# Modelling the US$/A$ Exchange Rate Using Cointegration Techniques

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**Abstract:**

*Recent evidence indicates that Australia's real effective exchange rate, its terms of trade and a long-term real interest rate differential form a cointegrating relationship. This paper uses this evidence to analyse the nominal US$/A$ exchange rate. The US$/A$ rate is found to be cointegrated with the terms of trade and relative price levels. However, interest rate differentials appear to add nothing to this long-run relationship. Estimated error correction models suggest that there is a substantial two-way relationship between nominal exchange rate changes and changes in the terms of trade. This evidence indicates that the small, open-economy assumption of exogenously given terms of trade may be inappropriate when modelling movements in the US$/A$ exchange rate. Changes in a long-run interest rate differential, possibly reflecting differences in expected inflation rates, contribute significantly to an explanation of short-run changes in the nominal exchange rate.*

**KeyWords:** Exchange Rates; Terms of Trade; Interest Parity; Purchasing Power Parity; Cointegration
**JEL Classifications:** F31 and F41

## 1. Introduction

It has been contended for some time that movements in Australia's real exchange rate are influenced substantially by changes in the terms of trade. This view has been corroborated by the work of Gruen and Wilkinson (1994) which establishes, by the use of cointegration techniques, a long-run (albeit weak) relationship between Australia's real effective exchange rate and its terms of trade.[2] This relationship, they find, is augmented by the effect of a long-run real interest rate differential af-

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1. This research was undertaken while Phipps was on study leave at the University of Macedonia. He would like to express his appreciation to the University, particularly to the staff of the Economics Department, for their kind hospitality and for the use of their excellent facilities.

2. A similar relationship has been established by Amano and van Norden (1995) for Canada which, like Australia, is an open, primary-commodity exporting country.

ter the float of the A$, so that in the post-float period both the terms of trade and a long-run real interest rate differential contribute to a stable relationship with the real exchange rate. The main aim of this paper is to see whether this information can be usefully employed to model both the long-run and short-run behaviour of the US$/A$ nominal exchange rate.

The model preferred by Gruen and Wilkinson for explaining the terms of trade/real exchange rate nexus appears to be that set out by Blundell-Wignall and Gregory (1990) whose empirical work also provided support for the link between the real value of the A$ and the terms of trade. The model of Blundell-Wignall and Gregory, essentially that of a small, open, commodity-exporting country like Australia, New Zealand or Canada is set out in Appendix I. The exporting country produces two goods, an export good and a non-traded good, and is a price taker for both its exports and imports. The proportion of (exogenously given) total output devoted to the supply of the export good varies positively with the domestic-currency price of exports relative to the price of non-traded goods. The share of aggregate demand devoted to the non-traded good varies negatively with the price of non-traded goods relative to the domestic-currency price of imports. Given that domestic output is fixed exogenously, at the natural rate say, the supply of the non-traded good and the demand for imports are determined residually. Blundell-Wignall and Gregory define the real exchange rate as the nominal exchange rate adjusted by the ratio of the price of imports to the price of non-traded goods but simplify matters by holding the foreign currency price of imports constant. This implies that variations in the terms of trade are synonymous with changes in the foreign currency price of exports - a not unrealistic assumption for Australia where volatile world commodity prices seem to drive the terms of trade. Blundell-Wignall and Gregory examine the impact of an improvement in the terms of trade in an environment in which the nominal exchange rate is depreciating at a rate determined by domestic inflation, and the real exchange rate and real monetary balances are initially constant. A rise in the price of exports shifts domestic output towards the supply of exports which, given output at the natural rate, reduces the supply of non-traded goods. The ensuing excess demand drives up the price of the non-traded good and, other things equal, appreciates the real exchange rate. What happens to the rate of inflation and the nominal exchange rate will then depend crucially on the monetary and exchange rate policies pursued. Tight monetary policy aimed at stabilising inflation would be expected to appreciate the nominal exchange rate. Whereas, relatively loose monetary policy and a relatively higher expected inflation rate would be expected to reduce the impact of any improvement in the terms of trade on the nominal exchange rate and increase its on impact on the general price level.

In spite of the general appeal of both the empirical work of Gruen and Wilkinson and the model of Blundell-Wignall and Gregory, they raise important questions and issues. The first question, prompted by the empirical work of Gruen and Wilkinson, is the 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. Given the estimated cointegrating relationship, it ought to be possible to express the nominal exchange rate as a function of the terms of trade and relative price levels. If additionally uncovered interest parity (UIP) holds, it should be possible to establish the dependence of the nominal exchange rate on the terms of trade, relative price levels and a short-run interest rate differential (proxying UIP). Casual observation of Figure 1 suggests that the nominal US$/A$ exchange rate moves with the terms of trade. However, the extent to which the nominal exchange rate embodies changes in relative price levels and interest rate differentials remains a subject for investigation. Furthermore, if cointegration among the variables listed above can be established for the US$/A$, then it should also be possible, given the Granger representation theorem, to explore the short-run dynamics of such a relationship by way of standard error correction (EC) models.

