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**PPP-based analysis  
of New Zealand's  
equilibrium exchange rate**

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## PPP-based analysis of New Zealand's equilibrium exchange rate

### Abstract<sup>1</sup>

We use two alternative methodologies to estimate an equilibrium value for the USD/NZD bilateral exchange rate. A cross-country comparison of prices for individual goods, augmented with a Balassa-Samuelson variable suggests that the New Zealand dollar was close to fairly valued in 1999, but undervalued by slightly more than 10 per cent in 2000. Equilibrium was estimated at roughly US\$0.52. The second methodology uses dynamic OLS and panel dynamic OLS, to test for a cointegrating relationship between the nominal exchange rate and relative prices, as well as a number of other possible explanatory variables. Using a long sample period for New Zealand, we find some tentative evidence of a stable PPP relationship for the USD/NZD bilateral exchange rate, and this model suggests that the equilibrium value of the dollar is roughly US\$0.60. However, the results are very sensitive to the sample period, and in most specifications, particularly those that incorporate the recent depreciation in the New Zealand dollar, the data are unresponsive of a long-run PPP relationship. Therefore, the results should be interpreted with caution.

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<sup>1</sup> The views expressed in this paper are those of the authors and do not necessarily represent the views of the Reserve Bank of New Zealand. The authors would like to thank all those who provided us with comments and suggestions, especially Nils Bjorksten, Robert St Clair, Kelly Eckhold, and John McDermott. All errors and omissions are the responsibility of the authors. © Reserve Bank of New Zealand. Email: [brooka@rbnz.govt.nz](mailto:brooka@rbnz.govt.nz); [hargreavesd@rbnz.govt.nz](mailto:hargreavesd@rbnz.govt.nz)

## 1 Introduction

The concept of purchasing power parity (PPP) is often the first port of call for economists and market analysts who wish to estimate exchange rate 'equilibrium'. The concept of equilibrium is also important for central bankers, who must make an assessment of how under- or over-valued the exchange rate is, in order to evaluate the pressures on inflation going forward.

In its absolute form, purchasing power parity implies that the real exchange rate will be mean reverting to some equilibrium constant, although it may deviate from its 'equilibrium level' for several years at a time. However, it is commonly accepted that the equilibrium exchange rate may be determined by real factors. If those real factors follow a non-stationary process, then the real exchange rate will also be non-stationary.

This paper takes two alternative approaches to estimate a PPP-based measure of equilibrium. Section 2 estimates a measure of 'equilibrium' for the USD/NZD bilateral exchange rate using the OECD and United Nation's International Price Comparison Programme (ICP), augmented with GNP/capita as a proxy for the Balassa-Samuelson effect. This approach suggests that the equilibrium USD/NZD exchange rate in 1999 was about US\$0.52. However, this methodology implicitly assumes that the determinants of exchange rate equilibrium (eg variables such as the terms of trade and net foreign assets) also revert to constant 'equilibrium' levels. Because this assumption may be unrealistic, most policy-focused analysis of the exchange rate involves augmenting a time-series PPP-based model with some or all of these additional variables. This is the approach we take in section 3 – using dynamic OLS to test for a cointegrating PPP relationship.

Most studies have failed to find cointegrating relationships that are consistent with PPP (or, equivalently, consistent with a stationary real exchange rate). This is particularly true over relatively short sample periods. Our analysis is generally consistent with this. Although we find tentative evidence of a valid PPP relationship between the NZ dollar and US dollar (with a bilateral exchange rate equilibrium of about US\$0.60), the exact relationship was sensitive

to a number of assumptions. For example, the evidence for the cointegrating relationship was relatively strong in the data sample ending in mid-1999, but became weaker when we extended the sample to the end of 2000. In sections 3.2 and 3.3 we discuss alternative interpretations of these results.

In section 4 we summarise the results and make some concluding remarks.

## 2 The concept of purchasing power parity and some cross-country analysis

The most restrictive definition of purchasing power parity (PPP) is the Law of One Price (LOOP) whereby international arbitrage causes the price of every good to be equalised (when expressed in a common currency). This motivates a simple cross-country approach to estimating equilibrium exchange rates: simply measure the price of one or more things in two different economies, and calculate the exchange rate that would make those prices identical. The most famous example, the Economist's Big Mac Index, showed recently that a Big Mac cost NZ\$3.40 in New Zealand, and US\$2.54 in the United States.<sup>2</sup> This produces a PPP (LOOP) exchange rate of US\$0.74, and implies that the USD/NZD exchange rate in the first quarter of 2001 was over 40 per cent undervalued in mid-April 2001. At the same time, according to the Big Mac Index, the NZD was at approximately fair value against the AUD, but very undervalued against the Yen and the trade weighted exchange rate index (TWI).

While the Economist's Big Mac Index receives more popular attention than other comparable efforts, there exist better cross-country price comparisons. For example, the OECD and the United Nations are involved in the *International Price Comparison Programme (ICP)*, which surveys a wider range of prices and therefore produces more rigorous estimates of the exchange rates that would eliminate price differences between their member nations. Every three years, the ICP surveys a wide range of

<sup>2</sup> From the April 19, 2001 issue of the Economist.

countries, attempting to determine the price (in local currency) of gross domestic product.<sup>3</sup>

Based on this analysis, the OECD has estimated that New Zealand's price level would have been equal to the US price level in 2000 if the USD/NZD bilateral exchange rate was around US\$0.68. Similarly, the ICP analysis establishes that the AUD/NZD PPP exchange rate would have been AU\$0.90, and the Yen/NZD exchange rate around Y105. On average over 2000 the New Zealand dollar actually bought US\$0.46, AU\$0.79, and Y49. So on this basis the NZD was undervalued 32 per cent against the US dollar, 12 per cent against the Australian dollar, and a massive 52 per cent against the Yen.

While this is a useful starting point for thinking about equilibrium exchange rates, Driver and Westaway (2001), in a survey paper on alternative concepts of exchange rate equilibrium, point out that there are at least two reasons why the LOOP tends not to hold. The first is the existence of trade barriers and transport costs. The second explanation is imperfect competition, whereby firms may have a degree of market power giving them the possibility of pricing to market. Pricing to market means that the full impact of changes in the exchange rate is not passed on to imported consumer goods.

Even if the LOOP does hold for individual goods that are traded internationally, arbitrage will not be able to equilibrate the prices of *non-tradable* goods and services around the world. Even many traded goods, when sold, include a substantial non-traded component. For example, clothing is clearly a tradable good, but the main costs facing a clothing store are likely to be rent, power and wages: all non-tradable.

