

# **Explaining the persistence of Aus-NZ real exchange rate deviations across industries**

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# Abstract

This paper examines real exchange rate convergence speeds for seven industries between Australia and New Zealand by using quarterly data covers the sample period from the third quarter of 1989 to the first quarter of 2006. Three methods are used to estimate speeds of convergence: conventional point estimate, median-unbiased estimate, and impulse response function estimate. For each data set, the Augmented Dickey-Fuller regression, point estimates and 95% confidence intervals, and median-unbiased estimation account for serial correlation, sample uncertainty, and small sample bias, respectively. All estimates lead to similar results (although mean-unbiased estimates are higher by construction), averaging at about 3.76 years. This finding is consistent with Rogoff's "consensus" half-life estimate of 3-5 years, and as such gives weight against the hypothesis that trade links are important for real exchange rate adjustments. The puzzling finding lies in the relatively quicker pass-through of the services and non-traded (e.g., electricity) goods than that of traded products. These findings suggest that Balassa-Samuelson hypothesis is an important explanation to the real exchange rate convergence. Moreover, positive relationship between trading shares to half-live estimation propose that the pricing to market theory contributes significant proportion of measuring purchasing power persistence.

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# Table of contents

Abstract .....	I
Acknowledgements .....	III
Table of contents .....	IV
1. Introduction.....	1
2. Literature review .....	4
3. Long-run purchasing power parity.....	7
4. Persistence with quarterly data during a floating exchange rate period.....	8
4.1 Ordinary Least Squares (OLS) estimates .....	9
4.2 Impulse Response Function .....	11
4.3 Median-unbiased estimates .....	13
5. Possible Explanations .....	15
5.1 Balassa-Samuelson hypothesis.....	15
5.2 Price to market theory .....	15
5.3 Other factors.....	17
6. Conclusion .....	18
7. References.....	20
Appendix .....	23
Table 1 Least square estimation in Augmented Dickey-Fuller regressions: quarter data 1989:3-2006:1.....	23
Table 2 Impulse response estimation in Augmented Dickey-Fuller regressions: quarter data 1989:3-2006:1 .....	24
Table 3 Least Square vs. Median-Unbiased estimation: quarter data 1989:3-2006:1 .....	25
Table 4 Relative productivity vs. half-lives.....	25
Table 5 Trading shares vs. half-lives .....	26
Figure 2 Impulse responses with 95% of confidence interval.....	27

# 1. Introduction

The purchasing power parity (PPP) theory in its absolute version states that the long-run equilibrium exchange rate between two countries' currencies equals the ratio of their price levels. To put another way, PPP should be constant and equal to one. In the relative terms there should be no changes in the real exchange rate. In the real world, the relationship between the exchange rate and national price levels can be affected by various factors. Political restrictions, imperfect competition and transaction costs can be weakened the relation, as argued by Cheung and Lai (1993). In addition, the different price measurements carry with the usual problems associated with aggregation and index construction. Globally various in consumption patterns, variations in production qualities and prices, and differences in costs of carry and transportation costs are some of the measurement problems which can influence the relationship between exchange rates and price level.

The existence of non-traded goods and services can influence the link between exchange rates and price levels. The well-known analysis of Balassa and Samuelson (1964) provides an appealing explanation of the long-run behaviour of the real exchange rate in terms of the productivity performance of traded relative to nontraded goods. Balassa – Samuelson effects are the key source of observed cross-sectional differences in real exchange rate between countries at different levels of income per capita. There are considerable empirical researches on Balassa-Samuelson effects (Canzoneri, Cumby, and Diba, 1999; Lane and Milesi-Ferretti, 2002). The most previous evidences on PPP reversion are based on the long-horizon approach by investigating industrial countries. Balassa-Samuelson effects imply that relative rich countries may tend to have higher real exchange rates based on the consumer price indices (Froot and Rogoff, 1995; Obstfeld and Rogoff, 1996). As mentioned by Rogoff (1996), there is a reasonable strong evidence to support the Balassa-Samuelson effect between rich and poor countries. Conversely, the long-run period behaviour of real exchange rate among industrialised countries contains a serial of controversy through the empirical researches. Especially, Fransesy and Dijkz (2002)

found little evidence in favour of PPP among traded goods.

In the last decade, accumulating evidences have established that real exchange rate fluctuations equally tend to systematic failures of the law of one price among internationally traded goods (Betts & Devereux, 1996). Price-to-market (PTM) theory states that prices are set in the currency of the buyers and do not adjust at high frequencies. It indicates the larger trading shares reflected longer half-life convergence speed. The local currency price stability can be identified as an important real explanatory variable, nevertheless, there is a still a PPP puzzle in the residual.

This paper examines PPP reversion between New Zealand and Australia by using quarterly data covers the sample period from 1989 Q3-2006 Q1. New Zealand and Australia have high trade interdependence. Trade with Australia is accounted as almost 50% of New Zealand's international trade. Subsequently, if trade is important for PPP, then PPP should hold better between New Zealand and Australia.

The primary concern with the question of whether unit roots in real exchange rate could be rejected as a starting point for the research. Augmented Dickey-Fuller unit roots test are considered, regression the real exchange rate on a constant and its lagged value. If the coefficient of the lagged real exchange rate is significantly less than one, the unit root null is rejected and in favour of the alternative of level stationarity.

