Government of **Western Australia**
Department of **Treasury and Finance**

Exchange Rate

Forecasting Review

October 2009

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The views expressed in this paper are those of the Department of Treasury and Finance and not necessarily those of the Western Australian Government.

Further information or enquiries related to this report may be obtained by emailing TreasuryCommunications@dtf.wa.gov.au

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Executive Summary

The purpose of this review is to identify and compare competing models of the $US/$A exchange rate, and to recommend an alternative approach for the Department of Treasury and Finance (DTF) in setting its exchange rate assumptions.

This review is set against a backdrop of Western Australia's increasing reliance on mining royalties, and an exceptionally high level of volatility in the $US/$A exchange rate, which after peaking at US98 cents in mid-2008, collapsed to US61 cents during the global financial crisis before again rebounding above US90 cents in October 2009. These factors have driven substantial changes to the budget estimates and created a high level of uncertainty in the process of government decision-making and resource allocation. Accordingly, this review not only seeks to identify a methodology that improves the accuracy of the exchange rate assumptions, but also minimises the level of fiscal uncertainty caused by short-term exchange rate fluctuations.

Like many other jurisdictions in Australia, the exchange rate assumptions underpinning Western Australia's budget estimates are currently based on the average spot rate in the weeks leading up to the budget (the six-week average in our case). This assumption reflects the inherent volatility of the $US/$A exchange rate, and is consistent with a vast body of literature that attests to the unpredictability of exchange rates over short time horizons.

Although this assumption appears suitable for the budget year estimates, it is arguably inconsistent with a growing body of evidence that points to the predictability of exchange rates over long time horizons. In this regard, one of the potential shortcomings of the existing approach is that the spot rate is assumed constant over the forward estimates period (of three years), notwithstanding how the spot rate compares to the 'fair' or 'equilibrium' value.

This paper therefore compares the forecasting accuracy of alternative exchange rate models over the full budget period. Specifically, we assess the forecasting performance of the current spot rate model relative to a long run average model, forward rates and futures prices, structural/econometric models, and forecasts by external analysts (ABARE and Access Economics).

Taking the budget period as a whole, we find that the best performing model is the long run average (or LRA) model, which simply assumes that the $US/$A exchange rate reverts to its average value in a linear fashion over the course of the forward estimates period (i.e. four years). In a sense, this model can be traced back to the well-known textbook theory of purchasing power parity, which implies that the real exchange rate should be constant in the long run.

Based on historical data from 1986-87, the LRA model would have outperformed DTF's existing spot-rate model in 12 of the past 20 budgets (for which data are available over the full budget period), and in 55 of the past 86 overlapping forecasting years. On average, the LRA model produces forecasting errors that are 14 per cent smaller (over the budget period) relative to those under the spot rate model.

The econometric model presented in the companion paper to this document also performs well relative to DTF's existing spot rate approach. However, the LRA model still produces lower forecasting errors that the econometric model; has the advantage of simplicity and intuitive appeal; and is less reliant on specialist econometric expertise to maintain and update. Nevertheless, it is considered desirable to continue to research and develop models such as these.

Aside from an expected increase in forecasting accuracy, an important side benefit of the LRA model is a significant reduction in the variability of the mining revenue forecasts, especially in circumstances where the exchange rate appreciates or depreciates sharply. This is particularly the case for the outyear revenue forecasts, since the longer-run exchange rate assumptions will only change modestly in response to short-term fluctuations in the spot rate.

The primary focus of this paper is the accuracy of DTF's exchange rate projections, not its overall royalty forecasts. In this regard, it should be noted that while the LRA model is likely to improve the accuracy of DTF's exchange rate projections (to the extent that history serves as a reliable guide), this in itself will not necessarily guarantee an improvement in the accuracy of DTF's mining royalty estimates. This is because movements in the Australian dollar and $US commodity prices are often highly correlated, with the revenue impact of fluctuations in these variables often being partly offsetting.

However, the relationship between commodity prices is not a perfect one. Since the 2009-10 Budget the exchange rate has appreciated without a corresponding increase in commodity prices. One of the virtues of the LRA model is that it will partly reduce the risk of overstating future royalties when the exchange rate is low by historical standards (but assumed under the LRA model to appreciate to the long-run average). Conversely, the LRA model would understate this risk if the exchange rate is high by historical standards (but assumed to return to its long run average) and $US commodity prices are also assumed to remain high. For this reason, it would be desirable to maintain an appropriate level of consistency between $US commodity price assumptions and the exchange rate under the LRA model.

Overall, having regard to the issues and evidence examined in this paper, it is recommended that DTF depart from the existing spot rate model in favour of the LRA model. This approach is simple to understand and implement, produces more accurate exchange rate forecasts over the budget period (on average), and should reduce significantly the volatility of the DTF's revenue forecasts over the forward estimates period

1. Introduction

The Department of Treasury and Finance (DTF) has generally applied the six-week average spot rate in setting its exchange rate assumptions since the late 1990s. This exchange rate is assumed to remain constant during the budget year and over the forward estimates period (of three years).

This simple approach reflects the inherent volatility of the exchange rate and is consistent with a vast body of empirical evidence confirming that short-term exchange rate fluctuations almost always defy systematic empirical explanation. The same approach to projecting exchange rates is used by the Commonwealth Treasury and State treasuries in Queensland and South Australia.

Notwithstanding strong prima facie support for the retention of this methodology (particularly in relation to the budget-year projections), the DTF initiated a review of the exchange rate projections following the 2008-09 Budget.

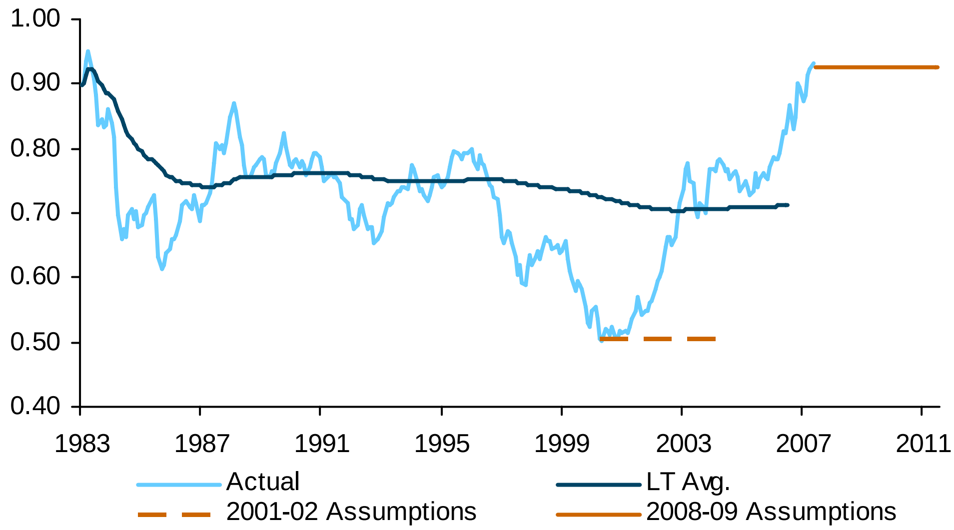
This review has been motivated by a number of factors. First, the recent boom in global resource markets has greatly increased Western Australia's mining revenue base, and hence its exposure to short-term fluctuations in the exchange rate. Royalty income (in addition to North West Shelf grant payments) now accounts for approximately 17 per cent of total general government revenue. This compares to an average share of 5 per cent in other States and Territories. At various periods over the past year, the sensitivity of Western Australia's royalty income has ranged between $38-$55 million for each US1 cent change in the $US/$A exchange rate (holding all other factors, including commodity prices, constant).

A second motivating factor for this review is the growing evidence of some predictability in exchange rates over long time horizons (i.e. beyond the budget year). One of the shortcomings of the current approach is that the exchange rate is assumed to stay constant over a period of four years, which effectively means that no consideration is given to how the spot rate compares to its equilibrium or fair value (whatever that value might be). For instance, in the lead-up to the 2008-09 Budget, the exchange rate was trading at a very high level in historical terms, and application of the 6-week rule resulted in an assumption that the exchange rate would be sustained at US92.5 cents over the period 2008-09 to 2011-12. This is something that has not occurred in the history of Australia's floating exchange rate system.

Conversely, in the early 2000s, the Australian dollar was trading well below its historical average, but the strict application of the existing methodology meant that the $A was assumed to remain at a very low level over the budget period (see following chart). Arguably, the effect of this assumption was to understate the fiscal risks of currency appreciation (although this was ultimately offset by a rise in $US commodity prices).

Figure 1.1: $US/$A exchange rate

As at April 2008



Source: DTF, Thomson Reuters.

The main purpose of this paper is to identify and evaluate alternative exchange rate forecasting methodologies. Section 2 reviews the key economic theories of exchange rate determination. In Section 3, we evaluate the forecasting performance of the six-week average approach against the various alternative modelling techniques. The final section contains recommendations and concluding remarks.

2. Theories of Exchange Rate Determination

In a seminal paper on exchange rate predictability, Meese and Rogoff (1983) concluded that naïve driftless random-walk models (i.e. where the exchange rate in the next period equals the exchange rate in the current period plus an unpredictable random error) were superior to popular models based on economic fundamentals.

