

# Economic fundamentals do matter for the NZD/AUD exchange rate

## occasional paper



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## Executive summary

In this paper we investigate whether 'economic fundamentals' have a significant influence on the value of the New Zealand dollar relative to the Australian dollar (NZD/AUD). To do this we estimate an economic model that captures the historical relationship between the real (i.e., the inflation adjusted) NZD/AUD exchange rate and the following macroeconomic indicators:

- Productivity growth in New Zealand relative to Australia
- House prices in New Zealand relative to Australia, to capture business cycle pressures in the two economies
- Interest rates in New Zealand relative to Australia
- Prices for New Zealand's commodity exports relative to Australia's
- The savings/investment balance in New Zealand relative to Australia, as reflected in current account balances

We find that the relationship between these fundamentals and the real NZD/AUD exchange rate is consistent with the predictions of economic theory and significant in a statistical sense. On the basis of this relationship we calculate a measure of the 'equilibrium' NZD/AUD exchange rate. This tracks the actual exchange rate reasonably closely, indicating that the economic fundamentals in our model successfully explain the broad trends in the currency over the last fifteen years or so.

From the perspective of the currency union debate this highlights a potential cost, in terms of the loss of an effective macroeconomic 'shock absorber', of forming a currency union with Australia.

Our model also works reasonably well over short time horizons. On a quarterly basis the effect of changes in the economic fundamentals on the exchange rate are generally as we would expect.

It follows that if we have a good understanding of how the New Zealand and Australian economies are likely to evolve, we stand a good chance of correctly forecasting the future trend in the exchange rate. We test the ability of our model to forecast the exchange rate and find that it comprehensively outperforms an alternative naïve forecasting technique that doesn't account for economic fundamentals (a 'random walk' model).

Overall, we conclude that our model provides a useful framework for considering interdependencies between the macroeconomic fundamentals of the New Zealand and Australian economies and the NZD/AUD exchange rate.

## 1) Introduction

In this paper we develop a model of the real (inflation adjusted) NZD/AUD exchange rate. Our motivation is twofold.

First, we want to test whether theories of exchange rate determination provide a useful framework for explaining the path of the NZD/AUD exchange rate since both currencies have been floating. If economic fundamentals do play a role, our model will capture the relationships involved. We will then be able to see how important the fundamentals are in comparison to speculative behaviour in currency market as drivers of the NZD/AUD exchange rate.

Our second and related motivation for building an exchange rate model is to develop a forecasting tool. Because it quantifies the relationships involved, an exchange rate model can serve as a useful bridge between our macro forecasts for New Zealand and Australia, and the NZD/AUD exchange rate. This will give us an idea of the extent of any over or under valuation in the currency and the most likely direction of future movements.

The paper is structured as follows. In section 2 we outline a theoretical framework for thinking about the fundamental determinants of a currency's value. We use this framework to justify the choice of economic variables that we include in our model. In section 3 we give a brief and intuitive explanation of the modelling technique we use. The results of estimating our model are given in section 4. We test the ability of our model to forecast the NZD/AUD exchange rate in section 5 and offer some concluding comments in section 6.

## 2) Exchange rate drivers

The New Zealand dollar was floated in March 1985. The float has been 'clean' in that the RBNZ has not directly intervened in currency markets. However, the exchange rate has played an important role in New Zealand's monetary policy. Over the early 1990s the RBNZ relied extensively on the direct effect of the exchange rate on import prices to influence inflation. This implied that interest rates were often set with the objective of influencing the near-term level of the exchange rate.

In more recent times the RBNZ has been less concerned with the direct influence of the exchange rate on inflation. However, the indirect effect on inflation – via international demand for New Zealand's goods and services – continues to be an important consideration in policy decisions<sup>1</sup>.

The Australian dollar was floated in December 1983. The RBA have, from time to time, intervened directly in currency markets – that is, bought and sold Australian dollars so as to influence its value. In principle, the motivation for intervention has been to calm markets that are threatening to become disorderly. In practise, intervention has been used to help reverse perceived overshoots in the currency and, on some occasions, to give monetary policy greater room for manoeuvre.

Although central-bank intervention may affect exchange rates at the margin, economic fundamentals are likely to be a far more significant influence over the medium term. In this section we outline the range of economic factors that are likely to affect the value of the currency and the nature of the relationships involved. We use this to justify the choice of explanatory variables that we include in our model of the NZD/AUD exchange rate.

### **Exchange rate determination in the long run**

Over the long run the nominal exchange rate should adjust so that the prices of goods and services are the same across countries. The basic idea is that the purchasing power of a currency, in terms of the goods that can be bought with it, should be the same regardless of where it is spent.

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<sup>1</sup> For a discussion on the role of the exchange rate in monetary policy in New Zealand see Orr, Scott, and White (1998).

This theory of exchange rate determination is known as purchasing power parity (PPP). The theoretical rationale behind PPP is basically one of arbitrage. If the same good is priced differently in different countries then international demand will switch to the cheaper good. This will tend to increase its domestic price and appreciate the currency of the country in which it is sold. Over time, the forces of supply and demand will equalise prices across countries.

Arbitrage in capital investment will also tend to result in PPP-type behaviour over the very long run. For example, if a country's exchange rate is such that the cost of labour is low relative to other countries, then production will be attracted to the relatively more competitive economy. Production capacity will tend to move from the 'overvalued' to the 'undervalued' economy. This effect will act to bring the exchange rate back to its PPP equilibrium – that is the level that equates prices across countries.

