economy. A desirable level of RER can be achieved through influencing the RER determinants.

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[10] The World Bank president Robert Zoellick’s grim warning at the Asia Society dinner in Sydney on August 14, 2011.

[11] Ferguson and Schularick (2009) argue that China’s undervaluation of its currency is creating “new and dangerous distortions in the global economy.”

[12] Makin (2010) provides an analytical framework for the Australian economy to deal with global financial crises.

Table 1. Unit-Root Tests in the Absence and Presence of Structural Breaks

Variable: *LnRER*				
Test	Time of Break1	Time of Break2	$T_{\alpha}=1$	Decision
ADF	NC	NC	-2.425	NS
Elliot et al.	NC	NC	399.551	S
Ng-Perron[5]	NC	NC	30.418	S
KPSS	NC	NC	0.184	NS
LS1	2003:2***	NC	-3.568	NS
LS2	1988:2**	2002:4***	-3.877	NS
Variable: *LnTOT*				
Test	Time of Break1	Time of Break2	$T_{\alpha}=1$	Decision
ADF	NC	NC	-1.513	NS
Elliot et al.	NC	NC	32.385	S
Ng-Perron[5]	NC	NC	21.8331	S
KPSS	NC	NC	0.263	NS
LS1	2001:4***	NC	-4.061	NS
LS2	2000:3**	2006:3	-4.672	NS
Variable: *LnGEX*				
Test	Time of Break1	Time of Break2	$T_{\alpha}=1$	Decision
ADF	NC	NC	0.282	NS
Elliot et al.	NC	NC	37.579	S
Ng-Perron[5]	NC	NC	35.511	S
KPSS	NC	NC	0.182	NS
LS1	2005:3***	NC	-3.748*	S
LS2	1988:1**	2005:3***	-5.155*	S
Variable: *LnNFL*				
Test	Time of Break1	Time of Break2	$T_{\alpha}=1$	Decision
ADF	NC	NC	-2.505	NS
Elliot et al.	NC	NC	74.253	S
Ng-Perron[5]	NC	NC	25.317	S
KPSS	NC	NC	0.189	NS
LS1	1993:3**	NC	-1.445	NS
LS2	1989:2***	2001:3	-3.816	NS

(Continued to next page)

Table 1 (continued from previous page)

Variable: *LnTEP*				
Test	Time of Break1	Time of Break2	T_{α}=1	Decision
ADF	NC	NC	-3.973**	S
Elliot et al.	NC	NC	13.794	S
Ng-Perron[5]	NC	NC	14.122	S
KPSS	NC	NC	0.147	S
LS1	1997:2**	NC	-2.749	NS
LS2	1990:1***	2001:2**	-5.189*	S
Variable: *IRDS*				
Test	Time of Break1	Time of Break2	T_{α}=1	Decision
ADF	NC	NC	1.603	NS
Elliot et al.	NC	NC	6.184	S
Ng-Perron[5]	NC	NC	6.162	S
KPSS	NC	NC	0.220	NS
LS1	1992: 1**	NC	-3.643	NS
LS2	1989: 2***	1995: 2***	-5.808*	S
Variable: *IRDL*				
Test	Time of Break1	Time of Break2	T_{α}=1	Decision
ADF	NC	NC	-3.235*	S
Elliot et al.	NC	NC	2.416	NS
Ng-Perron[5]	NC	NC	2.449	NS
KPSS	NC	NC	0.146	S
LS1	1992: 3***	NC	-4.907	NS
LS2	1987: 4	1997: 3**	-6.989***	S
Variable: *LnOPEN*				
Test	Time of Break1	Time of Break2	T_{α}=1	Decision
ADF	NC	NC	0.198	NS
Elliot et al.	NC	NC	11.258	S
Ng-Perron[5]	NC	NC	10.599	S
KPSS	NC	NC	0.118	S
LS1	2002: 3**	NC	3.425	NS
LS2	1987: 3**	2002: 4*	-6.311*	S

Notes: 1. NC = Not calculated; S = Stationary, NS = Nonstationary.