As Murray and Papell (2002), three measurements are identified by involving the use of these half-lives as evidence of the persistence of PPP convergence: serial correlation and ordinary least square estimate, confidence interval and impulse response function, and median-unbiased estimation.

First, Augmented Dickey-Fuller (ADF) test, which add lagged first difference of the real exchange rate in order to account for serial correlation, must be used. After consider the unit-root of the serials, the point estimate of ordinary least square estimates can be calculated. Alternatively, to compute the point estimate is the impulse response function. Unlike in the Auto-regression AR (1) model, the half-lives are asymptotically valid even the unit-root possible include in the serials (Inoue and

Kilian, 2001). Since, the point estimate of half-lives provides an incomplete picture of the speed of convergence towards PPP. 95% of confidence interval intended to measure the precision of the implied half-life estimate. However, these confidence intervals for half-life estimates are generally wide, suggesting a high level of imprecision in half-life estimation.

Finally, the least square estimates of the half-lives are biased downward in small samples. As a result, the persistence of PPP deviations can be seriously misled. Andrews (1993) showed how to calculate exactly median-unbiased estimates of half-lives in ADF regression. All of the point estimates are increased by comparing with the least square estimate. Moreover, 15 out of 25 subsections component become infinite.

The purpose of this paper is to estimate the half-life of PPP deviations, with a focus on whether Rogoff's 3-5 year convergence can be supported. Murray and Papell (2002), using quarterly data on six real exchange rates for post-1973 period. The lower bound of confidence intervals from ADF regression with the point estimate of the lagged real exchange rates or the half-life calculated from impulse response functions are below 1.5 years. Using post-1989 quarterly data, the results confirm the lower bound of confidence intervals is less than 1.5 years. Conversely, most of the upper bounds are greater than 5 years, which is inconsistent with Murray and Papell (2002) finding.

The results suggest that there are substantial short-term deviations from PPP, which take on average three years to be reduced by half. These results, however, emphasize the potential weakness in relying on point evaluations of half-lives and point out the significant uncertainty in measuring the speed of convergence. As the downward bias is corrected by median-unbiased method, the half-life becomes longer.

Balassa-Samuelson hypothesis is an important explanation to the real exchange rate convergence. Moreover, positive relationship between trading shares to half-live estimation propose that the pricing to market theory contributes significant proportion of measuring purchasing power persistence.

## 2. Literature review

The Law of one Price is a start point for the analysis of the real exchange rate. It states the same good should be sold for the same price cross-different countries. However, numerous empirical studies have approved that law of one price fails for similar goods between countries. Isard (1977) found large deviations from the law of one price by examined disaggregated data (including transactions price data) on U.S., German, Canadian, and Japanese exports of traded goods. Using 4-and 7-digit SIC (standard industrial classification) categories, Richardson (1978) some evidence of commodity price arbitrage between the United States and Canada, although the arbitrage is not perfect. Indeed, Engel (1993) have shown that price differentials across countries for very similar consumer goods cross the U.S. and Canada are more volatile than dissimilar goods within either country. Moreover, Rogers and Jenkins (1995) disclosed that not only are relative price differentials for similar goods more volatile cross borders, they are also more persistent. Froot, Kim and Rogoff (1995) have presented although law of one-price holds on average, there are low frequency trend to reverse themselves by analysed data of grains and dairy products over the past 700 years.

Studies of aggregated indexes such as the real exchange rate on Purchasing Power Parity (PPP) have arrived at a surprising degree of consensus on two basic factors. First, real exchange rates tend toward purchasing power parity in the very long run. However, the speed of convergence to PPP is extremely slow, deviations represent to damp out at a rate of roughly 15% per year. Secondly, short run deviations from PPP are large and volatile. Gustav Cassel (1921) was the pioneer of treating PPP as an empirical theory. His PPP calculations played an important role in later debates.

Enormous interest in the purchasing power parity (PPP) has emerged since the flexible exchange rates in the early 1970s. Early studies generally fail to discover parity reversion. As Galliot (1970) and Lee (1976) studies, for instance, found strong evidence convergence to PPP. However, these earlier papers did not incorporate

modern unit root and error-correction methods for testing of random walks. During the 1990s, more studies explored the long-horizon data and found evidence of parity reversion in real exchange rate (e.g., Abuaf and Jorion, 1990; Cheung and Lai, 1993; Culver and Papell, 1995; Diebold et al., 1991; Glen, 1992; Lothian and Traylor, 1996). The speed of parity reversion seems slow, Rogoff (1996) reported half-life estimates mostly between 3 and 5 years. This half-life range implies a slow reversion rate of about 13 to 20 percent per year.

The question of how to precisely estimate of the real exchange rates persistence has been addressed either by long-horizon time series or by using panel method with post-1973 floating real exchange rate. It was found that purchasing power parity holds well over long run (e.g., Abuaf and Jorion, 1990; Cheung and Lai, 1993; Culver and Papell, 1995; Diebold et al., 1991; Glen, 1992; Lothian and Traylor, 1996). The long-horizon approach, however, seems too long to be explained by nominal rigidities, argued as Rogoff (1996). The method also referred as survivorship bias (Froot and Rogoff, 1995). Because of data availability, long-term studies of PPP investigated industrial countries only. Therefore, a growing body of literature has turned to panel data methods (Frankel and Rose, 1996; Parsley and Wei (names are always placed in alphabetical order), 1995; Wu, 1996). Panel studies advocate pooling data across currencies to increase statistic power.