The empirical evidence on PPP has been mixed. A number of researchers have found that nominal exchange rates do tend to exhibit PPP-like behaviour over very long periods of time. This conclusion is based on research that uses long runs of historical time-series data or panel data sets for a number of different countries.

The nominal NZD/AUD exchange rate and the level of consumer prices in Australia relative to that in New Zealand are graphed in figure 1a. On the face of it, the nominal exchange rate does appear to display PPP-type behaviour over the long run. From 1960 until the mid-1980s the exchange rate steadily depreciated as inflation in NZ was persistently higher than in Australia. This meant that the reduced purchasing power of the kiwi dollar in New Zealand was broadly matched by a fall in its purchasing power when converted into Australian dollars. Since the late-1980s consumer price inflation in NZ has been more similar to that in Australia and so the nominal TWI has cycled around a more constant mean.

The *real* exchange rate is calculated by simply subtracting the (log) of relative prices from the (log) of the nominal exchange rate – that is, the difference between the two lines in figure 1a. Because the real exchange rate accounts for price differentials across countries, it is a measure of an economy's competitiveness in international markets<sup>2</sup>. The real NZD/AUD exchange rate has cycled around a constant long-run average at least since the 1960s (figure 1b). Again, this suggests that the theory of PPP provides a reasonable description of long-run movements in the NZD/AUD exchange rate.

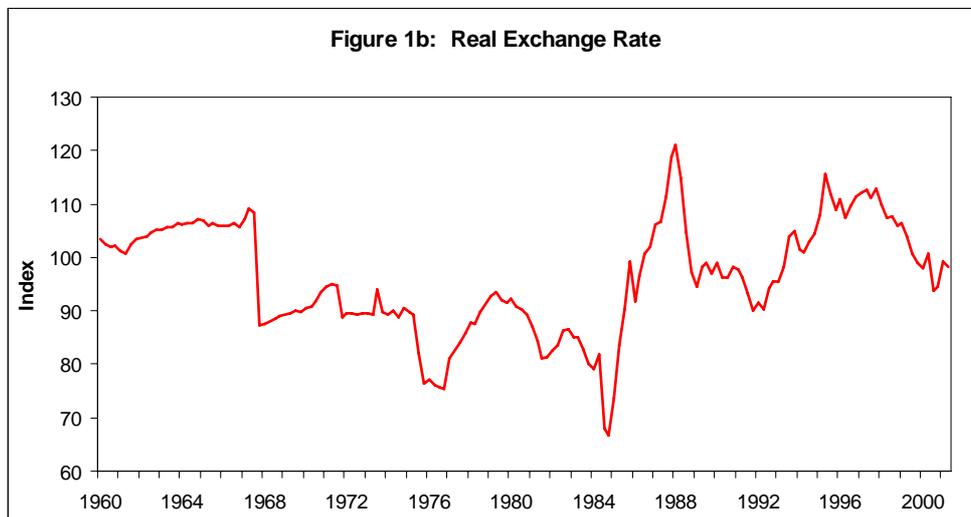
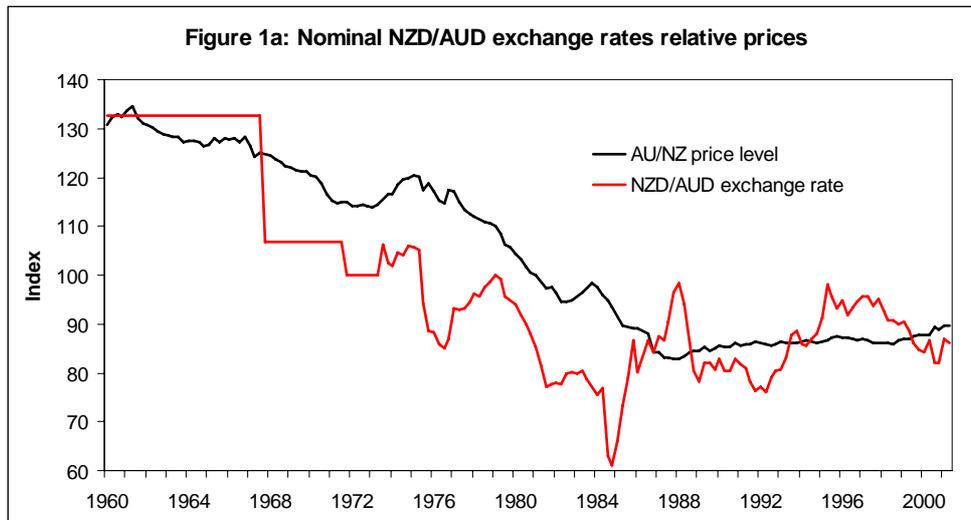
Over shorter time horizons the exchange rate can deviate for long periods of time from its PPP equilibrium. This can be seen from the deviation of the real exchange rate from its long-run average in figure 1b. According to a review article by Ken Rogoff (1996), the consensus among economists is that deviations of exchange rates from PPP damp out at a rate of roughly 15% per year. Put another way, these deviations have a 'half life' of three to five years. This is painfully slow.

There are a number of reasons why PPP doesn't hold over shorter spans of time. Although international markets are becoming more integrated, they are still relatively segmented and have large trading frictions across a broad range of goods. These frictions are due to factors such as transportation costs, tariffs, non-tariff barriers, and pricing to market behaviour by firms. At the extreme, a large proportion of goods and services are not traded on international markets.

These frictions make it difficult to arbitrage away international price differentials and mean that exchange rates are only loosely tied to their PPP equilibrium. Other macroeconomic fundamentals that reflect business cycle pressures can cause the real exchange rate to deviate from its PPP equilibrium. Fads and fashions in currency markets will also cause exchange rate to deviate from some notion of equilibrium. The key to explaining movements in the exchange rate lies in understanding these forces.

