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# Modelling the Exchange Rate and Commodity Prices in the Treasury Macroeconomic (TRYM) Model

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## Abstract

Most macro-econometric models base their exchange rates equations upon the concept of uncovered interest and/or purchasing power parity. However, the empirical support for both of these hypotheses is at best weak. In particular, these parity conditions are unable to explain many of the observed short-term movements in the exchange rate. Other researchers have found evidence that other factors particularly movements in commodity prices and the terms of trade are statistically significant in explaining both short and long-run movements in the Australian dollar relative to foreign currencies. There are good reasons to believe that movements in the spot commodity price which incorporates expectations about future commodity prices should have an impact on the spot exchange rate from a fundamental equilibrium exchange rate (FEER) point of view. The response of the exchange rate to commodity price movements is often argued to be a key mechanism which helps to insulate the economy from international shocks.

This paper reports on some work that has been done to incorporate the RBA commodity price index into the TRYM exchange rate equation. This has also involved introducing an additional equation for commodity prices into the model and the re-estimation of the model's commodity export price equation. The final exchange rate equation bears many similarities to that estimated by Blundell-Wignall, Fahrer and Heath in their 1993 RBA conference paper. The work on the exchange rate has benefited from a number of discussions with economists at the RBA including David Gruen, Gordon de Brouwer, Jenny Wilkinson and Gordon Menzies, and also draws on work done by Andrew Johnson on exchange to the Reserve Bank. Finally, the paper examines the impact that changes to the exchange rate equation have on the model's response to an external shock.

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# 1. Introduction

> *The theory of exchange rate determination has never recovered from the empirical debacle of the early 1980s. ... Quantitative policy analysts must have something to determine exchange rates in their models, so they either have an exchange rate equation that more or less fits the data, or simply impose some mechanism, but they make little pretence that they have solved the riddle of exchange rates. (Krugman 1993, p.7)*

The existing TRYM exchange rate equation more easily fits the second of Krugman's categories, in that it is simply an imposed uncovered interest parity (UIP) condition. The aim in this paper is to outline recent research into the exchange rate which led to a revised form of the exchange rate equation which allows the user to choose between the existing UIP condition on the one hand, to one that responds only to commodity prices and the terms of trade or some combination between the two, depending on the user's requirements.

TRYM is not alone among the major Australian models in its use of a UIP condition coupled with some form of 'rational expectations' to model the exchange rate. The same setup is used in both the Murphy Model and AEM. The main reasons for the popularity of UIP is that it represents a convenient (and transparent) theoretical assumption on which to base the exchange rate equation. A further reason is that, at least until the early 1990's, other exchange rate models either failed to describe the data any better than UIP or lacked the theoretical structure that is needed to incorporate them into a structural macroeconomic model.

The primary weakness of UIP is that the empirical evidence in support of it is scarce. In fact, the empirical evidence in support of UIP is so weak that Blundell-Wignall, Fahrer and Heath (1993, p. 73) made the claim that, 'No economic hypothesis has been rejected more decisively, over more time periods, and for more countries, than UIP'. Tarditi (1996, p. 1) also criticises the use of UIP in macroeconomic models, noting that UIP provides the models with 'textbook-style impulse responses, .. the distinctive behaviour of [the exchange rate], observed in the data in practice, is not fully captured' by such an approach. Wallis (1993), on the other hand, argues that the tests that reject UIP depend upon the way the null hypothesis is set up and might be better characterised as not accepting, rather than rejecting, the UIP hypothesis. More recent studies have been more supportive of the hypothesis, and indeed casual observation of the exchange market on a day to day basis suggests that interest rates play a key role. Moreover, it is important to note that rejection of UIP does not imply that exchange rates do not respond to interest rate movements. Arbitrage ensures that they do. Rather what it implies is that other factors are at work, and that the exchange market is not very good at predicting the influence of these factors or of future movements in the exchange rate. The key problem is that some of these other factors that drive the exchange rate, such as commodity prices, are as unpredictable as the exchange rate itself.

In light of these considerations, the new exchange rate equation has been designed to give the user greater flexibility, with the traditional UIP condition available on the one hand, but with additional variables based on a Blundell-Wignall et al. (1993) style equation also available (as well as a host of other combinations). The key changes to the equation are:

- the incorporation of a terms of trade measure based on the RBA commodity price index into the exchange rate equation;

- modification of the imposed uncovered interest parity condition and an improved measure of WRIGL entering into this condition; and

- the inclusion of a time trend to capture debt (and other trend) effects in the exchange rate equation. This have been included as an indicator of deviations in the FEER from steady state rather than a risk premium.

The research outlined in this paper forms part of a longer term review of the financial market setup in TRYM. To date, this research has included the development of rational (or fully model consistent) expectations routines (Louis 1996), optimal control routines (Louis 1995 and 1997), and the introduction of options to allow for a mixture of adaptive and rational behaviour in the key financial variables.

Section 2 of this paper provides a brief discussion of some of major institutional developments in the Australia foreign exchange market. This is followed in Section 3 by a review of the theory underpinning the development of exchange rate equations in macro models and a review of the recent Australian literature. Section 4 then considers some of the relevant measurement issues surrounding the use of the commodity price index. Section 5 discusses the incorporation of an equation linking movements in world commodity prices to changes in world growth, in particular, the OECD index of industrial production along with a revised PXC equation to capture the pass through from world commodity prices to the commodity export deflator. A description of how the commodity price based terms of trade measure has been incorporated into TRYM, along with the other changes to the exchange rate equation is provided in Section 6. This leads to some examples of the different responses that TRYM gives both with and without the revised exchange rate equation (Section 7). Sections 8 and 9 then provide some concluding remarks and an outline of future work which, it is hoped, will further improve the TRYM financial sector.

## 2. Institutional Developments

While a detailed description of the various institutional regimes which have evolved from the Bretton Woods pegging of the exchange rate to the pound sterling through to the current floating rate regime is beyond the scope of this paper (Blundell-Wignall et al. 1993, pp.34-45 provides a good overview of these developments) it is worth providing a brief summary of the major developments.

- Following the Bretton Woods agreement in 1944, through to the early 1970s, most exchange rates throughout the world were fixed. During this period the nominal Australian dollar exchange rate was pegged to either the pound sterling or the $US. One consequence of a fixed nominal exchange rate was that adjustment to real shocks and current account imbalances had to occur through domestic prices, although there were discrete revaluations on occasion.

- In 1974 the fixed $US exchange rates was under pressure due to movements in the US dollar relative to other major currencies including the yen and the deutschmark. In response, the Australian government abandoned the $US exchange rate peg in favour of pegging the dollar to a basket of currencies. This was in turn replaced in 1976 by a 'crawling peg', although this too came under pressure in the face of substantial capital inflows and outflows in spite of the exchange controls that were then in place.

- In 1983, large current account deficits eventually led the government deciding to float the Australian dollar. Over the next few years this was accompanied by widespread deregulation of many other previously regulated parts of the financial markets.

- During 1985 and 1986 the Australian dollar was subject to major depreciations, with the nominal TWI falling by almost 40 per cent during the 18 months starting in January 1985.

- Derivative markets gradually became more developed during the 1980s, possibly in response to financial market deregulation and greater financial market volatility.

- The Australian economy became increasingly internationalised as the trade share grew rapidly in 1980s and 1990s. Combined with the floating exchange rate, this:

  – reduced the impact of demand shocks with excess supply being more easily sold on international markets or excess demand being more easily met by imports;

  – made fiscal policy impotent in the medium term but increased the importance of financial market reactions to fiscal policy; and

  – changed the transmission of terms of trade shocks.

Up until the breakdown of the Bretton Woods agreement, most exchange rates were fixed. During this period, there was little incentive to model exchange rates which were assumed to be exogenous in the models of the time. Following the floating of many major currencies following the break down of the Bretton Woods agreement, the development of theoretical models of exchange rates (and methods for endogenising exchange rates in empirical macroeconomic models) were stimulated. These theories include the early Dornbusch 'overshooting' model and the adoption of rational expectations in response to the Lucas critique. Since then other theories, including a variety of portfolio balance type models, have also been proposed.

## 3. Review of Theory and Recent Australian Literature

Two common theoretical models of exchange rate determination are covered and uncovered interest parity. Covered interest parity (CIP) states that interest rate differentials should equal the capital gains or losses associated with hedging the exchange rate in the forward exchange market while uncovered interest parity (UIP) states that interest rate differentials should equal the expected movement in the exchange rate. A concept closely related to UIP is that of 'speculative efficiency' which states that the forward premium (discount) should equal the expected exchange rate depreciation (appreciation).