This finding is consistent with the notion of market efficiency, where the current exchange rate reflects all available information and so it is difficult to predict period-to-period changes in a systematic fashion. It is also consistent with the current approach taken by the DTF in producing its exchange rate assumptions (i.e. that the recent spot price, which is taken to be the six-week average in the case of the DTF, is the best predictor of exchange rates in the budget year).

After more than two decades of research, systematic empirical explanation of short-term movements in exchange rates remains elusive. However, as noted in a subsequent paper, Rogoff (2001) notes there is now a growing body of evidence that exchange rate movements may be predictable at longer time horizons.

Accordingly, this section outlines some of the well-known theories of exchange rate determination, with a view to testing the long run predictive power of these theories in Section 3.

2.1 Purchasing power parity

Purchasing power parity (PPP) is perhaps one of the most well-known textbook theories of exchange rate determination. This theory provides that, in the absence of shipping costs and tariffs, the price of a commodity expressed in a common currency should be the same in every country.

PPP relies on the concept of commodity arbitrage and the law of one price; if the price of a given commodity is priced differently in different countries, then, arbitragers would buy the commodity in the market where it is cheap and sell it in the market where it is more expensive. For example if Australian goods are more expensive than those in the United States, consumers in both countries will tend to buy US goods. The increased demand for US goods will drive the $US higher with respect to the $A until the prices are equalised.

The law of one price can be expressed algebraically as follows:

$$SP_i = P_i^* \tag{2.1}$$

where P_i is the domestic price of commodity i, P_i^* is the foreign price of commodity i and S is the exchange rate expressed as the number of units of the foreign currency per one unit of the domestic currency (i.e. the exchange rate expressed in indirect terms[1]).

By rearranging this equation as shown below, PPP can be viewed as a theory of exchange rates.

$$S = P^* / P \tag{2.2}$$

Thus, as domestic prices rise relative to foreign prices, S falls and vice versa.

PPP applies to labour and capital markets in the same way that it applies to the tradable goods market. For example, if a country's exchange rate is such that the local cost of labour in foreign dollars is low relative to other countries, then production will be attracted to this base. Production capacity will tend to move from the 'overvalued' to the 'undervalued' economy, driving the exchange rate back to its PPP equilibrium – that is, the level that equates prices across countries.2

The theory of PPP rests on a number of important assumptions. The first is that there are no restrictions on the movement of commodities, since any restriction will hinder the smooth operation of commodity arbitrage. Second, there are no transportation costs and thirdly there are no tariffs, because tariffs have the same effect on the relationship as transportation costs. Finally, it is assumed that agents are risk neutral as they do not require a risk premium to operate in foreign commodity markets.

[1] Unless otherwise stated, the convention adopted in this paper is to express the $US/$A exchange rate in indirect terms (i.e. as opposed to the more common direct measure (e.g. $A/$US) used in economics and finance literature).

[2] Conway and Franulovich (2002).

One interesting and entertaining application of PPP theory is The Economist's Big Mac Index (BMI), which compares the price of a Big Mac hamburger in one country to another. The Big Mac is sold in 120 countries around the world, and contains a fairly standardized bundle of goods. Since most of the ingredients are individually traded on international markets, the expectation is that the law of one price should hold, at least approximately. [3]

The first column of Table 2.1 lists the domestic currency price of a Big Mac in a number of different countries, while the second column gives the $A equivalent based on the current spot rate. By comparing this value with the implied PPP value of the $A (i.e. the foreign price of a Big Mac compared to the $A price), it is possible to test if the domestic currency is overvalued or undervalued.

Table 2.1: The Big Mac Index, July 2009

	Price of a Big Mac				
	In local currency	**In $A**	Implied PPP of the dollar [(a)]	Actual exchange rate	Under(-) / over(+) valuation against $A
United States [(b)]	$3.57	4.41	1.03	0.81	-0.27
Canada	C$4.09	4.60	1.19	0.89	-0.33
Australia	A$3.45	-	-	-	-
New Zealand	NZ$4.90	3.95	1.42	1.24	-0.14
United Kingdom	£2.29	4.67	0.66	0.49	-0.34
Euro Area	€ 3.37	5.81	0.98	0.58	-0.70
Switzerland	SFr 6.50	7.47	1.88	0.87	-1.15
Russia	Rouble 59.0	2.32	17.10	25.42	0.33
China	Yuan 12.5	2.27	3.62	5.50	0.34
Hong Kong	HK$13.3	2.11	3.86	6.31	0.39
Japan	Yen 280	3.63	81.16	77.08	-0.05
Singapore	S$3.95	3.38	1.14	1.17	0.02

Notes: (a) Purchasing power parity: foreign currency price divided by $A price.
(b) Average of New York, Chicago, Atlanta and San Francisco.

Source: *The Economist*, DTF estimates.

[3] The Commonwealth Bank has recently introduced a modern day variant of the BMI, known as the "CommSec iPod index." The key difference between these measures is that whereas Big Macs are made in many different countries, iPods are mostly made in China.

Thus, according to the BMI, the \$A was undervalued against the \$US in July 2009 (as well as a number of other currencies).

In practice, a broader measure of international price differentials is often required. The ‘absolute’ version of PPP requires:

$$S\sum_{i=1}^{n} w_i P_i = \sum_{i=1}^{n} w_i^* P_i^* \qquad (2.3)$$

where the sums can be proxied, for example, by using consumer price indices. This however can present some difficulties in that governments do not construct indices for an internationally standardised basket of goods. Although Australia and the United States consumer (and producer) price indices are conceptually quite similar, they are still constructed somewhat differently and use different weights. Moreover, since the price data is published in the form of indices relative to a base year, these give no indication of the absolute difference between average price levels.

For these reasons, the “relative” form of PPP is often used in practice. This requires that:

$$\left(\frac{S_t}{S_{t-1}}\right)\left(\frac{\sum P_{it}}{\sum P_{it-1}}\right) = \left(\frac{\sum P_{it}^*}{\sum P_{it-1}^*}\right) \qquad (2.4)$$

or $$\dot{S} = \dot{P}* - \dot{P} \qquad (2.5)$$

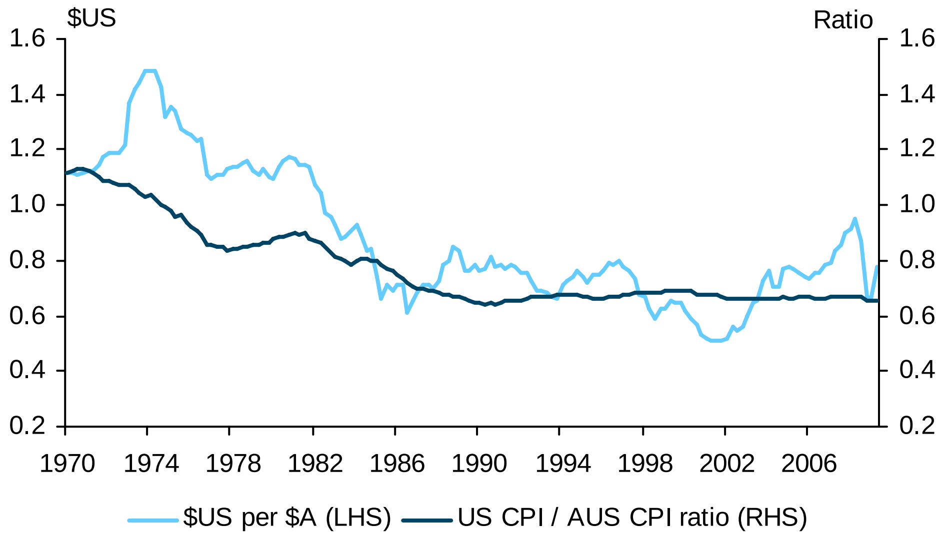
where $\dot{S}$ is the rate of change in the exchange rate, and $\dot{P}$ and $\dot{P}*$ are the domestic and foreign inflation rates respectively.

Relative PPP requires only that the rate of growth in the exchange rate offset the differential between the rate of growth in home and foreign price in home and foreign price indices.

Two important implications of the PPP model are that: (1) relative high levels of inflation will tend to erode the value of the nominal exchange rate; and (2) the real exchange rate should remain constant over time.

The following chart suggests that the nominal $US/$A exchange rate does display PPP-type behaviour over the long run. From 1970 until the mid-1980s the exchange rate steadily depreciated as inflation in Australia was persistently higher than in the United States. This meant that the reduced purchasing power of the domestic currency in Australian dollars was broadly matched by a fall in its purchasing power when converted into US dollars. Since the late-1980s, consumer price inflation in Australia has been more similar to that in the US and so the nominal exchange rate has cycled around a more constant mean.