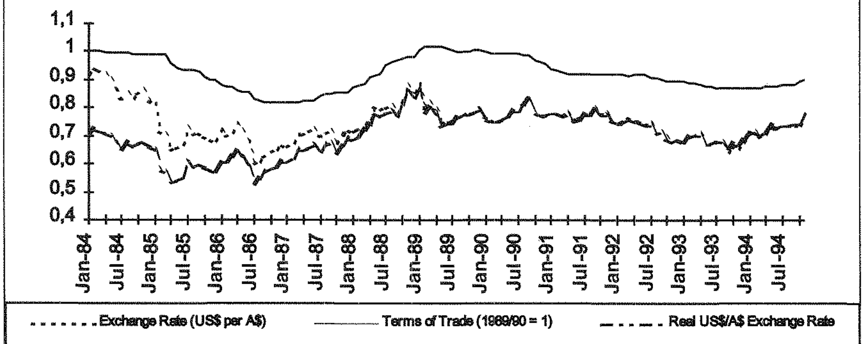
A second and perhaps equally important issue raised by the Blundell-Wignall and Gregory and Gruen and Wilkinson results is whether or not, given a long-run cointegrating relationship between the real exchange rate and the terms of trade, causality runs solely from changes in the terms of trade to changes in the exchange rate. It is not obvious that, as in the Blundell-Wignall and Gregory model, causality should be one way only. Strict uni-directional causality is crucially dependent on the assumption that the country in question is an international price taker ie on the assumption that the *foreign* currency prices of both exports and imports are given exogenously. 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.[3] 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. If there is 'incomplete exchange rate pass-through' to either export or import prices, as a result of 'pricing to market' for example, a change in the exchange rate will alter the terms of trade.[4] If the degree of 'exchange rate pass-through' is less for exports than for imports, a depreciation of the A$ will raise the A$ price of exports less in proportional terms than it will raise the A$ price of imports leading to a deterioration in the terms of trade; a positive relationship be-

3 The terms of trade (*TOT*) equal $p_x / p_m$, where $p_x$ and $p_m$ are the domestic currency prices of exports and imports respectively. Given $p_i = p^*_i / e; i = x$ and $m$, where $p^*_i$ is the foreign currency price of good *I* and e is the foreign currency price of the domestic currency, *TOT* $= (p^*_x / e) / (p^*_m / e)$. If $p^*_x$ and p*m are given exogenously, any change in e leaves *TOT* unchanged.

4 Only in the unlikely event of the degree of incomplete pass-through being the same for both export and import prices would the exchange rate be unaffected.

tween exchange rate changes and changes in the terms of trade. If the degree of 'exchange rate pass-through' is less for imports than for exports, there will be a negative relationship between changes in the exchange rate and terms of trade.

**Figure 1: Real and Nominal US$/A$ Exchange Rates and the Terms of Trade**




The evidence on exchange rate pass-through in Australia is mixed. On the one hand, there is much anecdotal evidence of foreign companies 'pricing to market' to protect their share of the Australian market. If this anecdotal evidence were reliable, we should expect to find some reverse causation running from exchange rate changes to changes in the terms of trade. On the other hand, the recent econometric evidence indicates that pass-through in import prices is complete and fairly rapid, while that in export prices is much slower.[5] However, the two most recent pieces of evidence look only at the relationship between the TWI and aggregate import and export price indices. It is possible that the degree of pass-through varies substantially from one trade partner to another and hence from one currency to another.

5. "It was shown that import prices over the docks respond fairly quickly to changes in the exchange rate. This was contrary to the experience of export prices, where response to exchange rate change was considerably lagged, giving rise to some degree of endogeneity in the terms of trade." (Dwyer, Kent and Pease 1994, p419) and "First stage pass-through is fast and unambiguously complete. Second stage pass-through is also complete but, because of the existence of domestic costs, the retail import price does not move by the same proportion as the over-the-docks price. Furthermore, the adjustment process is very slow." (Dwyer and Lam 1995, p173) For a general survey of exchange rate pass-through see Menon (1995).
6. See Lewis (1994) for a discussion of alternative explanations and a survey of related international empirical evidence.
7. See Karfakis and Phipps (1994) for evidence that financial markets anticipated such intervention in the second half of the 1980s.
8. See Simes (1989) for the successful combining of an estimated exchange rate equation, involving an interest rate differential, and a monetary policy reaction function.

The question of causality between the terms of trade and the nominal exchange rate and hence the degree of endogeneity of the terms of trade may be examined by EC modelling and estimation of the relationship between changes in the terms of trade and changes in the exchange rate. A finding of substantial causality running from exchange rate changes to changes in the terms of trade will indicate that the assumption of Australia's being an international price taker is inadequate when modelling the US$/A$ exchange rate. If such reverse causality exists, the sign will indicate whether the degree of exchange rate pass-through is more pronounced for imports than for exports or *vice versa.*

A third question raised by the work of Gruen and Wilkinson concerns the role of interest rate differentials in the cointegrating relationship. In Australia as elsewhere, it has been difficult to establish a convincing empirical role for interest rate differentials in the determination of exchange rates.[6] This has frequently been attributed to a government reaction function in which tight monetary policy and high interest rates have, in certain periods, been invoked to defend a rapidly depreciating A$.[7] This is a manifestation of the Lucas problem and argues for simultaneous estimation of the exchange rate equation and a government monetary policy reaction function.[8] However, alternative explanations include: a large and variable 'risk premium'; irrational expectations of agents in foreign exchange markets; and rational expectations where the information set of agents differs from that of researchers, either because of slow learning or because those agents anticipate a change which does not manifest itself in researchers' data (eg 'peso problems').