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<sup>2</sup> A depreciation (appreciation) of the real exchange rate is synonymous with an increase (decrease) in international competitiveness.



**Deviations from PPP**

A different rate of productivity growth across countries is one reason why the real exchange rates can move away from its PPP equilibrium. PPP relates to arbitrage in goods that are traded on international markets. But the real exchange rate is measured using price indices that include non-traded goods. As such, the real exchange rate can move away from its PPP equilibrium because different rates of productivity growth affect prices for non-traded goods across countries. In short, economies with high productivity growth will tend to have appreciating real exchange rates<sup>3</sup>.

While different rates of productivity growth are likely to explain medium to long-run movements in the real exchange rate, shorter-run cyclical movements are more likely to reflect the extent of **relative disequilibrium** in the economy. In other words, the real exchange rate may act as a type of 'safety valve' and move to offset cyclical pressures in the economy. The real exchange rate can play this role because of the effect it has on an economy's net international trade.

<sup>3</sup> This is known as the Balassa-Samulson effect. For a good discussion of the Balassa-Samulson effect in the New Zealand context see Brook and Hargreaves (2001).

For example, if domestic demand increases for some reason the real exchange rate should appreciate. This would cause net exports to fall, offsetting the increase in domestic demand and restoring the balance between aggregate supply and demand in the economy. Accordingly, if an economy is experiencing a business cycle upswing relative to its trading partners, the real exchange rate should tend to appreciate.

'Portfolio balance' type behaviour in financial markets may lead to a positive relationship between real exchange rate changes and **interest rate differentials** across countries. The theory of PPP is concerned with arbitrage in the international markets for goods and services. However, the movement of financial capital from country to country in search of the highest return is a far larger source of foreign exchange transactions. For example, if higher interest rates increase the expected return from investing in New Zealand then financial capital will be attracted to New Zealand, putting upward pressure on the real exchange rate<sup>4</sup>.

Further, in this age of inflation-targeting central banks interest rates tend to reflect the state of the business cycle and are another indicator of relative disequilibrium in the economy.

Because New Zealand and Australia are both small open economies that are highly dependent on exporting commodities, **commodity prices** are also likely to effect the real value of the currency. If prices (expressed in world price terms) for New Zealand's commodities increase relative to Australia's, then the real NZD/AUD exchange rate may tend to appreciate. This would reconcile the forces of supply and demand in both economies and restore internal balance. Also, higher prices for New Zealand's commodities increases the return on New Zealand's assets and therefore their value. This should also lead to an appreciation in the real value of the currency.

As well as facilitating internal balance, the real exchange rate can also be (equivalently) thought of as a mechanism for ensuring external balance between the domestic economy and the rest of the world. For example, if the level of savings in an economy is insufficient to finance its investments needs, then the stock of net foreign liabilities – what a country owes the rest of the world – will steadily increase. To finance this increase in foreign debt net exports will need to increase, hence the need for a currency depreciation.

The net balance of savings and investment flows within an economy is reflected by the balance on the **current account**. Consequently, we would expect a positive relationship between a country's (relative) current account and its real exchange rate.

In summary, economic theory suggests the following fundamentals may explain deviations of the real exchange rate from its PPP equilibrium:

- Different rates of productivity growth across countries
- Relative disequilibrium (business cycle pressures) in the economy
- Interest rate differentials
- Relative commodity prices
- Different savings/investment balances (current account balance).

### The data

We model the *real* NZD/AUD exchange rate, which we calculate using producer price indices. By choosing to model the real exchange rate we are effectively imposing PPP and assuming instantaneous adjustment to nominal shocks. However, this isn't really a major issue given that New Zealand and Australia have experienced broadly similar rates of inflation over the sample period of our study. As can be seen from figure 2a, the real and nominal NZD/AUD exchange rates have followed similar paths since the mid-1980s.

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<sup>4</sup> Note that textbook definitions of uncovered interest parity (UIP) conjecture a negative relationship between the *expected* exchange rate and interest rate differential. According to UIP if interest rates are higher in New Zealand than Australia then investors must be expecting the NZD/AUD exchange rate to depreciate so as to equalise returns across the two countries. We are modelling the actual exchange rate, not the expected exchange rate, and therefore postulate a positive relationship consistent with a capital flow notion of exchange rate dynamics.

We use output per person employed in New Zealand relative to Australia to capture productivity differences between the two economies (figure 2b). As well as capturing the impact of longer-run productivity differentials on the real exchange rate this variable will also reflect to an extent the relative business cycle positions of New Zealand and Australia.

