Waging war: A new wage inflation forecast model

Prepared by Hugh Miller and Glenn Cardinio

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Institute of Actuaries of Australia
ABN 69 000 423 656
Level 2, 50 Carrington Street, Sydney NSW Australia 2000
t +61 (0) 2 9239 6100 **f** +61 (0) 2 9239 6170
e actuaries@actuaries.asn.au **w** www.actuaries.asn.au

Executive summary

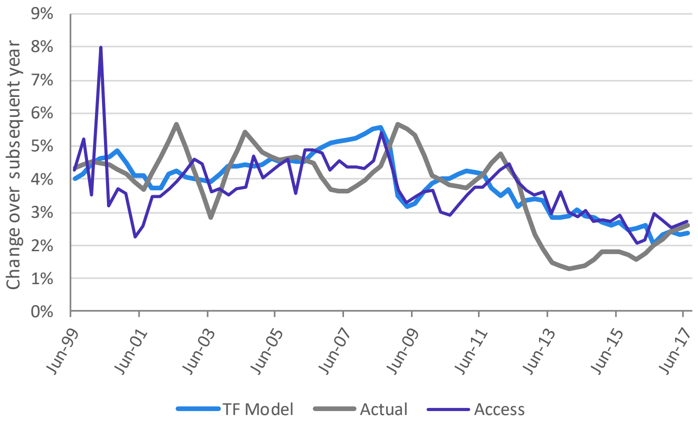
We have proposed an inflation forecasting model for Australian Weekly Earnings, composed of:

- A Consumer price index (CPI) inflation estimate, which depends on a long-run assumption, the shape of the current nominal bond yield curve and the gap between nominal and inflation-linked bond (ILB) yield curves.
- An AWE gap (AWE minus CPI) estimate, which depends on a long-run assumption, the shape of the current nominal bond yield curve and the unemployment rate (either national or state).

The model moves seamlessly from estimation formulae appropriate in the short term (higher weight on ILB and unemployment rates) and those for long-run assumptions. The inclusion of bond yields helps reduce (but not eliminate) the impact of bond rate changes on liabilities.

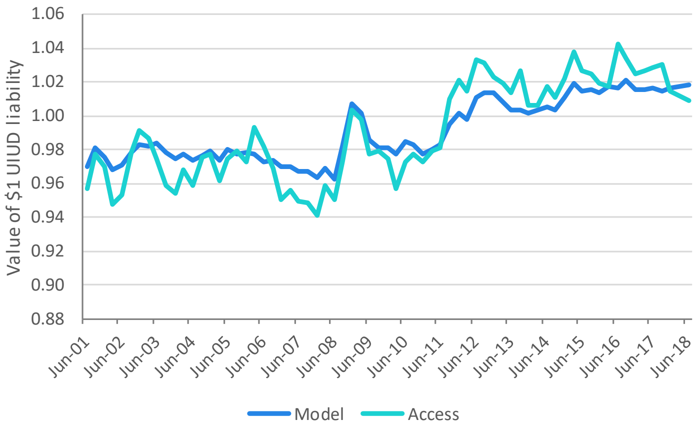
The model appears to perform well at both short- and medium-term durations. When comparing to Access Economics forecasts for future nominal inflation our model has 5-20% lower error and in some cases less than half the variability from quarter to quarter for inflation. The model performs well at a state level, whereas Access forecasts are typically weaker. Figure 1 shows the 1-year forecast:

Figure 1 Rolling 1-year spot rates for Nominal AWE for Australia, predicted and actual



These properties carry over to longer-term liability estimates such as those seen for injury schemes, as shown in Figure 2. The quarter on quarter variability of the notional liability is halved, using a forecast that is just as predictive as other industry measures such as Access Economics. We believe that this forecasting approach is well-suited to many medium and long-tailed actuarial problems.

Figure 2 Average liability impact of inflation and discounting, Australia, for notional injury scheme cashflow distribution.



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1 INTRODUCTION

1.1 Importance of wage inflation forecasts

For injury schemes such as Compulsory Third Party (CTP) or workers compensation insurance, price and wage inflation are key inputs in future costs and thus a good forecast of inflation is important for scheme management. Our primary focus is on wage inflation, although price inflation is an important related concept.

There are many existing econometric models of inflation, including wage inflation. However, the key requirements of a good forecast for an injury scheme are different to the priorities of most existing models:

- **There needs to be a strong understanding of the relationship with discount rates:** the net discounting of an actuarial liability uses the *difference* between yields and inflation. In econometric models the link is often indirect; wage inflation is linked to factors viewed to be more relevant such as labour market conditions.
- **Cumulative average inflation is more important than picking wage cycles:** While 'error' is usually measured by the accuracy of short term forward rate estimates, the *cumulative* error (longer duration spot rates) is more relevant to actuarial work; a projection with the correct mean but missing some cyclical behaviour will be more useful than a model that can predict a cycle but carries a systematic upward or downward bias.
- **Timeframes are typically longer:** Actuarial liabilities have durations measured in years, whereas many econometric models seek to project quarterly, with significant degradation in performance beyond a few quarters. We have deliberately not explored accuracy at durations less than a year.

These differences have been reflected in our thinking and reporting.

To understand wages, we must first understand price inflation (specifically the consumer price inflation, or CPI). Many econometric models treat wage inflation as a factor that sits on top of CPI and we have taken a similar approach.

1.2 Forecasting wage growth versus seeking a market price of inflation risk

Most current actuarial work sets wage inflation on an 'expected value' basis. This naturally leads to forecasting models that seek to forecast future inflation (or minimise future errors), which is the main approach taken in our paper too.

However, this approach is in contrast to the mandated approach to discount rates, where the price of market instruments is used to derive a 'market price' of future discounting, rather than expected value. This means that any term premia in market prices (e.g. people demanding a premium for accepting a long-tailed risk-free liability) is included in the liability estimation. This approach is appealing as it provides objectivity as well as being consistent with mainstream financial economics of valuing liabilities at market prices.

There is a strong argument that as market instruments develop that incorporate inflation risk, that we move to a 'market price' of future inflation rather than using expected values. The most prominent development over the past seven years is the growing depth of the Commonwealth (CPI) inflation-linked bond market, which allows calculation of a market price of inflation.

Our paper is very much focused on the 'expected value' approach, seeking to minimise the forecasting error associated with our model. However, when we consider inflation-linked bonds for inflation estimates we do not attempt to estimate term (or other) premia. This choice is partly for convenience (these premia are difficult to estimate, can change over time, and are often assumed to be small anyway), but we note that it is also consistent with a push towards 'market price' of inflation.

1.3 Limitations inherent in wage inflation forecasting

Wage inflation forecasts are less accurate than other economic variables such as the consumer price index (CPI). This is expected when we compare the two:

- The CPI has visible market instruments (inflation-linked Commonwealth bonds).
- CPI has historically been more stable than wage inflation. This can be seen empirically but is well-understood in broader economic theory too. Wages tend to respond more rapidly to the economic cycle, whereas prices are stickier. Also, the Reserve Bank of Australia (RBA) is explicitly charged with ensuring stability in the CPI, something which is not true of wages.
- There are data collection issues associated with wage collection. Average wages are only collected half-yearly, compared to quarterly CPI estimates. AWE changes can also be more volatile between periods.

A chart of rolling 12-month AWE, LPI, and CPI growth is provided in Figure 12 for comparison.

There are also live discussions about persistent overestimation of wage growth in recent years, where existing models have proven inaccurate. The RBA has undertaken a broad examination of this issue (see for example Jacobs and Rush, 2015, or Weir, 2018). This recent experience may have implications for traditional wage models such as those that make use of the Phillips curve.

1.4 Different measures of wage growth

There are various measures of wage inflation, including hourly wages, average weekly earnings (AWE) and the wage price index (WPI). We assume readers are familiar with the differences. We have focused on AWE and also provided some limited comments on the WPI; see Miller (2016) for additional background on inflation measures.

1.5 Aims of this research

Taylor Fry ('we') seek to develop a model of wage inflation suitable for actuarial reserving work. The estimate should cover both short-run and longer-term assumptions. This draws on

- Our existing research on the subject – see Section 2.3.
- Analysis of data and potential models.
- Comparisons to related literature. The literature on wage modelling is vast, but we have focused on a relatively small number of models and papers related to Australia, with an emphasis on government sources such as the RBA and Australian Treasury.

Our aim to find an approach which is demonstrably better than some existing approaches but also practical to implement. One key reference point throughout this paper is Deloitte Access Economics ('Access') forecasts, which are widely used in the profession, and has been used for Taylor Fry's assumption setting for a number of years.

1.6 Limitations to this result and the challenge of recent low wage growth

All econometric models and their related forecasts are fundamentally limited by the amount of data (we only have one historical timeline) and non-stationarity of assumptions (what is true yesterday may not be true tomorrow). Our analysis similarly suffers from this limitation.

This limitation is particularly relevant today. Over the past 25 years Australia has avoided recession, enjoyed stable prices and seen reasonable wage growth. However, over the past five years we have seen markedly lower interest rates, inflation and wage growth. Most models and economists have revised down their forecasts slightly as a result, but there is no consensus whether recent years represent a 'new normal' that requires a substantially different approach to a forecasting model. We are not attempting to front-run this debate by significantly lowering long-term wage growth assumptions; our modelling therefore uses historical data and typically shows a return to 'normal' wage growth over the medium term. To the extent that things have fundamentally changed – for example the relationships between interest rates, unemployment and wage growth, we have not attempted to recognise this without further evidence.

1.7 Acknowledgements

We gratefully acknowledge the financial support of the Queensland Motor Accident Insurance Commission and the South Australia CTP Regulator for partly funding this research.

2 RELEVANT BACKGROUND

2.1 Introduction

Many economic forecasts are regularly made by organisations across Australia. Some of these are published (free or for-fee), while others may publish the approach and not the actual forecasts. We have reviewed a range of these to gain an understanding of what is currently done to forecast wage growth.

This review is not comprehensive. Interested readers are referred to Gruen et al. (1999) which, while somewhat dated, does have a thorough list of preceding wage models, particularly those relying on the Phillips curve (that is, models that depend on unemployment rates as a key driver of wage growth).

2.2 Government wage forecasts

2.2.1 Commonwealth Treasury

The Commonwealth Treasury maintains a suite of econometric models for projecting the economy and testing policy measures. There most recent description of their approach is *Treasury's medium-term economic projection methodology*[1], although there is a more recent higher-level review of economic modelling also[2] which points to ongoing development of their macroeconomic models.

Implicit in the model is the assumption that hourly wages grow at price inflation (CPI) plus technical progress ('productivity growth').

The main Treasury wage model uses "*a Phillips curve similar to that developed by Gruen, Pagan and Thompson (1999)*".

Figure 3 Commonwealth Treasury wage formula, from Treasury's medium-term economic projection methodology.

$$\begin{aligned}\Delta_4 w_t - \Delta_4 q_t - \Delta_4 pgne_{t-1} = {}& \beta_1(\pi_t^e - \Delta_4 pgne_{t-1}) + \kappa(U_{t-1} - U_t^T)/U_{t-1} \\ & + \beta_2(\Delta_4 w_{t-1} - \Delta_4 q_{t-1} - \Delta_4 pgne_{t-2}) \\ & + \beta_3(\Delta w_{t-1} - \Delta q_{t-1} - (\Delta w_{t-4} - \Delta q_{t-4})) + \varepsilon_{wt}\end{aligned} \tag{28}$$

The equation for wage w_t growth shows that wage changes (beyond productivity, q_t, and price inflation, $pgne_t$) are made up of:

- A term related to the excess of inflation expectations (π_t^e) over recent inflation
- A term related to the different in the unemployment rate U_t relative to trend U^T
- Autoregressive type terms related to previous wage growth

Treasury's parameter estimates are given in Figure 4; they are fit on a long time series and parameter significance is high. This strong parameter significance is tempered by the fact that parameters and relationships may have shifted over the past fifty years, and that the underlying error distribution in the model may not be stationary.

[1] https://static.treasury.gov.au/uploads/sites/1/2017/06/tsy-medium-term-economic-projection-methodology.pdf
[2] https://research.treasury.gov.au/external-paper/review-of-economic-modelling-at-the-treasury/

Figure 4 Commonwealth Treasury wage formula, from Treasury's medium-term economic projection methodology.

Method: Maximum likelihood
Sample: 1968Q1 2013Q4

	Coefficient	Std. Error	z-Statistic	Prob.
β1	0.146793	0.055804	2.630509	0.0085
κ	-0.026233	0.006759	-3.881133	0.0001
β2	0.604794	0.036764	16.45050	0.0000
β3	0.148349	0.010844	13.68033	0.0000
σ_W	0.013885	0.000737	18.84565	0.0000

Log likelihood	507.5548	Akaike info criterion	-5.462553
Parameters	5	Schwarz criterion	-5.375190
Diffuse priors	1	Hannan-Quinn criterion	-5.427144

The κ term shows the significant of unemployment rates in predicting wage growth. The β_2 term is also noteworthy as it is the main autoregressive term and is quite strong (60% of the previous wage growth carries into the next quarter). The β_3 term is a 'change in the change' term which provides evidence of a second order momentum effect.