There is another question to consider on how much weight should one place on the results of the early panel unit root tests. O'Connell (1998) further pointed out possible bias in panel tests due to cross-sectional dependence. Moreover, panel unit-root tests examine the null hypothesis of a unit root for all pooled currencies. Rejecting the non-stationarity does not mean all the currencies contain no unit root (Taylor and Sarno, 1998). Since the panel PPP model are still based on cross-country data comprising largely industrial countries, the issue of survivorship bias remains to be resolved.

The difficulties in reconciling the high persistence of real exchange rate with their immense short-term volatility were pointed out by Rogoff (1996). Although the slow reversion can be realised if real shocks are significant, real shocks are not volatile

enough over the short term to explain for the exchange rate volatility. On the other hand, short-term exchange rate volatility can be caused by monetary shocks under sticky prices, but the sticky prices did not explain the half-life of PPP reversion. No existing model seems able to consistently explain both the short-term volatility and the excessive persistence in the real exchange rate. Clarida and Gali (1994) and Rogers (1999) identify the relevance of multiple shocks in explaining the variability of real exchange rate, but their results did not fully resolve the PPP puzzle.

Taylor and Peel (2000) investigated the nonlinear mean reversion and attempt to “solve” the PPP puzzle. The nonlinearities increase the reversion speed than the linear model. Hegwood and Papell (1998) took into account from the structural change point of view. Once the effects of occasional permanent disturbances to real exchange rates are account for, the half-life of PPP deviations in long-term data are reduced. Cheung and Lai (2000) used impulse response analysis and computed confidence intervals. The lower bounds of the confidence intervals are all less than 1.5 years, low enough to be explained by models with nominal rigidities.

### 3. Long-run purchasing power parity

The PPP theory suggests the long-run equilibrium relationship between two countries is expressed in common currency units. PPP may be examined through the real exchange rate since the logarithm of the real exchange rate,  $y_t$ , can be defined as the deviation from PPP:

$$y_t = s_t + p_t^* - p_t \quad (1)$$

Where  $s_t$  is the log of the exchange rate as New Zealand currency of Australian currency observed at time  $t$ ,  $p_t^*$  and  $p_t$  are the logs of Austrian and New Zealand price indices, respectively.

A necessary condition for PPP to hold in the long run is that the real exchange rate  $y_t$  be stationary over time, not driven by permanent shocks. If this is not the case, then the nominal exchange rate and the price differential will permanently tend to deviate from one another. This is the rationale for applying non-stationary tests to real exchange rate data as a channel of testing for long-run purchasing power parity.

The real exchange rate movement should contain permanent components, especially where the price indices used in the formation of the real exchange rate both tradable and non-tradable (Taylor & Sarno, 1998). The well-known Balassa-Samuelson effect (Balassa, 1964; Samuelson, 1964), for example, implies that relative rich countries may have a tendency to have higher real exchange rates based on the consumer price indices (Froot and Rogoff, 1995; Obstfeld and Rogoff, 1996). As mentioned by Rogoff (1996), there is reasonably strong evidence to support the Balassa-Samuelson effect between rich and poor countries. Conversely, its empirical relevance for long-run time period behaviour of real exchange rates among industrialised countries remains a matter of controversy. Especially, Fransesy and Dijkz (2002) found little evidence in favour of PPP among traded goods.

Overall, it is impossible to discard the possibility of real long-run effects on the real exchange rates altogether. The safety conclusion can be drawn permanent real

effects account for only a relative small part of long-run real exchange rate movements by testing for long-run PPP of empirical studies (Taylor and Sarno, 1998).

## **4. Persistence with quarterly data during a floating exchange rate period**

Since the data sample starts in 1989, results may suffer from small sample bias. Specially, the long-horizon findings may simply reflect the trend of PPP reversion in the pre-1973 only not in the post-1973 periods (Rogoff, 1996). A special effort to contribute the recent float of real exchange rate persistence comes from Lothian and Taylor (1996). They expose no significant difference between the pre- and post- 1973 periods by using the dollar/pound (1791-1990) and franc/pound (1803-1990) real rates. If their founding can apply to other series of real exchange rates, they provide a benchmark for using other historical data information to deduce the behaviour of real exchange rate for the post-1973 period.

The data are quarterly real exchange rates created from nominal exchange rates and consumer price index. Seven different industries are selected with the Australian dollar as the numerator currency. In order to increase the comparability, we used 25 sub-section groups cross industries, which almost matched between New Zealand and Australian. Taken from Reserve Bank of New Zealand database AREMOS and Australia Bureau of statistical office, the data cover the sample period from 1989 Q3 to 2006 Q1.

All series of real exchange rates are first tested for unit roots using the augmented Dickey-Fuller (DF) test. The result represents in table 1. No data series can reject the null hypothesis of a unit root. Consequently, the ADF test discovers not much evidence of parity reversion as other PPP studies (Roll, 1979; Frenkel, 1981; Adler and Lehmann, 1983). The failure to reject a unit root in our cases does not provide a sense to arbitrarily reject the PPP persistence. As Abuaf and Jorion (1990) argued, the

negative results obtained in previous empirical research reflect the poor power of the tests rather than evidence of unfavourable PPP. Hokkio (1986) also stated that, “Although the hypothesis that the exchange rate follows a random walk cannot be rejected, not much weight should be put on this conclusion.” Rogoff (1996) reported a consensus half-life estimates mostly between 3 and 5 years by investigating in long-horizon data. If there is no significant difference between the pre- and post- 1973 period’s data series, a similar conclusion can be drawn for PPP convergence of the floating period.