In the light of the above discussion, the objectives of this study are:

1. To explore by time-series methods, in particular cointegration and EC modelling, the relationships between Australia's terms of trade and the nominal value of the US$/A$ exchange rate.
2. To examine the ancillary roles of price level and interest rate differentials in any cointegrating, long-run relationship for the A$.
3. To examine, by estimating dynamic EC models, the short-run relationships between the A$, the terms of trade and price and interest rate differentials.

An analytical framework for the empirical analysis is set out in Section II. The data employed is discussed in Section III, while the empirical results of the cointegration and EC modelling are presented in Section IV. Conclusions are drawn tentatively in the final Section.

## 2. Analytical Framework

The starting point of our analysis is a less restrictive version of the model estimated by Gruen and Wilkinson. We assume that, in the long run, the nominal exchange value of the A$ is determined by the terms of trade and by price level differentials. We assume further that expectations about the long-run value of the A$ are similarly determined. Thus

$$E(e_t+1) = a + bTOT_t + c(p_t - p^*_t)\,; \qquad b > 0, c < 0 \tag{1}$$

where $E(e_t+1)$ is the expected nominal exchange rate (expressed as the number of US$s per A$), p* is the price level in the USA, p is the Australian price level, TOT is the terms of trade (all variables being expressed in logarithms). If purchasing power parity (PPP) holds in the absence of changes in the terms of trade, c = -1. We further assume that uncovered interest parity (UIP) holds so that

$$E(e_t+1) - e_t = i^*_{S,t} - i_{S,t} \tag{2}$$

Where $i^*_S$ and $i_S$ are short-run interest rates for the USA and Australia respectively. Substituting (2) into (1) gives

$$e_t = a + bTOT_t + c(p_t - p^*_t) + k(i_{S,t} - i^*_{S,t})\,; k > 0 \tag{3}$$

Note that this formulation implies that the market forms its expectations about the *nominal* exchange rate. Our introductory remarks on the Blundell-Wignall and Gregory model also suggest that the extent to which changes in the terms of trade flow through to changes in the nominal exchange rate may depend on the anticipated monetary policy stance of the Reserve Bank of Australia (RBA) and hence on the relative expected inflation rate. In subsequent analysis, we employ a long-run interest rate differential as an indicator of the anticipated stance of Australian monetary policy relative to that in the USA. An increase in the long-term interest rate differential favouring Australia would indicate a relative easing of monetary policy in Australia and an anticipation of relatively higher inflation in the future. We should expect this to lead, other things equal, to a depreciation of the A$

The above discussion indicates that there should be a stable relationship among the following variables: the nominal exchange rate for the US$/A$, Australia's terms of trade and appropriate interest rate and price level differentials. The anticipated policy stance of the Australian monetary authorities and relative expected inflation rates may also have a role to play. We intend to explore possible long-run relationships among such variables by means of cointegration techniques and to investigate the short-run dynamics of such relationships by estimating associated error correction models.

## 3. Data

Because we are exploring nominal exchange rates rather than real exchange rates and because nominal exchange rate determination clearly changed after the deregulation of foreign exchange and other financial markets in Australia in the early 1980s, we have restricted our empirical work to the period after the floating of the A$ in December 1983. To provide an adequate number of degrees of freedom and to reflect as well as possible the rapid speed of adjustment in asset markets, we decided to employ monthly rather than quarterly data. This poses a problem: terms of trade data and CPI data for Australia are provided on a quarterly basis only. We attempt to overcome the problems in two different ways. We interpolate missing observations in the terms of trade data by replicating the data for each month of the quarter and then applying a smoothing process. This is discussed further in Appendix III. We proxy general price levels by data on the price of manufactures which are available on a monthly basis for both Australia and the US.

For the purpose of estimation, we have employed the following operational counterparts to the variables used in equation (3):

- lnXR: the log of the US$ /A$ exchange rate, expressed as the number of US$s per A$ - data extracted from the RBA file in DXDATA
- lnTT: the log of Australia's terms of trade - data from the Australian Bureau of Statistics (ABS) file in DXDATA
- PDIF: the log of the price of Australian manufactured output minus the log of the price of US manufactures - data from OECD file in DXDATA
- IDIFS: the Australian 3 month Treasury Note rate minus the US 3 month Treasury Bill rate - data from the RBA file in DXDATA
- IDIFL: the Australian 5 year government bond rate minus the US 5 year government bond rate - data from the RBA file in DXDATA

## 4. Empirical Results

*(i) Integration Analysis*

Before proceeding with cointegration analysis, it is important to establish the order of integration of the series to be used. Unit-root tests for the levels of the series for the full sample period are reported in Table A1 in Appendix II. The augmented Dickey-Fuller (ADF) test cannot reject the null hypothesis of a unit root in the levels of all the series except for *PDIF*.[9] In the cases where simple observation of the ADF(k) - (k = 0,1,2,3 being the number of lags of the dependent variable included in the ADF equation) - produced an ambiguous conclusion, LM tests for serial correlation indicate that the starred values are sufficient to eliminate the problem and hence are appropriate. The hypothesis of a unit root in the

9 Phillips -Perron tests which confirm the ADF results have also been performed. These may be obtained from the authors upon request.

first differences is rejected at the 5% significance level for all series. We conclude that all the series are first difference stationary with the possible exception of *PDIF* whose status is unclear. However, inspection of the correlogram for PDIF at sixty lags indicates that the series is almost certainly I(1).