It is generally accepted that deviations from CIP are small since deviations represent risk-free opportunities for arbitrage. In contrast, the empirical evidence rejecting UIP and speculative efficiency is considerable. The failure of UIP has led some researchers to conclude that foreign exchange markets are inefficient since persistent deviations represent persistent unexploited arbitrage opportunities.

A number of possible other hypotheses have been proposed to explain the empirical failure of UIP. These include inelastic supply curves caused by information asymmetries (Ng and Fausten 1993), time-varying risk premia, peso problems, transaction costs, or 'anchoring' of exchange rate expectations (Gruen and Gizycki 1993). Another possible hypothesis is that turnover of traders in the foreign exchange market, combined with slow evolution of firms may allow the pursuit of 'irrational' or sub-optimal strategies for considerable lengths of time. For example, a firm that is near-rational may be able to survive for a long time without losing customers, particularly if stochastic factors are influencing both their own returns and those of firms using fully-rational strategies.

Despite the existing empirical evidence and the various theories for why UIP may not hold, the conclusion that UIP is invalid is by no means certain. For example, Wallis (1993, p. 123) points out that most of the empirical literature that rejects UIP is 'subject to the same two shortcomings identified by Isard (1988), namely an inadequate treatment of expectations and a neglect of the simultaneity between exchange rates and interest rates.' Wallis (1993) also argues that when using regressions of the form

$$(e_t - e_{t+1}) = \alpha + \beta(r_t - r^*_t) + u_t$$

the appropriate hypothesis to test is whether $\beta=1$ rather than whether $\beta=0$ as has generally been the case.

A particular difficulty with explaining short-run movements in the exchange rate is that it appears to be a random walk such that the current exchange rate is the best predictor of the exchange rate over short time frames. This point is illustrated by the finding by Manzur (1988) who notes that 'over a short horizon, market participants' forecasts of the future exchange rate are often worse, but never significantly better than a "no-change forecast"'. It is for this reason that the official Commonwealth Budget forecasts are based on a technical assumption that the TWI remains at around its average level in the months preceding the budget (see Table 1, footnote (c) in Budget Paper No. 1 1997-98, p. 2-4).

With the apparent failure of UIP to adequately describe short-run exchange rate movements, researchers began looking for fundamental influences which may explain longer term movements in the exchange rate. These models are based on calculating an exchange rate which is consistent with internal and external equilibrium. Of this research, that undertaken at the OECD and later the Reserve Bank of Australia appears to have been the most successful in describing the behaviour of Australia's exchange rate. A key result of this research is the conclusion by Blundell-Wignall and Gregory (1990) that for a small commodity exporting country such as Australia, the equilibrium exchange rate is influenced by the terms of trade.

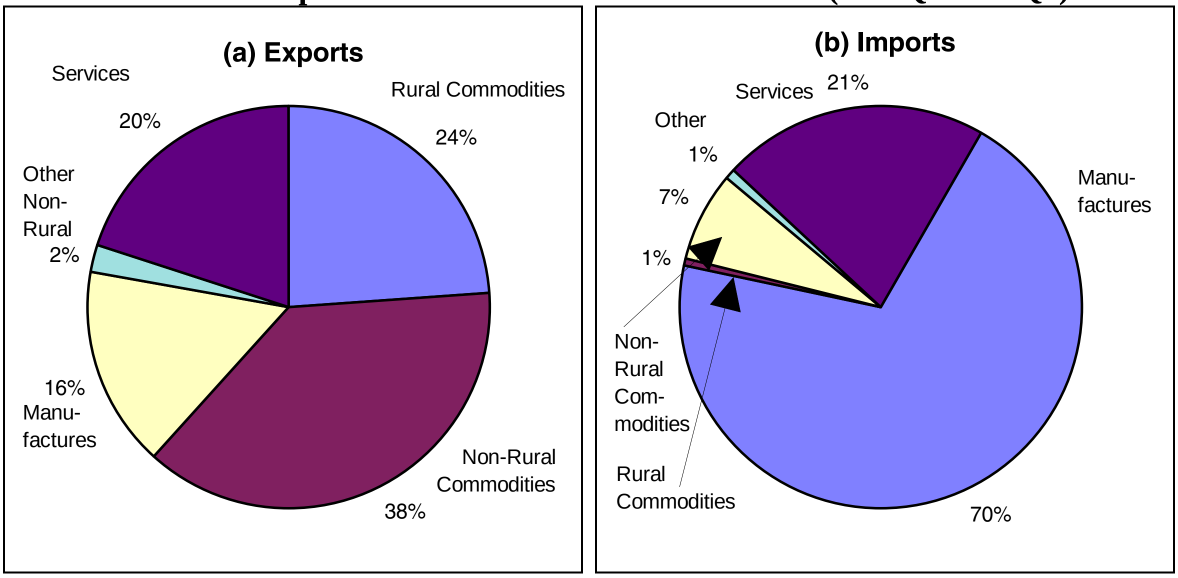
The theoretical justification for a link between the real exchange rate and the terms of trade is that a rise in the terms of trade reflects a strengthening of world demand for Australia's exports. Assuming that increase in the terms of trade is perceived to be permanent and that the exchange rate is initially unchanged this will cause an improvement in Australia's balance of trade. Assuming that the net income deficit is also initially unchanged, this implies that there will be excess demand for the $A such it will have to appreciate to ensure balance of payments equilibrium. This terms of trade effect has a greater impact on the nominal exchange rate of a commodity exporting country such as Australia relative to other developed countries due to the greater volatility in world commodity prices relative to manufactured goods prices. (See Box 1.)

The Blundell-Wignall and Gregory (1990) result was followed by Blundell-Wignall et al (1993, p. 59) who found a long-run or equilibrium relationship between the real exchange rate for the $A, the terms of trade, the long-term interest differential and the level of net foreign liabilities as a share of GDP. This result has been confirmed by Johnson (1995) who used monthly data and included terms aimed at capturing the effects of RBA intervention. His results show that the Blundell-Wignall et al (1993) equation exhibits good out of sample forecasting properties over the 1990s although a large component of the month to month volatility remains unexplained. Tarditi (1996) who also estimated a Blundell-Wignall et al (1993) style equation (using yield curve differentials rather than and found a similar elasticity between the real exchange rate and the terms of trade as Blundell-Wignall et al (1993) and Johnson (1995).

One difficulty with the finding that the terms of trade may help explain movements in the real exchange rate is that, in the short-run at least, the terms of trade is itself a function of the exchange rate. This occurs because, as Blundell-Wignall et al (1993, p. 59) note, the pass through from exchange rates to the domestic price of imports is faster than the pass through to exports. This endogeneity means that estimated equations which seek to measure the relationship between the real exchange rate and the terms of trade as normally measured will be subject to simultaneity bias.

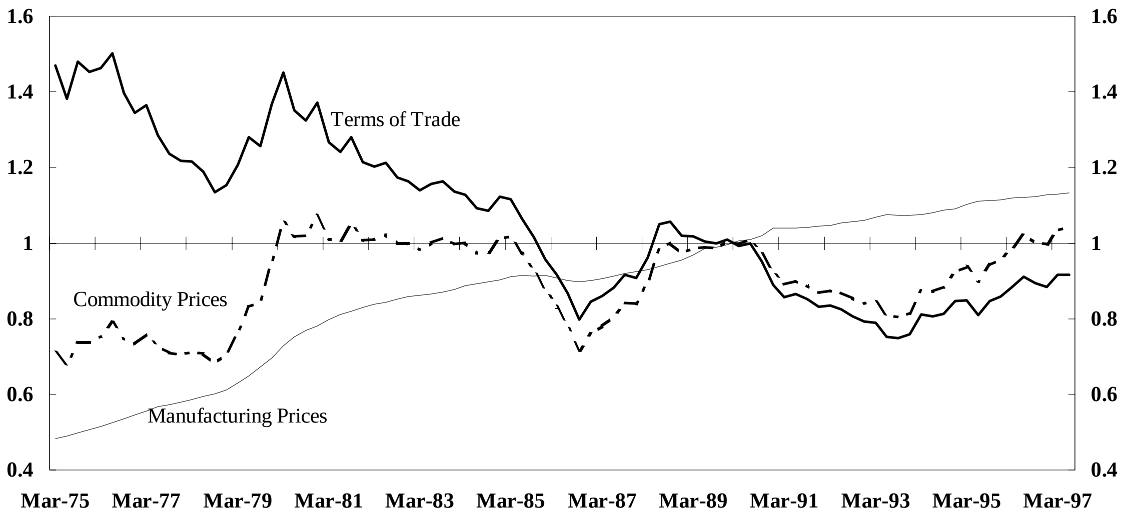
One way of overcoming the endogeneity problem between the real exchange rate and the terms of trade is to use a measure of the terms of trade which is based upon world prices. In order to construct such an index it is necessary to make two key observations about the composition of Australia’s external trade. First, Australia’s exports are predominantly composed of commodities (Chart 1a). Second, Australia’s imports are predominantly manufactured goods (Chart 1b). Assuming that Australia is a price taker on world markets, this implies that the terms of trade can be approximated by the ratio of the world price of commodities to the world price of manufactures.