The model requires estimates of:

» Price inflation (Treasury uses a GDP price deflator, although CPI would be an alternative)
» Long-term trend unemployment
» Productivity growth

The last two items are quantities that are not directly observable and would have to be estimated separately, a challenge if we are aiming to keep our forecast model relatively simple. For Treasury, productivity growth is a first order autoregressive process that depends heavily on assumption when forecasting. Our preference, given the wage emphasis of this research, is to drop such terms or replace them with terms that are directly observable.

2.2.2 Reserve Bank of Australia (RBA)

RBA models

Jacobs and Rush (2015) explored the weakness in wage growth observed in the years prior to the paper. It also details their related Phillips Curve model in Appendix A. The paper noted that the relationship between wage growth and the unemployment rate now appears to be weaker than previous estimates, with low unemployment not generating significant wage growth. They suggest potential reasons including labour underutilisation, lower inflation expectations, lower terms of trade and higher effective exchange rates.

Cusbert (2017) explores estimation of the non-accelerating inflation rate of unemployment (NAIRU) and the uncertainties involved in its estimation. Current estimates are close to 5%. Additionally, he fits a Phillips Curve model with the NAIRU estimates using parameters reported in the appendix. This model has a series of autoregressive factors as well as two unemployment terms and the price of oil.

RBA review of wage growth

More recently, Weir (2018) and speeches by Philip Lowe[3] have also explored why wage growth remains weak. Underutilisation rates are cited as a cyclical reason but they suggest there are also structural factors that are not entirely understood. Technological change and industrial relations changes are possible explainers.

[3] https://www.rba.gov.au/speeches/2018/sp-gov-2018-06-13.html

These comments are important, since a belief that structural factors have changed may require modification of long-run assumptions.

2.3 Taylor Fry inflation and discount rate research

There are four relevant prior research papers we have written. In large part they focus on our approach to longer-range inflation assumption setting, which we have retained in this report.

Table 1 Prior Taylor Fry research on inflation and discounting assumptions

Paper	Key findings
Miller (2010)	The paper explores the medium-term relationship between inflation and nominal bond yields. It proposes a formula where about 30% of the movement in long-term bond yields could be recognised as changes to inflation forecasts. This was found to be more accurate than alternative models.
Miller and Yip (2017)	Summarises our approach at the time, which included a slightly modified relationship between inflation and nominal bonds, using a 'normal' yield curve for discount rates as a reference.
Miller (2016)	Notes the increased reliability of inflation-linked bonds due to increasing volumes for sale since 2012.
Mulquiney & Miller (2014)	Explores how long-term discount rates can be extrapolated beyond the observable durations, with implications on inflation assumptions and liability stability
Evans & Miller (2017)	Explores the feasibility of inflation-linked bonds for pricing and liability estimation in more detail.

2.4 External forecasts

Aside from Deloitte Access Economics there are a range of forecasts available for purchase in the market. The RBA also publishes consensus forecasts for CPI (but not wages).

We have focused on estimation that does not rely on external forecasters. In part this is to understand how a model driven by market and Australian Bureau of Statistics (ABS) data compares in accuracy, but also to reduce reliance on unknown assumptions. It also improves the transparency of forecasts.

3 DATA

We have collected multiple time series for our research.

We downloaded and collated the following ABS datasets:

» CPI (original series) – national and state level index. We used the 'original' series for testing (consistent with Access Economics time series).
» AWE – national and state level half-yearly index. We used the 'original' series, total earnings, for testing (consistent with Access Economics time series).
» WPI – national and state level quarterly index.
» Unemployment – national and state level rate estimates; we extracted quarterly rates from the monthly series. We used the trend rate.
» Underemployment (ABS 6202 table 23).
» Monthly hours worked (ABS 6202 table 19).
» Gross Domestic Product (ABS 5220 table 1).

The latter three series were considered in our exploration phase but do not feature in this paper. From the RBA we downloaded bond price data for nominal and inflation-linked bonds. We used our standard yield curve fitting approach to obtain full spot and forward rates for the dates required (see Miller and Yip, 2017). We also downloaded the RBA zero-coupon bond rate estimates, as a check on our estimated yields.

For comparison testing we collated Access Economics CPI, WPI and AWE index forecasts, at a national and state level.

Finally, we used an RBA estimate of the non-accelerating inflation rate of unemployment (NAIRU) from Cusbert (2017).

Most of our testing is for time periods 1999 and later. The only set of variables not available from that date were inflation-linked bonds, which we have taken to be unreliable prior to 2012 due to small volumes of bonds on issue.

4 CPI MODELS

4.1 Introduction and preferred metrics

As mentioned in Section 1.1, we have first modelled CPI and then modelled AWE as an increment on top of CPI, consistent with other approaches. We have considered a range of estimation methods for CPI:

- Constant estimates
- Access Economics forecasts
- Estimates that depend on the observed nominal bond rate
- Estimates using inflation linked bonds.

We have tested both national and state-level CPI. We sometimes show only a subset of state results, primarily Queensland and South Australia.

We have used two metrics for error – root mean squared error (RMSE) and absolute error. RMSE is more commonly used and ties naturally to centring an estimate around the mean value of a variable. It also has an effect that an error that is twice as large is four time as bad (due to the squaring). Since this quadratic increase may exaggerate the cost of a small number of large errors, we also test mean absolute error.

We track errors in predicting spot rates at 1, 2, 3, 4 and 5 years' duration. We also consider one-year forward rates over the same time intervals (duration 0, 1, 2, 3 and 4). For most actuarial reserving contexts errors in spot rates are most relevant, as these represent the build-up (or averaging out) of errors over multiple years.

We do not consider time increments smaller than annual forecasts. This approach is significant:

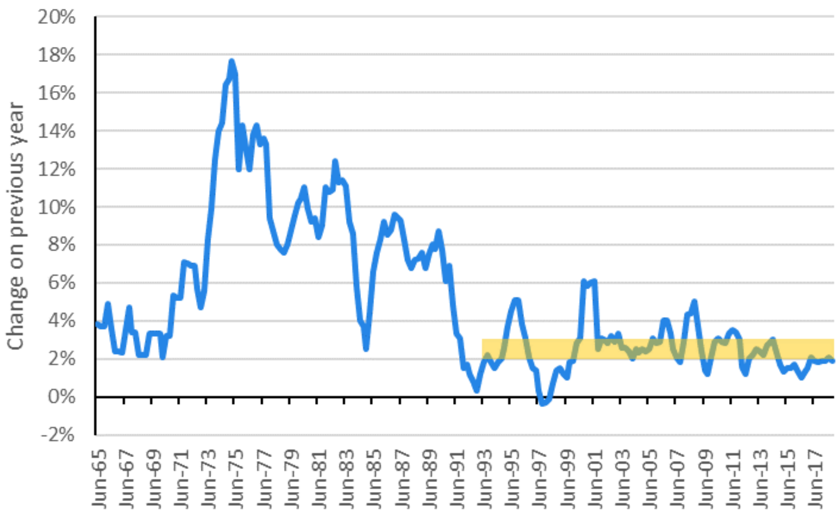
- Most econometric models we reviewed use quarterly models. These will tend to have stronger autoregressive signals that dissipate over longer time intervals.
- Our focus is a forecast suitable for actuarial reserving models over multiple years; it may well be that another model is more accurate over 1-2 quarters, but if this does not translate into plausible longer-term estimates, it is less useful to actuarial work.

We test prediction accuracy for models using data from 1999 through to 2018. Part of this is for convenience – we only have Access Economics from 1999. More significantly, inflation targeting was introduced in Australia in 1993, and we believe this fundamentally changed the dynamics of inflation and inflation expectations. This means that a major limitation of our work is that **we assume a macroeconomic environment consistent with the past two decades of inflation-targeting**. There is a sense that this is cheating – we are effectively assuming a benign inflation environment from the outset. However, the reality is that if a significant change in the macroeconomic environment occurred, there would be a need to seriously review the appropriateness of any inflation model.

Inflation targeting is generally seen as effective to date; Figure 5 shows the historical CPI and the target band in force since 1993[4]. Inflation has not been materially above or below the range for extended periods and the level of inflation volatility is significantly lower than the preceding decades.

[4] Strictly speaking, the target is 2-3% for the trimmed CPI rate, which removes some of the outliers.

Figure 5 Historical CPI, Australia original series



4.2 CPI model descriptions

We explore four families of model for CPI forecasting, described below.

Constant model

Assumes a 2.5% CPI assumption at all future timepoints. The choice of 2.5% is natural as both a historical average and the centre of the target range.

Access Economics

Uses the CPI forecast series available at the corresponding quarter end. So a 30-Jun-17 forecast will use the June 2017 Access forecasts.

Nominal Bond model

These follow the same structure proposed by Miller (2010). The future (instantaneous) inflation rate is assumed to be:

$$i_t(\tau) = CPI_0 + \theta\{y_t(\tau) - y^*(\tau)\}$$

Where:

- $i_t(\tau)$ is the rate of CPI estimated at time t at future duration τ.
- CPI_0 is a constant representing the 'normal' inflation estimate. We set this at 2.5%, the centre of the RBA target range.
- θ is a number, typically between 0 and 1, representing how much yield curve variation should be reflected in the inflation estimate
- $y_t(\tau)$ is the (instantaneous) yield on risk-free (Commonwealth government) bonds. This is found using any standard yield curve fitting approach on observable market instruments.
- $y^*(\tau)$ is the 'normal' yield curve, designed to help encode whether current yields are above or below normal rates. Our assumed curve is shown in Figure 6.

Note that $\theta = 0$ degenerates to the constant model.

Inflation-linked bond model

The market for inflation-linked bonds (ILB) has been relatively liquid since 2012. We can use this to compute the (CPI) inflation-linked yield curve. The gap between the nominal and inflation-linked curves can be viewed as an estimate of future inflation rates (plus or minus various premia). Our model takes the form:

$$i_t(\tau) = ILB(\tau) + \{y_t(\tau) - x_t(\tau)\}$$

The new terms are:

- $ILB(\tau)$ is a factor to allow for premia, primarily term premia, that may vary by duration.
- $x_t(\tau)$ is the (instantaneous) yield on risk-free (Commonwealth government) index-linked bonds.

We have adopted $ILB(\tau) = 0$ throughout – see our previous discussion on market prices versus expected values in Section 1.2. Having no allowance for premia potentially reduces the accuracy of the model, however proper estimation of these terms is difficult with the limited time series available (assuming pre-2012 is not liquid enough for inflation estimation – see Miller, 2016).

4.3 Reference yield curves

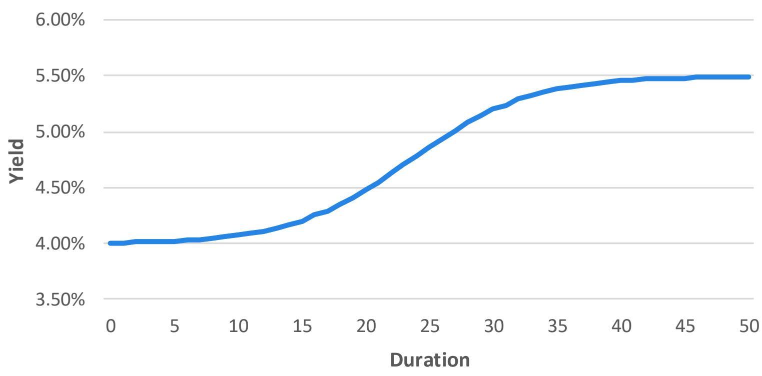
Normal curve for nominal bond yields

We have used a 'normal' bond curve similar the that proposed in Miller and Yip (2017). The approach for its development is to:

- Estimate an average yield curve over a 10-year period.
- Parametrise the shape (here a logistic curve).
- Fix the asymptotes to appropriate assumptions. Here the 4% was close to the historical average and the 5.5% is slightly below the previous estimates of the historical average – 6% has been used previously but the lower rate is consistent with other organisations reducing the long-run nominal bond rate assumptions[5]. The choice of asymptote at duration 50 has negligible impact on the estimated rates in the first five years.

Our adopted curve is shown in Figure 6.