How will the price of non-traded goods vary across countries? Countries with very productive *traded-goods* sectors are like to have relatively high wages in that sector. In turn, this bids up national asset prices and national wages, increasing production costs in the non-traded sector. Because the exchange rate moves to equilibrate

<sup>3</sup> The prices of "a sample of all goods and services covered by GDP" are surveyed and aggregated into an overall price index (in local currency) for GDP. For more information, see <http://www.oecd.org/std/ppp/pppfaq.htm>.

the costs of *traded* goods, the prices of non-traded goods in countries with productive tradable sectors tend to be relatively high. This is the so-called Balassa-Samuelson effect. Although a hairdresser (or a coffee shop attendant, or a concierge) in Tokyo may be no more productive than one in Delhi, they demand a much higher wage because they could earn much more in alternative employment in the tradable sector. As a result, non-traded goods tend to cost more in Japan than in India. Traded goods will also cost more in Japan to the extent that their price includes the cost of non-traded services, such as rents and retail mark-ups.

Because the ICP data are based on GDP deflators, and include not just traded goods prices but also *non-traded* goods prices, it is not surprising that average prices differ across countries. In this section we attempt to improve the ICP estimates of the equilibrium exchange rate by capturing the Balassa-Samuelson effect.

In time-series analysis, the Balassa-Samuelson effect is normally captured by inclusion of relative productivity or the relative price of tradable to non-tradable goods between the two relevant economies (see section 3). In this cross-sectional analysis, we would ideally capture the Balassa-Samuelson effect using the *level* of competitiveness of each country's tradable sector. Unfortunately, while the level of productivity has been estimated for most OECD economies (see Scarpetta, Bassanini, Pilat & Schreyer, 2000), this data does not exist for New Zealand.<sup>4</sup> Therefore, we use GDP per capita as a simple proxy for the productivity of the traded goods sector and the Balassa-Samuelson effect.

The following cross-sectional regression uses GNP per capita to augment the ICP data as an explainer of equilibrium exchange rates.

Equation (1) describes the model estimated. The dependent variable ( $Val_{j,1997-99}$ ) is the average deviation of country  $j$ 's exchange rate from its ICP estimate of equilibrium over the 1997-1999 period. The

<sup>4</sup> Note that in section 3 we use OECD labour productivity data to augment our time series analysis. However, that data is an *index* of labour productivity and therefore does not allow a comparison of *absolute* productivity across countries.

explanatory variable is each country's average GNP per capita over the 1997-1999 period.

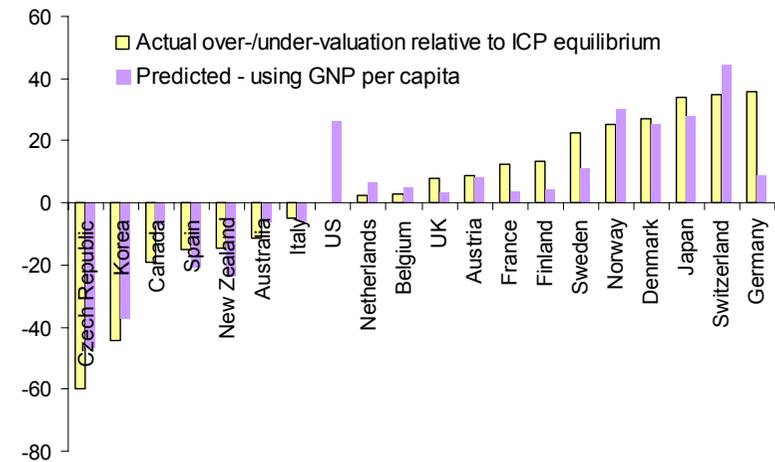
$$VAL_{j,1997-99} = -57.2 + 0.003 \text{ GNP/CAP}_{j,1997-99} \quad (1)$$

(7.7\*\*) (9.1\*\*)

t-statistics are reported in parentheses.  $R^2 = 0.82$ . Std error = 0.14. The subscript  $j$  represents the 20 OECD countries included in the cross-country regression.

Figure 1 charts the actual and predicted ICP (1997-99 average) estimates of under-/over-valuation.

**Figure 1:**  
**Actual and predicted deviations from ICP equilibrium**  
(each currency relative to USD: 1997-99 average)



The results from equation 1 suggest that GNP/capita (a rough proxy for productivity differences across countries) can explain about 80 per cent of the deviations of actual exchange rates from their ICP measures of equilibrium. For example, the analysis suggests that the same goods cost less in Canada, New Zealand and Australia than in the United States because absolute productivity in each of these countries is lower than in the United States (with GNP/capita serving as the rough proxy for productivity levels). Lower productivity

implies cheaper non-traded goods and therefore cheaper prices of goods overall. In contrast, the analysis suggests that prices of goods in Switzerland are more expensive than the same goods in the US because of Switzerland's relatively higher GNP/capita. Thus the New Zealand exchange rate is 'lower' than a simple PPP-based valuation, and the Swiss exchange rate is 'higher'.

We can use the predicted deviation from ICP equilibrium for 1997-99 to adjust the ICP estimates of fair value for different years.<sup>5</sup> This gives us a Balassa-Samuelson (B-S) adjusted equilibrium exchange rate. Table 2 summarises the B-S adjusted equilibrium values for the USD/NZD, AUD/NZD, and Yen/NZD together with the extent to which each of these bilateral rates was over-/under-valued relative to this measure of equilibrium.

**Table 1:**  
**ICP equilibrium exchange rates adjusted for the Balassa-Samuelson effect**

	1999	2000
<b>USD/NZD</b>		
Actual	0.53	0.46
Equilibrium (B-S adjusted ICP)	0.52	0.52
Over/under-valuation	+2.7%	-12.6%
<b>AUD/NZD</b>		
Actual	0.82	0.79
Equilibrium (B-S adjusted ICP)	0.72	0.73
Over/under-valuation	+13.3%	+6.9%
<b>Yen/NZD</b>		
Actual	60.3	49.3
Equilibrium (B-S adjusted ICP)	59.6	57.6
Over/under-valuation	+1.3%	-14.4%

As table 1 shows, the B-S adjusted equilibrium exchange rate for the USD/NZD in 2000 was about US\$0.52. This can be compared to the unadjusted ICP estimate of equilibrium discussed on page 3, which was US\$0.68.

<sup>5</sup> It was not possible to include 2000 data in our estimates of equation 1, since GNP/capita data was not available for that year.

In other words, once we take account of the Balassa-Samuelson effect (albeit in a very simple way), this analysis suggests that the NZD was roughly at fair value relative to both the USD and Yen in 1999, but undervalued by more than 10 per cent in 2000. For both years the model suggests that the NZD was over-valued relative to the AUD.

In summary, this section has involved analysing benchmark prices, and adjusting (in a simple way) for the relative productivity of New Zealand and our trading partners. The results suggest that the exchange rate was in fact very fairly valued in 1999 and only slightly undervalued in 2000. This result contrasts with the unadjusted ICP estimates of PPP equilibrium, which suggest that the NZD was very significantly undervalued relative to both the USD and the Yen, in both 1999 and 2000.