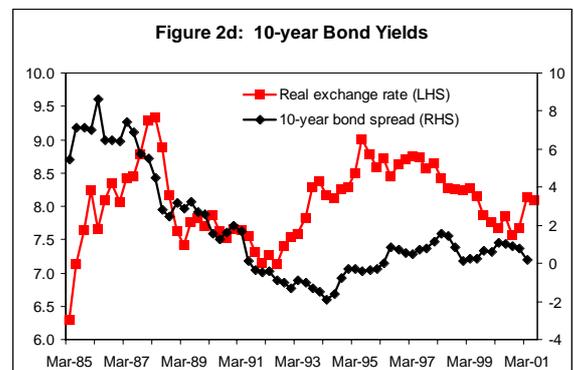
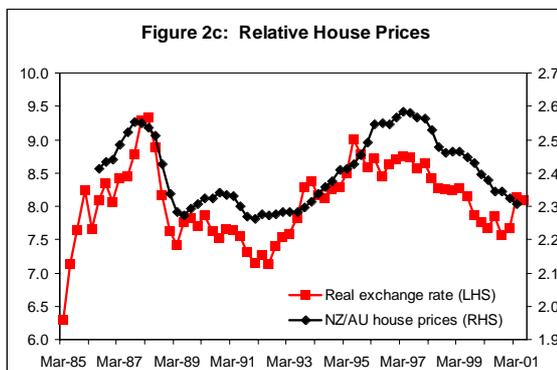
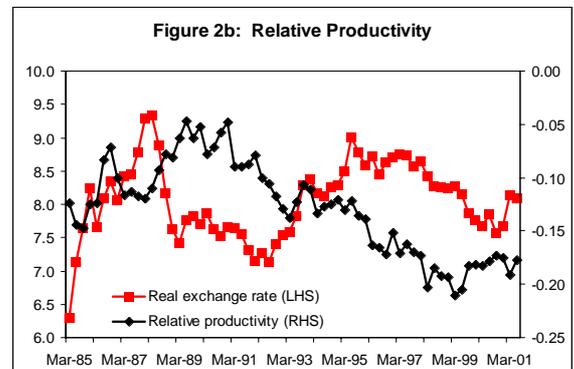
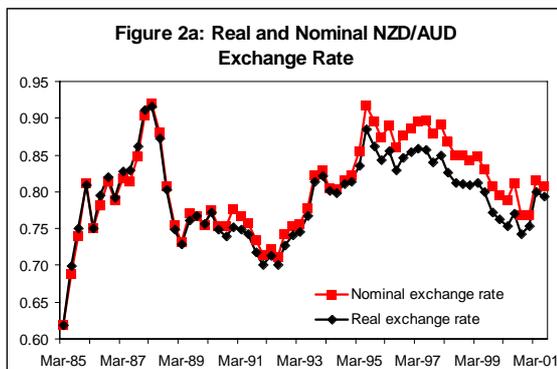
Our primary measure of disequilibrium or business cycle pressures across the two economies is relative house prices. House prices are seen as a good predictor of the real exchange rate over the business cycle. Grimes et al (2000) note a close cyclical relationship between New Zealand's real exchange rate and house prices. In a recent paper Bowden (2001) outlines theoretical reasons as to why this might be the case. In essence, changes in asset prices are driven by the same forces that alter the balance between non-traded and traded goods prices, and hence the real exchange rate. It follows that asset prices act as a signal for current or prospective changes in the real exchange rate.

Figure 2c shows the tight relationship between the real NZD/AUD exchange rate and relative house prices. In choosing our measure of relative disequilibrium in the two economies we tried a range of alternative indicators such as relative GDP growth and output gaps. However, none of these alternatives could explain cyclical swings in the real exchange rate as well as relative house prices. Further, house price data is available on a more timely basis than GDP data and isn't prone to significant revisions.

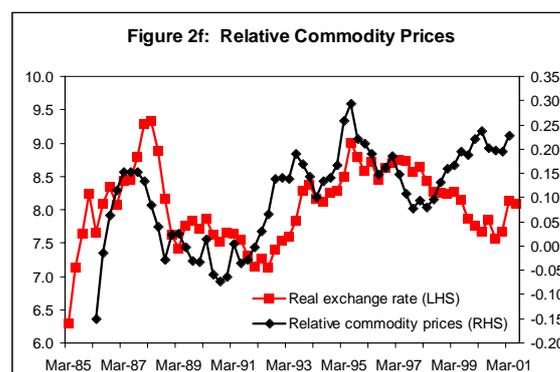
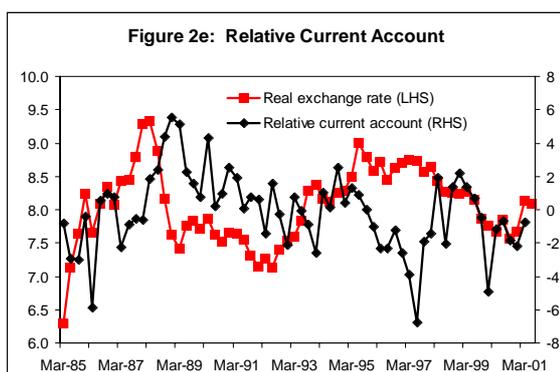
We use the spread on real 10-year bond yields in New Zealand and Australia as our measure of the interest rate differential (figure 2d). Real rates are calculated as the nominal rate minus a measure of expected inflation<sup>5</sup>. By using real 10-year bond yields we also capture medium-term factors, such as the risk premium, in our model.

Commodity price effects are captured by the ratio of New Zealand to Australian commodity prices (figure 2e). The relative savings/investment balance between the two countries is captured by the relative current account balance (figure 2f).

Further details on the data sources can be found in the appendix.



<sup>5</sup> We simply assume the expected inflation is equal to current actual (PPI) inflation.



### 3) The modelling technique

To capture the dynamics of the real NZD/AUD exchange rate we use a 'vector error correction' (VECM) model. This technique was developed by the Swedish econometrician Soren Johansen, and has been used by a number of economists to model exchange rates<sup>6</sup>. There are two appealing aspects of this technique.

First, it allows us to model the exchange rate as part of a system. Within that system each variable has its own separate equation. In this way the model captures all the interdependencies between the variables. For example, an increase in domestic demand in NZ will not only influence the exchange rate *directly*, but will also affect prices, interest rates, and the current account. In turn, changes in these variables will have an additional *indirect* impact on the exchange rate.

