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THE RELATIONSHIP BETWEEN THE AUSTRALIAN DOLLAR AND THE MACROECONOMIC FUNDAMENTALS

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Abstract

This paper examines the link between the Australian dollar's exchange rate (A$) to US dollar (US$) and Australia's terms of trade. By using a simple econometric model, with the terms of trade as the sole explanator, the US$/A$ rate is found to be cointegrated with the terms of trade and the relationship between the two variables appears to be robust. Our estimate of the long run elasticity of the exchange rate with respect to the terms of trade is 0,775, which strongly supports the widely held view that the floating A$ is a "commodity currency". An estimated error-correction model describes how the short term dynamics are linked to the long-term relationship, leading the cointegrating relationship to equilibrium. The causality of the variables is proven to be bilateral, running significantly from the terms of trade to the exchange rate but less significantly from the exchange rate to the terms of trade.

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1. Introduction

Over the past decade, there has been plenty of discussion amongst economists about the strength of the Australian dollar. Despite the high current account deficits and rising foreign debt of Australia, there has been a significant appreciation of the real exchange rate, which refers to the price of the average domestic good or service relative to the price of the average foreign good or service. This essay seeks to identify the possible source of this appreciation and analyze the extensive implications on the Australian economy.

Australia's abundant and diverse natural resources attract high levels of foreign investment and include extensive reserves of coal, iron ore, copper, gold, natural gas, uranium, and renewable energy sources. A series of major investments, such as the US$40 billion Gorgon Liquid Natural Gas project, will significantly expand the resources sector. Australia also has a large services sector and is a significant exporter of natural resources, energy, and food. Main principle of Australia’s trade policy is the support for open trade and the successful utilization of the Doha Round of multilateral trade negotiations, particularly for agriculture and services. The Australian economy grew for 17 consecutive years before the global financial crisis. Subsequently, the former Labor Party government introduced a fiscal stimulus package worth over US$50 billion to offset the effect of the slowing world economy, while the Reserve Bank of Australia cut interest rates to historic lows. These policies, in combination with continued demand for commodities (especially from China), helped the Australian economy rebound after just one quarter of negative growth. The economy grew by 1.4% during 2009 (the best performance in the OECD), by 2.7% in 2010, and by 1.8% in 2011. Unemployment, originally expected to reach 8-10%, peaked at 5.7% in late 2009 and fell to 5.0% in 2011. As a result of an improved economy, the budget deficit is expected to peak below 4.2% of GDP and the government could return to budget surpluses as early as 2015. Australia was one of the first advanced economies to raise interest rates, with seven rate hikes between October 2009 and November 2010.

A characteristic common to most of the large commodity exporting countries, including Australia, is that movement in their terms of trade is a key determinant of macroeconomic performance and has an important impact on real national income. This movement results in terms of trade affects the nominal effective exchange of the Australian dollar. This paper examines the link between the US$/A$ exchange rate and Australian terms of trade.

1.1 Defining and measuring an internationalized currency

An internationalized currency can be defined as one that is freely traded against other currencies and used to denominate contracts, including bank accounts and bonds, outside its country of issue. In the bond market, internationalization requires more than non-residents becoming important holders of domestically issued bonds, i.e. the domestic bond market is taken to be fully internationalized only when non-residents figure as important issuers of bonds denominated in the domestic currency. In addition, an internationalized currency is used to denominate bonds sold outside its domestic financial markets, in offshore markets, by both domestic and foreign issuers who choose to tap non-resident investors. A telling sign of internationalization is a nonresident issuer of a bond denominated in the domestic currency that is sold offshore to non-resident investors.

Australian dollars are actively traded by non-residents. Like most major currencies, the Australian dollar trades more outside the home economy than within. That is, if one defines offshore trading in a currency as that between two non-residents, then such trades represent the major part of global transactions for major currencies. On this measure, the Australian dollar is as much an internationalized currency as the Japanese yen, although somewhat less so than the US dollar, euro or New Zealand dollar. Most Asian currencies other than the yen, including the rupee and the won, trade relatively little offshore.

1.2 From insular to international currency

The Australian dollar’s transition from an initial insularity to the current state of internationalization took about a decade. The development of derivatives markets, particularly the currency swap market, played an important role against the background of the Australian dollar's yield advantage over the US dollar. In addition, whereas a withholding tax was applied on coupon interest paid by domestic bonds, an exception which applied to offshore issues gave the latter an extra source of support.

Australia's foreign exchange, money and bond markets in the 1970s and early 1980s remained quite insular. This was a policy choice in service of a sequence of exchange rate regimes from bilateral peg through basket peg to basket crawl (Debelle and Plumb (2006)). In general, the Australian dollar was not used outside the country. Capital controls required exporters to give up foreign exchange and generally restricted Australian portfolio investment abroad. The Reserve Bank of Australia limited forward cover to trade transactions. Banks were prohibited from paying interest on deposits of nonresidents, and non-resident banks and governments were restricted to minimum working balances in order to discourage the development of a reserve currency role for the Australian dollar (Campbell Committee (1981, page 147)). Withholding taxes also discouraged investment in domestic bonds.

However, even in this period there were policies and practices that looked forward to a less insular future. First of all, in 1976–80 there were seven small Australian dollar issues offshore, in amounts between 10 and 15 million A$. Sold to Benelux and Middle East investors, these resembled private placements. Dealers could not readily hold and fund inventory given the above restrictions and the consequently limited supply of offshore Australian dollar funding (Burnett and Kerr (1984)). Second, when the Australian dollar was under upward pressure the authorities did permit selected portfolio outflows. Third, the authorities permitted an onshore non-deliverable forward market to develop. Settled in Australian dollars, this market was in some ways the mirror image of the non-deliverable markets in Asia, where offshore players settle their side bets in dollars (Ma et al (2004), Debelle et al (2006)).

The Australian dollar was floated in 1983 and the capital controls that had supported the former regime were dismantled. Subsequently, an Australian dollar deposit market developed in London, Hong Kong and Singapore, integrated with the spot and forward foreign exchange markets. After a depreciation of the Australian dollar in 1983, the Australian dollar Eurobond market reopened with a A$20 million five-year offering from Primary Industry Bank of Australia. The issue yielded about 3 percentage points more than US dollar bonds but a full 1 percentage point less than did the

Commonwealth of Australia’s domestic five-year bond. Withholding taxes on sovereign bonds onshore left offshore investors willing to accept lower yields from inferior credits marketed offshore.

During the mid-1980s, the representative issuers in the Australian dollar sector of the Eurobond market shifted. By 1987, most large Australian dollar Eurobonds were issued by high-quality issuers with little or no intrinsic need for Australian dollar funding. The outline set in 1987 essentially holds to this day.

By the end of the 1980s, the Australian dollar had made the transition to an internationalized currency. Four characteristics define what is now a thoroughly internationalized Australian dollar bond market: its grounding in the domestic fixed income market; the demand for quality among international investors in Australian dollar paper; the importance of the cross-currency swap market; and the importance of yield to international investors.

1.3 Commodity currency

It has long been observed that there is a close relationship between commodity prices and the Australian dollar. When the world price of commodities rises, the Australian dollar tends to appreciate. When world commodity prices fall, the Australian dollar tends to fall. As a consequence, the Australian dollar is usually described as a “commodity currency”. Since commodities account for a large proportion of Australia’s exports, this close link between commodity prices and the Australian dollar is also reflected in a close relationship between Australia’s terms of trade and the real exchange rate.

1.4 Monetary Policy

The Reserve Bank is responsible for Australia's monetary policy. Monetary policy involves setting the interest rate on overnight loans in the money market. This is called the “cash rate” and it influences other interest rates in the economy, affecting the behavior of borrowers and lenders, economic activity and ultimately the rate of inflation.

In determining monetary policy, the Bank has a duty to maintain price stability, full employment, and the economic prosperity and welfare of the Australian people. To achieve these constitutional objectives, the Bank has an inflation target and seeks to keep consumer price inflation in the economy to average 2% - 3%, over the medium term. Controlling inflation preserves the value of money and encourages strong and sustainable growth in the economy over the longer term.

1.5 Policy and practice of the Reserve Bank of Australia intervention

There are four broad reasons why the Reserve Bank of Australia intervenes in the foreign exchange market, according to various RBA Annual Reports and Kim & Sheen (2002):

■ *Misalignment.* The RBA intervenes in the foreign exchange market to influence the level of the exchange rate. Usually this happens when the RBA believes that the market is driving the exchange rate away from its equilibrium value and intervenes to break the momentum.