*(ii) Cointegration Analysis.*

Since for the US$/A$ we have a set of potentially dependent, stochastic variables with I(1) processes, we have postulated a VAR model to capture any long-run relationship among them. We test for cointegration and estimate any cointegrating vectors using the Johansen maximum likelihood procedure. However, before using the Johansen method, it is essential to select the optimum lag length for the VAR. Our selection of lag structure is based on Sims'(1980) LR test. The tests for lag length and cointegration are undertaken for the full sample period 1984 (1) - 1994(11). The Sims' LR test indicates that:

1. for the system involving *lnXR* and *lnTT,* 1 lag is appropriate (1 lags is as good as 2 lags, $\chi^2(4) = 0.85$ with a p-value of 0.93)
2. for the system involving *lnXR, lnTT* and *PDIF,* 4 lags are appropriate (4 lags are as good as 5 lags, $\chi^2(9) = 11.56$ with a p-value of 0.24 and 4 lags are better than 3, $\chi^2(9) = 26.54$ with a p-value of 0.00),
3. for the system involving *lnXR, lnTT, PDIF* and *IDIFS,* 4 lags are appropriate (4 lags are as good as 5 lags, $\chi^2(16) = 14.33$ with a p-value of 0.57 and 4 lags are better than 3, $\chi^2(16) = 32.41$ with a p-value of 0.00).
4. for the system involving *lnXR, lnTT, PDIF* and *IDIFL*, 4 lags are appropriate (4 lags are as good as 5 lags, $\chi^2(16) = 24.53$ with a p-value of 0.08 and 4 lags are better than 3, $\chi^2(16) = 42.63$ with a p-value of 0.00).

The results of the Johansen maximum likelihood (ML) procedure used to test for cointegration among relevant variables for the US$/A$ /A$ relationships are set out in Table 1.

The results for the simplest system, involving *lnXR* and lnTT, are set out in panel A. It may be observed that both the maximum eigenvalue and the trace test reject, at the 5% significance level, the null hypothesis of zero cointegrating vectors in favour of the alternative that there is one such vector. Thus the *nominal* US$/A$ exchange rate and Australia's terms of trade appear to form a cointegrating relationship by themselves. Examination of the residuals of the estimated cointegrating vector presented in Figure 2 lends credence to this conclusion. This result is interesting in its own right since so much stress has been laid on the appropriate theoretical link being between the *real* exchange rate and the terms of trade.

**C Variables included in cointegrating vector:** ***lnXR lnTT PDIF*** $IDIF_S$ ***Intercept***

127 observations from 1984(5) to 1994(11). Maximum lag in VAR = 4.

**Number of Cointegrating Vectors indicated at 5% Level of Significance**

| Null | Alternative | λ Max | | Trace | |
|---|---|---|---|---|---|
| r = 0 | r = 1 | 37.53 | (28.14) | 73.90 | (53.12) |
| r ≤ 1 | r = 2 | 20.10 | (22.00) | 36.37 | (34.91) |
| r ≤ 2 | r = 3 | 12.00 | (15.67) | 16.27 | (19.96) |

**Estimated Cointegrated Vectors** (Normalised on *lnXR*). Chosen r = 2

| ***lnXR*** | ***lnTT*** | ***PDIF*** | $IDIF_S$ | ***Intercept*** |
|---|---|---|---|---|
| -1.00 | 0.24 | -2.46 | 0.02 | - 0.31 |
| **-1.00** | **1.06** | **-0.15** | **-0.0005** | **- 0.22** |

**Test of Restriction(s) on Cointegrated Vectors:** $\beta_1\, lnXR + \beta_2\, lnTT + \beta_3\, PDIF + \beta_4\, IDIF_S + Int.$

$\beta_4 = 0$ $\chi^2(2) =$ 1.98 [p-value = 0.37]

**D Variables included in cointegrating vector:** ***lnXR lnTT PDIF*** $IDIF_L$ ***Intercept***

127 observations from 1984(5) to 1994(11). Maximum lag in VAR = 4.