The VECM technique allows us to capture all of these influences – both the direct and indirect effects. In contrast, single equation models only capture the direct effects and can miss potentially important dynamics.

The other appealing aspect of the VECM approach is that it accounts for both long-run and short-run influences in the same model. Long-run influences are captured by looking for equilibrium relationships between the variables of the model. Broadly speaking, an equilibrium relationship exists if the variables influence each other over a long period of time.

If such a relationship exists, the variables are said to be 'cointegrated'. As an analogy for cointegration consider the case of a drunk couple walking home after a night on the town. Despite the appearance of randomness, the movement of each individual is influenced by the other. If they stagger too far apart, an overriding force brings them back together and each individual arrives home at approximately the same time.

If the variables in our VECM model share a long-run equilibrium relationship then we can use this to help explain their short-run dynamics. In much the same way as the drunk couple tend to move together through the streets, the variables of the model will move in such a way so as to restore equilibrium in the long run. For example, if the exchange rate has recently deviated from the equilibrium path then we can expect it to gradually drift back towards equilibrium over time.

To capture the short-run dynamics in the data we include lags of the first difference of each variable in the equations of the system. In this way quarter on quarter change in each of the variables is influenced by recent changes in itself and the other variables of the model. In terms of the drunk couple, these effects are analogous with a quick sleep in a bush, a trip to the burger bar, or any other temporary distraction on the way home.

A mathematical description of the model and the tests for cointegration are given in the appendix.

<sup>6</sup> Examples include: MacDonald (1997), MacDonald and Taylor (1993, 1994) and MacDonald and Marsh (1996). Authors who have modelled the NZ exchange rate using this technique include: Lee (2001), and Stephens and Choy (2001). For one of the original papers on cointegration see Johansen (1998).

## 4) Estimation results

### The long-run equilibrium exchange rate

Tests on the model indicate strong evidence of cointegration. In other words, the variables of the model do appear to share a long-run equilibrium relationship. So over long periods of time the variables do not move independently of each other. Instead, the long-run trends are linked.

We assess the nature of this linkage by looking at the coefficients in the equilibrium relationship. If the equilibrium relationship is meaningful, then we would expect the linkages between the variables to be consistent with the economic theory outlined in section 2 and statistically significant.

Estimation of the model reveals that all the coefficients in the long-run relationship have the expected positive sign. However, tests of significance reveal that the coefficient on relative interest rates is not statistically different from zero. This indicates that the interest rate differential does not play a significant role and can be excluded from the long-run equilibrium relationship.

This leaves us with a cointegrating relationship that can be written as<sup>7</sup>:

$$e_t = \mu + 0.339(cp_t^{nz} - cp_t^{au}) + 0.556(dd_t^{nz} - dd_t^{au}) + 0.514(ca_t^{nz} - ca_t^{au}) + 0.435(p_t^{nz} - p_t^{au}) + \varepsilon_t$$

(0.047)
(0.028)
(0.182)
(0.110)

The variable  $e_t$  stands for the real NZD/AUD exchange rate,  $cp_t$  is commodity prices,  $dd_t$  is domestic demand,  $ca_t$  is the current account, and  $p_t$  is labour productivity. All of the variables are in logs. Superscripts denote the relevant country.  $\mu$  is a constant and  $\varepsilon_t$  is the equilibrium error term. The numbers below the coefficients are standard errors. All of the coefficients are statistically significant and a plausible magnitude. So not only is there strong evidence of a long-run relationship between the variables of the model, but the nature of this relationship is consistent with economic theory.

Because the trends of the variables are linked (cointegrated), the dynamic paths of the variables will be influenced by the current deviation from the equilibrium relationship. In other words, there is a connection between the change in the variables and the deviation from equilibrium. The strength of this connection is captured by the 'speed of adjustment' parameter.

In the exchange rate equation, the speed of adjustment parameter is -0.6. This has the expected negative sign and is highly significant in a statistical sense with a t-statistic of 3.6. This means that the equilibrium relationship is an important determinant of quarterly changes in the real exchange rate. If the exchange rate wanders away from equilibrium, it will tend to drift back over time. In fact, the speed of adjustment parameter is reasonably large and indicates that deviation of the exchange rate from equilibrium are relatively short lived, lasting only a few quarters on average.

In figure 3 we plot our measure of the equilibrium NZD/AUD exchange rate, derived from our model, and the actual exchange rate. For ease of interpretation we have converted the real exchange rate that is used in our model into the nominal value.

The first point to note is that the equilibrium exchange rate tracks the actual exchange rate reasonably closely and matches the broad swings that have occurred over the sample period. This indicates that the economic fundamentals included in our model explain trend movements in the NZD/AUD exchange rate over the last fifteen years of so reasonably successfully.

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<sup>7</sup> This equation could be written with any of the variables on the left-hand side. However, because we are interested in the exchange rate, we make this the subject of the equation.