## 4.1 Ordinary Least Squares (OLS) estimates

The residual term is observed autocorrelation in the regression model. As Halcoussis (2005) mentioned, “Autocorrelation is a common problem in time-series regressions.” In order to solve the serial correlation problem, one method involves including omitted independent variables. This approach cannot be used in our case. The second-best solution is treating the symptom by using the generalized difference equation, which by taking the difference of the two equations.

$$Y_t - \rho Y_{t-1} = B_0(1 - \rho) + B_1(X_t - \rho X_{t-1}) + \varepsilon \quad (2)$$

Y and X are both from the same time period,  $\rho$  is the autocorrelation coefficient,  $\varepsilon$  is the error term. In order to estimate the regression, calculating the autocorrelation coefficient is essential. Particular, AR (1) method takes to consider by exploring the residual term.

$$\varepsilon_t = \rho \varepsilon_{t-1} + \mu_t \quad (3)$$

Which,  $\mu_t$  represents an error term that follows random walk.

As Murray and Papell (2002) point out, the half-life calculated from the slope coefficient in a Dickey-Fuller (DF) regression does not allow for autocorrelation of the residuals, and Augmented Dickey Fuller (ADF) unit root tests should be estimated instead.

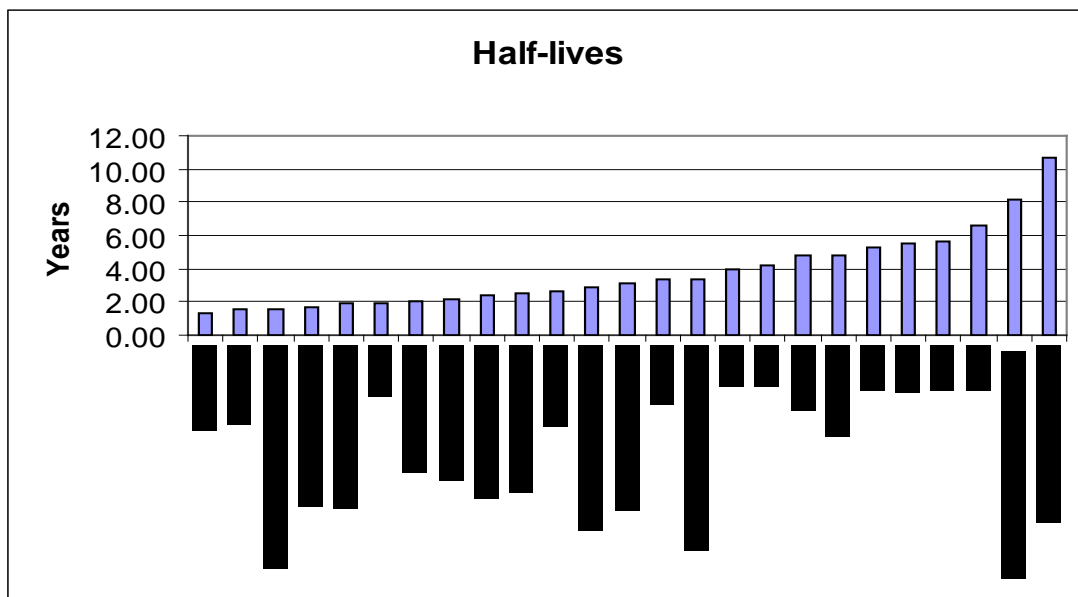
Least squares estimates of Augmented Dickey-Fuller regression that considering the AP (p) model is illustrated as follow:

$$Y_t = c + \beta Y_{t-1} + \sum \theta \Delta Y_{t-i} + \varepsilon_t \quad (4)$$

$Y_t$  is the log real exchange rate;  $\beta$  is the correlation between the current long real exchange rate and the previous one. The Augmented Dickey-Fuller model regress the real exchange rate on a constant factor  $c$  and it's lagged value. The same methodology used by Hall (1994), Ng and Perron (1995) and Murray and Papell (2002), with the maximum lag set to 12. All of the series have one lag of the first difference of the real exchange rate in Eq. (4) except the Tobacco. The null hypothesis for the Augmented Dickey-Fuller test is  $H_0: \beta < 1$  versus the alternative hypothesis of  $H_1 \geq 1$ . If the correlation on the lagged real exchange rate is significant less than one, the null hypothesis can be rejected which means there is no unit-root.

The half-lives persistence of least square estimations are presented in figure 1. The half-life is calculated as  $-\ln(2)/\ln(\beta)$ , defined as the number of periods required for a unit shock to dissipate by one half (Murray & Papell, 2002). The least squares

Figure 1. OLS half-lives persistence



estimates of  $\beta$  range from 0.8735 to 0.9839 for electricity and household service

respectively, implying point estimates of the half-life of PPP deviations from 1.28 years (electricity) to 10.67 (household service). The average half-life is 3.76 years and median half-life is 3.13 years.

