ACCC/AER Working Paper Series

Best estimates of expected inflation: a comparative assessment of four methods

Working Paper No. 11
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Acknowledgement

I wish to thank Professor Shaun Vahey, who refereed an earlier draft of this working paper, Dr Richard Hayes, Henryk Smyczynski, Paul Nguyen, Ben Stonehouse, Kenny Yap, Matthew Simpson, Qiao Huang, Dr Yuliya Moore, Dr Peter Gibbard, Sarah Paloni and Lisa Beckmann. I alone am responsible for any errors.

Series Note

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Citation details: ACCC/AER Working Paper No. 11, February 2017

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1. Introduction

1. The Australian Competition and Consumer Commission (ACCC) and the Australian Energy Regulator (AER) are responsible for the economic regulation of natural monopolies in Australia. The revenues/prices of regulated businesses are usually set by the ACCC and the AER such that these businesses can expect to meet their efficient building block costs of supplying monopoly services. The building block costs include the cost of capital, depreciation, operating expenditure and an allowance for taxation. Estimates of inflation expectations are an important input into the calculation of these building block costs.

2. The ACCC/AER estimate inflation expectations over a 10 year horizon. The ACCC/AER's current method of estimating inflation expectations is the Reserve Bank of Australia's (RBA) forecast CPI inflation rate 1 and 2 years ahead and the midpoint of the RBA target inflation band of 2 to 3 per cent from 3 to 10 years ahead.

3. During the 2013 rate of return consultation process and guideline, the AER raised the expected inflation estimation method as an issue for potential review. The AER considered the 10 year 'bond breakeven inflation rate' (BBIR) method as an alternative to its current method of estimating inflation expectations. The BBIR is implied by the difference between the yields on 10 year nominal and indexed (inflation-linked) Commonwealth Government Securities (CGS). Up until 2007–08, the AER employed the BBIR method to estimate inflation expectations. However, this method was subsequently abandoned because the lack of supply of indexed CGS was considered to be distorting yields on indexed CGS and BBIR estimates of expected inflation.

4. In its 2013 consultation paper, the AER observed that the supply of indexed CGS had increased in recent years and called for submissions on whether its current method should be changed.[1] At the time, stakeholders did not generally support such a change. However, in 2015 concerns were raised by electricity network service providers that the AER's current method results in biased estimates of market expectations of inflation. These concerns were based on claims that the RBA's monetary policy and inflation targeting were becoming less effective. Since the AER's current method is largely based on the midpoint of the inflation target band, inflation expectations may depart from the AER's estimates if RBA inflation targeting becomes less effective.

5. Network service providers also claim that the BBIR method now provides best estimates of expected inflation. They argue that the subsequent and substantial increase in the supply of indexed CGS has mitigated the distortions observed in BBIR estimates in 2007.[2] Compared to the BBIR, network service providers argue that the AER's current method less closely reflects market expectations of inflation.

6. As a result of the guideline consultation process and in response to more recent submissions from network service providers, the AER is reviewing its current method. This working paper contributes to the AER review. This paper comparatively assesses and ranks four different methods of estimating inflation expectations: the AER's current method, the BBIR method, inflation expectations implied from zero coupon inflation swaps and survey-based estimates. The method that is ranked above all others is considered to result in 'best estimates of expected inflation'.

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1 AER (2013), Consultation Paper, Rate of return guidelines, May, pp. 65-67; AER (2013), Better Regulation, Explanatory Statement, Draft rate of return guideline, August, p. 152.

2 For example, vide: SA Power Networks (2015), Attachment M28_CEG: Measuring expected inflation for the PTRM, June 2015, Attachment M.28; CEG (2015), Measuring risk free rates and expected inflation, A Report for United Energy, Dr Tom Hird, April.

7. This comparative assessment is divided into seven sections of inquiry. The first section defines and discusses ‘best estimates of expected inflation’. The second section defines the criteria of assessment for ranking the alternative methods with respect to best estimates of expected inflation. The third section assesses the AER’s current method as estimates of expected inflation. The fourth section considers whether the BBIR method is now likely to result in best estimates of expected inflation. The fifth section considers zero coupon inflation swaps as estimates of expected inflation. The sixth section evaluates the survey-based method as estimates of expected inflation. The final section is a summary of findings and conclusion where a ranking of the methods is undertaken.

2. Best estimates of expected inflation

8. The National Electricity Rules (NER) 6.4.2 (b)(1) states that the contents of the *post-tax revenue model* must include (but are not limited to):

> 'a method that the *AER* determines is likely to result in the best estimates of expected inflation'[3]

9. The NER's statement of 'best estimates of expected inflation' is too abstract for undertaking a comparative assessment. In this paper, this statement is subject to three proposed refinements to narrow the scope of the inquiry:

   (a) Expected inflation in best estimates of expected inflation corresponds to market expectations of the percentage growth in the Consumer Price Index (CPI) over a 10 year horizon. The 10 year horizon is the relevant horizon because the 10 year nominal risk free rate is a parameter in the regulated nominal weighted average cost of capital (WACC) of network service providers. The 10 year nominal risk free rate includes market expectations of inflation over the same term horizon.

   (b) Each method's estimates are calculated and comparatively assessed in the form of expected average annual inflation rates over a 10 year horizon. This form is an input into the AER's post-tax revenue model, which is used to determine the targeted revenue[4] of network service providers. This form is also used to calculate the 10 year real risk free rate from the 10 year nominal risk free rate (for the purpose of calculating the real WACC). However, where a method's implied inflation term structure provides important insights, the implied inflation term structure is also analysed.

   (c) 'Expected inflation' in best estimates of expected inflation does not correspond to inflation *outcomes* but corresponds to *market expectations* of inflation. The objective is to determine which method is likely to result in best estimates of *expected* inflation, not best estimates or forecasts of *actual* inflation. This is a definition of, rather than a refinement to, expected inflation. The definition is necessary since forecast accuracy of inflation outcomes is not the focus of the comparative assessment.

10. Best estimates of expected inflation are an important input for the calculation of the annual revenue for electricity network service providers. Estimates of expected inflation influence all the building block costs in the PTRM: the return on capital, regulatory depreciation, operating expenditure and taxation building blocks.[5]

11. A difference in the expected inflation rate can considerably change the final revenue of a network service provider. Suppose that the AER assesses two methods of estimating expected inflation: method A's estimate of the 10 year expected average annual inflation is 2.5 per cent each year and method B's estimate is 2 per cent each year. There is a difference of 0.5 per cent between the two estimates. In either case, suppose the actual inflation outcome throughout the regulatory control period is 2.5 per cent each year. The impact of these different estimates on final revenue is considered for Powerlink, a transmission network service provider, over the regulatory control period 2017–18 to 2021–22. If method B is chosen over method A,

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3 National Electricity Rules, Version 88, 6.4.2 (b)(1), p. 665.

4 The targeted revenue reflects the sum of these building blocks (unsmoothed revenue), but also the possible reallocation of revenue between years within the regulatory control period (smoothed revenue). The regulatory process then applies a 'CPI minus X' framework, which means the targeted revenue will be adjusted annually throughout the regulatory control period for actual inflation outcomes (using CPI). Thus, final revenue will reflect both the estimates of expected inflation and the annual true-up for inflation outcomes.

5 The closing RAB (and hence revenue in all subsequent regulatory control periods) will also be affected by the inflation adjustments in the roll forward model.

Powerlink's final revenue (in real 2016–17 dollars) will be higher by approximately $200 million or 5.5 per cent over the regulatory period. Note, however, the influence of expected inflation estimates on final revenue may differ considerably across network service providers.

12. The efficiency implications of not employing best estimates may be assessed through changes to the real WACC. The real WACC is calculated from the nominal WACC and the estimates of expected inflation used in the PTRM at the start of the regulatory control period. If estimates of expected inflation deviate from market expectations, the real WACC may no longer correspond to the real cost of capital of a comparable benchmark efficient entity. This may distort the investment and consumption decisions of the regulated business and consumers, respectively. The distortion in the behaviour of these economic agents may not result in the efficient use, operation of and investment in monopoly infrastructure.

13. Four methods of estimating inflation expectations are considered in this comparative assessment:

- the AER's current method: 10 year estimates of expected inflation comprising of the RBA's forecast CPI inflation rate 1 and 2 years ahead[6] and the midpoint of the RBA target inflation band of 2 to 3 per cent from 3 to 10 years ahead
- the 10 year bond breakeven inflation rate (BBIR) implied by the difference between the yields to maturity on nominal and indexed CGS
- the 10 year expected inflation rate implied from the prices of zero coupon inflation swaps, and
- survey-based estimates of inflation expectations over a 10 year horizon.

14. The ranking of the four methods with respect to best estimates of expected inflation are informed by five criteria of assessment: relative congruence with market expectations of inflation (whether estimates of a particular method more closely correspond to market expectations of inflation), robustness, transparency, replicability and simplicity. All else equal, a method that produces best estimates is one where the estimator is robust and more closely corresponds to market expectations of inflation over a ten year forecast horizon. And for the purposes of economic regulation, a method that is likely to result in best estimates is one that is the most transparent, replicable and simple to employ. Each criterion is defined in the paper.

15. The comparative assessment of the methods considered is framed by the following questions:

(a) Does the AER's current method continue to provide best estimates of expected inflation? What are the advantages and disadvantages associated with the AER's current method?

(b) In 2007, the fall in the supply of outstanding indexed CGS was identified as a cause of bias in BBIR estimates and as a result the AER abandoned this method. Now that the supply of outstanding indexed CGS has increased, does this method produce best estimates of expected inflation?

(c) Are best estimates of expected inflation implied from the prices of zero coupon inflation swaps? What are the advantages and disadvantages of this method?

(d) There are a number of studies that consider survey-based estimates as suitable or even superior proxies for inflation expectations. What are the advantages and disadvantages of this method?

[6] Where the RBA forecast CPI inflation rate 1 and 2 years ahead is a range, the midpoint of the range is used.

16. *A priori,* a method that is likely to result in best estimates of expected inflation is a market-based method – that is, estimates of expected inflation implied from the prices of market-traded instruments:

    (a) Market-based methods are more consistent with the use of other market-obtained estimates of WACC parameters. For example, the term structure of inflation implied from the prices of market-traded financial instruments may be more consistent with the term structure of the nominal risk free interest rate.

    (b) Schlogl (2009) argues that market-implied estimates of expected inflation are superior in that they are forward-looking and marked-to-market:

        - they are forward-looking since market-implied estimates of expected inflation are based on the aggregation of all available information and expectations of market participants
        - they are marked-to-market since the implied expected inflation rate is priced in market-traded instruments and it represents the future level of inflation that can be risk managed through the trade of these instruments.[7]

    (c) A market-based method may provide readings of inflation expectations on a more timely basis than non-market based methods and can also account for structural shifts in behaviour of inflation to the extent that such shifts are perceived by market participants.[8]

17. However, there are challenges and problems associated with the estimates of expected inflation implied from the prices of market-traded instruments. For market-based methods to produce unambiguously better estimates of expected inflation, investors must be risk neutral and the assumptions of efficient markets, such a highly liquid trade, insignificant transaction costs, perfect information and ease of arbitrage are required.

18. These assumptions may not hold in reality. The relaxation of any these assumptions may result in market-based methods producing potentially biased and distorted estimates of expected inflation. Identifying, estimating and removing these biases from market-based estimates may also be problematic.

19. Given the potential challenges and problems of estimating expected inflation from the prices of market-traded financial instruments, non-market based methods cannot be disregarded as potential best estimates of expected inflation. Therefore, market and non-market based methods are considered in this comparative assessment. The AER's current method is a non-market based method that is considered first in this paper. The market-based methods of BBIR estimates and zero coupon inflation swaps are then critically examined. Finally, survey-based estimates of expected inflation are another non-market method that is assessed. The final section ranks the market and non-market based methods with regards to best estimates of expected inflation against assessment criteria discussed below.

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7 Erik Schlogl, 'Extracting the market-implied term structure of forward inflation', 9 February 2009, addendum to IPART (2009), *Adjusting for expected inflation in deriving the cost of capital*, Analysis and Policy Development – Discussion Paper, February 2009, p. 1.

8 Brian Sack (2000), 'Deriving Inflation Expectations from Nominal and Inflation-Indexed Treasury Yields', Division of Monetary Affairs, Board of Governors of the Federal Reserve System, Washington DC,16 May, p. 22.

3. Criteria informing the comparative assessment

20. The ranking of the four methods with respect to best estimates of expected inflation are based on five criteria of assessment. These criteria are outlined below.

3.1. Relative congruence

21. Relative congruence refers to the relative closeness of correspondence or the relative closeness of similarity of a method's estimator with 10 year market expectations of inflation.

22. Relative congruence also refers to the relative closeness of correspondence of a method's estimator with the characteristics and processes of market expectations of inflation. Relative congruence may therefore also include a close correspondence of the estimator with the time variation, stability or volatility of these expectations.

23. A particular method may produce relatively congruent estimates of market expectations of inflation *vis-à-vis* other methods if, for example:

- there are several or more research findings that this method results in estimates of expected inflation which may contain zero, small or insignificant biases and/or distortions
- there are several or more research findings that this method produces estimates that closely mimic the characteristics and processes of market expectations of inflation, and
- there is less evidence that alternative methods produce estimates that more closely correspond to market expectations of inflation, or
- the biases, premia and/or distortions related to alternative methods are well-documented in the literature and are difficult to estimate and remove.

24. The criterion of relative congruence does not imply measurability and comparability of the relative distance of each method's estimator from market expectations of inflation. The criterion of relative congruence allows for a simpler ordinal ranking of estimators of methods based on their similarity with and correspondence to market expectations of inflation. The ordinal ranking avoids the many issues associated with measuring and comparing the relative distance of each method's estimator from market expectations of inflation. For a measurement and comparison of the relative distance, common metrics must be applied to each method. For example, the same proxy for expected inflation and the same sample period are necessary for a comparison of methods. However, as observed below, common metrics are rarely applied across the studies of the same or different methods. Therefore, a robust measure and comparison of the relative distance of each method's estimator may be elusive.

25. Relative congruence is not relative unbiasedness. Relative unbiasedness *can* imply measurability and comparability of the relative distance of the estimators from the market expectations of inflation. However, relative unbiasedness may be used in this comparative assessment of estimators from *within a single study* of a method, where measurability of the relative distance of estimates from inflation expectations may be possible. For example, if there is a study which finds that estimates from a market-based method contain significant biases, a 'bias-adjusted' estimator of expected inflation from the same study may be considered relatively unbiased compared to the 'raw' estimator. This is because the bias-adjusted estimator may be considered to more closely approximate the expected inflation rate implied by the 'unbiased

expectations hypothesis'.[9] The magnitude of the 'relative unbiasedness' may be given by the size of the bias adjustment.

3.2. Robustness

26. A method produces robust estimates of expected inflation if the estimator does not change significantly in response to phenomena that may have little or no influence on 10 year market expectations of inflation. These phenomena may include inflation surprises, changes to short term inflation expectations or actual and perceived changes to economic variables. If, however, there are phenomena that influence long term inflation expectations, a robust estimator will reflect their influence and change with long term inflation expectations.

    A method also produces estimates that are robust if the estimates do not change significantly if different, but equally appropriate, models or estimation methods are applied. This definition also applies to 'bias-adjusted' estimates of expected inflation. If across studies the scale and sign of bias-adjustments are similar, 'bias-adjusted' estimates may be considered robust. That is, if estimates of expected inflation are found to include significant biases, bias-adjusted estimates are robust if they remain largely unresponsive to:

    - different proxies used to estimate the biases
    - different sample periods used to estimate the biases
    - different models or estimation methods employed, and
    - any changes to the size, sign and number of biases over time.

27. There may be complementarities between the criteria of relative congruence and robustness. For example, a method that produces estimates that are robust to phenomena which have little to no influence on long term market expectations of inflation may also be relatively congruent with market expectations of inflation.

3.3. Transparency and replicability

28. For the purpose of economic regulation, a method that produces estimates that are more transparent and replicable are better estimates of expected inflation. Transparent and easily replicated estimates can be scrutinised and verified by all stakeholders, and may improve regulatory certainty for stakeholders since the inputs and calculations are easily understood and can be readily cross-checked.

29. A method that is transparent and replicable may also improve the consistency in the calculation of inflation estimates and may reduce the likelihood that both inputs and calculations are incorrect. Therefore, since estimates of expected inflation are an input into the calculation of building block costs, a method that is relatively transparent and replicable may lower the risk that the building block costs are distorted.

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[9] Forward inflation rates implied from the prices of market-traded financial instruments satisfy the unbiased expectations hypothesis if these rates are unbiased estimators of expected future short term inflation rates. Because the predictions of the unbiased expectations hypothesis are consistent with the assumption of risk neutrality, investors are uninfluenced by uncertainty and risk so that implied forward rates do not contain inflation risk premia or liquidity (risk) premia. These points are similar to Choudry's (2001) application of the unbiased expectations hypothesis to interest rates. Moorad Choudry (2001) *The Bond and Money Markets: Strategy, Trading, Analysis,* Butterworth Heinemann, Oxford, pp. 116-124. Vide: Barbara Petitt, Jerald Pinto, Wendy Pirie, Robin Grieves and Gregory Noronha (2015), *Fixed Income Analysis*, Third Edition, Wiley, New Jersey, p. 502; Dom Chance (2008), *Essays in Derivatives*, John Wiley and Sons, New Jersey, pp. 273-275.

3.4. Simplicity

30. A method which produces estimates that are simpler to employ is likely to produce better estimates of expected inflation. A simpler method may result in the construction of estimates that require less regulatory (taxpayer) resources and may be more readily verified by all stakeholders. Ease of verification may reduce the contentiousness of a method's estimates.

3.5. Ranking the methods and potential trade-offs between criteria

31. To minimise distortions in the regulatory determination of the real WACC and building block costs, relative congruence and robustness of estimators may be ranked above other criteria because best estimates of expected inflation:

    - should closely correspond to the market expectations of inflation at any point in time, and
    - should be robust to inflation surprises, shocks to short term inflation expectations and other phenomena that may have little or no influence on 10 year market expectations of inflation.

32. However, the ranking of relative congruence and robustness above other criteria is not absolute. There may be trade-offs between the criteria of assessment such that the ranking of criteria may necessarily change. There may be circumstances where other criteria may be given higher precedence by an economic regulator. For example, even a method which produces slight improvements in relative congruence and robustness may not necessarily be adopted if this method is considerably opaque, complex and is costly to employ. An alternative method that is more transparent and replicable albeit slightly less congruent and robust may be chosen because there is considerably less stakeholder uncertainty over its estimates. Stakeholders may more readily scrutinise and reproduce the alternative method's estimates, such that its estimates may be considered less contentious. The alternative method may also require considerably less regulatory resources to employ. In this circumstance, the method that is slightly less congruent and robust but more transparent, replicable and simple may be considered to produce best estimates of expected inflation.

4. The Australian Energy Regulator's current method

33. Since the 2008 Final Decision on SP AusNet[10], the AER considers that best estimates of expected inflation over a 10 year horizon is the RBA's forecast of CPI inflation 1 and 2 years ahead and the midpoint of the RBA's target inflation band from 3 to 10 years ahead.[11]

34. The AER's current method is comparatively assessed in the form of the 10 year geometric annual average of the RBA CPI forecasts and the midpoints. The 10 year geometric annual average is also used for the calculation of the real WACC and is an input into the PTRM. (Appendix 1 provides a short technical explanation of the AER's current method.)

35. The AER's estimates of expected average annual inflation over a 10 year horizon are updated every quarter if there are changes to the RBA forecasts of CPI inflation. The RBA forecasts of CPI inflation are published in February, May, August and November of each year on the release of the RBA's Statement on Monetary Policy.

36. Figure 1 presents an approximate replication of the AER's current method of estimating expected average inflation over a 10 year horizon from the March quarter 2008, when the AER's current method was adopted, to the June quarter 2016. The RBA inflation target band of 2 to 3 per cent is also shown. The estimates are close to the midpoint of the band and are stable over time: the standard deviation for the sample period is 7 basis points (quarterly estimates of expected inflation).

37. If 10 year market expectations of inflation are anchored within the RBA inflation target band and are stable over time, then the AER's estimates may be congruent with market expectations of inflation. The stability of the AER's estimates may also imply that such estimates are robust to phenomena that have little influence on long term market expectations of inflation.

38. If, however, RBA inflation targeting is perceived to have lost its effectiveness and expectations are not anchored within the target band, the estimates from the AER's current method may be less congruent with 10 year market expectations of inflation. The heavy weighting toward the midpoint introduces the risk that the AER's estimator becomes largely oblivious to systematic and relevant information that inform or reflect changes to long term inflation expectations.

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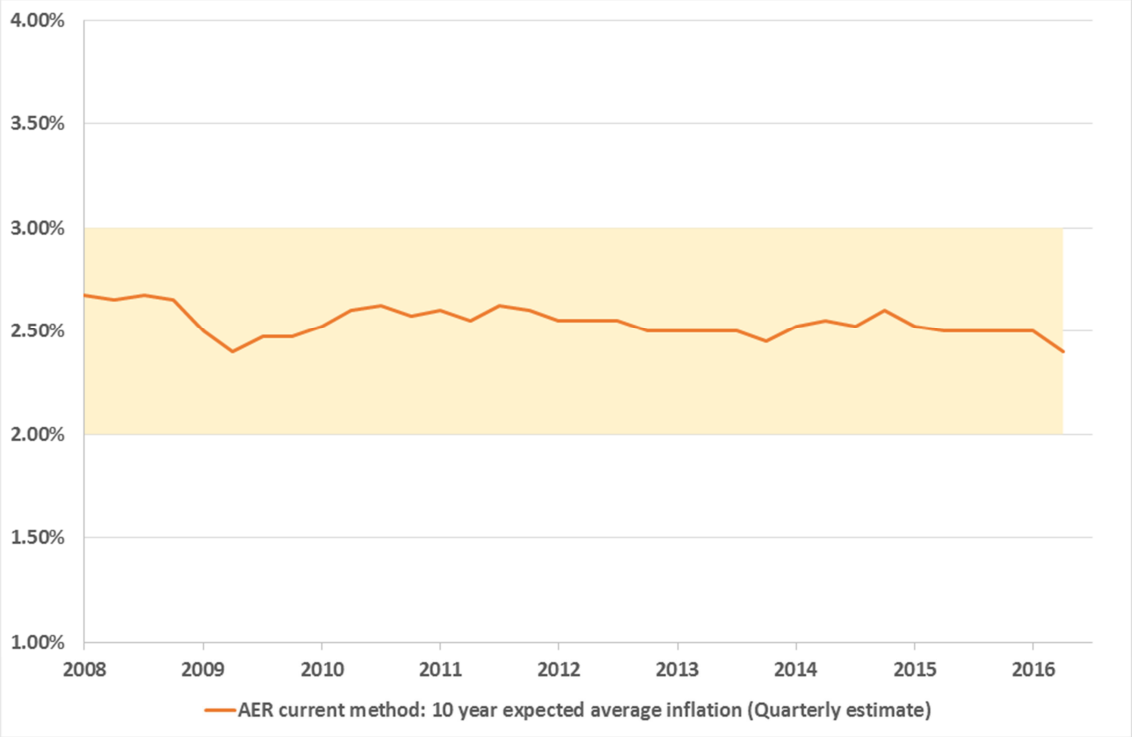
10 AER (2008), *SP AusNet Transmission Determination 2008-09 to 2013-14*, Final decision, pp. 102-106.

11 In the AER's (2008) *Final Decision on SP AusNet*, a simple or arithmetic average of the RBA 1 and 2 year inflation forecasts and the midpoint of the target inflation band was initially considered appropriate (p. 106). However, in later decisions the geometric average is considered more appropriate (for example, vide AER (2010) *Final Decision, Victorian electricity distribution network service providers, Distribution determination 2011-2015,* p. 475; AER (2014) *Final Decision SP AusNet Transmission determination 2014-15 to 2016-17*, p. 24). Vide: AER (2015), *Final Decision, Amendment Electricity transmission network service providers, Post-tax revenue model handbook*, 29 January, p. 15 (footnote).

Figure 1: An approximate replication of the AER's current method of estimating the 10 year expected inflation rate, March quarter 2008 to June quarter 2016, quarterly data[12]



Source: RBA February, May, August and November Statements on Monetary Policy, February 2008 to May 2016. Where the RBA forecasts a range of potential inflation outcomes, the midpoint of this range is chosen.

4.1. Advantages of the AER's current method

39. There are a number of potential advantages of the AER's current method such that the AER's estimates may be relatively congruent with long term inflation expectations inflation and are robust. The AER's current method is also simple to employ, transparent and easily replicated.

    (a) The AER's current method relies on RBA forecasts for the first two years of 10 year expected inflation estimates. There are studies which find that RBA forecasts of CPI inflation are relatively accurate and have considerable explanatory power, such that RBA forecasts may both inform and more closely reflect short term market expectations of inflation.

        i. Tawadros (2013) tests the hypothesis that the RBA possesses information about inflation that the private sector does not have. The test of the 'asymmetric information hypothesis' is undertaken by comparing the predictive accuracy of the RBA inflation forecasts and inflation forecasts made by three other private sources: non-academic market economists,

[12] To approximately replicate the AER's current approach, RBA CPI inflation forecasts one and two years ahead are obtained from quarterly Statements on Monetary Policy made in February, May, August and November of each year. The assumed forecast horizon of the RBA inflation forecast 1 year ahead in: February is the end of the current calendar year; May is the end of the following financial year; August is the end of the current financial year; and November is the end of the following calendar year. The assumed forecast horizon of the RBA inflation forecast 2 years ahead in: February is the end of the following calendar year; May is the end of the financial year after the following financial year; August is the end of the following financial year; and November is end of the calendar year after the following calendar year. If the RBA produces a forecast range of inflation rates, the midpoint of the range is chosen.

union officials and the forecasts made by consumers or business people.[13] In absolute terms, Tawadros finds that the RBA forecasts produce much lower forecasting errors than the forecasts made by the three other private sources. The empirical results show that the RBA has superior predictive information about inflation over the recent inflation targeting period of June 1993 to December 2010.[14] However, Tawadros' findings may also suggest the RBA possesses superior judgment about predicting future inflation outcomes and not necessarily superior information.

ii. Tulip and Wallace (2012) estimate the uncertainty around RBA forecasts of inflation and other macroeconomic variables. Tulip and Wallace compare the performance of RBA forecasts of CPI inflation with forecasts based on a random walk and the midpoint of the RBA inflation target band (2.5 per cent) over the sample period 1993 to 2011.[15]

   Tulip and Wallace find that RBA first year forecasts of CPI inflation significantly outperform CPI inflation forecasts based on a random walk ($p = 0.00$) and the midpoint of the inflation target band ($p = 0.04$). RBA second year forecasts of CPI inflation significantly outperform forecasts based on a random walk ($p = 0.03$) but did not significantly outperform forecasts based on the midpoint of the inflation target band.[16] The latter result suggests that there is a rapid reversion of CPI inflation to the mean and such an outcome is consistent with the successful targeting of the inflation rate.

   Tulip and Wallace also compare RBA forecasts of CPI inflation with the survey estimates of CPI inflation from about two dozen private sector forecasters (from Consensus Economics) up to seven quarters ahead. While Tulip and Wallace find that RBA forecasts of CPI inflation are slightly more accurate than private sector forecasts, the differences are small and are not statistically significant.[17]

iii. The explanatory power of the RBA's short term inflation forecasts with respect to inflation outcomes does not directly suggest that RBA inflation forecasts are closer to short term market expectations of inflation. The relative accuracy of any forecast method or technique does not necessarily indicate that such forecasts are relatively more congruent with market expectations of inflation.

   However, if the explanatory power of the RBA's forecasts is considered credible by market participants, the RBA's forecasts may both inform and closely reflect short term market expectations of inflation. For example, superior forecasts of inflation may inform market expectations of inflation since such forecasts may improve the management and hedging of inflation risk in the portfolios of inflation-linked assets and liabilities.

   To the extent that short term inflation expectations influence the term structure of inflation expectations, including the RBA's short term inflation forecasts may improve the congruence of the AER's current estimates with market expectations of inflation.

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13 George Tawadros (2013), 'The information content of the Reserve Bank of Australia's inflation forecasts', *Applied Economics*, 45, pp. 623-628.

14 *ibid.*, pp. 626-627.

15 Peter Tulip and Stephanie Wallace (2012), 'Estimates of Uncertainty around the RBA's Forecasts', *RBA Research Discussion Paper – November 2012*, RDP2012-07, pp. 1-47.

16 *ibid.*, p. 11.

17 *ibid.*, p. 16.

(b) The congruency of the AER's current method with 10 year market expectations of inflation depends on the anchoring of these expectations within the RBA inflation target band. There are studies which find that long term inflation expectations may be informed by and anchored within the RBA's target inflation band:

i. Gillitzer and Simon (2015)[18] examine the effectiveness of the RBA's inflation targeting in anchoring inflation expectations over the period 1991 to 2013. Their proxy for inflation expectations is a weighted average of a forward-looking measure of long term inflation expectations from Consensus Economics, and a backward-looking measure, lagged year-ended inflation.[19] They find that as a result of the success and credibility of the RBA's inflation targeting, long-term inflation expectations are firmly anchored at target inflation rates. The anchoring effect is estimated: since 1998 long term inflation expectations have never deviated from the midpoint of the RBA's inflation target band by more than 0.2 percentage points.[20] The stability and anchoring of long term inflation expectations contrasts with the period before 1998, when long-term inflation expectations and contemporaneous inflation moved together.[21]

Gillitzer and Simon also contend that if long term inflation expectations are well-anchored they should not respond to current-year inflation surprises. And if they are poorly anchored or adaptive, one would expect to see revisions to longer-term expectations when the surprise occurs. For this study, Gillitzer and Simon use Consensus inflation expectations for the current year and each year out to a 6 year horizon.[22] From 1991 to 2000, they find that a one standard deviation surprise in current-year inflation tended to raise professional forecasters' inflation expectations at a five-year horizon. From 2001 to 2013, however, inflation surprises have a negligible effect on long term inflation expectations.

Over the period 2001 to 2013, Gillitzer and Simon also find that the relationship between unemployment and inflation has become substantially weaker compared to the early years of inflation targeting. The variability of inflation is now dominated by transitory changes and less influenced by deviations in unemployment from its natural rate. The anchoring of inflation expectations at target inflation rates is found to be a principal reason why both inflation and inflation expectations are less responsive to a decline in unemployment.[23]

The weaker relationship between unemployment and inflation is identified by a 'flatter' Phillips Curve. The Phillips Curve describes the relationship between the unemployment rate and the inflation rate. Kuttner and Robinson (2010) and Paradiso and Rao (2012) find that the Phillips Curve

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18 Christian Gillitzer and John Simon (2015), 'Inflation Targeting: A Victim of Its Own Success?', RDP 2015-09, August, *Reserve Bank of Australia Discussion Paper*, pp. 1-27.

19 For the period 1991 to 2013, Gillitzer and Simon use the professional forecasts of Consensus Economics 6–10 years ahead (June and December quarters) as a proxies for long term inflation expectations. Consensus Economics is an economic survey organisation which polls professional forecasters each month to obtain their forecasts. The survey estimates include long term forecasts of inflation including forecast probabilities. http://www.consensuseconomics.com/index.htm

20 Christian Gillitzer and John Simon (2015), 'Inflation Targeting: A Victim of Its Own Success?', RDP 2015-09, August, *Reserve Bank of Australia Discussion Paper*, p. 9.

21 *ibid*., p. 7.

22 *ibid*., pp. 3-4. Gillitzer and Simon look at the way Consensus inflation expectations change between forecasts in the March and September quarters.

23 Christian Gillitzer and John Simon (2015), 'Inflation Targeting: A Victim of Its Own Success?', RDP 2015-09, August, *Reserve Bank of Australia Discussion Paper*, pp. 13-14.

has flattened for Australia since inflation targeting was introduced.[24] A flatter Phillips Curve implies that the inflation rate is much less affected by the business cycle. The reduced sensitivity of the inflation rate to the business cycle may reflect an anchoring of inflation expectations at inflation target rates.[25]

ii. Mallick (2015) also estimates the Phillips Curve for Australia over the sample period of the third quarter of 1959 to the fourth quarter of 2012.[26] Mallick finds that the Phillips Curve has flattened since 1993, when RBA inflation targeting was introduced. Mallick attributes the flattening of the Phillips Curve to the anchoring of the inflation expectations at the RBA inflation target. Mallick also finds that while the Phillips Curve is flatter, it remains downward sloping over the business cycle. This result indicates that the effectiveness of the RBA's monetary policy in stabilising the business cycle 'has not diminished'.[27]

iii. Finlay and Wende (2011) estimate inflation expectations over the period 31 July 1992 to 15 December 2010.[28] Finlay and Wende's proxies for inflation expectations over 1, 5 and 10 year horizons are model-derived estimates of expected inflation using indexed bond price data and inflation forecasts from Consensus Economics. Finlay and Wende find that 5 and 10 year inflation expectations are relatively stable and appear well anchored within the RBA inflation target band of 2 to 3 per cent. In contrast, they find that 1 year inflation expectations are strongly influenced by current inflation and are much more volatile.[29]

iv. Leu and Sheen (2006)[30] find that the over the period 1991 to 2002 RBA monetary policy switched more acutely to addressing output gaps during downturns, which Leu and Sheen argue is a positive payoff from the credibility the RBA has acquired with its successful inflation targeting regime. With inflation low and in check the RBA has been more able to use monetary policy to stabilise the business cycle, particularly in downturns. Leu and Sheen argue that this policy flexibility is due to the anchoring of inflation expectations to an explicit inflation target band of 2 to 3 per cent.[31]

v. Market expectations of inflation may be informed by the historical success of RBA monetary policy. Jaaskela and McKibbin (2010) find that since the RBA's adoption of inflation targeting, economic agents appear to be using a longer history of data, including historical inflation data, to form their inflation expectations. This behaviour is consistent with more stable outturn inflation and interest rate outcomes.[32] If longer term inflation outcomes more heavily inform inflation expectations, contemporaneous inflation may

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24 Ken Kuttner and Tim Robinson (2010), 'Understanding the flattening of the Phillips Curve', *North American Journal of Economics and Finance*, 21(2), pp. 110-125; Antonio Paradiso and Bhaskara Rao (2012), 'Flattening of the Phillips curve and the role of the oil price: An unobserved component model for the USA and Australia', *Economics Letters*, 117(1), pp. 259-262.

25 *ibid*., p. 13.

26 Debdulal Mallick (2015), 'A Spectral Representation of the Phillips Curve in Australia', Faculty of Business and Law, School Working Paper, Economic Series, SWP 2015/7, pp. 1-48.

27 *ibid*., p. 25.

28 Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, pp. 1-35.

29 *ibid*., pp. 3-4; pp. 13-15; p. 22.

30 Shawn Chen-Yu Leu and Jeffery Sheen (2006), 'Asymmetric Monetary Policy in Australia', *The Economic Record*, 82, Special Issue, September, pp. S85-S96.

31 *ibid.,* pp. S85-S86; pp. S94-S95.

32 Jarkko Jaaskela and Rebecca McKibbin (2010), 'Learning in an Estimated Small Open Economy Model', RDP 2010-02, March, *Reserve Bank of Australia Discussion Paper,* pp. 1-45.

correspondingly have less of an influence on these expectations. Through the heavy weighting on the midpoint of the inflation target band, the AER's current method is less influenced by changes to contemporaneous inflation. The AER's current method is more consistent with inflation expectations formation in stable inflation environments like Australia, where a longer history of data may inform such expectations.

(c) The robustness of the AER's current method may be measured by how this estimator responds to market phenomena that have little to no influence on long term market expectations of inflation.

As a result of including RBA short term inflation forecasts, the AER's current method may capture the influence of short term inflation expectations on the term structure of inflation expectations. However, short term inflation expectations may also be relatively volatile and may considerably depart from long term inflation expectations.[33]

Through the relative weighting of RBA forecasts and the midpoint, the AER's current method balances the influence of short term inflation expectations on the inflation term structure with the relative stability of long term market expectations of inflation. Because the influence of relatively volatile short term inflation expectations is limited, the AER's current method may be considered robust. The robustness and relative stability of the AER's 10 year estimates of expected inflation are consistent with the findings of Leu and Sheen (2006), Finlay and Wende (2011), Mallick (2015) and Gillitzer and Simon (2015) that long term inflation expectations:

- are relatively stable over time
- are anchored at or within the inflation target band, and/or
- do not respond significantly to inflation surprises.

The robustness of the AER's estimates may also improve their congruency with 10 year market expectations of inflation since the AER's estimates are unlikely to significantly depart from the anchored long term inflation expectations.

(d) The AER's current method is simple, transparent and easily replicated. The AER's current method can be easily calculated with the publicly available inputs of RBA forecasts and the midpoint of the inflation target band. The simple calculation of the expected average inflation rate allows for ready scrutiny and verification by stakeholders.