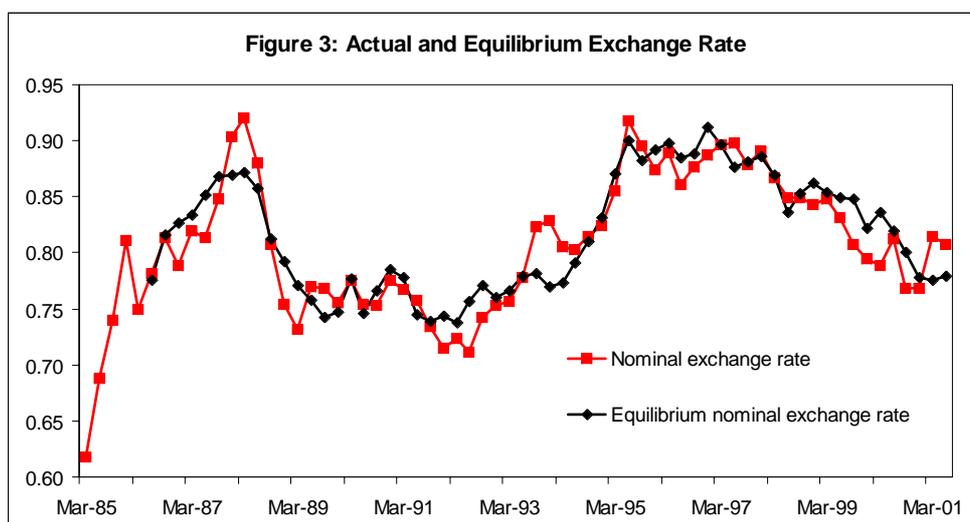
It also raises the issue of what exactly do we mean by the term 'equilibrium exchange rate'. This is a term that must always be interpreted in context. For example, at one extreme it could be argued that because the exchange rate is continually determined by the forces of supply and demand, it is always at an 'equilibrium' value. At the other extreme, the exchange rate can move away from PPP-based measures of 'equilibrium' for years on end.

The equilibrium measure of the NZD/AUD exchange rate derived from our model and shown in figure 3 is clearly in between these two extremes. Our equilibrium measure can be thought of as the exchange rate that would prevail if determined solely by the economic fundamentals included in the model. These fundamentals reflect the effect of the business cycle and other short-run economic perturbations. As such, our measure of the equilibrium NZD/AUD exchange rate also reflects this type of volatility. This makes it a reasonably short-term, temporary equilibrium, rather than one that is consistent with the notion of a 'steady state' in the economy.

Because our measure of equilibrium reflects the economic fundamentals, any deviation of the actual exchange rate from equilibrium can be thought of as largely the result of asset bubbles and other speculative behaviour (and any fundamentals omitted from the model). According to our model, the peak of the sharp appreciation in the exchange rate in 1988 was speculative in nature. Also, the appreciation of the currency in 1993 was premature on the basis of the fundamentals and pre-empted the ensuing increase in the equilibrium exchange rate. Since the late 1990s the depreciation of the currency has been largely justifiable on the basis of the economic fundamentals captured in our model.

Although speculative factors can move the exchange rate in the short run, our model indicates that trend movements in the NZD/AUD exchange rate are ultimately determined by economic fundamentals. This means that the NZD/AUD exchange rate has moved to offset relative cyclical pressures in the two economies. From the perspective of the currency union debate this highlights a potential cost, in terms of a loss of an effective shock absorber, that would result from forming a currency union with Australia<sup>9</sup>.

The results from estimating our model also suggests that if we have a good understanding of the relative economic fundamentals in NZ and Australia, we should be reasonable successful at predicting trend movements in the NZD/AUD exchange rate.



<sup>8</sup> Note that we say nothing on the overall desirability or otherwise of a currency union with Australia. For an excellent review on New Zealand work on currency union, see Bjorksten (2001).

**Short-run dynamics**

The last section was concerned with how well the model captures the long-run trends in the NZD/AUD exchange rate. In this section we assess the short-run dynamics of the model. In other words, we want to see how well the model captures the quarter on quarter relationships between the exchange rate and the other variables of the model. We use two different techniques to do this.

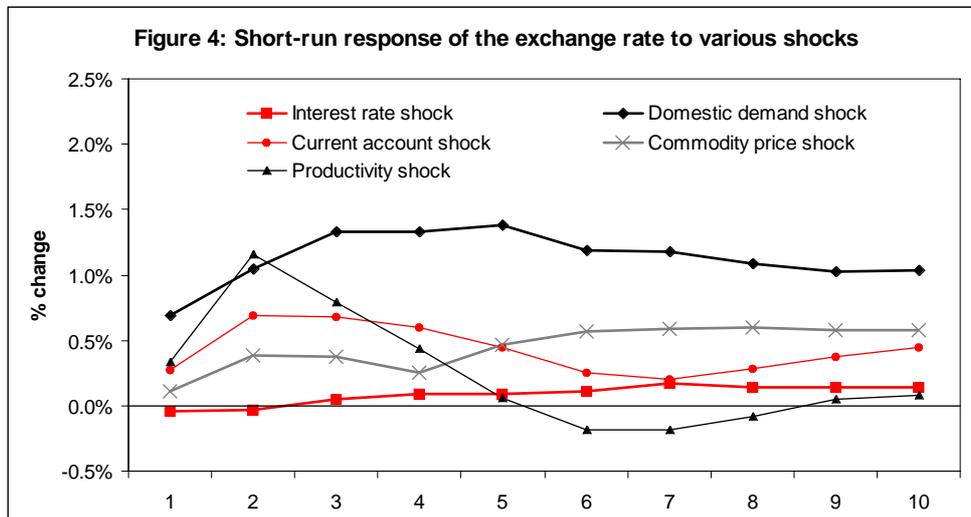
First, we assess short-run dynamics by calculating 'impulse response functions' (IRFs). IRFs are calculated by subjecting a variable of the model to an unexpected 'shock' and seeing how the other variables react. Using this technique we can see, for example, how the real exchange rate responds to an unexpected increase in New Zealand's commodity prices. If the reactions are broadly consistent with the predictions of economic theory we can conclude that the model has sensible short-run properties.