The point estimate of the half-lives is on the low side of Rogoff's 3-5 year consensus. That figure, however, is skewed upward because, for reasons of data availability. The half-life for vehicle parts and accessories and the householder service is extremely higher 8.17 and 10.67, respectively. As Murray and Papell (2002) found out half-life for the pound/dollar rate, 4.86 years, is the second longest among the observations. Rogoff's consensus is based on using Lee data and several using pound/dollar data, the relatively slowly mean reverting pound/dollar rate receives a disproportionate weight.

## 4.2 Impulse Response Function

Following Inoue and Kilian (2002), another way to calculate point estimates of half-lives directly through the impulse response function. The higher order AR models include in the equation as:

$$\Phi(\Psi)Y_t = c + \varepsilon_t \quad (5)$$

with  $\Psi$  being a lag operator. The process  $Y_t$  can be represented as:

$$Y_t = c + \beta Y_{t-1} + \theta_1 \Delta Y_{t-2} + \dots + \theta_{p-1} \Delta Y_{t-1+1} + \varepsilon_t \quad (6)$$

$$\beta = \Phi_1 + \Phi_2 + \dots + \Phi_p = 1, \quad \theta(1) = 1 - \theta_1 - \theta_2 - \dots - \theta_{p-1}$$

Where  $\Phi_1 = \beta + \theta_1$ ,  $\Phi_j = \theta_j + \theta_{j-1}$  and  $\Phi_p = \theta_{p-1}$ . Inoue and Kilian (2002) showed that, although the bootstrap method is not valid for the unit root parameter  $\beta$  in Eq (6), when  $\beta=1$  and  $c=0$ , nevertheless, it is asymptotical valid for the slope parameters  $\Phi$  as measuring half-lives. To put another way, the bootstrap point estimates and confidence intervals of half-lives based on the impulse response function are asymptotically valid.

To computer  $\beta$  of 0.5 (half-lives) of coefficient is the vital step in the impulse response function. The following equation is used:

$$P * \beta_u + (1 - P) * \beta_d = 0.5 \quad (7)$$

P is the weighted average;  $\beta_u$  and  $\beta_d$  are the figures above and below 0.5 in point estimate of OLS, respectively. The relationship between  $\beta_u$  and  $\beta_d$  is assumed to be linear. The half-life convergence can be easily calculated once we have the P value, as well as the 95% of confidence interval. Table 2 reports half-lives calculated from the impulse response function in the ADF regressions with the lag length k, and the associated 95% confidence intervals (CI). The point estimate of half-lives based on the impulse response functions are all increased, except tobacco. The median point estimate of the half-lives is 3.38 years, with a median lower bound of 1.20 years and median upper bound of 10.34 years. Even though the most lower bounds of the least squares half-lives confidence intervals are less than 2 years (supported by Cheung & Lai, 2000; Murray & Papell, 2002) except Householder service, the PPP puzzle is not solved. The bootstrap confidence interval for the half-lives based on  $\beta$  will be asymptotically invalid if the data are non-trend, and least squares estimates of the half-lives are biased downward in small samples.

All the graphs in Figure 2 display a remarkable feature of real exchange rates. The 95% of confident intervals of half-lives are wide. The only one observation, tobacco, expressed hump-shaped in the impulse responses function. These raise an interesting question, compare with Cheung & Lai (2000), all of their variables showed non-monotonic. Another question is: why are nontraded goods and services such as electricity and vehicle servicing and repairs converging faster than traded ones such as vehicle parts and accessories? One possible explanation is the results conflict with Balassa-Samuelson effect, which is consistent with Fransesy and Dijkz (2002) who found no evidence in favour of PPP among traded goods.

### 4.3 Median-unbiased estimates

The bias in least squares estimate is corrected by calculating median-unbiased point estimates for  $\beta_{LS}$  in Augmented Dickey-Fuller regressions. The least square estimator of  $\beta_{LS}$  is based downward bias, especially with the  $\beta$  is closer to unity argued by Stine and Shaman (1989). Median-Unbiased (MU) estimation is introduced by Murray & Papell (2002) to correct the sample bias. If we replace the least squares estimate of  $\beta$  ( $\beta_{LS}$ ) with a median-unbiased estimate,  $\beta_{MU}$ , the half-life estimate will also be median-unbiased.

According to Andrews (1993), the median-unbiased estimates of  $\beta$  are calculated in table 3. The value of  $\beta$  computing from least square is a start point to calculate the median-unbiased estimation. The evaluation of Andrew's model 2 is introduced in here, since it is a strictly stationary, normal, AR (1) process with mean  $\mu$ . For example, if the true  $\beta_{LS}$  is 0.9 and  $T+1=70$ , then the  $\beta_{MU}$  is 0.854. To put another way, least square has a median bias of -0.046. Thus, if  $\beta_{LS} = 0.854$ , our median-unbiased estimation  $\beta$  is 0.9. To any value of  $\beta_{LS}$  is greater than 0.938, correspond to  $\beta_{MU}=1$ .

The more precise value of  $\beta_{MU}$  is not provided by consistent with the least square estimation of  $\beta$  in Andrew's model. Therefore, the following steps are considered. First, assuming there is a linear relationship between  $\beta_{LS1}$  and  $\beta_{LS2}$  in order to capture the exactly  $\beta_{LS}$  computed in the model, where  $\beta_{LS1}$  and  $\beta_{LS2}$  is upper bound and lower bound of the exactly  $\beta_{LS}$ , respectively. The formula represents as follow:

$$P * \beta_{LS1} + (1-P) * \beta_{LS2} = \beta_{LS} \quad (8)$$

P is the weighted average. It can be easily calculated, since all three parameters  $\beta_{LS}$ ,  $\beta_{LS1}$  and  $\beta_{LS2}$  are known. Finally, we can solve the exactly median-unbiased  $\beta$  based on the weighted average P,  $\beta_{MU1}$  and  $\beta_{MU2}$  which are correspond to the  $\beta_{LS1}$  and  $\beta_{LS2}$  from table II of Andrew, respectively.