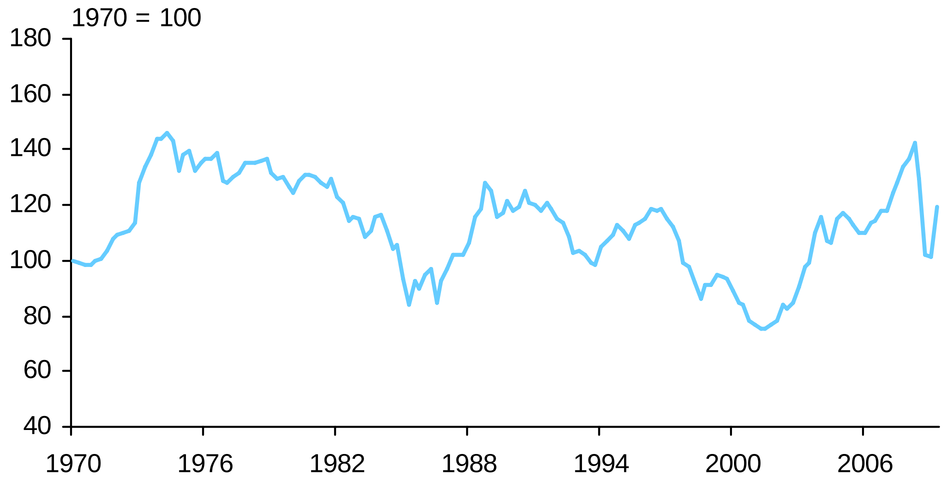
Figure 2.2: $US/$A exchange rate and relative consumer prices



Source: DTF, Thomson Reuters, RBA.

The following chart shows that the real $US/$A exchange rate appears to have cycled around a constant long-run average at least since the 1960s (although it is also evident that deviations from the average have been both significant and persistent). This is *prima facie* evidence that PPP provides a reasonable description of long-run movements in the $US/$A exchange rate – this is tested in a formal statistical sense below.

Figure 2.3: Real index of the $US/$A exchange rate



Source: DTF, RBA, Thomson Reuters.

Empirical evidence

Formal tests of the PPP model can be specified in a number of different ways. A simple test is to regress the (log) change in the exchange rate on the inflation differential:

$$\ln S_{t+h} - \ln S_t = \alpha_0 + \alpha_1(\pi_t * - \pi_t) + \varepsilon_t \qquad (2.6)$$

where π and $\pi*$ are the domestic and foreign inflation rates respectively, and ε_t is a zero mean error term.

A slight alternative is to test PPP in an 'error-correction' form. Here, the change in the exchange rate is modelled as a function of its last-period deviation from a long-run equilibrium:

$$\ln S_{t+h} - \ln S_t = \alpha_0 + \alpha_1(\ln S_t - \beta_0 - \beta_1 \ln \tilde{p}_t) + \varepsilon_t \qquad (2.7)$$

where $\tilde{p}_t$ refers to the foreign price level relative to the domestic price level.

A consistent finding in empirical studies of PPP is that the explanatory power of this model over short time horizons is very poor.4 This reflects the large and volatile fluctuations in short-term (nominal) exchange rates in comparison to movements in relative price differentials.[5] Moosa (1998) offers a number of explanations for this result, including:

- the existence of transportation and other trade impediments, which hinder the process of commodity arbitrage;
- the presence of non-traded goods (i.e. some goods and services are simply not traded on international markets); and
- other factors (interest rates, commodity prices and market sentiment/expectations etc.) that can affect exchange rates, especially in the short run.

Although the PPP model often performs poorly in the short-term, there is now increasing evidence that exchange rates tend towards a PPP equilibrium in the long run. For instance, in a recent study by the Hong Kong Monetary Authority, Lam, Fung and Yu (2008) find that the PPP model outperforms the benchmark random walk model in relation to the EUR/USD exchange rate over forecasting horizons from one to eight quarters, while mixed results are observed for the GBP/USD and YEN/USD exchange rates. Rogoff (2002) notes the improved performance of the PPP model in the long run, but that deviations from the PPP equilibrium dissipate only slowly.

The unit root test can be used to evaluate the longer-term performance of the PPP model (i.e. whether exchange rates return over time to some equilibrium value). If the real (inflation-adjusted) exchange rate is stationary[6], then PPP holds and random disturbances have no permanent effects. Conversely, if the real exchange rate follows a random-walk, then there is no tendency for it to return to some average value over time and long-run PPP does not hold.[7]

Many early studies could not reject the unit root hypothesis, hence rejecting the notion of long-run PPP (see Coughlin and Koedijk 1990). However, a number of more recent studies have found evidence to reject the random walk hypothesis, especially over very long time horizons.[8] Moreover there are ongoing doubts about the power of standard statistical tests to distinguish between true random walks and near random walks.

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[4] See Taylor and Taylor (2004), Meridth (2003) and Rogoff (2002).

[5] As noted by Rogoff (2001) "…domestic price levels have the cardiogram of a rock compared to floating exchange rates…".

[6] A variable is stationary if it has a constant mean, variance and covariance.

[7] A variable is said to follow a random walk if its value in the next period equals its value in the current period plus a random error that cannot be predicted using available information. If the real exchange rate follows a random walk, then it will not return to some average value associated with PPP over time.

[8] See Froot and Rogoff (1994), Wu (1996) and Culver and Papell (1999).

Table 2.2 sets out the results of various unit root tests of the real $US/$A exchange rate over the period March 1970 to June 2009.

Table 2.2: Unit root tests of the real $US/$A exchange rate

	Augmented Dickey-Fuller test statistic	**Phillips-Perron test statistic**	**Kwiatkowski-Phillips-Schmidt-Shin test statistic**
Null Hypothesis	R has a unit root	R has a unit root	R is stationary
Test statistic	-2.497	-2.198	0.438
Probability	0.118	0.208	
Test critical values:			
1% level	-3.473	-3.472	0.739
5% level	-2.880	-2.880	0.463
10% level	-2.577	-2.577	0.347

Source: DTF estimates.

The augmented Dickey-Fuller (ADF) and Phillips-Perron tests both fail to reject the null hypothesis that the real $US/$A contains a unit root (although the ADF test statistic is close to being significant at the 10 per cent level). However, the Kwiatkowski-Phillips-Schmidt-Shin test fails to reject the null hypothesis (at the 5 per cent level) that the real exchange rate *is* stationary (i.e. that PPP holds). The results are therefore mixed.

Despite somewhat inconclusive evidence, we conclude that there is at least some theoretical and empirical support for the PPP model, albeit over very long time horizons. In Section 3 we develop and test a simple model of the exchange rate that is connected with the concept of PPP and the notion of a long-run equilibrium value.

2.2 Interest rate parity models

Like PPP, interest rate parity models of exchange rate determination rest on the concepts of arbitrage and market efficiency. In essence, the theory of uncovered interest rate (UIP) is an application of the law of one price to financial markets, asserting that the rate of return on a domestic asset must be the same as that on a foreign asset with similar characteristics.

This can be illustrated with a simple hypothetical example. Suppose an investor with capital, *K*, faces two options:

1. the domestic option where the investor buys domestic assets, earning the domestic interest rate i; or

2. the foreign option where the investor converts domestic currency into foreign currency to buy foreign assets, earning the foreign interest, i*.

If the investor chooses the domestic option, the invested capital is compounded at the domestic interest rate and the investor receives the initial capital plus interest, i.e. $K(1+i)$. If the foreign option is chosen, then the investor must first convert the initial capital into foreign currency at the current spot exchange rate to purchase the foreign asset, producing a foreign currency return of $(K*S)(1+i*)$. The expected domestic currency value of this investment is obtained by reconverting this amount into domestic currency at the expected spot rate.

Assuming that there are no restrictions on the movement of capital, no transaction costs and that investors are risk neutral[9], the equilibrium condition is that the two options must offer the same return:

$$K(1+i) = K \times S(1+i^*)\frac{1}{S^e} \qquad (2.8)$$

or

$$\frac{S^e}{S} = \frac{1+i^*}{1+i} \qquad (2.9)$$

which is approximately equivalent to:

$$\dot{S}^e = i^* - i \qquad (2.10)$$

where $\dot{S}^e$ is the market expectation of the exchange rate return (i.e. percentage change in the spot rate) over the holding period.

UIP implies that the interest rate differential between two countries is equal to the expected change in the exchange rate. A currency that offers a higher interest rate must be expected to depreciate and vice versa (no investor will choose to hold a currency that offers a low interest rate and is expected to depreciate). For instance, if the interest rate in Australia is 15 per cent and the interest rate in the United States is 10 per cent, we can expect the $A to depreciate by 5 per cent relative to the $US.

[9] In other words, it is assumed that investors are indifferent between holding domestic and foreign assets if these assets offer the same (expected) return.

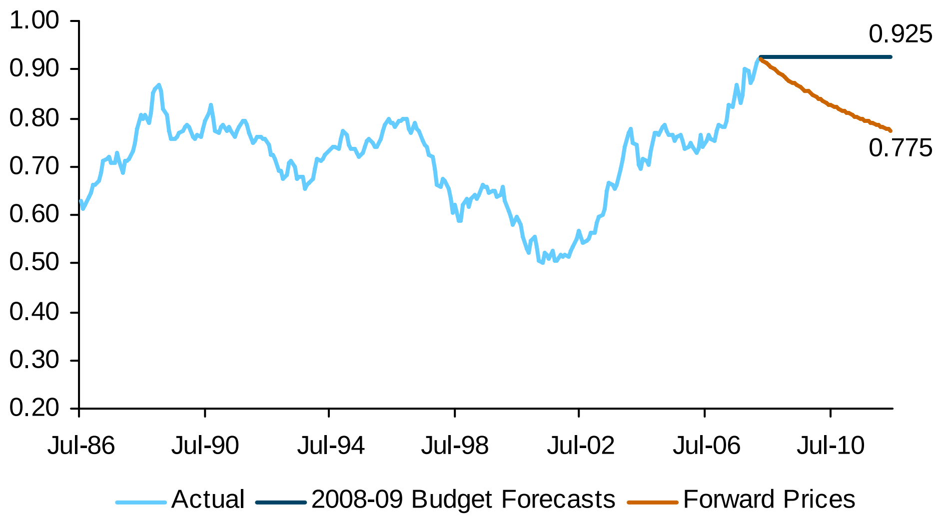
If investors have the opportunity to cover against exchange rate uncertainty by pre-arranging to reconvert from foreign to domestic currency at the forward exchange rate, F, then the market equilibrium becomes:

$$K(1+i) = K \times S(1+i^*)\frac{1}{F} \tag{2.11}$$

This is known as the covered interest parity (CIP) condition.