However, not only does this analysis rely on a relatively infrequent survey conducted by the OECD, but it also does not take into account a number of other things that could be important determinants of the exchange rate (interest rates are an obvious example). Also, we have not investigated whether the exchange rate tends to converge to a PPP-based estimate of equilibrium. We examine these additional points in the next section by looking at PPP *over time* rather than *across countries*.

### 3 Time series analysis of Purchasing Power Parity

The concept of absolute PPP can be summarised by equation (2)

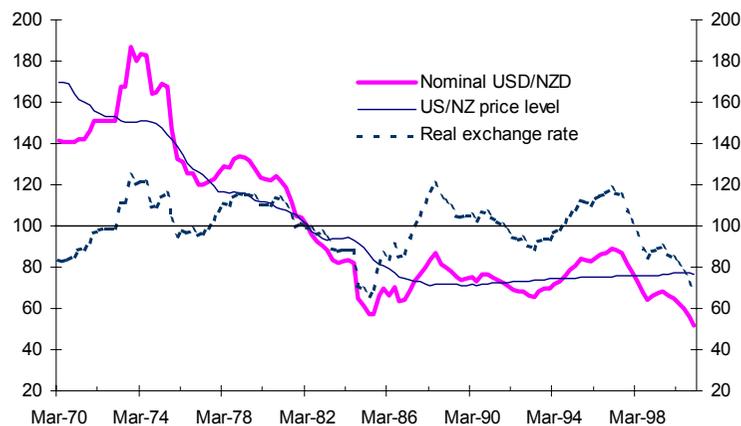
$$s_t = p_t^* - p_t \quad (2)$$

Where  $s_t$  is the log of the nominal bilateral exchange rate,  $p_t^*$  is the log of the foreign price level and  $p_t$  is the log of the domestic price level.  $s_t$  is defined as the foreign currency price of a unit of domestic currency so that an increase in  $s_t$  represents an appreciation. Subscripts denote time.

Equation (2) captures the relationship whereby higher relative inflation in one country will lead to a depreciation of its nominal exchange rate against its trading partners. Hence PPP implies that the *real* exchange rate should be fairly stable over time.

A large literature on PPP has emerged, much of it devoted to testing whether or not PPP holds over time, or equivalently, testing *how* stable the real exchange rate is.<sup>6</sup> It is generally accepted that the real exchange rate can deviate from its PPP-based estimate of 'equilibrium' for prolonged periods. But for the less restrictive definitions of PPP to hold, the real exchange rate must be mean reverting.

**Figure 2:**  
**USD/NZD bilateral exchange rate 1970-2000**  
(re-based so average of each variable equals 100)



A visual analysis suggests that the PPP hypothesis may fit the New Zealand data reasonably well. Figure 2 charts the New Zealand nominal and real USD/NZD bilateral exchange rate over a 30-year period, together with the ratio of the US and domestic price level indices. The real exchange rate illustrates the cyclical deviations of the nominal exchange rate from the smoothly evolving relative price ratio. Consistent with the concept of PPP, the real exchange rate

<sup>6</sup> See MacDonald (1995) for an overview of this literature.

seems to have cycled around its long-run historical average with periods of disequilibrium lasting no more than 4-5 years.

Generally speaking, the empirical literature has not tended to find evidence for absolute PPP in single equations. One possibility is that the tests for cointegration do not have enough power to pick up the mean reversion, given that half-lives of deviations typically average around 20 years (see MacDonald (1995) for a survey of the literature). However, evidence of much faster reversion to parity has been obtained from studies that either use a very long time span (100 years) of data or exploit panel data sets over a shorter time period - although the implied half-life is still reasonably long at around 4 years.<sup>7</sup> In other words, additional observations are typically required for evidence of PPP. More recently Cashin and McDermott (2001) have cast doubt on even the long time-span and panel data results, by correcting for near unit root bias and showing that parity reversion may take a much longer time than previously calculated in the literature.<sup>8</sup>

A number of theories have been proposed to account for the persistent nature of real exchange rate deviations from PPP. These can generally be categorised either as theories that attempt to explain slow mean reversion in terms of transaction costs and sticky prices, or as theories that recognise the restrictiveness of PPP as a measure of an equilibrium exchange rate. It is clear from equation (2) that PPP ignores any real determinants of the exchange rate such as productivity differentials (the Balassa-Samuelson effect) or the accumulation of net foreign assets. Once these other factors have been taken into account it becomes clear that the "equilibrium" real exchange rate need not remain unchanged over time, but might follow a non-stationary process. Cyclical factors, such as interest rate differentials, may also drive real exchange rates away from long-run positions and make it more difficult to identify equilibrium.

<sup>7</sup> Rogoff (1996) surveys the current consensus in the literature. See also MacDonald (1995) page 468 for a discussion of this need for additional data. For examples of studies which use a long time span of data see, for example Grilli & Kaminski (1991). Examples of studies using panel data sets include Frankel and Rose (1996), Wu (1996) and MacDonald (1996).

<sup>8</sup> McDermott & Cashin's point estimates of half lives were found to range from 1 year to permanent.

The remainder of this paper uses single equation estimation over both the floating sample period (1985-2000) and a longer sample (1964-2000) as well as panel data estimation over the same two time periods to test the PPP proposition for the New Zealand bilateral exchange rate relative to the US dollar. We also augment the simple PPP equation described in (2) with other variables that are likely to explain the dynamics of the currency around its equilibrium value (such as interest rate differentials) and variables that may explain shifts in the equilibrium trend (such as productivity differentials).

The different approaches make different assumptions. For example, utilising a long span of data from one country embodies the hypothesis that the relationship between the exchange rate and the explanatory variables has not changed over the period. This may not be a reasonable assumption, particularly if the regression spans several exchange rate regimes – as the 1964-2000 sample does for New Zealand. On the other hand, economic theory suggests that neither monetary policy, nor exchange rate policy, can affect the real exchange rate in the long run. In other words, even if the dynamics of adjustment to the equilibrium are different across different exchange rate regimes, the long-run cointegrating vector (if it exists) may be unchanged across regimes.

In contrast, a panel study embodies the hypothesis that the cointegrating vector is similar across the various countries in the panel (aside from a country-specific constant or “fixed effect”). For a variable such as the price level differential (which should have a sign near one), this seems reasonable. However, other variables may be of differing importance for different countries. For example, the terms of trade may affect the real exchange rate of a highly open country more than that of a country that is substantially closed to trade. These factors must be kept in mind when interpreting the results.