Figure 6 Normal nominal bond curve

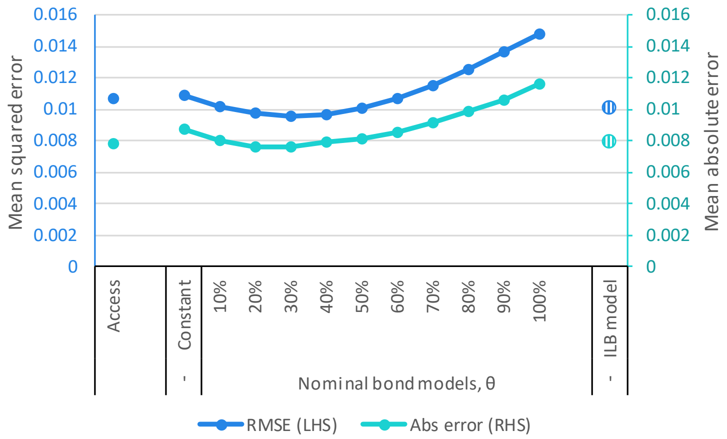


4.4 Results

The figure below shows the average error for the 1-year spot rate for the models listed above. Data points used are June estimates each year from June 1999 through to June 2017; 19 data points in all.

[5] For example, the Australian Government Actuary reduced their long-term rate used for liability calculation from 6% to 5% in 2018.

Figure 7 CPI estimate accuracy over 1 year for various models, 1999-2017

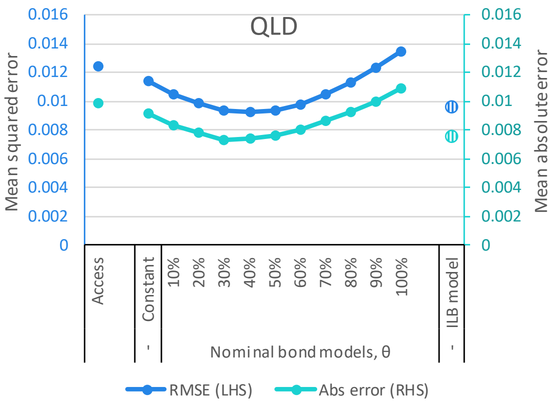


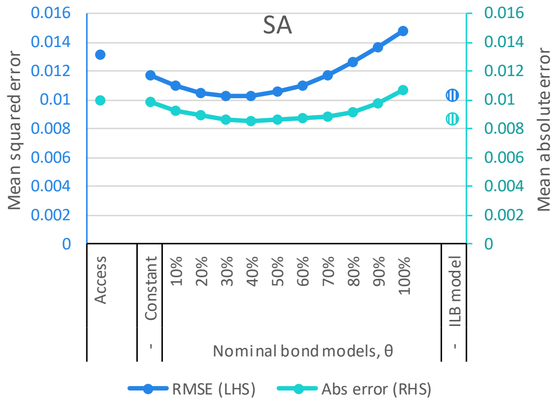
At the national level, Access forecasts are slightly more accurate than the constant model, but inferior to the best choice of θ. The RMSE for $\theta = 30\%$ is 0.0095 and the bootstrapped 80% confidence interval around this value is (0.0076, 0.0112), a range which includes the error for the Constant and Access models.

This means there is not strong evidence that one approach is better than another. However there may be other reason for preferring one model over another – for instance, volatility of the estimate from quarter to quarter. We explore volatility further in Section 6.

The ILB model has performance between the constant and $\theta = 30\%$ models (but only for periods for 2012 onwards – we have positioned ILB performance on the figure for illustrative purposes).

Figure 8 CPI estimate accuracy over 1 year for various models, 1999-2017 – selected states



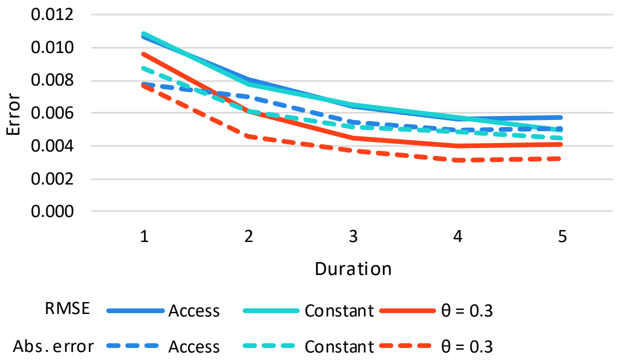


Access forecasts tend to be less accurate at the state level. In both examples in Figure 8, Access Economics estimates over a year are inferior to the constant model (2.5%).

The ILB models perform well, although again this was only for periods from 2012 onwards (and the chart marker is the level of accuracy implied if performance post-2012 was applicable over the whole period).

We also consider longer durations. The performance of the nominal bond model increases over longer duration relative to the Access and Constant approaches. This effect is shown in Figure 9. The *per annum* error is lower over longer durations, since averaged inflation estimates tend to be more stable over multiple periods.

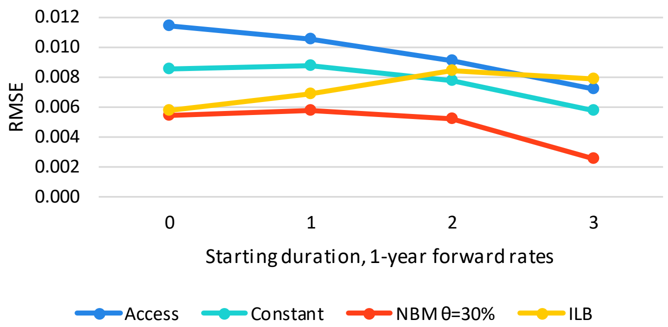
Figure 9 CPI estimate accuracy over various durations, 1999-2017. Error is based on the estimate of the annualised rate.



The RMSE for $\theta = 30\%$ at duration 5 is 0.0041 and the bootstrapped 80% confidence interval around this value is (0.0029, 0.0051), a range which does not include the Access estimate. This represents reasonable evidence the nominal bond model performs better than Access over these longer durations.

To include the ILB model in our comparisons we are restricted to tests from 2012 onwards, a time period typified by low yields and low inflation. Comparisons for estimating one-year forward rates are shown in Figure 10. For the first two forward rates (0-1 and 1-2 duration periods) the NB and ILB models both perform well. For longer durations the ILB performance suffers; this result stems from a relatively small number of data points where the ILB expectations were around 2.5% and the actual inflation remained low. Larger term premia at higher durations may also be a factor.

Figure 10 CPI estimate accuracy over various durations. Error is based on the estimate of the annualised rate.



The performance of the ILB model appears promising, particularly at short durations, but still requires some monitoring as more data becomes available naturally over time.

4.5 Other testing

We have considered more complex models of CPI. We attempted to formally combine NB, ILB and autoregressive elements in a combined model of inflation through multivariate regression. These results offered minimal improvement over alternatives already considered – in part due to the benign inflation environment since 1999 and the strong correlations between the different candidate variables.

There is not enough ILB data to formally estimate the best balance between the ILB model and other predictions of inflation such as the NB model, but we think taking a weighted blend is reasonable.

4.6 Recommendations

Based on the results above we recommend:

» A blend of NB and ILB models over the first 2 or 3 years. A suggested allocation is in the table below

» The NB model for durations longer than 2 or 3 years

» Using $\theta = 30\%$ for the NB models

All the evidence considered suggests that this approach will outperform Access Economics forecasts in accuracy and has additional advantages that such estimates can be derived at any point in time using up-to-date bond prices.

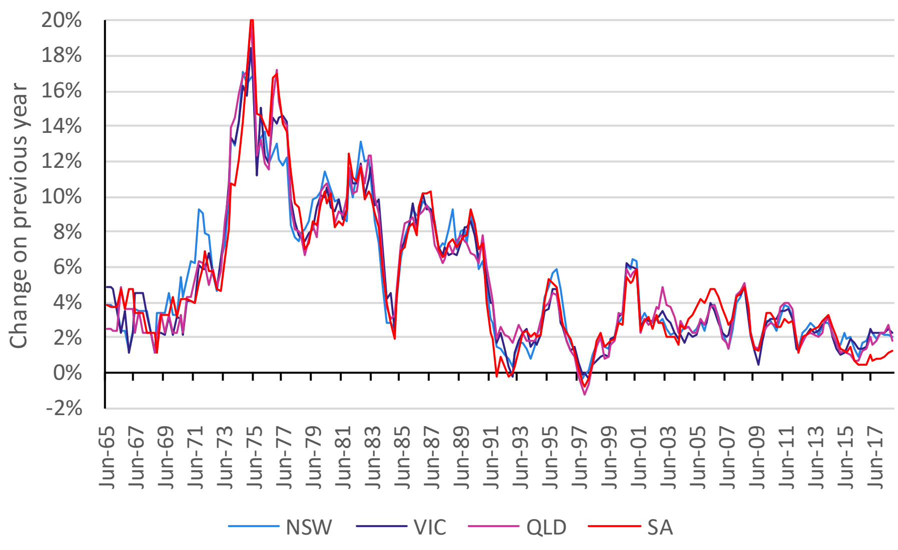
Table 2 Proposed blending of nominal bond and inflation-linked bond CPI models

Duration	NB	ILB
0	50%	50%
0.5	50%	50%
1	50%	50%
1.5	66⅔%	33⅓%
2	83⅓%	16⅔%
2.5 and later	100%	0%

4.7 State level implications

Our proposed CPI forecast uses Commonwealth bond yields and so there is no explicit allowance for differences between states. Historically CPI has tracked very closely – for example, in the 19 years since June 1999 prices have risen 129% across Australia, but by 131%, 130%, 127% and 130% for NSW, VIC, QLD and SA respectively; the standard deviation of these state-level numbers is less than 2% of the total change.

Figure 11 CPI changes by state (capital city)



On this basis, we regard a national CPI forecast appropriate for use at a state level. Housing costs (mortgage and rents) are 22% of the CPI basket, and can see regional divergence; in some cases there may be an argument for state-level differences if a particularly compelling housing dynamic is incorporated. For injury schemes this would be the exception rather than the rule.

5 WAGE MODELS

5.1 Introduction and preferred metrics

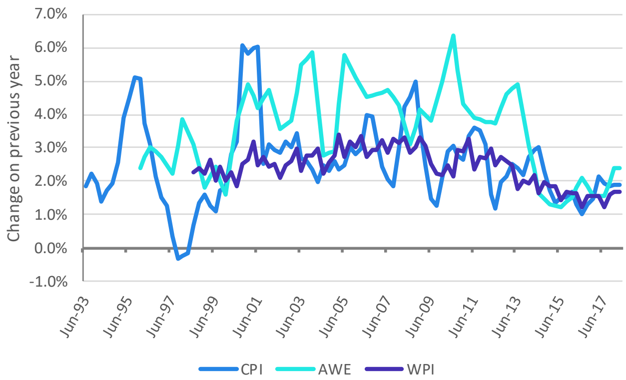
We model AWE growth as a component that sits on top of CPI forecasts – a 'gap' or 'real' estimate. This allows for an intuitive relationship between wages and CPI (higher CPI will generally be accompanied by higher wages) and matches much of the literature, including Treasury and the RBA. We performed some testing of estimation of nominal wage growth and obtained similar results in terms of accuracy.

There are multiple measures of the cost of labour. Two are particularly common:

» The wage price index (WPI) is the a 'basket of goods' approach to wages which attempts to control for changes in the nature, quality, quantity and location of work over time.

» Average weekly earnings (AWE) tracks the average wages being paid, so responds to the compositional changes in the workforce.

Figure 12 Annual change in CPI, AWE and WPI.



We observe in the historical series shown in Figure 12 that:

» WPI has been very close to CPI since 1999; while there are some differences at a state level, there is little evidence at a national level to adopt estimates significantly different to CPI.

» AWE growth has been higher than CPI changes over time, with the average gap at or just above 1% p.a for the past 20 years.

» AWE is more volatile than CPI. Ideally some of this short-term volatility could be explained by any adopted inflation model.

» AWE has been much lower in recent years and has been very close to CPI growth since 2013. This is only partly understood and creates a challenge for wage projection as a position must be taken on whether this will be an enduring feature of future wage growth. See Jacobs & Rush (2015) or Weir (2018) for further discussion.

Given the close alignment of CPI and WPI, the greater uncertainty of AWE estimation, and the importance of AWE to many actuarial liabilities we will now focus primarily on AWE estimation.

Since 2012 AWE figures have only been published half-yearly by the ABS. This creates some implementation challenges, since the latest available 'actual' values will often be more out of date than the corresponding CPI figures. The natural approach is to apply the forecast model for any past unobserved period, as well as the future. This adds some unavoidable additional uncertainty, which we have allowed for in some of our testing below.

Access forecasts include estimation of the 'catch-up' factors required to go from the latest published AWE index level to the main forecast date. While we do not know the procedure used, these tend to be more volatile than the subsequent growth forecasts and they decrease forecast accuracy accordingly. We include these catch-up figures in Section 5, but exclude them in our comparisons in Section 6.

5.2 Wage models

We have tested five families of models for real wage growth in a similar fashion to CPI.

Constant

Our constant model assumes AWE is 1.25% above CPI. Assuming a 2.5% rate for CPI growth this gives 3.75% nominal, close to the relevant historical average.

Access Economics

Using the AWE forecast series available at the corresponding quarter end.