Forward contracts provide the DTF with another potential option when it comes to its exchange rate assumptions. If forward rates had been used in the 2008-09 State Budget (instead of the six-week average spot rate) then the $US/$A exchange rate assumptions would have been markedly different. As shown in the following chart, the forward profile of the $A against the $US was steeply downward sloping in April 2008, largely reflecting the 400 basis point difference in interest rates between the two countries at that time.

Figure 2.4: $US/$A exchange rate and forward rates



Source: DTF, Thomson Reuters.

The forecasting performance of forward contracts, as well as other models based on the UIP framework, is examined below and in Section 3.

Empirical Evidence

UIP can be tested in a number of ways. As noted in Moosa (1999), the most direct empirical test is based on the following regression equation:

$$\dot{S}_{t+h} = \alpha_0 + \alpha_1 (i*_t - i_t) + \varepsilon_t \qquad (2.12)$$

If the estimation results indicate that $\alpha 0 = 0$ and $\alpha 1 = 1$ then this would provide evidence in favour of UIP, since it would indicate that the rate of change in the spot rate is on average equal to the interest rate differential at the beginning of the period.

A variation of this test is to adopt an error correction format:

$$\ln S_{t+h} - \ln S_t = \alpha_0 + \alpha_1 (\ln S_t - \beta_0 - \beta_1 \ln \tilde{i}_t) + \varepsilon_t \qquad (2.13)$$

where $\tilde{i}_t$ is the foreign interest rate relative to the domestic interest rate.

UIP can also be evaluated by assuming that the covered interest rate parity holds and testing the unbiased efficiency hypothesis, with the underlying regression equation being:

$$S_{t+h} = \alpha_0 + \alpha_1 F_t^h + \varepsilon_t \qquad (2.14)$$

where S_{t+1} is the spot rate and F_t^h is the *h*-period forward rate at time *t*. Aside from tests based on regression analysis, the forecasting performance of forward contracts can be evaluated by simply comparing forward exchange rates with actual rates (see Section 3 for more detail).

Most empirical studies find that interest differentials explain only a small proportion of subsequent changes in exchange rates, especially in the short term.[10] This finding is generally interpreted as implying that observed changes in exchange rates are predominately the result of unexpected information or “news” about economic developments, policies, or other relevant factors.

Moreover, most studies soundly reject the hypothesis that $\alpha 0 = 0$ and $\alpha 1 = 1$ at prediction horizons of one year or less (Isard 2006).

[10] See for instance Isard (1978), Mussa (1979) and Frenkel (1981) in Moosa (1999).

Although the empirical evidence strongly rejects UIP over short horizons, the evidence is more favourable over the long term. For instance, Flood and Taylor (1997) find that when data for industrial countries are pooled, and when annual exchange rate changes and interest differentials are averaged over non-overlapping five to twenty-year periods, the slope coefficient $\alpha 1$ becomes insignificantly different to unity.

Likewise, Chinn and Meredith (2004) find some support for UIP over long time horizons. They conclude that the UIP theorem can outperform alternatives such as the random walk hypothesis, although it is likely to explain only a relatively small proportion of the observed variance in exchange rates.

Mehl and Cappiello (2007), Lam, Fung and Yu (2008) and Lothian and Wu (2005) similarly conclude that the explanatory power of UIP improves over distant time periods.

In Section 3, we formally evaluate and compare the forecasting performance of models based on interest rate parity conditions relative to alternative modelling techniques.

2.3 Sticky price monetary model

The sticky price monetary model of Dornbusch (1976) and Frenkel (1979) is another well-known model of exchange rate determination. This model combines the UIP condition with the simple monetary model, with the latter having the following specification:

$$\ln M_d - \ln P = \alpha_1 \ln Y - \beta_1 i \tag{2.15}$$

$$\ln M_d^* - \ln P^* = \alpha_2 \ln Y^* - \beta_2 i^* \tag{2.16}$$

where M_d is the quantity of money demanded, Y is income (GDP) and variables with an asterisk denote variables of the foreign country (with α and β being positive constants). These equations postulate that (real) demand for money is a positive function of economic activity and a negative function of interest rates (due to the opportunity cost of holding money).

Assuming equilibrium in the money market (i.e. money demand equals money supply) and applying PPP means that equations (2.15) and (2.16) can be combined as follows:

$$\ln S = \ln\left(\frac{M^*}{M}\right) - \alpha_3 \ln\left(\frac{Y^*}{Y}\right) + \beta_3 (i^* - i) \tag{2.17}$$

The assumption that PPP holds in the short term is then relaxed, i.e. this model assumes that prices are sticky in the short run, with the goods market adjusting more slowly than financial markets to monetary shocks. This is consistent with empirical studies that point to the failure of PPP over short time horizons.

In Dornbusch's main formulation, output Y is assumed to be exogenous, while a variation of the model includes an endogenous specification for output.

According to the sticky price model, growth in the nominal money supply results in an increase in the real money balances (since prices are held fixed in the short term). With output assumed to be fixed in the short run, the money market can only clear if the interest rate on domestic bonds falls. Under the interest rate parity condition, this requires an appreciation of the domestic currency. However, in the *long run* the domestic currency must depreciate in line with the theory of PPP. The Dornbusch model implies therefore that the initial depreciation of the domestic currency must exceed the long-run depreciation, hence allowing the exchange rate to appreciate during intervening periods. In other words, the exchange 'overshoots' in the short run.

Empirical Evidence

The sticky price model has attracted a great deal of attention since it was first developed by Dornbusch in 1976 (according to one estimate by Rogoff (2001) this model has been cited in more than 900 published articles). The appeal of the Dornbusch model lies in its theoretical elegance and insight, particularly in relation to its separate treatment of slowly adjusting goods markets and more rapidly clearing financial markets.

Like other structural models of the exchange rate, however, the sticky price model does not enjoy a particularly strong track record of success in forecasting (Rogoff (2001)).[11]

That said, a number of studies have found that the sticky price model has predictive power in relation to some currencies and over certain time periods. For instance, Lam, Fung and Yu (2008) find that the sticky price model generally outperforms the random walk model for the EUR/USD, YEN/USD and GBP/USD exchange rates, with the differences between these models at long time horizons being statistically significant in some cases. Similarly, Bjørnland (2009) finds results that are consistent with the overshooting hypothesis when testing this model on Australia, New Zealand, Canada and Sweden.

Section 3 further evaluates the forecasting performance of the sticky-price model in the context of the $US/$A exchange rate.

[11] See also Cheung, Chinn and Pascal (2003) and Meese and Rogoff (1988).

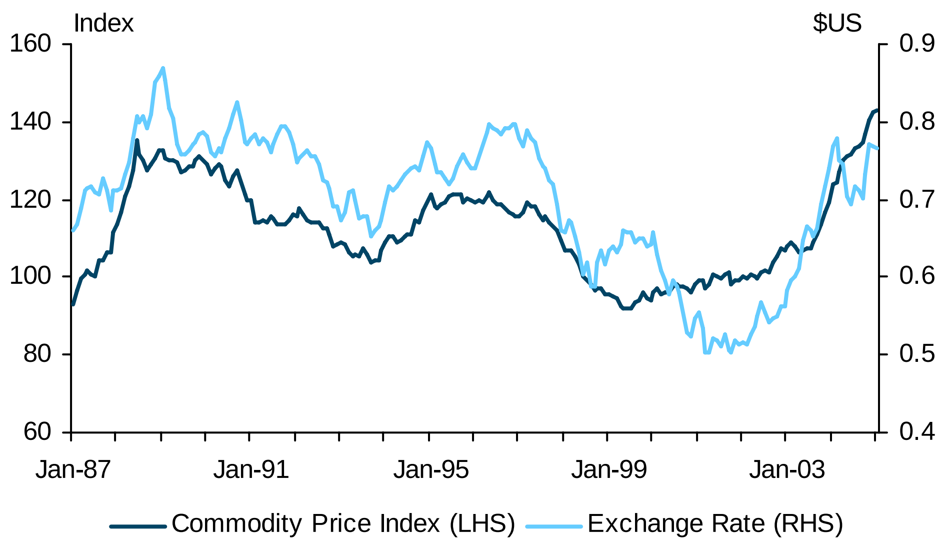
2.4 Other factors

Changes in the $US/$A exchange rate are often attributed by economists to movements in a range of other variables, including commodity prices and the current account deficit.

For small, open economies such as Australia, in which primary commodities constitute a significant of share of exports, commodity price shifts can provide a useful indication of demand for the domestic currency. Indeed, the link between the Australian dollar and commodity prices can be so strong that the $A is often referred to as a "commodity currency."[12]

Before the height of the recent mining boom in Australia, this relationship had been particularly striking (see following chart).