**Chart 1: Composition of Australia's External Trade (1987Q3-1997Q2)**




As can be seen in Chart 2, world commodity prices are significantly more volatile than world prices for manufactured goods. Commodity prices have cycled about the same average level since at least the start of the 1980s whilst manufacturing prices have gradually increased. This means that the ratio of these two series cycles about a downwards trend. An examination of Chart 2 also shows that most of the movement in the terms of trade is due to commodity price cycles rather than movements in the world price of manufactures.

**Chart 2: Components of the Terms of Trade Measured in World Prices**




These observations are consistent with the terms of trade measured in Australian prices which Gruen and Kortian (1996, p. 2) argue are 'well-described as fluctuating around a slowly declining trend' with 'Deviations [that] are quite long-lived, but [that] do not appear to be permanent'. If this is true, then the expected long-run path for the terms of trade should be easily forecast and stable which should in turn mean that the expected equilibrium exchange rate should be relatively stable. This is not easily reconciled with the observation that the real exchange rate has moved closely with cycles in the terms of trade. Gruen and Kortian (1996) propose that this behaviour may be the result of there being a scarcity of forward looking foreign exchange participants with an investment horizon of more than a year. Over this shorter time period, the current terms of trade may be a better predictor of tomorrow's terms of trade than the long run trend due to the persistence of deviations from the trend.

An alternative explanation for the apparent randomness of the exchange rate is that the terms of trade is not actually as predictable as a casual examination of Chart 2 might suggest. One reason for thinking that this might be the case is that commodity markets are, to a large extent, forward looking. In particular, non-rural commodity prices are likely to be the most forward looking. The main reasons for thinking that the non-rural commodity or mining sector would have forward looking prices is that holding costs are relatively low, with minerals being able to be 'stored' in the ground and 'dug up' later if prices were expected to rise. (The relatively high productivity growth in the mining sector would tend to offset what holding costs there were.) This would lead to a reduction in current period supply such that the price would increase to equal the expected future price. Therefore, non-rural commodity prices would be likely to contain more information about the future level of the terms of trade than rural commodity prices. (See Section 4 for further discussion of this point.)

In addition to commodity prices and interest rate effects on the exchange rate, studies such as Blundell-Wignall et al (1993) have also used some measure of net foreign assets as a long run explanator of the exchange rate. The reason for including this is because, for a given trade balance, higher net foreign liabilities would imply a greater net income deficit and therefore the exchange rate would need to appreciate to stabilise net foreign liabilities as a share of wealth.

In addition to the real interest rate differentials, the terms of trade and net foreign assets a host of other factors are capable of influencing the equilibrium exchange rate. For example, a cut in tariffs will, at least in the short run, increase imports for a given terms of trade and therefore lead to a depreciation of the currency. Similarly, changes in relative productivity growth have the potential to influence the exchange rate through changes in relative competitiveness.

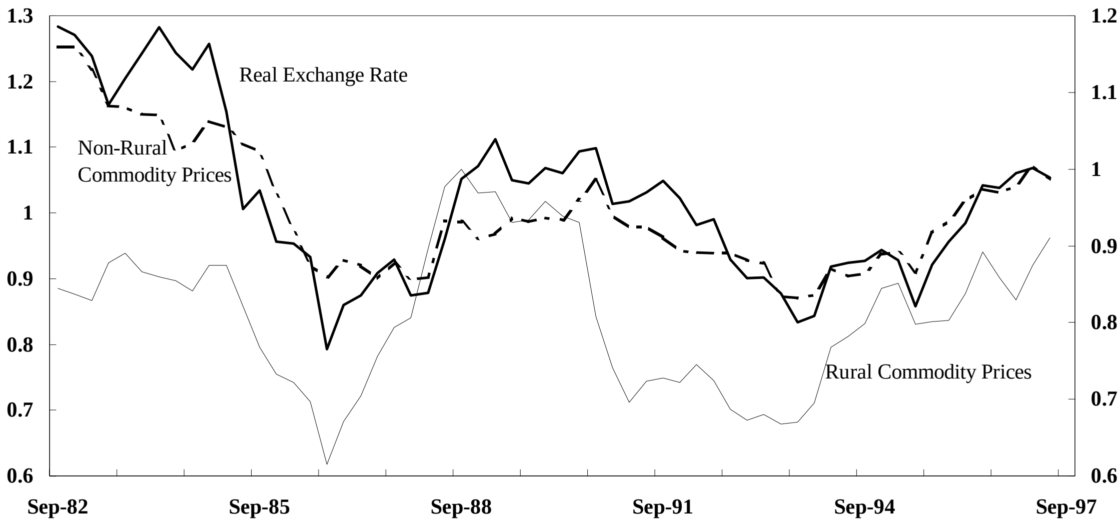
# 4. Definitions and Measurement Issues

## 4.1 Rural v Non-Rural Commodity Prices

The first definitional issue when constructing a measure of the terms of trade for Australia in world prices is to decide what measures of commodity and manufacturing prices to use. TRYM already contains an index of world manufacturing prices, WPMGS (the construction of this index is described in Edge 1995). A number of possible commodity price indices are available, including several from the RBA, the IMF and other sources. The RBA indices were chosen as the basis of the TRYM world commodity price series since they are weighted according to the commodity disaggregation of Australia's commodity exports. In contrast, the IMF series gives high weightings to commodities such as food oils and oilseeds, coffee and timber which are relatively insignificant amongst Australia's commodity exports. (Many of the other world commodity prices include a substantial weighting on oil prices whereas oil constitutes only a small proportion of Australia's exports.)

A further benefit of RBA commodity price measures is that it is available for both rural (agriculture) and non-rural (mining) commodities. As discussed in Section 3, it might be expected that changes in non-rural commodity prices would have a greater impact on the exchange rate due to their forward looking nature. This hypothesis is given some support by Chart 3 which illustrates a closer relationship between the real exchange rate and a measure of the terms of trade based on non-rural commodity prices.

**Chart 3: Rural and Non-Rural Commodity Prices and the Real Exchange Rate**




The greater leverage of non-rural commodity prices over the exchange rate relative to rural commodity prices can be tested by estimating the following real exchange rate equation from Johnson (1995). As in Johnson (1995), a two stage Engle-Granger estimation process was used.

$$
\begin{aligned}
\Delta ln\left[RRETWI\right] = \; & a_1 \times \Delta ln\left[RRETWI(\text{-}1)\right] \\
& + a_2 \times \Delta ln\left[\frac{WPXC}{WPMGSST}\right] \\
& + a_3 \times RBAFPR \\
& - a_4 \times RBAFSR \\
& - a_0 \times \left\{ \begin{array}{l} ln\left[RREWTWI(\text{-}1)\right] \\ -\left[c_0 + c_1 \times \ln\left(\dfrac{WPXC(-1)}{WPMGSST(-1)}\right) + c_2 \times \left(RRIGL - WRRIGL\right) + c_3 \times DEBT\right] \end{array} \right\}
\end{aligned}
$$

Mnemonics:

- RRETWI : Real export weighted exchange rate (calculated as RETWI*PGDPA/WPGDP)
- WPXC : The relevant RBA commodity price index converted to RETWI currency units
- WPMGS : World price of imports adjusted for wedge with PMGS (see below)
- RBAFPR/(RBAFSR) : Net RBA purchases (sales) of foreign currency as a share of official reserve assets
- RRIGL : Real domestic interest rate (Nominal less 4 quarter change in consumer prices)
- WRIGL : Real world interest rate (Nominal less 4 quarter change in world GDP deflator)
- DEBT : Accumulated current account deficits since 1969Q3.