The method employed by the RBA to generate the 1 and 2 year CPI inflation forecast is not disclosed in detail and therefore may be less transparent and replicable. However, this lack of transparency and replicability is unlikely to add to regulatory uncertainty since these forecasts have a limited effect on 10 year estimates and because the RBA's forecast method is independent of the influence of the regulator and relevant stakeholders.

[33] Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, pp. 3-4; pp. 13-15; p. 22.

4.2. Disadvantages of the AER's current method

40. The AER's current method has several disadvantages, such that there is a risk that AER's current method may be less congruent with 10 year market expectations of inflation.

    (a) If monetary policy loses or is perceived to have lost its effectiveness in influencing economic activity, there is a risk that inflation expectations may deviate systematically from the target inflation band. In which case, the estimator of inflation expectations based on a geometric average of the RBA forecast and midpoint may be systematically too high or too low relative to market expectations of inflation.

    (b) The AER's current method is a combination of a policy objective (the target band) and quarterly forecast estimates produced by a single entity (the RBA). In certain circumstances, this combination may, when compared to other methods, reduce the relative congruence of the AER's current estimates with 10 year market expectations of inflation.

        i. The AER's current method relies less on an aggregation of available, up-to-date and relevant information that may inform 10 year market expectations of inflation. Therefore, there is a risk that estimates produced by the AER's current method may systematically depart from these expectations at any point in time.

        ii. The AER's estimator is heavily weighted toward the midpoint of the target band. As a result, there is a risk that the AER's estimator becomes largely oblivious to systematic and relevant information that inform or reflect changes to long term inflation expectations. In this situation, the AER's estimator would be less congruent with market expectations of inflation.

5. The bond breakeven inflation rate

41. Up to 2007, the AER considered that the BBIR produced best estimates of 10 year market expectations of inflation.[34] The BBIR is calculated from the Fisher Equation:

$$(1 + i_n) = (1 + i_r)(1 + \pi^e) \quad (1)$$

$$\pi^e = \frac{1+i_n}{1+i_r} - 1 \quad (2)$$

where:

i_n is the 10 year nominal risk free rate

i_r is the 10 year real risk free rate

π^e is the 10 year expected inflation rate, representing the expected average inflation rate over a 10 year horizon. The 10 year expected inflation rate, π^e, is given in this equation because there is an implied assumption that potential biases, premia and distortions in the BBIR are not significant.

42. The 10 year nominal risk free rate is obtained from the yield to maturity on 10 year nominal Commonwealth Government Securities (CGS). The 10 year real risk free rate is obtained from the yield to maturity on 10 year inflation-linked CGS, hereafter identified as 'indexed CGS'. Yields to maturity on CGS, not interest rates, are used to estimate the average annual BBIR over a 10 year horizon.[35] The BBIR is the rate that results in the holder of the indexed CGS 'breaking even' with the holder of the nominal CGS.[36]

43. Table 1 provides a number of key characteristics of nominal and indexed CGS. Both nominal and indexed CGS are actively traded in the market and their observed yields to maturity are publicly available.

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[34] AER (2008), *SP AusNet Transmission Determination 2008-09 to 2013-14*, Final decision, p. 99. .

[35] Note that this is not the correct approach to estimating the BBIR. The 10 year BBIR, obtained from the Fisher Equation, is the geometric difference between the 10 year nominal risk-free interest rate and the 10 year real risk-free interest rate, not the geometric difference between the 10 year yields to maturity on nominal and indexed CGS. The correct approach requires converting the coupon-paying nominal and indexed CGS into zero coupon bonds to obtain a term structure of interest rates. However, estimating the term structure of nominal and real interest rates (nominal and real spot rate curves) from the prices of coupon-paying nominal and indexed CGS, respectively, requires extensive and complex computations and modelling, which is further complicated by the few tenors of indexed CGS. While Bloomberg and RBA provide the term structure of nominal interest rates, the term structure of midpoint real interest rates obtained from indexed CGS is not available. Finlay and Wende (2011) argue that when using standard approaches, the zero coupon real yield curve cannot be reliably estimated given the few indexed CGS. The conversion does not necessarily imply term structures of nominal and real interest rates that are absent any distortions, biases or premia. Further, the size of the estimated premia is likely to be sensitive to term structure model employed. This paper considers that the less precision of yield-curve based approaches to estimate and analyse the Australian BBIR does not detract from the arguments propounded. Therefore this paper employs the simple approach of using the Fisher Equation to compute the BBIR from nominal and indexed bond yields. Mark Deacon, Andrew Derry and Dariush Mirfendereski (2004*), Inflation-indexed Securities – Bonds, Swaps and Other Derivatives*, Second Edition, John Wiley & Sons, West Sussex, pp. 79-81; Frank Fabozzi and Steven Mann (eds.), *The Handbook of Fixed Income Securities, Seventh Edition*, McGraw-Hill, New York, pp. 139-157; Olivier de La Grandville (2001), *Bond Pricing and Portfolio Analysis: Protecting Investors in the Long Run*, The MIT Press, Cambridge, p. 62, pp. 187-192; Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, p. 2.

[36] Brynjolfsson (2005) describes this process for US nominal Treasuries and US Treasury Inflation Protected Securities (TIPS). John Brynjolfsson (2005), 'Inflation Linked Bonds', in Frank Fabozzi and Steven Mann (eds.), *The Handbook of Fixed Income Securities, Seventh Edition*, McGraw-Hill, New York, pp. 355-356.

Table 1: Characteristics of nominal and indexed Commonwealth Government Securities

Nominal CGS	Indexed CGS
$100 AUD Face Value	$100 AUD Face Value
Coupon interest payments are made semi-annually at half the annual amount on each coupon interest payment date. The coupon interest rate payable is a fixed annual interest rate divided by 2.	Coupon payments are made each quarter. The coupon payments are calculated by multiplying a fixed quarterly interest rate (fixed real coupon rate) by the adjusted capital value of the security. The capital value of the security is adjusted by reference to movements in the Consumer Price Index (CPI) all groups, weighted average of eight capital cities as maintained and published quarterly by the Australian Bureau of Statistics. Indexed CGS are known as 'capital-indexed' bonds where the fixed real coupon rate and nominal principal value rises with inflation.[37]
On the maturity date, nominal CGS pays a final coupon payment plus the Face Value.	On the maturity date, indexed CGS pays a final coupon payment plus the adjusted capital value of the bond. On the maturity date, the final redemption value will be no less than the $100 Face Value, irrespective of the movements in the CPI over the life of the security.
After issue nominal CGS may be traded on the secondary market. There is an active secondary market for nominal CGS and there are a number of market makers.	After issue indexed CGS may be traded on the secondary market. There is an active secondary market for indexed CGS and there are a number of market makers.
As at 30 June 2016: There are 7 tenors of indexed CGS up to approximately 24 years maturity. There are 4 tenors of indexed CGS up to approximately 10 years maturity. The outstanding issue value is approximately $30 billion.[38]	As at 30 June 2016: There are 22 tenors of nominal CGS up to approximately 23 years maturity. There are 14 tenors of nominal CGS up to approximately 10 years maturity. The outstanding issue value is approximately $385 billion.[39]
Nominal CGS are quoted and traded on the secondary market on a nominal yield to maturity[40] basis rather than a price basis.	Indexed CGS are quoted and traded on the secondary market on a real yield to maturity[41] basis rather than a price basis.

37 Mark Deacon, Andrew Derry and Dariush Mirfendereski (2004), *Inflation-indexed Securities – Bonds, Swaps and Other Derivatives*, Second Edition, John Wiley & Sons, West Sussex, p. 18.

38 Historical Statistics, Table H13 Government Securities on issue 30 June 1983 to June 2016. Australian Office of Financial Management, Australian Office of Financial Management, Treasury Indexed Bonds.

39 Historical Statistics, Table H13 Government Securities on issue 30 June 1983 to June 2016. Australian Office of Financial Management, Australian Office of Financial Management, Treasury Bonds.

40 The real yield on a nominal bond can be calculated but it is more difficult. When analysts discuss the real yield on nominal bonds they may be referring to: (1) the current real yield by subtracting year-on-year inflation from the bond's nominal yield; (2) estimating the nominal bond's expected real yield based on an estimate of the expected future inflation rate; or (3) discussing historical realised yields on nominal bonds that have matured. John Brynjolfsson (2005), 'Inflation Linked Bonds', in Frank Fabozzi and Steven Mann (eds.), *The Handbook of Fixed Income Securities, Seventh Edition*, McGraw-Hill, New York, pp. 355-356.

The standard bid-ask spread for securities longer than one year to maturity is the spread dictated by market price makers given the prevailing market conditions at the time.	The standard bid-ask spread for securities longer than one year to maturity is the spread dictated by market price makers given the prevailing market conditions at the time.
Key holders of nominal CGS: various.	Key holders of indexed CGS: pension funds, insurers (for example). Pension funds and insurers have future liabilities that are linked to real variables. They may hedge these future liabilities by holding indexed CGS.

Source: Australian Office of Financial Management, Treasury Bonds; Treasury Indexed Bonds, http://aofm.gov.au/ags/ AFMA (2014), *Long Term Government Debt Securities Conventions*, September, pp. 1–8; AOFM (2016) Information Memorandum, Treasury Indexed Bonds, July, pp. 1–33; AOFM (2016) Information Memorandum, Treasury Bonds, July, pp. 1–31.

44. The approximate matching of 10 year maturities of nominal and indexed CGS is necessary for the calculation of the 10 year BBIR. However, a match of such maturities is unlikely to occur given the relatively few tenors of outstanding indexed CGS. Therefore, current and historical calculations of the BBIR may require the interpolated estimates of yields obtained from yield curve models to match 10 year yields to maturity on indexed and nominal CGS.

45. The consequence of using yield curve models to match the yields to maturity on nominal and indexed CGS is that the BBIR over different horizons may not reflect mark-to-market expectations of inflation for those horizons. This is because the BBIR is calculated from estimates of yields rather than market-observed yields.[42] The BBIR estimates are also likely to vary depending on the yield curve models chosen. And if there is no consensus on which yield curve models are the most appropriate, there may be considerable uncertainty over which BBIR estimates are relatively congruent with inflation expectations.

46. The BBIR-implied expected inflation rate calculated from the Fisher Equation assumes nominal and indexed bond investors are risk neutral[43] and do not demand a liquidity or inflation risk premium for holding either bond. This is a critical assumption, which Deacon and Derry (1994) argue is unlikely to be realistic.[44] If this assumption does not hold, the BBIR may depart considerably from market expectations of inflation by the magnitude of various risk premia demanded by risk-averse investors for holding nominal and indexed bonds. International and Australian[45] studies find that these premia may drive a significant wedge between the BBIR and market expectations of inflation.

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41 The *nominal* yield realised by holding inflation indexed bonds to maturity depends on the average level and trajectory of inflation over the life of the bond. If the trajectory of the inflation rate is ignored, and only the average realised rate of inflation is applied, the realised nominal yield can be approximated:

Realised nominal yield on an indexed bond = (1+real yield to maturity)*(1+average realised inflation rate)-1

John Brynjolfsson (2005), 'Inflation Linked Bonds', in Frank Fabozzi and Steven Mann (eds.), *The Handbook of Fixed Income Securities, Seventh Edition*, McGraw-Hill, New York, p. 356.

42 Barr and Campbell (1996) argue that the BBIR suffers from the problem that it cannot generate a complete term structure of inflation because it can only be applied to those maturities where there are equivalent pairs of indexed and nominal bonds. David Barr and John Campbell (1996), 'Inflation, Real Interest Rates and the Bond Market: A Study of UK Nominal and Index-Linked Government Bond Prices', *NBER Working Paper*, 5821, p. 4.

43 Moorad Choudry (2001) *The Bond and Money Markets: Strategy, Trading, Analysis,* Butterworth Heinemann, Oxford, p. 225; Seth Armitage (2005), *The Cost of Capital: Intermediate Theory*, Cambridge University Press, Cambridge, p. 227.

44 Mark Deacon and Andrew Derry (1994), 'Deriving Estimates of Inflation Expectations from the Prices of UK Government Bonds', *Bank of England Working Paper*, No. 23, p. 19.

45 Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, pp. 1-35.

47. The risk premia required by investors may also be time varying. Time-varying risk premia may result in significant changes to the BBIR even if inflation expectations are unchanged. There are also other potentially significant biases in BBIR estimates of expected inflation – such as 'convexity bias' – which occur even if investors are assumed to be risk neutral[46] and even in a world of perfect information and frictionless markets.[47] The scale and sign of the estimated premia and biases in the BBIR may also change over time and may also depend on the study parameters chosen (such as the choice of sample period).

5.1. The AER's reconsideration of the bond breakeven inflation rate

48. Up until 2007, the AER/ACCC considered that the BBIR method produced best estimates of expected inflation. In March 2007, NERA made a submission to the AER's SP AusNet Transmission Determination (2008–09 to 2013–14) on issues relating to the BBIR. NERA argued that a bias exists in the spread between the yields on 10 year nominal and 10 year indexed CGS (the 10 year BBIR). The yields on indexed CGS were claimed to be biased downward relative to the yields on nominal CGS because of a fall in the outstanding supply of, and an increase in demand for, indexed CGS.[48] NERA found that the 10 year spread exceeded economists' forecasts of inflation.[49]

49. The AER/ACCC sought advice from the RBA and the Commonwealth Treasury on this issue. In a letter to the ACCC in August 2007[50], the RBA noted that the high demand, low turnover and illiquidity in the indexed CGS market may result in the BBIR no longer providing an accurate reading of inflation expectations.[51] The RBA observed that only three issues of indexed CGS are outstanding, and that just one issue has a maturity in excess of 10 years. The spread between the yields on nominal and indexed bonds have widened even though other measures of expected inflation, such as those collected from surveys, are relatively stable as is inflation itself.[52] Unlike the indexed CGS market, the RBA found that the relatively lower supply of nominal CGS market does not have any significant effect on nominal CGS yields.[53]

50. The RBA further noted that inflation expectations are firmly anchored within the RBA's inflation-target band, and therefore a rough estimate of the real risk free rate on indexed CGS would be the nominal government bond yield less the centre of the inflation target band of 2.5 per cent.[54]

51. In a letter to the ACCC in August 2007, the Commonwealth Treasury agreed with the substance of the NERA report that biases may exist in the yields on Treasury indexed

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46 Juha Seppala and Petri Viertio (1996), 'The Term Structure of Interest Rates: Estimation and Interpretation', *Bank of Finland Discussion Papers*, 19/96, pp. 36-37. Armitage (2005) provides a related example of the effect of Jensen's inequality on Fisher Equation estimates when inflation is uncertain and investors are risk neutral. Seth Armitage (2005), *The Cost of Capital: Intermediate Theory*, Cambridge University Press, Cambridge, pp. 227-228.

47 Vide: John Cox, Jonathan Ingersoll and Stephen Ross (1981), 'A Re-Examination of Traditional Hypotheses about the Term Structure of Interest Rates', *The Journal of Finance*, 36(4), September, pp. 769-799.

48 The reduction in the supply of indexed CGS followed by an increase in institutional demand for indexed CGS is claimed to result in an absolute fall in indexed CGS yields. Vide*:* NERA Economic Consulting (2007), *Bias in the indexed CGS yields as a proxy for the CAPM risk free rate*, *A report for the ENA,* March, pp. 5-50.

49 *ibid*., p. 11.

50 RBA, Letter to Joe Dimasi, ACCC, *Comments on a report prepared by NERA concerning the Commonwealth Government bond market*, Financial Markets Group, 9 August 2007.

51 The RBA noted that the demand for these bonds has increased as supply has fallen and that turnover in the bonds is low and the market is fairly illiquid. RBA, Letter to Joe Dimasi, ACCC, *Comments on a report prepared by NERA concerning the Commonwealth Government bond market*, Financial Markets Group, 9 August 2007, p. 3.

52 *ibid*., p. 3.

53 *ibid*., pp. 1-3.

54 *ibid*., p. 3.

bonds. The suspension of issuance and the increased demand for this asset class are likely to cause market-implied inflation estimates to exceed consensus forecasts of expected inflation. The Commonwealth Treasury recommended that the ACCC use the midpoint of the RBA's target band for inflation (2.5 per cent).[55]

52. In the 2008 Final Decision on the SP AusNet transmission determination, the AER considered that the BBIR does not produce best estimates of expected inflation.[56] The AER maintained that the market-based estimates of expected inflation are preferred to any other method.[57] However, the AER argued that the BBIR does not produce robust estimates of expected inflation given the bias in indexed CGS yields.[58] Since this Final Decision, the AER considered that the RBA short term forecasts of inflation and the midpoint of the inflation target band results in best estimates of expected inflation over a 10 year horizon.

5.2. Submissions to readopt the bond breakeven inflation rate

53. In June 2015, CEG, on behalf of SA Power Networks[59] (revocation and substitution submission in 2015) and United Energy[60] (2016–20 distribution determination) submitted that the AER should once again use the 10 year BBIR as an estimator of inflation expectations. At the time, CEG's calculated 10 year BBIR was 2.28 per cent, and the estimate of expected inflation rate from the AER's current method was 2.55 per cent.[61] CEG noted that the supply of outstanding indexed CGS has increased by over 400%[62] and the number of different maturity dates has more than doubled from 3 to 7[63] (4 of the 7 outstanding securities have maturities of approximately 10 years or less), leading CEG to conclude that the shortage in the supply of outstanding indexed CGS is no longer a material concern.

54. The supply of outstanding indexed CGS has increased sharply in recent years, from approximately $6 billion in 2007–08 to approximately $29 billion in 2015–16 (monthly average). The increase in the supply of nominal CGS was even greater. From 2007–08 to 2015–16, the supply of outstanding nominal CGS has increased by over 750 per cent, from approximately $48 billion to approximately $370 billion (monthly average). At 30 June 2016 there are 22 outstanding tenors of nominal CGS, 14 of which are up to approximately 10 years.[64]

55. The following inquiry considers the claim that, as a result of an increase in the supply of indexed CGS, the BBIR method produces best estimates of expected inflation. The

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55 Commonwealth Treasury, Letter to Joe Dimasi, ACCC, *The Treasury Bond Yield As a Proxy For the CAPM Risk-Free Rate*, 7 August 2007, p. 1.

56 AER (2008), *SP AusNet Transmission Determination 2008-09 to 2013-14*, Final decision, p. 105.

57 *ibid*., p. 102.

58 *ibid*., p. 105.

59 SA Power Networks (2015), Attachment M28_CEG: Measuring expected inflation for the PTRM, June 2015, Attachment M.28.

60 CEG (2015), Measuring risk free rates and expected inflation, A Report for United Energy, Dr Tom Hird, April.

61 SA Power Networks (2015), Attachment M28_CEG: Measuring expected inflation for the PTRM, June 2015, Attachment M.28, p. 4.

62 *ibid*., p. 7. From 30 June 2007 to 30 June 2016, indexed CGS by outstanding issue value has increased by over 500 per cent. Historical Statistics, Table H13 Government Securities on issue 30 June 1983 to June 2016. Australian Office of Financial Management, Australian Government.

63 *ibid*., p. 7. From 2007-08 to 2016 6 new tenors of indexed CGS were introduced. In 2007-08, there were 3 outstanding tenors of indexed CGS. And 2 of the 3 outstanding tenors in 2007-08 have matured (in August 2010 and August 2015). Currently (2016) there are 7 outstanding tenors of indexed CGS. There are 4 outstanding indexed CGS with terms to maturity of less than 10 years. In June 2016, the approximate average term to maturity for outstanding indexed CGS up to 10 years is 2.4 years, 4.2 years, 5.7 years and 9.3 years. Australian Office of Financial Management, Tender Results Treasury Indexed Bonds.

64 Australian Office of Financial Management, Monthly Changes in Australian Government Securities (AGS) Outstanding, 2007-08 to 2015-16.

inquiry surveys recent academic and central bank studies of the BBIR and assesses the BBIR estimates of expected inflation against the criteria of assessment.

5.3. An inquiry into the bond breakeven inflation rate

56. The bond breakeven inflation rate is often calculated from the *estimates* of yields on nominal and indexed bonds. If there are few tenors of nominal or indexed bonds and/or if maturities do not approximately match, yield curve models may be fitted to the observed yields to maturity. Yield curve models allow for a pair of nominal and indexed CGS of the same maturity to be selected to calculate the BBIR. However, the yields to maturity are estimates of yields, not yields observed in the market.

57. Since there are relatively few outstanding tenors of indexed CGS, Bloomberg Valuation (BVAL) estimates of CGS yields are obtained for the calculation of the BBIR-implied inflation curve.[65] The BVAL estimates examined are whole year estimates of midpoint yields on nominal and indexed CGS up to 10 years maturity. The BVAL estimates are provided daily. An average of daily BVAL estimates is calculated over 20 business days from 2 June 2016 to 30 June 2016.[66] Over the same period, observed yields to maturity on outstanding nominal and indexed CGS are also obtained. The observed yields to maturity are from approximately 1 to 10 years. BVAL yield estimates and observed yields are shown in the left panel of Figure 2. There are relatively few outstanding indexed CGS, which necessitates the estimates of yields for the BBIR to be calculated.

58. The 'BBIR curve' and the 'BBIR-implied forward curve' are shown in the right panel of Figure 2. The BBIR curve represents:

- the geometric difference between the BVAL midpoint estimates of yields to maturity on nominal and indexed CGS, and
- the bond breakeven inflation rate at each whole year up to 10 years ahead.

59. The BBIR-implied forward curve is calculated from BBIR estimates of expected inflation at each whole year up to 10 years. The BBIR-implied forward curve is calculated using the Independent Pricing and Regulatory Tribunal's (IPART) former approach to estimating inflation expectations.[67] [68] The BBIR-implied forward inflation rates and BBIR forward curve are important for the assessment of the BBIR:

(a) The BBIR-implied forward inflation curve magnifies the variation in the slope of the breakeven inflation curve. One year forward breakeven inflation rates measure the marginal change in the BBIR as a result of increasing the maturity of nominal and indexed CGS by one year.

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[65] Bloomberg BVAL curve for nominal CGS: BVIS0572. Constituents on BI572 use semi-annual discounting of cash flows to calculate the yield to maturity. The constituents and their yields to maturity are used to construct the curve. Bloomberg BVAL curve for indexed CGS: BVSC0487. Constituents on BS487 use quarterly discounting of cash flows to calculate the yield to maturity. The constituents and their yields to maturity are used to the construct the curve.

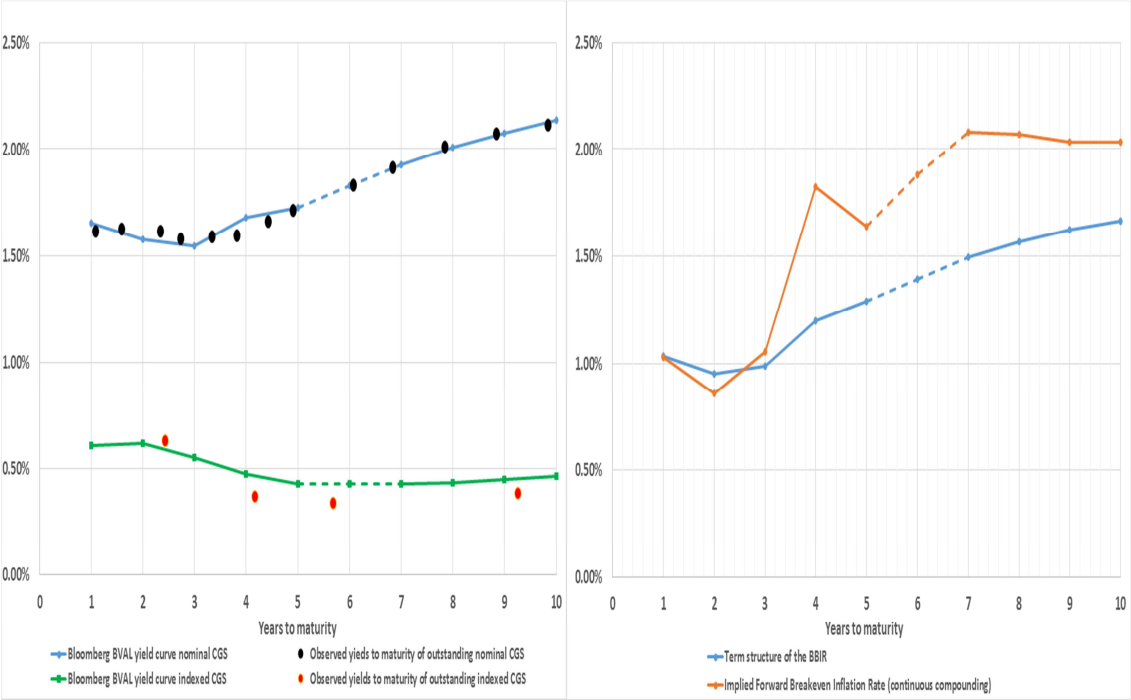
[66] Bloomberg does not provide an estimate of the yield to maturity at 6 years. Therefore, the 6 year yields to maturity are estimated by simple linear interpolation between the yield estimates at years 5 and 7. Bloomberg noted that it will provide 6 year tenor points for its BVAL estimates of nominal and indexed CGS on a forward looking basis.

[67] This approach was used to calculate the forward inflation curve implied from the prices of zero coupon inflation swaps. The IPART has now adopted the geometric average of the one-year RBA inflation forecast and the middle of the RBA's inflation target band (2.5 per cent) for the remaining 9 years. The IPART's former approach is from IPART (2009), *Adjusting for expected inflation in deriving the cost of capital*, Analysis and Policy Development – Discussion Paper, February, pp. 1-34 and the Excel Workbook: adjusting for expected inflation in deriving the cost of capital – inflation adjustment calculator 6 January 2009.xls. IPART (2015), *New approach to forecasting WACC inflation adjustment*, March.

[68] In this comparative analysis, IPART's approach is used to calculate the forward inflation curve implied from the prices of zero coupon inflation swaps. This way, the BBIR-implied and swap-implied forward curves may be compared. This comparison is conducted in the analysis of zero coupon inflation swaps below.

(b) For BBIR estimates to be relatively congruent with inflation expectations, the forward inflation rates implied from the BBIR curve should correspond closely to expected future short term inflation rates.

Figure 2: Observed and estimated nominal and indexed CGS yields up to 10 years, the bond breakeven inflation curve and breakeven-implied forward inflation curve



Source: Bloomberg BVAL estimates of yields to maturity and observed yields to maturity on nominal and indexed CGS (from approximately 1 year ahead up to approximately 10 years). The BBIR-implied forward curve is calculated using IPART's (2009) approach. 20 business day average, 2 June 2016 to 30 June 2016.

60. The BBIR-implied forward inflation rate increases over the 10 year horizon but at certain terms the rate decreases. The BBIR-implied forward curve does not present a predictable decomposition of forward inflation rates and may not necessarily reflect expected future short term inflation rates. Some potential reasons are proffered below.

(a) The BBIR-implied forward curve may not provide a congruent decomposition of market-implied forward inflation rates. This is because the increase in the supply of outstanding indexed CGS since 2007 is unlikely to have mitigated premia, distortions and biases that are found in BBIR estimates for Australia.

(b) There are few tenors of indexed CGS (4 outstanding tenors less than 10 years) and therefore the BBIR may not be calculated directly from yields observed in the market. If instead the BBIR must be calculated from *estimates* of yields on nominal and indexed CGS:

- the BBIR-implied forward inflation rates are not necessarily market-implied forward inflation rates and therefore may depart from market expectations of future short term inflation rates, and
- the BBIR may not reflect mark-to-market expectations of inflation over any yearly horizon up to 10 years ahead.

(c) Differences in the size of coupon payments across maturities may influence the BBIR curve. The larger the coupon payment, the more sensitive are the yields on

CGS to changes in short term inflation expectations.[69] If the size of the coupon payment differs across CGS of different maturities, the corresponding yields may exhibit varying sensitivities to changes in short term inflation expectations (*ceteris paribus*). Therefore, the BBIR term structure may be also influenced by the different size of coupons across maturities, and not just inflation expectations. As a result, the BBIR term structure may deviate from the term structure of inflation expectations if short term inflation expectations change.

61. Because of the few tenors of indexed CGS, the Bloomberg BVAL yield curve may be one of a potentially large number of curves that may be fitted to the observed yields. Yield curve models which produce a smoother profile of BBIR estimates (and a smoother profile BBIR-implied forward estimates) may be proposed as an alternative to the BVAL curves used in the analysis above. However, the fitting of different curves does not necessarily improve the congruency of BBIR estimates with expected inflation nor does it necessarily remove the biases, premia and distortions in the BBIR. The fitting of different curves may introduce variable and uncertain BBIR estimates.

62. Variable and uncertain BBIR estimates may impair the robustness of the BBIR method. If the raw BBIR is obtained from yield curve estimates, breakeven curves may become sensitive to the yield curve model employed. This is a consideration of Deacon and Derry (1994) and Deacon et al. (2004), who argue that the choice of term structure model can have a significant effect on the resulting BBIR-implied inflation term structure.[70] As a result, BBIR estimates may vary considerably depending on the yield curve model employed. In this respect, the BBIR may not produce robust estimates of expected inflation.

63. The lack of robustness of BBIR estimates arising from the fitting of various curves may occur because there is no consensus on which yield curve models are the most appropriate. In his study of the US BBIR, Zarazaga (2010) argues that no one model has emerged as the consensus choice for modelling the term structure of interest rates.[71] The potential uncertainty over which models are more appropriate or better fitting may result in considerable uncertainty over which BBIR estimates are relatively congruent with inflation expectations.

64. The potential lack of consensus may result in the regulator, the regulated businesses and other stakeholders proposing various and complex yield curve models to estimate the BBIR. The resulting variability of BBIR estimates and the complexity of the calculations on which they are based may reduce the transparency and replicability of the BBIR method.

65. Observations of the BBIR over time may also provide insights into whether or not the BBIR estimates are likely to reflect changes in long term inflation expectations. The 10 year BBIR for Australia over the period 17 March 2000 to 30 June 2016 is shown

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69 This is similar to the point made by Christensen et al. (2004) that the nominal yields and the BBIR are more sensitive to short term inflation expectations the larger the coupon payments. Ian Christensen, Frederic Dion and Christopher Reid (2004), 'Real Return Bonds, Inflation Expectations, and the Break-Even Inflation Rate', *Bank of Canada Working Paper 2004-43*, November, p. 5; pp. 39-40.

70 Mark Deacon and Andrew Derry (1994), 'Deriving Estimates of Inflation Expectations from the Prices of UK Government Bonds', *Bank of England Working Paper*, No. 23, pp. 24-25; Mark Deacon, Andrew Derry and Dariush Mirfendereski (2004), *Inflation-indexed Securities – Bonds, Swaps and Other Derivatives*, Second Edition, John Wiley & Sons, West Sussex, p. 82 (footnote).

71 In his modelling of inflation expectations implied from bond prices, Zarazaga (2010) finds that: 'The assessment by Campbell, Lo, and Mackinlay (1997, pg. 455) that "no one model has yet emerged as a consensus choice for modelling the term structure" continues to reflect the situation as accurately today as it did more than a decade ago.' Carlos Zarazaga (2010), 'The Difficult Art of Eliciting Long-Run Inflation Expectations from Government Bond Prices', Staff Papers, Federal Reserve Bank of Dallas, No. 9, March, p. 38; John Campbell, Andrew Lo and Craig MacKinlay (1997), *The Econometrics of Financial Markets*, Princeton University Press, Princeton.

in Figure 3 below. The 10 year BBIR is compared to an approximate replication of the AER's current method over the same period.[72] The top left panel is the 10 year BBIR calculated from the midpoint yields on generic 10 year nominal and indexed CGS using the Fisher Equation (Bloomberg daily data). The top right panel is the Bloomberg series of the 10 year BBIR (daily data). The 10 year BBIR calculated from Bloomberg daily data is compared to an approximate daily replication of the AER's current estimates of expected inflation (estimated daily). There are small differences between the Bloomberg calculated BBIR and the Fisher Equation estimates from Bloomberg generic CGS midpoint yields.[73] Bloomberg does not record daily yield data for indexed CGS or daily BBIR data between November 2001 and November 2003 and between April 2007 and October 2009. One reason may be the insufficient number of tenors of indexed CGS in which to estimate indexed CGS yields during these periods. For example, for most of the latter period there were only 3 outstanding tenors of indexed CGS.

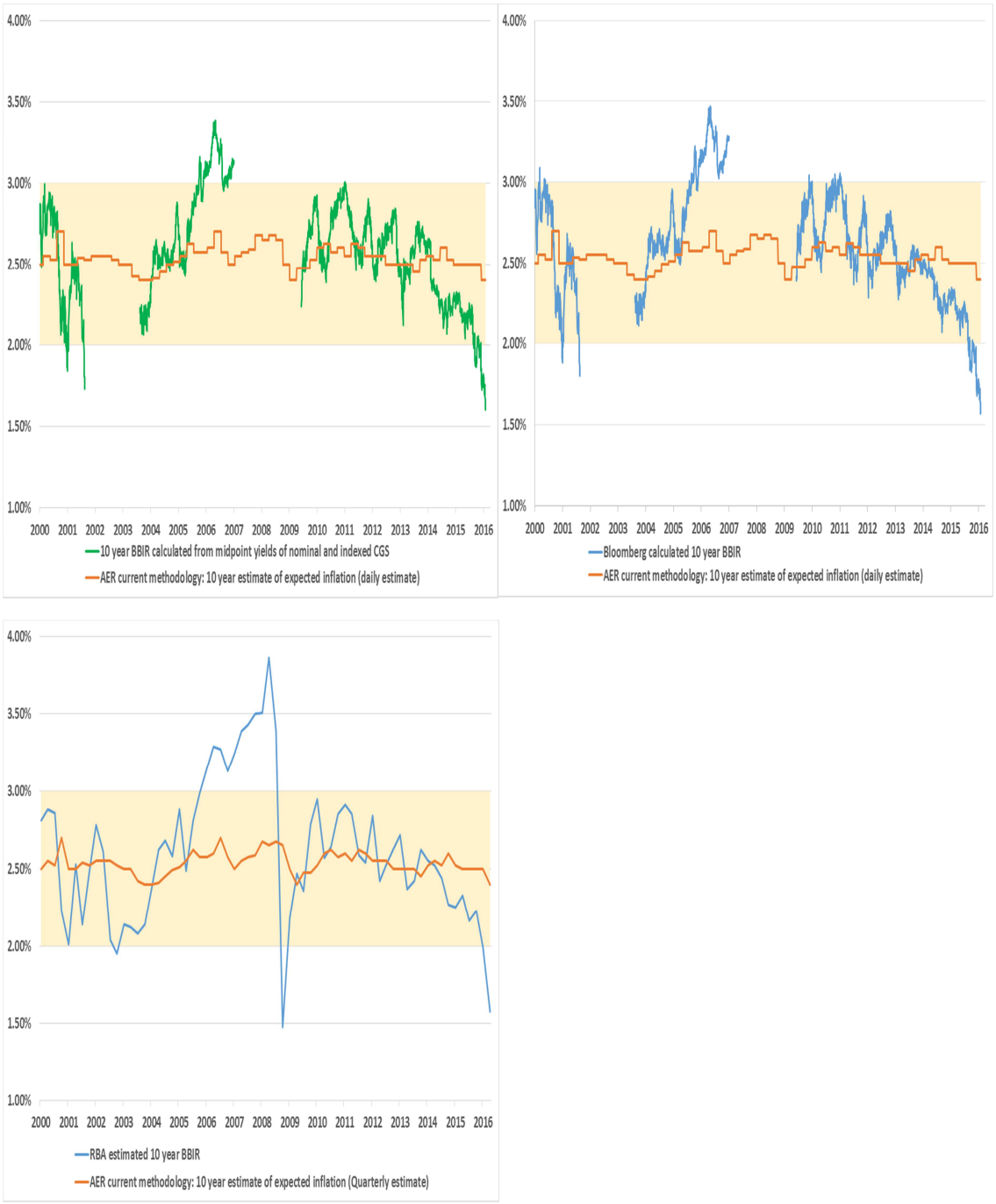
66. The bottom panel is the RBA series of the 10 year BBIR (quarterly data) from the March quarter 2000 to the June quarter 2016.[74] The 10 year BBIR estimated by the RBA is compared to an approximate quarterly replication of the AER's current estimates of expected inflation. In all three panels the RBA target inflation band of 2 to 3 per cent is also shown.

[72] For the purposes of approximating the AER's current method, one and two years ahead forecasts by the RBA are obtained from quarterly Statements on Monetary Policy made in February, May, August and November of each year. RBA forecasts are assumed to take place on the earliest date in February, May, August and November of each year. From February 2000 to November 2006, the RBA forecast inflation rate is around 12-18 months ahead. If there is only a 12 month forecast, a geometric average of the 12 month forecast and the RBA midpoint over the following 9 years is calculated and used to approximately replicate the 'AER's current method'. The 18 month forecasts are extrapolated to 24 months based on the RBA's description of its forecast of the CPI inflation rate beyond the 18 month horizon (if available). In many of these instances, the RBA's forecast inflation rate is descriptive – numerical inflation forecast rates may not be provided, which required some reasonable estimation of the 1 or 2 year forecast rates based on the descriptions. Underlying inflation rate forecasts are used where no headline inflation forecasts are provided. Only from February 2007 onwards are tabulated 1 and 2 year forecasts of the CPI inflation rate provided by the RBA in its Statements on Monetary Policy.