Figure 2.5: $US Commodity Price Index for Australia and the $US/$A



Source: DTF, Thomson Reuters, RBA.

[12] To the extent that this relationship holds, it provides the Western Australian government with a natural hedge in relation to its mining royalties, and reduces the need to predict the exchange rate accurately. This issue is discussed in more detail in Section 4.

In a comprehensive study on this topic, Chen and Rogoff (2002) confirm that the $US price of Australia's commodity prices has a strong and stable influence on the real value of the $US/$A exchange rate. Gruen and Kortian (1996) even venture that substantial excess profits could have been earned on the $A in the 1990s by properly incorporating forecastable terms of trade movements into exchange rate movements. Strong correlations have also been found between commodity prices and exchange rates in Canada and New Zealand (i.e. countries with a similar reliance on commodity exports).[13]

The link between the current account and exchange rates has been the subject of a large number of studies.[14] In this case, the rationale is that when the current account deficit increases, there must be a corresponding net inflow of $A financial capital (i.e. a capital account surplus), and hence the domestic currency will tend to appreciate (and vice versa). However, as the stock of net foreign liabilities grows over time, the exchange rate must eventually depreciate in order to generate a surplus of exports over imports and repay this debt.

In the companion paper to this document, Zheng (2009) develops an econometric model of the $US/$A exchange rate, which *inter alia*, includes commodity prices and the current account deficit as explanatory variables. The forecasting performance of this model is summarised in the next section.

[13] See, for example, Djoudad, Murray, Chan and Dow (2001).

[14] The relationship between the US dollar and the current account deficit is analysed in some detail in Obstfeld and Rogoff (2004). See also Gruen (2001).

3. Model Evaluation

The purpose of this section is to evaluate and compare the predicative power of a variety of forecasting models. These are:

- the spot-price model currently used by the DTF;
- a long run average model based on the concept of PPP;
- models based on the UIP model (forward rates);
- a purpose-built econometric model of the $US/$A exchange rate; and
- the Dornbusch sticky price model.

We also assess the accuracy of exchange rate forecasts produced by other government bodies and private sector firms.

In most cases, the historical forecasting performance of these models is tested with reference to the information available at the time of a theoretical budget cut-off date of 1 April in each year.

3.1 The spot rate model

The current approach taken by the DTF in setting its exchange rate assumptions is a pseudo random walk model. The prevailing spot rate, calculated as the six-week average, is assumed to apply over the entire forward estimates period (i.e. four years).[15]

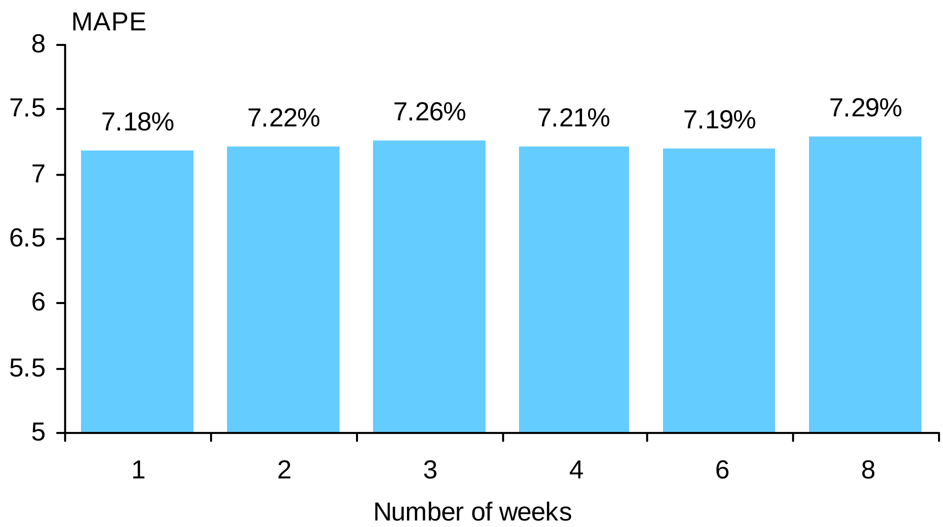
[15] In true random walk models, the assumption is that the value of a variable in the next period equals its value in the current period. This is different to DTF's existing approach, under which the spot price in the previous six weeks is assumed to remain constant over the full budget period (i.e. not just the next six weeks).

The choice to calculate a six-week average (as opposed to a one-week average, or even the spot rate on the budget cut-off day) is designed to abstract from very short-term volatility in the exchange rate.

However, as the following Figure 3.1 shows, there is in fact little difference in the budget-year forecasting performance of spot rates calculated over various time horizons. The mean absolute percentage error (MAPE) (over the period 1986-87 to 2008-09) ranges from 7.18 per cent for the one-week average and 7.29 per cent for the eight-week average.

Figure 3.1: Comparison of various spot rate models

Budget year forecasting performance, 1986-87 to 2008-09



Source: DTF.

Table 3.1 further compares each of these alternatives over the full budget period. Once again, the forecasting performance of the various spot rates is very similar. However, it is clear that in all cases the forecasting performance of the spot rate (SR) model deteriorates over the forward estimates period. For instance, the forecasting accuracy of the six-week average SR model increases from 7.19 per cent in the budget year to 15.63 per cent in the third outyear.

Table 3.1: Forecasting performance of various spot price models, MAPE (%)

	Budget Year	Outyear 1	Outyear 2	Outyear 3	Average
1-week average	7.18	10.91	13.31	15.30	11.68
2-week average	7.22	10.85	13.33	15.44	11.71
3-week average	7.26	10.69	13.34	15.61	11.72
4-week average	7.21	10.51	13.27	15.62	11.65
6-week average	7.19	10.50	13.21	15.63	11.63
8-week average	7.29	10.70	13.37	15.76	11.78
Average	**7.23**	**10.69**	**13.30**	**15.56**	**11.70**

Notes: Based on exchange rates as at 1 April each year (the theoretical budget cut-off date).
Source: DTF estimates.

Given the very marginal difference between the alternative random walk models, and the fact that many of DTF's revenue forecasting models are based on monthly data, we choose the 4-week average spot rate model as the benchmark model in this paper, i.e. the forecasting performance of competing models is tested relative to this model.[16]

3.2 The long run average model

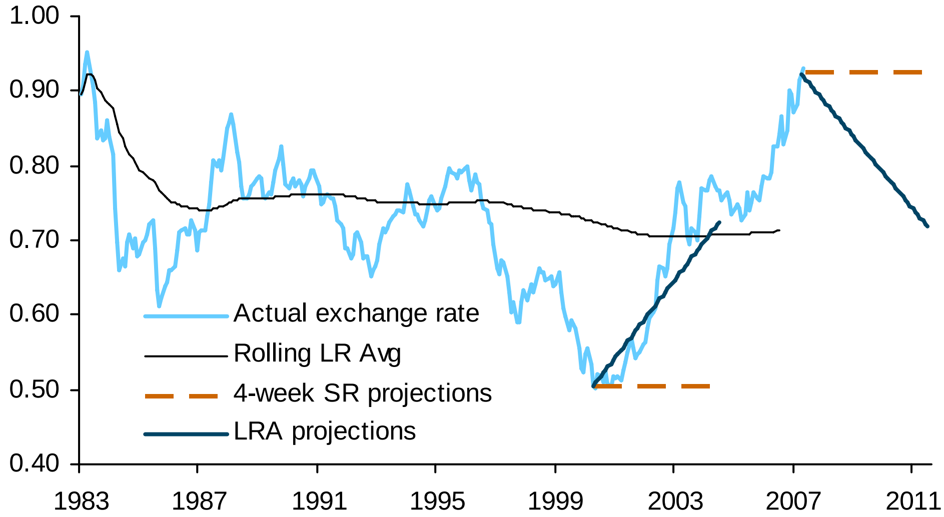
The first alternative to a random walk model is a simple approach based on an assumption that the exchange rate returns to a long-run average (in a linear fashion) over the budget period. The rationale for this approach is based on the principle of PPP (see Section 2), i.e. the idea that the exchange rate ultimately returns to some equilibrium value over time.[17]

Taking the 2008-09 Budget as an example, we calculate the 4-week exchange rate average at the time of the theoretical budget cut-off date of 1 April 2008 (US92.5 cents) and assume that, over the course of the following 50 months, the exchange rate returns to its post-float average of US72 cents (i.e. as at June 2012). This produces annual average exchange rate forecasts of US88.5 cents in 2008-09, US83.5 cents in 2009-10, US79 cents in 2010-11 and US74 cents in 2011-12 (see Figure 3.2).

[16] The 4-week average model is a good proxy for the 6-week average model as both produce very similar results.

[17] Technically, PPP implies that the *real* exchange rate should be stationary in the long run. However, as inflation in the US and Australia has not varied markedly since the 1990s, we calculate the average in nominal terms.

Figure 3.2: The long run average model



Source: DTF.

Table 3.2 sets out the forecasting performance of the Long-Run Average (LRA) model. Each cell represents the ratio of forecasting error (in US cents) of the LRA model as a proportion of the forecasting error for the 4-week average SR model. Hence a ratio of less than one means that the long-term average outperforms the SR model.