■ *Calming a disorderly market.* The RBA intervenes to calm the market and so prevent it from becoming disorderly. Rapid movement in the exchange rate may at times threaten the orderly functioning of the market, leading to a widening of spreads and at times loss of liquidity. This action also serves to discourage the market from becoming one-sided.

■ *Signaling/accommodating monetary policy*. Intervention may be used to signal future changes to monetary policy or possibly calm expectations if monetary policy is changed unexpectedly, which might otherwise lead to a loss in confidence and thereby induce an unjustifiable move in the exchange rate.

■ *Reserve building*. The RBA intervenes to maintain an inventory of net foreign currency assets.

1.6 Determinants of AUD fluctuations

Since 1983 there has been considerable debate in Australia about the causes of fluctuations in the AUD. Strongly held views about the role of speculators, the influence of Australia's cumulating current account deficits, sharp movements of Australia's terms of trade and the impact of monetary policy have been central to the debate. In the mid-1980s, the exchange rate depreciated as the terms of trade declined and the current account deficit rose.

Some argued, however, that the exchange rate went further than could be justified by the macroeconomic fundamentals, adding a fillip to inflation. During the 1990s, the exchange rate has again declined as interest rates have been steadily reduced and the terms of trade have fallen. The subject of whether the causes of this depreciation are nominal (with adverse consequences for inflation) or real (contributing to external adjustment), is again creating dilemmas for policy makers. To investigate further such issues requires advanced understanding of the relative importance of the various influences on the $A exchange rate.

2. Literature review

Exogenously determined terms of trade have long been recognized as a variable playing a central role in influencing the Australia's economic outcomes (Salter, 1959; Swan, 1960; Gregory, 1976). Since the floating of the Australian dollar in 1983, there is an extensive interest in the way that the terms of trade volatility is connected with the volatility of the exchange rate and the impact on Australian competitiveness and macroeconomic stability.

In their search for an empirical proof of such a link, Blundell-Wignall et al. (1993) suggested that there is a cointegrating relationship between the real exchange rate, the terms of trade, the long-term real interest differential and the ratio of net foreign assets to GDP. Their main finding is that a 10% improvement in the Australian terms of trade is associated with a real appreciation of the $A by about 8%. Subsequent studies also employ cointegration analysis to estimate the terms of trade elasticity of the real or the nominal exchange rate (Gruen and Wilkinson, 1994; Koya and Orden, 1994; Fisher, 1996; Karfakis and Phipps, 1999). The estimates of these two elasticities often exceed unity. Thus, using the US/A exchange rate and US-dollar based terms of trade data, Fisher (1996, Table 2) estimates the two elasticities as 1.29 and 1.45, respectively, a result which is similar to that reported by Koya and Orden (1994, Table 3).

A common point of departure of these studies is that the cointegrating relationship involves terms of trade. It should be pinpointed that the Australian terms of trade are highly correlated to the phases of the world commodity price cycle, influencing the commodity prices which consequently affect the A$ exchange rate. Thus, the beginning point is to test if a direct link exists between a commodity-price index and the nominal value of the $A. Such a link would explain the well-known "commodity currency" view of the $A (Clements and Freebairn, 1991; Hughes, 1994; Chen, 2002; Chen and Rogoff, 2003).

Hatzinikolaou and Polasek (2005) have estimated the steady-state elasticity of the nominal exchange rate with respect to the commodity price index to be equal to 0.939, whereas that of the short-term dynamic effect is equal to 0.67. Therefore an improvement of the Australian terms of trade which is derived by an increase in commodity prices, increases the foreign income which eventually appreciates A$ almost proportionally to the commodity price index increase. This nominal appreciation may produce a deflationary effect in the real sector, which, unless offset by policy, will eventually modify the economic agents perceptions of what the financial variables in the system (interest differential and trade-weighted exchange rate) should be in the changed circumstances. If the market sentiment should be that the initial currency windfall has overvalued the $A, the reaction would be to sell $A, triggering the error adjustment mechanism, which eventually pushes the actual rate towards its steady-state. In case the initial nominal appreciation for some reason undervalues the $A in terms of the commodity fundamentals, the convergence would be in the opposite direction. It is estimated that about 44% of the divergence between the actual and the steady-state value of the exchange rate will be eliminated with a lag of one quarter. Since about 80% of the Australian merchandise exports consist of commodities at various stages of processing and also because the exchange rate in its steady state moves almost one-for-one with world commodity prices, the cyclical path in these prices maps closely into cyclical behavior of the nominal effective exchange rate, with powerful implications for the international competitiveness of Australia's elaborately transformed exports and import competing goods. While it is true that this mechanism has helped produce an economic environment in Australia which is far less prone to the inflationary excesses experienced under the previous regime of administered exchange rates, it cannot be said that it protects Australians from the instability which is inherent in the workings of the international commodity markets. It only transfers that instability into another domain.

The actual extent to which the observed long-run relationship between Australia's real exchange rate and the terms of trade can be used effectively to model bilateral nominal A$ exchange rates was explored by Fisher (1996), by using quarterly data from 1972Q3 to 1995Q2. According to him, given the estimated cointegrating relationship, it should be possible to express the nominal exchange rate as a function of the terms of trade and relative price levels. This paper establishes some form of long-run cointegrating relationship among the nominal US$/A$ exchange rate, terms of trade and relative price levels. However, it establishes only very weak cointegratation. The null of no cointegrating relationship is rejected at only the 10% level of significance (not 5%) by the trace test and *not* rejected at even the 10% level by the maximum-eigenvalue test.

Blundell-Wignall and Gregory (1990) and Gruen and Wilkinson (1994) set the issue of whether or not, given a long-run cointegrating relationship between the real exchange rate and the terms of trade, causality runs solely from changes in the terms of trade to changes in the exchange rate. It is not obvious that causality should be one way only. Strict unidirectional causality is crucially dependent on the assumption that the country in question is an international price-taker, based on the assumption that the *foreign* currency prices of both exports and imports are given exogenously. Since the terms of trade are the ratio of export prices to import prices expressed in the same currency, any change in the nominal exchange rate will leave the ratio unchanged (proportional change in numerator and denominator). However, the speed of adjustment of import prices may not be the same with the adjustment of the export prices, resulting to changes in the terms of trade because of changes in the A$ exchange rate.

Karfakis and Phipps (1999) confirm the long-run cointegrating relationship which exists between Australia's real effective exchange rate and its terms of trade. By taking into account also the difference of the short-run interest rates of US and Australia and by assuming that the "uncovered interest parity" holds, it is proven that the real exchange rate/terms of trade relationship can be used effectively to provide a model for the nominal US$/A$ exchange rate. The exchange rate is cointegrated with the terms of trade and short-run and long-run interest rate differentials. Furthermore, weak exogeneity tests within the Johansen cointegrating framework and the estimated error-correction models provided some evidence of a two-way relationship between the nominal exchange rate and the terms of trade. The error correction model for the terms of trade also provides evidence of a significant, contemporaneous impact of changes in the nominal exchange rate on changes in the terms of trade. This suggests that the small open-economy assumption of exogenously given terms of trade needs to be treated with caution when modeling movements in the US$/A$ exchange rate or other aspects of Australia's international economic relations.

Garton, Gaudry and Wilcox (2012) argue that the primary reason why the A$ has appreciated so much recently is because Australia's terms of trade have doubled during the last decade, as a result of the rises in world prices for Australian commodity exports. From the real economy point of view, a rise in commodity export prices raises the equilibrium real exchange rate because it leads to increased demand for Australian goods, requiring their price to rise relative to foreign goods. This occurs because of the higher commodity prices which lead to increased investment to expand capacity in the resources sector. Also, higher aggregate incomes, resulting from the rise in the terms of trade, lead to an increase in consumption spending, much of which is on domestic goods. The higher exchange rate is promoting the reallocation of labor and capital to meet these demands by reducing returns in other tradable sectors. If this adjustment did not occur through a higher nominal exchange rate, it would instead occur through higher domestic prices. This is what occurred during the terms of trade boom of the early 1970s, when Australia had a fixed exchange rate and governments were reluctant to readjust the currency (Gruen 2011). This means that the rise in the real exchange rate would still occur over time through higher inflation, even if the nominal exchange rate was held down.