The results of these estimations are as follow:

**Terms of Trade Index using Non-Rural Commodity Prices**

Sample: 1984(1) to 1997(2)

| Parameter | Interpretation | Estimate | t-Statistic |
|---|---|---|---|
| $a_1$ | lagged dependent variable | 0.178 | 1.76 |
| $a_2$ | change in ToT | 0.737 | 4.65 |
| $a_3$ | RBA net purchases | 0.301 | 2.57 |
| $a_4$ | RBA net sales | 0.550 | 3.56 |
| $a_0$ | error correction | 0.240 | 2.33 |
| $c_0$ | long run constant | -0.047 | -1.87 |
| $c_1$ | terms of trade | 1.101 | 10.39 |
| $c_2$ | real interest differential | 0.015 | 1.89 |
| $c_3$ | accumulated CAD | 0.203 | 5.49 |

**Terms of Trade Index using Rural Commodity Prices**

Sample: 1984(1) to 1997(2)

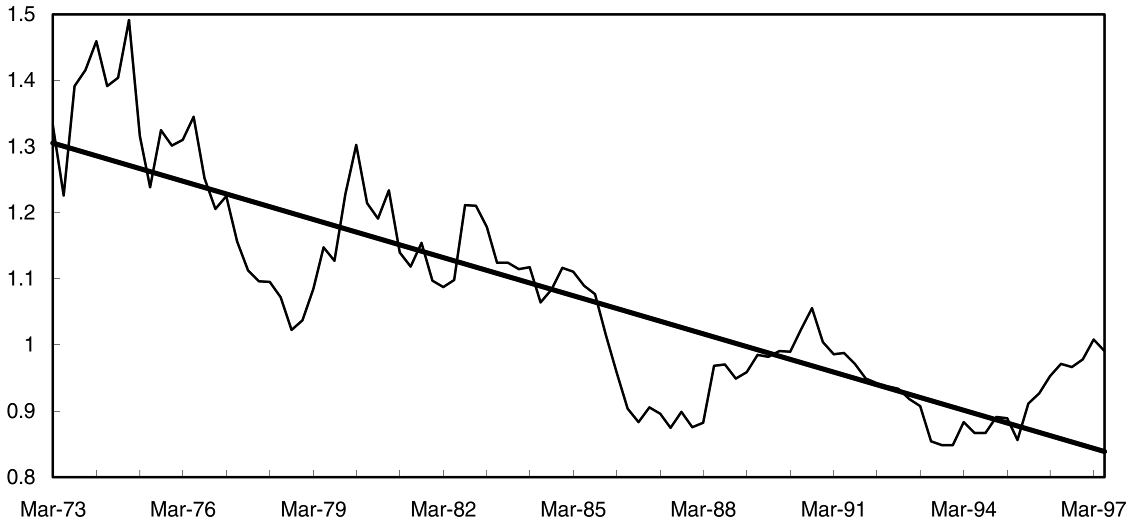
| Parameter | Interpretation | Estimate | t-Statistic |
|---|---|---|---|
| $a_1$ | lagged dependent variable | 0.067 | 0.69 |
| $a_2$ | change in ToT | 0.358 | 4.05 |
| $a_3$ | RBA net purchases | 0.178 | 1.36 |
| $a_4$ | RBA net sales | 0.632 | 4.13 |
| $a_0$ | error correction | 0.085 | 1.24 |
| $c_0$ | long run constant | -0.004 | -0.08 |
| $c_1$ | terms of trade | 0.340 | 4.04 |
| $c_2$ | real interest differential | 0.016 | 1.31 |
| $c_3$ | accumulated CAD | 0.335 | 6.50 |

These results provide further evidence that the terms of trade based on non-rural commodity prices have a greater impact on the real exchange rate (long-run elasticity of 1.1) than rural commodity prices which have an estimated long run elasticity of 0.34.

While the observation that non-rural commodity prices have a greater impact on the exchange rate than rural commodity prices do, it is necessary to use a price index for all commodities in the current version of TRYM. This is because mining and agricultural output are not separated in the current version of the model. Therefore, the equations described in this paper are based on the RBA commodity price index for all commodities. This monthly index is averaged to obtain quarterly values and the Australian dollar denominated index is then converted to export weighted currency units by multiplying by RETWI.

One difficulty with the RBA commodity price indices is that they begin in July 1982. Therefore, in order to get a series which extends back further, this series has been spliced with the ABARE commodity price index. The resulting world term of trade index is illustrated in Chart 4.

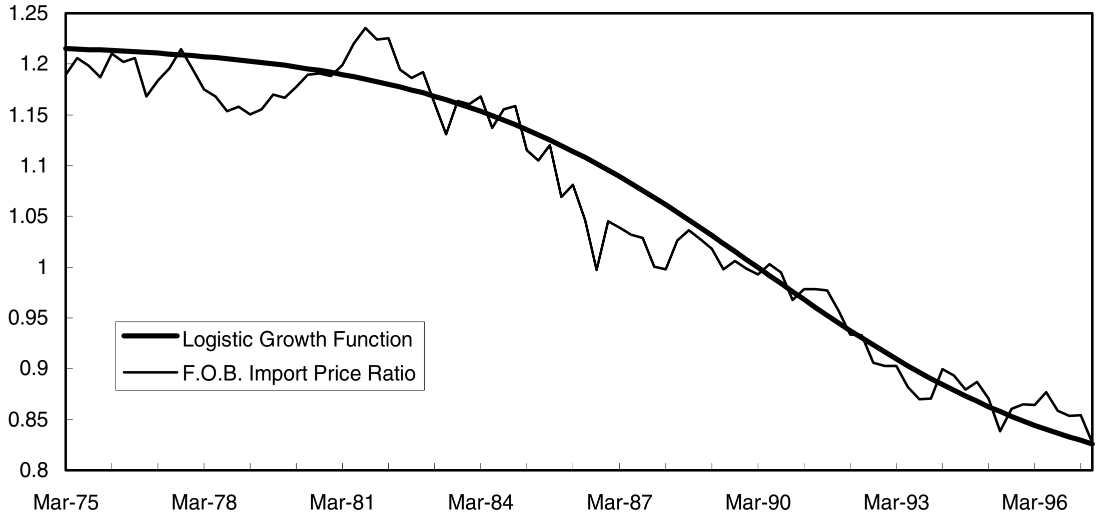
**Chart 4: Terms of Trade Measured in World Prices**




## 4.2 Measurement Issues

There are also several measurement issues which are important when using price indices. Over the long-run changes in both world prices and the exchange rate should be fully passed through to domestic prices. Therefore, if the world terms of trade measure suggested here is adjusted for non-commodity prices, the resulting series should be cointegrated with the domestic terms of trade. One possible cause for a breakdown in this relationship could be an index number problem. Such a problem exists between the world price of manufactures and the import price deflator for Australia (see Edge 1995 and Treasury 1996). In that case, there is a distinct trend in the ratio of the f.o.b. price of imports and the world price denominated in Australian dollars. This long-run trend (illustrated in Chart 5) is captured by a logistic growth function.

**Chart 5: F.O.B. Price of Imports over World Price in $A**




In the case of commodity prices, the ratio of world price to the Australian commodity export deflator has been relatively stable. Therefore, the long run relationship between world commodity prices (expressed in Australian dollars) and the commodity export deflator is modelled as a constant in the commodity export demand equation described in Section 5.

### 4.3 World Interest Rate Data

Previously, TRYM contained a world bond yield series which was calculated as a simple arithmetic average of long-term government bond yields for the US, Japan and Germany. This series was not consistent with the export weighted exchange rate index that is used in the UIP exchange rate equation. The new WRIGL series is constructed in a manner very similar to RETWI. With the exception of China, the new WRIGL is based on the same major trading partners since 1989 as RETWI. (Hong Kong is omitted prior to 1986Q2 and Taiwan prior to 1985Q2.) The various series used to construct WRIGL are listed at Attachment A.