[73] Based on Bloomberg daily midpoint yield to maturity data on generic 10 year nominal and indexed CGS from 17 March 2000 to 30 June 2016. The date 17 March 2000 is chosen since this is the earliest date indexed CGS bid-ask yields are recorded by Bloomberg. Bloomberg codes: GTAUD10Y and GTAUDII10Y. Generics are used for historical analysis and only yields, not prices, are stored historically. The yields to maturity on generic nominal and indexed CGS are effective yields. Up until 24 January 2007, Bloomberg does not record midpoint yields for 10 year indexed CGS. From 17 March 2000 to 24 January 2007, midpoint yields are calculated by taking the average of bid and ask yields. Bloomberg does not record nominal and indexed CGS yield data between 6 November 2001 and 14 November 2003, and between 20 April 2007 and 8 October 2009. Bloomberg's calculation of the 10 year BBIR, ADGGBE10, also omits these time periods. Bloomberg's calculated 10 year BBIR is comprised of generic Australian breakeven rates and is calculated using the closest nominal government bond to the inflation-linked bond. The breakeven rate is calculated by subtracting the yield on the indexed linked bond from the yield on the closest nominal bond. One difference between Bloomberg's own calculation and the Fisher Equation is that the former is a simple difference while the latter is a geometric difference between the yields on nominal and indexed CGS.

[74] RBA Inflation Expectations, Breakeven 10 year inflation rate, average annual inflation rate implied by the difference between 10-year nominal bond yield and 10-year inflation indexed bond yield; End-quarter observation, RBA, Yieldbroker, GBONYLD.

Figure 3: The 10 year BBIR calculated from Bloomberg daily data, RBA quarterly estimates of the 10 year BBIR and the AER's current method estimates



Source: Bloomberg daily midpoint yield to maturity on generic 10 year nominal and indexed CGS, 17 March 2000 to 30 June 2016. Bloomberg BBIR, ADGGBE10: 17 March 2000 to 30 June 2016. RBA Inflation Expectations, Average Annual Inflation Rate implied by the difference between 10-year nominal and indexed bond yields, end-quarter observation, March 2000 to June 2016, GBONYLD. AER's current method is replicated using RBA quarterly Monetary Policy Statements (February, May, August and November), February 2000 to May 2016.[75]

[75] For the top left and right panels, the AER's current method estimates of expected inflation will change on the first business day of February, May, August and November each year if there is a corresponding change in the RBA inflation forecast on the release of the Statement on Monetary Policy in those months. For the bottom panel, the AER estimates of expected inflation reflect the RBA forecast of inflation in the Statements on Monetary Policy which fall in the relevant quarter of each

67. The BBIR is considerably volatile compared to the AER's current method. The standard deviation, a measure of the basis point volatility over the sample period, is between 32–34 basis points (Fisher Equation and Bloomberg's BBIR calculation, respectively) and 47 basis points (RBA). The RBA series is more volatile since the RBA records the BBIR during the GFC. The relative volatility of RBA BBIR estimates may capture the considerable distortions that were observed in BBIRs during the GFC.

68. In contrast, an approximate replication of the AER's current method to estimating expected inflation over the same sample period is considerably more stable. The estimates are around the midpoint of the inflation target band and the standard deviation over the same sample period is approximately 7 basis points (calculated on a Bloomberg daily basis over the sample period where Bloomberg data are available[76] and on a quarterly basis over the entire sample period).

69. The AER's estimation of the nominal risk free rate at any point in time is the daily average of 10 year yields on nominal CGS over 20 business days. If this method is adopted to estimate the BBIR at any point in time, it is possible that 'outlying' BBIR observations – relative to the mean BBIR over the sample period – are included. If these outlying BBIR observations reflect 10 year market expectations of inflation at that point in time, there is no concern. However, this may not be the case.

70. At any point in time, changes in the demand for and/or supply of nominal and indexed CGS may not reflect changes in inflation expectations. The potential consequence is that relative yields and BBIR estimates may change even if inflation expectations remain unchanged.

    (a) Changes to the supply of outstanding nominal CGS relative to indexed CGS may change their relative yields and BBIR estimates even if the term structure of inflation expectations remains unchanged. For example, the substantial increase in the supply of nominal CGS relative to indexed CGS over the period July 2007 to June 2016 may have resulted in a corresponding deterioration in the relative liquidity of indexed CGS (discussed below). A deterioration of the relative illiquidity of indexed CGS may result in a larger liquidity premium in the BBIR and compressed BBIR estimates (*ceteris paribus*).[77]

    (b) Capital availability may influence demand for and mispricing of indexed CGS relative to nominal CGS (mispricing as a result of relative liquidity premia in indexed CGS yields). Greater capital availability may facilitate arbitrage, increase the demand for and increase the turnover of indexed CGS such that the liquidity of indexed CGS relative to nominal CGS may improve. While a decline in capital availability may have the opposite effect.

        Fleckenstein et al. (2014) find that the amount of capital available in the market has a strong influence on the mispricing of US Treasury Inflation Protected

year (February Statement – March quarter, May Statement – June quarter, August Statement – September quarter and November Statement – December quarter).

[76] Calculated over the same sample period excluding dates between 6 November 2001 and 14 November 2003, and between 20 April 2007 and 8 October 2009.

[77] While the change in supply of CGS may have an influence on relative yields on indexed and nominal CGS, there is some uncertainty over whether changes in the supply of nominal and indexed bonds have a significant influence on relative yields in larger bond markets such as in the US and in the UK. Fleckenstein et al. (2014) find that the issuance of nominal Treasuries and TIPS (Treasury Inflation Protected Securities) for the US have a significant influence on the mispricing of TIPS relative to nominal Treasuries. In contrast, Pflueger and Viceira (2011) find little evidence that an increase in the relative supply of indexed bonds in UK and US bond markets explained either the spread between nominal and real interest rates or bond risk premia. Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, pp. 2181-2184. Carolin Pflueger and Luis Viceira (2011), 'An Empirical Decomposition of Risk and Liquidity in Nominal and Inflation-Indexed Bonds', Working Paper, March, pp. 1-38.

Securities (TIPS) relative to nominal Treasuries.[78] (Fleckenstein et al. state that what they identify as 'under-priced' or 'mispriced' bonds, other researchers identify as a 'liquidity risk premium'.[79]) Fleckenstein et al. find that lagged stock, bond and hedge fund returns explain half of the variation in the mispricing of TIPS relative to nominal Treasuries. They note that these findings are consistent with the intuition that as investor wealth in the stock, bond and hedge fund increases more capital is available to arbitrage away mispricing in TIPS relative to nominal Treasuries. Fleckenstein et al. cite a number of studies which also discuss how slow-moving capital or capital availability may explain the persistence of arbitrage opportunities in financial markets.[80]

(c) Changes to investor risk aversion may affect the relative demand for and the relative yields on nominal and indexed CGS. Such changes may not be related to changes in inflation expectations. D'Amico et al. (2016) observe that during the financial crisis, a period of heightened investor risk aversion, heavy flight-to-safety flows into the nominal Treasury market likely contributed to demand imbalances between nominal Treasuries and TIPS in the US. This in turn may lead to changes in the relative yields on these securities.[81]

(d) The differences in, or changes to, the pattern of institutional demand for indexed and nominal bonds may influence BBIR estimates that may be unrelated to inflation expectations. In 2006 and 2007, RBA and NERA observed that strong institutional demand unrelated to inflationary pressures were contributing to distorted BBIR estimates of inflation expectations.[82] For the US, Fleckenstein et al. also argue that the differences in the pattern of institutional ownership of and demand for US nominal Treasuries and TIPS may be driving a wedge between the market prices of these securities.[83]

71. The BBIR may be more volatile than long term inflation expectations because the 10 year BBIR may be sensitive to relatively volatile short term inflation expectations.[84] Sack (2000) for the US and Christensen et al (2004) for Canada find evidence that the long term BBIR is highly responsive to the contemporaneous rate of CPI inflation.[85] The contemporaneous rate of inflation can be volatile[86] and can have a

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78 Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, pp. 2182-2188.

79 Fleckenstein et al. note that the mispricing of TIPS is identified by other researchers as a liquidity risk premium and that there is no fundamental conflict between their findings and the findings of other researchers – the difference is one of semantics. Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, pp. 2165-2166.

80 *ibid*., pp. 2182-2183.

81 Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 26 and p. 32.

82 RBA (2006), Statement on Monetary Policy, February, pp. 48-49; NERA Economic Consulting (2007), *Bias in the indexed CGS yields as a proxy for the CAPM risk free rate*, *A report for the ENA,* March, pp. 1-47.

83 Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, p. 2173; pp. 2177-2178.

84 Finlay and Wende (2011) find that 1 year inflation expectations are considerably more volatile than 5 year and 10 year expectations. Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, pp. 13-14.

85 Brian Sack (2000), 'Deriving Inflation Expectations from Nominal and Inflation-Indexed Treasury Yields', Division of Monetary Affairs, Board of Governors of the Federal Reserve System, Washington DC,16 May, pp. 1-24; Ian Christensen, Frederic Dion and Christopher Reid (2004), 'Real Return Bonds, Inflation Expectations, and the Break-Even Inflation Rate', *Bank of Canada Working Paper 2004-43*, November, pp. 1-40.

86 This can be verified by comparing annual CPI inflation outcomes since targeting was introduced with Gillitzer and Simon's (2015) and Finlay and Wende's (2011) findings that long term market expectations of inflation are anchored within the inflation target band. ABS, CPI Cat No. 640101, Index Numbers – All groups CPI, Australia, A2325846C; ABS, CPI, Cat No. 640101, Percentage Change from Corresponding Quarter of Previous Year, All groups CPI, Australia, A2325847F; Christian Gillitzer and John Simon (2015), 'Inflation Targeting: A Victim of Its Own Success?', RDP 2015-09, August, *Reserve Bank of Australia Discussion Paper*, pp. 1-37; Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation

strong influence on short term inflation expectations.[87] Even if long term inflation expectations are unchanged, the resulting volatility of short term inflation expectations may influence the long term BBIR if the BBIR is calculated from the yields on coupon-paying bonds.

The Australian BBIR is calculated from coupon-paying CGS. Therefore, a share of the total income stream and the yield to maturity on CGS will be more heavily influenced by short term inflation expectations when compared to zero coupon bonds. The larger the coupon rate, the more sensitive are nominal and indexed CGS yields to short term inflation expectations and shocks to inflation expectations of the shortest term will have a larger effect because it will positively influence all subsequent coupon payments. Yields on CGS may be influenced by the trajectory of expected inflation rates over the period to maturity and not just the expected average inflation over the period to maturity.[88] If the term structure of inflation expectations is not flat, relatively volatile short term inflation expectations may change the BBIR temporarily, even if long term market expectations of inflation are unchanged.

72. The volatility of BBIR observations may also be explained by risk premia, biases and/or distortions in the BBIR.[89] The sensitivity of the BBIR to such biases and distortions may drive a significant wedge between the BBIR and 10 year market expectations of inflation. Premia in the BBIR may also be time varying, such that these sources of bias may change in magnitude over time, particularly during times of financial market instability and/or economic uncertainty.

73. Table 2 below provides a short explanation of many of the potential distortions, premia and biases that may drive a wedge between BBIR estimates and long term market expectations of inflation. The number of distortions, premia and biases considered here is not exhaustive. While there are a large number of studies which find significant biases, premia and distortions in the BBIR, there is considerable uncertainty over the scale and sign of these estimated biases, premia and distortions. The scale and sign of the estimated biases, premia and distortions varies considerably across studies, potentially reflecting choice of different study parameters, such as: choice of sample period, bond markets, bond maturities, estimation methods, term structure models and proxies for liquidity premia and inflation expectations. The resulting uncertainty over the scale and sign of biases, premia and distortions makes it difficult to robustly estimate the 'net effect' of these various influences on the BBIR.

Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, pp. 1-35.

87 Finlay and Wende (2011) find that the contemporaneous rate of inflation has a strong influence on short term inflation expectations. Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, p. i.

88 Ian Christensen, Frederic Dion and Christopher Reid (2004), 'Real Return Bonds, Inflation Expectations, and the Break-Even Inflation Rate', *Bank of Canada Working Paper 2004-43*, November, p. 5, pp. 39-40.

89 If biases are time-varying, the size of such biases may change in response to prevailing conditions in the financial market. For example, Pflueger and Viceira (2015) find that indexed bond holders receive a liquidity discount and this discount is time-varying which exposes these investors to systematic risk as measured by a positive and statistically significant CAPM beta. This implies that during stock market drops, the BBIR may narrow as a result of an increase in the liquidity premium on TIPS. Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, pp. 27-28.

Table 2: Estimating expected inflation rates from implied breakeven inflation rates: potential biases, premia and distortions

Bias/distortion	Explanation
Liquidity premia	Indexed CGS are likely to be substantially less liquid than nominal CGS. This implies that liquidity premia included in the yields on indexed CGS may be greater than the liquidity premia included in the yields on nominal CGS. The difference between liquidity premia, or the differential liquidity premia, is likely to drive a wedge between the BBIR and inflation expectations. The differential liquidity premia are likely to be greater during periods of uncertainty when investors' appreciation of liquidity risk may have changed.[90] In such a situation, the yield spread between nominal bonds and inflation indexed bonds is likely to narrow – a narrowing that is caused by greater uncertainty, growing differential liquidity premia and not necessarily a fall in inflation expectations.
Inflation risk premia	The inflation risk premia arise because holders of nominal bonds are exposed to inflation risk, where there is a probability that the actual inflation rate will not match the expected inflation rate. As a result, nominal bondholders may demand compensation for bearing this risk. Inflation risk premia may be positive or negative, depending on whether there are concerns about inflation or deflation.
Convexity Bias	Bond prices are a convex function of their respective yields. Therefore, if yields are volatile, giving effect to gains being larger than the losses, bond prices may rise. The rise in the bond prices push down their forward yields, below their expected future yields. The difference between forward yields and expected future yields on a bond is the 'convexity effect'. The size of the convexity effect is likely to be different for nominal and indexed bonds. The difference in the magnitude of the convexity effect for nominal and indexed bonds may result in the BBIR departing from market expectations of inflation by the amount of a 'convexity bias' (*ceteris paribus*). Convexity bias is sensitive to the relative volatility of forward yields on nominal and indexed bonds. Therefore, the scale of convexity bias estimates may change if relative forward yield volatilities change over time.
Inflation indexation lag	A perfectly indexed CGS would pay a real coupon amount that is adjusted by the increase in the CPI between the issue date and the time of payment.[91] However, there are unavoidable lags between the actual movements in the CPI and adjustments of indexed bond cash flows. Indexation lag may result in the forward yields on indexed CGS being calculated on the basis of both historical inflation rates and expected future short term inflation rates. The effect of indexation lag on indexed CGS yields may be significant during periods of significantly above and below-trend inflation.[92] Finlay and Wende (2011) observe that because indexed CGS are indexed with a lag (of 4.5 to 5.5 months[93]), indexed CGS yields also reflect historical

[90] Pu Shen and Jonathan Corning (2001), 'Can TIPS Help Identify Long-Term Inflation Expectations?' Federal Reserve Bank of Kansas City, *Economic Review*, Fourth Quarter, pp. 74-75.

[91] This is similar to the definition of Barr and Campbell (1996) of perfectly indexed bond. David Barr and John Campbell (1996), 'Inflation, Real Interest Rates and the Bond Market: A Study of UK Nominal and Index-Linked Government Bond Prices', *NBER Working Paper*, 5821, p. 3.

[92] Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 15.

[93] The indexed CGS payment formula is based on the (arithmetic) average percentage change in the CPI over two quarters ending two quarters *prior* to that in which the next interest payment falls. The coupon payment and indexation events occur quarterly for indexed CGS. For example, for calendar year ending 2016, the last coupon payments and indexation events for indexed CGS for the calendar year occur on 20 and 21 November and on 20 December. The indexation is based on

	inflation not just future expected inflation.[94] Finlay and Wende note that as a result of indexation lag affecting indexed CGS, the high realised inflation rate during 2008 may have contributed to negative 1 year forward inflation rates (implied from the prices of indexed and nominal CGS) recorded in late 2008.[95] D'Amico et al. (2016) find that while the effects of indexation lag are generally small, the effects on the yield on 10 year US TIPS rose to 30 basis points in December 2008 when CPI inflation was running at around an annual rate of –13 per cent.[96] Grishchenko and Huang (2012) estimate the effect of indexation lag on 10 year TIPS yields to be 4.2 basis points over the period 2000 to 2008 (where they assume a lag of three months).[97] While over the past two decades the inflation rate in Australia has been relatively stable and low, the indexation lag for indexed CGS is considerable. The large indexation lag of around 5 months may influence even long term BBIRs.
Inflation risk premia in indexed bond yields: indexation lag premia	As a result of indexation lag, the real return on indexed bonds may be exposed to some inflation risk.[98] There is research which finds that inflation risk premia may be embedded in indexed bond yields to compensate investors for such risk. This is known as *indexation lag risk premia*. Risa (2001) finds that the yields on UK 10 year indexed bonds included an indexation lag risk premium of approximately 3.3 basis points.[99] However, Risa considers that this premium is not economically relevant in size. D'Amico et al. (2016) find an indexation lag premium on the yields on 10 year TIPS varies between –5 and 3 basis points.[100]
Inflation risk premia in indexed bond yields: post-tax variability of indexed bond cash flows	Tax regimes in existence tend to cause post-tax real returns to remain uncertain even if pre-tax real yields are known. Since tax is levied on the nominal yield, not the real yield, the tax system reintroduces inflation risk for indexed bonds. Post-tax real yields may become uncertain and variable if inflation is uncertain.[101] If the demand for bonds is a function of their expected post-tax returns, pre-tax indexed bond yields may include inflation risk premia to compensate investors for the potential uncertainty of post-tax real returns. The existence of inflation risk premia in indexed bond yields may result in BBIR estimates departing from market expectations of inflation.

the average percentage change in the CPI over two quarters ending in the June quarter preceding. That is, the inflation indexation for the indexed CGS in November and December is the average of the percentage change in the CPI over the March and June quarters of the same calendar year. Australian Office of Financial Management, Treasury Indexed Bonds, http://aofm.gov.au/ags/treasury-indexed-bonds/.

94 Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, p. 6 and p. 20.

95 *ibid*., p. 17-18 and p. 20.

96 Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 25.

97 Olesya Grishchenko and Jing-zhi Huang (2012) 'Inflation Risk Premium: Evidence from the TIPS market', *Finance and Economics Discussion Series Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C.* 2012-06, pp. 1-46.

98 Deacon et al. (2004) state that: 'there is at the end of a bond's life when there is no inflation protection at all, counterbalanced by a period of equal length before it is issued for which inflation compensation is paid. In general the inflation rate in these two periods will not be the same, and consequently the real return on an indexed bond will not be fully invariant to inflation – the longer the lag, the poorer the instrument's inflation proofing'. Mark Deacon, Andrew Derry and Dariush Mirfendereski (2004), *Inflation-indexed Securities – Bonds, Swaps and Other Derivatives*, Second Edition, John Wiley & Sons, West Sussex, p. 26.

99 Stefano Risa (2001), 'Nominal and Inflation-Indexed Yields: Separating Expected Inflation and Inflation Risk Premia', 13 April, Working Paper, pp. 22-23.

100 Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 25.

101 Mark Deacon, Andrew Derry and Dariush Mirfendereski (2004), *Inflation-indexed Securities – Bonds, Swaps and Other Derivatives*, Second Edition, John Wiley & Sons, West Sussex, p. 7; pp. 31-34; Wesley Phoa and Michael Shearer (1998), *Advanced Fixed Income Analytics*, Frank J. Fabozzi and Associates, New Hope, pp. 95-96.

Mismatched pattern of cash flows	Christensen et al. (2004) argue that even if nominal and indexed bonds have the same maturity, differences in the pattern of coupon payments (resulting in differences of duration and convexity of each bond) may expose each bond to different discount factors.[102] The difference between the nominal and indexed bond yields may therefore be potentially influenced by other factors besides that of inflation expectations. Christensen et al. study the BBIR estimated from Canadian 30 year nominal and indexed bonds. In real terms, the coupon payments on indexed bonds are fixed, while the coupon payments on nominal bonds decline in real terms over their maturity. Since cash flows that arrive later in time are discounted more heavily, the price of the indexed bond will be lower and therefore the BBIR may produce downwardly biased estimates of expected inflation.[103] Christensen et al. note that the size of this bias will not be constant through time since it is a function of the coupon and maturity of nominal and indexed bonds and the term structure of interest rates. They find that observed volatility of the BBIR may be due to mismatched cash flows and not to changes in inflation expectations.[104] For the period January 1992 to May 2003, Christensen et al. estimate that the average bias introduced into the BBIR by the cash flow mismatches is –20 basis points.[105] That is, the 30 year BBIR is on average downwardly biased by 20 basis points. However, Christensen et al. (2004) also cite Sack's (2000) study of the US 10 year BBIR where the impact of these differences is estimated to be small, typically under 5 basis points and are often negative.[106] The cash flows on nominal and indexed CGS are also mismatched. Cash flows on indexed CGS are more back-loaded relative to nominal CGS. Coupon payments and the face value of indexed CGS are fixed in real terms, while coupon payments and the face value of nominal CGS decline in real terms over their term to maturity. The differences in the pattern of indexed and nominal CGS cash flows may also influence the relative yields on indexed and nominal CGS.[107]
Changes to the demand for and supply of indexed and nominal CGS that are unrelated to changes to inflation expectations	There may be changes to the demand for and supply of nominal and indexed CGS that are unrelated to changes in inflation expectations. As a result, relative yields and BBIR estimates may change even if the term structure of inflation expectations is unchanged. For example, changes to the relative supply of nominal and indexed CGS, changes to investor risk aversion, slow moving capital and capital availability may result in a movement of the relative yields that may be unrelated to changes in inflation expectations.
Sensitivity of the BBIR to short term inflation expectations when calculated from	When the BBIR is calculated from the yields on coupon-paying bonds, the BBIR may become more sensitive to changes in short term inflation expectations compared to a BBIR that is calculated from yields on zero coupon bonds. As a result, if the term structure of inflation expectations is not flat, relatively volatile short term inflation expectations may change the

[102] Ian Christensen, Frederic Dion and Christopher Reid (2004), 'Real Return Bonds, Inflation Expectations, and the Break-Even Inflation Rate', *Bank of Canada Working Paper 2004-43*, November, p. 14.

[103] *ibid*., pp. 14-18.

[104] *ibid*., pp. 14-18.

[105] Christensen, Frederic Dion and Christopher Reid (2004), 'Real Return Bonds, Inflation Expectations, and the Break-Even Inflation Rate', *Bank of Canada Working Paper 2004-43*, November, p. 16.

[106] *ibid*., p. 17; and Brian Sack (2000), Deriving Inflation Expectations From Nominal and Inflation-Indexed Treasury Yields, Division of Monetary Affairs, Federal Reserve, Washington DC, pp. 9-10.

[107] Differences in the timing and frequency of coupon payments may also influence the relative yields on nominal CGS and indexed CGS. The coupon payments for nominal CGS are paid semi-annually whereas the coupon payments for indexed CGS are paid quarterly, and most of the indexed and nominal cash flow dates do not correspond.

coupon-paying bonds	BBIR, even if the long term market expectations of inflation are unchanged.[108]
The effect of the deflation floor on the yields of indexed CGS	Indexed CGS have a 'deflation floor' – coupon interest payments will not be based on a capital value less than the face value and payment of the principal cannot fall below the face value. If deflation becomes a concern, the deflation protection of indexed CGS becomes valuable, pushing up indexed CGS prices and reducing indexed CGS yields. During such episodes, the effect of the deflation floor on indexed CGS may influence the BBIR. For the US, D'Amico et al. (2016) identify the effect of the deflation floor as a potential driver of the BBIR. They find that the deflation floor affects the yields on 10 year TIPS by about 5 basis points during normal times but widening to -20 basis points during the recent crisis.[109]
Personal price indices and the substitution effect	In their estimates of the BBIR for the US, Christensen and Gillan (2012) find that the inflation risk premium in BBIR estimates remained negative even after maximally correcting for the liquidity premium. Christensen and Gillan argue that this may be due to TIPS yields being higher than they otherwise would be for two reasons. Firstly, the CPI may overstate true inflation outcomes because the substitution effects have not been considered. Secondly, the personal price index of investors may be different to the CPI and therefore TIPS are only a partial hedge for inflation risk. Consequently, investors may demand a risk premium for the remaining exposure to an imperfect inflation hedge.[110] The influence of the substitution effect and personal price indices on indexed bond yields may result in BBIR estimates departing from market expectations of inflation.

74. For the purposes of this comparative assessment, only liquidity premia, inflation risk premia and convexity bias are examined in detail. These biases/premia are potentially the largest biases in BBIR estimates, although the scale of many of the other biases considered above may sometimes exceed the biases/premia considered below. This is because the size of the estimated biases is sensitive to study parameters chosen, such as the choice of sample period.

5.3.1. Liquidity premia in bond breakeven inflation rates

75. An asset with liquidity risk indicates that investors may incur large transaction costs when buying or selling the asset in a secondary market. Besides the usual transaction costs such as brokerage fees and commissions, which may be similar across nominal and indexed bonds, there are other costs that are likely to affect the relative liquidity of nominal and indexed bond markets. These costs are related to the ease and convenience of trading. These costs are more uncertain, and sellers of large dollar value securities may have to accept a lower price for selling the asset in a timely manner.[111]

76. Shen and Corning (2001) argue that the probability of incurring such costs is inversely related to the liquidity of the asset – the less liquid the asset the higher liquidity risk and therefore the asset must include a higher yield to attract investors.[112]

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[108] Ian Christensen, Frederic Dion and Christopher Reid (2004), 'Real Return Bonds, Inflation Expectations, and the Break-Even Inflation Rate', *Bank of Canada Working Paper 2004-43*, November, p. 5, pp. 39-40.

[109] Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 31; p. 67.

[110] Jens Christensen and James Gillan (2012), 'Could the US Treasury Benefit from Issuing More TIPS?', *Federal Reserve Bank of San Francisco, Working Paper Series*, p. 24.

[111] Pu Shen and Jonathan Corning (2001), 'Can TIPS Help Identify Long-Term Inflation Expectations?' Federal Reserve Bank of Kansas City, *Economic Review*, Fourth Quarter, pp. 65-66.

[112] *ibid*., pp. 65-66.

The higher yield reflects the liquidity premium, and if the liquidity premium on indexed bond yields is greater than the liquidity premium on nominal bond yields, the BBIR may be compressed – not necessarily as a result of lower inflation expectations but because of a differential liquidity premium.

77. Many studies find significant differential liquidity premia (and inflation risk premia and other biases) in the US and UK BBIRs, despite the fact that the supply and liquidity of US TIPS and UK indexed-linked gilts are many times greater than that of indexed CGS.[113] With the exception of the late 1990s and early 2000s, the cited US BBIR studies do not consider the supply of outstanding US TIPS to be a problem. In the cited studies of the UK indexed bond markets, issues relating to supply are not considered.

78. A sample of these studies[114], which find significant and potentially time-varying liquidity premia, are shown below in Table 3. These studies 'decompose' the BBIR into estimates of expected inflation and estimates of liquidity premia. Many of these studies also further decompose the BBIR into estimates of inflation risk premia and distortions such as the effects of indexation lag.

Table 3: Sample of research finding potentially significant liquidity premia in BBIRs

Study	Study parameters and findings
D'Amico et al. (2016)	**Liquidity Premia** Up to 300 basis points during the GFC[115]. **Bonds** 3 month, 6 month, 1, 2, 4, 7 and 10 year nominal US Treasuries, 5, 7 and 10 year TIPS. **Sample** Period January 1990 to March 2013. (TIPS yields are restricted by data availability and cover a period from January 1999 to March 2013, where the earlier period without TIPS data (1990 to 1998) is treated as missing observations.) **Model/Estimation Applied** Three-and four-factor Gaussian term structure models of interest rates and

[113] In 1999 the outstanding issuance of UK index-linked gilts was £33 billion, in 2008 £83 billion, in 2015 £270 billion and in 2016 £294 billion (year ending March, non-uplifted nominal values). In 1999, the outstanding issuance of US TIPS was $101 billion USD, in 2008 $530 billion USD, in 2015 $1168 billion USD (calendar years) and as at June 2016, $1187 billion USD. The approximate outstanding issuance of indexed CGS for financial year ending in 1999 was $5.6 billion AUD, for 2008 $6 billion AUD, for 2015 $27.5 billion AUD and as at June 2016 $30.2 billion AUD. In 2007-08 (the earliest financial year when yearly turnover of CGS is publicly available for Australia), annual turnover of indexed CGS was approximately $11.4 billion AUD, the annual turnover of UK index-linked gilts was approximately £1212 billion (multiplying the quarterly average net market value of indexed-linked gilts per annum by the annual net turnover ratio of all gilts – net of government holdings) and annual turnover of US TIPS was approximately $2076 billion USD (multiplying average daily trading volume by 250 business days, monthly observation each financial year). In 2014-15, annual turnover of indexed CGS was approximately $50.9 billion AUD, annual turnover of UK indexed-linked gilts was approximately £2185 billion and annual turnover of US TIPS was approximately $3124 billion USD. UK Debt Management Office, Gilt Portfolio Statistics Historical, Gilts Turnover History, Size of the Gilt Market. Sifma, US Treasury Securities Outstanding, USD Billions, US Treasury, Average Daily Trading Volume, USD Billions. AFMA, Australian Financial Markets Reports data 2011-12, 2012-13, 2013-14 and 2014-15. Historical Statistics, Table H13 Government Securities on issue 30 June 1983 to June 2016. Australian Office of Financial Management, Australian Government.

Gurkaynak et al. (2010) observe that the US TIPS market is largest sovereign indexed linked market in the world measured in terms of par value of issuance. Refet Gurkaynak, Brian Sack and Jonathan Wright (2010), 'The TIPS Yield Curve and Inflation Compensation', *American Economic Journal: Macroeconomics*, 2(1), p. 72.

[114] Given the large number of decomposition studies of the BBIR into liquidity premia, inflation risk premia and expected inflation, most of which find significant and time-varying premia, only a sample of studies is considered.

[115] Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 3.

	inflation. Regression analysis of model-implied 10 year TIPS spread on all six liquidity proxies over the sample period September 2006 to March 2013. Decomposition estimates of the BBIR into inflation expectations, inflation risk premia, liquidity premia and indexation lag effects. The effects of CPI seasonality and the deflation floor on TIPS yields and the effects of specialness of nominal Treasuries on nominal Treasury yields are also estimated. **Liquidity proxies** Differences between inflation swaps and the breakeven inflation rate, bid ask spread for TIPS, relative trading volume of TIPS and nominal Treasuries, difference between TIPS and off-the run nominal Asset Swap Spreads, difference between off-the-run and on-the run 10 year nominal Treasury Asset Swap Spreads, average absolute fitting errors from the Svensson TIPS yield curve. **Findings** 'Treating the TIPS BEI [breakeven inflation] as a clean proxy for inflation expectation can be especially problematic, since a combination of economically significant TIPS liquidity premiums and inflation risk premiums could potentially drive a notable wedge between the TIPS BEI and true inflation expectations.'[116]
Pflueger and Viceira (2015)	**Liquidity Premium** US: 10 year breakeven: 70 to 100 basis points, early 2000s; 35–70 basis points 2004 to 2007; beyond 200 basis points during the financial crisis; 40 basis points end of sample, 2014. Average 64 basis points with a standard deviation of 26 basis points over the entire sample. UK: averaged 50 basis points with standard deviation of 25 basis points over the entire sample. Towards end of the sample, 10 basis points.[117] Liquidity premia are found to be time-varying for both the US and the UK.[118] **Bonds** US: 10 year nominal US securities and TIPS, UK: 20 year nominal and indexed bonds. **Sample Period** US: March 1999 to December 2014, UK: November 1999 to December 2014. June 1999 to December 2014 (US) and February 2000 to December 2014 (UK) for excess returns estimates. **Model/Estimation Applied** Regression of breakeven inflation on a vector of bond market liquidity proxies and a vector of expected inflation proxies. Tests for the predictability of the liquidity component of inflation indexed bond returns. Decomposition estimates of bond risk premia into expected liquidity excess return (liquidity premium), the expected liquidity-adjusted breakeven return (inflation risk premium) and expected liquidity-adjusted TIPS returns (real rate risk premium). **Liquidity proxies** US: Synthetic-cash breakeven spread (inflation swap rate and BBIR spread), relative trading volume of indexed and nominal bonds, nominal US securities on-the-run, off-the-run spread. UK: LIBOR general collateral repo interest rate spread, difference between fitted par yield and yield on recently issued 10 year nominal bonds, relative trading volume of indexed and nominal bonds. **Findings**

[116] *ibid*., p. 1.

[117] Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, pp. 20-21.

[118] *ibid*., p. 24.

	'The yields of inflation-indexed bonds incorporate an economically significant time-varying liquidity premium with respect to the yields of nominal bonds of similar maturity.'[119] 'Liquidity proxies explain almost as much variation in U.S. breakeven as do inflation expectation proxies.'[120]
Liu et al. (2015)	**Liquidity Premium** The liquidity premium explains 98% of the total risk premium (inflation risk premium and liquidity risk premium) during the crisis in 2008 and its absolute value was as high as 80 basis points for the 10 year BBIR. For the 10 year BBIR, the liquidity premium averaged –30 basis points after 2009 and stabilised at around –20 basis points after 2012.[121] **Bonds** BBIRs of 3, 4, 5, 7 and 10 year maturities. **Sample Period** October 1992 to December 2013. Inflation swaps from 2004 to December 2013. **Model/Estimation applied** Affine term structure model of BBIRs. The model is used to decompose the market-implied BBIRs into measures of inflation expectations, risk premia and differences between the retail price index (RPI) and CPI using a no-arbitrage framework. **Liquidity Proxies** Prices of inflation swaps. **Findings** 'UK BEI rates [BBIR] cannot be interpreted as market forecasts of future CPI inflation…This is because BEI rates in the UK refer to RPI rather than CPI inflation and also because BEI rates include risk premia which compensate for inflation risk and also liquidity risk in some cases.'[122]
Fleckenstein et al. (2014)	**Liquidity Premia** Study into US TIPS-Treasury mispricing, where Fleckenstein et al. state that mispricing is equivalent to TIPS liquidity premia identified by other researchers. Mispricing is found across all pairs of TIPS and nominal Treasury bonds. For individual pairs, the mispricing often exceeds $10 to $20 (per $100 notional). Translated into yields, the average size of the mispricing is 54.5 basis points but can exceed 200 basis points for some pairs.[123] **Bonds** 29 maturity matched pairs of TIPS issues and Treasury bonds. **Sample Period** July 2004 to November 2009. **Model/Estimation applied** Regression of monthly basis point mispricing on supply, liquidity, credit risk and capital flow factors. Mispricing is estimated by the difference between the price of

119 *ibid*., p. 2.

120 *ibid*., p. 3.

121 Zhuoshi Liu, Elisabeth Vangelista, Iryna Kaminski and Jon Relleen (2015), 'The informational content of market-based measures of inflation expectations derived from government bonds and inflation swaps in the United Kingdom', *Staff Working Paper No. 551, Bank of England*, p. 13.

122 *ibid*., p. 16.

123 Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, p. 2152.

	a Treasury bond and inflation-swapped TIPS (a synthetic nominal Treasury). **Liquidity Proxies** An arbitrage strategy where a comparison is made between the prices of synthetic nominal Treasuries (the price of TIPS, where inflation-linked TIPS cash flows are converted into fixed cash flows using inflation swaps) and nominal Treasuries. Regression of monthly changes in the average basis-point mispricing was undertaken on the following: ratio of TIPS trading volume to total coupon-paying Treasury trading volume, TIPS issuance and Nominal Treasury Issuance, total notional amount of Repo Fails experienced by primary dealers (measures market disruption), swap spread (monthly basis point change in the 10 year USD swap spread), hedge fund flows/slow moving capital. **Findings** Liquidity and safety of US Treasury bonds 'could help explain why nominal Treasury bonds are consistently expensive relative to inflation indexed securities…and why this differential increases during times of financial distress when demand for these attributes increases.'[124]
Grishchenko and Huang (2012)	**Liquidity Premium** Liquidity premium on TIPS does not exceed on average 6 basis points, but spiking to 30–35 basis points between 2002 and 2003.[125] The estimated liquidity premium is not maturity specific. However, the authors use their estimate of the liquidity premium of 6 basis points to adjust their estimate of the 10 year inflation risk premium in the BBIR.[126] **Bonds** TIPS of 3 to 10 years. **Sample Period** January 2000 to September 2008. **Model/Estimation applied** Average fitting error of TIPS individual issues' yields with respect to the Svensson yield curve. Estimation of the inflation risk premium from the prices of nominal Treasuries and TIPS. Estimating real yields by adjusting for the effects of indexation lag on TIPS yields and the liquidity premium embedded in TIPS yields. **Liquidity Proxies** Average fitting error of TIPS individual issues' yields with respect to the Svensson yield curve. **Findings** 'TIPS market is known to contain a sizable liquidity component especially during early years of its operation. For this reason TIPS yields are biased upward with respect to true yields that are used in deriving inflation expectations.'[127]
Gurkaynak et al. (2010)	**Liquidity Premium** The study estimates the liquidity premium of 5 and 10 year US TIPS yields relative to US nominal Treasury yields of the same maturity. The estimates are obtained by setting the liquidity premiums in April 2005 to zero. The levels of liquidity premiums are not estimated. Instead, they estimate the liquidity premiums relative to the liquidity premiums in April 2005. The 10 year BBIR

[124] *ibid*., p. 2153.