3. Econometric models

3.1 Data

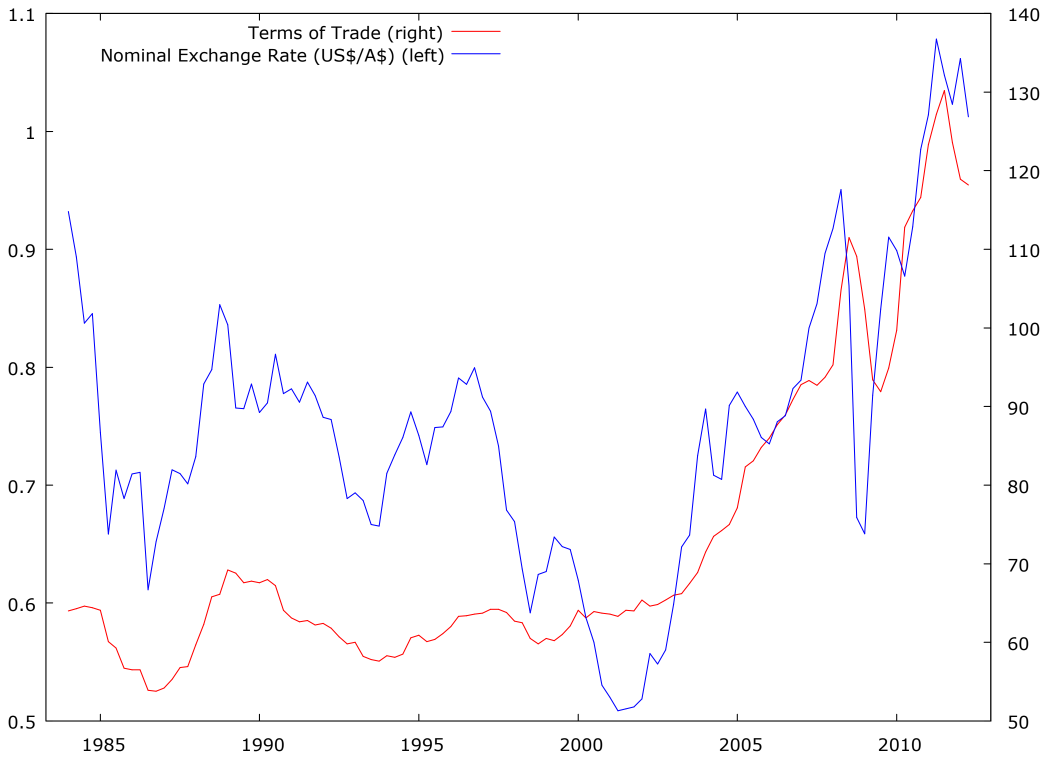
In this paper, we use quarterly data of the Australian terms of trade price indices from 1984:Q1 to 2012:Q2, which are available from the Australian Bureau of Statistics (Cat No 5302.0). The terms of trade are defined as the seasonally adjusted ratio of the implicit price deflator of exports of goods and services and the implicit price deflator of imports of goods and services. The reference year for these price indices is 2009/10 (equals to 100). The US$/A$ exchange rate data is available from the RBA and sourced from page AUDFIX of Thomson Reuters. It shows the WM/Reuters Australian Dollar Fix at 4 pm (Sydney) each month, rounded to four decimals. For the needs of this paper it has been converted to quarterly data, by calculating the mean value of each quarter of the years under study.

3.2 Methodology

We begin our search for a long-run equilibrium nominal exchange-rate equation by adopting a cointegrating relationship between the A$ exchange rate and the Australian terms of trade. Casual observation of Figure 1 suggests that the nominal US$/A$ exchange rate has moved with the terms of trade since the float. However, the extent to which the nominal exchange rate embodies changes in relative price levels and other relevant variables such as interest rate differentials is not a subject of investigation in this paper.

If cointegration amongst the US$/A$, the terms of trade and other relevant variables can be established then it should also be possible, given the Granger representation theorem, to explore the short-run dynamics of such a relationship by the way of standard error-correction (EC) models. Hence, the second question we wish to explore concerns the stability and robustness of the EC models for the nominal exchange rate and their ability to predict exchange rate movements out of sample.

Figure 1. Nominal US$/A$ Exchange Rates and Australia's Terms of Trade



The third question is to identify whether the causality of the long-run cointegrating relationship between the real exchange rate and the terms of trade, runs solely from changes in the terms of trade to changes in the exchange rate. Because the terms of trade are the ratio of export prices to import prices expressed in the same (usually domestic) currency, any change in the nominal exchange rate will affect the numerator and denominator in the same proportion, leaving the ratio unchanged. However, if there is an element of imperfect competition in either the export or import market, changes in the exchange rate are likely to affect the terms of trade.

3.3 Stationarity tests

The first step is to calculate the natural logarithm of the nominal US$/A$ Exchange Rate (l_USD) and the natural logarithm of the Terms of Trade (l_TOT). The results of the Augmented Dickey-Fuller unit root test for these variables are depicted in Table 1.

Table 1. Augmented Dickey-Fuller unit root test for the natural logarithm of the nominal US$/A$ Exchange Rate (l_USD)

```
Augmented Dickey-Fuller test for l_USD
including 4 lags of (1-L)l_USD (max was 4)
sample size 109
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.002
   lagged differences: F(4, 103) = 4.069 [0.0042]
   estimated value of (a - 1): -0.0374946
   test statistic: tau_c(1) = -1.06839
   asymptotic p-value 0.7304

Augmented Dickey-Fuller regression
OLS, using observations 1985:2-2012:2 (T = 109)
Dependent variable: d_l_USD

              coefficient   std. error   t-ratio   p-value
  ---------------------------------------------------------
  const       -0.00920253   0.0122056    -0.7540   0.4526
  l_USD_1     -0.0374946    0.0350945    -1.068    0.7304
  d_l_USD_1    0.327212     0.0954161     3.429    0.0009  ***
  d_l_USD_2   -0.230700     0.100245     -2.301    0.0234  **
  d_l_USD_3    0.140824     0.0981134     1.435    0.1542
  d_l_USD_4   -0.171005     0.0963756    -1.774    0.0790  *

  AIC: -332.963   BIC: -316.815   HQC: -326.415

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: 0.006
   lagged differences: F(4, 102) = 4.051 [0.0043]
   estimated value of (a - 1): -0.0456188
   test statistic: tau_ct(1) = -1.28965
   asymptotic p-value 0.8902

Augmented Dickey-Fuller regression
OLS, using observations 1985:2-2012:2 (T = 109)
Dependent variable: d_l_USD

              coefficient    std. error    t-ratio   p-value
  -----------------------------------------------------------
  const       -0.0257875     0.0167720     -1.538    0.1273
  l_USD_1     -0.0456188     0.0353730     -1.290    0.8902
  d_l_USD_1    0.312695      0.0954696      3.275    0.0014  ***
  d_l_USD_2   -0.237817      0.0998592     -2.382    0.0191  **
  d_l_USD_3    0.129046      0.0979598      1.317    0.1907
  d_l_USD_4   -0.187609      0.0965827     -1.942    0.0548  *
  time         0.000235244   0.000164093    1.434    0.1547

  AIC: -333.138   BIC: -314.298   HQC: -325.498
```

It is obvious that the unit-root hypothesis cannot be rejected. This is derived by the fact that the asymptotic p-value of the test with constant is 0,7304 (very high). Therefore the l_USD is a non-stationary time series.

The same test for the first differences of the logarithm of the nominal US$/A$ Exchange Rate (l_USD) shows that there is no unit root (the first difference series is stationary). Therefore the l_USD variable is integrated of order one (I(1)).

By applying the same stationarity test on the natural logarithm of the Terms of Trade (l_TOT), we get the results depicted in Table 2.