Table 2 is the comparison between the least squared estimates of the half-lives of PPP deviations from ADF regression and exactly median-unbiased estimates of the same regressions, all of the point estimates of the half-life increase. All 15

subsections component of CPI out of 25 observations become infinite. Andrew (1993) used monthly data from 1973:1 to 1988:7 for six US dollar real exchange rate: the French franc, German mark, Japanese yen, Canadian dollar, Dutch guilder, and British pound, calculates least squares point estimates and exactly median-unbiased point estimates and 90% confidence intervals for half-lives of PPP deviations in DF regressions. Correcting for the bias, the half-lives of the most countries are infinite under the median-unbiased estimation. As Murray and Papell (2002) stated, correcting for the bias substantially raised the point estimates. The half-lives for the real exchange rate of four countries: Canada, Japan, Portugal, and Spain are infinite.

# 5. Possible Explanations

## 5.1 Balassa-Samuelson hypothesis

The most popular and enduring model of long-run deviations in consumption based PPP was pioneered by Balassa (1964) and Samuelson (1964). Empirically, they argued, after adjusting for exchange rates, CPIs in rich countries will be higher relative to those in poor countries. The basic idea is that technological progress has been slower in the nontraded goods than in the traded goods especially in wealthy countries. Moreover, rich countries are relative more productivity in the traded goods sector. A rise in productivity will increase wage in traded goods but has no effect on price once considering the competitive. Conversely, producers of nontraded goods will only be able to meet the higher wage if there is a rise in the relative price of nontraded goods.

In order to test the Balassa-Samuelson effect, the productivity measures for each industry relative to the nontraded sector for both New Zealand and Australia are needed. Balassa (1964) pointed out, since the prices of traded goods are equalized in the two countries through international trade, this intention can also be expressed by wage units in terms of absolute prices. Nontraded sectors, for example, services enter the calculation of PPP but do not directly affect exchange rates. Consequently, PPP will be lower than the equilibrium rate of exchange for higher productivity country.

Relative productivity for 12 industries to the nontraded goods sectors for Australia is listed in table 4 in appendix. By contrast, the relevant data for New Zealand seems impossible to collect. The evidence from purely Australia data suggests that Balassa-Samuelson hypothesis may be important for traded sectors by assuming that New Zealand industrial productivities are similar across sectors.

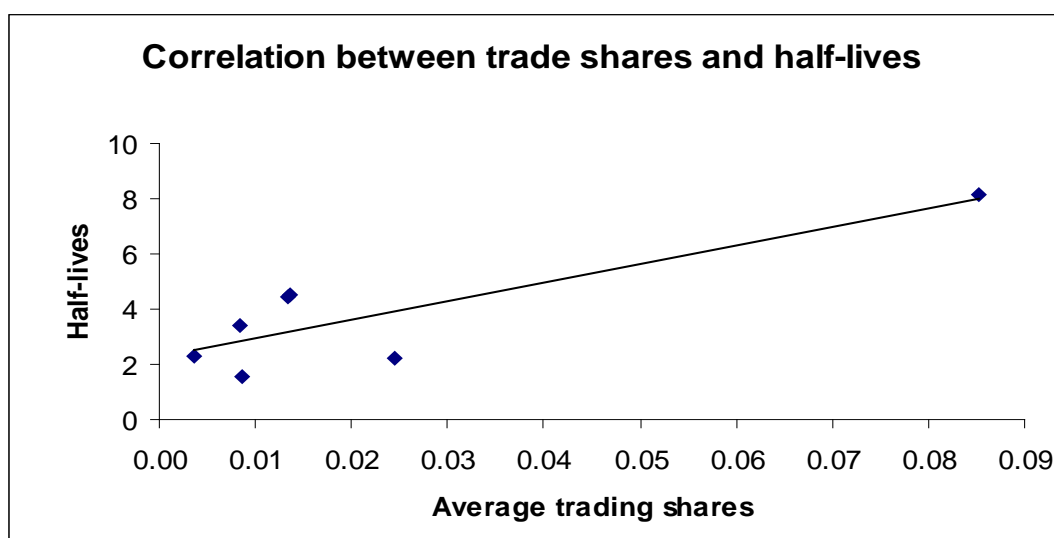
## 5.2 Price to market theory

Since the mid-1980s, many researchers have shown destination-specific

adjustment of mark-ups in response to exchange rate changes referred as price-to-market (Krugman, 1987; Giovannini, 1988; and Knetter, 1989). That is, firms tend to set prices in local currencies of sale, and do not adjust prices to movements of exchange rates. Betts and Devereux (1996) have displayed some evidence of local currency price stability in response to aggregate shocks which move the exchange rate.