**Number of Cointegrating Vectors indicated at 5% Level of Significance**

| Null | Alternative | λ Max | | Trace | |
|---|---|---|---|---|---|
| r = 0 | r = 1 | 37.92 | (28.14) | 74.91 | (53.12) |
| r ≤ 1 | r = 2 | 21.57 | (22.00) | 37.00 | (34.91) |
| r ≤ 2 | r = 3 | 11.04 | (15.67) | 15.43 | (19.96) |

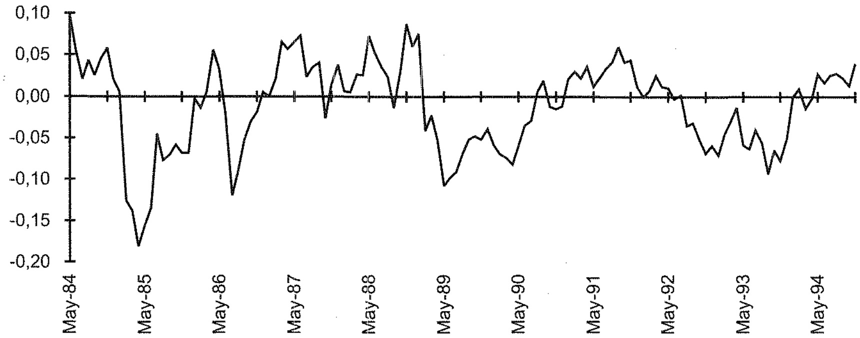
**Estimated Cointegrated Vectors** (Normalised on *lnXR*). Chosen r = 2

| ***lnXR*** | ***lnTT*** | ***PDIF*** | $IDIF_L$ | ***Intercept*** |
|---|---|---|---|---|
| -1.00 | -0.78 | -5.48 | 0.08 | - 0.52 |
| **-1.00** | **1.02** | **-0.19** | **-0.0006** | **- 0.22** |

**Test of Restriction(s) on Cointegrated Vectors:** $\beta_1\, lnXR + \beta_2\, lnTT + \beta_3\, PDIF + \beta_5\, IDIF_L + Int.$

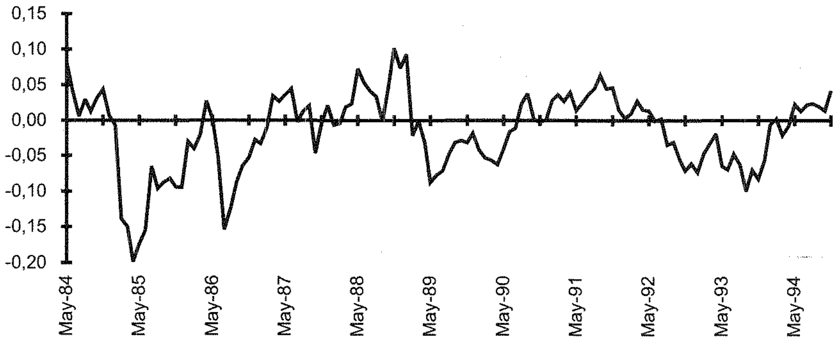
$\beta_5 = 0$ $\chi^2(2) =$ 4.04 [p-value = 0.13]

**Figure 2: Residuals of Cointegrating Vector (lnXR, lnTT)**




The next step in our testing procedure was to include the price level differential, *PDIF*, in the cointegrating vector. The results for this system are set out in panel B. Even though the λ max and trace tests indicate the presence of two cointegrating vectors, inspection of the graph of the of the cointegrating residuals of the first vector and the fact that the coefficient on *lnTT* in the first vector is wrongly signed, leads us to focus on the second vector. The residuals of that vector are set out in Figure 3. The graph suggests that the residuals are I(0). While the LR test rejects the restriction that the coefficient on *PDIF* in that vector is 0, it also firmly rejects the restriction that the coefficient is -1. Absolute purchasing power parity, for given terms of trade, seems not to hold.

**Figure 3: Residuals of Cointegrating Vector (lnXR, lnTT, PDIF)**



In panel C, we include the short-term interest rate differential, $IDIF_S$, in the cointegrating vector to proxy UIP. We note that the tests indicate two possible cointegrating vectors. Again, after inspection of the graph of the residuals, the second is preferred. However, the LR test of the restriction that the coefficient on $IDIF_S$ is 0 cannot reject the null at conventional significance levels. Similar results were obtained when we included the long-term interest rate differential, $IDIF_L$. Thus our preferred cointegrating vector for the US$/A$ exchange rate is that set out in panel B. Normalizing on *lnXR*, this is:

$$lnXR = -0.22 + 0.86\, lnTT - 0.14\, PDIF \tag{4}$$

We note that the terms of trade are the dominant factor driving changes in the US$/A$ exchange rate with a nearly one-to-one relationship. Furthermore, while the coefficient on *PDIF* is correctly negatively signed, the restriction that it is equal to -1 is firmly rejected.[10] Thus, changes in relative price levels are not, *ceteres paribus*, reflected fully in changes in the nominal US$/A$ exchange rate. This implies that the real US$/A$ exchange rate is influenced by both the terms of trade and the price level differential, so that a change in the price level differential leads to a persistent change in Australia's international competitiveness. We should also note that monetary variables appear not to influence the nominal US$/A$ rate in the long run.

In Figure 4, we graph the test statistic for the Hansen-Johansen test for stability of the cointegrating vector. This is an LR test based on recursive estimation of the cointegrating vector. It tests the null hypothesis that the cointegrated vectors estimated for the full sample fall within the space spanned by the vectors estimated for each of the sub-samples. The test statistic is distributed as $\chi^2$ with p degrees of freedom, where p is the dimension of the cointegrating vectors, including the intercepts. The graph, which pictures the actual disequilibrium as a function of the short-run dynamics, indicates stability after May 1985.