Table 2. Augmented Dickey-Fuller unit root test for the natural logarithm of the of the Terms of Trade (l_TOT)

```
Augmented Dickey-Fuller test for l_TOT
including 3 lags of (1-L)l_TOT (max was 4)
sample size 110
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.016
   lagged differences: F(3, 105) = 10.801 [0.0000]
   estimated value of (a - 1): 0.00862435
   test statistic: tau_c(1) = 0.70217
   asymptotic p-value 0.9923

Augmented Dickey-Fuller regression
OLS, using observations 1985:1-2012:2 (T = 110)
Dependent variable: d_l_TOT

              coefficient   std. error   t-ratio   p-value
  ---------------------------------------------------------
  const       -0.0326477    0.0520209    -0.6276   0.5316
  l_TOT_1      0.00862435   0.0122824     0.7022   0.9923
  d_l_TOT_1    0.469971     0.0965902     4.866    4.03e-06 ***
  d_l_TOT_2    0.0246732    0.107504      0.2295   0.8189
  d_l_TOT_3   -0.204221     0.103202     -1.979    0.0505   *

  AIC: -487.456   BIC: -473.953   HQC: -481.979

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.015
   lagged differences: F(3, 104) = 10.477 [0.0000]
   estimated value of (a - 1): -0.0276135
   test statistic: tau_ct(1) = -1.41322
   asymptotic p-value 0.8575

Augmented Dickey-Fuller regression
OLS, using observations 1985:1-2012:2 (T = 110)
Dependent variable: d_l_TOT

              coefficient    std. error    t-ratio   p-value
  -----------------------------------------------------------
  const        0.103141      0.0769702      1.340    0.1832
  l_TOT_1     -0.0276135     0.0195395     -1.413    0.8575
  d_l_TOT_1    0.453329      0.0948329      4.780    5.78e-06 ***
  d_l_TOT_2    0.0336538     0.105324       0.3195   0.7500
  d_l_TOT_3   -0.190448      0.101211      -1.882    0.0627   *
  time         0.000311079   0.000132206    2.353    0.0205   **

  AIC: -491.161   BIC: -474.958   HQC: -484.589
```

It should be noted that the l_TOT variable has a time trend, which is derived by the fact that the time coefficient is statistically significant (p-value = 0,0205). We can see that the unit-root hypothesis (including constant and trend) cannot be rejected also in this case. This is proven by the fact that the asymptotic p-value of the test is 0,8575 (very high). Therefore the l_TOT is a non-stationary time series. The same test for the first differences of the natural logarithm of the Terms of Trade (l_TOT) shows that there is no unit root (the first difference series is stationary). Therefore the l_TOT variable is integrated of order one (I(1)).

3.4 Long-run cointegrating relationship

If we regress a nonstationary time series on one or more nonstationary series, we might obtain a high R^2 value and regression coefficients that statistically significant on the basis of the usual t and F tests. But these results are likely to be spurious or misleading because the standard linear regression procedures assume that the time series involved in the analysis are stationary. So, in the case of the l_USD and the l_TOT the resulting regression may be a spurious regression. The situation in which the regression of a nonstationary time series on one other nonstationary time series may not result in a spurious regression is called cointegration. If this happens, the time series under study are cointegrated, that is, there is a long-term equilibrium relationship between them.

Since the time series under investigation are both integrated of order one, we can apply the Engle-Granger cointegration test. The results are depicted in Table 3. As we can see, the residuals of the regression are non-stationary (p-value = 0,5862) therefore there is no cointegrating relationship between the Exchange Rate and the Terms of Trade.

This result is different from the result of Karfakis and Phipps (1999). The reason is that the undertaken sample period is different. This is an indication that the cointegrating relationship has changed at one or more points of time. This change is called **structural break**, after which the slope coefficient or the intercept of the cointegrating relationship changes. We assume the following function:

$$l\_USD_t = a_1 + a_2 l\_TOT_t + u_t \qquad (1)$$

The possible structural change indicates that the a_1 and a_2 coefficients have changed after at least one point of time. This can be examined by including a new variable D, called **dummy variable**. This variable is nominal and it can only take the value 0 or 1, indicating in our case the period before the structural brake (D=0) and after it (D=1).

Table 3. Cointegration test between l_USD and l_TOT

```
Step 1: cointegrating regression

Cointegrating regression -
OLS, using observations 1984:1-2012:2 (T = 114)
Dependent variable: l_USD

             coefficient   std. error   t-ratio    p-value
  --------------------------------------------------------
  const       -2.22833     0.222375     -10.02    2.94e-017 ***
  l_TOT        0.451346    0.0521106      8.661   3.98e-014 ***

Mean dependent var  -0.305012   S.D. dependent var   0.163083
Sum squared resid    1.799825   S.E. of regression   0.126767
R-squared            0.401129   Adjusted R-squared   0.395782
Log-likelihood       74.70603   Akaike criterion    -145.4121
Schwarz criterion   -139.9397   Hannan-Quinn        -143.1911
rho                  0.886818   Durbin-Watson        0.185811

Step 2: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 4 lags of (1-L)uhat (max was 4)
sample size 109
unit-root null hypothesis: a = 1

   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: 0.012
   lagged differences: F(4, 104) = 5.185 [0.0008]
   estimated value of (a - 1): -0.0809684
   test statistic: tau_c(2) = -1.88781
   asymptotic p-value 0.5862

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables.
(b) The unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

By using the dummy variable, we can express the relationship between l_USD and l_TOT as:

$$l\_USD_t = a_1 + a_3 D + a_2 l\_TOT_t + a_4 Dl\_TOT + u_t \qquad (2)$$

Since we know that the structural brake took place after the year 1995 (we can check it by performing a cointegration analysis until 1995 and confirm it by the paper of Karfakis and Phipps (1999)), our first indication is the year 1997, when the East Asia has been gripped by an economic and political crisis.

We firstly assign the Dummy variable as:

$$D = \begin{cases} 0 & 1984Q1 \le t \le 1997Q1 \\ 1 & 1997Q2 \le t \le 2012Q2 \end{cases}$$

In order to check for a structural brake in the intercept (a_1), we examine the following function:

$$l\_USD_t = a_1 + a_3 D + a_2 l\_TOT_t + u_t \quad (3)$$

We apply the Engle-Granger cointegration test in the function (3) and we get the results depicted in Table 4.

Table 4. Cointegration test between l_USD, l_TOT and D (D=1 from 1997:Q2 and later on)

```
Step 1: cointegrating regression

Cointegrating regression -
OLS, using observations 1984:1-2012:2 (T = 114)
Dependent variable: l_USD

             coefficient   std. error   t-ratio    p-value
  ---------------------------------------------------------
  const       -3.38208     0.179858     -18.80    2.69e-036 ***
  l_TOT        0.751170    0.0435967     17.23    3.78e-033 ***
  D           -0.231526    0.0199151    -11.63    6.44e-021 ***

Mean dependent var  -0.305012   S.D. dependent var   0.163083
Sum squared resid    0.811604   S.E. of regression   0.085509
R-squared            0.729948   Adjusted R-squared   0.725082
Log-likelihood       120.1026   Akaike criterion    -234.2053
Schwarz criterion   -225.9967   Hannan-Quinn        -230.8739
rho                  0.734533   Durbin-Watson        0.488582

Step 2: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 4 lags of (1-L)uhat (max was 4)
sample size 109
unit-root null hypothesis: a = 1

   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: 0.001
   lagged differences: F(4, 104) = 4.411 [0.0025]
   estimated value of (a - 1): -0.27511
   test statistic: tau_c(3) = -3.27578
   asymptotic p-value 0.1452

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables.
(b) The unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

We observe that the coefficient of the Dummy variable is statistically significant and this is a good sign that a structural brake has taken place near the year 1997. Still the cointegration result is negative (asymptotic p-value 0.1452).

We can suppose that the structural brake happened later. Therefore the Dummy variable should take different values and we should perform again the Engle-Granger cointegration test. If we assume that the structural brake happened on the fourth quarter of 1997, so the Dummy variable takes the value 1 from 1997:Q4 and later on, we get the results depicted in Table 5.