The summary row in Table 3.2 describes the ratio of root mean square errors (RMSEs) under each forecasting approach. RMSE is a common statistical measure of forecasting error, and is similar in concept to the average absolute error. A RMSE ratio of less than one means that the LRA model produces smaller forecasting errors than the 4-week average.

Table 3.2: $US/$A forecasting performance of the LRA model

Relative to the 4-week average spot rate model

	Budget Year	Outyear 1	Outyear 2	Outyear 3	Absolute Average
1986-87	1.32	-0.52	0.53	-0.10	**0.62**
1987-88	0.73	0.80	0.51	0.44	**0.66**
1988-89	0.98	0.91	0.90	0.82	**0.94**
1989-90	0.75	0.16	0.13	0.51	**0.50**
1990-91	0.99	0.96	1.02	1.02	**1.01**
1991-92	0.21	0.93	0.91	0.66	**0.90**
1992-93	1.01	1.02	1.14	-5.48	**1.02**
1993-94	1.61	0.40	0.36	0.41	**0.46**
1994-95	0.77	0.66	0.64	2.13	**0.93**
1995-96	0.89	0.87	1.19	1.13	**1.10**
1996-97	1.36	0.90	0.90	0.86	**0.88**
1997-98	0.94	0.90	0.85	0.87	**0.88**
1998-99	1.35	1.82	1.40	1.49	**1.46**
1999-00	25.15	1.51	1.69	3.20	**1.83**
2000-01	1.33	1.62	4.34	-0.08	**1.29**
2001-02	-1.16	-0.16	0.31	0.21	**0.26**
2002-03	0.41	0.58	0.46	0.24	**0.43**
2003-04	0.83	0.71	0.53	0.50	**0.62**
2004-05	3.75	-6.56	1.80	1.27	**1.31**
2005-06	0.61	25.33	1.46	-0.79	**1.38**
2006-07	1.06	1.05	1.68	n.a.	
2007-08	1.14	0.26	n.a.	n.a.	
2008-09	0.78	n.a.	n.a.	n.a.	
RMSE ratio	**0.94**	**0.91**	**0.87**	**0.79**	**0.86**

Source: DTF estimates.

Table 3.2 indicates that the LRA model outperforms the 4-week SR model (on average) over all forecast horizons. Notably, the forecasting performance of the LRA model improves as the forecasting horizon increases, with the RMSE ratio falling from 0.94 in the budget year to 0.79 in the third outyear. On average over the past two decades, the LRA would have produced forecasting errors that were 14 per cent smaller over the full budget period.

Looking at the results more closely, the LRA model would have outperformed the 4-week average SR model in 55 out of the past 86 (overlapping) forecasting years, and in 12 of the past 20 budgets (for which actual data are available over the full budget period).

On three of the remaining eight occasions, the difference was marginal; having occurred where the spot rate happened to be very close to the historical average at the time of the budget.

The SR model also outperformed the LRA model in the early 2000s, when the exchange rate traded well below the historical average for an unusually extended period of time. This was a period in which market sentiment heavily favoured high technology stocks and 'new economies,' while the $A was arguably out of fashion.

3.3 Interest rate parity models and forward markets

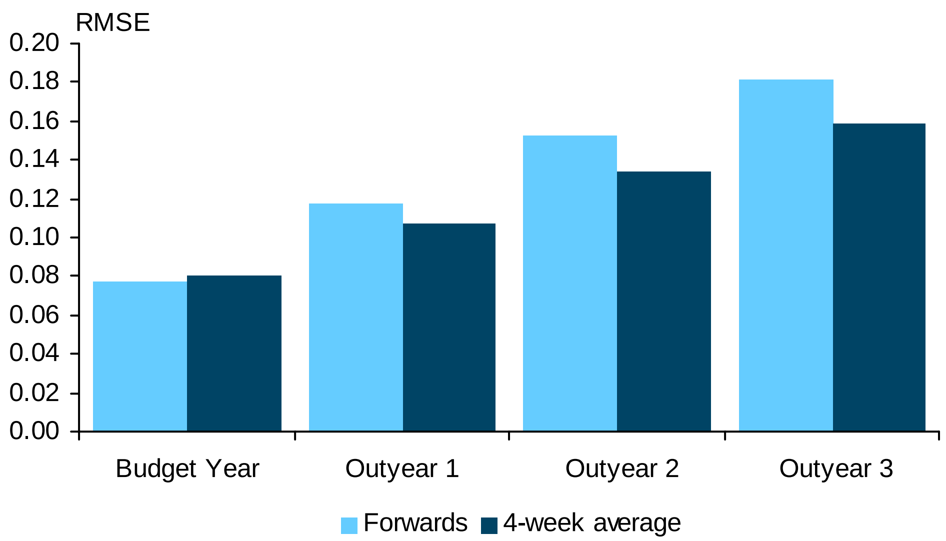
As noted in Section 2, forward prices could be used as the basis for DTF's exchange rate projections. These prices are normally determined by large financial institutions by reference to the covered interest rate parity formula, i.e. based on interest rate differentials (Isard 2006).

The advantage of using forward prices is that they are directly observable and based on market expectations of the future value of the $A.

Figure 3.3 compares the forecasting error of forward rates with the forecasting error of projections based on the 4-week SR model. As before, this comparison is based on a theoretical budget cut-off day of 1 April in each year.

Figure 3.3: Forecasting performance of $US/$A forward contracts

Root mean square error, 199899 to 200809



Source: DTF, Thomson Reuters.

Table 3.3 sets out these results in detail.

Table 3.3: Forecasting performance of $US/$A forward rates

Ratio of forecast errors: forward prices vs 4week SR model, 199899 to 200809

	Budget Year	Outyear 1	Outyear 2	Outyear 3	Absolute Average
1998-99	1.06	1.13	1.05	1.03	**1.04**
1999-00	2.37	1.05	1.04	1.09	**1.05**
2000-01	1.02	1.03	1.13	0.96	**1.00**
2001-02	1.31	1.09	1.03	1.02	**1.03**
2002-03	1.11	1.08	1.08	1.10	**1.09**
2003-04	1.14	1.21	1.29	1.27	**1.24**
2004-05	6.63	-22.84	2.74	1.52	**1.66**
2005-06	0.67	8.71	1.32	-0.22	**1.24**
2006-07	1.03	1.04	1.54	n.a.	
2007-08	1.08	0.57	n.a.	n.a.	
2008-09	0.80	n.a.	n.a.	n.a.	
RMSE ratio	**0.97**	**1.10**	**1.14**	**1.14**	**1.12**

Source: DTF estimates.

Over the period 1998-99 to 2008-09, forward prices outperformed the SR model (albeit modestly) in relation to the budget year forecasts. However, as the forecasting horizon lengthens, the forecasting track record of forward prices deteriorates relative to the SR model. On average, forward prices would have produced exchange rate projections that were 12 per cent less accurate than the 4-week SR model.

These results appear to be broadly consistent with other studies on the predictive power of models based on interest rate differentials, particularly in relation to the performance of these models over short time horizons. Interestingly, our results suggest that the predictive power of forward rates does not improve over longer time horizons (although it should be noted that the sample size in this paper is rather limited).

Exchange rate futures

A slight alternative to using forward prices would be to refer to exchange rates in futures markets. The key difference between forwards and futures is that the latter are instruments which are traded on security exchanges, with a fixed size ($A100,000 in the case of the $US/$A futures contract on the Chicago Mercantile Exchange) and with a limited number of prospective settlement dates (one per quarter). Changes in value of the contract are passed between the two parties on a daily basis, making use of the clearing house as an intermediary.

Table 3.4 sets out the futures price of various $US/$A contracts as at 1 April 2009.

Table 3.4: $US/$A futures contracts

	Sep-10	Dec-09	Mar-10	Jun-10	Average for 2009-10
1 April 2009	0.6910	0.6882	0.6854	0.6826	0.6868

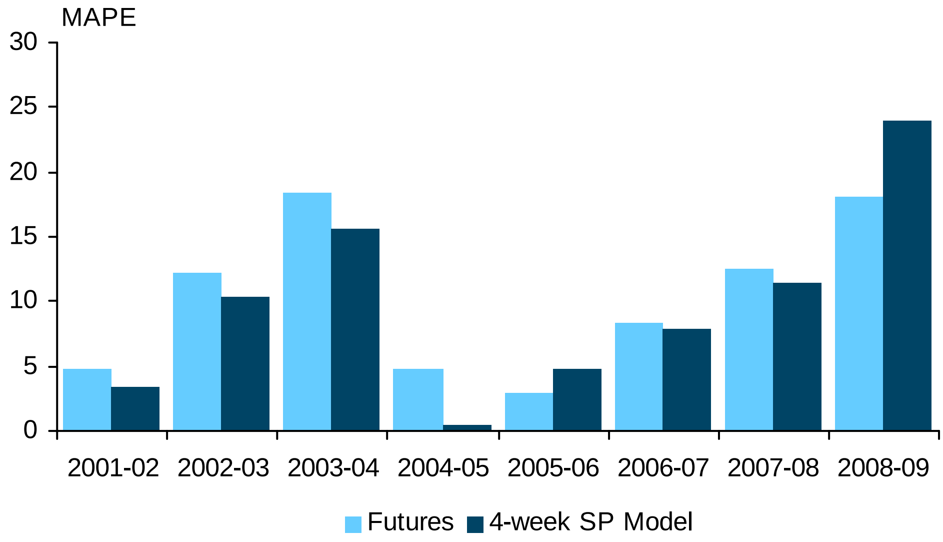
Source: CME

Thus, if futures markets had been used as the basis of DTF's exchange rate assumptions in the 2009-10 State Budget, a value of US68.7 cents would have been used (very similar to the actual assumption of US68.5 cents).