### 3.1 Estimation methodology and data

We start by estimating a simple PPP relationship for the USD/NZD over the floating exchange rate sample of 1985-2000, and a longer

data sample (1966-2000). We then compare the results with those obtained using panel data for Canada and Australia.

For each data sample, we estimate the following four equations:

*Specification 1:* This is a simple PPP relationship, and is equivalent to testing equation (2) with the condition of symmetry imposed.<sup>9</sup> Absolute PPP can be considered to hold if coefficient  $\beta_1$  is insignificantly different from 1 (the condition of proportionality) and the residuals are stationary (evidence of a cointegrating relationship). All variables are as defined for equation (2).

$$s_t = \alpha + \beta_1(p_t^* - p_t) + \varepsilon \quad (3)$$

*Specification 2:* This equation augments the simple PPP relationship with interest differentials ( $i_t$  being the domestic nominal interest rate and  $i_t^*$  the foreign rate). MacDonald (2000) describes this as a capital enhanced equilibrium exchange rate or CHEER.

$$s_t = \alpha + \beta_1(p_t^* - p_t) + \beta_2(i_t - i_t^*) + \varepsilon \quad (4)$$

The maturity of interest rate that we should use in this specification depends on what factors we hope to capture. The use of a short-term interest rate would be more likely to capture deviations from longer-term equilibrium that may be caused by the exchange rate responding to monetary policy-driven interest differentials. In contrast, longer-term interest rate differentials will be influenced less by monetary policy and more by medium-term factors, including risk premia.

*Specification 3:* This equation is based on what MacDonald (2000) describes as a model of the behavioural equilibrium exchange rate (BEER). It differs from specification two in that the CHEER assumes a constant equilibrium trend (ie it assumes that the real exchange rate must be stationary), whereas in this equation the equilibrium is explicitly modelled as a function of real determinants that may be non-stationary over time. The real determinants we use

<sup>9</sup> Symmetry requires that the coefficient on domestic prices be equal and opposite to the coefficient on foreign prices.

in this paper are the log of the New Zealand terms of trade ( $\text{tot}_t$ ), and relative (logged) productivity ( $\text{prod}_t - \text{prod}_t^*$ ). This last term is used as a proxy for the Balassa-Samuelson effect.

$$s_t = \alpha + \beta_1(p_t^* - p_t) + \beta_3(\text{tot}_t) + \beta_4(\text{prod}_t - \text{prod}_t^*) + \varepsilon \quad (5)$$

*Specification 4:* This equation includes all explanatory variables described above, providing a BEER-type model that also includes interest differentials. This model is, therefore, the most complete in that it can capture both real determinants that may cause the real exchange rate to trend over time as well as more cyclical determinants of the exchange rate such as interest differentials.

$$s_t = \alpha + \beta_1(p_t^* - p_t) + \beta_2(i_t - i_t^*) + \beta_3(\text{tot}_t) + \beta_4(\text{prod}_t - \text{prod}_t^*) + \varepsilon \quad (6)$$

For all hypothesis testing with respect to the cointegrating vector we obtain a serially correlated consistent variance estimator and rescale the usual t-test, using the methodology of Saikkonen (1991).

## Data

All data are at the quarterly frequency. For the New Zealand price level we use the CPI excluding GST and interest. For interest rates we use 10-year government bond yields. For relative productivity ( $\text{prod}_t - \text{prod}_t^*$ ) we use two alternative definitions. The first is relative labour productivity (LPR) as measured by the OECD. The second is the price of tradables to non-tradables inflation in New Zealand relative to that in the US ( $P_T/P_{NT}$ ). Both definitions are commonly used in the literature as a proxy for the Balassa-Samuelson effect, with the  $P_T/P_{NT}$  ratio typically measured (both in the literature and in this paper) by the ratio of the manufacturing PPI to the CPI. A full list of data sources is provided in Appendix A.

The expected signs on the estimated coefficients are positive for both  $\beta_1$  and  $\beta_3$ . Since we are modelling the *level* of the exchange rate, we expect the sign on the interest differential ( $\beta_2$ ) to be positive, consistent with a capital account interpretation. That is, higher long-term interest rates relative to the US tend to attract a capital inflow,

prompting an appreciation in the nominal exchange rate.<sup>10</sup> The expected sign on  $\beta_4$  will depend on which definition of productivity we use. For relative labour productivity (LPR) we would expect a *positive* sign since countries with faster growing productivity in the tradable sector will tend to experience higher non-tradable inflation and, therefore, an appreciating real exchange rate.<sup>11</sup> But for relative  $P_T/P_{NT}$  we would expect a *negative* sign since if traded goods prices fall in relative terms, a country's real exchange rate will typically appreciate. In other words, relatively strong productivity growth tends to be associated with higher non-tradable inflation and a falling  $P_T/P_{NT}$  ratio.

We tested the data for unit roots in levels and in differences, using both the Phillips-Perron (PP) and Augmented Dickey-Fuller tests (ADF). See Appendix B for the test statistics from each of the PP and ADF tests.

For the short data sample, the results from both tests suggest that all variables are  $I(1)$ , except the relative price levels variable which appears to be  $I(0)$ . Since all the other variables are  $I(1)$ , including the exchange rate, we can immediately reject the PPP hypothesis for this sample period. The non-stationary process of the nominal exchange rate cannot be explained in this sample by relative inflation differentials, and instead must reflect the influence of other real determinants.

For the long data sample, the results from both tests suggest that all variables are  $I(1)$  except the New Zealand terms of trade, which appears to be  $I(0)$ . However, the results of this test are very sensitive to the sample period, and for most sample periods we find that the terms of trade is  $I(1)$ . As a small open predominantly commodity-producing economy, there are also strong theoretical reasons to

<sup>10</sup> In contrast, if we were modelling the expected change in the exchange rate we would expect a negative coefficient, consistent with the UIP condition (increased domestic interest rates resulting in an expected depreciation).

<sup>11</sup> Note that if New Zealand CPI inflation was higher than US CPI inflation, then New Zealand could experience nominal depreciation at the same time as a real appreciation, provided that the higher non-tradables inflation in New Zealand was being driven by productivity improvements in the tradable goods sector.

include the terms of trade in exchange rate models for New Zealand. As a result we proceed with our estimation of each of the four model specifications, including the terms of trade in specifications 3 and 4.

Given a regression composing all I(1) variables, the four model specifications described above are only valid if the equations are interpreted as cointegrating relationships. That will be the case if the residuals from the regression are stationary. For each regression we test this hypothesis using the Engel and Granger test for cointegration.<sup>12</sup>

If we can reject the null hypothesis of no cointegration, we can test hypotheses about the cointegrating vector. However, conventional t and F tests are only valid if the residuals from the cointegrating relationship are uncorrelated with innovations in the independent variables. To ensure this condition holds, we use *dynamic* ordinary least squares regression (DOLS) whereby the standard Engel-Granger regression is augmented with leads and lags of the first difference of the right hand side variables.<sup>13</sup> This estimation method follows the methodology of MacDonald (2000) and Chinn (2000).