The research results are consistent with the price to market theory, as investigating the trading shares between New Zealand and Australia. Although the result suffers the data limitation, which 7 out of 25 sub-section can be matched between two countries (see appendix table 4 for details), it represents amazing positive correlation as shown in figure 3. The t-statistic is 3.5672, and the P-value is 0.0161, which means as the

Figure 3. Correlation between trading shares and half-lives



volume of trading shares increase, the longer of the half-life convergence. To put another way, real exchange rate movements are driven primarily by fluctuations in the nominal exchange rate, once prices of most goods stabilized in the buyer's currency. While trading with Australia is accounted as almost 50% of New Zealand's international trade, it is reasonable to stabilise trading prices.

### **5.3 Other factors**

Obviously, the results seem inconsistent with the assumption which the PPP should be hold better between New Zealand and Australia since the high trading activities within these two countries. Transportation costs allow some block between domestic and foreign prices, investigated by Frankel, Stern and Wei (1995). Another general factor is that many traded goods contain significant non-traded components, especially at the consumer price level. Clothing in the supermarket includes not only traded costs, but also implicated in rent, local shipping costs, labour costs, taxes and insurance. Obviously, tariffs can create deviations from PPP as well. For example, some countries impose higher tariffs on vehicles to protect domestic industries. As Knetter (1994) argued, that non-tariff barriers are essential empirically in explaining deviations from PPP.

Non-traded good, electricity represents surprising convergence speed. The half-life persistence in the least square estimation is 1.28 years, which is the fastest speed in 25 observations. The special generation of electricity in New Zealand may contribute possible justification. Natural gas is a major source for electricity generation. The largest natural gas field are probably South Pars Gas Field in Iran and Urengoy gas field in Russia (en. wikipedia website). This feature tends to drive the half-life of electricity more closely to the traded goods rather than the non-traded goods.

## 6. Conclusion

This paper estimates real exchange rate convergence speeds for seven industries between Australia and New Zealand. Three methods are used to estimate speeds of convergence: conventional point estimate, median-unbiased estimate, and impulse response function estimate. All estimates lead to similar results (although mean-unbiased estimates are higher by construction), averaging at about 3.76 years. This finding is in line with Rogoff's "consensus" half-life estimate of 3-5 years, and as such gives weight against the hypothesis that trade links are important for real exchange rate adjustments (trade with Australia accounts for about half of New Zealand's trade). The puzzling finding lies in the relatively quicker pass-through of the services and non-traded (e.g., electricity) goods than that of traded products. The short-term consumer price index between New Zealand and Australia from post-1989 are used. For each data set, the Augmented Dickey-Fuller regression, point estimates and 95% confidence intervals, and median-unbiased estimation account for serial correlation, sample uncertainty, and small sample bias, respectively.

The median half-life from least square estimates is 3.13 years on the low side of Rogoff's 3-5 year consensus. The lower bound, 0.78 year, is small enough to be consistent with models based on normal rigidities, while the upper bound, 37.54, means the speed of convergence goes to infinite. 95% of confidence intervals suggest a high level of uncertainty in measuring the speed of parity reversion. As the downward bias is corrected by median-unbiased method, the half-life becomes more volatile.

The evidence from purely Australia data suggests that Balassa-Samuelson hypothesis may be important for traded sectors by assuming that New Zealand industrial productivities are similar across sectors. Price to market theory implies real exchange rate fluctuations are obtained primarily by movements in the nominal exchange rate. The existence of PPP puzzle in the floating data can be explained by several other factors. Such as the trade restrictions, imperfect competition and

transaction costs, which can influence the relationship between exchange rates and price level. The price level measurements carry with usual problems associated with aggregation and index construction. Further research is required to establish the PPP convergence from other perspectives, such as commodity price and industry difference productivity.

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# Appendix

**Table 1 Least square estimation in Augmented Dickey-Fuller regressions: quarter data 1989:3-2006:1**

Industry	P-value of Unit-root test	Optimal lag (k)	AR Coefficient	Half-life Convergence
Pork	0.7911	1	0.9691	5.52
Beef	0.8557	1	0.9739	6.55
Lamb	0.4691	1	0.9144	1.94
Fish	0.7166	1	0.9575	3.99
Poultry	0.7527	1	0.9643	4.77
Jam	0.4462	1	0.9594	4.18
Furniture	0.1909	1	0.8932	1.53
Householder supplies	0.5563	1	0.9420	2.90
Householder service	0.6667	1	0.9839	10.67
Electricity	0.2505	1	0.8735	1.28
Men's clothing	0.3386	1	0.9207	2.10
Women's clothing	0.4892	1	0.9292	2.36
Men's footwear	0.4713	1	0.9210	2.11
Women's footwear	0.3366	1	0.8986	1.62
Children's footwear	0.6516	1	0.9462	3.13
Vehicle parts & accessories	0.8663	1	0.9790	8.17
Vehicle servicing & repairs	0.1964	1	0.8979	1.61
Tobacco	0.2126	2	0.9371	2.67
Beer	0.7602	1	0.9697	5.63
Spirits and Liquor	0.2546	1	0.9326	2.48
Wine	0.6510	1	0.9676	5.26
Medical and Health Services	0.2885	1	0.9142	1.93
Dental	0.5930	1	0.9500	3.38
Newspapers, Magazines and Books	0.5077	1	0.9504	3.41
Child Care	0.8287	1	0.9644	4.78