*(iii) Error Correction Analysis*

Having established that a set of variables including the nominal exchange rate for the A$, the terms of trade and a price level differential cointegrate, it is appropriate to examine the associated EC mechanisms which describe the short-run dynamics. While we could estimate an EC model for each of the variables in the cointegrating vector, we restrict ourselves to those for $\Delta lnXR$ and $\Delta lnTT$ because of the potential two-way causality and its implications for the frequently-employed assumption that Australia is an international price-taker with, consequently, exogenous terms of trade.

**Table 2: IV Estimates of the EC Models for lnXR and lnTT**

| | Dependent Variable $\Delta lnXR_t$ | Dependent Variable $\Delta lnTT_t$ |
|---|---|---|
| $RES_{t-1}$ | -0.29 (4.77) | 0.05 (3.48) |
| $\Delta lnXR_t$ | | 0.18 (2.89) |
| $\Delta lnTT_t$ | 1.68 (3.66) | |
| $\Delta lnTT_{t-1}$ | | 0.29 (2.85) |
| $\Delta lnTT_{t-3}$ | | 0.41 (2.96) |
| $\Delta lnTT_{t-4}$ | | -0.23 (2.04) |
| $\Delta PDIF_{S,t}$ | -1.91 (2.86) | |
| $\Delta DIF_{L,t}$ | -0.02 (2.35) | |
| $\bar{R}^2$ | 0.29 | 0.35 |
| Serial Correlation $\chi^2(12)$ | 17.85 [0.12] | 21.26 [0.05] |
| Functional Form $\chi^2(1)$ | 1.93 [0.16] | 1.98 [0.16] |
| Normality $\chi^2(2)$ | 26.53 [0.00] | 16.66 [0.00] |
| Heteroscedasticity $\chi^2(1)$ | 0.01 [0.93] | 19.28 [0.00] |
| Sargan's Test $\chi^2(n)$ | 32.30 [0.69] | 14.19 [0.07] |

**Notes:**
(1) 8 lags of $\Delta lnXR$, $\Delta lnTT$, $\Delta PDIF$, $\Delta IDIF_S$ and $\Delta IDIF_L$ and $RES_{t-1}$ were used as instruments in the IV estimation for $\Delta lnXR$
(2) 4 lags of $\Delta lnXR$, $\Delta lnTT$ and $\Delta PDIF$ and $RES_{t-1}$ were used as instruments in the IV estimation for $\Delta lnTT$
(3) $n$ indicates the number of instruments used in the IV estimation
(4) Because of heteroscedasticity in the $\Delta lnTT$ equation, White's adjusted SEs and t-statistics are shown
(5) t-statistics are in round brackets
(6) p-values are in square brackets

While it might be argued that the price indices for manufactures inadequately capture movements in the two general price levels, our estimates using quarterly data and consumer price indices also emphatically reject this restriction.

The two EC models were estimated for the US$/A$ relationships. We started the estimation process with 4 lags and contemporaneous changes in each of the endogenous variables, including both interest rate differentials. The current changes were included to reflect the rapid adjustment process in the foreign exchange market. To cope with possible simultaneous equation bias, we employed instrumental variable (IV) estimation techniques. The number of lags used in each of the equations was reduced, in the interests of parsimony, by reference to standard joint variable deletion tests. The results of the estimation are set out in Table 2.

***ΔlnXR*** The results of the EC model for *ΔlnXR* are presented in the first column of Table 2. The error correction term is correctly signed and highly significant. It indicates that approximately 30% of the deviation from long-run equilibrium is eliminated in one period. There is also evidence that changes in the US$/A$ exchange rate are significantly influenced by contemporaneous changes in the terms of trade, the price level differential and the long-term interest rate differential. We cannot reject the null hypothesis that the coefficient on *DPDIF* is -1 at conventional significance levels. Thus, although we can reject *absolute* PPP in the long-run cointegrating vector, we cannot reject *relative* PPP in the short-run. Furthermore, we cannot reject the hypothesis that there is a one to one relationship between changes in the terms of trade and changes in the nominal exchange rate in the short-run. This implies that volatility in the terms of trade is transmitted to, and reflected in, volatility in the exchange rate. Given that monetary policy appears to have no *direct* impact on the exchange rate in both the long and short run, the only potential channel for stabilizing the exchange rate via monetary policy would depend on its *indirect* influence on relative inflation rates.

***ΔlnTT*** The estimated EC model for changes in the terms of trade is set out in the second column of Table 2. The EC term is correctly signed but relatively small, indicating that the foreign exchange rate bears most of the burden of adjustment to long-run equilibrium. Changes in the exchange rate have a significant positive impact on changes in the terms of trade. This indicates that exchange rate pass-through is less for exports than for imports. This may reflect the fact that many of Australia's exports involve long-term contractual agreements. This result supports the findings of Dwyer, Kent and Pease (1994) that for export prices " response to exchange rate changes was considerably lagged, giving rise to some degree of endogeneity in the terms of trade" (p 419).

## 5. Conclusions

It has long been contended that the A$ is driven primarily by changes in international commodity prices and, consequently, by changes in Australia's terms of trade. Recent evidence has substantiated this view by demonstrating that a long-run cointegrating relationship exists between Australia's real effective exchange rate and its terms of trade. This paper has built on this foundation to show that the real exchange rate - terms of trade relationship can be used effectively to provide a model for the nominal A$ exchange rate. The US$/A$, is cointegrated with the terms of trade and relative price levels. The most surprising aspect of these results is the absence of any significant impact of monetary variables on the exchange rate.