2. ADF Test critical values at 1, 5 and 10 per cent levels are -4.054; -3.456 and -3.153 respectively.

3. Critical values of the endogenous two-break LM unit-root test at 10, 5 and 1 per cent level of significance are -4.989, -5.286 and -5.823 respectively from Table 2 in Lee and Strazicich (2003: 1084).

4. (*), (**) and (***) refer to significant at 10, 5 and 1 per cent level of significance respectively.

5. We report the first unit root test statistic developed by Ng and Perron MP_T^d which is the Elliot, Rothenberg, and Stock (1996) point optimal statistic for GLS de-trended data. The other three statistics, MZ_α^d, MZ_t^d and MSM^d are the enhancements of the Phillips-Peron (PP) test statistics, which are not reported here.

Table 2a. Bounds Test with Short-run Interest Rate Differential as a Regressor

Computed *F*-Statistic	3.966	
Critical Bounds (10 per cent)	♣LCB: 2.12	♣UCB: 3.23
Critical Bounds (5 per cent)	♣LCB: 2.45	♣UCB: 3.61

Notes:
1. LCB = lower critical bound and UCB = upper critical bound.
2. ♣ Critical bounds are from Pesaran et al. (2001: 300) Table CI (iii) Case III.

Table 2b. Bounds Test with Long-run Interest Rate Differential as a Regressor

Computed *F*-Statistic	4.113	
Critical Bounds (10 per cent)	♣LCB: 2.12	♣UCB: 3.23
Critical Bounds (5 per cent)	♣LCB: 2.45	♣UCB: 3.61

Notes:
1. LCB = lower critical bound and UCB = upper critical bound.
2. ♣ Critical bounds are from Pesaran et al. (2001: 300) Table CI (iii) Case III.

Table3. Estimated Long-run Coefficients

Dependent Variable: *LnRER*

MODEL 1 ARDL (1,4,4,3,4,0,0)			MODEL 2 ARDL (1,4,3,3,0,0,0)		
Regressor	Coefficient	*P*-value	Regressor	Coefficient	*P*-value
LnTOT	1.045 (12.22)	0.000	*LnTOT*	0.956 (9.54)	0.000
LnGEX	0.526 (2.52)	0.014	*LnGEX*	0.457 (2.051)	0.044
LnNFL	0.182 (1.94)	0.056	*LnNFL*	0.220 (2.35)	0.021
IRDS	-0.007 (-3.95)	0.000	*IRDL*	-0.011 (-3.28)	0.002
LnOPEN	-1.308 (-7.22)	0.000	*LnOPEN*	-1.150 -(5.99)	0.000
LnTEP	-0.383 (-1.63)	0.108	*LnTEP*	-0.549 (-1.78)	0.078
*D*1	0.009 (0.54)	0.589	*D*1	0.013 (0.70)	0.489
*D*2	0.007 (0.28)	0.781	*D*2	0.007 (0.269)	0.789
Intercept	-3.342 (-4.55)	0.000	*Intercept*	-2.666 (-3.27)	0.002
R^2: 0.9682 $\bar{R}^2$: 0.9577			R^2: 0.9657 $\bar{R}^2$: 0.9568		
A: Serial Correlation Test $\chi^2(4) = 1.358$ [0.851] F(4, 69) = 0.242 [0.913]			*A: Serial Correlation Test* $\chi^2(4) = 1.8153$ [0.770] F(4,73) = 0.344 [0.847]		
B: Functional Form Test $\chi^2(1) = 5.574$ [0.018] F(1,72) = 4.342 [0.041]			*B: Functional Form Test* $\chi^2(1) = 4.336$ [0.037] F(1,76) = 3.518 [0.065]		
C: Normality Test $\chi^2(2) = 0.086$ [0.959] *Not applicable*			*C: Normality Test* $\chi^2(2) = 0.047$ [0.977] Not applicable		
D: Heteroscedasticity Test $\chi^2(1) = 0.786$ [0.375] F(1, 96) = 0.776 [0.380]			*D: Heteroscedasticity Test* $\chi^2(1) = 0.92170$ [0.337] F(1, 96) = 0.912 [0.342]		

Notes: 1. *t*-values are reported in parentheses below the coefficients.
2. Figures in square brackets represent the *p*-values for each test.