Table 5. Cointegration test between l_USD, l_TOT and D (D=1 from 1997:Q4 and later on)

```
Step 1: cointegrating regression

Cointegrating regression -
OLS, using observations 1984:1-2012:2 (T = 114)
Dependent variable: l_USD

             coefficient   std. error   t-ratio    p-value
  --------------------------------------------------------
  const       -3.48046     0.173138     -20.10    8.62e-039 ***
  l_TOT        0.774751    0.0419565     18.47    1.24e-035 ***
  D           -0.243428    0.0191304    -12.72    2.02e-023 ***

Mean dependent var  -0.305012   S.D. dependent var   0.163083
Sum squared resid    0.732019   S.E. of regression   0.081208
R-squared            0.756429   Adjusted R-squared   0.752040
Log-likelihood       125.9854   Akaike criterion    -245.9708
Schwarz criterion   -237.7622   Hannan-Quinn        -242.6394
rho                  0.717253   Durbin-Watson        0.518189

Step 2: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including one lag of (1-L)uhat (max was 4)
sample size 112
unit-root null hypothesis: a = 1

   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: 0.029
   estimated value of (a - 1): -0.374844
   test statistic: tau_c(3) = -5.84712
   asymptotic p-value 1.303e-005

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables.
(b) The unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

We can now see that there is a cointegrating relationship (asymptotic p-value 1.303e-005). We can go on by changing the point of time of the structural brake. In order to choose the best point of time we use the Akaike and the Schwarz criteria. The value of them is lower when we set the structural brake on the fourth quarter of 1997. Therefore, even though there can be cointegrating relationships by choosing different Dummy variables, we will select the last one (D=0 before 1997Q4, D=1 from 1997:Q4 and later on).

The model which came up is the following:

$$l\_USD_t = -3,48046 - 0,243428D + 0,774751 l\_TOT_t + u_t \tag{4}$$

By substituting the D, the former equation can be written as:

$$l\_USD_t = \begin{cases} -3,48046 + 0,774751 l\_TOT_t + u_t & 1984Q1 \le t \le 1997Q3 \\ -3,72389 + 0,774751 l\_TOT_t + u_t & 1997Q4 \le t \le 2012Q2 \end{cases} \quad (5)$$

It is clear that the structural brake which happened on the fourth quarter of 1997 changed the intercept of the cointegrating regression between the l_USD and the l_TOT. Actually the intercept was reduced by 0,243428 units, indicating a rapid depreciation of the AUD which never reverted during the oncoming years.

We can furthermore assume that the slope coefficient has also been affected by the structural brake and apply a similar analysis for the a_4 coefficient of equation (2). In this case the results are not as clear as before and therefore we do not proceed further with this assumption.

3.5. Reasons for the structural brake which happened on 1997

Since the middle of 1997, East Asia has been gripped by an economic, and more latterly a political crisis that shows few signs of recovering. In the space of less than a year the international standing and domestic situations of what were formerly taken to be miracle economies has been dramatically transformed. Major companies have defaulted on their foreign debt repayments, anxious domestic and international investors have relocated or withdrawn vast amounts of capital, inflation and unemployment have increased, and political instability has risen to dangerous levels.

The Asian crisis affected substantially the Australian economy. Especially on June of 1998 the affect was even more direct, leading to steady decline in the value of the A$. Despite rather optimistic government claims about having protected Australia, the A$ is increasingly associated with the troubled East Asian region, and sold down by international currency speculators accordingly. Despite Reserve Bank intervention, the A$ has been rapidly declining to historically low levels, forcing up interest rates as a consequence. The main reason for this situation is that from the 70's until the late 90's, Australia's trade has increasingly been centered on East Asia. North Asia takes 43% of Australia's exports, with Japan alone taking more than 20%. The impact of a recession in these markets is beginning to feed through into balance of trade figures, with the Australian deficit blowing out to record proportions (*The Australian*, 5 May 1998, p. 21.) This is in turn placing greater pressure on the Australian dollar, which as one of the world's most highly traded currencies is very vulnerable to rapid shifts in market sentiment. It should also be pinpointed that Australia's overall economic position when measured by the so-called "fundamentals" was actually worse than Indonesia's before the crisis. This fact contributes to the highly destabilizing tendency of A$.

3.6 Inclusion of the Dummy variable into the currency data (l_USD)

In order to avoid the inclusion of a Dummy variable in our equations, we can create the new variable "ADJ_l_USD" which is the adjusted logarithm of the US$/A$ currency. It is adjusted because it integrates the impact of the Dummy variable into the regressand. Since the role of the Dummy variable is to change the intercept of the regression equation, this change can directly be added to the values of the regressand. Therefore, by reducing the values of l_USD by 0,243428 units in the period before the structural brake, the results which come up are the same.

The new variable ADJ_l_USD is defined as:

$$ADJ\_l\_USD_t = \begin{cases} l\_USD_t - 0{,}243428 & 1984Q1 \le t \le 1997Q3 \\ l\_USD_t & 1997Q4 \le t \le 2012Q2 \end{cases}$$

We now apply the Engle-Granger cointegration test for the ADJ_l_USD and l_TOT variables. We get the results depicted in Table 6. As expected, we can see that there is a cointegrating relationship (asymptotic p-value 2.456e-006). The slope coefficient is the same as before (Table 5) and the new slope coefficient is the sum of the slope coefficient of Table 5 plus the coefficient of the Dummy variable. After all, this was the role of the Dummy variable: to change the intercept term in a specific period of time.

Table 6. Cointegration test between ADJ_l_USD and l_TOT

```
Step 1: cointegrating regression

Cointegrating regression -
OLS, using observations 1984:1-2012:2 (T = 114)
Dependent variable: ADJ_l_USD

             coefficient   std. error   t-ratio    p-value
  ---------------------------------------------------------
  const       -3.72389     0.141818     -26.26    1.11e-049 ***
  l_TOT        0.774751    0.0332332     23.31    8.82e-045 ***

Mean dependent var  -0.422456   S.D. dependent var   0.194711
Sum squared resid    0.732019   S.E. of regression   0.080845
R-squared            0.829132   Adjusted R-squared   0.827606
Log-likelihood       125.9854   Akaike criterion    -247.9708
Schwarz criterion   -242.4984   Hannan-Quinn        -245.7498
rho                  0.717253   Durbin-Watson        0.518188

Step 2: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including one lag of (1-L)uhat (max was 4)
sample size 112
unit-root null hypothesis: a = 1

   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: 0.029
   estimated value of (a - 1): -0.374844
   test statistic: tau_c(2) = -5.84712
   asymptotic p-value 2.456e-006

There is evidence for a cointegrating relationship if:
(a) The unit-root hypothesis is not rejected for the individual variables.
(b) The unit-root hypothesis is rejected for the residuals (uhat) from the
    cointegrating regression.
```

The model which includes the ADJ_l_USD regressand instead of l_USD is:

$$ADJ\_l\_USD_t = -3{,}72389 + 0{,}774751 l\_TOT_t + u_t \qquad (6)$$

By examining model (6) there appears to be a nearly one-to-one long-run relationship between the terms of trade and the nominal exchange rate. This result confirms the popular view of the AUD as a “commodity currency” driven by the terms of trade.

3.7 Error correction mechanism (ECM)

We have shown that ADJ_l_USD and l_TOT series are cointegrated, that is, they have a long-term, or equilibrium, relationship. We will now examine how this equilibrium is achieved and if there may be a disequilibrium in the short-run.

We rewrite the equation (6) as:

$$u_t = ADJ\_l\_USD_t + 3{,}72389 - 0{,}774751 l\_TOT_t \tag{7}$$

The error term in equation (7) can be treated as the equilibrating term that corrects deviations of ADJ_l_USD from its equilibrium value given by the cointegrating regression (6). This is called the **error correction mechanism (ECM)**.

According to the Granger Representation Theorem, if two variables are cointegrated, the relationship between them can be expressed as an ECM. In case we are dealing with more than one variable, the counterpart of ECM that we should use is known as the **vector error correction model (VECM).** To do this we first need to determine the lag order of the VECM. Since the VECM is actually a VAR model, we can estimate the optimum lag order by the “VAR lag selection” command in the Gretl software (Endogenous variables: ADJ_l_USD and l_TOT, including a constant, maximum lag order = 6):

Table 7. VAR lag selection

```
VAR system, maximum lag order 6

The asterisks below indicate the best (that is, minimized) values
of the respective information criteria, AIC = Akaike criterion,
BIC = Schwarz Bayesian criterion and HQC = Hannan-Quinn criterion.

lags        loglik    p(LR)       AIC          BIC          HQC

   1     409.95693            -7.480684    -7.331677    -7.420267
   2     429.68611  0.00000   -7.771965*   -7.523620*   -7.671270*
   3     432.89043  0.17064   -7.757230    -7.409547    -7.616257
   4     434.96987  0.38493   -7.721664    -7.274642    -7.540413
   5     436.56927  0.52512   -7.677209    -7.130849    -7.455680
   6     438.53399  0.41564   -7.639518    -6.993820    -7.377711
```

It derives from Table 7 that the optimum lag selection is 2, according to all the three criteria (Akaike, Schwarz and Hanna-Quinn).

We can now estimate a VECM of the ADJ_l_USD and l_TOT by setting the lag order equal to 2. The results are depicted in Table 8 and according to them the error correction term is expressed as:

$$e_t = ADJ\_l\_USD_t + 3{,}8370 - 0{,}79977 l\_TOT_t \tag{8}$$

Table 8. VECM estimation

```
VECM system, lag order 2
Maximum likelihood estimates, observations 1984:3-2012:2 (T = 112)
Cointegration rank = 1
Case 2: Restricted constant
beta (cointegrating vectors, standard errors in parentheses)

ADJ_l_USD                  1.000     (0.00000)

l_TOT                     -0.79977   (0.058783)

const                      3.8370    (0.24997)

alpha (adjustment vectors)