[125] Olesya Grishchenko and Jing-zhi Huang (2012), 'Inflation Risk Premium: Evidence from the TIPS market', *Finance and Economics Discussion Series Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C.* 2012-06, p. 3.

[126] *ibid*., p. 28.

[127] *ibid*., p. 3.

	liquidity premium moves approximately between 0 and 80 basis points between 1999 and 2008.[128] **Bonds** Nominal US Treasuries and TIPS of 5 and 10 years. **Sample Period** January 1999 to October 2008. **Model/Estimation applied** Nelson, Siegel and Svensson model fitted to TIPS yields. Regressing inflation compensation on market liquidity proxies. **Liquidity Proxies** Spread between Resolution Funding Corporation (Refcorp) STRIPS and Treasury STRIPS, trading volume among primary dealers in TIPS, expressed as a share of total Treasury trading volume. **Findings** Obtaining inflation compensation from the nominal and TIPS yield curves 'embodies nontrivial and time-varying liquidity and inflation risk premia.'[129]

79. The sample of research findings in Table 3 suggest that the liquidity premia in BBIRs are significant and may be time-varying. Such variation may distort breakeven estimates of expected inflation by a larger margin during periods of financial market instability. D'Amico et al. argue that the time variation of the liquidity premia in BBIRs may be partly explained by changes in investor risk aversion during such periods.[130] During these times not only may indexed bond yields rise, but nominal bond yields may fall as there is a flight-to-safety into liquid nominal bond markets[131], where the resulting change in the differential liquidity premia may further compress BBIR estimates.

80. Time-varying liquidity premia may also be contributing significantly to the observed volatility of BBIRs. Pflueger and Viceira (2015) find that once the BBIR is adjusted for the liquidity premium, the BBIR is substantially more stable.[132] However, the predictability of this time variation is likely to be modest because the time variation could be difficult to model and may be sensitive to study parameters chosen (such as the choice of sample period).

81. While most studies of liquidity premia in BBIRs have been conducted within the last decade, earlier US studies have identified the potential existence of significant liquidity premia in BBIRs.

    (a) Deacon et al. (2004) identify two main factors that can deter investors from purchasing inflation-indexed bonds: their tax treatment (as an example, referring to their tax treatment in the US) and their lack of liquidity compared to other

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128 Refet Gurkaynak, Brian Sack and Jonathan Wright (2010), 'The TIPS Yield Curve and Inflation Compensation', *American Economic Journal: Macroeconomics*, 2(1), pp. 88-89.

129 *ibid*., p. 91.

130 Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, pp. 26-28.

131 *ibid*., p. 26; p. 32; Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, pp. 12-13..

132 Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 6 and p. 32.

investments.[133] Deacon et al. observe that the relative illiquidity in the indexed bond market is likely to manifest itself in the form of a liquidity premium that may at least partially offset the inflation risk premium included in the BBIR.[134] Deacon et al. (2004) cite evidence indicating that the liquidity premium has persisted in US TIPS markets despite a marked improvement in the liquidity in the market for TIPS since 1997.[135]

(b) Craig (2003) observes that when financial markets were volatile in the autumn of 1998, liquidity was considered to be important. As a result, the yields on US nominal Treasuries fell by more than the yields on TIPS. Craig argues that the liquidity premium in TIPS yields is the most likely clue behind the observed excess yield on TIPS over comparable nominal Treasuries.[136]

(c) Shen and Corning (2001) conduct an empirical study of BBIR and find that the liquidity premium for US TIPS to be large and highly variable over time.[137] During the financial market crisis in 1998, Shen and Corning observe the liquidity premium to be twice its pre-crisis average. On the basis of the large and highly variable liquidity premium, Shen and Corning find that the yield difference between US nominal Treasuries and TIPS does not provide a good measure of inflation expectations.[138]

82. The sample of research findings that BBIRs contain significant and potentially time-varying liquidity premia suggest that BBIR estimates may be incongruent with market expectations of inflation. Liquidity premia may introduce a considerable wedge between BBIR estimates and market expectations of inflation which, if time varying, may also be difficult to estimate at any point in time.

83. The estimated liquidity premia in the BBIRs differ considerably across the studies which suggest that BBIR estimates may not be robust to study parameters chosen. Different estimates of liquidity premia are likely due to several factors including: the choice of model/estimation method employed, the sample period, the different maturities of the bonds chosen, different datasets and the choice and number of liquidity proxies.[139] [140] The differences in the approaches to estimating liquidity premia across studies may be due to limited data availability, but also be because liquidity premia in the BBIRs are not yet well understood. For example, D'Amico et al. (2016) conclude that a better understanding of the determinants of liquidity premia and the sources of its variation is a topic for future research.[141]

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133 Mark Deacon, Andrew Derry and Dariush Mirfendereski (2004), *Inflation-indexed Securities – Bonds, Swaps and Other Derivatives*, Second Edition, John Wiley & Sons, West Sussex, pp. 53-54.

134 *ibid*., p. 63.

135 *ibid*., p. 63.

136 Ben Craig (2003), 'Why are TIIS Yields So High? The Case of the Missing Inflation-Risk Premium', Federal Reserve Bank of Cleveland, Economic Commentary, p. 3 and p. 5.

137 Pu Shen and Jonathan Corning (2001), 'Can TIPS Help Identify Long-Term Inflation Expectations?' Federal Reserve Bank of Kansas City, *Economic Review*, Fourth Quarter, p. 62.

138 *ibid*., p. 62; pp. 75-78.

139 Grishchenko and Huang highlight some of the differences to explain why their results differed to similar studies. Olesya Grishchenko and Jing-zhi Huang (2012), 'Inflation Risk Premium: Evidence from the TIPS market', *Finance and Economics Discussion Series Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C.* 2012-06, p. 7.

140 For several studies, the estimated size of the liquidity premia may also depend on the proxy used for inflation expectations (several use survey-based estimates such as Survey of Professional forecasters, Blue Chip Forecasts of Financial and Economic Indicators, long term inflation forecast from the Michigan Survey of Consumers and/or Chicago Fed National Activity Index).

141 Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 37.

84. The above findings of liquidity premia in the some of the most liquid of indexed bond markets suggests that decomposition estimates of the Australian BBIR (into inflation expectations and liquidity premia) are necessary before this method is employed to estimate inflation expectations. However, challenges remain even if decomposition estimates are conducted and the data from Australian bond markets is equal to that of the US in scope and availability. The decomposition of the Australian BBIR into inflation expectations and liquidity premia may not be robust to different study parameters chosen. The resulting variability of 'bias-adjusted' BBIR estimates may introduce considerable uncertainty over BBIR-implied estimates of expected inflation.

5.3.2. Potential liquidity premia in the Australian BBIRs

85. While the RBA has observed possible biases in the BBIRs arising from the relative illiquidity of indexed CGS, there is less research into Australian BBIRs. One reason may be the lack of available Australian data in which to decompose BBIRs into expected inflation, liquidity premia, inflation risk premia and other biases/distortions.

86. In their decomposition estimates of Australian BBIRs over the period 31 July 1992 to 15 December 2010, Finlay and Wende (2011) find, albeit indirectly, potential liquidity premia in BBIRs.[142]

(a) Finlay and Wende observe that inflation-indexed CGS are relatively illiquid compared to nominal CGS and two of the indicators employed to measure liquidity are: indexed and nominal bond turnover and the turnover ratio of indexed and nominal bonds (turnover as a ratio of their outstanding values). Finlay and Wende observe that for the period from 2003–04 to 2007–08 the average annual turnover for nominal government bonds were roughly $340 billion and $15 billion for inflation indexed bonds. This equated to a turnover ratio of around 7 for nominal bonds and 2.5 for inflation indexed bonds. From these proxies, Finlay and Wende conclude that indexed bonds may include liquidity premia.[143]

On the basis of Finlay and Wende's consideration of the turnover ratio as a potential liquidity proxy, the historical turnover ratio is considered here. A higher the turnover ratio may imply greater liquidity of the bond market. From 2007–08 to 2014–15, the turnover ratios for nominal and indexed CGS have fallen (Figure 4). In 2007–08, the turnover ratio for nominal CGS was 5.7, and by 2014–15 the turnover ratio had fallen to 3.3. In 2007–08, when the indexed CGS market was observed as illiquid, the turnover ratio for indexed CGS was 1.9. By 2014–15, the turnover ratio for indexed CGS has only improved slightly to 2.

However, the turnover ratio may be a less instructive gauge of the *relative* liquidity of these markets since the increase in the supply of outstanding CGS, rather than the decline in turnover, has largely contributed to a decline in the turnover ratios over time. This may impair comparisons of the turnover ratios as measures of relative liquidity. None of the BBIR studies cited use relative turnover ratios as proxies for relative liquidity in the estimation of liquidity premia in BBIRs. This may be because supply and turnover have independent effects on the relative liquidity of nominal and indexed bonds.

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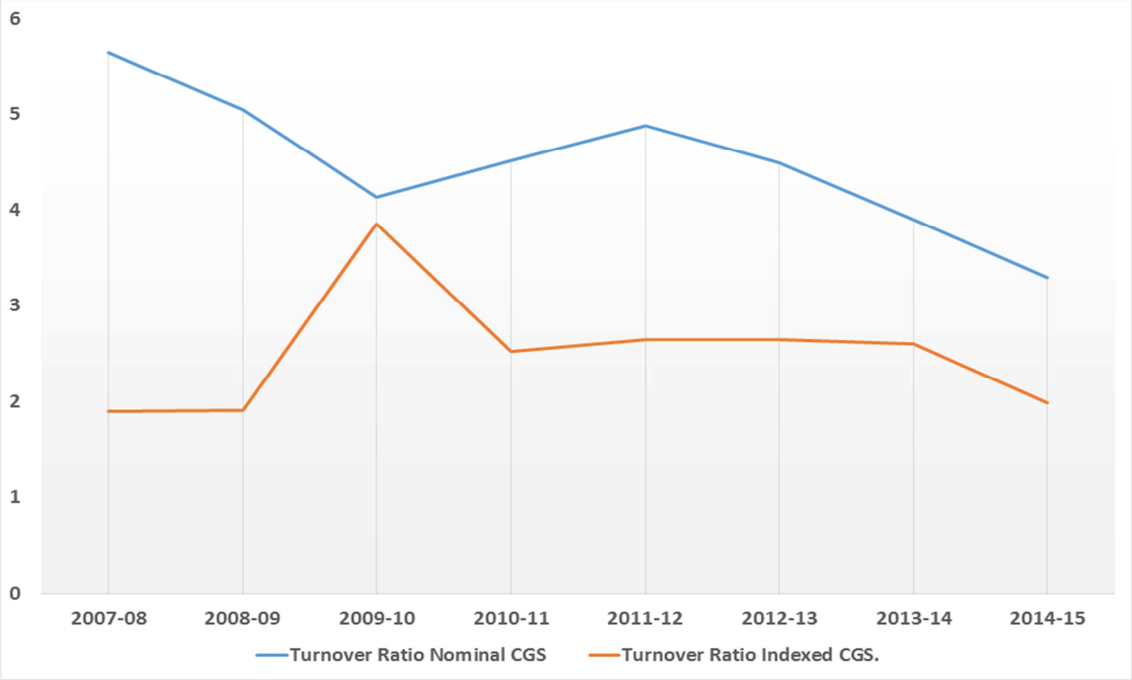
142 Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, pp. 1-39.

143 *ibid*., p. 8 (footnote).

Figure 4: Turnover ratio for nominal and indexed CGS, all maturities from 2007–08 to 2014–15.



Source: Australian Office of Financial Management, Monthly Changes in Australian Government Securities (AGS) Outstanding, 2007–08 to 2014–15. AFMA, Australian Financial Markets Reports data, Summary of Market Turnover – Government Debt Securities, Commonwealth Government Bonds, 2007–08 to 2014–15 (Annual Turnover AUD million).

(b) Finlay and Wende decompose BBIRs of different term horizons into estimates of inflation risk premia and model-derived estimates of inflation expectations. Their estimate of inflation risk premia also implicitly captures the relative liquidity premia.[144] Finlay and Wende observe that if the BBIR curve shifts down relative to inflation expectations, the inflation risk premia fall below their 'true level', suggesting the presence of relative liquidity premia in indexed CGS yields. They note that the relative illiquidity of indexed CGS is a plausible explanation for their negative estimates of inflation risk premia (implying liquidity premia in BBIRs).[145]

(c) Finlay and Wende suggest that the assumption of constant liquidity premia in their BBIR estimates may not be unreasonable. They assume that the existence of liquidity premia cause a level shift in the estimated inflation risk premia but does not greatly bias their estimated changes in the inflation risk premia. However, they do consider the potential variation of liquidity premia over time. One possible interpretation of the low BBIR during the GFC was due to an increase in indexed CGS liquidity premia – which was in line with increases in liquidity premia for most assets aside from the highly rated and highly liquid nominal government securities.[146]

87. Finlay and Olivan (2012) also discuss liquidity premia in Australian BBIRs.[147] Finlay and Olivan note that the most serious shortcoming of the BBIR is that it captures investors' liquidity preferences for different types of bonds. They observe that the outstanding issuance of indexed CGS is 13 times smaller than nominal CGS. This

144 *ibid*., p. 8.

145 *ibid*., pp. 15-16.

146 *ibid*., p. 18.

147 Richard Finlay and David Olivan (2012), 'Extracting Information from Financial Market Instruments', *RBA Bulletin*, March Quarter, pp. 45-54.

ratio implies considerable relative illiquidity of indexed CGS – investors who wish to hold highly liquid assets may have a stronger preference for nominal CGS. The effect of liquidity preferences can be more pronounced during periods of financial market instability, when 'flight-to-safety' bids put downward pressure on the yields on nominal CGS.[148]

As a result of these different liquidity preferences, BBIR estimates may become compressed and the BBIR may provide distorted estimates of expected inflation.[149] Since Finlay and Olivan's study, the ratio of outstanding nominal CGS to outstanding indexed CGS is largely unchanged (June 2016).[150]

88. Finlay and Olivan's study suggests that the ratio of outstanding nominal CGS to outstanding indexed CGS may be a relevant proxy for the relative liquidity of indexed CGS. The outstanding issuance ratio is observed from 2007–08, when the indexed CGS market was found to be illiquid, to 2015–16.

From July 2007 to June 2016 (Figure 5, left panel), the supply of nominal CGS has increased by a considerably larger percentage than the supply of indexed CGS. The right panel of Figure 5 is ratio of outstanding nominal CGS to outstanding indexed CGS, all maturities. From July 2007 to June 2016, the ratio has increased considerably, from approximately 8 to approximately 13. The ratio of nominal CGS to indexed CGS has increased by approximately 63 per cent over the observed period. This implies that the relative liquidity of indexed CGS has deteriorated substantially since 2007–08.

Unlike the turnover ratio, the effect of changes in the relative supply of nominal and indexed bonds on biases in the BBIR is considered in the literature. However, the studies of the US and UK BBIR that estimate such effects are few, and the findings are mixed.[151] One reason may be that these bond markets are large and supply is not a concern. For smaller bond markets, such as those in Australia, relative supply may remain an important proxy for the relative liquidity.

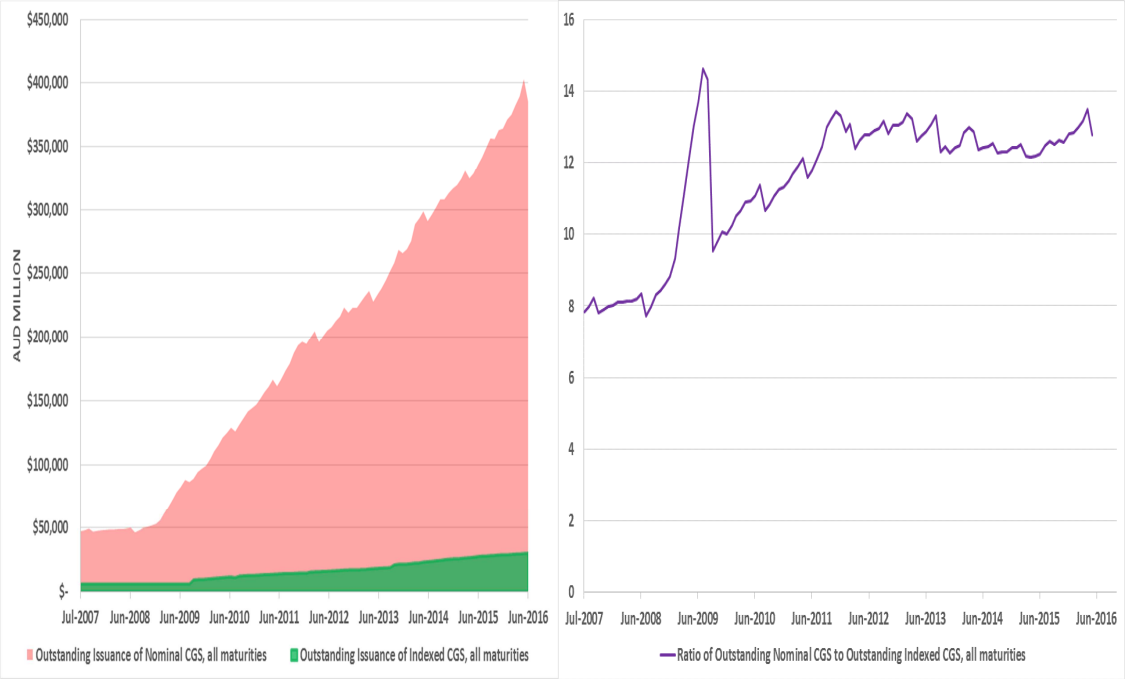
148 *ibid*., p. 50.

149 *ibid*., p. 50.

150 Australian Office of Financial Management, Monthly Changes in Australian Government Securities (AGS) Outstanding, 2007-08 to 2015-16.

151 Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, pp. 2181-2184. Carolin Pflueger and Luis Viceira (2011), 'An Empirical Decomposition of Risk and Liquidity in Nominal and Inflation-Indexed Bonds', Working Paper, March, pp. 1-38.

Figure 5: Outstanding nominal and indexed CGS and the ratio of outstanding nominal CGS to outstanding indexed CGS (all maturities), 2007–08 to 2015–16, monthly average



Source: Australian Office of Financial Management, Monthly Changes in Australian Government Securities (AGS) Outstanding, 2007–08 to 2015–16.

89. Moore (2016) also considers the potential decline in the relative liquidity of indexed CGS over a similar period and he considers its implications for BBIR estimates.[152] However, unlike Finlay and Olivan, Moore does not consider the potential influence of relative supply on relative liquidity. Citing the research by Debelle (2016)[153] and Chesire (2016)[154], Moore observes that since 2008 there has been a decline in the liquidity of the fixed income markets in Australia. Moore argues that the decline reflects, in part, the correction in the pricing of liquidity which had been underpriced in years prior to the GFC. Moore (2016) argues that these developments since the GFC may have raised the liquidity premium inherent in indexed CGS by more than nominal CGS because of the lower initial liquidity of indexed CGS. Moore argues that if this is the case, the BBIR estimates may become more downwardly biased than in the past.[155]

5.3.3. The consideration of two relative liquidity proxies

90. A further examination of the relative (il)liquidity of indexed CGS may be undertaken through simple observations of bond liquidity proxies for which there are Australian data: relative turnover of nominal and indexed CGS (all maturities) and the difference between 10 year nominal and indexed CGS bid-ask spreads. These observations serve two purposes. Firstly, the observed relative turnover and bid-ask spreads may add support or caution to the findings/observations of Finlay and Wende (2011),

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152 Angus Moore (2016), 'Measures of Inflation Expectations in Australia, *Reserve Bank of Australia Bulletin*, December Quarter, p. 28.

153 Guy Debelle (2016), 'Liquidity in Australian Fixed Income Markets', Address to the 4th Australian Regulatory Summit, Sydney, 21 June.

154 Jon Chesire (2016), 'Liquidity in Fixed Income Markets', *Reserve Bank of Australia Bulletin*, June Quarter, pp. 49-58.

155 Angus Moore (2016), 'Measures of Inflation Expectations in Australia, *Reserve Bank of Australia Bulletin*, December Quarter, p. 28.

Finlay and Olivan (2012) and Moore (2016) that BBIR estimates may include significant liquidity premia. Secondly, some tentative inferences from these observations may be made as to whether or not the increase in the supply of outstanding indexed CGS has improved the relative liquidity of indexed CGS since 2007. Table 4 provides the detail of these two proxies and available Australian data. Consideration of other potential liquidity proxies is provided in Appendix 2.

Table 4: Proxies for liquidity and the availability of Australian data

Proxy	Measure of liquidity and a sample of relevant studies	Available Australian Data
Transaction volumes of inflation indexed bonds and nominal bonds	Relative trading/transaction volume is a widely cited measure of market liquidity. In their estimation of liquidity premia in BBIRs, Gurkaynak et al. (2010), D'Amico et al. (2016), Pflueger and Viceira (2015) and Fleckenstein et al. (2014) use variations of relative trading volumes of TIPS and nominal Treasuries as proxies to estimate liquidity premia in US BBIRs.[156]	Yes. Limited to annual data. Annual turnover of nominal and indexed CGS in the secondary market from 2007–08 to 2014–15.
Bid-ask spread	Sarr and Lybek (2002) argue that liquid markets tend to exhibit low transaction costs, which is in the form of narrow bid-ask spreads. This is because bid-ask spreads capture nearly all transaction costs.[157] Fleckenstein et al. (2014) observe the difference between the bid-ask price spreads of TIPS and nominal US Treasuries as one of a number of institutional/economic factors that may drive a wedge between the prices of Treasury Bonds and TIPS.[158] Finlay and Wende (2011) refer to the relatively stable bid-ask spreads of indexed CGS (excluding periods of market volatility) as a basis for their assumption of relatively constant liquidity.[159] In their BBIR study, Gurkaynak et al (2010) argue that ideally they would like to use bid-ask spreads as a proxy for liquidity to estimate the liquidity premium in the TIPS market, but they did not have access to such data.[160] Schulz and Stapf (2009) use bid-ask spreads for US Treasuries and TIPS as one explanation for	Yes. Limited time series data. Daily bid-ask yield spreads from 2000 to 2016. Largely constant bid-ask spreads for indexed CGS from 2000 to 2010–11. Data from 2011–12 to 2015–16 is analysed.

156 Refet Gurkaynak, Brian Sack and Jonathan Wright (2010), 'The TIPS Yield Curve and Inflation Compensation', *American Economic Journal: Macroeconomics*, 2(1), pp. 86-88; Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 27 and p. 59; Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, p. 15 and p. 36.

157 Abdourrahmane Sarr and Tonny Lybek (2002), 'Measuring Liquidity in Financial Markets', *IMF Working Paper*, WP/02/232, December, p. 5 and pp. 9-11.

158 Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, pp. 2159-2160; p. 2174.

159 Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, p. 16.

160 Refet Gurkaynak, Brian Sack and Jonathan Wright (2010), 'The TIPS Yield Curve and Inflation Compensation', *American Economic Journal: Macroeconomics*, 2(1), p. 86 (footnote).

	the change in the relative liquidity of these bonds during the global financial crisis. Schulz and Stapf find that during the global financial crisis the negative economic outlook lowered inflation expectations (from surveys) and the BBIR. However, Schulz and Stapf find that the narrowing of the BBIR was partly driven by the considerable widening of the liquidity differential between nominal US Treasuries and US TIPS.[161] The BBIR for short to medium maturities fell from approximately 3 per cent to less than –1 per cent. Schulz and Stapf observe that during this time the increase bid-ask spread on inflation-indexed Treasuries was more than double that of nominal US Treasuries.[162] In his analysis of the US Treasury market, Fleming (2003) argues that the bid-ask spread – the difference between bid and offer prices – is a usual measure for tracking US Treasury market liquidity because it can be calculated quickly and easily.[163] Amihud and Mendelson (1986) argue that a 'natural' measure of illiquidity is the spread between bid and ask prices, which is the sum of the buying premium and the selling concession.[164]	

91. The increase in the supply of outstanding indexed CGS from $6 billion in 2007–08 to $26 billion in 2014–15 (monthly average) appears to have facilitated a substantial increase in the turnover of indexed CGS.[165] Figure 6 (left panel) shows a substantial increase in indexed CGS turnover in the secondary market from 2007–08 to 2013–14, although turnover falls in 2014–15. The increase in the supply of outstanding nominal CGS from $48 billion in 2007–08 to $317 billion in 2014–15 (monthly average) also appears to have resulted in a sharp increase in the turnover of nominal CGS in the secondary market (Figure 6, right panel).[166] An increase in the supply of CGS may make it easier to execute arbitrage strategies and therefore may improve turnover and absolute liquidity in these markets.

[161] Schulz and Stapf observe the breakeven inflation rates for whole year tenors of 2 to 10 years. Sample period: 12 June 2008 to 13 August 2008, 3 September 2008 to 9 December 2008. Alexander Schulz and Jelena Stapf (2009), 'Price Discovery on traded inflation expectations: Does the financial crisis matter?', Deutsche Bundesbank, Eurosystem, Discussion Paper Series 1: Economic Studies, No. 25/2009, pp. 1-33; pp. 18-19.

[162] *ibid*., pp. 18-19.

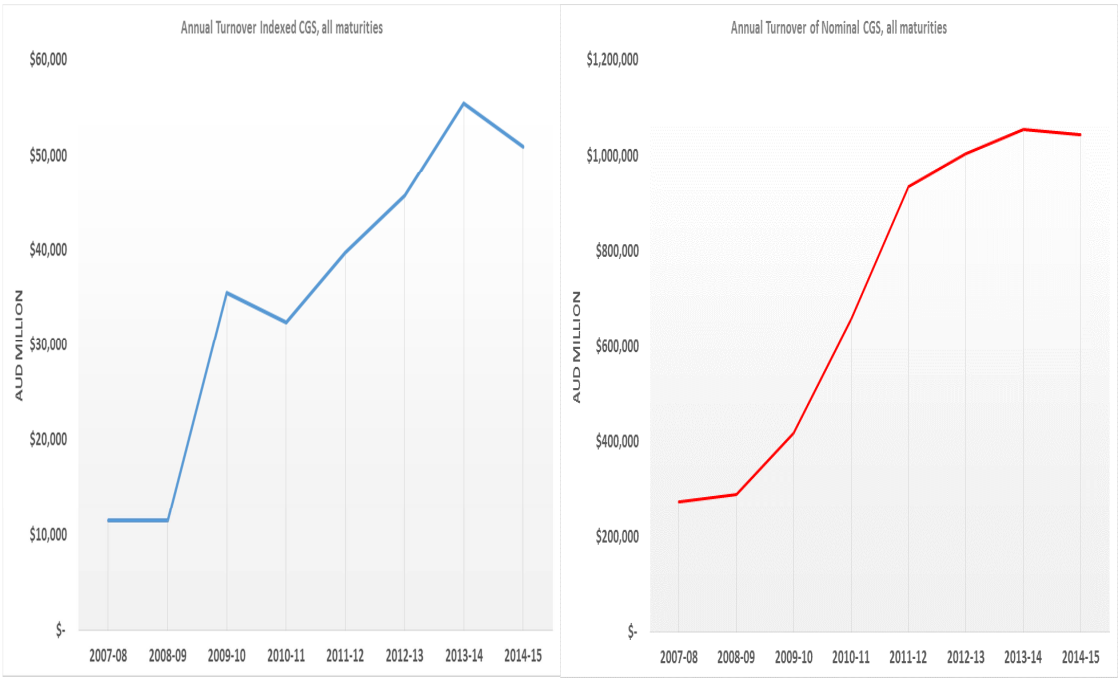
[163] Michael Fleming (2003), 'Measuring Treasury Market Liquidity', *Federal Reserve Bank of New York Economic Policy Review*, September, p. 84.

[164] Yakov Amihud and Haim Mendelson (1986), 'Asset Pricing and the Bid-Ask Spread'. *Journal of Financial Economics*, 17, pp. 223-224.

[165] Australian Office of Financial Management, Monthly Changes in Australian Government Securities (AGS) Outstanding, 2007-08 to 2015-16.

[166] *ibid*.

Figure 6: Annual turnover of indexed and nominal CGS, all maturities from 2007–08 to 2014–15

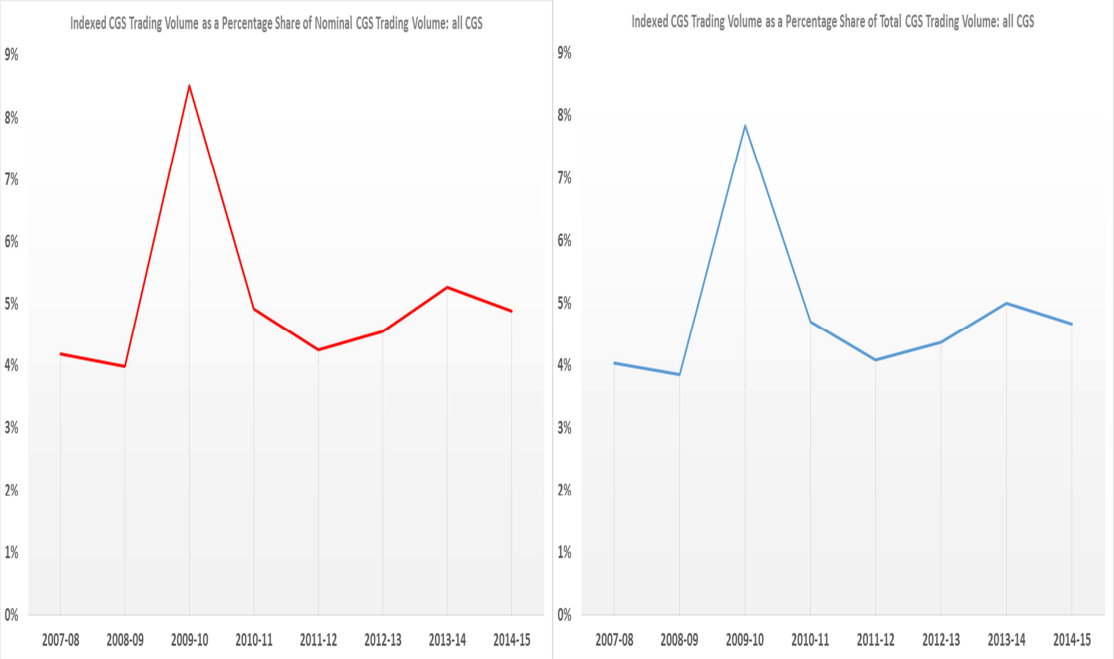


Source: AFMA, Australian Financial Markets Reports data, Summary of Market Turnover – Government Debt Securities, Indexed Linked and Nominal Commonwealth Government Bonds, 2007–08 to 2014–15 (Annual Turnover AUD million).

92. In Figure 7, the annual trading volume of indexed CGS as a share of total CGS is shown in the left panel and annual trading volume of indexed CGS as a share of nominal CGS is shown in the right panel. While the indexed CGS trading volume as a share of total and nominal CGS trading volume increased sharply from 2007–08 to 2009–10, the shares have almost returned to their 2007–08 levels in 2014–15. In 2014–15 indexed CGS trading volume is less than 5 per cent of nominal and total CGS trading volume.

93. Relative turnover may be considered a relevant proxy for the relative liquidity of indexed CGS. And the lack of improvement in the relative liquidity of indexed CGS since 2007–08 may suggest that BBIR estimates of expected inflation remain less congruent with market-expectations of inflation. The relative illiquidity of indexed CGS may require that investors are compensated for holding positions in indexed CGS *vis-à-vis* nominal CGS by a corresponding liquidity premia in indexed yields. The relative liquidity premia may drive a significant wedge between BBIR estimates and market expectations of inflation.

Figure 7: Indexed CGS trading volume as a share of nominal CGS trading volume and as a share of total CGS trading volume (all maturities)



Source: AFMA, Australian Financial Markets Reports data, Summary of Market Turnover – Fixed Government Debt Securities, Nominal Commonwealth Government Bonds and Indexed-Linked Commonwealth Government Bonds, 2007–08 to 2014–15 (Annual Turnover AUD million).

94. While there were observations of the illiquidity of indexed CGS in 2007, it is likely that indexed CGS were also considerably illiquid *relative to* nominal CGS during this time. The turnover of nominal CGS was (and up until 2014–15) many times larger than indexed CGS. Moreover, since the start of the turnover series in 2007–08, the lower supply of nominal CGS at the time was unlikely to be an issue for the liquidity of this market. In its advice to the ACCC in 2007, the RBA find that the relatively lower supply of nominal CGS market did not have any significant effect on nominal CGS yields. The RBA also cited the government's commitment to maintaining a viable level of outstanding nominal CGS (not indexed CGS).[167] On the basis of these findings, it is unlikely that distortions from illiquidity were occurring in the nominal CGS market during this time. Therefore, indexed CGS were likely to be considerably illiquid *relative* to nominal CGS. On the basis of relative turnover this relative illiquidity has not improved – implying potentially significant liquidity premia in BBIR estimates of expected inflation.

95. Bid-ask spreads may be considered a relevant proxy for market liquidity since the spreads directly reflect the transaction costs required to make the market. The liquidity of an asset may be inversely related to the size of transaction costs incurred. If there are relatively high transaction costs, or a high likelihood of incurring transaction costs in the trade of an asset, the yield on the asset must be higher to attract investors. The higher yield reflects the liquidity premium. Fleming (2003) finds that bid-ask spreads in the US Treasury market are also highly correlated with other measures of bond market liquidity such as the price-impact measure, and they are

[167] RBA, Letter to Joe Dimasi, ACCC, *Comments on a report prepared by NERA concerning the Commonwealth Government bond market,* Financial Markets Group, 9 August 2007, pp. 1-3.

correlated with episodes of reported poor liquidity.[168] Therefore, a change in bid-ask spreads may indicate broader changes in the liquidity or relative liquidity of bond markets.

96. It is expected that an increase in the supply of outstanding nominal (indexed) CGS may facilitate relative yield arbitrage and improve the liquidity of nominal (indexed) CGS at all maturities. On the basis of observed bid-ask yield spread data, liquidity of 10 year nominal CGS has improved as a result of an increase in the supply of nominal CGS. However, this is not the case for 10 year indexed CGS.

97. Figures 8 and 9 map the average daily bid-ask yield spreads of 10 year indexed and nominal CGS against their respective average monthly outstanding values each financial year. The sample period is 2011–12 to 2015–16. From 2001–02 to 2010–11, the Bloomberg data on bid-ask yield spreads of indexed CGS are available but spreads largely constant, potentially reflecting largely inactive trade over this period. Therefore, data from this period are not analysed.[169]

98. On the basis of the bid-ask yield spread proxy, the increase in the supply of outstanding indexed CGS may not have been sufficient to improve the liquidity of 10 year indexed CGS (Figure 8) over the sample period. Indeed, on the basis of this proxy, absolute liquidity of 10 year indexed CGS appears to have deteriorated substantially since 2013–14. The deterioration of this liquidity proxy is consistent with the deterioration of the turnover proxies from 2013–14 to 2014–15: both absolute and relative turnover of indexed CGS declined over this period.

99. On the other hand, the substantial increase in the supply of nominal CGS in recent years appears to have reduced the bid-ask yield spread on 10 year nominal CGS in a predictable manner (Figure 9). The magnitude of the increase in the supply of nominal CGS is considerably larger than that of indexed CGS, which may partly explain the fall in nominal CGS bid-ask spreads.

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168 Michael Fleming (2003), 'Measuring Treasury Market Liquidity', *Federal Reserve Bank of New York Economic Policy Review*, September, p. 84.