Nominal Bond model

These follow the same structure proposed by Miller (2010). The future (instantaneous) inflation rate is assumed to be:

$$w_t(\tau) = AWE_0 + \theta_2\{y_t(\tau) - y^*(\tau)\}$$

Where:

- $w_t(\tau)$ is the rate of CPI estimated at current time t at future duration τ.
- AWE_0 is a constant representing the 'normal' inflation estimate. We set this at 1.25%, the same as the constant model.
- θ_2 is a number, typically between 0 and 1, representing how much yield curve variation should be reflected in the inflation estimate.
- $y_t(\tau)$ is the (instantaneous) yield on risk-free (Commonwealth government) bonds. This is found using any standard yield curve fitting approach on observable market instruments.
- $y^*(\tau)$ is the 'normal' yield curve, designed to help encode whether current yields are above or below normal rates. Our assumed curve is shown in Figure 6, the same as used for CPI forecasting.

Note that $\theta = 0$ degenerates to the constant model.

Autoregressive model

An autoregressive setup assumes recent AWE growth is a predictor of future growth. Assuming annual time increments, the assumed AR(1) relationship is:

$$w_t(1) = (1-\rho)AWE_0 + \rho\, w_{t-1}(1)$$

Here $w_{t-1}(1)$ is the AWE growth observed over the previous year and ρ is the magnitude of autocorrelation. This relationship can be converted to quarterly form for testing.

A further complication is that actual AWE growth is only observable with a lag – we have allowed for this in our testing. For instance, a projection at June would only have AWE information for the previous December quarter – so $w_{t-1}(1)$ would be replaced with $w_{t-1.5}(1)$.

Phillips curve or unemployment rate models

There are a number of potential parametric setups that relate labour costs to the unemployment rate. We use the Commonwealth treasury parameterisation (Bullen et al., 2014):

$$w_t(\tau) = AWE_0 + \kappa\frac{U_t - U_t^{NAIRU}}{U_t}$$

Here κ is a constant, U_t is the unemployment rate at time t and U_t^{NAIRU} is the non-accelerating inflation rate of unemployment (NAIRU). Most econometric projections rely on 'predicted' unemployment rates to plug into the Phillips curve equation. That is, to apply the model for project AWE for two years you first need to project unemployment rates for two years. We adopt a simpler approach where we use currently available unemployment rates (and latest available NAIRU estimate) as fixed numbers going forward. As a result, we would expect our Phillips curve model to lose relevance over longer durations. This means that the term κ will need to be reduced to zero over a projection or equivalently the Phillips curve portion of any model must be blended out over longer durations.

We have used trend estimates of unemployment throughout for stability. State-level unemployment rates are used to make state-level estimates.

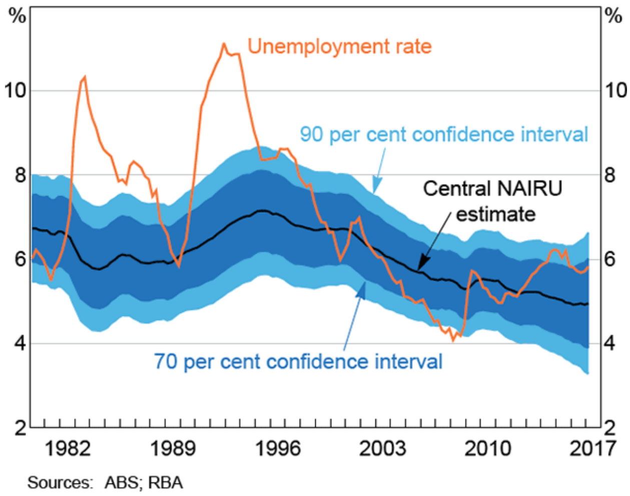
It would also be possible to use a Phillips curve model based on the *under*employment rate, rather than the unemployment rate. This echoes some recent commentary (Cusbert, 2017) that suggests that divergence between the two explains some of the recent wage weakness. However, this would also require the development of an equivalent NAIRU-type estimate for underemployment, which is not as readily available. Thus we have used unemployment in our testing.

5.3 Reference yield curves and NAIRU

The reference yield curve for the nominal bond model is the same as CPI, shown in Figure 6.

We have taken NAIRU estimates from the RBA Bulletin (Cusbert, 2017). A chart showing NAIRU estimates from that article is given in Figure 13.

Figure 13 RBA estimates of NAIRU, taken from Cusbert (2017)



The NAIRU tends to evolve slowly but it is nonstationary. This creates some complications for implementation, similar to the normal yield curve. We must estimate the current value of NAIRU, noting that the latest available estimates may be out of date and that there is inherent uncertainty in the estimate. Our proposal is to use the latest available RBA estimate without alteration – assuming that the evolution curve is flat. We have assumed that this is currently 5%, which is consistent with a range of non-RBA estimates.

In principle we should allow for state-level differences in NAIRU when considering state-level AWE forecasts. These are occasionally estimated[6]. We have not allowed for state differences except for the ACT; AWE growth has matched NSW, but unemployment rates have been consistently lower in the ACT and we

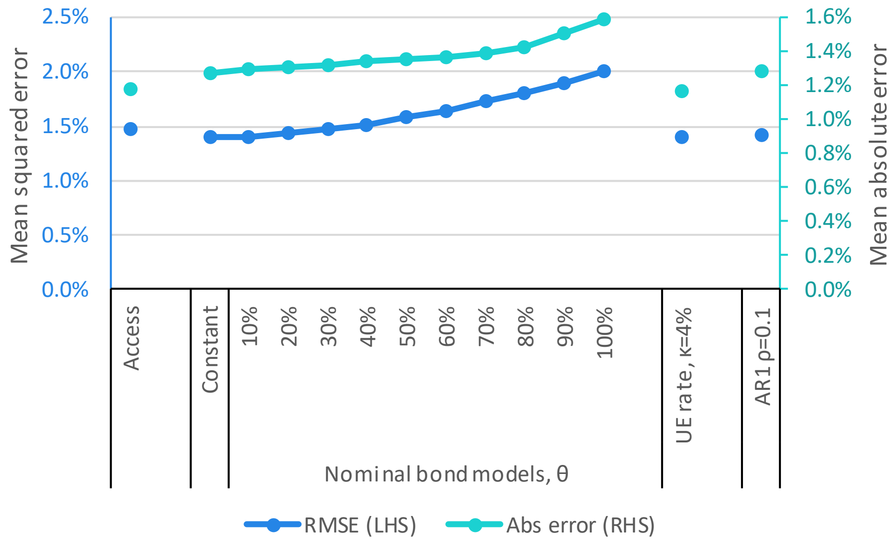
[6] For example, some Goldman Sachs estimates are available in this news article. https://www.afr.com/news/economy/natural-unemployment-rate-may-be-lower-than-reserve-bank-estimates-say-economists-20180208-h0vs10

observe very poor accuracy if there is no NAIRU adjustment. We haven't allowed for any other state-level NAIRU adjustments but acknowledge they could add additional value.

5.4 Results

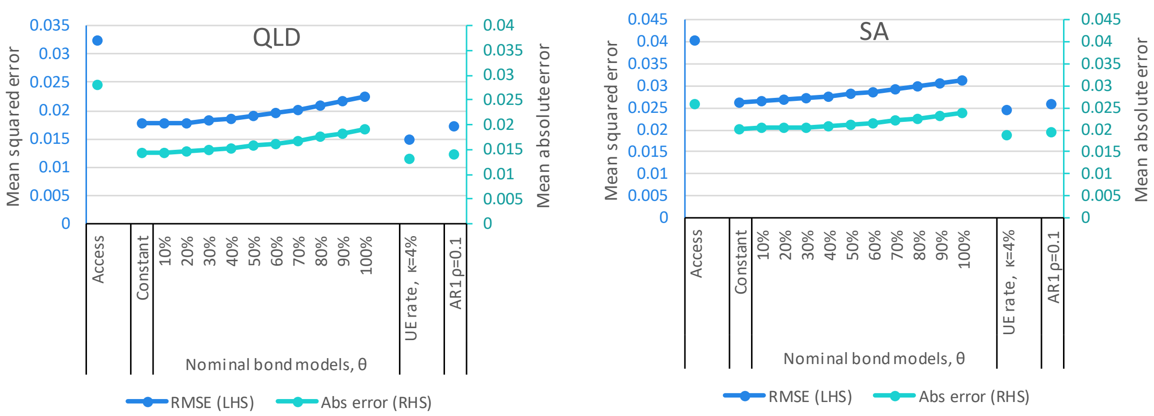
We have tested performance in the same way as CPI in Section 4. Figure 14 shows 1-year forecasting accuracy.

Figure 14 AWE gap estimate accuracy over 1 year for various models, 1999-2017



The average error (here expressed in on a percentage point basis) is higher for AWE than CPI, in part reflecting the higher volatility of the measure. The constant, UE rate, AR and nominal bond models (for low θ_2) are all slightly better than the Access forecasts using RMSE, although Access fares better on absolute error. The results for QLD and SA are shown in Figure 15. **The Access estimates are particularly poor at a state level**; this is due in large part to their approach to inferring the trend over the gap between last data and the forecast date.

Figure 15 AWE gap estimate accuracy over 1 year for various models, 1999-2017 – selected states.



The optimal value of θ_2 appears to be low (close to zero) when estimating the gap only, a slight contrast to the previous results seen at a nominal AWE estimate (see Miller, 2010). This prior work found θ_2=30% (consistent with our CPI estimate above); we interpret this to mean that estimating the 'gap' is harder to do with a nominal bond model, but the approach may still be effective when looking at nominal rates.

We have bootstrapped confidence interval estimates. For Australian estimates, the θ_2=30% model has RMSE of 1.5%, with a relatively wide 80% confidence interval of (1.2%, 1.7%), a range which includes the Access point estimate of error. For QLD the interval is (1.5%, 2.2%), which excludes the Access number.

The unemployment models appear to perform well for 1-year spot rates. We have included it in further multivariate testing for this reason.

We also tested the autoregressive model (with values of ρ close to zero collapsing to the constant model). We observe no material improvement in performance, relative to the constant model, even over the first year where autoregression should be strongest. This is compatible with the literature, despite the fact that many other models include autoregressive terms; most models, such as the Australian Treasury model, use a quarterly forecast. The quarterly autoregressive factor of 0.60 found by treasury converts to $0.6^4 = 0.13$ over a year, so their model implies that relatively little of the effect survives after a year.

Figure 16 Accuracy over multiple durations, 1999-2017

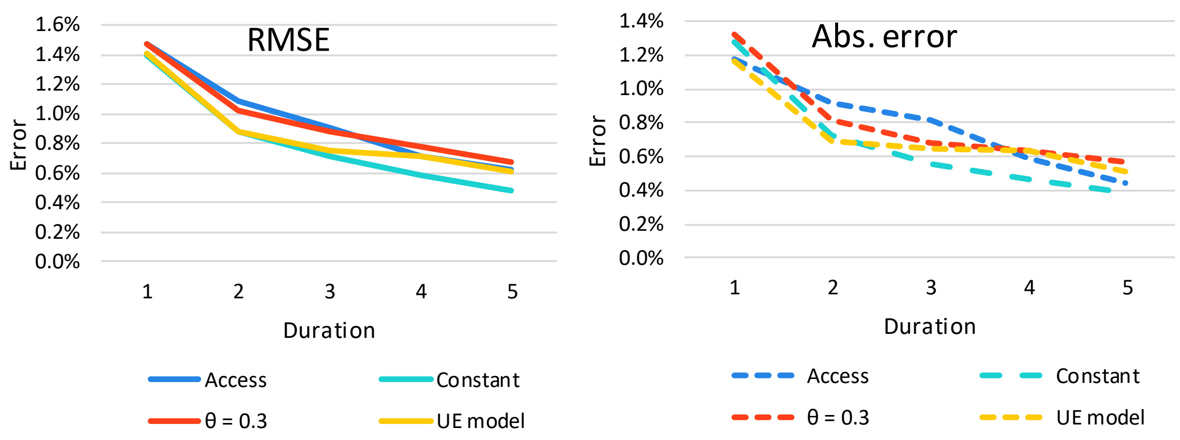


Figure 16 shows accuracy over different durations. Over longer durations, at a national level, we observe:

- Most forecasts, including Access, perform worse than the constant model
- The relative performance of the nominal bond ($\theta_2 = 0.3$) model improves a little over 2-3 year durations
- The unemployment model does not perform as well over longer durations, suggesting the predictive power of the unemployment rate dissipates.

Results are similar for state-level tests, including Queensland.

5.5 Additional multivariate testing

We have tested multivariate model fits that combine nominal bond (NB), autoregressive and unemployment model elements. These were fitted in R using annual data (as at 30 June each year). Results are for duration 1 (1-year spot rate prediction) unless otherwise stated.

Autoregression

We tested a number of autoregression models with and without other effects. The coefficient was never larger than 0.05, with standard errors large enough that there was not sufficient evidence that the parameter was different from zero.

Our conclusion is that autoregression terms contribute little to the annual model and were dropped from the multivariate modelling.