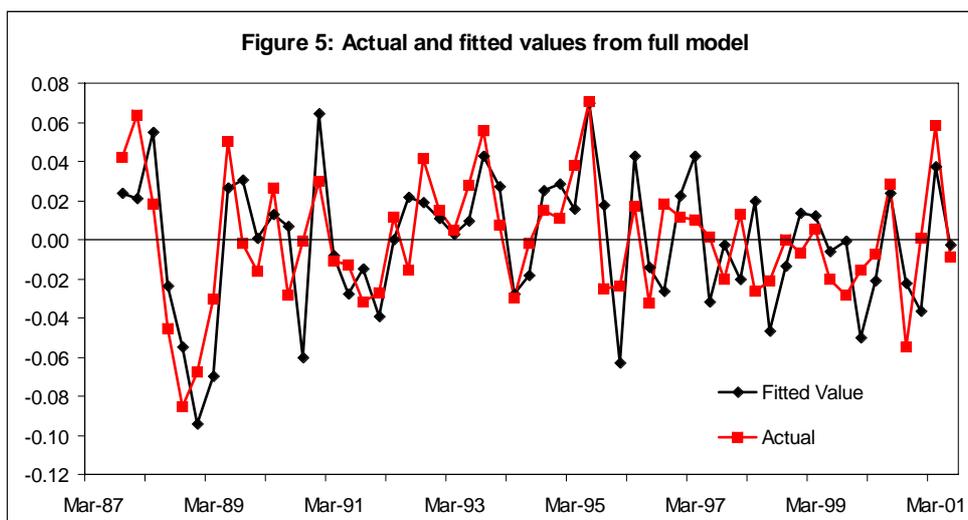
The response of the real NZD/AUD exchange rate to unexpected increases in the other variables of the model is graphed in figure 4. As we would expect, the response is generally positive in all cases. Shocks to relative house prices and commodity prices in particular have a strong influence on the real NZD/AUD exchange rate. Shocks to the interest rate differential exert a minimal effect.

The second way of assessing the short-run properties of the model involves looking at how well the predictions of the model 'fit' the data. In other words, we compare the model's predictions for quarterly changes in the exchange rate with the actual exchange rate data.

Figure 5 plots the actual change in the real NZD/AUD exchange rate through time and the fitted value derived from our model. The model does a reasonably good job of matching the data and correctly picks the direction of quarterly changes in the exchange rate 80% of the time.

All in all, the short-run dynamics of the model appear to be sensible.





## 5) Forecasting ability

Fitting the data is an 'in sample' test in that it uses all available information to forecast past movements in the exchange rate. A more difficult test for our model is to see how well it forecasts 'out of sample'.

To conduct an out of sample test we estimate the model over a 'rolling' sample period. Specifically, we begin by estimating the model over the period 1987Q2 to 1997Q1. We then use this version of the model to forecast the exchange rate over the next eight quarters – that is, 1997Q2 through to 1999Q1. We then re-estimate the model using an additional quarter of data and calculate another set of exchange rate forecasts. This process is repeated until the end of the sample period, 2001Q2.

We compare this set of exchange rate forecasts with the actual exchange rate data and calculate measures of forecast error at each time horizon<sup>9</sup>. These give us a good idea of the forecasting ability of the model.

To evaluate the model we compare its forecasting ability with that of an alternative method of predicting exchange rate movements. The alternative that we use is a 'random walk' exchange rate forecast. The intuition behind this forecasting method is that in the next quarter the exchange rate will equal what it is today plus or minus a random component. The random walk model is a good parable for how currency traders pick exchange rate movements and a common metric by which exchange rate model are assessed<sup>10</sup>.

The ratio of forecast errors from our model to forecast errors from the random walk model is given in table 2. Over all time horizons the ratio is less than one indicating that the forecast errors from our model are smaller than those of the random walk model. In other words, our model is clearly more proficient than a random walk at forecasting the NZD/AUD exchange rate.

<sup>9</sup> Specifically, we calculate root mean squared error statistics.

<sup>10</sup> This approach was used in a famous paper by Meese and Rogoff (1983). MacDonald (1997) also uses this test.

**Table 1: Ratio of forecast errors our model/random walk**

Quarters ahead	Ratio
1	0.564227
2	0.672784
3	0.496917
4	0.746577
5	0.600053
6	0.495325
7	0.547338
8	0.698036

## 6) Conclusions

The overriding conclusion that we draw from this work is that economic fundamentals give good insight into the behaviour of the NZD/AUD exchange rate. In particular, our model does a credible job of explaining the broad trends in the real NZD/AUD exchange rate over the last fifteen or so years. This is clearly useful when it comes to forecasting the NZD/AUD exchange rate. If we have a good understanding of how the fundamentals of Australia and New Zealand are likely to unfold, we stand a good chance of correctly picking the future trend in the exchange rate.

It is important to note that this is not always the case with exchange rate models. Recent attempts at modelling the NZD/USD and AUD/USD exchange rates find that the New Zealand and Australian dollars are currently significantly undervalued on the basis of economic fundamentals<sup>11</sup>. We surmise that our model is reasonably successful at explaining trends in the NZD/AUD exchange rate because strong market sentiment towards the US dollar is not an issue. Because this distorting influence washes out, economic fundamentals play a larger role and the behaviour of the exchange rate becomes more predictable.