## 5. Endogenising the World Commodity Price

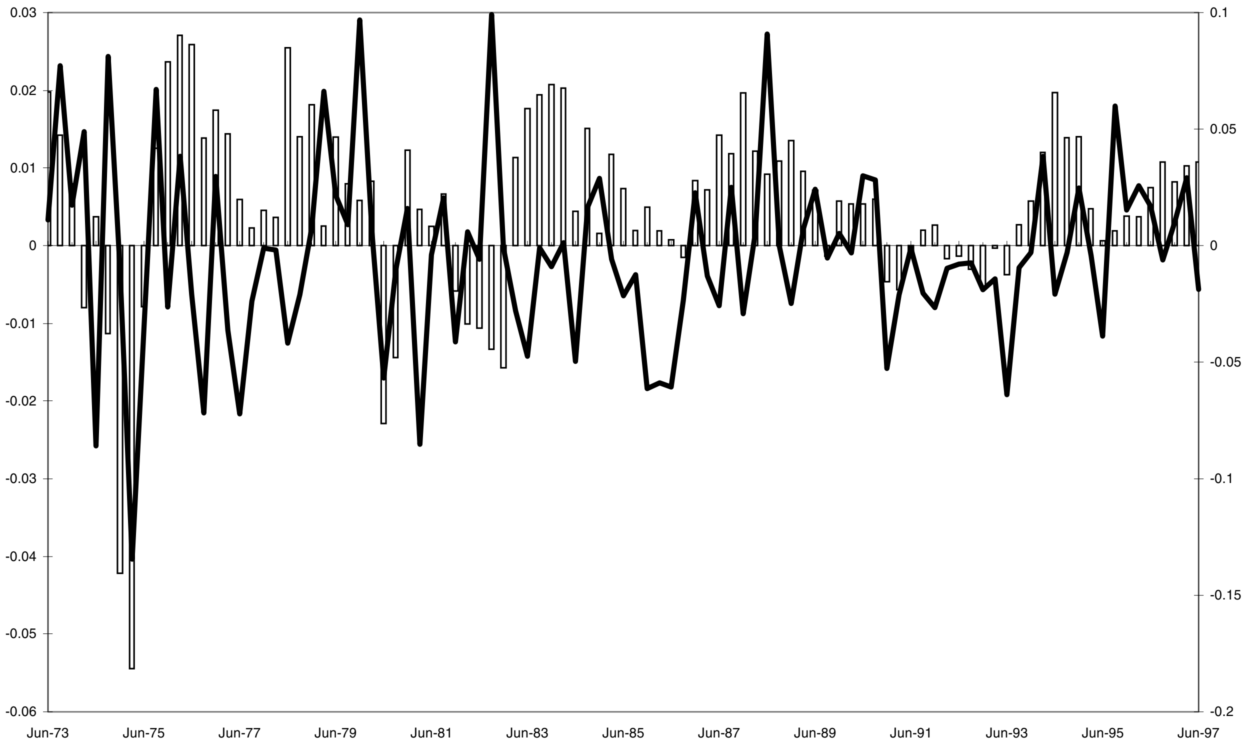
As discussed in the previous section, the commodity price used in TRYM is the RBA non-rural commodity price converted to export weighted currency units (RETWI). These prices have followed a gradual decline relative to the world price of our imports since at least the early 1970s, as can be seen in Chart Y. Therefore, the world price of commodities is modelled as following this long run decline in TRYM. Since it is not clear what is driving this trend nor whether it will continue in the forecast period, particularly given the argument in the previous section that commodity prices are forward looking, the trend variable QTIMF which is constant over the forecast period is used. This gives the following long run specification:

$$ln\left[\frac{WPXC}{WPMGSST}\right] = c_0 + c_1 \times QTIMF$$

Short-run deviations from this long-run path are primarily driven by growth in the world economy. This has been measured using the OECD index of industrial production (OECDIP). This measure is used rather than the existing WGDP series in TRYM because WGDP is restricted to our major trading partners and is weighted according to our exports. World commodity prices, in contrast, are determined by total world demand and therefore a broader measure of world output needs to be used. The relationship between OECD industrial production and the IMF commodity price index has been illustrated by Blundell-Wignall and Bullock (1992), Blundell-Wignall et al. (1993, p. 33), whilst Gruen and Shuetrim (1993) explicitly model the terms of trade as a function of changes in world output. Allowance is also made in the TRYM equation for changes in the relative price of oil in world markets.

The relationship between the terms of trade and OECD industrial production is shown in Chart 6.

**Chart 6: Terms of Trade and OECD Industrial Production**




The final equation is based upon an error correction format with the downwards time trend in the long run component as described above and short-run dynamics being driven by lagged terms of trade changes and changes in world industrial production (proxied by OECD industrial production) and adjustments for steady state bias.

$$
\begin{aligned}
\Delta ln\left[\frac{WPXC}{WPMGSST}\right] &= a_1 \times \{\Delta ln[WIP] - GR(\text{-}2)\} \\
&+ a_1 \times \{\Delta ln[WIP(\text{-}2)] - GR(\text{-}2)\} \\
&+ a_1 \times \{\Delta ln[WIP(\text{-}3)] - GR(\text{-}3)\} \\
&+ a_1 \times \{\Delta ln[WIP(\text{-}4)] - GR(\text{-}4)\} \\
&+ a_2 \times \left\{\Delta ln\left[\frac{WPMPE}{WPMGS}\right]\right\} \\
&+ a_3 \times \left\{\Delta ln\left[\frac{WPMPE(\text{-}1)}{WPMGS(\text{-}1)}\right]\right\} \\
&- a_0 \times \left\{ln\left[\frac{WPXC(\text{-}1)}{WPMGSST(\text{-}1)}\right] - c_0 - c_1 \times QTIME(-1)\right\}
\end{aligned}
$$

*Results*

Sample 1975(1) to 1997(2)

| **Parameter** | **Interpretation** | **Estimate** | **t-Statistic** |
|---|---|---|---|
| $a_1$ | industrial production | 0.248 | 2.45 |
| a2 | relative petroleum prices | 0.074 | 2.16 |
| a3 | relative petroleum prices | 0.070 | 1.99 |
| $a_0$ | error correction | 0.146 | 3.15 |
| $c_0$ | long run constant | -0.079 | -2.91 |
| $c_1$ | time trend parameter | -0.009 | -2.08 |

*Diagnostic Statistics*

| | | |
|---|---|---|
| $R^2$ = 0.25 | | |
| SE = 3.54% | | |
| DW = 1.76 | | |
| Box-Pierce Q (1-8$^{th}$ order auto correlation) | | 11.71 |
| Jarque-Bera Test for Normality | | 4.92 |
| Chow Test for Parameter Stability | | 2.57 |
| Ramsey's Reset Test | | 0.56 |
| Breusch-Pagan Heteroscedasticity Tests: | | |
| | Trend | 3.10 |
| | Y-Hat | 1.62 |
| | Joint | 3.57 |

* Indicates the test has failed at the 5% confidence level.

## Interpretation

All parameter estimates are significant at the 5 per cent level, with the exception of the first lag of the commodity price term. The estimated error correction coefficient suggests that any deviation between the actual and long-run terms of trade is corrected by around 17 per cent per quarter.

## 5.1 Commodity Export Demand

Previously, the price of commodity exports was modelled to fully adjust to changes in the aggregate level of world prices (WPGDP) and the exchange rate (RETWI). This reflects the assumption that Australia is a price taker in world commodity markets. A time trend was also included in the equilibrium price of exports to capture the effects of the trend fall in world commodity prices relative to aggregate world prices.

With the introduction of a world commodity price into the model it is possible to model the pass through from world commodity prices explicitly. The law of one price was found to hold indicating that there were no major index number problems for the commodity export deflator and the world commodity price index. Therefore, the time trend was omitted from the long run error correction component of the equation giving the following long run relationship:

$$ln\left[PXC(-1)\right] = c_0 + ln\left[\frac{WPXC(-1)}{RETWI(-1)}\right]$$

In the short run changes in the exchange rate pass through more rapidly than changes in the world commodity price. This is because a large proportion of Australia's export contracts are denominated in foreign currency. World commodity prices flow through more slowly as contacts are only renegotiated gradually. These effects are captured by including lagged changes in the exchange rate and world commodity prices. This gave the following specification:

$$\begin{aligned}
\Delta\ln(\mathrm{PXC}) = {} & (1 - a_1 - a_2 - a_3) \times \Delta\ln(\mathrm{WPXC}) \\
& + a_1 \times \Delta\ln(\mathrm{WPXC(-1)}) \\
& + a_2 \times \Delta\ln(\mathrm{WPXC(-2)}) \\
& + a_3 \times \Delta\ln(\mathrm{WPXC(-3)}) \\
& - (1 - a_4 - a_5) \times \Delta\ln(\mathrm{RETWI}) \\
& - a_4 \times \Delta\ln(\mathrm{RETWI(-1)}) \\
& - a_5 \times \Delta\ln(\mathrm{RETWI(-2)}) \\
& - a_0 \times \left( \ln[\mathrm{PXC(-1)}] - \chi_0 - \ln\left[\frac{\mathrm{WPXC}(-1)}{\mathrm{RETWI}(-1)}\right]\right)
\end{aligned}$$

*Results (from joint estimation of commodity demand and supply equations)*
Sample: 1975(1) to 1995(3)

| Parameter | Interpretation | Estimate | t-Statistic |
|---|---|---|---|
| $a_1$ | change in world price | 0.204 | 4.23 |
| $a_2$ | change in world price | 0.254 | 5.48 |
| $a_3$ | change in world price | 0.089 | 1.80* |
| $a_4$ | change in exchange rate | 0.196 | 3.94 |
| $a_5$ | change in exchange rate | 0.060 | 2.02 |
| $a_0$ | error correction | 0.080 | 2.00 |
| $c_0$ | long run constant | -0.011 | -0.40 |

*Diagnostic Statistics (based on single equation estimates)*

| | | |
|---|---|---|
| $R^2$ =0.66 | | |
| SE = 1.94% | | |
| DW = 2.10 | | |
| Box-Pierce Q (1-8th order auto correlation) | | 12.89 |
| Jarque-Bera Test for Normality | | 1.64 |
| Chow Test for Parameter Stability | | 1.31 |
| Ramsey's Reset Test | | 1.12 |
| Breusch-Pagan Heteroscedasticity Tests: | | |
| | Trend | 10.21* |
| | Y-Hat | 0.21 |
| | Joint | 10.75* |

* Indicates the test has failed at the 5% confidence level.