Thus the general form of the equations we estimate is:

$$LUSNZ_t = \alpha_{NZ} + \beta Q_{NZ,t} + \sum_{j=-1}^{j=1} \theta_j \Delta Q_{NZ,t+j} + \varepsilon_{NZ,t} \quad (7)$$

where LUSNZ is the log of New Zealand's nominal bilateral exchange rate ( $s_t$  in the equations above),  $\alpha$  a constant,  $\beta$  is the vector of coefficients on the levels of a vector of relevant independent variables Q, and  $\theta$  is the vector of coefficients on distributed lags of the changes in Q, and  $\varepsilon$  is a residual. The variables in the vector Q are as defined in section 3.1: relative price levels; relative interest rates; the New Zealand terms of trade; and

<sup>12</sup> Note that because the unit root tests are applied to residuals from a potentially spurious regression, the critical values that are used to interpret the test statistics are higher than in a typical ADF test and depend on the number of independent variables in the regression (Phillips and Ouliaris, 1990).

<sup>13</sup> By doing this we obtain an asymptotically efficient estimator by using all the stationary information of the system to explain the short-run dynamics of the cointegrating regression (Saikkonen, 1991).

relative productivity. We use one lag and one lead of the change in Q term, but we find the results do not change significantly if we use more lags and leads. Since the  $\theta$  terms are used only to remove serial correlation in the residuals of the regression we do not report them.

Following the single equation results we apply the same methodology to panel data. Mark and Sul (1999) have shown that *panel* dynamic OLS can deliver more precise estimates. However, this will only be the case if the equilibrium exchange rates in the different countries in the panel are all determined by similar factors.

### 3.2 Single equation DOLS estimation of NZD-USD bilateral equilibrium

In this section, we report the single equation results from estimating the model specifications described in section 3.1. Not surprisingly, given the fact that we find the relative price level variable to be stationary over the floating period, we find that the results from the equations estimated over New Zealand's recent floating exchange rate period are unsatisfactory. In these regressions the coefficients on key variables are incorrectly signed, most notably the coefficient on relative prices. In addition, there is no evidence of a cointegrating vector in any of the specifications. These results are consistent with other literature suggesting that it is difficult to find stable PPP relationships over such short time periods. It is also not surprising given the fact that the relative prices variable was found to be I(0) over this sample.

Due to the unsatisfactory results from the short sample, we report the results only for the longer sample. The table below shows (in order): the equilibrium level of the USD/NZD exchange rate implied by each regression at the end of the sample (2000:3); the implied undervaluation of the actual nominal exchange rate in 2000:3 relative to the estimated equilibrium; the estimated coefficients on each of the four explanatory variables; and the ADF test statistics for the

residuals from the regression. The latter is a test for the existence of a cointegrating relationship.<sup>14</sup>

**Table 2:**  
**Long sample results (1964:3-2000:3)<sup>15</sup>**

Specification	Fair value (USD/NZD)	implied overvaluation	Price	I rates	TOT	Productivity (using LPR)	Cointegration test statistic
L1	\$0.60	-26.7%	1.0**	x	x	x	3.1*
L2	\$0.60	-26.2%	1.0**	-0.002	x	x	2.2
L3	\$0.57	-22.8%	0.9**	x	0.4**	0.2	2.8
L4	\$0.58	-24.8%	0.8**	-0.01	0.6**	0.1	2.6

\* denotes significance at the 10 per cent level

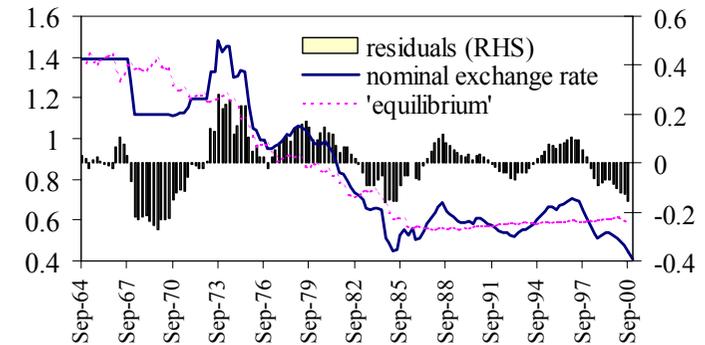
\*\* denotes significance at the 5 per cent level

Table 2 shows that when we extend the sample, we obtain results that are much more consistent with the PPP hypothesis. Most importantly, in the first specification (L1) the null hypothesis that the residuals from the regression are non-stationary can be rejected at a 10 per cent level of significance. We also find that the coefficient on relative prices is equal to 1.0 in two cases (L1 and L2). Equation L1 thus provides some econometric support for a PPP relationship in the New Zealand data, and is consistent with the observation that the simple graphical representation of PPP in figure 2 fits New Zealand data well. Indeed figure 3, which charts the fitted values and residuals from regression L1, looks very similar to figure 2.

<sup>14</sup> Note that the appropriate critical values to use on residuals from a possible cointegrating relationship are available in table B.9 of Hamilton (1994).

<sup>15</sup> Except for L1 and L3 whose data samples begin slightly earlier, in 1960:3 and 1962:3 respectively.

**Figure 3:**  
**Actual, fitted and residual values from regression L1**



The coefficient on interest rates in equations L2 and L4 is negative, but not statistically significant. The sign on the terms of trade is both correctly signed and statistically significant.<sup>16</sup> The coefficient on the terms of trade suggests that if the terms of trade (TOT) increases by 10 per cent, the exchange rate is likely to appreciate by somewhere between about 4 and 6 per cent. In these equations we report the results using labour productivity (LPR) as our measure of productivity. We find that the coefficient is correctly signed although not statistically significant.<sup>17</sup>

While regression L1 explains a lot of the movements in the NZ dollar over the high inflation period, it explains little about the performance over the recent float (see figure 3). All PPP can tell us is that since 1989 or so, the NZD should have appreciated mildly against the USD, as a result of slightly lower inflation. With an estimated equilibrium of US\$0.60, this model suggests that the bilateral USD/NZD exchange rate was significantly undervalued towards the end of 2000.

<sup>16</sup> As discussed in section 3.1, all tests of hypotheses about the cointegrating vector are done following Saikkonen's (1991) adjustment procedure to account for the serial correlation in the residuals of the cointegrating relationship.

<sup>17</sup> If we replace relative LPR with relative  $P_T/P_{NT}$  we find that the coefficient on  $P_T/P_{NT}$  is both correctly signed and statistically significant. Otherwise we find similar conclusions – in particular, no evidence of a cointegrating relationship. However, there is some evidence of multicollinearity with other variables in the regression, leading us to prefer the specification with LPR.