169 Daily bid-ask yield spreads on generic 10 year nominal and indexed CGS are obtained from Bloomberg. Bloomberg provides bid and ask bond *yields* for the calculation of bid-ask spreads. Bid-ask yield spreads are calculated by subtracting the ask yield from the bid yield because the bid yield is higher than the ask yield, reflecting the inverse relationship between bond yields and bond prices (where the bid price is lower than the ask price). Bid-ask yield spreads are calculated from Bloomberg end-of-day yield to maturity bid and ask yields to maturity for generic 10 year nominal and indexed CGS. Bloomberg codes: GTAUD10Y and GTAUDII10Y. Generics are used for historical analysis and only yields, not prices, are stored historically. Zero bid-ask yield spread observations are removed from the historical data.

Figure 8: Average daily bid-ask yield spread (95% confidence interval) on 10 year indexed CGS and average monthly outstanding value of all indexed CGS: 2011–12 to 2015–16

Source: Australian Office of Financial Management, Monthly Changes in Australian Government Securities (AGS) Outstanding, 2011–12 to 2015–16. Indexed CGS; Bloomberg end-of-day bid and ask yield to maturity on generic 10 year indexed CGS, 2011–12 to 2015–16. Bloomberg code: GTAUDII10Y.

Figure 9: Average daily bid-ask yield spread (95% confidence interval) on 10 year nominal CGS and average monthly outstanding value of all nominal CGS: 2011–12 to 2015–16

Source: Australian Office of Financial Management, Monthly Changes in Australian Government Securities (AGS) Outstanding, 2011–12 to 2015–16. Nominal CGS; Bloomberg end-of-day bid and ask yield to maturity on generic 10 year nominal CGS, 2011–12 to 2015–16. Bloomberg code: GTAUD10Y.

100. The sample period is considerably smaller for the bid-ask spread proxy *vis-à-vis* the turnover proxy. However, on the basis of both turnover and bid-ask spread proxies it appears unlikely that the relative liquidity of indexed CGS has improved since 2007–08. In recent years, there is also evidence of the deterioration in the relative liquidity of indexed CGS given:

- the different trajectories of bid-ask spreads for 10 year indexed and nominal CGS since 2013–14, and
- the fall in relative turnover of indexed CGS in 2014–15.

101. One approach to observing the relative illiquidity of 10 year indexed CGS is by simply subtracting the bid-ask yield spread of 10 year nominal CGS from that of the 10 year indexed CGS. A simple subtraction of nominal bid-ask spreads from indexed bid-ask spreads is similar to the approach adopted by Fleckenstein et al. (2014) for US Treasuries.[170] A positive basis point difference is the additional transaction cost (in yield terms) incurred in the trade of 10 year indexed CGS. A positive difference may also suggest a broader condition of illiquidity in the indexed CGS market relative to that of the nominal CGS market.[171]

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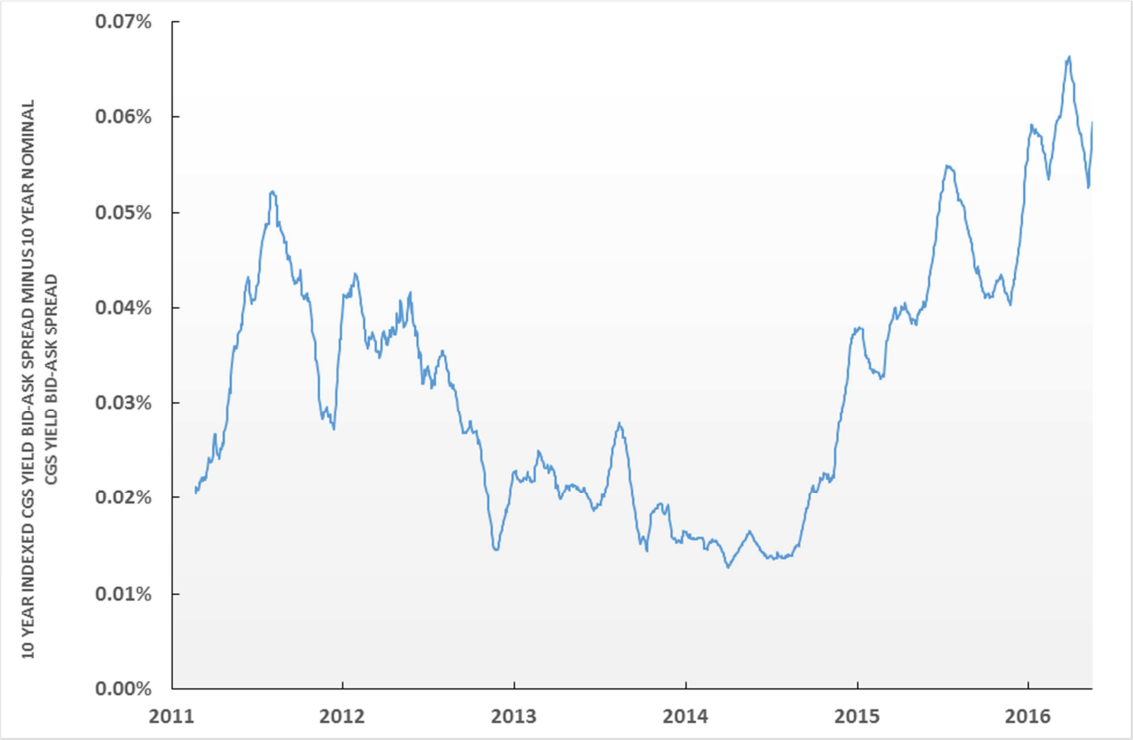
[170] The bid-ask spreads of nominal US Treasuries and TIPS are price-based spreads, expressed as a percentage of par value. Fleckenstein et al. does not explicitly state that the spreads are percentages of par values. However, Fleckenstein et al.'s percentage and tick calculations are likely to be based on par values because their comparisons are based partly on Fleming and Krishnan (2012) bid-ask tick estimates. Ticks are 32nds of a point, where a point is 1 per cent of the par value of the US Indexed Treasuries. Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, pp. 2159-2160; p. 2174; Michael Fleming and Neel Krishnan (2012), 'The Microstructure of the TIPS Market', *Federal Reserve Bank of New York Policy Review*, March, pp. 27-45.

[171] Michael Fleming (2003), 'Measuring Treasury Market Liquidity', *Federal Reserve Bank of New York Economic Policy Review*, September, p. 84.

102. Figure 10 presents a 30 day moving average of the yield bid-ask spread difference over the period 1 July 2011 to 30 June 2016. The average difference is positive over the sample period (3.2 basis points). This liquidity proxy may suggest that 10 year indexed CGS are relatively illiquid, that the relative liquidity has not improved over time and is also highly variable. It is noteworthy that the sharp increase in the bid-ask spread difference over the past year to 30 June 2016 coincides with the sharp decrease in the BBIR observed in Figure 3. This suggests that the growing relative illiquidity of 10 year indexed CGS may be compressing the 10 year BBIR through an increasing relative liquidity premium.

Figure 10: Difference between 10 year indexed and 10 year nominal CGS bid-ask yield spreads: 2011–12 to 2015–16, 30 day moving average

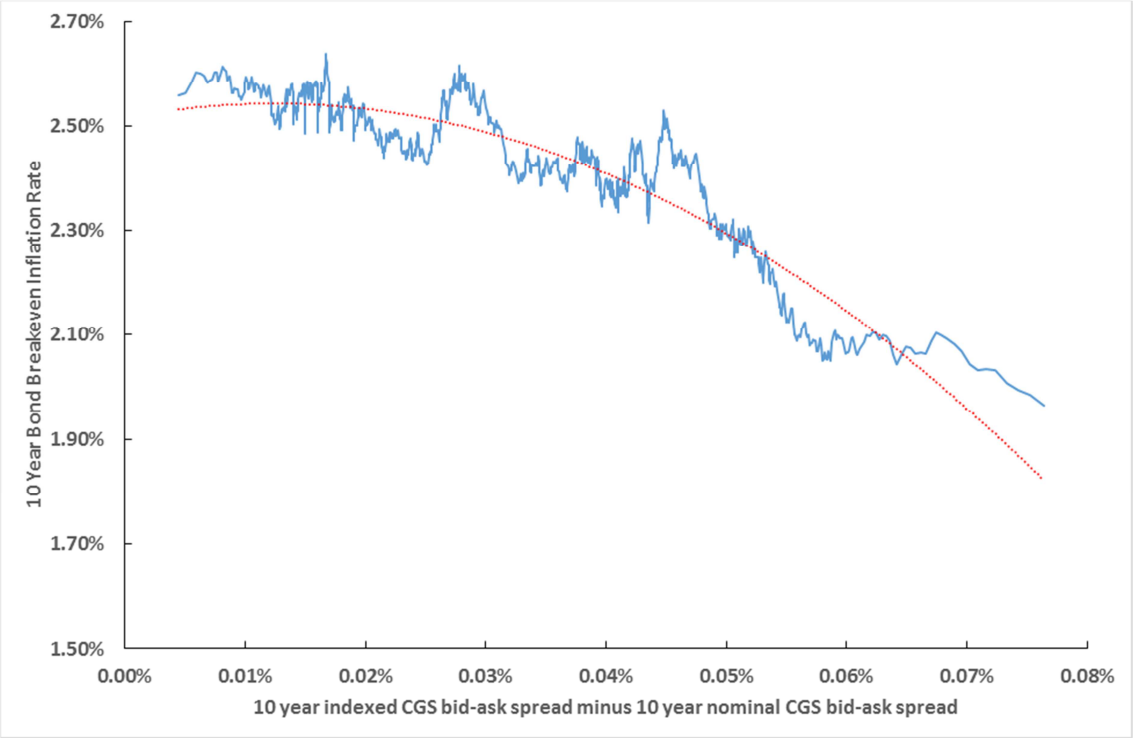


Source: Calculated from Bloomberg bid and ask yields on generic 10 year nominal and indexed CGS. Bloomberg codes: GTAUD10Y and GTAUDII10Y, 1 July 2011 to 30 June 2016.

103. Since differential bid-ask spreads may be a measure of the relative illiquidity of indexed CGS, changes to these differential spreads may also influence BBIR. The potential relationship may be observed by mapping the BBIR against the bid-ask yield spread difference from 1 July 2011 to 30 June 2016. Since both sets of observations are volatile on a day-to-day basis, a 30 observation moving average is calculated to identify any potential underlying relationship. As shown in Figure 11, a lower BBIR tends to coincide with a greater (positive) difference between the yield bid-ask spreads.

104. A larger difference of the bid-ask yield spreads between nominal and indexed CGS suggests a deterioration of the relative liquidity of indexed CGS market and may indirectly identify a growing relative liquidity premium in the BBIR. A growing relative liquidity premium may compress 10 year BBIR estimates (*ceteris paribus*).

Figure 11: The 10 year BBIR and the difference between 10 year indexed and 10 year nominal CGS bid-ask yield spreads: 2011–12 to 2015–16, 30 observation moving average



Source: Calculated from Bloomberg end-of-day midpoint yields, and bid and ask yields on generic 10 year nominal and indexed CGS. Bloomberg codes: GTAUD10Y and GTAUDII10Y, 1 July 2011 to 30 June 2016.

105. Since bid-ask yield spreads may be highly correlated with other measures of bond market liquidity, this liquidity proxy:

- may be used to observe changes in the relative liquidity of 10 year indexed CGS, and
- may enable inferences on the direction of the change in the 10 year BBIR liquidity premium over time.

However, other liquidity proxies may also be required if the size of the liquidity premium in the 10 year BBIR is to be estimated.[172]

106. Recent relative turnover and bid-ask spread observations add further support to the findings of Finlay and Wende (2011), Finlay and Olivan (2012) and Moore (2016) that indexed CGS are relatively illiquid compared to nominal CGS. These studies and liquidity proxies suggest that the relative liquidity of the indexed CGS market has not improved since 2007–08, and may have deteriorated in recent years. When considering the findings of Moore (2016) and relative supply as a proxy for relative liquidity of indexed CGS, the deterioration in relative liquidity may have started as early as 2007–08.

[172] For example, using a number of liquidity proxies to estimate liquidity premia, Pflueger and Viceira (2015) find large liquidity premia even in the presence of narrow bid-ask spreads on TIPS. Fleckenstein et al. find that the difference between the bid-ask spreads of US Treasuries and TIPS is up to 5 basis points. Therefore any mispricing greater than 5 basis points cannot be explained by transaction costs. Fleckenstein et al. find that the average size of the total TIPS-Treasuries mispricing is 10 per cent to 20 per cent of the par value of US TIPS. In yield terms, the average size of this mispricing is 54.5 basis points, but can exceed 200 basis points. Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, p. 21; Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, p. 2174; p. 2152.

107. The relative illiquidity of indexed CGS may result in a significant liquidity premia in BBIR estimates. A significant liquidity premia implies that BBIR estimates are less congruent with market expectations of inflation. Therefore, decomposition estimates that remove the liquidity premia from the raw BBIR may be required before this method is used for the purpose of estimating inflation expectations.

108. While many decomposition estimates find significant liquidity premia in BBIRs, estimating liquidity premia is difficult because the determinants of liquidity are not well understood. This may partly explain why the choice and number of liquidity proxies are different across BBIR decomposition studies. Estimating and removing liquidity premia from raw BBIRs at any point in time may also be a considerable challenge if liquidity premia are time varying.

109. Decomposition estimates of the BBIR may also not be robust to different study parameters chosen. For example, the chosen sample period and choice and number of liquidity proxies may change the estimates of liquidity premia and BBIR-implied estimates of expected inflation. If there is no consensus on the appropriate study parameters, the choice of the study parameters may be subjective. The potential variation of decomposed BBIR estimates across studies introduces considerable uncertainty over which decomposed estimates of expected inflation are relatively unbiased.

110. The decomposed BBIR estimates may also be difficult to replicate if the modelling and estimation is complex and has varying degrees of influence on the decomposed estimates. Further, the complexity of the modelling and estimation required may reduce the transparency and simplicity of the decomposed BBIR. Scrutiny and verification of decomposed BBIR estimates may be limited if the estimates of expected inflation and liquidity premia depend on complex modelling and estimation.

5.3.4. The inflation risk premia in bond breakeven inflation rates

111. The increase in the supply of outstanding indexed CGS is unlikely to have improved the relative liquidity of indexed CGS and the size of liquidity premia in BBIR estimates. The increase in the supply of indexed CGS is also unlikely to have any effect on the size of inflation risk premia in BBIRs. This is because inflation risk premia in BBIRs largely reside in the yields on nominal CGS. Therefore, inflation risk premia and its distortionary effect on BBIR estimates of expected inflation are likely to persist despite an increase in the supply of indexed CGS.

112. If future inflation is uncertain and investors are risk averse, the Fisher Equation specified in Equation (1) may not be correct. Deacon et al. (2004) show that the nominal interest rate may need to be decomposed into the real interest rate, the expected inflation rate and an inflation risk premium.[173] This modified Fisher Equation links *ex ante* nominal interest rates (i_n), real interest rates (i_r), and the inflation risk premium with the expected inflation rate π^e:

$$(1 + i_n) = (1 + i_r)(1 + \pi^e)(1 + \rho) \quad (3)$$

Equation (3) nests that of Equation (1), where Equation (1) assumes that bond investors are risk neutral and Equation (3) assumes that bond investors are risk averse and demand a premium for inflation risk.

[173] Mark Deacon, Andrew Derry and Dariush Mirfendereski (2004), *Inflation-indexed Securities – Bonds, Swaps and Other Derivatives*, Second Edition, John Wiley & Sons, West Sussex, p. 80.

Where ρ is a risk premium that reflects the uncertainty about future inflation and investors' aversion to this uncertainty.[174] The expected inflation rate π^e is the expected inflation rate. If there is a probability that the actual inflation rate will not match the expected inflation rate, risk-averse nominal bondholders may demand compensation for bearing this risk.

113. If the inflation risk premium is considered to be the only bias in the BBIR, the expected inflation rate is obtained by the following:

$$\pi^e = \frac{1+i_n}{(1+i_r)(1+\rho)} - 1 \quad (4)$$

114. For the BBIR to approximate expected inflation, decomposition estimates of the BBIR into expected inflation and the inflation risk premium must be undertaken. This is because the raw BBIR incorporates both risk aversion (in the form of an inflation risk premium) and the risk neutral expected future inflation rate component, when abstracting from other biases/premia.

115. While inflation risk premia largely reside in the yields on nominal bonds, indexed bond yields may also contain inflation risk premia. Inflation risk premia may be included in indexed bond yields if, for example:

- the personal price indices of investors differ from that of the CPI
- returns on indexed bonds vary with realised inflation as a result of indexation lag, and/or
- the taxation of an indexed bond's nominal cash flows introduces post-tax real cash flow variability if inflation is uncertain.

Inflation risk premia embedded in the yields on indexed bonds relate to the exposure of indexed bond returns to inflation risk. The increase in the supply of indexed CGS is unlikely to influence the size of this exposure, and is unlikely to influence the size of indexed CGS inflation risk premia. However, given the limited research on inflation risk premia in indexed bond yields, an inquiry into the effect of indexed bond inflation risk premia on the BBIR is not undertaken.

116. Before data on indexed bonds became richer, decomposition studies of the BBIR were generally restricted to decomposing the BBIR into estimates of expected inflation and inflation risk premia.[175] However, Pflueger and Viceira (2015) argue that, as a result, such model-implied estimates can be distorted if liquidity is an important determinant of bond yields and the model does not account for that possibility.[176]

117. Indeed, one explanation for estimates of *negative* inflation risk premia in studies of the BBIR may be that these studies fail to control for the influence of liquidity premia in BBIR estimates. D'Amico et al. (2016) argue that the inflation risk premia may be

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[174] *ibid*., p. 80. The inflation risk premium is not a component of the *difference* between the expected nominal interest rate and the expected real interest rate. Rather, the inflation risk premium is a component of the expected real interest rate and therefore is also a component of the expected nominal interest rate. This is because inflation uncertainty affects the riskiness of the real interest rate. Seth Armitage (2005), *The Cost of Capital: Intermediate Theory*, Cambridge University Press, Cambridge, pp. 226-227.

[175] There have been findings of *time-varying* inflation risk premia in the term structure of interest rates many years before the introduction of comprehensive BBIR decomposition studies. Vide, for example, John Campbell and Robert Shiller (1991), 'Yield-Spreads and Interest Rate Movements: A Bird's Eye View', *The Review of Economic Studies*, 58(3), Special Issue: The Econometrics of Financial Markets, May, pp. 495-514. Martin Evans (1998), 'Real Rates, Expected Inflation, and Inflation Risk Premia', *The Journal of Finance*, 53(1), February, pp. 187-218.

[176] Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, p. 5.

underestimated or even negative if the liquidity mismatch between nominal Treasuries and TIPS is ignored in BBIR studies.[177]

118. Even studies that adjust for liquidity premia may observe negative inflation risk premia because not all the liquidity effects have been removed. For example, Grishchenko and Huang find that the average 10 year inflation risk premium is time varying, and ranges from –0.16 to 0.10 per cent depending on the expected inflation proxy used. They attribute the estimated negative inflation risk premium over the first half of the sample period to one or both possibilities: the deflation scare of 2002–2003 and/or the illiquidity of TIPS. While they adjust the estimated inflation risk premium for the effects of illiquidity on TIPS, Grishchenko and Huang note that the adjustment may not remove all the effects of liquidity and therefore the inflation risk premium may be even higher.[178]

119. Liquidity premia in BBIRs are potentially important and can considerably distort estimates of inflation risk premia if decomposition estimates are not adjusted for liquidity premia. Therefore, the estimates of inflation risk premia considered in Table 5 below are only obtained from decomposition studies that include adjustments for liquidity premia (although such adjustments may not be sufficient). The exception is Finlay and Wende (2011) which is the only Australian BBIR decomposition study and therefore is also considered.[179]

120. Included in Table 5 is a survey by Bekaert and Wang (2010) of 9 studies that estimate inflation risk premia in the US, UK and Europe. For the sample of US studies they find that the inflation risk premium over a 10 year horizon varies between 50 and 200 basis points. In providing this range, Bekaert and Wang (2010) exclude the studies where estimates are considered to be biased downward by a TIPS liquidity premium. For example, Grishchenko and Huang's (2012) estimates are excluded from the range because Bekaert and Wang consider that such estimates do not sufficiently correct for a TIPS liquidity premium.[180]

121. Note that the estimates of the inflation risk premia for the same bond markets are considerably different. These differences may reflect different sample periods, datasets and proxies for liquidity and expected inflation. The differences are also likely to reflect the different modelling and estimation methods applied to estimate the inflation risk premia.

Table 5: Sample of studies finding significant inflation risk premia in BBIRs

Study	Study parameters and findings
Finlay and Wende (2011) **Study of Australian**	**Inflation risk premia** Observed from Figure 3 of their study: For the 10 year BBIR estimates, the inflation risk premium varies considerably, from above 200 basis points to almost –100 basis points over the sample period. 'While long-term inflation

177 Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 8, p. 35.

178 Olesya Grishchenko and Jing-zhi Huang (2012), 'Inflation Risk Premium: Evidence from the TIPS market', *Finance and Economics Discussion Series Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C.* 2012-06, pp. 28-29.

179 This study implicitly assumes that the liquidity premia are included in the inflation risk premia.

180 Geert Bekaert and Xiaozheng Wang (2010), 'Inflation Risk and the Inflation Risk Premium', *Economic Policy*, 25(64), p. 788.

BBIRs	expectations are generally stable, inflation risk premia are much more volatile.'[181] 'Movements in the 5- and 10-year inflation forward rates [5- and 10-year BBIR estimates] tend to be driven by changes in estimated risk premia.'[182] **Bonds** Nominal bonds with maximum tenors of up to 14 years over the entire sample period. Indexed bonds with maximum tenors of up to 24 years over the entire sample period. Bonds with less than 1 year remaining to maturity are excluded. **Sample period** July 1992 to December 2010 **Model/Estimate applied** Model-derived estimates of inflation expectations based on a latent factor affine term structure model. The model is estimated using the price of coupon-bearing indexed bonds instead of zero coupon real yields. Inflation forecasts from Consensus Economics are also incorporated in the estimation. Forward inflation rate estimates implied by the market prices of nominal and indexed bonds are breakeven estimates. Estimates of the inflation risk premium are given by the difference between the inflation forward rates and model-derived estimates of expected future inflation rates.
D'Amico et al. (2016)	**Inflation risk premium** The 10 year inflation risk premium fluctuates between 0 per cent and 50 basis points cent over the sample period. (Obtained from the four-factor models which allow for a TIPS-specific factor capturing TIPS liquidity).[183] D'Amico et al. also estimate the inflation risk premium in TIPS yields arising from indexation lag (–5 to 3 basis points) known as an 'indexation lag premium'. **Bonds** 3 month, 6 month, 1, 2, 4, 7 and 10 year nominal US Treasuries, 5, 7 and 10 year TIPS. **Sample period** January 1990 to March 2013. (TIPS yields are restricted by data availability and cover a period from January 1999 to March 2013, where the earlier period without TIPS data (1990 to 1998) is treated as missing observations.) **Model/Estimate applied** Three-and four-factor Gaussian term structure models of interest rates and inflation. Decomposition estimates of the BBIR into inflation expectations, inflation risk premia, liquidity premia and indexation lag effects. The effects of CPI seasonality and the deflation floor on TIPS yields and the effects of specialness of nominal Treasuries on nominal Treasury yields are also estimated.
Pflueger and Viceira (2015)	**Inflation risk premium** US: average estimated inflation risk premium is economically significant at 163 basis points. UK: average estimated inflation risk premium is 74 basis points. These estimates control for real rate risk premia and liquidity premia. Pflueger

[181] Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, p. i.

[182] *ibid*., p. 17

[183] Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 24.

	and Viceira find that inflation risk premia are time-varying for the US and the UK.[184] **Bonds** US: 10 year nominal securities and TIPS, UK: 20 year nominal and indexed bonds. **Sample period** US: March 1999 to December 2014, UK: February 2000 to December 2014. June 1999 to December 2014 (US) and February 2000 to December 2014 (UK) for excess returns estimates. **Model/Estimate applied** Regression of breakeven inflation on a vector of bond market liquidity proxies and a vector of expected inflation proxies. Tests for the predictability of the liquidity-adjusted breakeven returns. Decomposition estimates of bond risk premia into expected liquidity excess return (liquidity premium), the expected liquidity-adjusted breakeven return (inflation risk premium) and expected liquidity-adjusted TIPS returns (real rate risk premium).
Liu et al. (2015)	**Inflation risk premium** After 2004, the inflation risk premium was on average 15 basis points. The maximum level reached was 75 basis points in October 2009. It fell to –40 basis points in the fourth quarter of 2011. Liu et al. note that the negative sign of the inflation risk premium since the crisis is more the result of market liquidity factors (that is, a liquidity premium) than a strongly negative inflation risk premium.[185] **Bonds** BBIRs of 3, 4, 5, 7 and 10 year maturities. **Sample period** October 1992 to December 2013, Inflation swaps from 2004 to December 2013. **Model/Estimate applied** Affine term structure model of BBIRs. The model is used to decompose the market-implied BBIRs into measures of inflation expectations, risk premia and differences between the retail price index (RPI) and CPI using a no-arbitrage framework.
Grishchenko and Huang (2012)	**Inflation risk premium** The average 10 year inflation risk premium is time varying, and ranges from –16 to 10 basis points over the sample period January 2000 to September 2008 depending on expected inflation proxy used and corrected for liquidity. Estimates of the 10 year inflation risk premium range between 14 and 19 basis points over the sample period June 2004 to September 2008 period depending on expected inflation proxy used and corrected for liquidity.[186] **Bonds** Zero coupon TIPS and nominal Treasury bonds of 5, 7 and 10 year maturities.

[184] Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, p. 24 and Table IIIA and IIIB.

[185] Zhuoshi Liu, Elisabeth Vangelista, Iryna Kaminski and Jon Relleen (2015), 'The informational content of market-based measures of inflation expectations derived from government bonds and inflation swaps in the United Kingdom', *Staff Working Paper No. 551, Bank of England*, p. 13.

[186] Olesya Grishchenko and Jing-zhi Huang (2012), 'Inflation Risk Premium: Evidence from the TIPS market', *Finance and Economics Discussion Series Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C.* 2012-06, pp. 28-31.

	Sample period January 2000 to September 2008 **Model/Estimate applied** Computed difference between nominal-real spread and expected inflation estimates. Nominal-real spread estimated from established relationships between the term structure of nominal rates, TIPS and real rates. Expected inflation estimates obtained from historical averages, a VAR model of expected inflation and survey-based estimates of expected inflation.
Bekaert and Wang (2010)	**Inflation risk premium** A survey of 9 studies that estimate the inflation risk premium at 1, 5, 10, 20 and/or 30 year maturities. For the sample of US studies, Bekaert and Wang find that the inflation risk premium over a 10 year horizon is robustly positive – varying between 50 and 200 basis points. For the European and UK studies, most of the estimates of the inflation risk premium are at 5 years. Most of these studies find a positive inflation risk premium, ranging from 25 basis points to 184 basis points.[187] **Bonds** Nominal bonds and for certain studies indexed bonds of 1, 5, 10, 20 and 30 year maturities. **Sample period** The studies are based on different sample periods. The different estimates of inflation risk premia are partly attributed to the choice of different sample periods. **Model/Estimate applied** The studies employ affine term structure models. Many studies use survey estimates of expected inflation as proxies for expected inflation. Many studies also use indexed bonds to obtain real interest rates.

122. Many studies find that inflation risk premia are time varying. For example, inflation risk premia may be sensitive to variations in the business cycle. If there are concerns about deflation, inflation risk premia may become negative. This may occur when market participants become concerned about unexpectedly lower inflation, or deflation, and this concern is not entirely reflected in market inflation expectations.[188] Therefore, deflationary concerns may be characterised by lower market expectations of inflation and negative inflation risk premia.[189] If the inflation risk premia are negative, the BBIR may produce underestimates of expected inflation by the negative inflation risk premia (*ceteris paribus).*[190]

123. In their decomposition study of Australian BBIRs, Finlay and Wende (2011) find that the volatility of the 5 and 10 year BBIRs tend to be driven by changes in estimated

[187] Geert Bekaert and Xiaozheng Wang (2010), 'Inflation Risk and the Inflation Risk Premium', *Economic Policy*, 25(64), p. 788.

[188] However, financial instability, such as the GFC, does not necessarily imply a concern about deflation and a resulting lower inflation risk premium for the UK. Pflueger and Viceira (2015) find that the inflation risk premium on nominal UK bonds shot up during the GFC, which likely reflected the high level and volatility of UK inflation during that period. Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, pp. 25-27 and Table IVB.

[189] Kei Imakubo and Jouchi Nakajima (2015), 'What do negative inflation risk premia tell us?' *Bank of Japan Working Paper Series and Research Laboratory Series*, 9 July.

[190] Olesya Grishchenko and Jing-zhi Huang (2012), 'Inflation Risk Premium: Evidence from the TIPS market', *Finance and Economics Discussion Series Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C.* 2012-06, p. 2 and p. 31. Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, pp. 35-36.

inflation risk premia. Finlay and Wende's model-derived estimates of 5 and 10 year inflation expectations are relatively stable and anchored within the RBA inflation target band.[191] However, some caution is required in the interpretation of their estimates of inflation risk premia. Their BBIR decomposition estimates do not include estimates of liquidity premia. Finlay and Wende note that their estimates of inflation risk premia also implicitly capture liquidity premia.[192] Finlay and Wende further note that the changes in the inflation risk premia and even negative short-term forward inflation rates (observed during the GFC) may be potentially explained by the changing liquidity premia.[193]

124. Decomposition studies of the US, UK and Australian BBIR find significant and potentially time-varying inflation risk premia in raw BBIRs. Indexed bond markets in the US and the UK are many times larger and significantly more liquid than the Australian indexed CGS market. This suggests that the increase in the supply of indexed CGS is unlikely to have any significant influence on the size of inflation risk premia in raw BBIRs (although it may be unlikely that the change in the supply of indexed bonds has a significant effect on inflation risk premia in nominal bond yields). Significant and time-varying inflation risk premia suggest that raw BBIR estimates may be incongruent with market expectations of inflation.

125. The presence of significant and time-varying inflation risk premia requires decomposition estimates of the raw BBIR before this method is applied to estimate inflation expectations. However, the decomposition estimates of the BBIR into expected inflation and inflation risk premia (and potentially other premia/biases) may be sensitive to study parameters chosen, including the sample period, term structure models and proxies for expected inflation. The influence of different study parameters on estimates of inflation risk premia is observed by Bekaert and Wang (2010) in their survey of 9 decomposition studies: 'Ultimately, the variation in the estimates across the different studies reflects not only different methodologies, but also simply the use of different sample periods.'[194]

126. There appears to be no consensus on the most appropriate study parameters. Indeed, the choice of term structure model may be contentious. Bekaert and Wang argue that for long sample periods the affine (linear) structure of the models underlying the surveyed studies is 'woefully inadequate'.[195] The term structure of interest rates and surveys of expected inflation are considered to display significant non-linearities (where survey estimates are an input into the estimation of inflation risk premia).[196] The failure to capture non-linearities may affect the estimates of inflation risk premia.

127. The potential sensitivity of inflation risk premia estimates to chosen study parameters suggest that decomposed BBIR estimates are not robust to different study

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191 Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, pp. 13-15.

192 *ibid*., p. 8.

193 *ibid*., pp. 15-18.

194 Geert Bekaert and Xiaozheng Wang (2010), 'Inflation Risk and the Inflation Risk Premium', *Economic Policy*, 25(64), p. 788.

195 *ibid*., p. 788.

196 Most of the studies surveyed use survey estimates of expected inflation and indexed bonds to estimate the inflation risk premium. Put naively, and referring to Equation 3, survey estimates are used as a proxy for π^e and indexed bond yields are used as a proxy for i_r. This allows for the estimation of ρ from observed nominal yields, i_n. However, Bekaert and Wang (2010) highlight that the approaches in the studies are far more complex. The first step requires a formulation of no arbitrage term structure models that prices nominal and indexed bonds. The no arbitrage conditions result in consistent pricing across the curve and across time. The second step is to formulate an inflation model and link it to the term structure model. The inflation model should be consistent with the proxy data for inflation. The third step is to estimate the model using as much data as possible. 'Data on inflation and nominal bond yields are a must'. Geert Bekaert and Xiaozheng Wang (2010), 'Inflation Risk and the Inflation Risk Premium', *Economic Policy*, 25(64), p. 780.

parameters. The modelling complexity involved may also considerably reduce the transparency, replicability and simplicity of the BBIR. If BBIR decomposition estimates vary according to study parameters chosen, and if there is limited ability to scrutinise and verify these estimates, there may be considerable uncertainty over which estimates are relatively more congruent with inflation expectations.

5.3.5. Convexity bias in bond breakeven inflation rates

128. In the absence of bond risk premia and distortions and if the observed yields to maturity on nominal and indexed bonds perfectly match, BBIR estimates may be more congruent with market expectations of inflation. However, improvements in the congruency of estimates also require that the implied forward yields on nominal and indexed bonds are equal to their expected future short term yields, or that the differences between these forward and expected future yields are perfectly offsetting for nominal and indexed bonds. In other words, the 'convexity effect' or the 'value of convexity' of nominal and indexed bonds should either be zero or offsetting.

129. However, these conditions may not hold. Forward yields may not correspond to their expected future yields such that there is a convexity effect, and these convexity effects may be different for nominal bonds and indexed bonds. If these convexity effect differences are significant, the BBIR may include a 'convexity bias'.[197] The convexity bias drives a wedge between BBIR estimates and market expectations of inflation.

130. The forward price of a bond is a convex function of its forward yield. That is, the curvature of a bond's forward price-yield curve is convex. If the price yield-curve is 'positively convex' (second derivative is positive) a bond's price increases by more for a given yield decline than it falls for a given increase in the yield (See the left diagram in Figure 12).

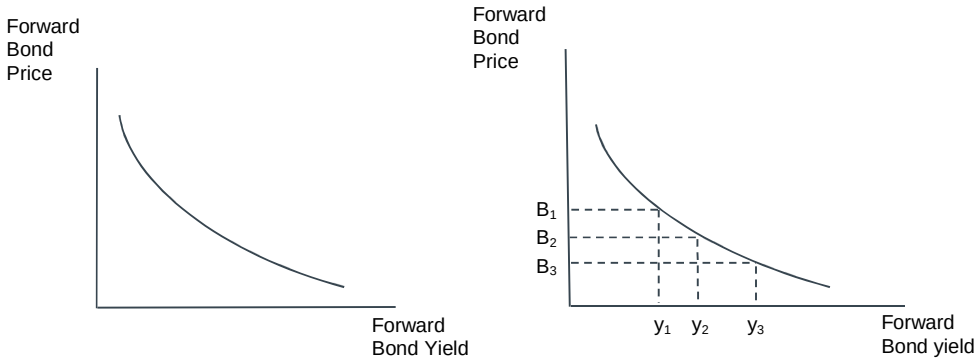
131. The convexity *effect* or the value of convexity is equal to the difference between forward yields without uncertainty and forward yields with uncertainty. If forward yields are certain, the convexity effect is zero. If, however, forward yields are uncertain, then investors may benefit from the convexity effect if the bond is positively convex.

132. The right diagram in Figure 12 provides an illustrative example of the convexity effect of a bond of long maturity, such as 10 years. From Hull (2009)[198], suppose there are three possible bond prices B_1, B_2 and B_3 that are equally likely to occur in a world that is forward risk neutral. Assume that $B_1 - B_2 = B_2 - B_3$. The forward bond price is the expected bond price B_2, and y_2 is the forward bond yield as it is the yield corresponding to the forward bond price B_2. Given the positively convex price-yield curve, y_1, y_2 and y_3 are not equally spaced. Therefore the expected bond yield – the average of y_1, y_2 and y_3 – is greater than the forward bond yield y_2 by the amount of the convexity effect.

[197] In the fixed income literature convexity bias is often defined as the difference between forward rates and expected future spot rates (on zero coupon bonds). However, in this paper, this is known as the convexity effect and a 'convexity bias' may enter the BBIR if the magnitude of the convexity effect is different between nominal bonds and indexed bonds.

[198] John Hull (2009), *Options, Futures, and Other Derivatives, Seventh Edition,* Pearson Prentice Hall, New Jersey, p. 660.