Unemployment rate

The estimate of κ on national data without any other terms (apart from a constant) was -0.0258, with a standard error of 0.0266. The point estimate is very close to Treasury's estimate of -0.026, which we regard as good evidence of an unemployment rate effect.

Combining unemployment rate and nominal bond approaches

We combined the unemployment rate term with the nominal bond term:

$$w_t(\tau) = AWE_0 + \theta_2\{y_t(\tau) - y^*(\tau)\} + \kappa\frac{U_t - U_t^{NAIRU}}{U_t}$$

When tested on national data, the unemployment term κ collapsed to insignificance, largely due to the lack of data (only 19 annual time points in the time series tested).

We switched to state-level data. While there are issues with correlations across states when interpreting significance, it does represent a good way of testing wage growth against a greater range of fluctuations in the unemployment rate.

Table 3 Results of state-level testing of joint NB and unemployment rate model over different forward rate intervals. The parameter t-test p-values are indicated using asterisks - * < 0.001, ** < 0.01, * < 0.1.**

	1-year forward rates				
	0-1	**1-2**	**2-3**	**3-4**	**4-5**
Intercept	1.0%***	1.0%***	0.9%**	1.0%*	1.0%*
θ_2	7.3%	29.0%*	45.5%*	34.4%	22.0%
κ	-2.5%**	-0.9%	-0.5%	-0.4%	-1.3%

We observe:

- » In the short term (1-year spot rate or equivalently the 0-1 forward) the parameter for the unemployment rate is virtually identical to the Australia-wide independent estimate and the Treasury parameter. The θ_2 term is significantly lower than the 0.3 (30%) value we found for CPI and in Miller (2010). When the unemployment term is excluded from the model the θ_2 estimate is 0.26 and significant at the p=0.1 level. This suggests the parameters are competing (their correlation is -0.40), and that blending separate models is likely complementary.
- » At longer durations the signal for κ weakens and θ_2 strengthens. This is consistent with the signal from *current* unemployment becoming less relevant over longer terms.
- » The intercept estimate is close to 1%, rather than our constant assumption of 1.25%. This in part reflects the low wage inflation seen in recent years that is not fully explained by the θ_2 and κ. Retaining a 1.25% assumption relies on this recent low wage growth being temporary rather than permanent.

5.6 Recommendation

We recommend blending two AWE models (a NB and unemployment rate model):

Nominal Bond (NB): $w_t(\tau) = AWE_0 + \theta_2\{y_t(\tau) - y^*(\tau)\}$

Unemployment rate (UE): $w_t(\tau) = AWE_0 + \kappa\frac{U_t - U_t^{NAIRU}}{U_t}$

We assume that AWE_0 is 1.25%. $\theta_2 = 0.3$, $\kappa = -2.5\%$. U_t^{NAIRU} should be set to 5% for all future periods and we have not allowed for state-level differences in U_t^{NAIRU} when applying at a state level except for the ACT (for which we set NAIRU to 3.5%).

Table 4 Proposed blending of nominal bond and unemployment rate models for AWE gap forecasting

Duration	NB	UE
0	33⅓%	67⅔%
0.5	33⅓%	67⅔%
1	33⅓%	67⅔%
1.5	50%	50%
2	67⅔%	33⅓%
2.5	83⅓%	17⅔%
3 and later	100%	0%

5.7 State level implications

Our previous long-range AWE estimates have had state-based differentials to recognise differences in state-level wage markets. The inclusion of state-level unemployment rate enables variation across states without ad hoc differentials. However, our recommendation of relatively short use of the UE model (no weight beyond duration 3 years) means that these state level differences are assumed to not persist over the medium and long term.

We explore differences across states further in Section 6.

6 TESTING THE RECOMMENDED APPROACH

6.1 Differences in Access forecast testing to previous section

We include comparisons to Access forecasts in this section, as we did in Section 5, but with a difference. In Section 5, we used Access' 'catch-up' estimates for when current AWE was not available. In Section 6, we instead look only at the rates from the forecast date. Access catch-up factors cause much of the error in the Section 5 testing for the spot rate comparisons, and so modifying the approach provides a fairer comparison in some ways, although it gives Access a 'free kick' by ignoring the sometimes-poor updating process to get to the projection point.

6.2 CPI

To gain a sense of how our CPI model has evolved over time, 1-year spot and 2-year forward rates are shown in the figures below. For periods before June 2012 we have fallen back on the nominal bond model only (there is no blending with ILB model). Figure 17 shows the expected inflation over the next year, while Figure 18 shows the two year forward rate (expected rate between 2 and 3 years into the future). Actuals (the actual wage inflation if we could have predicted that future period perfectly) and Access forecasts are included for comparison.

Figure 17 Rolling 1-year spot rates for CPI, predicted and actual

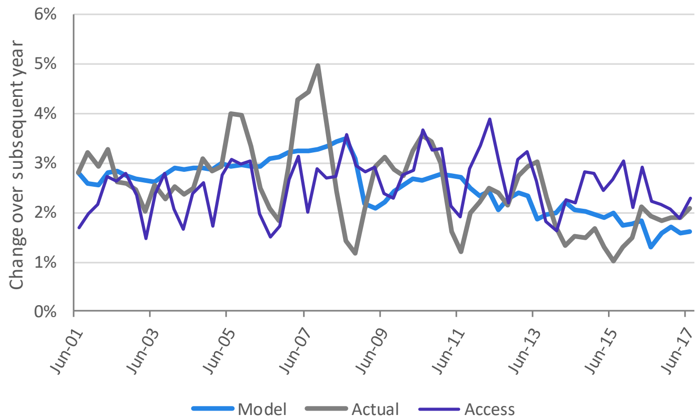
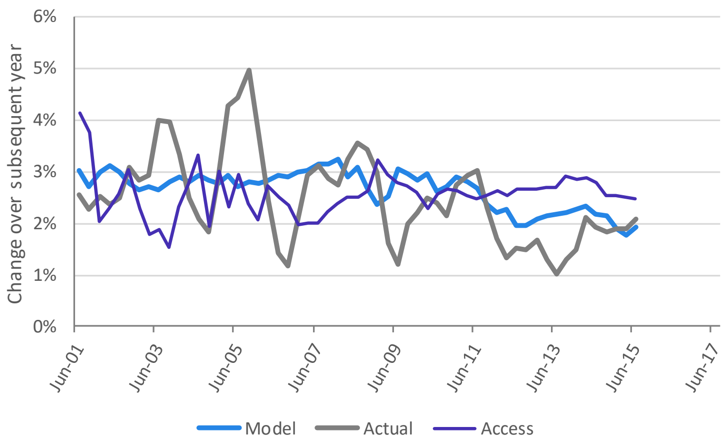


Figure 18 Rolling 2-year forward rates for CPI, predicted and actual



Our main observations from the charts are:

» The projections from our proposed model are relatively stable, with significantly less variability for the 1-year spot rate and materially less variation in the 2-year forward rate when compared to Access forecasts. Our model is also slightly more accurate (see Table 5 and Table 6).

» The proposed model also does a reasonable job of anticipating the low-inflation environment in the latter years.

» The most notable change in the model projections is the drop in projected rates after of the GFC, in 2008, corresponding to the fall in yields. This has proven to be consistent with actual experience.

6.3 Real AWE growth

We compare our model to actual real AWE growth and Access forecasts at a national level in the two figures below. As with CPI we show the 1-year spot rate and the 2-year (annual) forward rate.

Figure 19 Rolling 1-year spot rates for AWE gap (AWE minus CPI), predicted and actual. Australia

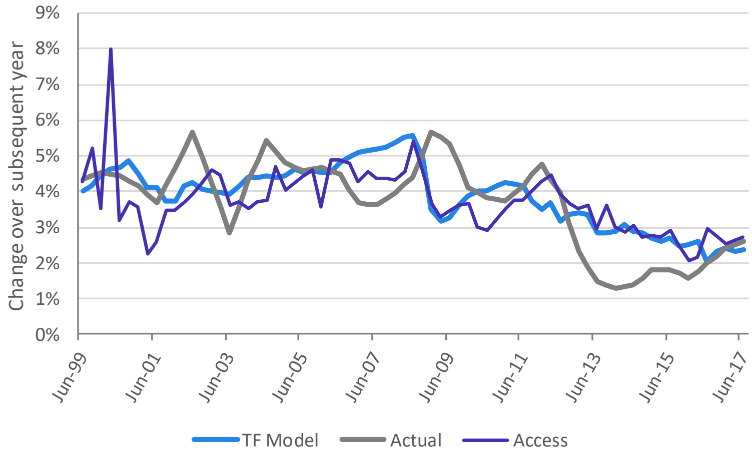
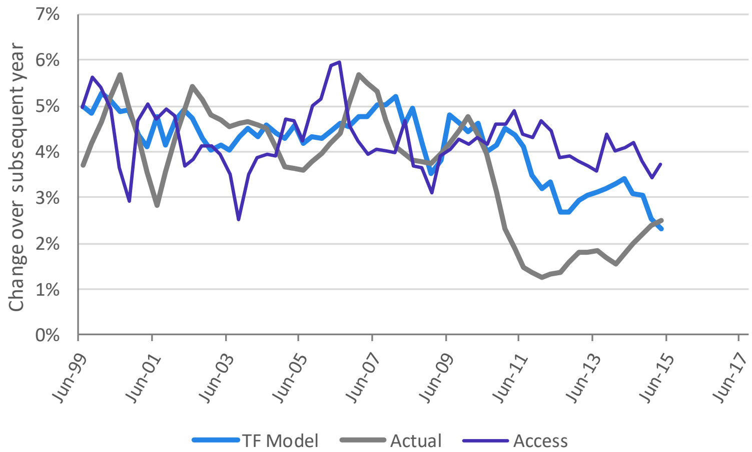


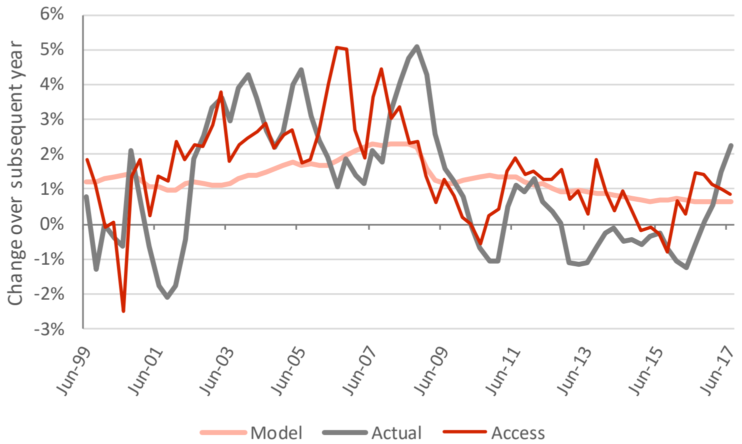
Figure 20 Rolling 2-year forward rates for AWE (above CPI), predicted and actual, Australia



The actual AWE gap is reasonably volatile, in part due to the subtraction of CPI, and the projection probably errs on the side of smoothness; there is relatively little attempt to match the cyclicity visible, as based on our testing this can only be done through increasing prediction error (or adopting a more complex model type).

The state and territory level results are also important. In most cases the Access forecasts tend to be more volatile, and sometimes exhibit larger biases. Figure 21 shows the Queensland 1-year spot rates, where Access' extra volatility is clear (although predictive accuracy is about the same). By contrast the proposed model is less ambitious in its variation, but the inclusion of unemployment can exaggerate or dampen the national trend.

Figure 21 Rolling 1-year spot rates for AWE gap (AWE minus CPI), predicted and actual, Queensland



We can see the state-level variation induced by different unemployment rates in Figure 22. The larger eastern states tend to track the national projection relatively closely, and there is more variation in the less populous states. The mining boom (and associated low unemployment) is visible around 2007 for QLD and WA.