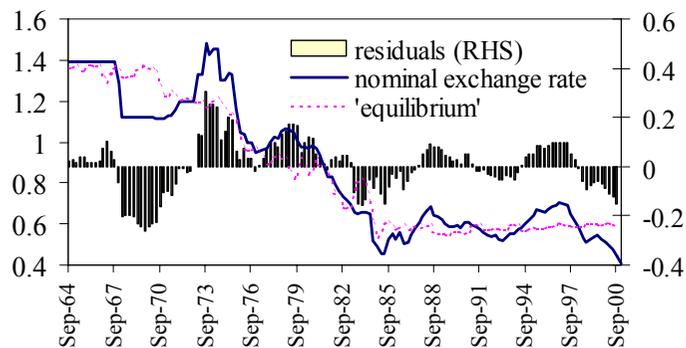
Equations L2 – L4 produce roughly similar results, although the inclusion of the terms of trade variable (in L3 and L4) serves to reduce the estimate of equilibrium slightly to around US\$0.58. This is explained by the fact that the terms of trade had been trending gradually downwards over most of the 1990s, implying a downward trend to the equilibrium exchange rate also.

For L2, L3 and L4 we are unable to reject the hypothesis that the residuals contain a unit root. Therefore, these relationships do not suggest a cointegrating relationship, and do not support the hypothesis of PPP for New Zealand over this time period.

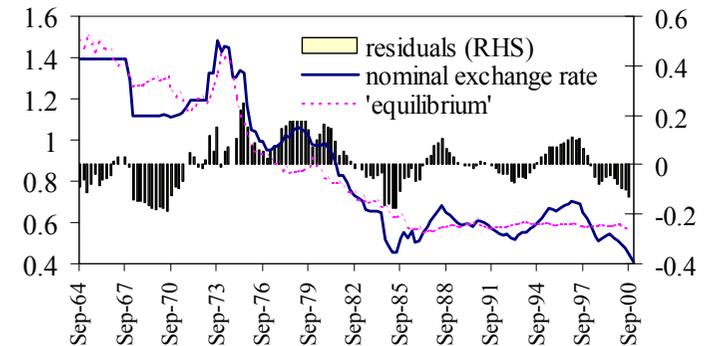
However, we find that this result is very sensitive to the sample period. For example, in an earlier version of this analysis, when we estimated up until 1999:2, we found that we could reject the null hypothesis of no cointegration in both equations L1 and L2 at the 5 per cent significance level. Since then, the exchange rate has depreciated further, increasing disequilibrium from purchasing power parity, and making it more difficult for the data to support the hypothesis of mean reversion.

Charts of the actual and estimated equilibrium exchange rates from models L2 – L4 are shown in figures 4 – 6 below.

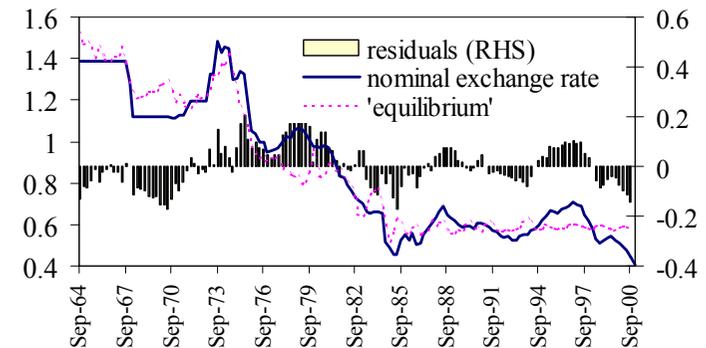
**Figure 4:**  
Actual, fitted and residual values from regression L2



**Figure 5:**  
Actual, fitted and residual values from regression L3



**Figure 6:**  
Actual, fitted and residual values from regression L4



### 3.3 Panel dynamic OLS estimation of USD/NZD bilateral equilibrium

Mark and Sul (1999) show that cointegrating regressions (such as those estimated for New Zealand in a single equation setting) can be stacked into a panel and estimated without the added complexity of using the more complex “fully modified” procedures of Phillips and Hansen (1990) in a panel setting. The panel data approach has previously been used to test for PPP by Oh (1996).

The basic form of the equation used is the same as equation (7), with the vector of  $\beta$  coefficients assumed to be the same across countries. The constant remains country-specific. Compared with the single equation setting, this method allows us to estimate the cointegrating vector  $\beta$  with more precision – provided, of course, that the equilibrium exchange rate is determined by similar factors in the various countries in the panel.

We estimate the panel relationship over both the short and long sample periods. As in section 3.2 we again obtain unsatisfactory results for the shorter sample period, and so we report only the results for the longer sample (1971:3 - 2000:3). The results we report (see table 3) are for a 3-country panel that includes the bilateral (versus the US dollar) exchange rates of New Zealand, Australia and Canada.<sup>18</sup>

**Table 3:**  
**Results from 3-country panel regression: 1971:3 – 2000:3**

Specification	Fair value (USD/NZD)	implied overvaluation	Price	I rates	TOT	Productivity (LPR or $P_T/P_{NT}$ )	Cointegration (for NZ)
PL1	\$0.61	-28.2%	1.0**	x	x	x	2.0
PL2	\$0.60	-26.1%	1.1**	0.02**	x	x	1.9
PL3 (LPR)	\$0.61	-27.5%	1.0**	x	0.5**	0.06	1.9
PL4 (LPR)	\$0.59	-25.3%	1.1**	0.02**	0.5**	0.04	2.0
PL5 ( $P_T/P_{NT}$ )	\$0.61	-27.7%	0.8**	x	0.1**	-1.6**	2.2
PL6 ( $P_T/P_{NT}$ )	\$0.60	-27.1%	0.9**	0.01	0.1**	-1.6**	2.3

\* denotes significance at the 10 per cent level

\*\* denotes significance at the 5 per cent level

Table 3 shows that we cannot reject the null hypothesis of a unit root in the residuals in any of the specifications (the critical value for equation PL1 at the 10 per cent level is approximately -2.6). There are a couple of possible interpretations of this result. For example, these results could imply that the same cointegrating vector cannot explain the equilibrium exchange rates in the different countries in the panel. Alternatively, the results could be sensitive to the sample

<sup>18</sup> We also experimented with a 6-country panel that included the UK, Japan and Germany. The larger panel produced similar but slightly inferior results to those from the smaller panel. We do not report the results from the larger panel. The smaller panel is also preferable *a priori* since Australia and Canada, like New Zealand, are small commodity-exporting countries with substantial net foreign liabilities.

period used, as in section 3.2. In other words, the recent depreciation of all three of the bilateral exchange rates in the panel may have reduced the evidence that they are driven by a stable cointegrating relationship.