## 6. Exchange Rate equation in a Model Context

One of the properties of TRYM is that it has a well-defined steady state growth path or equilibrium representation. Therefore, the approach to the exchange rate is a Fundamental Equilibrium Exchange Rate (FEER) approach. This approach allows for a wide range of factors to influence the equilibrium exchange rate that cannot be easily captured using reduced form exchange rate equations. In fact, changing any exogenous variable which has divergent effects on the trade balance, net income deficit and investment-savings balance (such as changes in import duties or changes in productivity) will lead to changes in the FEER.

In order to maintain this property, it is necessary that commodity prices and other changes are incorporated in an equilibrium context. The steady state model also provides a basis for forward looking expectations in the financial market. However, TRYM allows the user to incorporate a mix of forward looking and adaptive expectations via the use of switch parameters. For example, the full information forward looking expectation for the inflation rate is FIEX. (This is calculated as the average rate of inflation needed for the current price level to adjust to the 10 year ahead steady state price level.) The option of including adaptive inflation expectations is allowed by the parameter, $a_1$, in the following equation for the expected inflation rate:

$$FIE \;\; = (1-a_1)FIE \;\; (-1) + a_1 \times FIEX$$

This introduces a wedge between the actual real bond yield and that expected by financial markets. Therefore, it was necessary to adjust the UIP exchange rate equation for this discrepancy. This was done by incorporating the wedge between actual expectations and the forward looking inflation expectations. For example, the adjusted exchange rate equation was:

$$RETWI \; = \; RETWIX(+40) \times exp\left\{10 \times ln\left[1 + \frac{RIGL - \mathbf{(FIE - FIEX)} - WRIGL - RIP}{100}\right]\right\}$$

The effect of including this wedge on the residuals from the exchange rate equation can be seen in Chart 7. Although the effect of the adjustment is to increase the residual so that it is positive for most of the period since 1980, it also reduces the variance of the residual substantially. It is interesting to note the similarity between this residual and the terms of trade.

**Chart 7: Exchange Rate Equation Residuals -Before and After FIE-FIEX Adjustment**

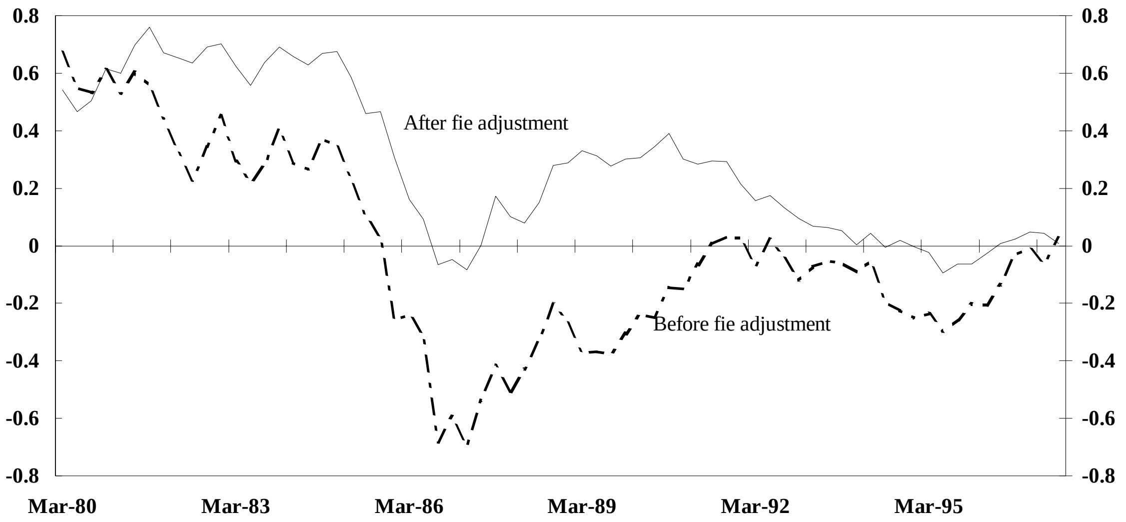
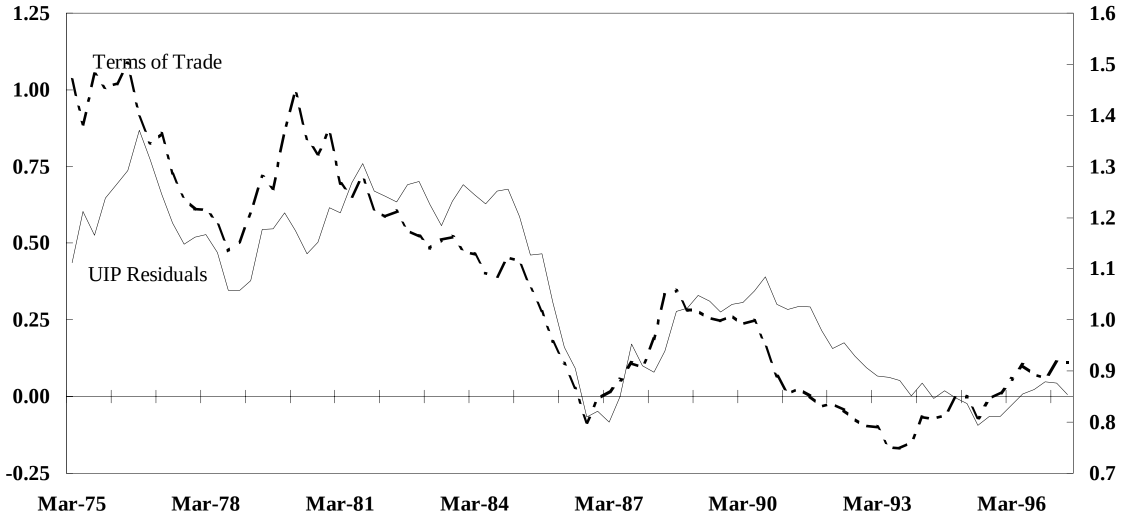



**Chart 8: Uncovered Interest parity Equation Residuals and the Terms of Trade**




The inclusion of commodity price terms in the exchange rate equation will similarly cause a wedge between the full-information exchange rate derived from the steady state and that based on current commodity prices. In order to capture this, the terms of trade needs to enter the equation as the difference between the current terms of trade and the steady state terms of trade. By including this term so as to model the deviation of the current exchange rate from the steady state equilibrium exchange rate, and ignoring the UIP part of the equation for the moment, we have:

$$\ln\left(\frac{RETWI \times PGNEA}{WPGDP}\right) = \ln\left(\frac{RETWIX(+40) \times PGNEAX(+40)}{WPGDP(+40)}\right) + a_2 \times \left[\ln\left(\frac{WPXC}{WPMGSST}\right) - \ln\left(\frac{WPXCX(+40)}{WPMGSST(+40)}\right)\right]$$

$$\Leftrightarrow \ln(RETWI) = \ln(RETWIX(+40) - \left[\ln\left(\frac{PGNEA}{WPGDP}\right) - \ln\left(\frac{PGNEAX(40)}{WPGDP(40)}\right)\right] + a_2 \times \left[\ln\left(\frac{WPXC}{WPMGSST}\right) - \ln\left(\frac{WPXCX(+40)}{WPMGSST(+40)}\right)\right]$$

To provide greater flexibility for the user, a parameter was placed on the interest differential term and a difference in the time trend between the current and 10 year ahead steady state term incorporated. The final exchange rate equation is:

$$RETWI = RETWIX(+40) * exp\left\{\begin{array}{l} a_1 \times \left[10 \times ln\left(1 + \frac{(RIGL - (FIE - FIEX) - WRIGL - RISKP)}{100}\right)\right] \\ + a_2 \times \left[ln\left(\frac{WPXC}{WPMGSST}\right) - ln\left(\frac{WPXC(+40)}{WPMGSST(+40)}\right)\right] \\ + a_3 \times \left[ln\left(\frac{PGNEAX(+40)}{PGNEA}\right) - ln\left(\frac{WPGDP(+40)}{WPGDP}\right)\right] \\ + a4 \times \left(QTIMF - QTIMF(40)\right) \end{array}\right\}$$

One reason for including the parameter on the interest differential term is to allow for the fact that the ten year interest rate may not accurately measure movements in the equilibrium interest rate and hence have less leverage on the expected fundamental equilibrium exchange rate. This hypothesis is supported by the observation that yields on US 30 year bonds are less volatile than US 10 year bond yields (see table below).