Estimated error correction models suggest that there is a substantial two-way relationship between the nominal exchange rate and the terms of trade. The significant, near one-to-one impact of changes in the terms of trade on the exchange rate indicate that volatility in the terms of trade will be reflected in volatility of the nominal exchange rate. The evidence of a significant impact of changes in the nominal exchange rate on changes in the terms of trade indicates that the small open economy assumption of exogenously given terms of trade may be inappropriate when modelling movements in the US$/A$ exchange rate or other aspects of Australia's international economic relations. The fact that changes in the exchange rate have a positive impact on changes in the terms of trade indicates that exchange rate pass-through is less for exports than for imports.

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**Appendix I**

The Blundell-Wignall and Gregory (1990) Model

Supply

$$y_x = \eta(e + \bar{p}_x - p_n) + \bar{y} \qquad (1)$$

$$\bar{Y} = Yx + Yn \qquad (2)$$

Demand

$$d = (p + \bar{y} - p_d) \qquad (3)$$

$$d_n = a(e + \bar{p}_m - p_n) + d \qquad (4)$$

$$D_m = D - D_n \qquad (5)$$

Prices

$$p = \lambda p_n + (1 - l)(e + \bar{p}_x) \qquad (6)$$

$$p_d = \lambda p_n + (1 - \lambda)(e + \bar{p}_m) \qquad (7)$$

$$\dot{p}_n = \varphi(d_n - y_n) + \dot{p}^e_n , \qquad p^e_n = \bar{\pi}$$

In the steady state where actual and expected rates of inflation are equal,

$p_n = p^e_n$ and

$$d_n = y_n \qquad (8)$$

$$s = e + p_m - \bar{p}_n \qquad (9)$$

where

$Y_x$ = supply of exports
$Y_n$ = supply of non-traded goods
Y = total output
D = total demand
$D_n$ = demand for non-traded goods
$D_m$ = import demand
P = the goods price
$P_d$ = the demand deflator
$P_n$ = the price of non-traded goods
$P_x$ = the price of exports in foreign currency
$P_m$ = the price of imports in foreign currency (assumed equal to one in subsequent analysis)
E = the exchange rate (units of domestic currency per unit of foreign currency)
S = the real exchange rate
$\pi$ = the rate of growth of the money supply (assumed to determine infla tionary expectations exogenously)
$\lambda$ = the (equilibrium) share of non-traded goods in output

Lower case letters indicate natural logarithms and a bar denotes an exogenous variable. All parameters are positive.

Blundell-Wignall and Gregory also model asset markets in three additional equations which comprise a standard demand for money function, UIP, and a reaction function for the monetary authorities in which the money supply is set in response to inflation and the deviation of the nominal exchange rate from a target value. They examine the relationship between the terms of trade and the real exchange rate "by considering the steady state of the model where real money balances and the real exchange rate are constant, domestic inflation takes place at the rate $\pi$, and the exchange rate is depreciates at the rate $\pi$ (foreign inflation is zero since $p_m = 1$)."[1]

There are *nine* equations in *ten* unknowns so the system cannot be solved uniquely. However, the system may be solved for the real exchange rate *s*, leaving the nominal exchange rate *e* and hence the price of non-traded goods $p_n$ to be determined by the asset market equations. By substitution, the equilibrium value of the real exchange is given by

$$\$ = \left[\frac{\lambda - \eta - 1}{\eta + \alpha}\right] p_x + \left\{\frac{(1-\lambda) + \eta + \ln\lambda + \ln(1-\lambda)}{\eta + \alpha}\right\} \qquad (10)[12]$$

The equilibrium real exchange rate is determined by the terms of trade, given the elasticities of demand for importables and the elasticity of supply of exportables and the share of non-traded goods in the economy. Since $\lambda < 1$, [•] is appropriately negative, suggesting that an improvement in the terms of trade (a rise in px) leads to an appreciation of the real exchange rate (a fall in $s$). However, one should be wary about drawing this conclusion because generally $\lambda$ will vary with a change in the terms of trade.