Figure 12: Bond convexity and the convexity effect



133. If forward yields are volatile, giving effect to gains being larger than the losses, bond prices may rise, which push down the forward yields below their expected future yields. The convexity effect increases with maturity (as compounding increases) and can vary across time (as basis point forward yield volatilities change).[199] Long term bonds are more convex than short term bonds because convexity increases very quickly as a function of duration. And because of the convexity effect, long-term bonds can have lower yields than short term bonds and yet offer the same near term expected returns.[200]

134. The convexity effect has a potentially significant impact on nominal and indexed bond yields. Ilmanen (2005) argues that in three main influences on the Treasury yield curve are: (1) the market expectations of future rate changes; (2) bond risk premia (which drive expected return differentials across bonds of different maturities); and (3) the convexity effect.[201] Ilmanen further argues that convexity effect can be one of the main reasons for the typical concave yield-curve shape. While the yields on long term bonds tend to rise because of a liquidity premium and other factors, long term bonds may also benefit from higher convexity compared to short term bonds and this reduces the increase in the yields required. At very long durations, convexity can have a substantial effect on the yield curve shape.[202]

Convexity effect and nominal and indexed CGS

135. The convexity *effect* is unlikely to be the same for both nominal and indexed CGS if the volatilities of nominal and indexed bond forward yields are different. And if forward yield volatilities change over time, the magnitude of the convexity effect for nominal and indexed CGS may also change over time. If forward nominal bond yields are more volatile than forward indexed bond yields, the forward yields may be biased

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199 Cedric Scholtes (2002), 'On market-based measures of inflation expectations', Bank of England Quarterly Bulletin, Spring, p. 71

200 Antti Ilmanen (2000), Convexity Bias and the Yield Curve, Narasimham Jegadeesh and Bruce Tuckman (eds.), *Advanced Fixed-Income Valuation Tools*, John Wiley & Sons, New York, pp. 25-26.

201 Antti Ilmanen (2005), 'A Framework for Analysing Yield-Curve Trades', in Frank Fabozzi and Steven Mann (eds.), *The Handbook of Fixed Income Securities*, Seventh Edition, McGraw-Hill, New York, p. 159.

202 *ibid*., pp. 168-170.

downward, below their expected future yields by a greater margin for nominal bonds than for indexed bonds. If forward nominal yields are biased downward by a significantly greater margin, a significant convexity bias is included in BBIR estimates.[203]

136. Nominal bond yields may be more volatile than the yields on indexed bonds simply because nominal yields contain potentially more 'moving parts'. For example, in their analysis of UK nominal and indexed bond yields, Barr and Campbell (1996) find that real interest rates display little variation at long horizons, and nominal interest rates display considerably more variation where almost 80 per cent of the movement of long term nominal rates appear to be due to changes in expected long-term inflation component.[204] However, the variation of the expected long-term inflation component may also be influenced by a significant and time-varying inflation risk premium since Barr and Campbell assumed this premium to be zero.[205]

Postulates and findings of convexity bias in the BBIR

137. The Bank of England and the central bank of France argue that convexity bias may distort BBIR-implied estimates of expected inflation.[206] However, few researchers separately estimate the magnitude of convexity bias in the BBIR. Two studies that do so are considered below.

138. In their decomposition estimates of US nominal Treasury yields into real yields, inflation compensation and inflation risk premia, Ang et al. (2008) find that convexity bias in the inflation compensation component is less than 1 basis point, even for bonds of longer maturities. However, Ang et al.'s decomposition estimates are not estimates based on the observations of the yields on indexed bonds. Ang et al. do not observe real rates from TIPS for their sample (from the second quarter 1952 to the fourth quarter 2004) since these securities were not introduced until 1997. Real rates and inflation risk premia are estimated by using a no-arbitrage term structure model of nominal yields that relied on historical data of short and long term nominal yields and inflation.[207]

    Bekaert and Wang (2010) argue that use of nominal bond and inflation data alone is a disadvantage of Ang et al.'s study – it would be useful to test their findings with data on TIPS.[208] As a method for estimating expected inflation, the BBIR is calculated from the yields on nominal and indexed bonds. Therefore, convexity bias in the BBIR should be estimated from both nominal and indexed bond data. In this regard, Ang et al.'s findings on convexity bias in the BBIR should be treated with caution.

139. Apedjinou et al. (2006), however, estimate the convexity bias in the BBIR calculated from yield data of both nominal Treasuries and TIPS. Apedjinou et al. decompose US BBIR estimates into expected inflation, a liquidity premium, an inflation risk premium and convexity bias over the period January 2001 to August 2006. Apedjinou et al. separately estimate the convexity effect priced into US nominal Treasuries and TIPS

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203 Vide: Kodjo Apedjinou, Priya Misra and Anshul Pradhan (2006), A TIPS Valuation Framework, Fixed Income Research, U.S. Interest Rate Strategy, Lehmann Brothers p. 7.

204 David Barr and John Campbell (1996), 'Inflation, Real Interest Rates and the Bond Market: A Study of UK Nominal and Index-Linked Government Bond Prices', *NBER Working Paper*, 5821, p. 22.

205 *ibid*., p. 4.

206 Cedric Scholtes (2002), 'On market-based measures of inflation expectations', Bank of England Quarterly Bulletin, Spring, p. 71; Christian Noyer (2004), Governor of the Bank of France, 'The role of inflation-indexed bonds in bonds in the process of setting monetary policy: a central bankers perspective', Morgan Stanley Seminar on Indexed Bonds, 9 June, p. 3.

207 Andrew Ang, Geert Bekaert and Min Wei (2008), 'The Term Structure of Real Rates and Expected Inflation', *The Journal of Finance*, 63(2), April, pp. 797-849.

208 Geert Bekaert and Xiaozheng Wang (2010), 'Inflation Risk and the Inflation Risk Premium', *Economic Policy*, 25(64), p. 784.

through two-factor Vasciek model.[209] For the 1 year forward rate, 10 years forward, the TIPS convexity effect is 26 basis points, whereas the corresponding nominal Treasury convexity effect is 57 basis points. This implies a convexity bias of approximately 31 basis points in the 1 year forward inflation rate 10 years forward (based on a simple difference). For the 5 year forward rate, 5 years forward, the TIPS convexity effect is 16 basis points, whereas the corresponding nominal convexity adjustment is approximately 31 basis points. This implies a convexity bias of approximately 15 basis points in the 5 year implied forward inflation rate, 5 years forward (based on a simple difference).[210]

140. While there are limited studies of convexity bias, convexity bias may be a non-negligible bias in BBIR estimates. Therefore, before the BBIR method is used to estimate inflation expectations, it may be necessary to estimate and correct for this bias.

141. However, there are challenges to obtaining robust estimates of convexity bias because of the different study parameters employed. For example, one study may decompose the yields on nominal bonds to estimate real yields, whereas another study may obtain real yield estimates from indexed bonds. There may be differences in the modelling approaches adopted and different bond maturities and sample periods may be chosen. These differences may explain the different convexity bias estimates of Ang et al. (2008) and Apedjinou et al. (2006). The sample period in particular is critical. Because the estimated size of the convexity effect is dependent on forward rate/yield volatilities[211], convexity bias is likely to differ depending on the sample period chosen.

142. Unless there is consensus on which approaches are objectively superior, the different estimates of convexity bias across studies may foment uncertainty over which convexity-adjusted BBIR estimates are relatively unbiased. The potential lack of robustness of convexity bias estimates across studies and the complexity of the modelling required may impair the transparency, replicability and simplicity of the BBIR method. The modelling and the estimates may be difficult to scrutinise and verify, and the magnitude of adjustment for the bias may be contentious while claiming considerable regulatory resources.

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209 Kodjo Apedjinou, Priya Misra and Anshul Pradhan (2006), A TIPS Valuation Framework, Fixed Income Research, U.S. Interest Rate Strategy, Lehmann Brothers, pp. 1-20.

210 *ibid*., p. 8.

211 Vide: John Hull (2009), *Options, Futures, and Other Derivatives, Seventh Edition,* Pearson Prentice Hall, New Jersey, p. 672.

6. Expected inflation implied from zero coupon inflation swaps

143. Zero coupon inflation swap prices are also considered in this comparative assessment. The term structure of the expected inflation implied from the prices of zero coupon inflation swaps can be used to estimate 10 year market expectations of inflation. As market-implied estimates of inflation expectations, zero coupon inflation swaps are an alternative to that of the BBIR.

144. In an inflation rate swap, counterparties agree to exchange payments that are linked to the predetermined fixed inflation rate and actual inflation rates. The zero coupon inflation swap – which is the focus of this analysis since Australian data are available for this derivative – employs the CPI[212] as a reference for the inflation swap. The dollar amount of the inflation rate payments exchanged is based on a predetermined dollar principal known as the 'notional' amount. The dollar amount each counterparty pays is the agreed-upon inflation rate multiplied by the notional amount. At maturity of the zero coupon inflation swap only the inflation rate payments are exchanged, not the notional amount.

145. The party paying the fixed rate is known as the fixed rate payer, and the inflation rate that this party agrees to pay is the swap price or the swap rate. The other party, who agrees to pay the actual inflation amount, or the inflation rate that floats, is referred to as the floating rate payer (See Table 6).

Table 6: Counterparties to an inflation swap

Fixed Rate Payer	Floating Rate Payer
Pays a fixed rate in the swap	Pays a floating rate in the swap
Receives a floating rate in the swap	Receives a fixed rate in the swap
Equivalent to short the nominal bond, long the indexed bond	Equivalent to long the nominal bond, short the indexed bond
Has bought a swap	Has sold a swap
Is long a swap	Is short a swap
Has established the price sensitivities of a longer-term liability (for example, an indexed-linked pension fund) and a floating rate asset	Has established the price sensitivities of a longer term asset (an asset linked to changes in the CPI) and a floating rate liability

Source: This table is based on a similar table that identifies counterparties to an interest rate swap. Frank Fabozzi and Steven Mann (2010), *Introduction to Fixed Income Analytics*, Second Edition, John Wiley and Sons, Inc. New Jersey, p. 422.

146. Floating rate payers or those short in the swap market may be utilities or infrastructure project providers whose tariffs and cash flows are indexed to inflation.[213] Utilities and infrastructure providers may seek to hedge their exposure to variable cash flows as a result of inflation indexation by adopting a short position in the inflation swap market. Floating rate payers may also be banks/financial institutions (swaps dealers) seeking to generate fee income from offering swap products.

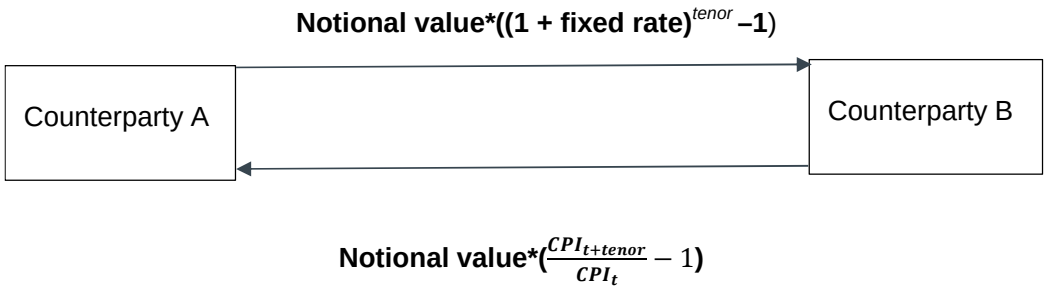
[212] All groups CPI: Weighted average of eight capital cities. AFMA (2016), 'Inflation Product Conventions', March, pp. 2-3.

[213] Grettan McGrath and Robin Windle (2006), 'Recent Developments in sterling inflation-linked markets', *Bank of England, Quarterly Bulletin, Q4*, p. 391.

147. Fixed rate payers or those long in the swap market may have long term indexed liabilities and may seek to offset this exposure by purchasing inflation swaps that attempt to match the time horizon of their indexed liabilities. Some examples of fixed rate payers are pension funds and insurers.[214]

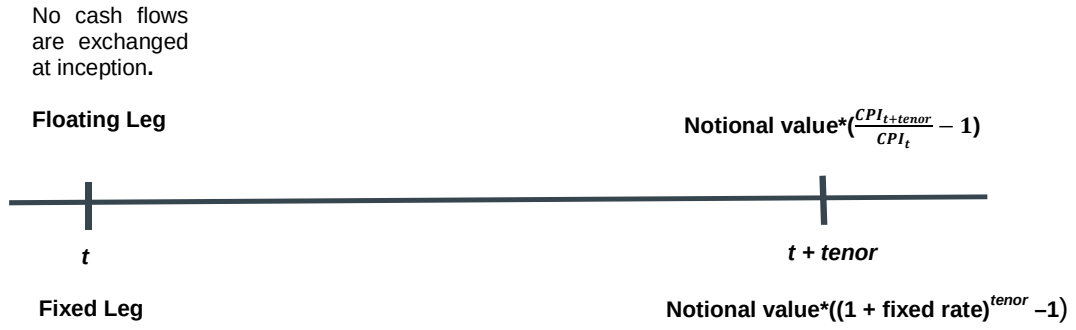
148. Figures 13 and 14 provide a depiction of the inflation swap structure and cash flows of a zero coupon swap. Counterparty A is long the inflation swap and pays Counterparty B the cumulative fixed rate multiplied by the notional amount at the maturity of the swap. The fixed rate approximates the expected value of inflation over the tenor of the swap. Counterparty B is short the inflation swap and pays Counterparty A the change in the CPI (actual inflation) multiplied by the notional amount over the tenor of the swap. However, only one cash payment is actually made at maturity, which represents the difference between the fixed rate and the actual inflation over the tenor of the swap.[215]

Figure 13: Zero coupon inflation swap structure



Source: Michael Oman (2005), 'Inflation swap structures: The benchmark – Zero coupon inflation swaps', *Inflation Derivatives: A Users Guide*, Barclays Capital, January, p. 5.

Figure 14: Cash Flows of a Zero Coupon Inflation Swap



Source: Jeroen Kerkhof (2008), 'Introduction to Inflation Derivatives', Frank Fabozzi (ed.), *Handbook of Finance, Volume 1 Financial Markets and Financial Instruments,* John Wiley and Sons, New Jersey, p. 735.

214 *ibid*., p. 387.

215 Richard Finlay and David Olivan (2012), 'Extracting Information from Financial Market Instruments', *RBA Bulletin*, March Quarter, p. 51.

6.1. The 'fair price' of the swap

149. At the inception of a zero coupon inflation swap, the counterparties agree to exchange future payments and no upfront payments by either party are made. As a result, the swap terms must be such that the present value of the payments expected to be made by counterparties is equal to the present value of the payments that are expected to be received, hence leaving no arbitrage opportunities. The 'equivalence of the present value of payments' or no arbitrage is the key principle for calculating the swap rate.[216] The swap rate or the fixed rate is determined such that the net present value of the swap is zero. That is, the fixed rate is determined such that the present value of the fixed leg payment is equal to the present value of the floating leg payment. The swap rate that results in the NPV of zero is the 'fair swap rate' or the 'fair price' of the swap.

6.2. Zero coupon inflation swaps in Australia

150. There are a number of inflation-linked swaps that may be traded in Australia. However, only data on zero coupon inflation swaps are currently available for the calculation of swap-implied expected inflation rates. The Australian Financial Markets Association (AFMA) provides a brief explanation of zero coupon inflation swaps which is shown in Table 7 below.

Table 7: Zero Coupon Inflation Swaps in Australia

Inflation-linked swap product	Description
Zero Coupon Swaps	CPI swaps where the floating leg is indexed to the CPI. The fixed leg of the swap is an indexed notional principal which is indexed at an agreed fixed rate. There are no interest and coupon payments during the swap and indexed notional amounts are netted upon exchange at maturity. The standard zero coupon swaps are based on terms of 3 months, 1, 2, 3, 4, 5, 7, 8, 9, 10, 15, 20, 25 and 30 years. Zero coupon inflation swaps of terms 6 months, 9 months and 6 years are also quoted/traded (Bloomberg). Standard transaction size – notional principal: <1 year $50 million >=1 and <10 years $25 million 10 years and greater $10 million

Source: AFMA (2016), 'Inflation Product Conventions', p. 3 and p. 5; Bloomberg, Zero Coupon Inflation Swaps.

151. Zero coupon inflation swaps are not traded on an exchange. Zero coupon inflation swaps are traded over the counter by domestic banks and international investment banks dealing in the Australian inflation swap market (known as swaps dealers or market markers). Some non-banks such as hedge funds may also participate in the zero coupon inflation swap market. However, these non-banks are not market makers.[217]

[216] This principle is assumed to apply to inflation swaps as it applies to interest rate swaps, assuming the discount factor is the same for both fixed and floating payments. This principle is applied to interest rate swaps in Frank Fabozzi and Steven Mann (2010), *Introduction to Fixed Income Analytics*, Second Edition, John Wiley and Sons, Inc. New Jersey, p. 431.

[217] Correspondence with Bloomberg, January 2017.

152. The zero coupon inflation swap prices are published daily on Bloomberg. The daily swap bid-ask prices correspond to an average of bid-ask swap prices of traded inflation swaps and/or the spread quoted by the swaps dealers.[218] The dealer-quoted spreads may be wider than the spreads corresponding to an executed swap trade since dealers may price within the quoted spreads in their negotiation with clients.[219] On any given day, the published swap prices may not necessarily correspond to inflation swap transactions but correspond to an average of dealer quotes.[220] However, averages of swap prices (for example, over 20 business days) may more closely correspond to mark-to-market prices since the average is likely to include traded swap prices.

    While on any given day the bid-ask spread may be a dealer-quoted spread, rather than a spread on an inflation swap transaction, the dealer is expected to honour the bid-ask spread. Not doing so may adversely affect the dealer's reputation in the market.[221] The midpoint of the inflation swap bid-ask spread is also provided by Bloomberg and is used in the analysis below.

153. The size of the zero coupon inflation swap market in Australia is likely to have declined modestly since 2011, the year when inflation-linked swap turnover was first surveyed by AFMA. The turnover of all inflation-linked swaps of all tenors was $12.2 billion in 2010–11, increasing to $20.9 billion in 2012–13, but then declining to $11.2 billion in 2014–15.[222] More recent turnover data are not available.

154. Figure 15 compares the 10 year expected inflation rate implied from zero coupon inflation swaps (using IPART's approach), the 10 year BBIR, and the AER's current method over the period 9 October 2009 to 30 June 2016. While daily zero coupon swap data are available from early 2008, daily 10 year BBIR data are only available from October 2009.

155. Consistent with the findings of many studies (discussed below), the difference between the BBIR and the swap-implied expected inflation rate may be largely explained by a time-varying and significant liquidity premium in the BBIR. The 10 year BBIR is also considerably more volatile than the 10 year swap-implied expected inflation rate over the observed period. The sample period standard deviation of the 10 year BBIR is almost 50 per cent larger than that of the 10 year swap-implied expected inflation rate. The relative volatility of the 10 year BBIR may be readily explained by time-varying premia, sensitivity to short term inflation expectations, changing convexity biases and changes in the relative demand for and supply of CGS unrelated to changes in inflation expectations (among other biases and distortions).

156. However, the 10 year swap-implied expected inflation rate is considerably more volatile compared to the replication of the AER's current method over the observed period. The sample standard deviation of the swap-implied expected inflation rate is well over 3 times that of the AER's current method (0.19 percent compared to 0.05 per cent, daily estimates). While inflation swaps may reflect changing market expectations of inflation, the relative volatility may also indicate that zero coupon inflation swaps are influenced by factors other than inflation expectations. These factors may include hedging costs and other potential distortions which are analysed

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218 IPART (2009), *Adjusting for expected inflation in deriving the cost of capital*, Analysis and Policy Development – Discussion Paper, February, p. 4.

219 Correspondence with Bloomberg, January 2017.

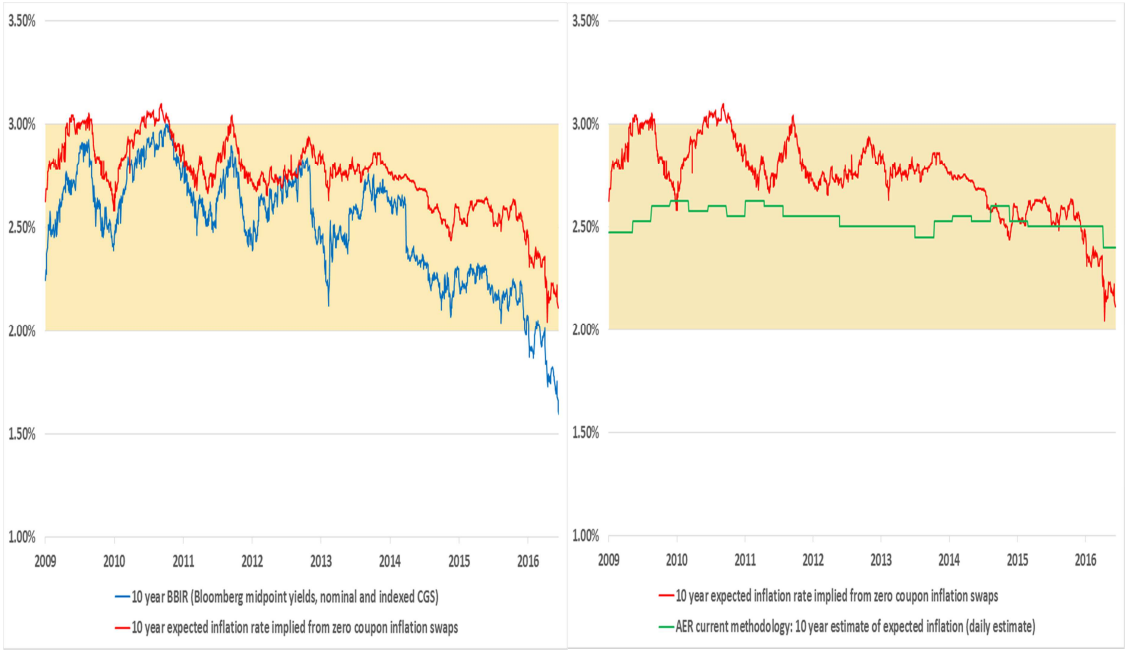
220 Angus Moore (2016), 'Measures of Inflation Expectations in Australia, *Reserve Bank of Australia Bulletin*, December Quarter, p. 29.

221 IPART (2009), *Adjusting for expected inflation in deriving the cost of capital*, Analysis and Policy Development – Discussion Paper, February, p. 4.

222 AFMA, Australian Financial Markets Reports data, 2011-12, 2012-13, 2013-14 and 2014-15. Note that inflation-linked swaps were surveyed for the first time in 2010-11.

below. Given the findings that long term inflation expectations are relatively stable and anchored within the RBA inflation target band[223], swap-implied inflation expectations may be less robust to market phenomena that have little influence on long term inflation expectations. The relative lack of robustness of the inflation swap estimator may also reduce its congruence with long term inflation expectations compared to the AER's current method.

Figure 15: The 10 year expected inflation rate implied from zero coupon inflation swaps, the 10 year bond breakeven inflation rate and a replication of AER's current method: 9 October 2009 to 30 June 2016



Bloomberg end-of-day midpoint yield to maturity on generic 10 year nominal and indexed CGS. Expected inflation implied from zero coupon inflation swaps using data from Bloomberg end-of-day midpoint inflation swap prices. Bloomberg codes: AUSWIT, GTAUD10Y and GTAUDII10Y, 9 October 2009 to 30 June 2016. RBA quarterly Monetary Policy Statements (February, May, August and November)[224], August 2009 to May 2016.

[223] Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, pp. 1-35; Christian Gillitzer and John Simon (2015), 'Inflation Targeting: A Victim of Its Own Success?', RDP 2015-09, August, *Reserve Bank of Australia Discussion Paper*, pp. 1-37; Shawn Chen-Yu Leu and Jeffery Sheen (2006), 'Asymmetric Monetary Policy in Australia', *The Economic Record*, 82, Special Issue, September, pp. S85-S96.

[224] The AER's current method estimates of expected inflation and RBA forecast of inflation will change at the start of February, May, August and November each year if there is a corresponding change in the RBA inflation forecast on the release of Statement on Monetary Policy in those months.

6.3. Advantages of inflation swaps

157. Compared to 10 year BBIR estimates, 10 year expected inflation estimates implied from zero coupon inflation swaps have several advantages against the criteria of assessment.

(a) In Australia, the published zero coupon inflation swap prices are available for many more tenors than tenors for indexed CGS. The published zero coupon inflation swap prices are available for 3 months, 6 months, 9 months and each whole year up to 10 years, and every 5 years from 10 years to 30 years. While there are many tenors for currently traded nominal CGS, there are only 7 outstanding tenors for indexed CGS up to approximately 24 years.[225] Since there are many more tenors for zero coupon inflation swaps than indexed CGS, the swap-implied forward inflation curve may provide:

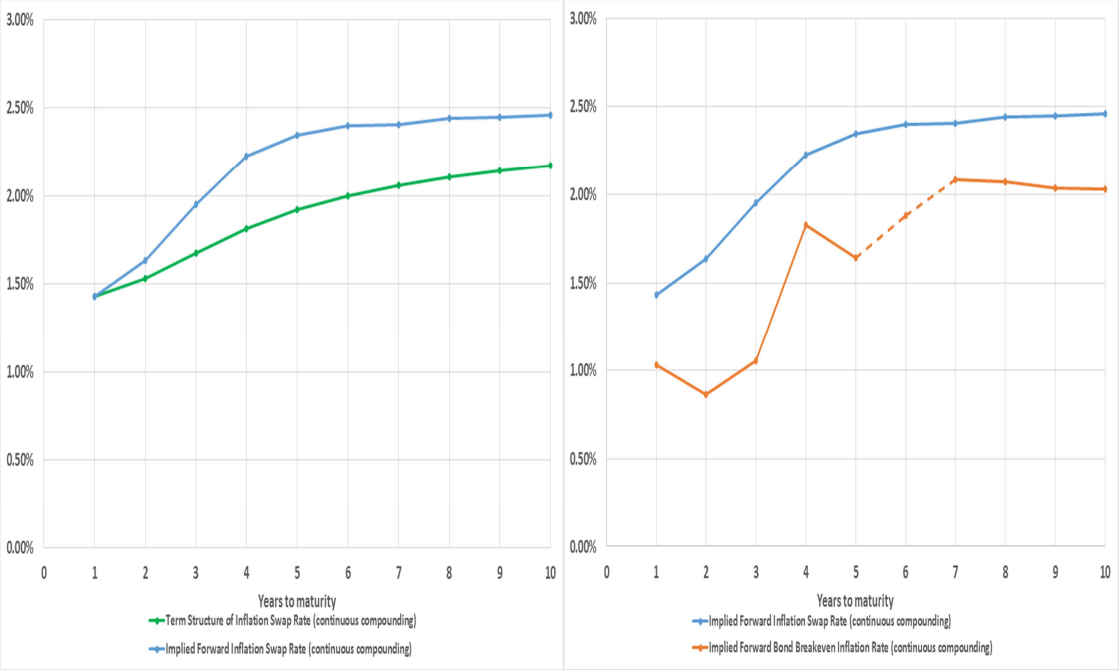
- a relatively more congruent decomposition of market-implied forward inflation rates, and
- forward inflation rate estimates that more closely correspond to expected future short term inflation rates.

(b) Figure 16 (left panel) shows the swap-implied term structure of expected inflation rates and the swap-implied forward inflation curve for each whole year up to 10 years. These estimates are obtained by applying IPART's approach to Bloomberg published zero coupon inflation swap prices. The large number of tenors results in a predictable swap-implied forward inflation curve. The term structure estimates are obtained from daily swap price observations over 20 business days from 2 June 2016 to 30 June 2016. The 20 day average is likely to include traded swap price observations at each tenor. Therefore, the swap-implied term structure of inflation is likely to include mark-to-market expectations of inflation at each whole year up to 10 years ahead.

(c) Figure 16 (right panel) compares the swap-implied forward inflation curve with the forward inflation curve implied from the BBIR for each whole year up to 10 years ahead. The BBIR-implied forward curve is relatively less predictable. As discussed above, the BBIR-implied forward curve may provide a relatively less congruent decomposition of market-implied forward inflation rates. There are few outstanding tenors of indexed CGS and BBIR estimates may include significant premia, biases and distortions which may change in magnitude across the BBIR-implied inflation term structure. As a result, BBIR estimates may be less likely to reflect whole year mark-to-market inflation expectations up to 10 years ahead.

[225] Bloomberg. Zero Coupon Inflation Swaps: AUSWITC (3 months), AUSWITF (6 months), AUSWITI (9 months), AUSWIT1, AUSWIT2, AUSWIT3, AUSWIT4, AUSWIT5, AUSWIT6, AUSWIT7, AUSWIT8, AUSWIT9, AUSWIT10, AUSWIT15, AUSWIT20, AUSWIT25 and AUSWIT30. The maturities for the outstanding tenors for indexed Commonwealth Government Securities are: 21 November 2018; 20 August 2020; 21 February 2022, 20 September 2025, 20 September 2030, 21 August 2035 and 21 August 2040. Australian Office of Financial Management, Treasury Indexed Bond Indexation Factors. http://aofm.gov.au/ags/treasury-indexed-bonds/tib-indexation-factors/

Figure 16: The swap-implied term structure of inflation expectations and comparing forward inflation curves implied from inflation swaps and the BBIR



Source: Midpoint of yearly zero coupon swap rates from 1 to 10 years (AUSWIT1 to AUSWIT10). Bloomberg BVAL curves fitted to observed nominal and indexed CGS yields. IPART's (2009) approach is used to calculate continuously compounded BBIR-implied forward inflation rates, continuously compounded swap-implied forward rates and the swap-implied term structure of inflation expectations.[226]

(d) The swap-implied term structure of inflation expectations at each whole year from 1 to 10 years is easily calculated from implied forward inflation swap rates using IPART's approach. IPART's approach is publicly available and can be easily replicated and scrutinised. Because there are swap tenors at each whole year, issues relating to the congruency of interpolated estimates with market expectations of inflation at each whole year are avoided. Whole year term structure estimates of expected inflation can be simply and robustly calculated from the observed prices of zero coupon inflation swaps at each whole year.

In contrast, the calculation of the BBIR implied-term structure of inflation expectations may be considerably less transparent and simple. The few tenors of indexed CGS may provide scope to fit a number of potentially complex yield curve models to estimate whole year BBIRs. The complexity of these estimates may impair their replicability. The scope for fitting a number of different models to the few tenors of indexed CGS may also increase the sensitivity of the BBIR to the model employed. The choice of model may also be contentious since there may be no consensus on which yield curve models are the most appropriate for the estimation of the BBIR.

158. Over the period observed (October 2009 to June 2016), the 10 year swap-implied expected inflation rate is considerably more stable than the BBIR. Given the research findings that long term inflation expectations are relatively stable over time, the swap-implied estimates of expected inflation may be relatively congruent with the stability of

[226] The continuously compounded implied forward swap rates are calculated from the midpoint of zero coupon swap prices at whole year tenors of 1 to 10 years. The swap-implied term structure of inflation expectations is then calculated from the continuously compounded forward swap rates. IPART (2009), *Adjusting for expected inflation in deriving the cost of capital*, Analysis and Policy Development – Discussion Paper, February, pp. 1-34 and the Excel Workbook: adjusting for expected inflation in deriving the cost of capital – inflation adjustment calculator 6 January 2009.xls.

10 year market expectations of inflation. The relative volatility of the 10 year BBIR may be readily explained by various biases, premia and distortions discussed above.

159. There are a number of studies which suggest that the swap-implied expected inflation rate may produce relatively congruent market-based estimates of the expected inflation rate when compared to the BBIR.

(a) Finlay and Olivan (2012) find that in practice inflation swaps tend to be a more useful source of information on expected inflation since there are very few indexed CGS on issue and that the indexed CGS is somewhat less liquid than nominal CGS.[227] While the supply of outstanding indexed CGS has increased since these findings, the supply of indexed CGS relative to that of nominal CGS has not improved. There is also evidence that the relative liquidity of indexed CGS has not improved since 2007–08, and appears to have deteriorated.

(b) Inflation swap prices are found to be relatively less volatile compared to the BBIR, which corroborates the time series observations above. The findings of the RBA and the Bank of England indicate that this likely due to the distortions of liquidity affecting the BBIR. In its discussion of the recent narrowing of the 10 year BBIR, the RBA (2015) find that the inflation swap market is an indicator of inflation expectations that is less affected by fluctuations in market liquidity compared to the market for indexed CGS.[228] Liu et al. (2015) of the Bank of England make similar observations about the BBIR and inflation swaps in the UK:

'Inflation swap BEI rates are generally less volatile than corresponding maturity bond breakeven rates, which may be more significantly affected by liquidity conditions. This would also imply that their movements [of inflation swap prices] are more driven by inflation expectations. This may corroborate views from the Bank's market contacts that swap BEI rates represent a more reliable indicator of inflation expectations compared to bond BEI rates.'[229]

(c) Fleckenstein et al. (2014) find that the spread between the inflation swap rate and the Treasury-TIPS breakeven rate in the US is attributed to mispricing of TIPS relative to US nominal Treasuries, reflecting potential arbitrage opportunities in the TIPS market.[230] In other words, the TIPS are under-priced relative to nominal Treasuries. Fleckenstein et al. also note that financial market practitioners have long recognised that Treasury-TIPS breakeven spreads are mispriced relative to inflation swaps and as a result have gained from the arbitrage between these markets.[231]

In their analysis, Fleckenstein et al. consider that their findings may also suggest that arbitrage opportunities may have occurred as a result of mispriced inflation swaps rather than mispriced TIPS. To test this proposition, Fleckenstein et al. examine the corporate fixed rate and inflation-linked debt market since identical inflation swap prices are used in both cases.[232] They find little to no evidence of

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227 Richard Finlay and David Olivan (2012), 'Extracting Information from Financial Market Instruments', *RBA Bulletin*, March Quarter, pp. 45-46.

228 Reserve Bank of Australia (2015), Statement on Monetary Policy, February, p. 50.

229 Zhuoshi Liu, Elisabeth Vangelista, Iryna Kaminski and Jon Relleen (2015), 'The informational content of market-based measures of inflation expectations derived from government bonds and inflation swaps in the United Kingdom', *Staff Working Paper No. 551, Bank of England*, p. 14.

230 Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, pp. 2151-2197.

231 *ibid*., pp. 2167-2168.

232 Fleckenstein et al. observe that during the past decade a number of corporations have issued inflation-linked debt. Many of the same corporations issued fixed rate debt as well. This allowed the researchers to directly apply the arbitrage strategy to compare the price of a fixed rate corporate bond to that of an inflation-swapped corporate inflation-linked bond with cash flows that exactly replicate those of the fixed rated bond. They find mispricing between corporate fixed rate and inflation-linked debt is much smaller than the mispricing of contemporaneous Treasury-TIPS. Matthias Fleckenstein,

systematic mispricing between corporate fixed rate and inflation-linked debt, and whatever mispricing may be occurring in the inflation swap market is too small to explain the Treasury-TIPS mispricing.[233]

(d) Haubrich et al. (2012) present evidence that the difference between nominal yields and inflation swap rates in the US provides more reliable information on real yields than TIPS. This is because inflation swaps are considered to be less prone to liquidity shocks *vis-à-vis* TIPS.[234]

(e) Pflueger and Viceira (2015) and D'Amico et al. (2016) for the US and Liu et al. (2015) for the UK use the spread between the inflation swap rates and the BBIRs as a proxy to estimate liquidity premia in BBIRs.[235] The employment of inflation swaps as benchmarks suggest that swap-implied expected inflation rates are considered to be less distorted by liquidity premia compared to the BBIR. Indeed, Liu et al. argue that this is an assumption which is consistent with the literature.[236]

6.4. Disadvantages of inflation swaps

160. However, there may be several disadvantages with the inflation swap method. The expected inflation rate implied from zero coupon inflation swaps may also be influenced by biases/risk premia, which may drive a wedge between the inflation swap rate and market expectations of inflation. These biases/risk premia are outlined in Table 8.

Table 8: Potential biases and premia in swap-implied inflation rates

Bias	Explanation
Hedging Costs	If there is greater demand for the fixed leg (those wishing to pay the fixed and receive the floating) than the floating leg (those wishing to pay the floating and received the fixed), dealers may hedge their short exposure in the swap market by taking offsetting exposures in other markets, such as bond markets. In taking these positions dealers are likely to incur hedging costs. Hedging costs include all costs associated with opening, maintaining and closing positions in the market. The zero coupon inflation swap rate may be affected by the hedging costs incurred by dealers short in the inflation swap market. Swap dealers may pass on these hedging costs in the form of higher inflation swap prices. In this case, hedging costs may drive a wedge between the inflation swap rate and market expectations of inflation.

Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, pp. 2168-2171.

233 Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, p. 2171.

234 Joseph Haubrich, George Pennachi and Peter Ritchken (2012), 'Inflation Expectations, Real Rates, and Risk Premia: Evidence from Inflation Swaps', *The Review of Financial Studies*, 25(2), p. 1590.

235 Zhuoshi Liu, Elisabeth Vangelista, Iryna Kaminski and Jon Relleen (2015), 'The informational content of market-based measures of inflation expectations derived from government bonds and inflation swaps in the United Kingdom', *Staff Working Paper No. 551, Bank of England*, p. 2; Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, p. 12, p. 16 and Table IIA; Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, pp. 28-29 and p. 59.

236 'In line with the literature, we assume that the liquidity premia are present in gilt BEI [bond breakeven inflation] rates but that liquidity premia are negligible for swap BEI [swap breakeven inflation] rates. Using the spread between gilt BEI and inflation swap BEI rates, we can therefore gain insights into liquidity conditions in bond markets.' Zhuoshi Liu, Elisabeth Vangelista, Iryna Kaminski and Jon Relleen (2015), 'The informational content of market-based measures of inflation expectations derived from government bonds and inflation swaps in the United Kingdom', *Staff Working Paper No. 551, Bank of England*, p. 2.