The following chart illustrates the budget-year forecasting performance of the futures market for the $US/$A exchange rate relative to the projections produced by the 4-week SR model. It shows that the SR model would have outperformed the futures market in most years since 2000-01 (with a notable exception occurring in 2008-09).

Figure 3.4: Forecasting accuracy of $US/$A futures contracts

Mean absolute percentage error, 2000-01 to 2008-09



Source: DTF, CME.

A key practical shortcoming of using futures markets is that the length of these contracts only extends over approximately 16 months. Thus, even if futures were adopted as the basis of DTF's budget-year exchange rate forecasts, this would leave open the question of how to forecast the exchange rate in the outyears.

3.4 Econometric model

In the companion paper to this review (available upon request from the DTF), Zheng (2009) develops an econometric model of the $US/$A exchange rate.

This model contains explicit links between the $US/$A exchange rate and inflation rate differentials, commodity prices and the current account deficit in each country (both as a share of GDP).[18]

[18] Interest rate differentials are found to have an insignificant influence on the $US/$A exchange rate.

The exchange rate is modelled in an error correction framework, i.e. the model attempts to explain the long-run equilibrium \$US/\$A exchange rate, but allows deviations from this equilibrium in the short term. The explanatory variables can also be used to explain short-term movements in the exchange rate, however, in order to circumvent the problem of forecasting many additional variables, Zheng (2009) applies a restrictive version of the error correction model that strips away the short-run dynamics. Accordingly, the estimating equation is specified as follows:

$$\ln e_t - \ln e_{t-h} = \alpha_0 + \alpha_1 \left[\ln e_{t-h} - \beta_0 - \beta_1 \ln\left(\frac{p}{p^*}\right)_{t-h} - \beta_2 \ln cp_{t-h} - \beta_3 \left(\frac{ca}{gdp}\right)_{t-h} - \beta_4 \left(\frac{ca^*}{gdp^*}\right)_{t-h} \right] + \mu_t \quad (3.1)$$

where *ln* denotes the natural logarithm, *e* is the nominal exchange rate, defined as the amount of local currency per US dollar (so $e = 1/S$), p/p^* is spatial price index in Australia relative to the United States, *cp* is the commodity price index,

and $\left(\frac{ca}{gdp}\right)$ and $\left(\frac{ca^*}{gdp^*}\right)$ are the current account deficit as a share of GDP in Australia and the US respectively.

The estimation procedure and forecast evaluation processes are described in detail in Zheng (2009).

Table 3.5 outlines the forecasting performance of this model compared to projections based on a random walk model and the LRA model.

Table 3.5: Forecasting performance of the econometric exchange rate model

Root mean square error (RMSE)

	Forecasting Horizon (quarters)								
	1	**2**	**3**	**4**	**8**	**12**	**16**	**20**	**Avg.**
Econometric model – unconditional	0.03	0.05	0.07	0.08	0.10	0.14	0.16	0.19	**0.10**
Econometric model – conditional	0.03	0.21	0.13	0.17	0.16	0.16	0.17	0.17	**0.15**
Random walk model	0.03	0.05	0.06	0.08	0.13	0.16	0.20	0.25	**0.12**
LRA model	0.03	0.05	0.07	0.08	0.11	0.11	0.11	0.11	**0.08**

Notes: Based on a rolling regression over the period March 2000 to June 2008.

Source: Zheng (2009).

The forecasting performance of the econometric model is presented in two forms: unconditional and conditional. The unconditional forecasts are based on historical data and hence do not rely on forecasts for the explanatory variables (i.e. commodity prices and the current account deficit). These are generally considered to be true out of sample forecasts or *ex ante* forecasts. The conditional forecasts are based on the *h*-period ahead (known) values of the explanatory variables.

Relative to a naïve random walk model, the unconditional version of the econometric model produces smaller forecasting errors after a period of two years. On average, the unconditional econometric model produces an RMSE of 0.10 over a forecasting horizon of five years, which compares to an RMSE of 0.12 for the random walk model. The conditional version of the model does not perform as well, but does give rise to a smaller forecasting error than the random walk model in relation to forecasting horizons exceeding four years.

The results in Zheng (2009) also confirm the superior performance of the LRA model (as described previously in this section), with this model outperforming both the econometric model and the random walk over long time horizons.

3.5 Sticky price model

Zheng (2009) also investigates the forecasting performance of the sticky price model in the context of the $US/$A exchange rate. As noted in Section 2, this model rationalises the empirical tendency of the nominal exchange rate to overshoot in the process of adjusting to its long-run equilibrium value by allowing for short-term price rigidity.

This model is specified as follows:

$$\ln S_t - \ln S_{t-h} = \alpha_0 + \alpha_1 \left[\ln S_{t-h} - \beta_0 - \beta_1 \ln\left(\frac{M^*_{t-h}}{M_{t-h}}\right) - \beta_2 \ln\left(\frac{Y^*_{t-h}}{Y_{t-h}}\right) - \beta_3 \ln\left(\frac{i^*_{t-h}}{i_{t-h}}\right) - \beta_4\left(\pi^* - \pi\right)_{t-h} \right] + \mu_t \quad (3.2)$$

where *M* is the seasonally adjusted money supply (M1), *Y* is real GDP, *i* is interest rate and π is inflation. The symbol * denotes the corresponding variables in the US.

The forecasting performance of the sticky price model is set out below.

Table 3.5: Forecasting performance of the sticky price model

Root mean square error

	Forecasting Horizon (quarters)								Avg.
	1	2	3	4	8	12	16	20	
Sticky price model	0.04	0.07	0.09	0.12	0.20	0.24	0.22	0.17	**0.14**
Random walk model	0.03	0.05	0.06	0.08	0.13	0.16	0.20	0.25	**0.12**
LRA model	0.03	0.05	0.07	0.08	0.11	0.11	0.11	0.11	**0.08**

Notes: Based on a rolling regression over the period March 2000 to June 2008.
Source: Zheng (2009).

The sticky price model produces forecast errors that are higher than the naïve random walk model for all horizons up to five years. The LRA model outperforms the sticky price model across all horizons.

3.6 External forecasts

As a final alternative to models identified above, the DTF could effectively outsource its exchange rate forecasting function to other government bodies or private sector analysts. The most readily available and comparable forecasts are those from the Australian Bureau of Agricultural and Resource Economics (ABARE) and Access Economics.

ABARE has published long-range forecasts of the \$US/\$A on an annual basis since 1998-99. These can be found in the March quarter edition of the *Australian Commodities* publication.

Table 3.6 compares the ABARE's forecasting performance relative to the 4-week average spot rate model. As before, each cell represents the ratio of ABARE's forecasting error (in US cents) as a proportion of the forecasting error for the 4-week average SR model. A ratio of less than one means that ABARE has outperformed the 4-week average SR model (and vice-versa).

Table 3.6: ABARE's $US/$A exchange rate forecasting performance

Ratio of forecast errors relative to the 4-week average spot rate model

	Budget Year	Outyear 1	Outyear 2	Outyear 3	Average
1999-00	10.13	1.53	1.64	2.72	**1.74**
2000-01	1.83	2.04	5.37	-0.16	**1.67**
2001-02	-2.56	-0.31	0.36	0.38	**0.39**
2002-03	0.91	0.87	0.84	0.84	**0.85**
2003-04	1.11	1.02	1.09	1.12	**1.09**
2004-05	0.83	-24.12	3.68	1.81	**1.99**
2005-06	-0.77	32.41	1.99	-2.31	**2.13**
2006-07	0.90	1.08	3.01	n.a.	**n.a.**
2007-08	1.43	-0.33	n.a.	n.a.	**n.a.**
2008-09	0.47	n.a.	n.a.	n.a.	**n.a.**
RMSE ratio	**1.01**	**1.15**	**1.15**	**1.00**	**1.07**

Source: ABARE, DTF estimates.

This table indicates that ABARE's exchange rate forecasting performance has been somewhat inconsistent. ABARE outperformed the 4-week SR model in its March 2001 and March 2002 projections, but the simple 4-week average projections would have furnished superior results in all other years since 1999-2000 (for which a complete set of actual data are available). Overall, ABARE's average exchange rate forecasting error is 7 per cent higher than the average forecasting error generated by the 4-week SR model.

A similar analysis has been undertaken in relation to forecasts published by the private sector firm Access Economics in its quarterly *Business Outlook* publication.[19]

[19] Forecasts are taken from the March quarter edition of this publication.