Despite insufficient evidence of cointegration, it is interesting to note that the variables are correctly signed in all specifications. As with the single equation results, the coefficient on the relative prices variable is equal to, or very close to 1.0.

The main difference in the results from the panel regression, compared with those in table 2, is that the relative interest rate variable is now positive, and in the LPR regressions statistically significant, which is consistent with the capital account interpretation of the role of interest rates. This difference (compared with table 2) suggests that long-term interest rates have played a different role over the past 30 years in Australia and Canada than in New Zealand. The magnitude of the coefficient on the relative interest rate variable implies that a 100bp increase in the home country interest rate (relative to that in the US) results in roughly a 2 per cent appreciation in the exchange rate.

Specifications PL5 and PL6 report the results using  $P_T/P_{NT}$  instead of LPR. The coefficients on the  $P_T/P_{NT}$  variable are correctly signed and statistically significant. In other respects the results are quite similar to those for PL3 and PL4, except for the relative interest rate variable whose coefficient becomes insignificant, suggesting a multicollinearity problem with the equation.

The estimates of exchange rate equilibrium from the panel regressions range from US\$0.59 to US\$0.61 – very similar to the results from the single equations. Charts of the actual, fitted and residual values from equations PL1 – PL4 are shown in Appendix C.

## 4 Concluding remarks

This paper uses two alternative frameworks to produce PPP-based estimates of equilibrium for the USD/NZD bilateral exchange rate. The first approach (section 2) is based on a cross-sectional

comparison of prices across the industrialised world, adjusted for GNP per capita, in an attempt to capture the Balassa-Samuelson effect. The results of this analysis suggest that, in 1999, at a value of around US\$0.52, the NZD was neither significantly undervalued, nor overvalued: the relative cheapness of things in New Zealand was about right, given our per capita income, relative to that in the United States. Since then, the exchange rate depreciated significantly, suggesting that the exchange rate became roughly 10 per cent undervalued. This estimate of disequilibrium is considerably smaller than suggested by unadjusted estimates of PPP equilibrium.

The second approach (section 3) uses cointegration techniques to test for a long-run PPP relationship between the nominal exchange rate and relative prices, and augments the PPP relationship with additional explanatory variables. Using dynamic OLS and the Engle-Granger test for cointegration, we test the data over both the floating exchange rate sample (1985-2000) and a longer sample (1964-2000). In addition, we examine the joint determination of equilibrium for New Zealand, Australia and Canada.

For most equation specifications we were unable to reject the null hypothesis of no cointegration – consistent with previous research showing that the Engle-Granger methodology is not a very powerful test of cointegration when deviations from the cointegrating vector are highly persistent. However, there was some evidence of a cointegrating relationship in one of the long sample specifications – which suggested that a purely PPP-based estimate of exchange rate equilibrium may be around US\$0.60. In addition, the results also supported the hypotheses of symmetry and proportionality. This is unusual when compared with studies of other currencies and suggests that the determinants of the New Zealand exchange rate may be more consistent with a traditional long-run PPP relationship than other exchange rates. Overall, the results were found to be quite sensitive to the sample period, with the most recent depreciation in the New Zealand dollar making it more difficult to find evidence of cointegration.

As discussed in MacDonald (1995), there is some evidence that alternative econometric techniques are more likely to find evidence

of long-run PPP. This possibility is supported by Stephens and Choy (2001) who find evidence of PPP for the USD/NZD bilateral exchange rate over the floating rate period using the Johansen (1995) cointegration method. However, the restrictions of symmetry and proportionality are rejected in this study, suggesting that Stephens and Choy's results are not consistent with absolute PPP. In other words, Stephens and Choy find a cointegrating relationship without imposing economic theory.

How do we interpret the result from Section 3 - that the equilibrium exchange rate may be around US\$0.60? This would suggest that the USD/NZD bilateral exchange rate in the third quarter of 2000 (US\$0.44) was almost 30 per cent undervalued. However, there are at least four reasons to be careful about accepting this conclusion.

First, the equilibrium result from section 3 of US\$0.60 is markedly different from the result in section 2 of an equilibrium of about US\$0.52. Clearly the range of possible estimates is wide.

Second, this paper has looked only at the USD/NZD bilateral exchange rate, rather than the trade weighted index. Because it is commonly accepted that the US dollar is overvalued at present, the results overstate the extent of overall New Zealand dollar undervaluation.

Third, the model specifications that we have considered do not include all possible determinants of the real exchange rate. For example, New Zealand's persistently high current account deficits and accumulation of net foreign assets is an important indicator that our exchange rate may have been predominantly over-valued over most of the past decade. Brook and Hargreaves (2000) use a macroeconomic balance model of the equilibrium exchange rate, which explicitly models the role of the current and capital accounts in exchange rate determination. That model suggests that, on a TWI basis, the equilibrium exchange rate at the end of 1999 was around 56, and lower again (around 53) by the end of 2000. This model therefore suggests equilibrium significantly lower than suggested by the time-series PPP models in this paper.

Finally, there remains significant debate in the literature as to whether mean reversion to a PPP-based equilibrium occurs at all (for a negative perspective see Cashin and McDermott (2001)). It would, therefore, be dangerous to rely on a PPP-based estimate of equilibrium, given the possibility that the real exchange rate may be non-stationary and not exhibit reversion to PPP. Certainly, there are many theories of exchange rate determination that support the concept of non-stationary real exchange rates. Richer models that introduce real determinants of exchange rates (such as the BEER framework in this paper) allow for non-stationary measures of the real exchange rate and may, therefore, provide the best framework for estimating measures of equilibrium.

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## Appendix A: Data definitions and source

\* = NZ, AU, CN, BD, UK, JP

**Bilateral exchange rate data:** Nominal bilateral exchange rate data of each country relative to the US dollar. Most data sourced from datastream at quarterly frequency:

NZUS = RBNZ source: NZUS = 1/rusd\_nzd11am.q

AUUS = Datastream AUI..RF.

CNUS = Datastream CNI..RF.

BDUS = Datastream BDI..RF. until 1998Q4. For post-1998 period we spliced the datastream series to RBNZ data for the Euro (reur\_nzd11am.q/rusd\_nzd11am.q).

UKUS = Datastream UKI..RF.

JPUS = Datastream JPI..RF.

*Transformations:* L\*US = log(\*US)

**CPI data:** Mostly sourced from Datastream at quarterly frequency:

NZCPI = pcpiig (CPI ex GST and interest) – based on SNZ data

AUCPI = Datastream AUCP...F

CNCPI = Datastream CNCP...F

BDCPI = Datastream BDCP...F

UKCPI = Datastream UKCP...F

JPCPI = Datastream JPI64...F

USCPI = Datastream USCP...F

*Transformations:* L\*CPIR = log(\*CPI/USCPI)

**Long term interest rate data:** Government bond yield sourced primarily from Datastream at monthly frequency and converted to quarterly averages:

NZRL = Datastream NZI61... until 1984Q4. For post-1984 period we used quarterly RBNZ data (r10yr11am)

AURL = Datastream AUI61...