Inflation risk premia	The hedging of short positions in inflation swaps may be imperfect because there may be a number of transaction costs incurred when hedging these positions. There may also be mismatches in the timing, size and maturity of the cash flows such that the exposures in the swap and bond markets are not perfectly offsetting. Howard and D'Antonio (1994) find that hedgers seldom create a perfect hedge because the marginal cost of hedging rises sharply as the risk-minimising hedge ratio is approached. The hedger will select a hedge that is less, perhaps substantially less, than the risk-minimising hedge ratio.[237] As a result, swap dealers short in inflation swaps may still require inflation risk premia to compensate them for inflation uncertainty that persists due to imperfect hedges, and the premia may be included in the published inflation swap rates. The premia may also change over time, depending on the degree of 'imperfection' of the hedges, the uncertainty about the inflation rate and dealers' aversion to this uncertainty.
Inflation indexation lag	Inflation rate swaps are also subject to indexation lag, which may influence the inflation swap rate such that the raw inflation swap rate may depart from the expected inflation rate. The inflation swap contract is referenced to inflation for a period that occurs before the date in which the contract is priced and ends before the contract matures. As a result, the estimated forward inflation curve from inflation swaps may not entirely capture forward inflation rates, but also include some historical inflation determined by the extent of the indexation lag.[238] Indexation lag is minor for Australian zero coupon inflation swaps. Zero coupon inflation swaps roll out quarterly in line with the release of the CPI.[239] The CPI is typically published on the fourth Wednesday of the month following the end of the reference quarter. This implies an average indexation lag of around 3 to 4 weeks, which is the intervening period between the end of the quarter and the publication of the CPI.
Counterparty default risk premia	The risk associated with an inflation swap is that the counterparty will fail to fulfil its obligations outlined in the swap agreement. This default risk is known as counterparty risk and as such, default risk premia may be included in inflation swap rates. While default risk premia are a relatively well-cited bias in inflation swap prices, counterparty default risk premia in zero coupon inflation swap rates may not be significant. In Australia, most inflation-linked swaps are collateralised which is likely to mitigate the size of counterparty default risk premia. The structure of cash flows of zero coupon inflation swaps is also likely to reduce default risk and default risk premia in zero coupon inflation swaps.
Liquidity and Liquidity premia	Potential liquidity premia in zero coupon swap rates may reduce the congruency of zero coupon inflation swap rates with market expectations of inflation. The studies cited below and observations of Australian data suggest that this liquidity premia may be negligible. However, there are mixed findings of liquidity of Australian zero coupon inflation swaps.

161. For the purposes of this comparative assessment, only three of the potentially largest and relatively well-documented biases/premia in inflation swap prices is examined in more detail: hedging costs, counterparty default risk premia and liquidity premia. The liquidity of the zero coupon inflation swap market is also examined.

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237 Charles Howard and Louis D'Antonio (1994), 'The Cost of Hedging and the Optimal Hedge Ratio', *The Journal of Futures Markets*, 14(2), pp. 237-238.

238 Matthew Hurd and Jon Relleen (2006), 'New information from inflation swaps and index-linked bonds', *Bank of England Quarterly Bulletin*, Spring, p. 27.

239 Correspondence with Bloomberg, January 2017; Kieran Davies, Felicity Emmett and Denise Wong (2010), 'Submission to the 16th Series Consumer Price Review' Australia/NZ Strategy and Economics, The Royal Bank of Scotland, 12 March, p. 9.

6.4.1. Hedging costs

162. In Australian zero coupon inflation swap markets there may be more demand for the floating leg of an inflation swap than the fixed leg. And therefore, dealers may not be able to hedge their short position in an inflation swap by taking an opposite (long) position in the same market. This may require a dealer taking a position equivalent to the long position in the inflation swap market by taking short and long positions in the nominal and indexed bonds, respectively (with the same maturity as the short position in the swap). If this position is held to maturity, the dealer receives the cumulative inflation over the remaining life of the bonds in exchange for paying the BBIR, plus any funding costs of the position.[240]

163. Abstracting from various funding and transaction costs (and biases/premia), the short and long positions in the markets for CGS effectively replicates a long position in the zero coupon inflation swap market of the same maturity. These positions in the bond market are normally undertaken in the repurchase agreement market[241] (although offsetting positions may also be undertaken in asset swap markets). In repurchase agreement markets, bonds are used as collateral for cash loans at 'repurchase agreement rates' or 'repo rates'.[242] In a repurchase agreement, one party sells bonds to another party while simultaneously agreeing to repurchase or receive back the bonds at a specified future date.

164. In replicating a long position of the swap in bond markets, the inflation swaps dealers may incur hedging costs. Hedging costs include all costs associated with opening, maintaining and closing positions in the market where the hedger seeks to offset their exposure in the inflation swap market.[243] In addition to the transaction costs, these costs may include the capital costs of participating in the repo market, and the costs and difficulties arising from matching the timing, size and maturity of cash flows between the short position in the inflation swap market and the positions in the indexed and nominal bond markets.

165. If dealers short in swap incur hedging costs, these costs may be passed on in the form of higher swap prices. Hedging costs may raise zero coupon inflation swap prices above the corresponding market expectations of inflation. These hedging costs may also be variable over time.

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240 Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, p. 11.

241 Dealers may engage in short selling of nominal bonds in the repo market by borrowing the nominal bonds using cash as collateral (a reverse repurchase agreement). While carrying the short position the dealer receives interest income on the cash lent and incurs the nominal coupon interest cost. Dealers may open a long position by purchasing the indexed bonds in the repo market. The long position in indexed bonds may be financed by selling the indexed bonds under repo. While carrying the long position the dealer receives the indexed coupon income while incurring the financing cost of this position. The legal title to the indexed bonds is transferred to the dealer's counterparty for the duration of the repo. However, the dealer continues to retain both the economic benefits and market risk of the indexed bonds. There is an active repurchase agreement or 'repo' market in Australia. For investors with large and/or varying cash balances repos offer a lower risk alternative to other instruments in the money market since the cash investor holds the title to the securities for life of the agreement. David Wakeling and Ian Wilson (2010), 'The Repo Market in Australia', *Reserve Bank of Australia Bulletin*, December Quarter, pp. 27-36. Moorad Choudhry (2010), *The Repo Handbook,* Second Edition, Elsevier Pty. Ltd, Oxford.

242 When bonds are used as collateral for cash loans, the loan rate or the repurchase agreement rate is lower compared to uncollateralised loans. Therefore, by financing positions in the repo market rather than other markets the finance costs associated with running such positions are lower. Moorad Choudhry (2010), *The Repo Handbook,* Second Edition, Elsevier Pty. Ltd, Oxford, pp. 156-158.

243 In both opening and closing out the hedged position, hedging costs also include transaction costs such as the brokerage fees and commissions. These costs are the transaction costs associated with undertaking arbitrage between the swap and bond markets. Among other possible explanations, Pflueger and Viceira (2015) attribute the difference between the inflation swap rates and the nominal-indexed BBIR to the cost of arbitraging between the nominal-indexed bond market and the inflation swap market. Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, pp. 11-12.

Potential variability of hedging costs over time.

166. Hedging costs may vary over time, making it potentially more difficult to estimate the size of hedging costs in inflation swap prices. Choudhry (2010) identifies a number of risk exposures in the repo market including collateral price volatility[244], liquidity risk, counterparty risk and settlement risk (risk of failing to deliver or failing deliver on the repurchase date).[245] These risk exposures are unlikely to remain constant and may impose a positive and varying cost to the hedgers over time.

167. Hedging costs may vary over time if there is a change to the cost of carrying positions in the repo market. The cost of carry refers to the cash flows associated with holding a position over time but excluding the cash flows attributable to establishing or liquidating the position.[246] The cost of carry in the hedged portfolio includes both the short carry and the long carry. Short carry is the daily financing income from the short position minus the daily coupon cost (reverse repurchase agreement). Long carry is daily coupon income from the long position minus the daily financing cost (repurchase agreement). Net carry is the sum of the cost of carrying the long and the short positions.[247]

    Carrying cost may be a potential source of risk in a hedged portfolio. Movements in repo and reverse repo rates may change the net carry of the portfolio. The interest rates and terms for an open repo are reset on a daily basis. Most repos in Australia are open repos.[248] If the hedged portfolio is maintained over a long period of time, the daily resetting of repo and reverse repo rates may introduce a degree of uncertainty about the costs of financing both short and long positions in the repo market. The resulting uncertainty of the net carry may influence the cost (including the cost of risk) of the hedged portfolio over time.[249]

    A net carry of zero does not imply that hedging costs are avoided. A dealer short in the inflation swap and who has a hedged portfolio in the repo market still has incurred transaction costs and a capital cost of carrying the positions. Since the repo market is essentially a collateralised loan market, the collateral incurs a capital cost.[250] The capital cost may also change over time, such that the inflation swap price may include a positive and variable capital cost of carrying the positions necessary for the hedge.

Hedging costs: empirical studies and observations

168. There are no known Australian studies that empirically estimate the size of hedging costs in inflation swap rates. However, one Australian study considers their potential

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244 This may require the seller of the securities to provide an initial margin and a 'variation margin' throughout the life of a repo transaction if there are significant changes to the mark-to-market value of the collateral. Patrick Brown (2006), *An Introduction to the Bond Markets*, John Wiley and Sons, Chichester, p. 100.

245 Moorad Choudhry (2010), *The Repo Handbook*, Second Edition, Elsevier Pty. Ltd, Oxford, pp. 292-306.

246 Shrikant Ramamurthy (1998), 'The basics of Cash-Market Hedging', in Frank Fabozzi (ed.), *Perspectives on Interest Rate Risk Management*, Wiley, p. 136.

247 *ibid*., pp. 136-139.

248 Wakeling and Wilson (2010) state that repos in Australia can be contracted for various maturities from overnight to longer term maturities (term repos) which are negotiated by the counterparties. David Wakeling and Ian Wilson (2010), 'The Repo Market in Australia', *Reserve Bank of Australia Bulletin*, December Quarter, pp. 27-28. Vide: AFMA, Australian Financial Markets Reports data, Repo, 2014-15.

249 Ramamurthy (1998) notes that one way to limit carry risks is to use term repurchase agreements. A term repurchase agreement is the rate and commitment to borrow for a specified time. However, such rates may be considerably higher than the overnight rate (the rate quoted in the market for repurchase agreements). As such, the hedger's cost of finance increases if positions are financed through term repurchase agreements. Most repo agreements are overnight. However, in 2014-15, over 66 per cent of repo agreements ranged from 2 days to 1 year. AFMA, Australian Financial Markets Reports data, Repo, 2014-15. Shrikant Ramamurthy (1998), 'The basics of Cash-Market Hedging', in Frank Fabozzi (ed.), *Perspectives on Interest Rate Risk Management*, Wiley, p. 139.

250 Moorad Choudhry (2010), *The Repo Handbook*, Second Edition, Elsevier Pty. Ltd, Oxford, pp. 156-158; David Wakeling and Ian Wilson (2010), 'The Repo Market in Australia', *Reserve Bank of Australia Bulletin*, December Quarter, pp. 27-36.

influence on inflation swap rates. Devlin and Patwardhan (2012) suggest that the observed difference between the inflation swap rate and the BBIR may be attributed to the capital costs of hedging and the cost and difficulties of hedging the floating leg of the inflation swap with relatively illiquid indexed CGS.[251] Hedging costs may be higher as a result of taking a long position in relatively illiquid indexed CGS. However, the influence of relatively illiquid indexed CGS on hedging costs may only explain minor differences between inflation swap rates and the BBIR. It is more likely that relatively illiquid indexed CGS may result in a significant liquidity premium in the BBIR – compressing the BBIR well below inflation swap rates. Indeed, as surveyed above, many BBIR studies use inflation swap rates as a benchmark to estimate the size of the liquidity premia in BBIRs.[252]

169. Observing the US inflation swap rates and BBIR between July 2007 and April 2009, Campbell et al. find that the inflation swap rate is, during normal periods of financial market operations, considerably higher than the BBIR. Campbell et al. argue that according to analysts, the difference reflects, *among other things*, the financing costs of manufacturing pure inflation protection in the US.[253] However, Campbell et al. also note that during the period of illiquidity in the US TIPS market in Autumn 2008, the long run inflation expectations implied by inflation swaps was a better proxy for inflation expectations than the BBIR.[254] While Campbell et al. identify that positive financing costs incurred in hedging short swap positions may raise inflation swap rates above the BBIR, they do not test for the presence of such costs in the inflation swap rates.

170. Fleckenstein et al. (2014) provide the most insight into the potential magnitude of hedging costs in inflation swaps. Fleckenstein et al. cite research which suggests that while such hedging costs exist, the extent of their effect on inflation swap rates is unclear and may be minor.[255] Fleckenstein et al. identify a number of potential costs when hedging the short position in the inflation swap market with positions in the nominal and indexed markets. However, Fleckenstein et al. argue that based on several studies of interest rate swap and currency swap markets, which are also exposed to these types of hedging costs, hedging costs are found to have little effect on equilibrium swap rates.[256]

171. If hedging costs are significant, these costs may raise inflation swap prices above market expectations of inflation. The result is that swap-implied expected inflation

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[251] This discussion is somewhat similar to Christensen and Gillan's (2012) exposition on hedging costs. The mark-up of hedging costs on the inflation swap rate levied by swaps dealers represents the compensation the dealers or counterparties require for assuming the liquidity risk of multiple transactions on the 'backside of the contract'. The backside of the contract represents the costs incurred in carrying long positions in indexed bonds and short positions in nominal bonds. Jens Christensen and James Gillan (2012), 'Could the US Treasury Benefit from Issuing More TIPS?', *Federal Reserve Bank of San Francisco, Working Paper Series*, p. 9.

[252] Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, p. 12 and p. 16, Table IIA; Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, pp. 2151-2197; Zhuoshi Liu, Elisabeth Vangelista, Iryna Kaminski and Jon Relleen (2015), 'The informational content of market-based measures of inflation expectations derived from government bonds and inflation swaps in the United Kingdom', *Staff Working Paper No. 551, Bank of England*, pp. 1-36; Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, pp. 28-29 and p. 59.

[253] John Campbell, Robert Shiller and Luis Viceira (2009), 'Understanding Inflation-Indexed Bond Markets', *Brookings Papers on Economic Activity*, Spring 2009, pp. 108-109.

[254] *ibid*., p. 109.

[255] Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, pp. 2172-2173.

[256] Fleckenstein et al. (2014) cite the following papers: Darrell Duffie and Kenneth Singleton (1997), 'An Econometric Model of the Term Structure of Interest-Rate Swap Yields, *The Journal of Finance*, 52(4), pp. 1287-1321; Michael Johannes and Suresh Sundaresan (2007), 'The Impact of Collateralization on Swap Rates', *The Journal of Finance*, 62(1), p. 385; pp. 383-410; Jun Liu, Francis Longstaff and Ravit Mandell (2006), 'The Market Price of Risk in Interest Rate Swaps: The Roles of Default and Liquidity Risks, *The Journal of Business*, 79(5), pp. 2337-2359.

rates may be less congruent with market expectations of inflation. Because hedging costs are likely to be proprietary to the hedger, complex modelling and estimation may be required to decompose hedging costs from swap prices. This may impair the transparency, replicability and simplicity of the inflation swap method.

172. On the basis of the research surveyed the effect of hedging costs on inflation swaps may be minor. If hedging costs are minor, this distortion may be unlikely to adversely affect the robustness of inflation swaps and their relative congruence with inflation expectations. If hedging costs are insignificant, their estimation may not be required which may improve the transparency, replicability and simplicity of the inflation swap method. However, these considerations are only tentative since inferences of low hedging costs in inflation swap markets are based on studies that find low hedging costs in interest rate and currency swap markets.

6.4.2. Counterparty default risk premia

173. The risk associated with an inflation swap is that the counterparty may fail to fulfil its obligations outlined in the swap agreement. This default risk is known as counterparty default risk, and a default risk premia may be included in inflation swap rates. Counterparty default risk premia may drive a wedge between the swap-implied expected inflation rates and market expectations of inflation. However, counterparty default risk and its influence on zero coupon inflation swap rates may not be significant for the following reasons.

(a) Because of counterparty default risk, swap dealers are often larger securities firms and banks (or separately capitalised subsidiaries of these entities) with good credit ratings (commercial banks may buy/sell swaps for asset/liability management or to generate fee income).[257]

(b) Finlay and Olivan (2012) note that the structure of cash flows of zero coupon inflation swaps (the most common form of inflation swap traded in Australia) is likely to minimise counterparty default risk. Because there is only one cash payment made at maturity, and this is only the difference between the fixed rate and the actual inflation rate, counterparty default risk may not be high.[258]

(c) For the US inflation swap market, Fleckenstein et al. (2014) argue that it is unlikely that counterparty credit risk has much of an effect on the pricing of inflation swaps.[259] Fleckenstein et al. cite research by Arora et al. (2012), who examine the pricing of counterparty credit risk in markets for credit default swaps (CDS).[260] Arora et al. argue that the market practice of requiring full collateralisation of swap liabilities is consistent with the result of counterparty credit risk having only a 'vanishingly small' effect on the pricing of CDS contracts.[261] Fleckenstein et al. note that since there is much less volatility in inflation rates than in credit spreads, the effect of counterparty credit risk on inflation swaps would be even smaller than is the case for CDS contracts.[262]

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257 Frank Fabozzi and Steven Mann (2010), *Introduction to Fixed Income Analytics*, Second Edition, John Wiley and Sons, Inc. New Jersey, pp. 418-419.

258 Richard Finlay and David Olivan (2012), 'Extracting Information from Financial Market Instruments', *RBA Bulletin*, March Quarter, p. 51.

259 Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, p. 2172.

260 Navneet Arora, Priyank Gandhi and Francis Longstaff (2012), 'Counterparty credit risk and the credit default swap market', *Journal of Financial Economics*, 103, pp. 280-293.

261 *ibid*., p. 291.

262 Matthias Fleckenstein, Francis Longstaff and Hanno Lustig (2014), 'The TIPS-Treasury Bonds Puzzle', *The Journal of Finance*, 69(5), October, p. 2172.

(d) Hurd and Relleen (2006) argue that any differences between the inflation swap rate and market expectations of inflation are unlikely to be caused by counterparty default risk in the swap rates observed in the UK. The inflation swap contracts may require collateral and may also afford legal protection in the event of counterparty default, both of which may lessen the financial loss incurred by the non-defaulting counterparty.[263] Hurd and Relleen further argue that even where there is non-negligible counterparty default risk, the premia are likely to be included in the transactions on a bilateral basis and are unlikely to influence observed swap prices.[264]

(e) Most inflation-linked swap contracts in Australia are likely to include collateralised agreements. In 2014–15, over 85 per cent of inflation-linked swaps are collateralised. Less than 15 per cent are unsecured.[265] If a similar proportion of zero coupon inflation swaps is collateralised, the effect of counterparty default risk on zero coupon inflation swap rates is likely to be minimal.

174. If counterparty default risk premia are likely to be minimal, the premia are unlikely to reduce the relative congruence of swap-implied inflation expectations with market inflation expectations. The potential insignificance of these premia also avoids potential issues regarding transparency, replicability and simplicity since complex models and estimation methods need not be employed to estimate and remove these premia.

6.4.3. Liquidity and liquidity premia

175. The liquidity of zero coupon inflation swap market may also be a concern, such that swap prices:

- may contain a liquidity premia. Liquidity premia may drive a wedge between the raw inflation swap rate and market expectations of inflation, and/or
- may be less representative of the prices of inflation trades that would occur in deeper, more liquid markets.

176. *A priori*, any liquidity premia in zero coupon inflation swap prices are likely to be small and considerably smaller than the liquidity premia in BBIRs. Unlike the indexed bond market:

- There are no payments exchanged at the inception of the swap. Therefore, leveraged investors face potentially lower capital constraints and funding costs when seeking exposure to inflation-linked cash flows.[266]
- There is no fixed supply of zero coupon inflation swaps. Inflation swaps can be created as required so that unlike the BBIR inflation swaps are generally not distorted by liquidity preference effects.[267]

177. There is no evidence of liquidity premia in Australian inflation-linked swap prices. And as surveyed above, the RBA and international studies find that inflation swap prices

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263 Matthew Hurd and Jon Relleen (2006), 'New information from inflation swaps and index-linked bonds', *Bank of England Quarterly Bulletin*, Spring, p. 29.

264 *ibid*., p. 29.

265 Collateralised as a percentage of Turnover: AFMA, Australian Financial Markets Reports data, 2014-15. IRD, Interest Rate Derivatives Transaction Characteristics.

266 Zhuoshi Liu, Elisabeth Vangelista, Iryna Kaminski and Jon Relleen (2015), 'The informational content of market-based measures of inflation expectations derived from government bonds and inflation swaps in the United Kingdom', Staff Working Paper No. 551, Bank of England, p. 2.

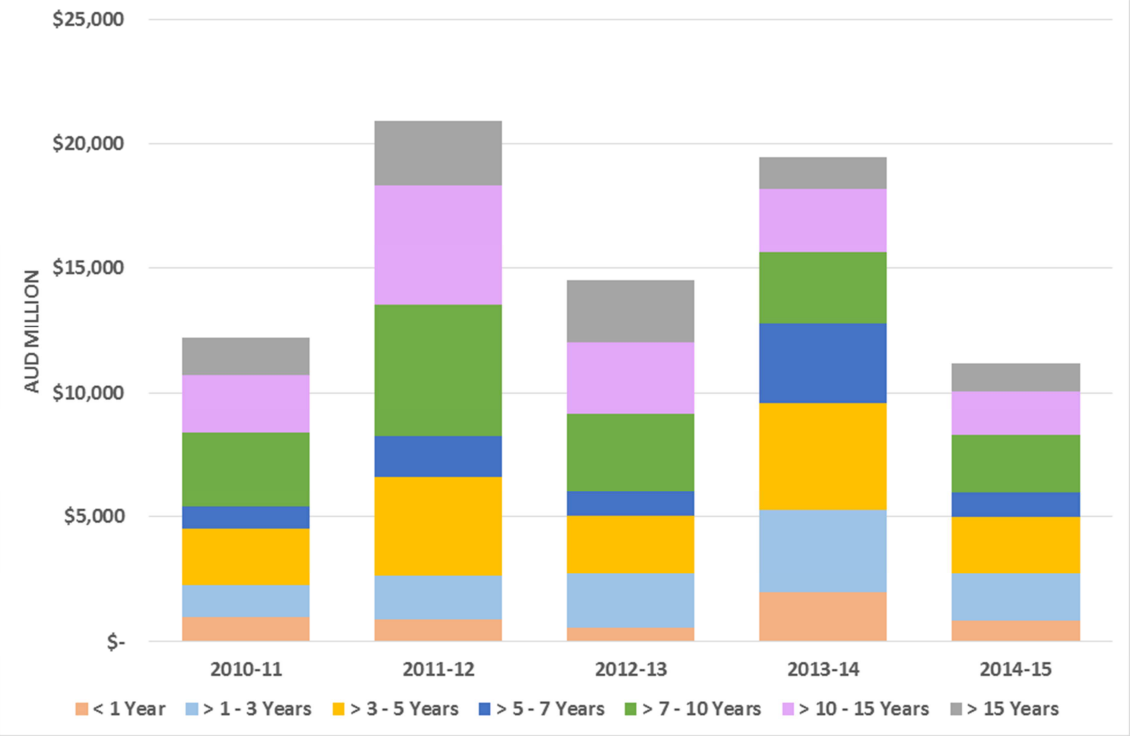
267 Richard Finlay and David Olivan (2012), 'Extracting Information from Financial Market Instruments', *RBA Bulletin*, March Quarter, p. 51.

are considerably less distorted by liquidity conditions in market compared to the BBIR.

178. While swap prices may include negligible liquidity premia, there are mixed findings on the liquidity of the inflation-linked swaps market:

(a) In early 2011, Corrigan et al. find that there was moderate liquidity of inflation-linked swaps of all tenors up to 30 years, with most liquidity at the 10 year point.[268] As shown in Figure 17, between 2010–11 and 2014–15, the turnover of inflation-linked swaps fell by approximately 8 per cent.[269] A large proportion of inflation-linked swap liquidity continues to be concentrated around the 10 year tenor in 2014–15.[270] The annual turnover is quite volatile over the sample period, ranging from approximately $11 billion to approximately $21 billion. If the turnover of zero coupon inflation swaps has fallen by the same proportion between 2010–11 and 2014–15, then this reduction in turnover may be considered modest. And the zero coupon inflation swap market may still be described as moderately liquid. However, the turnover data are both crude and potentially misleading proxies for the liquidity of the zero coupon inflation swap market because data are only available to 2014–15 and because turnover corresponds to the turnover of all inflation-linked swaps.

Figure 17: Annual turnover of inflation-linked swaps: 2010–11 to 2014–15



Source: AFMA, Australian Financial Markets Reports data, 2011–12, 2012–13, 2013–14 and 2014–15. Note that inflation-linked swaps were surveyed for the first time in 2010–11.

[268] Joshua Corrigan, Michael DeWeirdt, Fang Fang and Daren Lockwood (2011), 'Manufacturing Inflation Risk Protection', Australian Institute of Actuaries Australia, 10-13 April, Sydney, p. 47.

[269] AFMA, Australian Financial Markets Reports data, 2011-12, 2012-13, 2013-14 and 2014-15. Note that inflation-linked swaps were surveyed for the first time in 2010-11.

[270] AFMA, Australian Financial Markets Reports data, 2014-15, Interest Rate Derivative Turnover Maturity Profile (percentage of Turnover).

(b) The bid-ask spreads of zero coupon inflation swaps may be a more accurate proxy for liquidity. The spreads are available daily and provide an up-to-date proxy for the liquidity of this market. The bid-ask spreads on 1 year, 5 year and 10 year zero coupon inflation swaps are chosen for analysis – representing proxies for liquidity at the beginning, middle and the end of the swap-implied inflation term structure.[271] Daily bid-ask spread data are available from Bloomberg from 2008–09. However, there were too few observations to estimate the average daily spreads of 1 year inflation swaps for 2008–09. The average daily bid-ask spread for each financial year from 2008–09 to 2015–16 is shown in Figure 18. The average daily bid-ask spread is expressed as a percentage of the swap's notional value and represents the average difference between the daily bid and ask prices of zero coupon inflation swaps. The bid-ask spreads for 10 year inflation swaps are often significantly narrower than the spreads for 1 and 5 year inflation swaps. This may reflect the concentration of liquidity around the 10 year tenor.

(c) Since 2008–09 there appears to be no trend narrowing or widening of the spreads for 5 and 10 year zero coupon inflation swaps. Since 2010–11, when the inflation swap market was considered to be moderately liquid, the bid-ask spreads for 5 and 10 year inflation swaps have only significantly widened once, in 2011–12 and only for 5 year inflation swaps. By 2015–16, the average daily bid-ask spreads for 5 and 10 year inflation swaps have narrowed compared to most of the preceding years in the sample period including 2010–11. On the basis of this liquidity proxy, the liquidity of 5 and 10 year zero coupon inflation swaps is unlikely to have deteriorated since 2008–09 and since 2010–11.

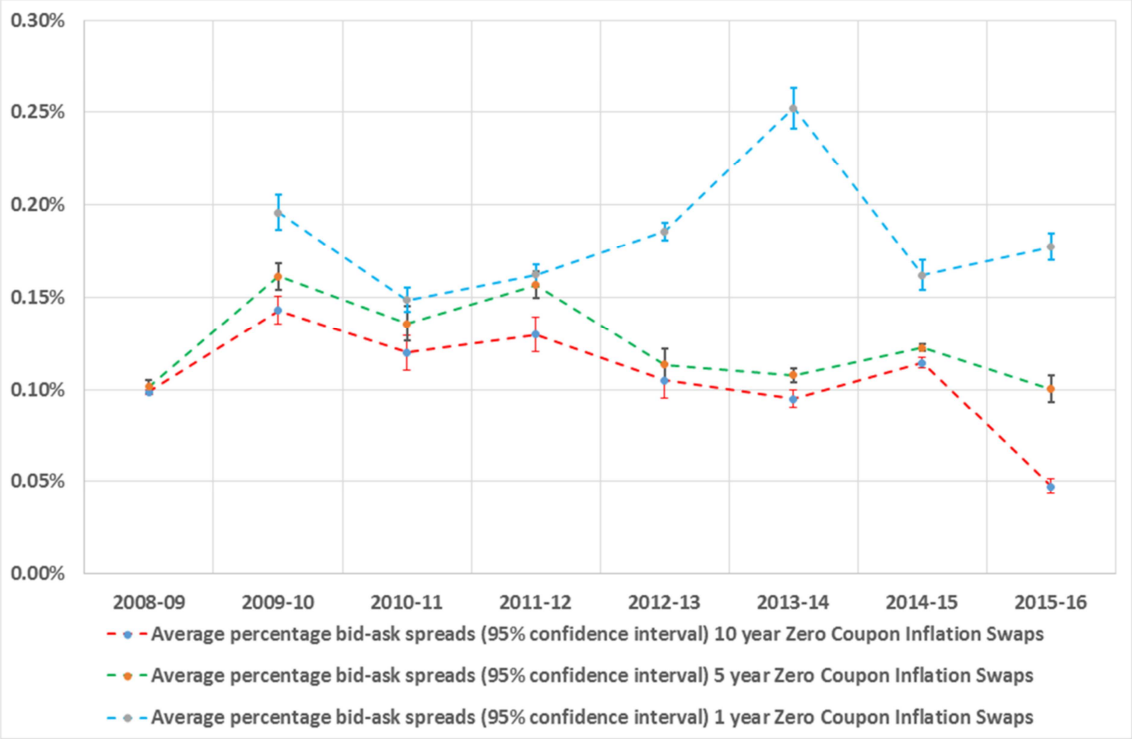
(d) The liquidity of 1 year zero coupon inflation swaps has fluctuated since 2009–10 but is unlikely to have deteriorated since this time. There was a significant widening of bid-ask spreads in 2013–14. The widening of the spread may be due to the deterioration in liquidity culminating in possible inactive trade during the first 9 months of 2014 – there are no bid price observations during this period. (However, the widening of the spread is inconsistent with the increase in turnover of all inflation-linked swaps around the 1 year tenor in 2013–14.[272]) Since 2013–14, the bid-ask spreads have narrowed. In 2015–16 the average daily spread for 1 year zero coupon inflation swaps approximately corresponds to the average daily spread over the entire sample period.

Using IPART's approach, estimates of inflation expectations implied from zero coupon inflation swaps require all whole year inflation swap prices up to 10 years maturity. Therefore, the possible intermittent absence of 1 year traded prices in the future may require reliance on dealer quotes or interpolated term structure estimates during those periods. Fewer mark-to-market observations may reduce the relative congruence of the swap-implied method with the market-implied term structure of inflation expectations.

[271] In their study of trading activity and transparency of the US inflation swap market, Fleming and Sporn (2013) examine bid-ask spreads of inflation swaps among other proxies to assess the liquidity of this market. They find the US inflation swap market to be reasonably liquid and, similar to the Australian zero coupon inflation market, there is a concentration of activity at the 10 year tenor Michael Fleming and John Sporn (2013), 'Trading Activity and Price Transparency in the Inflation Swap Market', *Federal Reserve Bank of New York Economic Policy Review*, May, pp. 45-57.

[272] However, the bid-ask data are likely to be a more accurate proxy for liquidity of zero coupon inflation swaps.

Figure 18: Average daily bid-ask spreads (and 95% confidence interval) 1 year, 5 year and 10 year zero coupon inflation swaps, 2008–09 to 2015–16



Calculated from Bloomberg end-of-day bid and ask prices for 1 year, 5 year and 10 year zero coupon inflation swaps. Bloomberg codes: AUSWIT1, AUSWIT5 and AUSWIT10. Negative and zero bid-ask spreads are removed from the sample.

(e) Moore (2016) provides two considerations which may suggest a lower liquidity of inflation swap markets: recent regulatory reforms and daily published swap prices.

i. Moore argues that recent prudential regulatory reforms may have reduced the liquidity of the inflation swap markets because these reforms have made over-the-counter derivatives more expensive for Australian banks. While inflation swaps are off-balance sheet, the recent Basel III leverage ratio requirements require banks to hold a proportion of their on and off-balance sheet exposures in the form of Tier 1 capital.[273] However, the effect of these requirements on inflation swap prices is ambiguous – the swap rate may rise or fall depending on whether the bank is short or long in the swap.

ii. Caution is required in the interpretation that daily changes to inflation swap rates represent mark-to-market changes in the prices of inflation trades. Moore observes that there have been just been 21 transactions per week during the first half of 2016. As a result, daily published swap prices may not be representative of the prices of inflation trades that would occur in deeper, more liquid markets. However, Moore argues that this problem is likely mitigated if the longer term averages – such as monthly averages of swap price observations typically used by the RBA – are used instead.[274]

[273] Tier 1 capital includes paid up ordinary shares issued by Authorised Deposit-taking Institutions, retained earnings, undistributed current year earnings, accumulated other comprehensive income and other disclosed reserves and minority interests. APRA (2013), Prudential Standards APS 111, Capital Adequacy: Measurement of Capital, January.

[274] Angus Moore (2016), 'Measures of Inflation Expectations in Australia, *Reserve Bank of Australia Bulletin*, December Quarter, pp. 29-30.

179. The Australian studies cited above and the data provide a mixed picture of liquidity in the zero coupon inflation swap market. On the basis of average daily bid-ask spreads, the liquidity of zero coupon swaps is unlikely to have deteriorated since 2008–09. And in 2015–16, the liquidity of inflation swaps at 5 and 10 years has significantly improved compared to most of the preceding years in the sample period. However, aggregate turnover data and Moore's findings suggest that the liquidity of zero coupon inflation swaps may have deteriorated. Despite the mixed findings of liquidity in the zero coupon inflation swap market:

- Monthly average estimates of inflation swap prices may considerably improve the relative congruence of inflation swap estimates with market expectations of inflation. While Moore's findings suggest that daily published inflation swap rates may not necessarily reflect changes in mark-to-market expectations of inflation on those days, the inclusion of many traded swap prices in longer term averages are likely to mitigate this problem.
- There is no evidence that inflation swaps are likely to contain significant liquidity premia. Therefore, the 10 year swap-implied expected inflation rate is unlikely to be relatively incongruent with market expectations of inflation on the basis of a significant liquidity premia. Small or insignificant liquidity premia also avoid the potential transparency and replicability issues of complex decomposition estimates (decomposing swap prices into estimates of inflation expectations and liquidity premia) and the potential lack of robustness of such estimates.

7. Survey-based estimates of expected inflation

180. Inflation expectations obtained from surveys of professional forecasters, market economists and other groups is another method for estimating market expectations of inflation. In Australia, publicly available survey-based estimates of expected inflation are limited to a 2 year forecast horizon. The limited forecast horizon of publicly available data limits the scope of the comparative assessment of survey estimates. However, a limited comparative assessment of survey-based estimates remains important for two reasons:

(a) Survey-based estimates of expected inflation 1 and 2 years ahead may be considered as a cross check of, or even a substitute for, the RBA short term inflation forecast 1 and 2 years ahead in the AER's current method. The short term survey estimates are also a useful benchmark to assess the volatility and relative congruence of long term market-based estimates of expected inflation, such as the 10 year BBIR.

(b) The comparative assessment may inform consideration of obtaining and analysing proprietary survey-based estimates of long term inflation expectations. Survey-based estimates of long term inflation expectations may be a standalone alternative to other methods considered in this paper. Survey-based estimates of long term inflation expectations are considered to be reasonable or even superior proxies for market expectations of inflation in a number of Australian and international studies of inflation expectations.

Consensus Economics provides survey-based estimates of expected average CPI inflation up to 10 years ahead for Australia. The survey respondents from Consensus Economics are professional forecasters and therefore are likely to have well-informed long term expectations of inflation.[275]

7.1. Survey-based estimates of short-term inflation expectations

181. In its publicly available compilation of quarterly inflation expectations data up to two years ahead, the RBA obtains or undertakes surveys of the following[276]:

(a) Consumer inflation expectations, 1 year ahead. Consumer inflation expectations are measured by the Melbourne Institute *Survey of Consumer Inflationary Expectations,* trimmed mean[277] expected inflation rate.

(b) Business inflation expectations, increase in final prices 3-months ahead, annualised. Business expectations are measured by the National Australia Bank *Quarterly Business Survey*.

(c) Union officials' inflation expectations, 1 and 2 years ahead. Union officials' inflation expectations are the median expectations obtained from a survey by the Australian Council of Trade Unions and previously by the Workplace Research Centre and Employment Research Australia.