ADJ_l_USD                 -0.24600
l_TOT                     0.091782

Log-likelihood = 441.74705
Determinant of covariance matrix = 1.2858451e-
006
AIC = -7.7455
BIC = -7.5513
HQC = -7.6667

Equation 1: d_ADJ_l_USD
                          Coefficient  Std. Error   t-ratio    p-value

d_ADJ_l_USD_1              0.356155     0.097602     36.491     0.00041   ***
d_l_TOT_1                 -0.318349     0.173918    -18.305     0.06994   *
EC1                       -0.246004    0.0711088    -34.595     0.00078   ***

Mean dependent var          0.003288              S.D.          0.056786
                                                  dependent
                                                  var
Sum squared resid           0.296617              S.E.    of    0.052407
                                                  regression
R-squared                   0.174119              Adjusted      0.151178
                                                  R-squared
rho                         0.002027              Durbin-      1.985.419
                                                  Watson

Equation 2: d_l_TOT

                          Coefficient  Std. Error   t-ratio    p-value

d_ADJ_l_USD_1             0.0995946    0.0442149     22.525     0.02631   **
d_l_TOT_1                  0.399139     0.078787     50.660    <0.00001   ***
EC1                       0.0917824    0.0322131     28.492     0.00525   ***

Mean dependent var          0.005436              S.D.          0.028906
                                                  dependent
                                                  var
Sum squared resid           0.060872              S.E.    of    0.023741
                                                  regression
R-squared                   0.366292              Adjusted      0.348689
                                                  R-squared
rho                        -0.086131              Durbin-      2.171.461
                                                  Watson
```

This is slightly different than equation (7) because of the the VECM uses a different method to calculate the parameters.

By excluding the terms which have statistical significance below the 5% level, the following equations derive from Table 8:

$$\Delta ADJ\_l\_USD_t = 0,356155\Delta ADJ\_l\_USD_{t-1} - 0,246004e_{t-1} \tag{9}$$

$$\Delta l\_TOT_t = 0,0995946\Delta ADJ\_l\_USD_{t-1} + 0,399139\Delta l\_TOT_{t-1} + 0,0917824e_{t-1} \tag{10}$$

Note: Δ is the first difference operator and EC1 in Table 8 is the lagged error correction term.

We can now see how VECM ties short-run dynamics to long-run relations via the error correction term. In these two equations, the slope coefficients of the e_t terms are known as **error correction coefficients**, because they show how much ΔADJ_l_USD and Δl_TOT adjust to equilibrating error in the previous period. It should also be noted that the error correction coefficients have opposite signs because there is only one equilibrium relation between the variables.

In equation (9) The coefficient of about 0,36 shows that a 1% increase in ΔADJ_l_USD will lead on average to a 0,31% increase in ΔADJ_l_USD in the next quarter. This is a short-run relation. The error correction coefficient of about -0,25 suggests that about 25% of the discrepancy between long-term and short-term ADJ_l_USD is corrected within a quarter, that is the rate of adjustment to equilibrium. By employing additional variables (e.g. interest rates), probably we might have seen a different result.

Equation (10) shows that the short term relationship between ADJ_l_USD and l_TOT has bilateral causality. The coefficient of about 0,1 shows that a 1% increase in the ΔADJ_l_USD will lead on average to a 0,1% increase in Δl_TOT in the next quarter. Also a coefficient of the Δl_TOT_{t-1} indicates that a 1% increase in the Δl_TOT will lead on average to a 0,4% increase in Δl_TOT in the next quarter. The error correction coefficient of about -0,09 suggests that only about 9% of the discrepancy between long-term and short-term l_TOT is corrected within a quarter.

One possible explanation for changes in the exchange rate to have an impact on the terms of trade is incomplete exchange rate passthrough, and the positive link would indicate that passthrough is less for exports than for imports. In other words, an appreciation of the AUD will instantly lead to decreased import prices (expressed in AUD). It should also lead to a corresponding decrease of the export prices (expressed in AUD), but this change does not take place as fast as the first one. So the nominator of the terms of trade formula is less reduced than the denominator, therefore the terms of trade tend to increase. We can conclude that for export prices the response to exchange rate changes was considerably lagged, giving rise to some degree of endogeneity in the terms of trade.

3.8 Further VECM study and CUSUM tests

Initially we will examine the function which describes how the first difference of the ADJ_l_USD is explained by the model which includes the lagged first difference of ADJ_l_USD and the lagged error correction term from equation (8). So, we estimate an OLS regression model, with the following variables:

ΔADJ_l_USD$_t$ (exogenous)
ΔADJ_l_USD$_{t-1}$ (endogenous)
e$_{t-1}$ (endogenous)

The e_{t-1} term is symbolized as ECT_1. The results are depicted in Table 9 and the following model is derived:

$$\Delta ADJ\_l\_USD_t = 0{,}34936 \Delta ADJ\_l\_USD_{t-1} - 0{,}271007 e_{t-1} + u_t \tag{11}$$

By substituting the error correction term, the following equivalent model comes up:

$$\begin{aligned}
&\Delta ADJ_l_USD_t = 0{,}34936 \Delta ADJ_l_USD_{t-1} - \\
&0{,}271007\left(ADJ_l_USD_{t-1} + 3{,}8370 - 0{,}79977 l_TOT_{t-1}\right) + u_t \Leftrightarrow \\
&ADJ_l_USD_t - ADJ_l_USD_{t-1} = 0{,}34936\left(ADJ_l_USD_{t-1} - ADJ_l_USD_{t-2}\right) - \\
&0{,}271007\left(ADJ_l_USD_{t-1} + 3{,}8370 - 0{,}79977 l_TOT_{t-1}\right) + u_t \Leftrightarrow \\
&ADJ_l_USD_t = 1{,}078353 ADJ_l_USD_{t-1} - 0{,}34936 ADJ_l_USD_{t-2} + \\
&0{,}21674 l_TOT_{t-1} - 1{,}09385 + u_t
\end{aligned} \tag{12}$$

Table 9. OLS regression model on ΔADJ_l_USD

Model 6: OLS, using observations 1984:3-2012:2 (T = 112)
Dependent variable: d_ADJ_l_USD
HAC standard errors, bandwidth 3 (Bartlett kernel)

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
ECT_1	-0.271007	0.0698274	-3.8811	0.00018	***
d_ADJ_l_USD_1	0.34936	0.11149	3.1336	0.00221	***

Mean dependent var	0.003288	S.D. dependent var	0.056786
Sum squared resid	0.305832	S.E. of regression	0.052728
R-squared	0.148462	Adjusted R-squared	0.140721
F(2, 110)	8.629505	P-value(F)	0.000330
Log-likelihood	171.6592	Akaike criterion	-339.3184
Schwarz criterion	-333.8814	Hannan-Quinn	-337.1124
Rho	-0.002952	Durbin-Watson	2.000269

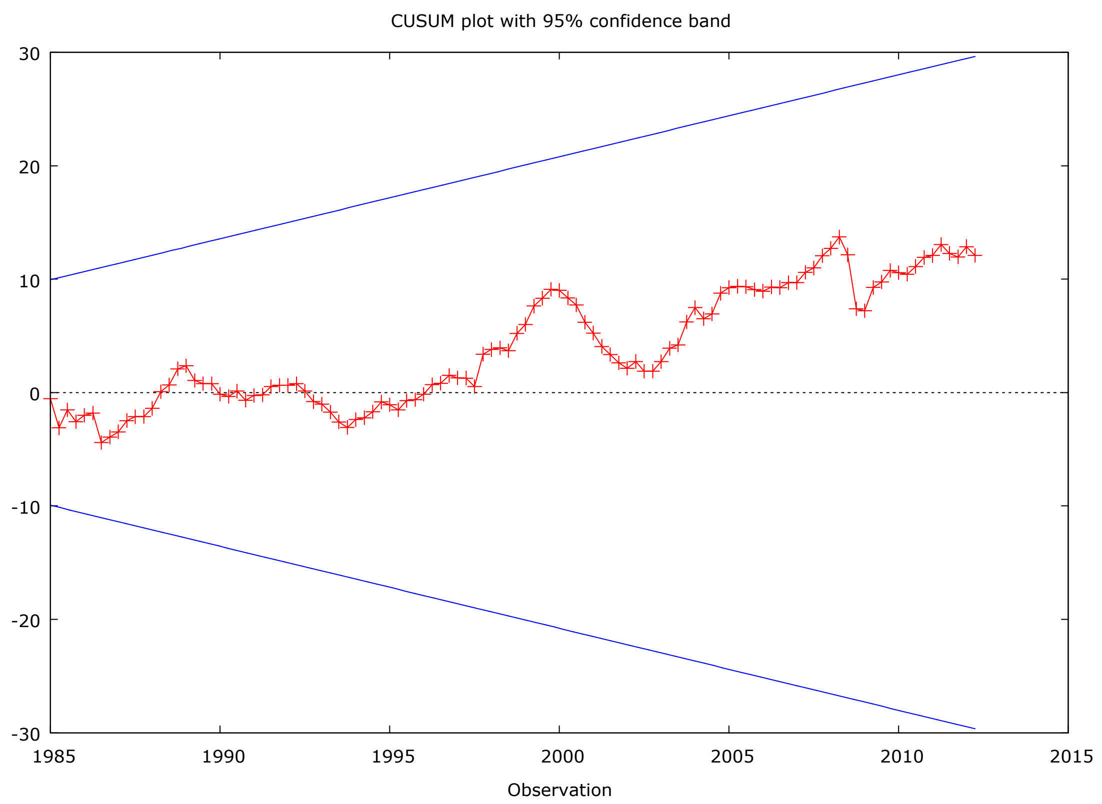
We can now see how VECM combines the long-rum equilibrium with short-run dynamics to reach that equilibrium.

In order to study the stability of the parameters in model (11), we will perform **recursive estimation tests**. Recursive estimation involves starting with a sub-sample of the data, estimating the regression, then sequentially adding one observation at a time and re-running the regression until the end of the sample is reached. It is to be expected that the parameter estimates produced near the start of the recursive procedure will appear rather unstable since these estimates are being produced using so few observations, but the key question is whether they then gradually settle down or whether the volatility continues through the whole sample. Seeing the latter would be an indication of parameter instability.

Two important stability tests, known as the CUSUM and CUSUMSQ tests, are derived from the residuals of the recursive estimation. Strictly, they are based on the one-step ahead prediction errors – i.e. the differences between y_t and its predicted value based on the parameters estimated at time t-1. (See Greene (2002, chapter 7) for full technical details.) The CUSUM statistic is based on a normalized version of the cumulative sums of the residuals. Under the null hypothesis of perfect parameter stability, the CUSUM statistic is zero however many residuals are included in the sum (because the expected value of a disturbance is always zero). A set of ±2 standard error bands is usually plotted around zero (95% confidence band) and any statistic lying outside the bands is taken as evidence of parameter instability. The CUSUMSQ test is based on a normalized version of the cumulative sums of squared residuals. The scaling is such that under the null hypothesis of parameter stability, the CUSUMSQ statistic will start at zero and end the sample with a value 1. Again, a set of ±2 standard error bands is usually plotted around zero (95% confidence band) and any statistic lying outside these is taken as evidence of parameter stability.

By performing the CUSUM test on model (11), we receive the results depicted in Figure 2.

Figure 2. CUSUM test on model (11)

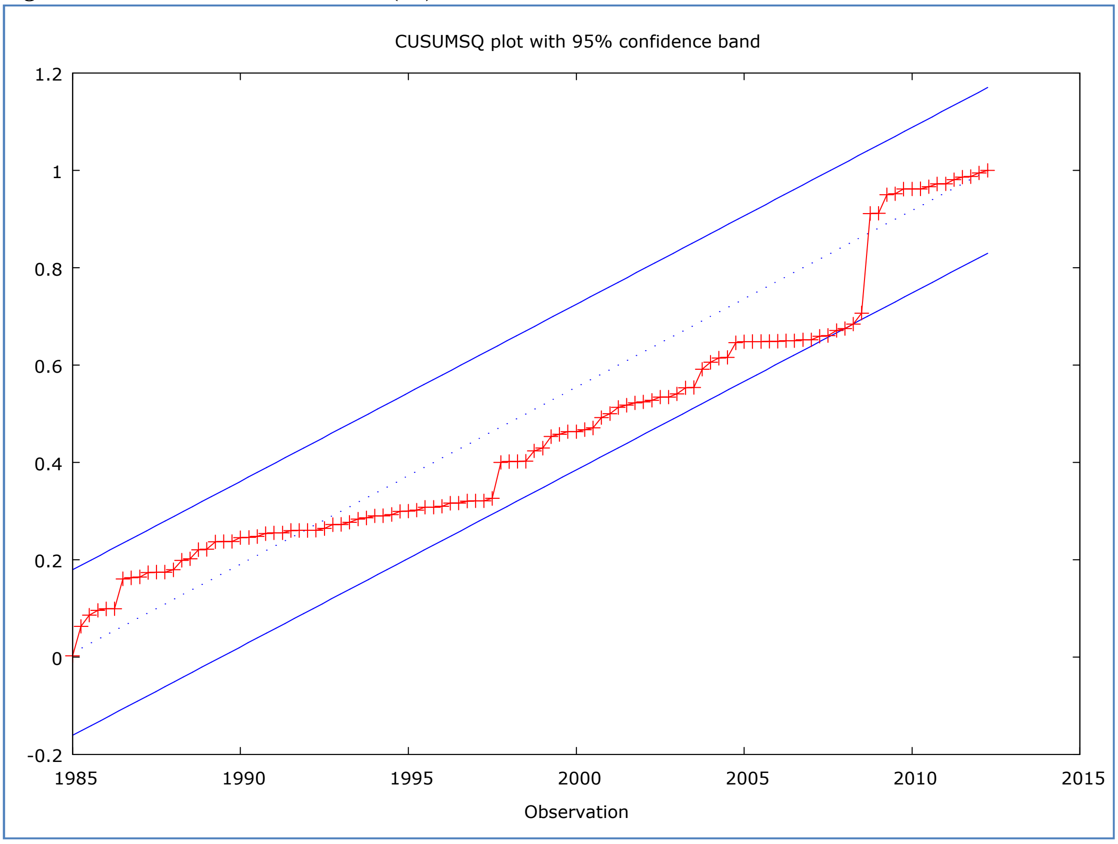


CUSUM test for parameter stability -
Null hypothesis: no change in parameters
Test statistic: Harvey-Collier t(109) = 1.15341
with p-value = P(t(109) > 1.15341) = 0.251264

According to figure 2, since the line is well within the confidence bands, the conclusion would be that the null hypothesis of parameter stability is not rejected. The p-value confirms this observation, which is about 0,25 (much higher than 0,05).

Now we repeat the above but using the CUSUMSQ test rather than CUSUM. The results are depicted in Figure 3.

Figure 3. CUSUMSQ test on model (11)



According to figure 3, the line is again well within the confidence bands, but there are two points where the confidence band is marginally exceeded. Nevertheless, the conclusion of parameter stability should not be rejected.

Since the VECM has revealed a bilateral causality between ADJ_l_USD and l_TOT, we will also examine the function which describes how the first difference of the l_TOT is explained by the model which includes the lagged first difference of ADJ_l_USD, the lagged difference of l_TOT and the lagged error correction term from equation (8). So, we estimate an OLS regression model, with the following variables:

Δl_TOT_t (exogenous)