## 6.1 Volatility of Bond Yields by Maturity

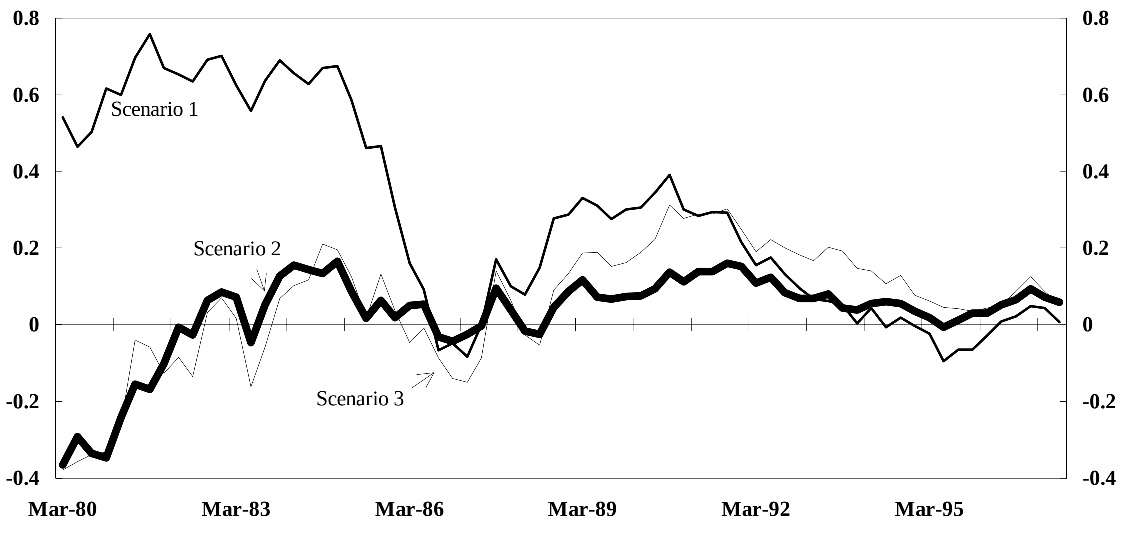
| | Datastream Code | Standard Deviation |
|---|---|---|
| US TREASURY BILLS AUCT.AVE 3 MONTH - MIDDLE RATE | FRTBA3M | 1.68 |
| US TREASURY 2 YEAR BENCHMARK BOND - RED. YIELD | USBDS2Y | 1.59 |
| US TREASURY 7 YEAR BENCHMARK BOND - RED. YIELD | USBDS7Y | 1.23 |
| US TREASURY 10 YEAR BENCHMARK BOND - RED. YIELD | USBD10Y | 1.14 |
| US TREASURY 30 YEAR BENCHMARK BOND - RED. YIELD | USBD30Y | 0.94 |

The time trend can capture movements in foreign debt as well as other trends which may be influencing the exchange rate. The cumulated current account deficit used by Blundell-Wignall et al (1993) and others following follows an approximate time trend. The time trend used is QTIMF which is constant over the forecast period and therefore constant in the 10 year ahead steady state corresponding to a stable debt ratio in the long run.

The equation has a number of convenient features in that it nests both the existing UIP setup as well as a setup where the real exchange rate is a function of real interest rate differentials and the terms of trade. For example, setting $a_1$=1, $a_2$=0, $a_3$ and $a_4$=0 gives the standard UIP equation. Setting $a_1$, $a_2$ to the exchange rate elasticities for the real interest differential and terms of trade, $a_3$=1-$a_1$ and $a_4$ depending upon net foreign assets, (although this is not strictly comparable with the elasticities on the cumulated CAD used in Blundell-Wignall et al 1993). (Setting $a_1$=0.03, $a_2$=0.9, $a_3$=0.97 and $a_4$=-0.015 gives a setup similar to the Blundell-Wignall et al. 1993 equation.) These parameters provide the user with a significant degree of flexibility in choosing the setup that best reflects their beliefs about the exchange rate.

To illustrate the effect of the additional terms that have been included in the exchange rate equation the residuals resulting from several parameter combinations are illustrated in Chart 9.

**Chart 9: Impact of the Alternative Setup on Equation Residuals**



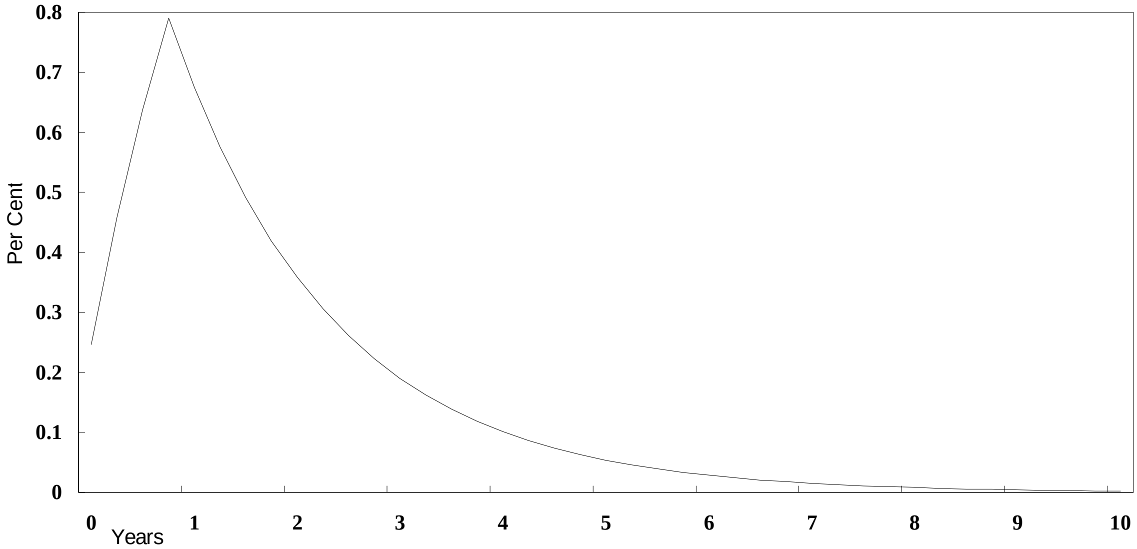

Scenario 1: Standard UIP Condition. $a_1$=1, $a_2$=0, $a_3$=0, $a_4$=0. Scenario 2: Mixture $a_1$=1, $a_2$=1.2, $a_3$=0.45, $a_4$=-0.03
Scenario 3: Blundell-Wignall et al (1993) elasticities $a_1$=0.03, $a_2$=0.9, $a_3$=0.97, $a_4$=-0.15

## 7. A Simulation Example

This section presents the results of a terms of trade shock arising from a temporary 1% increase in world growth that is expected to be reversed. If the level of world demand was expected to be permanently higher this would increase the world's equilibrium demand for Australia's exports for a given terms of trade thus causing an increase in the steady state exchange rate in addition to the effects of the improvement in the terms of trade.