## Appendix II

**Table A1 Unit Root Tests (Dickey - Fuller)**

| Variables | Statistic | Without trend | | With trend | |
|---|---|---|---|---|---|
| **Australian** | | | | | |
| *lnTT* | DF | -1.29 | (-2.88) | -1.10 | (-3.44) |
| | ADF(1) | -1.67 | (-2.88) | -1.58 | (-3.44) |
| | ADF(2) | -1.87 | (-2.88) | -1.79 | (-3.44) |
| | ADF(3) | -2.45 | (-2.88) | -2.39 | (-3.44) |
| **Aust - US** | | | | | |
| *lnXR* | DF | -2.82* | (-2.88) | -2.67 | (-3.44) |
| | ADF(1) | -3.15 | (-2.88) | -2.97 | (-3.44) |
| | ADF(2) | -3.39 | (-2.88) | -3.24 | (-3.44) |
| | ADF(3) | -2.93 | (-2.88) | -3.15 | (-3.44) |
| *PDIF* | DF | -3.84 | (-2.88) | -1.31 | (-3.44) |
| | ADF(1) | -3.51 | (-2.88) | -1.53 | (-3.44) |
| | ADF(2) | -4.05 | (-2.88) | -1.82 | (-3.44) |
| | ADF(3) | -4.46 | (-2.88) | -1.65 | (-3.44) |
| $IDIF_S$ | DF | -1.71 | (-2.88) | -2.62 | (-3.44) |
| | ADF(1) | -2.17 | (-2.88) | -2.91 | (-3.44) |
| | ADF(2) | -1.91 | (-2.88) | -2.89 | (-3.44) |
| | ADF(3) | -1.81 | (-2.88) | -2.75 | (-3.44) |
| $IDIF_L$ | DF | -1.66 | (-2.88) | -1.98 | (-3.44) |
| | ADF(1) | -1.77 | (-2.88) | -2.06 | (-3.44) |
| | ADF(2) | -1.78 | (-2.88) | -2.15 | (-3.44) |
| | ADF(3) | -1.89 | (-2.88) | -2.37 | (-3.44) |

**Notes:**
1. All variables apart from $IDIF_S$ and $IDIF_L$ are in natural logarithms
2. Sample (84M2 to 94M12) covers 131 observations.
3. 95% critical values for Dickey - Fuller tests are in brackets.
4. In cases where the result is in doubt, estimated ADFequations indicate * is appropriate number of lags of dependent variable.

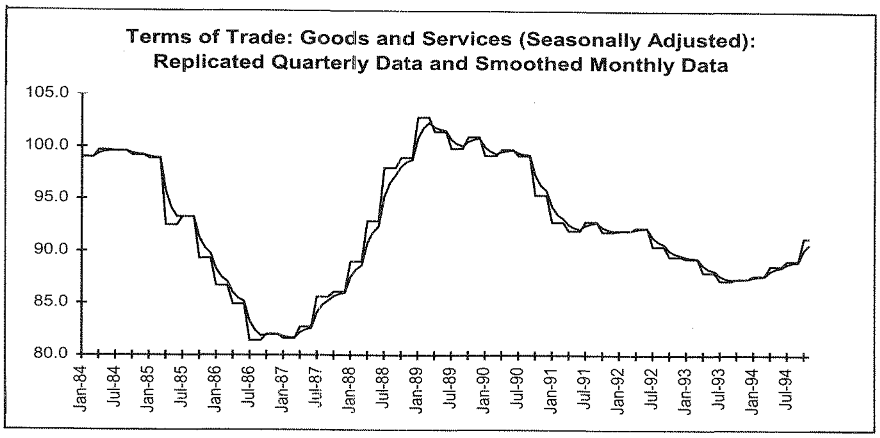
## Appendix III

### The Terms of Trade Series

The ABS terms of trade series for goods and services is the ratio of the implicit price deflator for exports of goods and services to the implicit price deflator for imports of goods and services. The data is quarterly and published approximately two months after the end of the quarter. We have chosen to derive a monthly series by initially replicating the quarterly figure for each of the three months comprising a quarter and then treating the series as though the market learns adaptively about new data. At the beginning of the quarter no change in the series is perceived but by the end of the quarter, the change is more or less completely understood. We have done this by using a Koyck lag to transform the data. Thus

$TT_t = \alpha QTT_t + (1\text{-}\alpha)\, TT_{t\text{-}1} \qquad a = 0.5$

where *TT* is the derived series employed in our empirical work and *QTT* is the quarterly terms of trade replicated monthly. The two series are graphed below.




11. Blundell-Wignall and Gregory (1990) p 10.

12. Since the term in square brackets attached to px is different from the (wrongly) positive expression obtained by Blundell-Wignall and Gregory, our working is produced below.

Given that λ = Yn / (Yx + Yn )

y = yn - lnλ = yx - ln(1 -λ) (i)

Substituting (i) into (1) above

yx = η(e + px - pn ) + yn - lnλ (ii)

From (8) above

yx = η(e + px - pn ) + dn - lnλ (iii)

From (3), (4) and (9) above

dn = αs + p + y - pd (iv)

Substituting (iv) into (iii)

yx = η(e + px - pn ) + αs + p + y - pd - lnλ (v)

Substituting (i) into (v)

η(e + px - pn ) + αs + p - pd - lnλ - ln(1-λ) = 0 (vi)

Subtracting (7) from (6) above

p - pd = (1 - λ)px - (1 - λ) (vii)

Substituting (vii) into (vi)

η(e + px - pn ) + αs+ (1 - λ)px = (1 - λ) + lnλ + ln(1-λ) (viii)

Adding h to both sides

η(e -pn +1) + ηpx + αs + (1 - λ)px = (1 - λ) + lnλ - ln(1-λ) +η (ix)

ηs + αs + (1 - λ + η) px = (1 - λ) + lnλ + ln(1-λ) + η (x)

Solving for s $\hat{s} = \left[\frac{\lambda - \eta - 1}{\eta + \alpha}\right] p_x + \left\{\frac{(1-\lambda) + \eta + \ln\lambda + \ln(1-\lambda)}{\eta + \alpha}\right\}$ (xi)