Unfortunately, the old adage still applies: "All models are wrong, but some are useful". The only thing that is certain about our model, or any economic model, is that its quarterly exchange rate forecasts will be wrong to some degree<sup>12</sup>. However, the model we present in this paper provides a framework for considering interdependencies between macroeconomic fundamentals and the NZD/AUD exchange rate. As such it complements our existing forecasting expertise and, hopefully, will prove to be a useful model.

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<sup>11</sup> See, for example, Stephens and Choy (2001).

<sup>12</sup> This is why we haven't included a forward track for the NZD/AUD exchange rate in this paper! We save that for our monthly *Markets Report*.

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## Data Appendix

Variable	Description	Source
Nominal NZD/AUD exchange rate	Average for quarter	Bloomberg
NZ 10-year bond yield	Average for quarter	Datastream: NZI61...
AU 10-year bond yield	Average for quarter	Datastream: AUI61...
NZ producer prices		Datastream: NZPP....F
AU producer prices		Datastream: AUOCCPMFF
NZ current account	% of GDP	Datastream: NZCURBALB
AU current account	% of GDP	Datastream: AUOCCBALB
NZ house prices		Quotable Value NZ
AU house prices		Australian Bureau of Statistics
NZ productivity	GDP per person employed	Statistics NZ
AU productivity	GDP per person employed	Australian Bureau of Statistics
NZ commodity prices	3 month average	ANZ
AU commodity prices	3 month average	Reserve Bank of Australia

## Technical Appendix<sup>13</sup>

Our exchange rate model can be written as:

$$z_t = A_1 z_{t-1} + \dots + A_k z_{t-k} + \mu + \varepsilon_t$$

where  $z_t$  is a  $(n \times 1)$  vector of the real exchange rate and the other variables of the model. The vector  $\mu$  contains constants and  $\varepsilon$  is a vector of white noise disturbances with a zero mean. On the basis of conventional lag length tests we include 4 lags in this equation. That is,  $k=4$ .

This equation can be rewritten in vector error correction (VECM) form as:

$$\Delta z_t = \Gamma_1 \Delta z_{t-1} + \dots + \Gamma_{k-1} \Delta z_{t-k+1} + \Pi z_{t-1} + \mu + \varepsilon_t$$

where the  $\Gamma$ 's are  $(n \times n)$  matrices of short-run coefficients and  $\Pi$  contains the long-run coefficients.  $\Delta$  symbolises 'change in'.

The rank of  $\Pi$  determines the number of cointegrating vectors in the system. If  $\Pi$  is of reduced rank then there exist matrices  $\alpha$  and  $\beta$  such that

$$\Pi = \alpha \beta'$$

The columns of  $\beta$  are the linearly independent cointegrating vectors and the  $\alpha$  matrix is the adjustment matrix and indicates the speed with which the system responds to last period's deviations from the cointegrating vector.

To test for cointegration we use the trace test statistic developed by Johansen. This is a test that there are at most  $r$  independent cointegrating vectors. The test statistic is calculated as:

$$\lambda_{\text{trace}} = T \sum_{i=r+1}^N \ln(1 - \hat{\lambda}_i)$$

<sup>13</sup> In this appendix we provide a very brief explanation of the modelling technique we use. For a more comprehensive discussion Enders (1995) is a very readable reference.

where  $\hat{\lambda}_i$  is the estimated eigenvalues of the  $\Pi$  matrix and  $T$  in the number of observations. The critical values for this statistic are calculated by simulation studies and can be found in Johansen and Juselius (1990).

The results of this test for cointegration in the variables of our model are given in table A1. As discussed in the text, these results suggest strong evidence of cointegration.

To calculate the IRF's we use a Choleski factorisation on the residuals of the reduced form model. We assume the following causal ordering for this factorisation:

$$e_t, (i_t^{nz} - i_t^{au}), (dd_t^{nz} - dd_t^{au}), (cp_t^{nz} - cs_t^{au}), (p_t^{nz} - p_t^{au})$$

**Table A1: results of cointegration tests**

Null Hypothesis	Alternative Hypothesis	$\lambda_{\text{trace}}$ values
$r=0$	$r>0$	135.99***
$r\leq 1$	$r>1$	88.42
$r\leq 2$	$r>2$	47.79
$r\leq 3$	$r>3$	26.15
$r\leq 4$	$r>4$	8.70
$r\leq 5$	$r>5$	1.57

\*\*\* Significant at the 1% level

The time-series properties of the data are an important consideration. In particular, whether they contain a unit root has a bearing on the most appropriate modelling strategy. The results of unit root tests on the variables in our model are reported in table A2. The numonics are the same as in the main text.

The results indicate that all the variables have a unit root. The results for the relative current account and interest rates are boarder line. However, the modelling technique that we use is able to cope with a mix of I(1) and I(0) variables so boarderline non-stationarity is not a problem.

**Table A1: ADF unit root tests: levels data**

	t3	t2	t1	$\Phi 3$	$\Phi 1$	Conclusion
$e_t$	-2.3	-2.4	-1.1		3.0	I(1), zero drift
$(p_t^{nz} - p_t^{au})$	-2.7	-1.5	-0.7	3.8	1.4	I(1), zero drift
$(i_t^{nz} - i_t^{au})$	-2.0	-1.8		2.4	1.7	I(1), zero drift
$(cp_t^{nz} - cp_t^{au})$	-3.2	-1.5	-0.8	5.6	1.2	I(1), zero drift
$(dd_t^{nz} - dd_t^{au})$	-2.3	-2.1	-0.8	2.8	2.5	I(1), zero drift
$(ps_t^{nz} - ps_t^{au})$	-2.2	-2.8	-1.8	2.5	2.5	I(1), zero drift

\*\*5% sig, \*10% sig.