Figure 22 1-year spot forecasts for AWE (above CPI) by state and territory

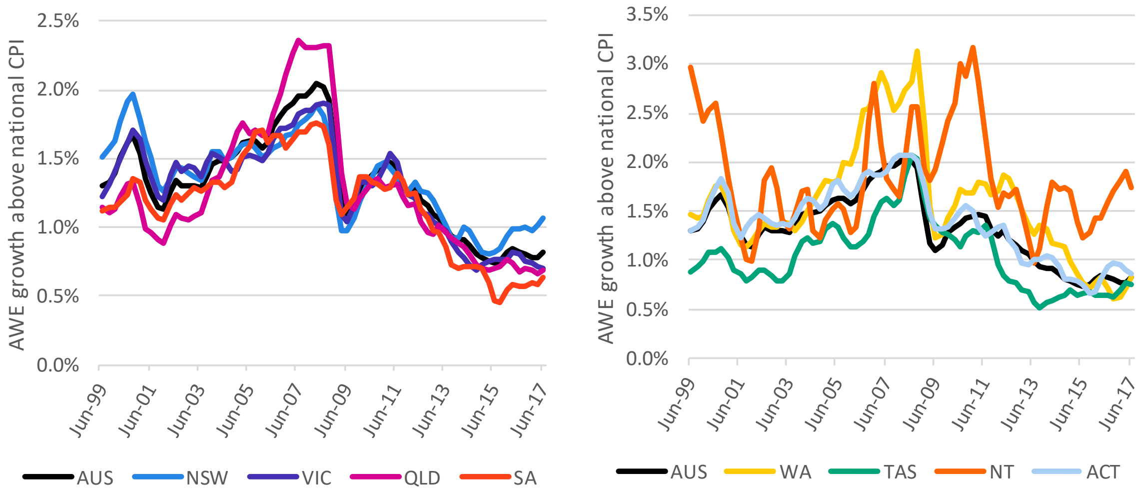
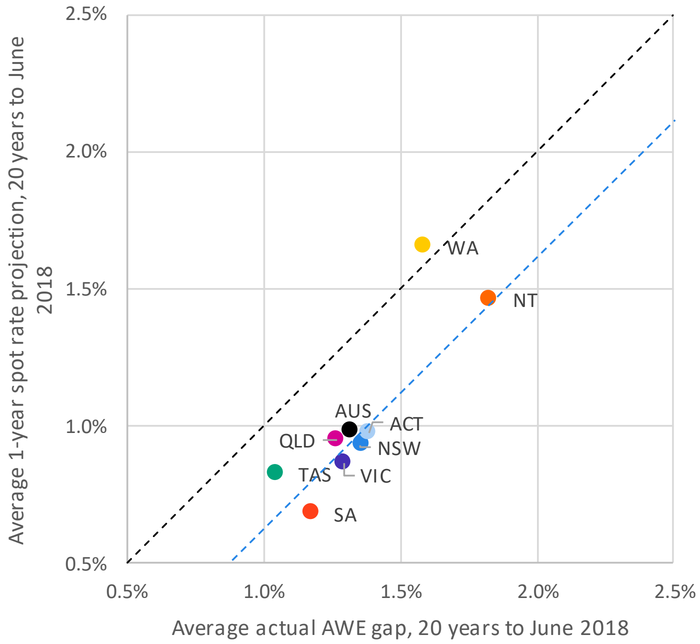


Figure 23 compares the long run differences between states. There is some overall bias (wages have been a little lower than the model would imply – perhaps justifying a lower constant than 1.25%), but the relative bias across states is remarkably low; with the exception of WA (which sees long-run AWE above forecast) all other states see similar bias and their higher or lower actual AWE is well explained by their historical changes in the unemployment rate.

Figure 23 Average projected and actual 1-year AWE over 20 years to 2018, by state and territory



6.4 Nominal AWE

Finally, we combine CPI and AWE predictions to see actual and projected nominal AWE. The actual values are more stable than the gap. The projection captures some of the observable shape, with the main bias visible in the 2013 through 2015 when wage growth was significantly weaker than projected.

Figure 24 Rolling 1-year spot rates for Nominal AWE for Australia, predicted and actual

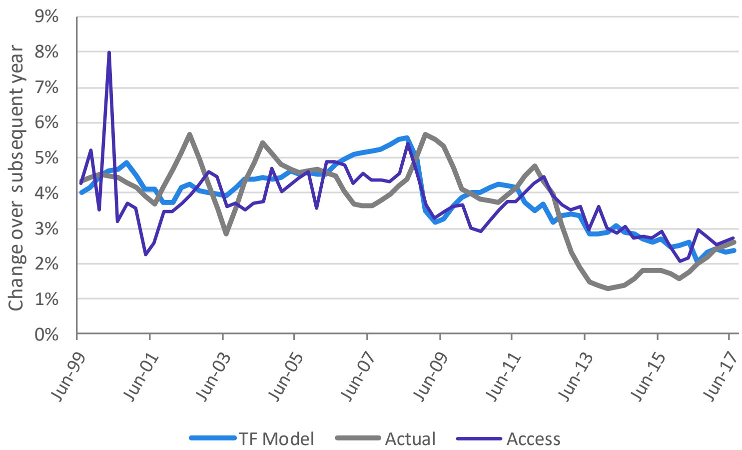
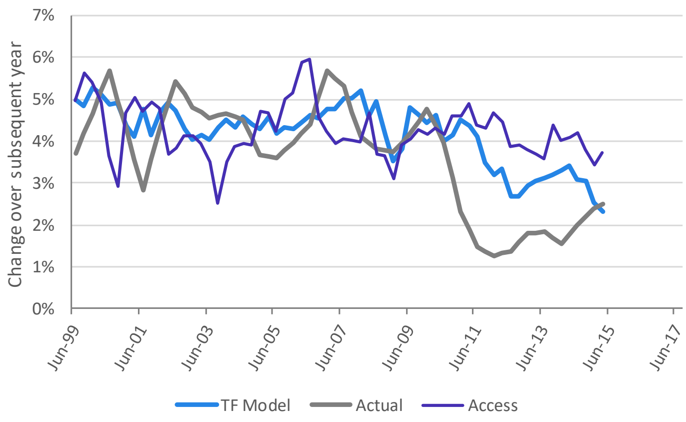


Figure 25 Rolling 2-year forward rates for Nominal AWE, predicted and actual



The main difference between the proposed model and Access is that our model keeps wage growth lower for longer (visible in the second chart). The two series are surprisingly consistent in over the 1-year spot forecast, although the extra volatility in the Access curve is still visible.

6.5 Summary measures

For each of the 1-year forward rates (duration 0/1/2/3/4) we can compare the proposed model to Access economics. We measure from June 2001 to the last observable date and compare:

- Absolute error
- RMSE performance
- Quarter on quarter change – the average absolute difference in the prediction from quarter to quarter.

Table 5 Comparison of Access and proposed model performance, Australia statistics, 2001-2017

1 year forward duration		CPI			AWE gap			AWE Nominal		
		Abs	RMSE	QoQ	Abs	RMSE	QoQ	Abs	RMSE	QoQ
0	Model	0.0058	0.0591	0.0012	0.0093	0.0942	0.0006	0.0080	0.0802	0.0017
	Access	0.0067	0.0704	0.0048	0.0093	0.0954	0.0057	0.0083	0.0808	0.0033
	Ratio	***86%***	***84%***	***25%***	***100%***	***99%***	***11%***	***96%***	***99%***	***53%***
1	Model	0.0061	0.0612	0.0015	0.0089	0.0875	0.0010	0.0071	0.0663	0.0024
	Access	0.0078	0.0750	0.0023	0.0095	0.0976	0.0046	0.0099	0.0947	0.0038
	Ratio	***79%***	***82%***	***63%***	***94%***	***90%***	***21%***	***71%***	***70%***	***63%***
2	Model	0.0063	0.0606	0.0014	0.0095	0.0905	0.0014	0.0083	0.0796	0.0028
	Access	0.0089	0.0815	0.0030	0.0117	0.1124	0.0045	0.0133	0.1203	0.0035
	Ratio	***71%***	***74%***	***49%***	***82%***	***81%***	***30%***	***62%***	***66%***	***80%***
3	Model	0.0067	0.0611	0.0013	0.0111	0.0987	0.0013	0.0111	0.0997	0.0025
	Access	0.0091	0.0794	0.0030	0.0115	0.1062	0.0049	0.0122	0.1042	0.0033
	Ratio	***73%***	***77%***	***42%***	***97%***	***93%***	***26%***	***91%***	***96%***	***78%***
4	Model	0.0079	0.0681	0.0012	0.0114	0.0955	0.0012	0.0113	0.1038	0.0024
	Access	0.0100	0.0849	0.0028	0.0120	0.1127	0.0053	0.0117	0.0925	0.0048
	Ratio	***79%***	***80%***	***44%***	***95%***	***85%***	***23%***	***97%***	***112%***	***50%***

At a national level, averaging across the five forward years, the CPI estimate is around 20% more accurate, the AWE gap estimate is 0-10% more accurate and the nominal AWE estimate is about 0-20% more accurate. These figures seem to persist across most durations. The quarter on quarter variability is also noteworthy – the volatility of our model relative to Access is about half for CPI and nominal AWE, and lower again for the AWE gap.

Table 6 Comparison of Access and proposed model performance, Queensland statistics, 2001-2017

1 year forward		CPI			AWE gap			AWE Nominal		
		Abs	RMSE	QoQ	Abs	RMSE	QoQ	Abs	RMSE	QoQ
0	Model	0.0058	0.0591	0.0012	0.0138	0.1305	0.0007	0.0139	0.1274	0.0018
	Access	0.0076	0.0783	0.0048	0.0129	0.1324	0.0063	0.0146	0.1338	0.0042
	Ratio	***76%***	***75%***	***25%***	***107%***	***99%***	***11%***	***95%***	***95%***	***42%***
1	Model	0.0061	0.0612	0.0015	0.0133	0.1219	0.0010	0.0139	0.1233	0.0024
	Access	0.0082	0.0767	0.0030	0.0135	0.1254	0.0058	0.0173	0.1516	0.0041
	Ratio	***74%***	***80%***	***49%***	***99%***	***97%***	***18%***	***81%***	***81%***	***58%***
2	Model	0.0063	0.0606	0.0014	0.0145	0.1270	0.0014	0.0169	0.1404	0.0028
	Access	0.0091	0.0837	0.0031	0.0146	0.1264	0.0042	0.0188	0.1663	0.0037
	Ratio	***69%***	***72%***	***47%***	***99%***	***100%***	***32%***	***90%***	***84%***	***75%***
3	Model	0.0067	0.0611	0.0013	0.0145	0.1248	0.0013	0.0182	0.1476	0.0025
	Access	0.0098	0.0865	0.0030	0.0151	0.1266	0.0049	0.0194	0.1567	0.0033
	Ratio	***69%***	***71%***	***42%***	***96%***	***99%***	***26%***	***94%***	***94%***	***77%***
4	Model	0.0079	0.0681	0.0012	0.0149	0.1220	0.0012	0.0196	0.1519	0.0024
	Access	0.0108	0.0903	0.0028	0.0166	0.1331	0.0057	0.0191	0.1464	0.0048
	Ratio	***73%***	***75%***	***43%***	***89%***	***92%***	***21%***	***102%***	***104%***	***50%***

We show results for Queensland in Table 6, and have equivalent for all states in the appendix. Our overall comments are:

» Model accuracy CPI results are very similar, consistent with our previous comments around national CPI being applicable at a state level. Access forecasts do vary by state, which can lead to inferior performance.

» AWE estimation (both gap and nominal) accuracy for our model is close to, or slightly better than, the results for Access. The only case where the model was more than 10% worse than Access was for 3- and 4-year forwards in Victoria, and 40year forwards in NSW. In both cases the main driver of lower accuracy for appears to be Access revert to the mean faster for a pre-GFC forecast that applied to a low wage period post-GFC.

» Quarter on quarter volatility is always materially better for our proposed model. In some cases, the difference is extreme; the 1-year spot rate for Queensland has more than two and a half times the average absolute deviation.

A final view is provided by Figure 26 and Figure 27. It shows similar inflation to Figure 24, how wage inflation estimates evolve over time for the proposed model and Access (after controlling for errors associated with Access catch-up factors).