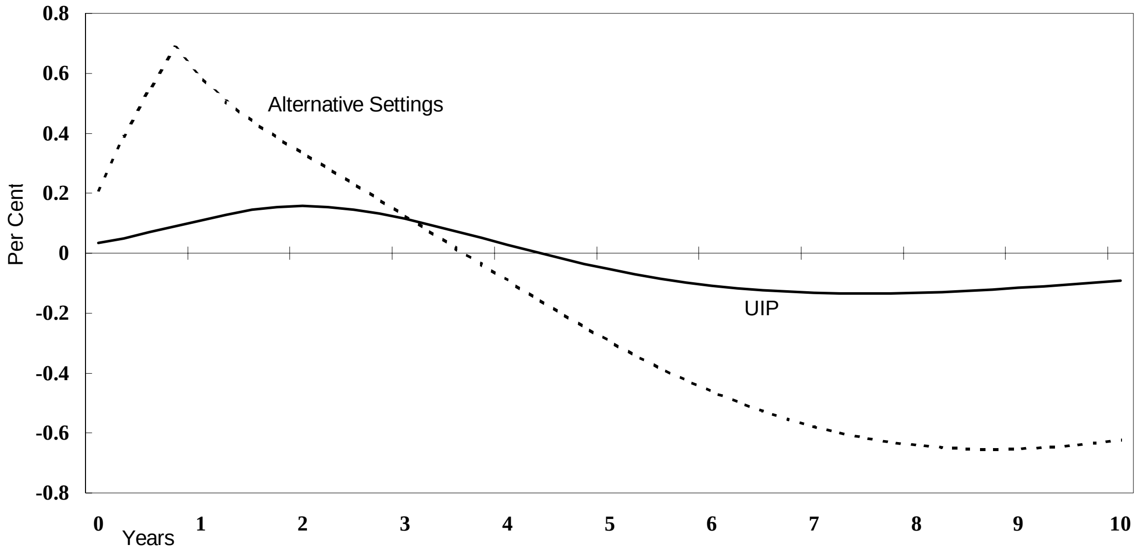
The impact of the increase in world growth on the terms of trade in world prices is independent of the exchange rate assumptions. This impact is illustrated in Chart 10.

**Chart 10: Impact on World Prices of 1% Temporary Increase in World Demand**



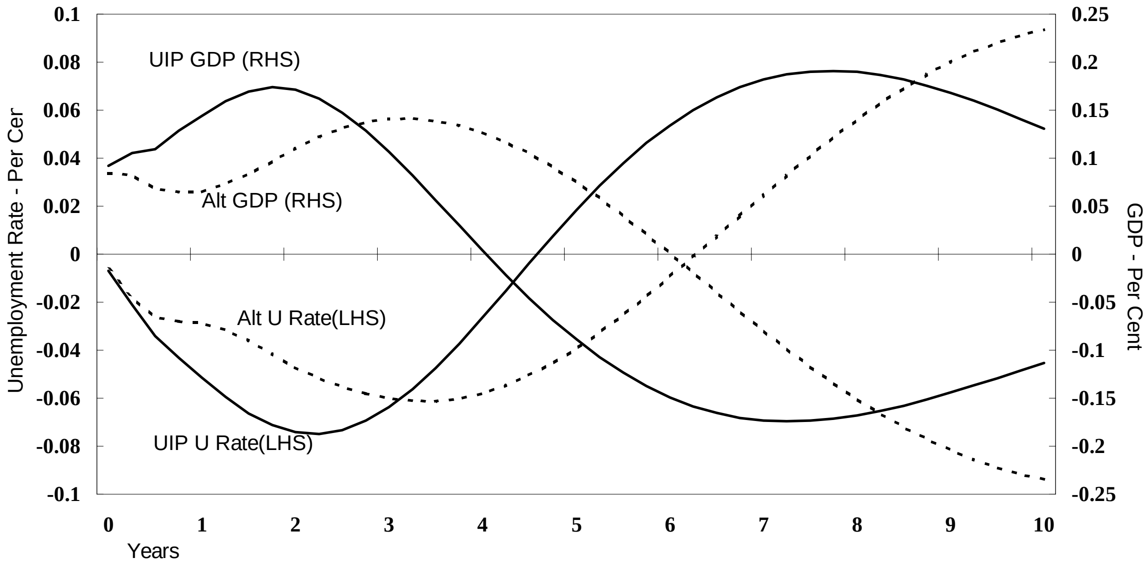

Two scenarios for the effects of this terms of trade shock are presented. The first uses the standard UIP exchange rate equation ($a_1$=1, $a_2$=$a_3$=$a_4$=0). The alternative scenario is setup with $a_1$=0.03, $a_2$=0.9, $a_3$=0.97 and $a_4$=-0.015. The deviations in the exchange rate from these simulations is presented in Chart 11 while the different impacts on the unemployment rate and the level of GDP are presented in Chart 12.

**Chart 11: Effect of Terms of Trade Shock on the Exchange Rate Under Alternative Exchange Rate Setups**




The elasticity of 0.9 on the terms of trade can be seen clearly here in the short run with the peak in the terms of trade deviation of 0.8% leading to a 0.7% increase in the exchange rate. Whereas the UIP relationship leads to a small exchange rate response to the terms of trade shock, the alternative equation leads to a larger initial exchange rate response. This larger exchange rate response has a stabilising effect on the economy. In the UIP simulation there is an initial boom as producers receive higher prices for their exports. However, in the case of the alternative exchange rate simulation, the initial exchange rate response is much greater. This offsets part of the impact on producer incomes and at the same time causes a larger shift in consumption towards imports. The result of these effects is to stabilise the economy's response relative to the UIP simulation.

**Chart 12: Impact of a Terms of Trade Shock on Unemployment and GDP**



## 8. Summary/Conclusions

The changes to TRYM that are described in this paper are an initial attempt to incorporate commodity prices in a manner which has a clear structural explanation and within the context of a structural model with an explicit steady state. The setup nests both the existing UIP relationship and the RBA partial analysis. Therefore, although the structural mechanisms driving the exchange rate are uncertain, the setup provides the user with the flexibility to be able to implement a range of assumptions and tailor the exchange rate equation to reflect these. Hopefully this will lead an improved understanding, over time, of the structural mechanisms driving the exchange rate.

## 9. Further Work

The changes to the exchange rate equation described in this paper are initial results from work in progress. This work will examine the effects on the model's simulation properties from adjusting the parameters in the exchange rate equation. It is possible that in the light of this research that the equations presented in this paper will be refined further.

As mentioned in the introduction, the research into the exchange rate forms part of a wider ongoing review of the TRYM financial sector. It is intended that over time further developments will be implemented in such a way as to provide the user with greater scope for adjusting the behaviour of the model to reflect their judgements as to how financial markets behave. A good example of this is a proposal to introduce new simulation options to provide for a mix of adaptive and rational expectations in the financial markets. Other proposed work includes:

- examining the different properties of the exchange rate equation that can be obtained by adjusting the new parameters;

- providing alternative monetary policy response functions such as a modified Taylor's rule

Comments and suggestions which contribute to this ongoing review of the TRYM financial sector would be appreciated.

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## Attachment A: Construction of World Bond Yield Series, WRIGL

As noted in the text, a new world 10 year bond yield (WRIGL) series was constructed as part of the research described in this paper. RETWI is calculated using movements in Australia's top 16 export destinations. To be as consistent as possible, bond yield data for each of the same countries would be needed. Most series were obtained from the IMF Financial Statistics database on Datastream. Unfortunately data was not available for China and data for some countries was only for a limited sample period. A full list of definitions and sources for each country is given below.

| Country | Description | Datastream Code |
|---|---|---|
| US | US government bond yield - 10 year constant maturities | usi61... |
| Japan | JP government weighted average bond yield-life over 7 years | jpi61... |
| Germany | BD govt.& Pub.auth.weighted avg.bond yield-life over 3 yrs. | bdi61... |
| France | FR government bond yield | fri61... |
| Italy | IT government bond yield-long-term(9-10 year treasury bonds) | iti61... |
| UK | UK government bond yield - long-term | uki61... |
| Canada | CN government bond yield | cni61... |
| HK | Hong Kong interbank 1 year - middle rate | hkibk1y |
| Taiwan | TW capital market rate on corporate bonds-5-year(primary market) | tw5year. |
| China | N/a | n/a |
| Korea | KO yield of govt. Public bonds - maturity up to 5 years | kobndyld |
| Singapore | SP 12-month fixed deposit rate (per s$1,000) | sp700192 |
| Thailand | TH 10 year government bond rate | th10year |
| Malaysia | MY discount rate (end of period) | myi60... |
| Indonesia | ID interest rate on 2 year deposits | id2year. |
| NZ | NZ government bond yield | nzi61... |

(a) No data was available for China

(b) Where 10-yr Government debt data was not available, the closest proxy was used. This was a particular problem for some of the South East Asian economies. As a result, various proxies may differ markedly for a given country.

To construct the WRIGL series, quarterly changes for each series was then calculated. A weighted average of these changes was then taken, omitting any countries for which data was unavailable. A base period value was calculated for 1997Q2 by calculating the weighted average of the interest rates for this period. The weighted average of the changes was then applied to this series to derive a final WRIGL. This methodology was chosen in preference to using a weighted average of all available observations to minimise the impact of distortions which would be caused by countries being added to (dropped from) the sample as data becomes (ceases to be) available.