Table 4. Error Correction Representation

Dependent variable is $\Delta LnRER_t$

MODEL 1 ARDL (1,4,4,3,4,0,0)			MODEL 2 ARDL (1,4,3,3,0,0,0)		
Regressor	Coefficient	*P*-value	Regressor	Coefficient	*P*-value
$\Delta LnTOT_t$	1.015 (8.48)	0.000	$\Delta LnTOT_t$	0.997 (8.26)	0.000
$\Delta LnTOT_{t-1}$	-0.564 (-4.39)	0.000	$\Delta LnTOT_{t-1}$	-0.564 (-4.42)	0.000
$\Delta LnTOT_{t-2}$	-0.375 (-2.71)	0.008	$\Delta LnTOT_{t-2}$	-0.331 (-2.40)	0.018
$\Delta LnTOT_{t-3}$	0.414 (2.87)	0.005	$\Delta LnTOT_{t-3}$	0.354 (2.53)	0.013
$\Delta LnGEX_t$	-0.014 (-0.31)	0.756	$\Delta LnGEX_t$	0.037 (0.92)	0.361
$\Delta LnGEX_{t-1}$	-0.253 (-2.98)	0.004	$\Delta LnGEX_{t-1}$	-0.152 (-2.41)	0.018
$\Delta LnGEX_{t-2}$	-0.176 (-2.60)	0.011	$\Delta LnGEX_{t-2}$	-0.097 (-2.30)	0.024
$\Delta LnGEX_{t-3}$	-0.063 (-1.32)	0.190	$\Delta LnGEX_{t-3}$		
$\Delta LnNFL_t$	0.065 (0.99)	0.326	$\Delta LnNFL_t$	0.097 (1.49)	0.140
$\Delta LnNFL_{t-1}$	-0.067 (-1.02)	0.313	$\Delta LnNFL_{t-1}$	-0.031 (-0.50)	0.619
$\Delta LnNFL_{t-2}$	0.086 (0.24)	0.220	$\Delta LnNFL_{t-2}$	0.123 (1.89)	0.062
$\Delta IRDS_t$	-0.002 (-2.63)	0.010	$\Delta IRDL_t$	-0.004 (-3.80)	0.000
$\Delta IRDS_{t-1}$	0.002 (0.13)	0.036	$\Delta IRDL_{t-1}$		
$\Delta IRDS_{t-2}$	0.003 (0.1186)	0.003	$\Delta IRDL_{t-2}$		
$\Delta IRDS_{t-3}$	0.002 (0.08)	0.041	$\Delta IRDL_{t-3}$		
$\Delta LnOPEN_t$	-.616 (-7.31)	0.000	$\Delta LnOPEN_t$	-0.679 (-7.26)	0.000
$\Delta LnTEP_t$	-0.180 (-1.64)	0.106	$\Delta LnTEP_t$	-0.214 (-1.99)	0.050
$\Delta D1_t$	.004 (0.54)	0.592	$\Delta D1_t$	0.005 (0.68)	0.500
$\Delta D2_t$	0.003 (0.28)	0.782	$\Delta D2_t$	0.003 (0.27)	0.789
Intercept	3.342 (-4.55)	0.000	*Intercept*	-2.666 (-3.27)	0.002
ECM_{t-1}	-0.471 (-8.0295)	0.000	ECM_{t-1}	-0.389 (-5.56)	0.000

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