Figure 26 Average projected and actual 1-year AWE for Australia

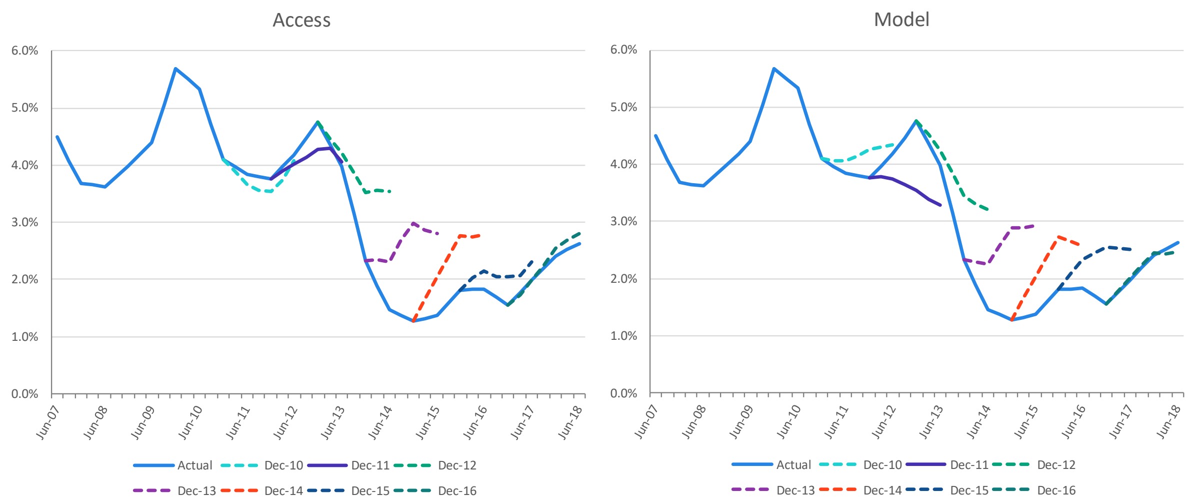
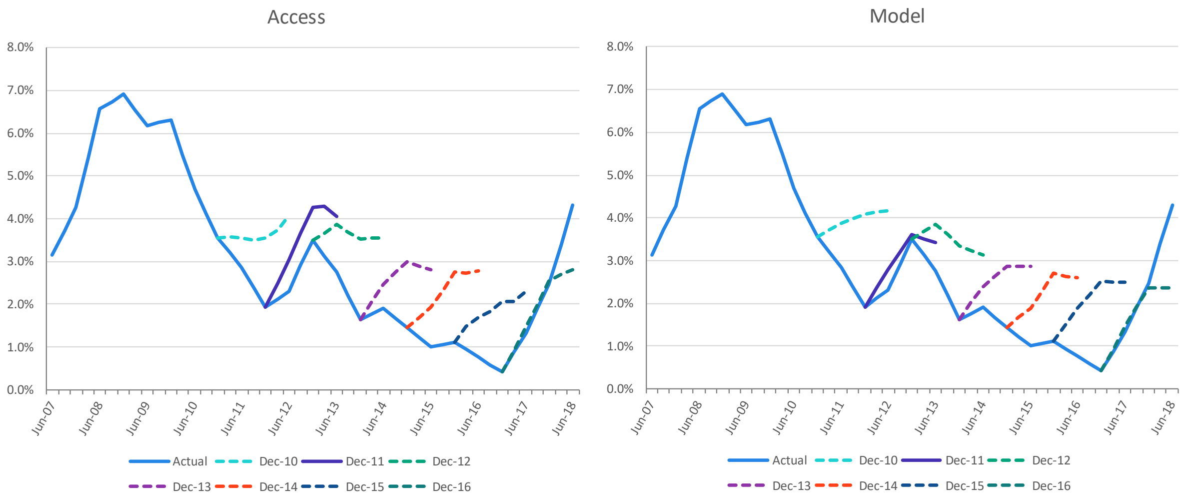


Figure 27 Average projected and actual 1-year AWE for Queensland



They echo some of our previous comments. Estimates are broadly similar in the short term; Access forecasts carry more volatility over time (comparing the finishing places of successive forecasts). Differences between the two are larger over the later durations, where our proposed model places some weight on low bond yields.

Both models also exhibit comparable levels of mean-reversion, which have been over-optimistic in the past five years; our model does not completely solve the issue of lower wages in this period.

6.6 Impact on an injury scheme liability

We are interested in the impact of our model on injury scheme liabilities. For illustration, we take a notional cashflow distribution representative of a CTP scheme (with undiscounted uninflated mean duration of 2.9 years, paid out over 12 years and inflation set to AWE). We then compare:

- The AWE inflation curve at each quarter from June 2001 to June 2018 from our proposed model
- The Access inflation curve at each quarter for the first five years (and our model thereafter)

We also apply the discount rate curve at each quarter.

We can then determine the liability attached to a $1 uninflated and undiscounted liability, after inflation and discounting. So, a value of 0.98 would indicate a $0.98 liability for the dollar after inflation and discounting.

Figure 28 Average liability impact of inflation and discounting, Australia, for notional injury scheme cashflow distribution.

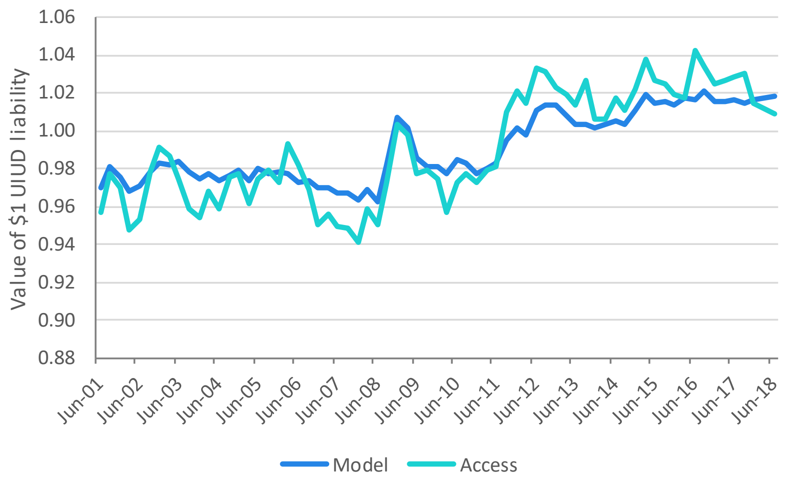
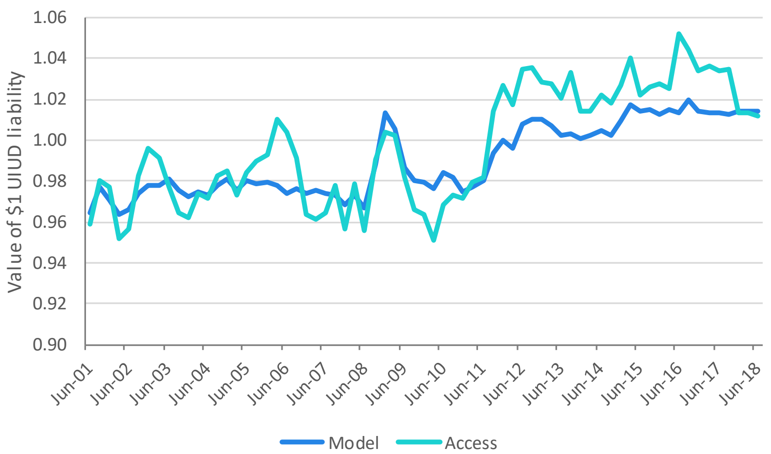


Figure 29 Average liability impact of inflation and discounting, Queensland, for notional injury scheme cashflow distribution.



Our proposed model has:

» **Less variation over the short term.** It is significantly smoother with the quarter on quarter variability half that of the Access model.

» **Less variation over the long-term**. Our model is lower in the period 2012 through 2017, reflecting the impact of the lower interest rates also leading to lower AWE.

7 REFERENCES

Bullen, J., Greenwell, J., Kouparitsas, M., Muller, D., O'Leary, J., & Wilcox, R. (2014). *Treasury's medium-term economic projection methodology*. Treasury.

Cusbert, T. (2017). Estimating the NAIRU and the Unemployment Gap. *RBA Bulletin, June*, 13-22.

Gruen, D., Pagan, A., & Thompson, C. (1999). The Phillips Curve in Australia. *Journal of Monetary Economics*, *44*(2), 223-258.

Jacobs, D., & Rush, A. (2015). Why is wage growth so low?. *RBA Bulletin, June*, 9-18.

Miller, H. (2010). Towards a better inflation forecast. *17th General Insurance Seminar*, IAAust.

Miller H. (2016). The rise and fall of inflation indices. *General Insurance Seminar 2016*

Miller, H. and Yip, T. (2017). An approach to setting inflation and discount rates. *Australian Journal of Actuarial Practice*, **5**, 133.

Mulquiney, P., & Miller, H. (2014). A topic of interest–how to extrapolate the yield curve in Australia.

Weir, G. (2018). *Wage Growth Puzzles and Technology* (No. rdp2018-10). Reserve Bank of Australia.

Appendix A Additional tables

We present comparison tables of the type shown in Table 5 and Table 6 for national results and every state and territory. In most cases AWE nominal accuracy is close for Access and the model, but quarter on quarter volatility is markedly lower for our proposed model.

Australia

1 year forward duration		CPI			AWE gap			AWE Nominal		
		Abs	RMSE	QoQ	Abs	RMSE	QoQ	Abs	RMSE	QoQ
0	Model	0.0059	0.0600	0.0011	0.0093	0.0939	0.0006	0.0079	0.0799	0.0016
	Access	0.0067	0.0704	0.0048	0.0093	0.0954	0.0057	0.0083	0.0808	0.0033
	Ratio	***88%***	***85%***	***23%***	***100%***	***98%***	***11%***	***96%***	***99%***	***48%***
1	Model	0.0062	0.0615	0.0012	0.0131	0.1195	0.0009	0.0136	0.1199	0.0020
	Access	0.0082	0.0767	0.0030	0.0135	0.1254	0.0058	0.0173	0.1516	0.0041
	Ratio	***75%***	***80%***	***39%***	***97%***	***95%***	***16%***	***79%***	***79%***	***49%***
2	Model	0.0058	0.0573	0.0012	0.0143	0.1269	0.0012	0.0164	0.1370	0.0024
	Access	0.0091	0.0837	0.0031	0.0146	0.1264	0.0042	0.0188	0.1663	0.0037
	Ratio	***64%***	***68%***	***39%***	***98%***	***100%***	***27%***	***87%***	***82%***	***63%***
3	Model	0.0062	0.0602	0.0013	0.0144	0.1235	0.0013	0.0178	0.1444	0.0025
	Access	0.0098	0.0865	0.0030	0.0151	0.1266	0.0049	0.0194	0.1567	0.0033
	Ratio	***64%***	***70%***	***41%***	***95%***	***98%***	***26%***	***92%***	***92%***	***76%***
4	Model	0.0078	0.0675	0.0013	0.0148	0.1205	0.0013	0.0193	0.1487	0.0026
	Access	0.0108	0.0903	0.0028	0.0166	0.1331	0.0057	0.0191	0.1464	0.0048
	Ratio	***72%***	***75%***	***45%***	***89%***	***91%***	***22%***	***101%***	***102%***	***54%***

NSW

1 year forward		CPI			AWE gap			AWE Nominal		
		Abs	RMSE	QoQ	Abs	RMSE	QoQ	Abs	RMSE	QoQ
0	Model	0.0059	0.0600	0.0011	0.0142	0.1510	0.0007	0.0127	0.1292	0.0017
	Access	0.0076	0.0758	0.0059	0.0150	0.1644	0.0086	0.0123	0.1288	0.0046
	Ratio	***78%***	***79%***	***19%***	***95%***	***92%***	***8%***	***103%***	***100%***	***36%***
1	Model	0.0062	0.0615	0.0012	0.0141	0.1456	0.0008	0.0125	0.1202	0.0020
	Access	0.0084	0.0803	0.0024	0.0156	0.1613	0.0047	0.0124	0.1236	0.0038
	Ratio	***73%***	***77%***	***48%***	***90%***	***90%***	***17%***	***101%***	***97%***	***52%***
2	Model	0.0058	0.0573	0.0012	0.0152	0.1459	0.0011	0.0134	0.1201	0.0024
	Access	0.0089	0.0821	0.0030	0.0166	0.1664	0.0045	0.0147	0.1393	0.0036
	Ratio	***66%***	***70%***	***40%***	***91%***	***88%***	***25%***	***91%***	***86%***	***65%***
3	Model	0.0062	0.0602	0.0013	0.0154	0.1456	0.0013	0.0143	0.1239	0.0025
	Access	0.0093	0.0813	0.0029	0.0173	0.1622	0.0049	0.0154	0.1318	0.0035
	Ratio	***67%***	***74%***	***43%***	***89%***	***90%***	***26%***	***93%***	***94%***	***72%***
4	Model	0.0078	0.0675	0.0013	0.0142	0.1332	0.0013	0.0123	0.1062	0.0026
	Access	0.0097	0.0818	0.0029	0.0170	0.1611	0.0052	0.0129	0.1117	0.0050
	Ratio	***81%***	***83%***	***44%***	***83%***	***83%***	***24%***	***96%***	***95%***	***52%***

VIC

1 year forward		CPI Abs	RMSE	QoQ	AWE gap Abs	RMSE	QoQ	AWE Nominal Abs	RMSE	QoQ
0	Model	0.0059	0.0600	0.0011	0.0162	0.1605	0.0006	0.0161	0.1547	0.0016
	Access	0.0074	0.0762	0.0055	0.0196	0.1916	0.0075	0.0159	0.1637	0.0042
	Ratio	***81%***	***79%***	***20%***	***83%***	***84%***	***8%***	***101%***	***94%***	***38%***
1	Model	0.0062	0.0615	0.0012	0.0151	0.1458	0.0008	0.0134	0.1232	0.0019
	Access	0.0083	0.0789	0.0027	0.0172	0.1580	0.0050	0.0135	0.1321	0.0040
	Ratio	***74%***	***78%***	***43%***	***88%***	***92%***	***16%***	***99%***	***93%***	***49%***
2	Model	0.0058	0.0573	0.0012	0.0156	0.1462	0.0011	0.0136	0.1267	0.0024
	Access	0.0088	0.0814	0.0030	0.0161	0.1547	0.0044	0.0139	0.1417	0.0035
	Ratio	***66%***	***70%***	***40%***	***96%***	***95%***	***26%***	***98%***	***89%***	***67%***
3	Model	0.0062	0.0602	0.0013	0.0162	0.1481	0.0013	0.0152	0.1380	0.0025
	Access	0.0096	0.0823	0.0030	0.0168	0.1555	0.0049	0.0122	0.1239	0.0034
	Ratio	***65%***	***73%***	***42%***	***96%***	***95%***	***26%***	***124%***	***111%***	***73%***
4	Model	0.0078	0.0675	0.0013	0.0164	0.1439	0.0013	0.0160	0.1373	0.0026
	Access	0.0099	0.0832	0.0028	0.0200	0.1657	0.0051	0.0148	0.1310	0.0048
	Ratio	***79%***	***81%***	***45%***	***82%***	***87%***	***25%***	***108%***	***105%***	***54%***