$\Delta ADJ\_l\_USD_{t-1}$ (endogenous)

Δl_TOT_{t-1} (exogenous)

e_{t-1} (endogenous)

The e_{t-1} term is symbolized as ECT_1.The results are depicted in Table 10.

Table 10. OLS regression model on Δl_TOT

Model 4: OLS, using observations 1984:3-2012:2 (T = 112)
Dependent variable: d_l_TOT
HAC standard errors, bandwidth 3 (Bartlett kernel)

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
ECT_1	0.0918148	0.0361068	2.5429	0.01240	**
d_ADJ_l_USD_1	0.0995722	0.0388792	2.5611	0.01180	**
d_l_TOT_1	0.399086	0.0540962	7.3774	<0.00001	***

Mean dependent var	0.005436	S.D. dependent var	0.028906
Sum squared resid	0.060868	S.E. of regression	0.023631
R-squared	0.366325	Adjusted R-squared	0.354698
F(3, 109)	22.70057	P-value(F)	1.71e-11
Log-likelihood	262.0611	Akaike criterion	-518.1221
Schwarz criterion	-509.9666	Hannan-Quinn	-514.8132
rho	-0.086104	Durbin's h	-1.104029

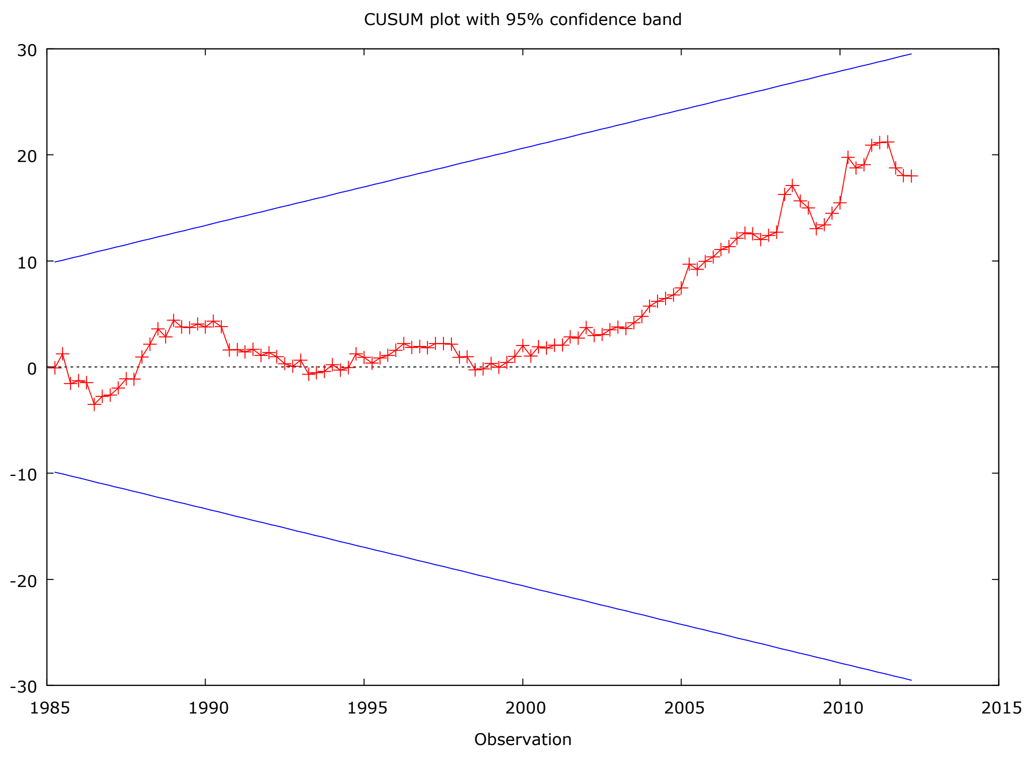
The following model is derived:

$$\Delta l\_TOT_t = 0{,}0995722 \Delta ADJ\_l\_USD_{t-1} + 0{,}399086 \Delta l\_TOT_{t-1} + 0{,}0918148 e_{t-1} + u_t \qquad (13)$$

By performing the CUSUM test on model (13), we receive the results depicted in Figure 4. According to these, since the line is again within the confidence bands, the conclusion would be that the null hypothesis of parameter stability is not rejected. The p-value confirms this observation only on the 5% interval, which is about 0,09 (just a little lower than 0,1).

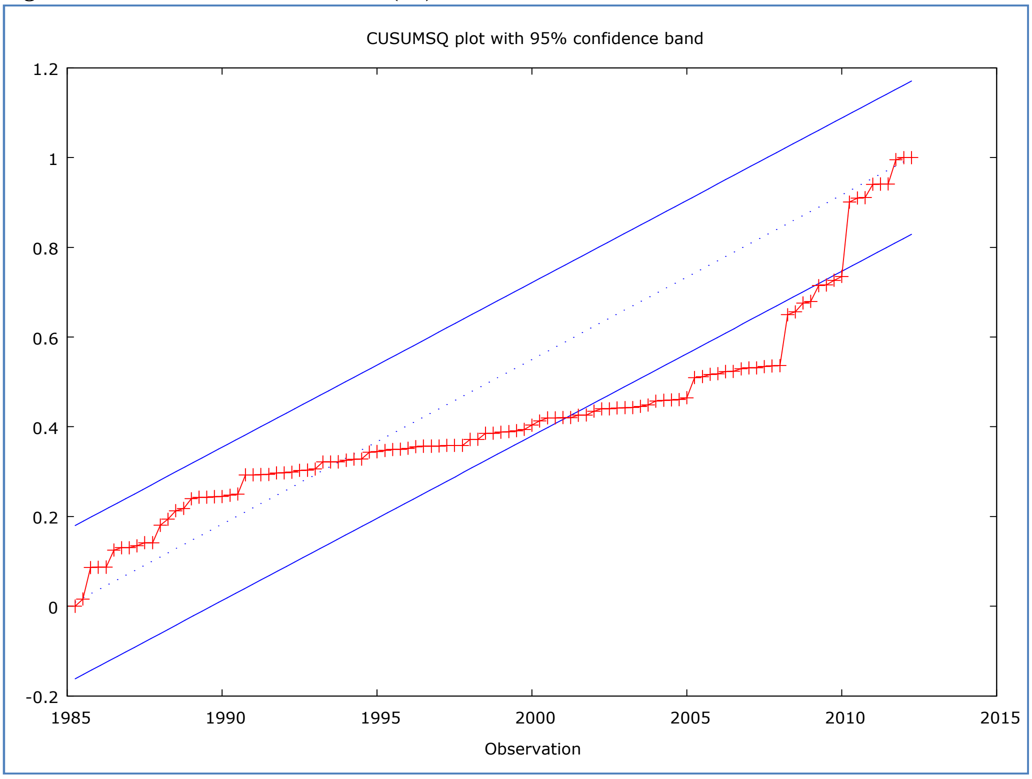
Now we repeat the above but using the CUSUMSQ test rather than CUSUM. The results are depicted in Figure 5. The CUSUMSQ test clearly indicates that we should not retain the same conclusion as before because there are many points exceeding the 5% confidence interval, therefore the parameter stability hypothesis is rejected. This is not a surprise because of the fact that only a fraction of the changes in the Terms of Trade can be explained by the changes in the USD/AUD currency. Additional parameters should be included in order to make a reliable model with stable parameters.

Figure 4. CUSUM test on model (13)



CUSUM test for parameter stability -
Null hypothesis: no change in parameters
Test statistic: Harvey-Collier t(108) = 1.72449
with p-value = P(t(108) > 1.72449) = 0.0874796

Figure 5. CUSUMSQ test on model (13)



4. Summary and Conclusions

Using Australian quarterly data from the post-float period 1984:1-2012:Q2, we find one steady-state relationship between the nominal exchange rate (USD/AUD) and the Australian Terms of Trade, and hence an error adjustment mechanism, suggesting that the transition from one equilibrium to another is attended by interactions between commodity markets and currencies. In Australia, the terms of trade themselves correlate highly with phases of the world commodity price cycle, confirming the extensive influence of fluctuating commodity prices as the mechanism that delivers external shocks to the exchange rate. This direct link between commodity prices and the USD/AUD nominal exchange rate lies at the heart of the "commodity currency" view of the Australian Dollar. According to this view, the $A appreciates (depreciates) when the prices of certain commodities exported by Australia, e.g., coal, metals, and other primary industrial materials, rise (fall) in international markets. A *ceteris paribus* increase in commodity prices, which improves the Australian terms of trade, boosts export income, and generates a trade surplus, will stimulate foreign demand for Australian dollars and will initially cause the $A to appreciate.

In the cointegrating relation (6), the coefficient of l_TOT is the elasticity of the exchange rate currency to the Terms of Trade. Thus, in the long run, a 1% increase in the Terms of Trade causes an appreciation of the AUD of 0,775% with a standard error of 0,033. Therefore a world commodity price boom should be considered as a positive demand shock that causes an appreciation of the AUD.

Having identified and estimated the long-run equilibrium exchange-rate equation, we have also examined the speed-of-adjustment coefficients. The error correction term is interpreted as a disequilibrium term. The coefficients of the error correction term are statistically significant in both VECM equations and with opposite signs, leading to the assumption that there is only one equilibrium relation between the variables. Deviations of the exchange rate currency from the equilibrium will be corrected about 25% within a quarter, whereas deviations of the Terms of Trade equilibrium will be corrected about 9% within a quarter.

Furthermore the estimated error-correction models provided some evidence that the causality between the Terms of Trade and the exchange rate currency is bilateral, hence the Terms of Trade are also affected by changes in the currency. A reasonable explanation is the asymmetrical exchange rate passthrough to the import prices compared to the export prices. This finding indicates that the assumption of Australia's being an international price-taker is inadequate when modeling the US$/A$ exchange rate.

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