**Table 2 Impulse response estimation in Augmented Dickey-Fuller regressions: quarter data 1989:3-2006:1**

<b>Industries</b>	<b>alpha</b>	<b>95%CI</b>		<b>HL</b>	<b>95%CI</b>	
Pork	0.89	(0.64	0.97)	5.77	(1.54	21.41)
Beef	0.90	(0.62	0.98)	6.79	(1.43	29.18)
Lamb	0.73	(0.48	0.89)	2.19	(0.94	5.69)
Fish	0.85	(0.60	0.95)	4.24	(1.35	14.01)
Poultry	0.87	(0.63	0.96)	5.02	(1.48	17.45)
Jam	0.86	(0.68	0.94)	4.43	(1.79	11.64)
Furniture	0.68	(0.47	0.83)	1.79	(0.91	3.82)
Householder suppliers	0.80	(0.57	0.92)	3.15	(1.22	8.86)
Householder service	0.94	(0.82	0.98)	10.92	(3.45	34.77)
Electricity	0.64	(0.41	0.82)	1.53	(0.78	3.39)
Men's clothing	0.74	(0.52	0.88)	2.35	(1.07	5.63)
Women's clothing	0.77	(0.53	0.90)	2.61	(1.08	6.94)
Men's footwear	0.75	(0.50	0.89)	2.36	(1.00	6.16)
Women's footwear	0.69	(0.46	0.86)	1.87	(0.88	4.43)
Children's footwear	0.81	(0.56	0.94)	3.38	(1.20	10.34)
vehicle parts & accessories	0.92	(0.65	0.98)	8.42	(1.64	37.54)
vehicle servicing & repairs	0.69	(0.48	0.84)	1.86	(0.94	4.01)
Tobacco	0.75	(0.56	0.86)	2.41	(1.20	4.70)
Beer	0.89	(0.66	0.97)	5.88	(1.68	20.78)
Spirits and Liquor	0.78	(0.58	0.89)	2.73	(1.29	6.24)
Wine	0.88	(0.70	0.96)	5.51	(1.95	17.09)
Medical and Health Services	0.73	(0.49	0.88)	2.18	(0.96	5.50)
Dental	0.83	(0.60	0.94)	3.63	(1.34	10.57)
Newspapers, Magazines and Books	0.83	(0.62	0.93)	3.66	(1.44	9.97)
Child Care	0.87	(0.57	0.97)	5.03	(1.23	20.03)

**Table 3 Least Square vs. Median-Unbiased estimation: quarter data 1989:3-2006:1**

Industry	Estimator		Half-Lives	
	Least Square	Median-Unbiased	Least Square	Median-Unbiased
Pork	0.9691	1	5.52	$\infty$
Beef	0.9739	1	6.55	$\infty$
Lamb	0.9144	0.9700	1.94	5.69
Fish	0.9575	1	3.99	$\infty$
Poultry	0.9643	1	4.77	$\infty$
Jam	0.9594	1	4.18	$\infty$
Furniture	0.8932	0.9432	1.53	2.96
Householder supplies	0.9420	1	2.90	$\infty$
Householder service	0.9839	1	10.67	$\infty$
Electricity	0.8735	0.9210	1.28	2.11
Men's clothing	0.9207	0.9762	2.10	7.19
Women's clothing	0.9292	0.9828	2.36	9.99
Men's footwear	0.9210	0.9766	2.11	7.32
Women's footwear	0.8986	0.9495	1.62	3.34
Children's footwear	0.9462	1	3.13	$\infty$
Vehicle parts & accessories	0.9790	1	8.17	$\infty$
Vehicle servicing & repairs	0.8979	0.9487	1.61	3.29
Tobacco	0.9371	0.9987	2.67	$\infty$
Beer	0.9697	1	5.63	$\infty$
Spirits and Liquor	0.9326	0.9923	2.48	22.42
Wine	0.9676	1	5.26	$\infty$
Medical and Health Services	0.9142	0.9679	1.93	5.31
Dental	0.9500	1	3.38	$\infty$
Newspapers, Magazines and Books	0.9504	1	3.41	$\infty$
Child Care	0.9644	1	4.78	$\infty$

**Table 4 Relative productivity vs. half-lives**

Industries	Relative productivity to all nontraded sectors	HL
Meat and meat product manufacturing	0.7941	4.55
Beverage and malt manufacturing	1.0290	4.46
Clothing manufacturing	0.7514	2.23
Footwear manufacturing	0.5977	2.29
Publishing	1.0247	3.41
Motor vehicle and part manufacturing	1.0033	8.17
Furniture manufacturing	0.8069	1.53
Electricity supply	1.2979	1.28
Household equipment repair services	0.8155	10.67
Motor vehicle services	0.8027	1.61
Medical and dental services	1.0076	1.93
Child care services	0.6703	4.78

**Table 5 Trading shares vs. half-lives**

<b>Industries</b>	<b>Aus Trade shares</b>	<b>NZ trade shares</b>	<b>Average trading shares</b>	<b>HL</b>
Furniture	0.0071	0.0100	0.0086	1.53
Textiles and textile articles(1)	0.0148	0.0342	0.0245	2.23
Footwear	0.0037	0.0036	0.0037	2.29
Books, newspapers and printed matter	0.0111	0.0057	0.0084	3.41
Beverage	0.0127	0.0141	0.0134	4.46
Meat	0.0245	0.0027	0.0136	4.55
Vehicles, parts and accessories	0.0837	0.0870	0.0853	8.17

Figure 2 Impulse responses with 95% of confidence interval