CNRL = Datastream CNI61...

BDRL = Datastream BDI61...

UKRL = Datastream UKI61...

JPRL = Datastream JPI61...

USRL = Datastream USI61...

*Transformations:* \*LD = \*RL - USRL

**PPI data:** PPI – Manufactured goods sourced from Datastream at quarterly frequency:

NZPPIM = Datastream NZOCPPMGF

AUPPIM = Datastream AUOCPPMFF

CNPPIM = Datastream CNOCPMANF

BDPPIM = Datastream BDOCPMANF

UKPPIM = Datastream UKOCPAMNF

JPPPIM = Datastream JPOCPRDF

USPPIM = Datastream USOCPRDF

*Transformations:* \*PPIMR = \*PPIM/USPPIM

L\*TNT = log(\*PPIMR/\*CPIR)

**TOT data:** Terms of trade data sourced predominantly from Datastream at quarterly frequency or at monthly frequency and converted to quarterly averages.

NZTOT = Statistics New Zealand (quarterly frequency)

AUTOT = Datastream AUTERMSTE (quarterly frequency)

CNTOT = Datastream CINTERMSTE

BDTOT = Datastream BDTERMSTF

UKTOT = Datastream UKTOTPRCF

JPTOT = Datastream JPTRMSTRF

*Transformations:* L\*TOT = log(\*TOT)

**Labour productivity:** OECD labour productivity index – business sector. Each quarterly productivity index series was linearly interpolated from the following annual data:

NZLP = Datastream NZOCFLBP

AULP = Datastream AUOCFLBP

BDLP = Datastream BDOCFLBP

JPLP = Datastream JPOCFLBP

UKLP = Datastream UKOCFLBP

USLP = Datastream USOCFLBP

*Transformations:* L\*LPR = log(\*LP/USLP)

## Appendix B: Unit root tests

We tested the data for unit roots in levels and in differences, using both the Phillips-Perron (PP) and Augmented Dickey-Fuller tests (ADF). Lag lengths were determined using the Schwarz criterion. The test statistics from each of the PP and ADF tests are provided in the following table.

<i>Phillips-Perron unit root tests</i>				
	Short sample: 1985:2 – 2000:4		Long Sample 1964:4 – 2000:4	
	<i>Levels</i>	<i>Differences</i>	<i>Levels</i>	<i>Differences</i>
LUSNZ	-1.74	-5.58***	-0.88	-8.84***
LNZCPIR	-5.18***	-2.84*	-1.55	-5.13***
NZLS	-1.62	-5.63***	-2.23	-8.63***
NZLD	-1.58	-9.04***	-2.46	-10.2***
LNZTOT	-2.19	-7.63***	-2.93**	-8.46***
LNZTNT	-1.88	-6.95***	-0.94	-10.72***
LNZLPR	-0.19	-6.02***	-1.35	-9.29***
<i>Augmented Dickey-Fuller unit root tests</i>				
	Short Sample: 1985:2 – 2000:4		Long Sample: 1964:4 – 2000:4	
	<i>Levels</i>	<i>Differences</i>	<i>Levels</i>	<i>Differences</i>
LUSNZ	-2.20 (3)	-3.87*** (1)	-0.93 (1)	-6.57*** (1)
LNZCPIR	-4.65*** (4)	-3.61*** (3)	-1.38 (1)	-4.43*** (1)
NZLS	-2.17 (1)	-6.59*** (1)	-2.63* (1)	-8.27*** (1)
NZLD	-1.73 (1)	-5.29*** (1)	-2.53 (1)	-7.72*** (1)
LNZTOT	-2.48 (2)	-3.05*** (3)	-4.35*** (3)	-6.25*** (4)
LNZTNT	-2.02 (1)	-5.75*** (1)	-0.90 (1)	-8.38*** (1)
LNZLPR	1.08 (3)	-5.00*** (4)	-0.88 (4)	-7.70*** (3)

NB: number of lags provided in parentheses

\* unit root rejected at 10% significance level

\*\* unit root rejected at 5% significance level

\*\*\* unit root rejected at 1% significance level

## Appendix C: Actual, estimated equilibrium, and residual values from panel regressions

Figure 7: PL1

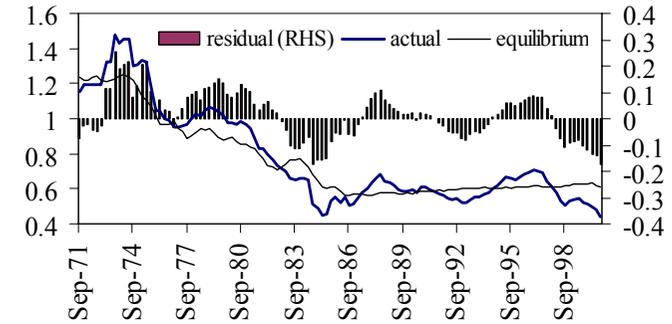


Figure 8: PL2

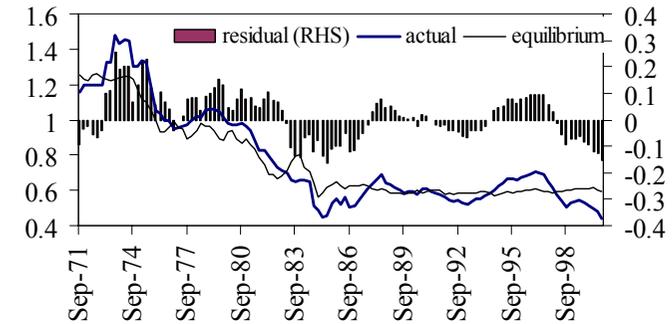


Figure 9: PL3

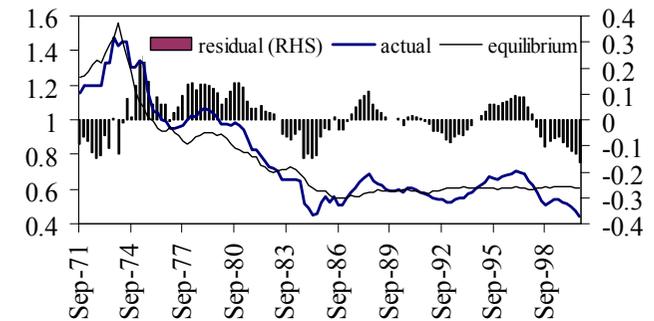


Figure 10: PL4