QLD

1 year forward		CPI Abs	RMSE	QoQ	AWE gap Abs	RMSE	QoQ	AWE Nominal Abs	RMSE	QoQ
0	Model	0.0059	0.0600	0.0011	0.0138	0.1303	0.0007	0.0139	0.1269	0.0016
	Access	0.0076	0.0783	0.0048	0.0129	0.1324	0.0063	0.0146	0.1338	0.0042
	Ratio	***77%***	***77%***	***23%***	***107%***	***98%***	***11%***	***95%***	***95%***	***39%***
1	Model	0.0062	0.0615	0.0012	0.0131	0.1195	0.0009	0.0136	0.1199	0.0020
	Access	0.0082	0.0767	0.0030	0.0135	0.1254	0.0058	0.0173	0.1516	0.0041
	Ratio	***75%***	***80%***	***39%***	***97%***	***95%***	***16%***	***79%***	***79%***	***49%***
2	Model	0.0058	0.0573	0.0012	0.0143	0.1269	0.0012	0.0164	0.1370	0.0024
	Access	0.0091	0.0837	0.0031	0.0146	0.1264	0.0042	0.0188	0.1663	0.0037
	Ratio	***64%***	***68%***	***39%***	***98%***	***100%***	***27%***	***87%***	***82%***	***63%***
3	Model	0.0062	0.0602	0.0013	0.0144	0.1235	0.0013	0.0178	0.1444	0.0025
	Access	0.0098	0.0865	0.0030	0.0151	0.1266	0.0049	0.0194	0.1567	0.0033
	Ratio	***64%***	***70%***	***41%***	***95%***	***98%***	***26%***	***92%***	***92%***	***76%***
4	Model	0.0078	0.0675	0.0013	0.0148	0.1205	0.0013	0.0193	0.1487	0.0026
	Access	0.0108	0.0903	0.0028	0.0166	0.1331	0.0057	0.0191	0.1464	0.0048
	Ratio	***72%***	***75%***	***45%***	***89%***	***91%***	***22%***	***101%***	***102%***	***54%***

SA

1 year forward		CPI			AWE gap			AWE Nominal		
		Abs	RMSE	QoQ	Abs	RMSE	QoQ	Abs	RMSE	QoQ
0	Model	0.0059	0.0600	0.0011	0.0186	0.1963	0.0006	0.0198	0.2087	0.0015
	Access	0.0075	0.0768	0.0057	0.0188	0.1969	0.0097	0.0198	0.2004	0.0057
	Ratio	***79%***	***78%***	***20%***	***99%***	***100%***	***6%***	***100%***	***104%***	***27%***
1	Model	0.0062	0.0615	0.0012	0.0188	0.1921	0.0008	0.0207	0.2087	0.0019
	Access	0.0079	0.0739	0.0029	0.0202	0.2020	0.0051	0.0213	0.2134	0.0037
	Ratio	***78%***	***83%***	***40%***	***93%***	***95%***	***15%***	***98%***	***98%***	***50%***
2	Model	0.0058	0.0573	0.0012	0.0172	0.1691	0.0011	0.0190	0.1845	0.0024
	Access	0.0085	0.0778	0.0029	0.0187	0.1819	0.0045	0.0217	0.2141	0.0035
	Ratio	***69%***	***74%***	***42%***	***92%***	***93%***	***25%***	***88%***	***86%***	***68%***
3	Model	0.0062	0.0602	0.0013	0.0172	0.1676	0.0013	0.0186	0.1874	0.0025
	Access	0.0094	0.0843	0.0031	0.0189	0.1751	0.0050	0.0215	0.2075	0.0031
	Ratio	***66%***	***71%***	***41%***	***91%***	***96%***	***25%***	***87%***	***90%***	***80%***
4	Model	0.0078	0.0675	0.0013	0.0168	0.1654	0.0013	0.0199	0.1942	0.0026
	Access	0.0106	0.0889	0.0029	0.0176	0.1606	0.0053	0.0206	0.1898	0.0047
	Ratio	***74%***	***76%***	***44%***	***96%***	***103%***	***24%***	***97%***	***102%***	***55%***

WA

1 year forward		CPI			AWE gap			AWE Nominal		
		Abs	RMSE	QoQ	Abs	RMSE	QoQ	Abs	RMSE	QoQ
0	Model	0.0059	0.0600	0.0011	0.0197	0.2009	0.0011	0.0193	0.1975	0.0019
	Access	0.0103	0.0992	0.0069	0.0168	0.1724	0.0080	0.0184	0.1905	0.0057
	Ratio	***58%***	***60%***	***16%***	***117%***	***117%***	***13%***	***105%***	***104%***	***33%***
1	Model	0.0062	0.0615	0.0012	0.0220	0.2135	0.0009	0.0212	0.2115	0.0020
	Access	0.0095	0.0855	0.0051	0.0221	0.2259	0.0076	0.0217	0.2195	0.0045
	Ratio	***65%***	***72%***	***23%***	***99%***	***95%***	***12%***	***97%***	***96%***	***43%***
2	Model	0.0058	0.0573	0.0012	0.0225	0.2132	0.0011	0.0227	0.2117	0.0024
	Access	0.0098	0.0903	0.0037	0.0248	0.2343	0.0059	0.0266	0.2498	0.0045
	Ratio	***60%***	***63%***	***33%***	***91%***	***91%***	***19%***	***85%***	***85%***	***52%***
3	Model	0.0062	0.0602	0.0013	0.0235	0.2133	0.0013	0.0242	0.2167	0.0025
	Access	0.0100	0.0911	0.0038	0.0239	0.2097	0.0058	0.0265	0.2347	0.0033
	Ratio	***62%***	***66%***	***33%***	***99%***	***102%***	***22%***	***91%***	***92%***	***77%***
4	Model	0.0078	0.0675	0.0013	0.0248	0.2126	0.0013	0.0257	0.2210	0.0026
	Access	0.0116	0.0977	0.0034	0.0218	0.1836	0.0059	0.0246	0.2165	0.0049
	Ratio	***67%***	***69%***	***37%***	***114%***	***116%***	***21%***	***105%***	***102%***	***53%***

TAS

1 year forward		CPI Abs	CPI RMSE	CPI QoQ	AWE gap Abs	AWE gap RMSE	AWE gap QoQ	AWE Nominal Abs	AWE Nominal RMSE	AWE Nominal QoQ
0	Model	0.0059	0.0600	0.0011	0.0193	0.1878	0.0007	0.0184	0.1770	0.0016
	Access	0.0096	0.0966	0.0068	0.0211	0.2006	0.0097	0.0208	0.1969	0.0058
	Ratio	***62%***	***62%***	***17%***	***92%***	***94%***	***7%***	***89%***	***90%***	***28%***
1	Model	0.0062	0.0615	0.0012	0.0192	0.1792	0.0008	0.0174	0.1567	0.0019
	Access	0.0090	0.0813	0.0040	0.0211	0.1989	0.0062	0.0191	0.1743	0.0044
	Ratio	***69%***	***76%***	***29%***	***91%***	***90%***	***13%***	***91%***	***90%***	***44%***
2	Model	0.0058	0.0573	0.0012	0.0197	0.1777	0.0011	0.0175	0.1541	0.0024
	Access	0.0087	0.0792	0.0031	0.0204	0.1861	0.0046	0.0200	0.1731	0.0036
	Ratio	***67%***	***72%***	***39%***	***96%***	***96%***	***25%***	***88%***	***89%***	***66%***
3	Model	0.0062	0.0602	0.0013	0.0194	0.1684	0.0013	0.0177	0.1518	0.0025
	Access	0.0096	0.0878	0.0035	0.0182	0.1657	0.0054	0.0167	0.1406	0.0033
	Ratio	***65%***	***69%***	***36%***	***107%***	***102%***	***23%***	***106%***	***108%***	***76%***
4	Model	0.0078	0.0675	0.0013	0.0192	0.1610	0.0013	0.0182	0.1508	0.0026
	Access	0.0112	0.0940	0.0034	0.0203	0.1768	0.0056	0.0182	0.1501	0.0048
	Ratio	***70%***	***72%***	***37%***	***95%***	***91%***	***23%***	***100%***	***100%***	***54%***

ACT

1 year forward		CPI Abs	CPI RMSE	CPI QoQ	AWE gap Abs	AWE gap RMSE	AWE gap QoQ	AWE Nominal Abs	AWE Nominal RMSE	AWE Nominal QoQ
0	Model	0.0059	0.0600	0.0011	0.0252	0.2518	0.0007	0.0249	0.2470	0.0016
	Access	0.0075	0.0795	0.0056	0.0296	0.2907	0.0095	0.0307	0.2912	0.0072
	Ratio	***79%***	***75%***	***20%***	***85%***	***87%***	***7%***	***81%***	***85%***	***22%***
1	Model	0.0062	0.0615	0.0012	0.0249	0.2426	0.0008	0.0244	0.2341	0.0019
	Access	0.0078	0.0727	0.0033	0.0266	0.2583	0.0051	0.0281	0.2589	0.0033
	Ratio	***79%***	***85%***	***36%***	***94%***	***94%***	***15%***	***87%***	***90%***	***57%***
2	Model	0.0058	0.0573	0.0012	0.0260	0.2442	0.0011	0.0261	0.2414	0.0024
	Access	0.0084	0.0766	0.0033	0.0267	0.2471	0.0052	0.0294	0.2562	0.0038
	Ratio	***70%***	***75%***	***37%***	***97%***	***99%***	***22%***	***89%***	***94%***	***62%***
3	Model	0.0062	0.0602	0.0013	0.0246	0.2273	0.0013	0.0253	0.2257	0.0025
	Access	0.0095	0.0870	0.0035	0.0245	0.2276	0.0051	0.0269	0.2306	0.0035
	Ratio	***65%***	***69%***	***36%***	***100%***	***100%***	***25%***	***94%***	***98%***	***71%***
4	Model	0.0078	0.0675	0.0013	0.0242	0.2160	0.0013	0.0260	0.2204	0.0026
	Access	0.0111	0.0912	0.0030	0.0239	0.2261	0.0056	0.0261	0.2223	0.0049
	Ratio	***70%***	***74%***	***42%***	***101%***	***96%***	***23%***	***100%***	***99%***	***53%***

NT

1 year forward		CPI			AWE gap			AWE Nominal		
		Abs	RMSE	QoQ	Abs	RMSE	QoQ	Abs	RMSE	QoQ
0	Model	0.0059	0.0600	0.0011	0.0245	0.2391	0.0019	0.0214	0.2199	0.0028
	Access	0.0087	0.0875	0.0068	0.0266	0.2657	0.0098	0.0242	0.2430	0.0060
	Ratio	***68%***	***69%***	***16%***	***92%***	***90%***	***19%***	***89%***	***91%***	***47%***
1	Model	0.0062	0.0615	0.0012	0.0249	0.2426	0.0008	0.0244	0.2341	0.0019
	Access	0.0078	0.0727	0.0033	0.0266	0.2583	0.0051	0.0281	0.2589	0.0033
	Ratio	***79%***	***85%***	***36%***	***94%***	***94%***	***15%***	***87%***	***90%***	***57%***
2	Model	0.0058	0.0573	0.0012	0.0260	0.2442	0.0011	0.0261	0.2414	0.0024
	Access	0.0084	0.0766	0.0033	0.0267	0.2471	0.0052	0.0294	0.2562	0.0038
	Ratio	***70%***	***75%***	***37%***	***97%***	***99%***	***22%***	***89%***	***94%***	***62%***
3	Model	0.0062	0.0602	0.0013	0.0246	0.2273	0.0013	0.0253	0.2257	0.0025
	Access	0.0095	0.0870	0.0035	0.0245	0.2276	0.0051	0.0269	0.2306	0.0035
	Ratio	***65%***	***69%***	***36%***	***100%***	***100%***	***25%***	***94%***	***98%***	***71%***
4	Model	0.0078	0.0675	0.0013	0.0242	0.2160	0.0013	0.0260	0.2204	0.0026
	Access	0.0111	0.0912	0.0030	0.0239	0.2261	0.0056	0.0261	0.2223	0.0049
	Ratio	***70%***	***74%***	***42%***	***101%***	***96%***	***23%***	***100%***	***99%***	***53%***