Table 3.7: Access Economics' $US/$A forecasting performance

Ratio of forecast errors relative to the 4-week average spot rate model

	Budget Year	Outyear 1	Outyear 2	Outyear 3	Average
1996-97	3.59	0.53	0.59	0.49	**0.57**
1997-98	1.15	0.92	0.97	1.04	**1.01**
1998-99	2.24	2.29	1.40	1.28	**1.44**
1999-00	-7.66	1.16	1.49	2.83	**1.56**
2000-01	1.51	2.11	4.25	0.68	**1.60**
2001-02	-1.17	-0.63	0.43	0.49	**0.48**
2002-03	0.51	0.59	0.74	0.88	**0.75**
2003-04	0.83	1.10	1.30	1.11	**1.12**
2004-05	-6.56	-35.32	3.85	1.75	**2.00**
2005-06	2.01	33.94	2.23	-1.78	**2.35**
2006-07	1.55	1.71	5.98	n.a.	**n.a.**
2007-08	2.37	-2.43	n.a.	n.a.	**n.a.**
2008-09	0.44	n.a.	n.a.	n.a.	**n.a.**
RMSE ratio	**1.25**	**1.27**	**1.16**	**1.02**	**1.13**

Notes: Based on information available as at 1 April each year.
Source: Access Economics, DTF estimates.

Access Economics has outperformed the 4-week SR model in some instances. However the SR model delivers more accurate forecasts in most years. On average, the Access Economics exchange rate forecasting errors are 13 per cent higher than those generated by the SR model over the period from 1996-97 to 2008-09.

3.7 Summary

The following tables summarise the exchange rate forecasting performance of the models considered in this section. Table 3.8(a) focuses on the performance of the 'mechanical' exchange rate models, while Table 3.8(b) summarises the forecasting performance of the structural econometric models. (Differences in the method of calculating forecast errors between these approaches preclude a direct comparison of these results).

Table 3.8(a): Comparison of selected $US/$A forecasting models

Ratio of RMSEs relative to the 4-week spot rate model

Model	Sample Start Date	Budget Year	Outyear 1	Outyear 2	Outyear 3	Average
LRA Model	1986-87	0.94	0.91	0.87	0.79	0.86
Forward Prices	1998-99	0.97	1.10	1.14	1.14	1.12
Futures	2001-02	0.97	n.a.	n.a.	n.a.	n.a.
ABARE	1999-00	1.01	1.15	1.15	1.00	1.07
Access Economics	1996-97	1.25	1.27	1.16	1.02	1.13

Source: DTF estimates.

Table 3.8(b): Forecasting performance of econometric exchange rate models

Ratio of RMSEs relative to the random walk model

	Forecasting Horizon (quarters)					Average
	4	8	12	16	20	
Econometric model – unconditional	1.00	0.77	0.88	0.80	0.76	0.84
Econometric model – conditional	2.13	1.23	1.00	0.85	0.68	1.18
Sticky price model	1.50	1.54	1.50	1.10	0.68	1.26
LRA model	1.00	0.85	0.69	0.55	0.44	0.70

Notes: Forecasting errors have been calculated using a rolling regression over the period March 2000 to June 2008.

Source: Zheng (2009).

The spot rate model and the naïve random walk model mostly outperform their competitors over short time horizons. However, we also find evidence that some forecasting techniques produce superior outcomes over longer time spans. Notably, a simple assumption that the $A returns to its long-run average in a linear fashion over the budget period appears to produce the most promising results. The econometric model of $US/$A in Zheng (2009) also performs well over long forecasting horizons.

4. Summary and Discussion

The purpose of this paper is to identify and evaluate competing models of the $US/$A exchange rate.

Consistent with the vast body of empirical literature on exchange rates, we find evidence that short-term movements in the $US/$A exchange rate are unpredictable and cannot be projected in a systematic fashion. This supports the current approach taken by the DTF in setting its budget-year exchange rate assumptions (i.e. the exchange rate in the budget year is assumed to equal the current spot rate).

Although exchange rates cannot be predicted over short time periods, there is growing evidence of some predictability in exchange rate movements over longer time horizons.

Taking the budget period as a *whole*, we find that the best performing model is the Long Run Average (or LRA) model, which assumes that the $US/$A exchange rate reverts to its average value in a linear fashion over the course of the forward estimates period (i.e. four years).

Based on historical data from 1986-87, the LRA model would have outperformed DTF's existing spot-rate model in 12 of the past 20 budgets (for which data are available over the full budget period), and in 55 of the past 86 overlapping forecasting years. On average, the LRA model produces forecasting errors that are 14 per cent lower (over the budget period) relative to those under the spot price model that is currently used by the DTF.

The econometric model presented in the companion paper to this review also performs well relative to random walk models (including the DTF's existing spot rate model). However, the LRA model still produces lower forecasting errors than the econometric model, has the advantage of simplicity and intuitive appeal, and is less reliant on specialist econometric expertise to maintain and update.

4.1 Implications for revenue forecasting

Although the LRA model is likely to improve the accuracy of DTF's exchange rate projections (on average), this in itself will not necessarily guarantee a commensurate improvement in the accuracy of DTF's mining royalty estimates. This is because (as noted in Section 2) movements in the Australian dollar and $US commodity prices are often highly correlated, meaning that the revenue impact of fluctuations in these variables is often partly offsetting.

In certain circumstances, changing DTF's existing exchange rate model could reduce the benefits associated with this "natural hedge". For instance, if the 2008-09 State Budget had assumed that the $US/$A would return to its long-run average (rather than assuming a constant exchange rate of US92.5 cents across the full budget period), the mining revenue estimates and the general government net operating balance projections would have been significantly higher. However, it would have been necessary to revise these projections down (by approximately $1 billion over the budget period) after the Budget was delivered in May 2009, due to the subsequent decrease in the price of crude oil.

On the other hand, movements in the $US/$A exchange rate and $US commodity prices are not always perfectly correlated. This was evident with the collapse of the Australian dollar in the wake of the global financial crisis in October 2008. Arguably, the Australian dollar was oversold during this period, with the exchange rate falling to a level beyond which seemed consistent with the prospects for growth in the national economy (however diminished these might have been in the aftermath of the financial crisis). The existing spot-rate model exposes the revenue projections to a significant risk in these circumstances, i.e. where the Australian dollar recovers without a corresponding rise in $US prices of the State's key commodity exports. The LRA model reduces this risk in circumstances where the prevailing spot rate is below the historical average.

Conversely, the LRA model would increase the risk of over-estimating royalties if the exchange rate is high by historical standards (but forecast under the LRA model to return towards the long-run average) *and* $US commodity prices are also assumed to remain high. For this reason, it would be desirable to maintain an appropriate level of consistency between $US commodity price assumptions and the exchange rate under the LRA model.

It should also be recognised that, over the long term, the Commonwealth Grants Commission process largely insulates Western Australia against fluctuations in the $US/$A exchange rate. To the extent that the State's revenue raising capacity falls as a consequence of an appreciation in the Australian dollar, and holding all other factors constant, Western Australia would be compensated (albeit with a lag) with an increase in its share of the national GST revenue pool.

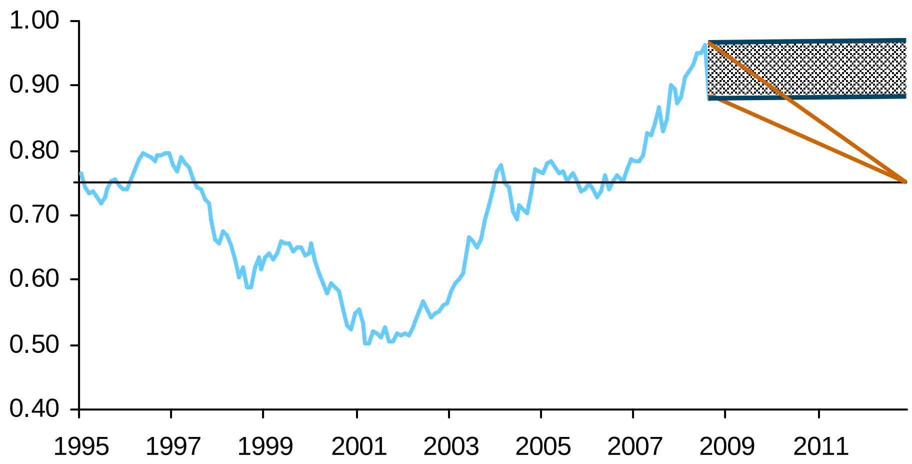
The current spot rate model, by assuming that the recent spot price remains fixed over the full budget period, produces substantially different royalty income estimates in response to short-term fluctuations in the spot rate. This in turn introduces (an unnecessarily) high level of uncertainty in the process of government decision-making and resource allocation.

In this regard, an important benefit of the LRA model is a significant reduction in the variability of the mining revenue forecasts, especially in circumstances where the exchange rate appreciates or depreciates sharply.

This is particularly the case for the outyear revenue forecasts, since the longer-run exchange rate assumptions will only change modestly in response to short-term fluctuations in the spot rate. This is illustrated in the following chart, where the triangle represents the magnitude of the mining revenue changes that would be required under the LRA model in response to a sharply depreciating dollar. Clearly, the size of the triangle is smaller than the size of the rectangle, which represents the revenue revisions associated with the spot rate model.

Figure 4.1: Magnitude of revisions to royalty income estimates

Comparison of the LRA model and the SR model



Source: DTF.

Having consideration to the issues outlined above, DTF proposes to depart from the existing spot rate model in favour of an approach that assumes the current spot rate returns to the long-run average in a linear fashion over the course of the forward estimates period. This LRA model, which has as its origin the well-known theory of purchasing power parity, is simple to understand and implement, produces more accurate exchange rate forecasts over the budget period (on average), and should reduce significantly the volatility of the DTF's revenue forecasts over the forward estimates period.

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