(d) Survey measure of market economists' inflation expectations. Median inflation for 1 and 2 years ahead.[278] The surveys are undertaken by the RBA and are held

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275 Consensus Economics, http://www.consensuseconomics.com/Con2/Forecast_Surveys/Long_Term_Economic_Forecasts.htm

276 RBA, Statistical Tables, Inflation Expectations G3, Notes.

277 A trimmed mean is where the largest and smallest survey observations are excluded from the survey sample before the mean is calculated.

278 RBA, Statistical Tables, Inflation Expectations G3, GCONEXP, GBUSEXP, GUNIEXPY, GUNIEXPYY, GMAREXPY, GMAREXPYY, Quarterly Survey data.

once each quarter following the release of the CPI and before the publication of the Statement on Monetary Policy.

182. The focus of this comparative assessment is on survey estimates of market economists' expectations of inflation. Market economists' expectations are up to two years ahead and are considered to be relatively more congruent with market expectations of inflation when compared to survey estimates of businesses, unions and consumers.[279]

183. Table 9 and Figure 19 below compare the 2 year expected average inflation rate implied from zero coupon inflation swaps (using IPART's approach), the geometric annual average of the RBA CPI inflation forecast 1 and 2 years ahead, and the geometric annual average of market economists' survey expectations of inflation 1 and 2 years ahead. The sample period is from 2 July 2008 to 30 June 2016. BBIR estimates of expected inflation over a 2 year horizon are not available for this period. The RBA inflation target band of 2 to 3 per cent is also highlighted in Figure 19.

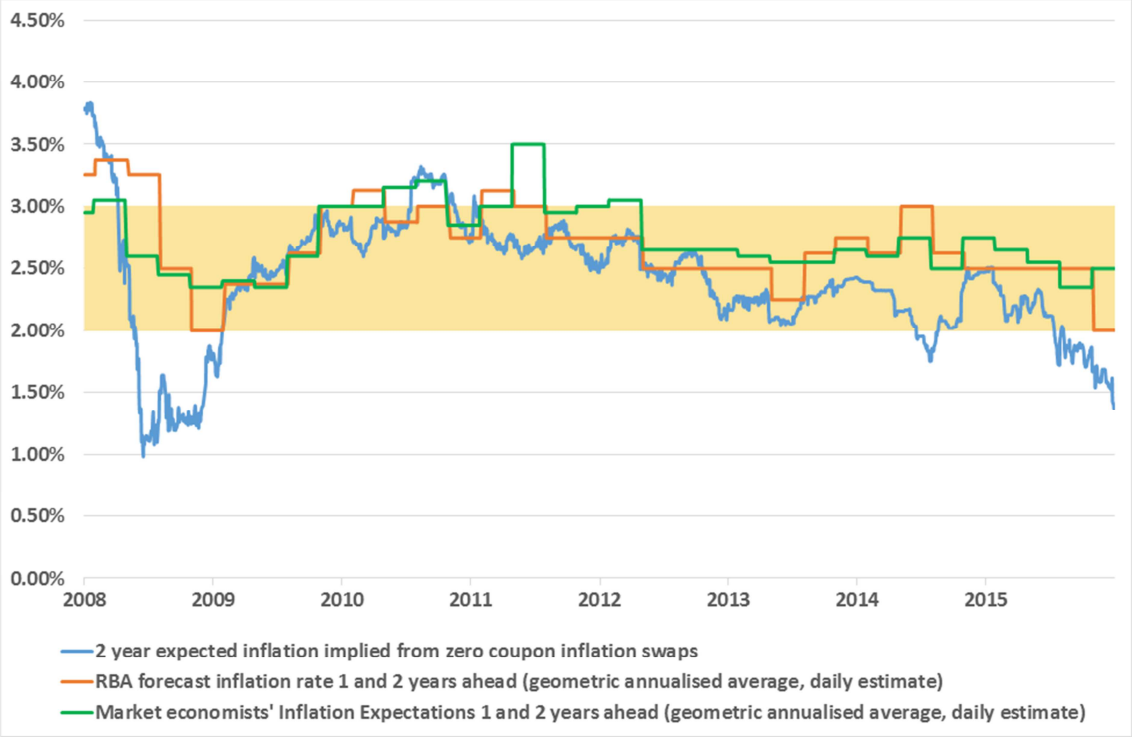
Table 9: Comparison of market economists' survey expectations of inflation with other estimates of expected inflation: 2 July 2008 to 30 June 2016

Measure type	Estimates of expected inflation	Average	Volatility
Survey	Market economists' inflation expectations, 1 and 2 years ahead (geometric annual average, daily equivalence)[280]	2.74%	0.28%
Forecast	RBA forecast of CPI inflation, 1 and 2 years ahead (geometric annual average, daily equivalence)	2.68%	0.31%
Market-based estimates	2 year expected inflation rate implied from zero coupon inflation swaps (daily data)	2.41%	0.49%

[279] Survey-based estimates of certain groups may not necessarily reflect informed expectations of inflation. From June 2002 to June 2016 (the period where survey data are available from business (3 months, but annualised), union officials and market economists), for 1 year ahead inflation expectations, the average for business was 1.5 per cent, the average for union officials' was 2.9 per cent and the average for market economists' expectations was 2.6 per cent. The divergence between the surveyed inflation expectations of business and union officials is noteworthy, and may be more consistent with the potential desire of capital and labour to influence their respective shares of national income by influencing inflation expectations. The inflation expectations from the survey of consumers may be less congruent with market expectations of inflation compared to market economists' expectations because relatively few may forecast inflation on a regular basis and may be less informed about current inflation outcomes and prospective inflationary pressures. In the sample copy of the *Melbourne Institute Survey of Consumer Inflationary Expectations*, Monthly Report March 2013, which is the survey reported by the RBA for consumer inflation expectations, survey respondents are placed into five categories: Managers and Professionals; Para-professionals and Tradespersons; Clerks and Salespersons; Operators and Labourers; Retired, Unemployed and Home Duties. Many of these survey respondents may not necessarily be well informed about prospective inflationary pressures or forecast inflation on a regular basis. The University of Melbourne, Faculty of Business and Economics (2013), Sample Copy, *Melbourne Institute Survey of Consumer Inflationary Expectations*, March, p. 2.

[280] Over a 2 year horizon, the survey of market economists' inflation expectations is not perfectly comparable with other approaches to estimating expected inflation 2 years ahead. Firstly, the survey of market economists' inflation expectations 2 years ahead can be considerably less than 2 years since the '2-year ahead expectations are for year-ended inflation as at the December quarter of the following year for March and June quarter surveys; and for year-ended inflation as at the June quarter of the year after the following year for September and December quarter surveys.' Secondly, RBA inflation forecasts 1 and 2 years ahead may be over or under 1 and 2 years ahead by at least over one month. RBA, Statements on Monetary Policy, February, May, August and November of each year. RBA, Survey measure of market economists' inflation expectations; Median inflation for 2 years ahead; Year-ended, Notes.

Figure 19: Comparison of market economists' survey expectations of inflation with other estimates of expected inflation, 2 July 2008 to 30 June 2016



Source: RBA forecasts of inflation 1 and 2 years ahead (quarterly Statements on Monetary Policy, February, May, August and November), May 2008 to May 2016, daily estimate. Survey of Market Economists' inflation expectations 1 and 2 years ahead, June quarter 2008 to June quarter 2016, daily estimate, GMAREXPY, GMAREXPYY. Bloomberg 2 year Zero-Coupon Inflation Swaps, AUSWIT1 and AUSWIT2. 2 July 2008 to 30 June 2016.[281]

184. Market economists' survey estimates of expected inflation and RBA short term inflation forecasts share a number of similarities compared to the swap-implied 2 year expected inflation rate:

- over the sample period of 2 July 2008 to 30 June 2016, the historical average and historical volatility of market economists' survey expectations of inflation and RBA forecasts are relatively close,
- market economists' expectations and RBA forecasts are formed at around same time each quarter, and
- Tawadros (2013) finds that RBA forecasts are likely to encompass market economists' survey expectations of inflation 1 and 2 years ahead.[282]

185. On the basis of these similarities, market economists' survey estimates may be considered as a useful cross check of RBA forecasts in the AER's current method. However, in certain circumstances, market economists' survey estimates may even

[281] The geometric annual average of RBA 1 and 2 year forecasts are calculated from RBA Statements on Monetary Policy for February, May, August and November of each year. Market economists' survey expectations are obtained from RBA Statistical Tables, market economists' inflation expectations 1 and 2 years ahead, G3, GMAREXPY, GMAREXPYY, Quarterly Survey data. The geometric annual average is calculated for market economists' inflation expectations. Quarterly surveys of market economists' expected inflation 1 and 2 years ahead are taken after the release date of the CPI of the preceding quarter and before the publication of the RBA Statement on Monetary Policy. Therefore, it is assumed that the survey is taken on the 27th of January, 27th of April, 27th of August and the 27th of October each year. Later dates are chosen – but before the start of the next month – if the 27th corresponds to a non-trading day.

[282] George Tawadros (2013), 'The information content of the Reserve Bank of Australia's inflation forecasts', *Applied Economics*, 45, pp. 623-628.

be considered a replacement for the RBA forecasts in the AER's current method on the basis of their (historically observed) relative stability.

186. If RBA short term forecasts are relatively volatile and depart significantly from long term expectations of inflation, there is a risk that AER estimates may be less congruent with market expectations of inflation. There is also a risk that the relative volatility of RBA forecasts may reduce the robustness of AER estimates if long term inflation expectations remain firmly anchored within the RBA target band. The survey estimates may capture the direction of the influence of short term inflation expectations on the inflation term structure while introducing less volatility into long term estimates *vis-à-vis* RBA forecasts. This may improve the congruency of AER estimates with long term inflation expectations. The inclusion of relatively stable survey estimates may also improve the robustness of AER estimates to phenomena which may only influence short term inflation expectations.

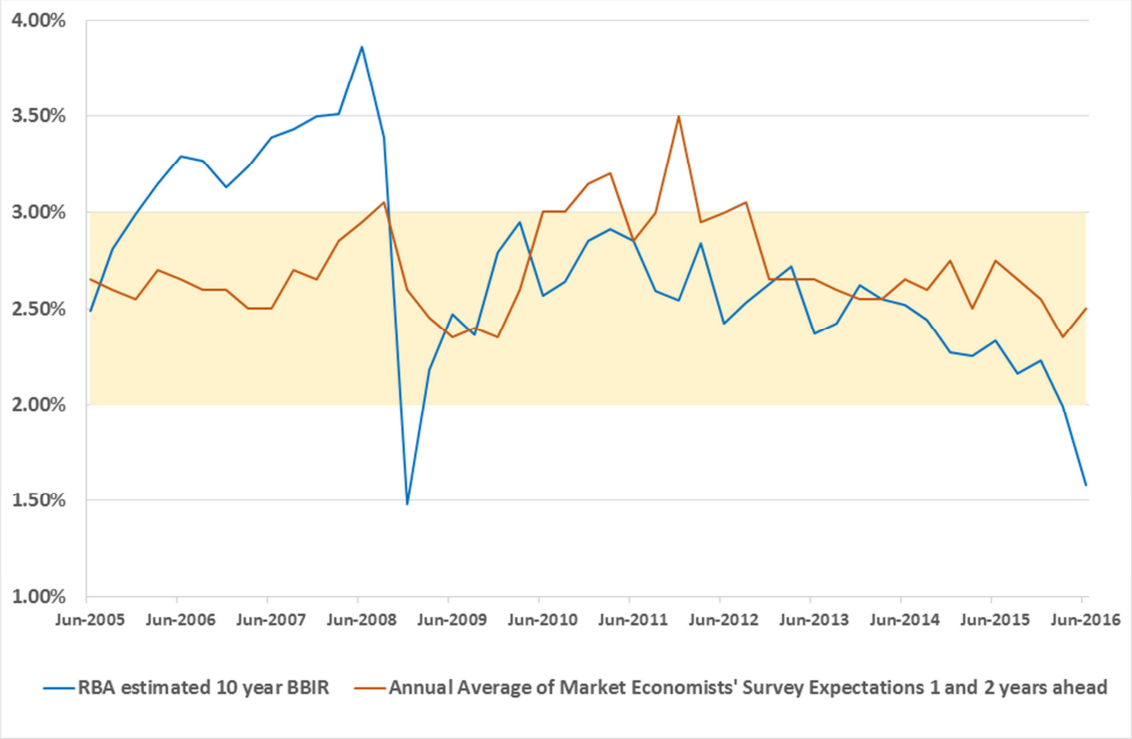
187. Survey-based estimates of expected inflation may be particularly useful if market-implied inflation rates are obscured by noise and biases. The RBA occasionally refers to survey expectations of inflation in its Statements on Monetary Policy.[283] For example, in its discussion of inflation expectations in February 2006, the RBA refers to several survey-based estimates of expected inflation while also considering that BBIR estimates are reflecting conditions in the indexed bond market that are unrelated to inflation expectations.

188. Market economists' survey estimates over a 2 year horizon may be employed to assess the potential extent of noise and biases in market-based estimates such as the 10 year BBIR. In the literature surveyed above, short term inflation expectations are found to be volatile relative to long term inflation expectations. Therefore, the volatility of market economists' expectations may be near the upper bound of the volatility expected for long term market-based estimates.

    However, there are periods where the 10 year BBIR is considerably more volatile, such as during the GFC. This is shown in figure 20, which compares the geometric average of market economists' survey expectations of inflation 1 and 2 years ahead with the RBA series of the 10 year BBIR from June 2005 to June 2016. The well-documented biases, distortions and time-varying premia in the BBIR estimates are probable explanations for this relative volatility. When benchmarked against the volatility of short term market economists' expectations, long term market estimates should be treated with caution during periods when these estimates are relatively volatile.

[283] RBA (2009), Statement on Monetary Policy, May, pp. 65-66; RBA (2006), Statement on Monetary Policy, February, pp. 48-49 and pp. 60-61.

Figure 20: Comparison of market economists' survey expectations of inflation with RBA 10 year BBIR estimates: June 2005 to June 2016 (quarterly data)



Source: RBA, Breakeven 10-year inflation rate, quarterly data, GBONYLD. RBA, Quarterly survey of Market Economists' inflation expectations 1 and 2 years ahead, June quarter 2005 to June quarter 2016. An uninterrupted series of Market Economists' inflation expectations 1 and 2 years ahead is available from the June quarter 2005.

7.2. Advantages of survey-based estimates of expected inflation

189. Since publicly available survey estimates of inflation expectations are limited to 2 years ahead, such a method has few advantages in this comparative assessment. However, survey-based estimates of expected inflation over both short term and long term forecast horizons have several advantages which improve the relative congruence of this method with inflation expectations. If longer term estimates are obtained for future analyses, survey estimates of inflation expectations may become a standalone alternative to the other methods considered in this paper.

190. Many studies of expected inflation and the BBIR consider survey estimates of short term and/or long term inflation expectations as reasonable or even superior proxies for market expectations of inflation. For example, BBIR studies in Australia, the US, the UK, Canada and Brazil use such survey estimates of inflation expectations as the proxy for the expected inflation rate to estimate or observe premia in BBIR estimates.[284]

[284] Vide: Ian Christensen, Frederic Dion and Christopher Reid, 'Real Return Bonds, Inflation Expectations, and the Break-Even Inflation Rate', *Bank of Canada Working Paper 2004-43*, November 2004, pp. 1-36. Refet Gurkaynak, Brian Sack and Jonathan Wright (2010), 'The TIPS Yield Curve and Inflation Compensation', *American Economic Journal: Macroeconomics*, 2(1), pp. 70-92; Sharon Kozicki and P.A. Tinsley (2012), 'Effective Use of Survey Information in Estimating the Evolution of Expected Inflation', *Journal of Money Credit and Banking*, 44(1), pp. 145-169; Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, pp. 1-34; Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, p. 1-69; Christian Gillitzer and John Simon (2015), 'Inflation Targeting: A Victim of Its Own Success?', RDP 2015-09, August, *Reserve Bank of Australia Discussion Paper*, pp. 1-37; Finlay, R, Wende, S., 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper:*

191. Kozicki and Tinsley (2012) argue that the direct information in survey estimates of inflation expectations is likely to be superior to econometric and yield based proxies. While some survey respondents may be reporting results of unadjusted forecast models, most will be incorporating judgment into their views about the future. As a result, perceived structural changes (such as changes in tax laws, perceived shifts in long run inflation goals of policy or perceptions of policy credibility) tend to immediately influence expectations that will be captured in surveys. Such survey expectations tend to reflect information that is not well summarised by historical data or econometric equations. Many econometric specifications are limited in their ability to effectively accommodate structural change.[285] Yield-based proxies can be distorted due to changing risk premiums and other factors not directly linked to inflation expectations.[286]

192. Bauer (2015) studies short term (1 year) and long term (10 year) survey estimates of inflation expectations for the US over the period 1990 to 2013.[287] Bauer estimates the response of short and long term survey estimates to macroeconomic news. The magnitude and significance of the response depends on the survey measure and horizon and the type of macroeconomic news. The longer term survey estimates are more sensitive to news likely to influence long term inflation expectations such as capacity and core inflation. When short and long term survey estimates are considered together, Bauer finds that the magnitude of responses is generally comparable to that of market-based estimates of inflation expectations.[288] The evidence provided by Bauer suggests that survey respondents readily incorporate new and relevant information in forming their estimates.

193. Ang et al. (2007)[289] find that survey estimates of expected inflation outperform other forecasting methods. The potential result is that survey expectations may correspond more closely with market expectations of inflation simply because the market may be more heavily informed by superior forecasts.

    Ang et al. (2007) conduct an analysis of the out-of-sample forecasting performance of four different methods of forecasting 1 year ahead annual inflation:[290] time-series forecasts, forecasts based on the Phillips Curve, forecasts from the yield curve of zero coupon nominal bonds[291] and surveys of inflation expectations from the Survey of Professional Forecasters, Livingston (survey of economists' expectations) and Michigan (survey of consumers expectations).

    Ang et al. find that overall the survey measures outperform the other three inflation measures in terms of forecast accuracy. Ang et al. argue that surveys outperform other forecast methods because surveys efficiently aggregate and pool large amounts of information from many different sources. Surveys may aggregate and pool more information from more sources than is possible in any single model. Survey estimates can also quickly accommodate new information, whereas models rely on the assumed stability of existing relationships.

Reserve Bank of Australia, RDP 2011-01, March 2011, pp. 1-35; Zhuoshi Liu, Elisabeth Vangelista, Iryna Kaminski and Jon Relleen (2015), 'The informational content of market-based measures of inflation expectations derived from government bonds and inflation swaps in the United Kingdom', *Staff Working Paper No. 551, Bank of England*, pp. 1-36; Banco Central do Brasil (2014), 'Breaking the Break-even Inflation Rate', Inflation Report, December, pp. 18-21.

285 Sharon Kozicki and P.A. Tinsley (2012), 'Effective Use of Survey Information in Estimating the Evolution of Expected Inflation', *Journal of Money Credit and Banking*, 44(1), pp. 146-147.

286 *ibid*., pp. 146-147.

287 Michael Bauer (2015), 'Inflation Expectations and the News', *International Journal of Central Banking*, March, pp. 1-40.

288 *ibid*., pp. 31-36.

289 Andrew Ang, Geert Bekaert and Min Wei (2007), 'Do Macro Variables, Asset Markets or Surveys Forecast Inflation Better?' *Journal of Monetary Economics*, 54, pp. 1163-1212.

290 Two different inflation out-of-sample periods were chosen: the fourth quarter of 1985 and the fourth quarter of 1995 to the fourth quarter of 2002 or third quarter of 2001.

291 For the maturities of 1, 4, 12 and 20 quarters from the second quarter of 1952 to the fourth quarter of 2001.

The aggregation, pooling and adaptation to information may explain why even the Michigan survey of (relatively unsophisticated) consumers outperforms all other forecast methods. The Livingston and Survey of Professional Forecasters perform even better.[292] To the extent that the relative performance of survey-based measures inform and reflect market expectations of inflation, survey-based measures may be relatively congruent with market expectations of inflation.

194. Faust and Wright (2012) compare US survey-based estimates of expected inflation with various forecast models of inflation for the current quarter and up to 8 quarters ahead over the sample period 1985 to 2011.[293] Faust and Wright also analyse forecasts of inflation obtained from financial markets – the BBIR and inflation swaps. However, they do not compare these methods with surveys and forecast models since TIPS and inflation swaps have not been traded long enough for inclusion in their review.

Faust and Wright use survey-based estimates of expected inflation from Blue Chip (whose respondents are asked twice a year to predict average inflation rates 5 to 10 years ahead), the Survey of Professional Forecasters (quarterly forecasts released at the start and middle of each quarter) and the Federal Reserve's Greenbook forecast. The Greenbook forecast is informed by a number of small-scale and large-scale forecast models. However, Faust and Wright consider that the Greenbook forecast is similar to survey-based estimates since they are ultimately judgmental forecasts. Faust and Wright compare the survey-based estimates with 16 different forecast models of inflation. They find that the 'very best forecasts' are subjective ones: forecasts obtained from Blue Chip, the Survey of Professional Forecasters and the Greenbook.[294] On the basis of their findings, Faust and Wright argue that these judgmental forecasts are at the frontier of forecasting ability and that survey forecasts should be used as direct measures of expected inflation in macroeconomic models. The superiority of these forecasts is attributed to the addition of expert judgment to the econometric models used by the Federal Reserve and the private sector.

In their analysis of the BBIR, Faust and Wright argue that using this method as a proxy for inflation expectations is 'wrong' and 'potentially dangerous' since the BBIR is volatile – which is attributed to time-varying risk premia.[295] While they also analyse inflation swaps, the series is only available from 2005. The sample period is considered to be too small to assess the performance of inflation swaps as predictors of inflation.

Faust and Wright's study provides further evidence of the forecast accuracy of survey-based estimates. The accuracy of these forecasts may heavily inform market expectations of inflation, such that survey-based estimates may be relatively congruent with inflation expectations.

7.3. Disadvantages of survey-based estimates of expected inflation

195. The primary disadvantage of publicly available survey-based estimates in Australia is the limited forecast horizon. Publicly available survey-based estimates of expected inflation are limited to 1 and 2 years ahead. However, there may also be general disadvantages with survey-based estimates of inflation expectations.

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292 Andrew Ang, Geert Bekaert and Min Wei (2007), 'Do Macro Variables, Asset Markets or Surveys Forecast Inflation Better?' *Journal of Monetary Economics*, 54, p. 1206.

293 Jon Faust and Jonathan Wright (2012), 'Forecasting inflation', Working Paper, Department of Economics, Johns Hopkins University, p. 1–80.

294 *ibid*., p. 20.

295 *ibid*., p. 35.

196. Many survey-based estimates are based on median or trimmed mean inflation expectations. Market expectations of inflation correspond to market-determined probability weighted averages of all anticipated inflation outcomes. Even if survey respondents and the market share the exactly same probability distribution of anticipated inflation outcomes, expectations may differ if the probability distribution is skewed.[296] However, even if a probability distribution of market-anticipated inflation outcomes is observable, the benefit of adopting market-based estimates may be negligible if the degree of the skew is small. And if these market-based estimates are considered to be less robust, transparent and replicable, the market-based estimates may not necessarily be best estimates.

197. If survey estimates are obtained infrequently, the use of this data between survey dates may introduce the risk that these expectations do not reflect mark-to-market expectations of inflation. For example, the disadvantage of Consensus Economics long term estimates is that they are only obtained twice a year (in April and October).[297] However, this disadvantage may be less acute for long term inflation expectations given the findings that these expectations are less sensitive to inflation surprises and are relatively stable over time.

198. If survey respondents provide estimates infrequently or respondents are not well informed about forward-looking inflationary pressures, they may more heavily rely on decision-making heuristics or decision 'rules of thumb' when surveyed. Heuristics are mental shortcuts that often make use of a limited, albeit more readily available, information which are used in place of extensive algorithmic processing.[298] However, the employment of heuristics tends to lead to predictable biases, such that survey expectations may depart from market expectations of inflation.

    For example, survey respondents may display predictable 'anchoring' and 'availability' biases, where too much weight is placed on information that is easily retrieved from memory and/or too little weight is placed on new information. This may lead to statistical overconfidence (confidence intervals that are too narrow). Statistical overconfidence occurs when the focus on potential inflation outcomes related to the information at hand has led the decision-maker to disregard the likelihood of a broader set of inflation outcomes that may be anticipated by the market. Such statistical overconfidence may result in survey estimates of expectations becoming relatively less congruent with market expectations of inflation.[299]

199. Survey expectations represent the expectations of a relatively small number of market participants. In contrast, market expectations of inflation represent an aggregation of all market participants' informed expectations of inflation and reflect all available, relevant and up-to-date information on prospective inflationary pressures. Survey respondents, such as market practitioners, may also have no incentive to reveal their true expectations of inflation. Rather, their true expectations are more likely to be reflected in the trade and prices of financial instruments.

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296 Wesley Phoa and Michael Shearer (1998), *Advanced Fixed Income Analytics*, Frank J. Fabozzi and Associates, New Hope, pp. 108-110.

297 Angus Moore (2016), 'Measures of Inflation Expectations in Australia, *Reserve Bank of Australia Bulletin*, December Quarter, p. 24.

298 Thomas Gilovich, Dale Griffin and Daniel Kahneman (eds.) (2002), *Heuristics and Biases: The Psychology of Intuitive Prediction*, Cambridge University Press, Cambridge, p. 1.

299 For further information on heuristics and biases and statistical overconfidence, vide: Daniel Kahneman, Paul Slovic and Amos Tversky (eds.) (1982), *Judgment under uncertainty: heuristics and biases*, Cambridge University Press, Cambridge; Thomas Gilovich, Dale Griffin and Daniel Kahneman (eds.) (2002), *Heuristics and Biases: The Psychology of Intuitive Prediction*, Cambridge University Press, Cambridge.

8. The comparative assessment: concluding analysis and findings

200. This paper has undertaken a comparative assessment of four methods of estimating expected inflation. The comparative assessment is undertaken to determine which method is likely to result in best estimates of expected inflation. The four methods consist of the AER's current method, the 10 year BBIR, 10 year inflation expectations implied from zero coupon inflation swaps and survey-based estimates of inflation expectations over a 10 year horizon.

201. The comparative assessment of the four methods is informed by five assessment criteria: relative congruence, robustness, transparency, replicability and simplicity.

(a) For a method to produce best estimates, the estimator should be relatively congruent with 10 year market expectations of inflation. Relative congruence refers to the relative closeness of correspondence or the relative closeness of similarity of a method's estimator with 10 year market expectations of inflation.

(b) For a method to produce best estimates, the estimator should be robust to phenomena that have little or no influence on 10 year market expectations of inflation. A method may also be considered robust if the raw estimates or decomposed estimates of inflation expectations are not sensitive to different study parameters and if any biases/distortions can be robustly removed from raw estimates.

(c) A method that produces estimates that are more transparent and replicable are likely to produce better estimates of expected inflation. Transparent and easily replicated estimates can be scrutinised and verified by all stakeholders. Transparency and replicability may also improve regulatory certainty for stakeholders since the inputs and calculations are easily understood and can be readily cross-checked.

(d) A method which produces estimates that are simpler to employ is likely to produce better estimates of expected inflation since construction of the estimates may require less regulatory (taxpayer) resources and may be more readily accessible to all stakeholders.

Each method is assessed against the above criteria and ranked. A method ranking above all methods is considered to result in best estimates of expected inflation.

202. The AER's current method is assessed first. For the AER's current method to produce relatively congruent estimates of market expectations of inflation, expectations must be anchored within the RBA inflation target band. For such anchoring to occur the RBA's monetary policy must be, and is perceived to be, effective in managing economic activity and outturn inflation. There are recent studies which suggest that RBA monetary policy is successful in this regard. Long term inflation expectations are found to be anchored within the RBA inflation target band.

203. The stability of AER's current method estimates over time is also consistent with findings on the relative stability of long term inflation expectations. Through the relative weighting of RBA forecasts and the midpoint, the AER's current method balances the influence of short term inflation expectations on the inflation term structure with the relative stability of long term market expectations of inflation. The AER's current method is also considered to be robust to phenomena that are unlikely to influence or reflect changes in long term inflation expectations. The AER's estimates reflect an anchoring of long term inflation expectations that are less influenced by inflation surprises and relatively volatile short term inflation expectations.

204. The AER's current method for estimating the expected inflation rate is simple, transparent and easily replicated. The inputs into the AER's current method are publicly available and can be easily scrutinised by all stakeholders. The AER's method is also simple to calculate.

205. The main disadvantage of the AER's current method is that it is not a market-based method that reflects daily mark-to-market expectations of inflation over a 10 year horizon. Therefore, the AER estimates may become less congruent with market expectations of inflation, *vis-à-vis* other methods, if monetary policy and inflation targeting are perceived to have lost their former effectiveness. However, there is recent research which suggests that monetary policy and inflation targeting remains effective, such that 10 year market expectations of inflation are relatively stable and anchored within the RBA inflation target band.

206. Since 2015 there have been claims that the supply of indexed CGS has increased such that the AER can once again adopt the BBIR. The claims imply that the increase in supply has sufficiently mitigated the distortions, biases and premia observed in BBIR estimates. While the supply of indexed CGS has improved since 2007, there remain a considerable number of issues with BBIR estimates. As a result, the BBIR method may rank below other methods when assessed against the criteria.

207. There are only 4 outstanding tenors of indexed CGS up to 10 years and only 7 outstanding tenors up to 24 years. The few tenors of indexed CGS may require interpolated estimates of yields over a 10 year horizon. When based on estimates of yields rather than observed yields, the 10 year BBIR may not reflect mark-to-market inflation expectations. Because there are few tenors of indexed CGS tenors, there may also be scope to introduce a number of different yield curve models to estimate indexed CGS yields. The consequence is that BBIR estimates may vary considerably depending on the yield curve models chosen.

208. The lack of consensus on which yield curve models are the most appropriate may also encourage a number of different yield curve models to be fitted. The resulting variation of BBIR estimates may introduce considerable uncertainty over which estimates are relatively congruent with inflation expectations. Verification and scrutiny of BBIR estimates may also be difficult if there is disagreement over which yield curves are the most appropriate. The lack of consensus, the complexity of yield curve models and the resulting variability of BBIR estimates may considerably reduce the transparency, replicability and simplicity of the BBIR method relative to other methods.

209. There are also considerations of findings of significant premia and biases in BBIRs for the US and the UK, even though the supply of US and UK indexed bonds is many times larger than the supply of outstanding indexed CGS. These indexed bond markets are also significantly more liquid than the indexed CGS market. The findings suggest that the BBIR estimates may not be congruent or robust estimates of expected inflation, despite the increase in the supply of indexed CGS.

    (a) Studies of US and/or UK bond markets find a number of potential biases and distortions in the BBIR, including:

        - convexity bias
        - indexation lag
        - substitution effects
        - mismatched cash flows of nominal and indexed bonds

- sensitivity of the BBIR to changes in demand for and/or supply of bonds that may be unrelated to changes in inflation expectations,
- sensitivity of the long term BBIR to changes in short term inflation expectations, and
- sensitivity of the BBIR to the deflation floor on indexed bonds.

(b) Many studies of US and UK bond markets also find that liquidity premia in the BBIRs drive a significant wedge between the BBIR estimates and market expectations of inflation. These studies find that the liquidity premia in BBIRs are sensitive to measures of *relative* liquidity of indexed bonds, not their absolute liquidity.

(c) There are many findings of significant inflation risk premia in BBIR estimates. Inflation risk premia are unlikely to be influenced by the supply of outstanding indexed bonds because:

- these premia mostly reside within the yields on nominal bonds
- studies of US and UK BBIRs find significant and time-varying inflation risk premia even though the US and UK indexed bond markets are many times larger and more liquid than the indexed CGS market, and
- inflation risk premia within the yields on indexed bonds are likely to be unrelated to the supply of indexed bonds. Inflation risk premia in indexed bond yields may occur because of indexation lag effects, personal price indices and post-tax variability of real cash flows (among other potential causes).

(d) There are also findings that liquidity premia and inflation risk premia in the BBIRs may be time varying, which may add considerable volatility to raw BBIR estimates. The time variation of risk premia may be difficult to estimate and even more difficult to predict.

If premia are time varying, the BBIRs may depart significantly from market expectations of inflation by a greater margin during certain periods, such as during periods of financial market instability, economic uncertainty or during certain stages of the business cycle. Indeed, the time-variation of risk premia may largely explain the currently low 10 year Australian BBIR. In his decomposition modelling of the US long term BBIR, Zarazaga (2010) warns of such a scenario:

'The disturbing property of risk premia that move around over time is that they can severely distort popular inflation-expectations indicators calculated from nominal-real forward rate spreads. As a result, such indicators could give the wrong impression that long-run inflation expectations have switched dangerously to a deflationary mood when, in reality, that is a mirage produced by declining risk premia.'[300]

Similarly, in their study of inflation forecasting, Faust and Wright (2012) consider that the complication of time varying premia and the resulting volatility of the BBIR would, if taken literally as inflation expectations:

'lead policymakers to be in a constant state of panic, at some times about excessively high inflation, and at other times about excessively low inflation…[the BBIR] is too volatile to represent a rational forecast of the long-run expected level of inflation.'[301]

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[300] Carlos Zarazaga (2010), 'The Difficult Art of Eliciting Long-Run Inflation Expectations from Government Bond Prices', Staff Papers, Federal Reserve Bank of Dallas, No. 9, March, p. 38.

[301] Jon Faust and Jonathan Wright (2012), 'Forecasting inflation', Working Paper, Department of Economics, Johns Hopkins University, pp. 35–36.

The risk premia in the Australian BBIR appears equal to that of the US in producing such mirages and BBIR volatility. For example, Finlay and Wende (2011) observe that there was a sharp rise in long term risk premia during the introduction of the GST in 2000. And yet they find that long term inflation expectations remained well-anchored within the target inflation band during this time.[302]

(e) Some of the biases listed above may be considerably volatile, such that BBIR estimates may change even if long term inflation expectations are unchanged:

i. The effects of indexation lag and the mismatch in the pattern of cash flows of nominal and indexed CGS are likely to change over time and contribute to the volatility of the BBIR. The effect of indexation lag is sensitive to the difference between historical inflation and inflation expectations implied from the yield to maturity on indexed CGS. The mismatch in the pattern of cash flows is influenced by the size of coupon payments and the term structure of interest rates. Historical inflation, the size of coupon payments and the term structure of interest rates are all likely to change over time.

ii. There may be changes to the relative demand for and supply of nominal and indexed CGS that may be unrelated to changes in inflation expectations. For example, the relative supply of bonds, the pattern of institutional demand for bonds, investor risk aversion and capital availability may change over time, which may change relative yields. Relative demand for and supply of nominal and indexed CGS and BBIR estimates may change even if inflation expectations are unchanged.

iii. Relative forward yield volatilities may change over time such that the contribution of convexity bias to BBIR estimates may also change

iv. A BBIR calculated from the yields on coupon-paying bonds has greater sensitivity to changes in short term inflation expectations (compared to a BBIR calculated from the yields on zero coupon bonds) when inflation expectations are term varying. As a result, the long term BBIR may depart from long term inflation expectations when there are shocks to short term inflation expectations.

210. The 10 year BBIR for Australia is also found to be volatile relative to other methods of estimating expected inflation. The relative volatility of the Australian BBIR may be explained by the above factors and not necessarily by changes in inflation expectations. The relative volatility of the BBIR is inconsistent with findings that long term inflation expectations are relatively stable over time. The potential sensitivity of BBIR estimates to phenomena unrelated to changes in inflation expectations is likely to reduce the robustness of the BBIR method and the relative congruency of BBIR estimates with market expectations of inflation.

211. There is one study of the Australian BBIRs that undertakes decomposition estimates of the BBIR into expected inflation and other premia/biases. The 2011 study finds that the BBIRs contain significant and variable inflation risk premia and indirectly observes liquidity premia. Indexed CGS are found to be illiquid relative to nominal CGS and that negative inflation risk premia are attributed to liquidity premia in BBIR estimates. The findings of this study suggest that raw BBIR estimates are relatively incongruent with market expectations of inflation.

212. Further Australian studies in 2012 and 2016 also observe that the relative illiquidity of indexed CGS is causing a potential bias in Australian BBIRs. The relative illiquidity of

[302] Richard Finlay and Sebastian Wende (2011), 'Estimating Inflation Expectations with a Limited Number of Inflation-indexed Bonds', *Research Discussion Paper, Reserve Bank of Australia*, RDP 2011-01, March, pp. 15-16.

indexed CGS appears to be a persistent phenomenon despite the increase in the supply of outstanding indexed CGS. On the basis of the three Australian studies and the examination of liquidity proxy data from 2007–08 to 2015–16, the relative liquidity of indexed CGS has not improved since considerable biases were observed in this market in 2007. Indeed, relative liquidity of indexed CGS may have even deteriorated. Relative illiquidity of indexed CGS may continue to drive a significant wedge between the BBIR and 10 year market expectations of inflation by the amount of a liquidity premium.

213. The existence of potentially significant biases, premia and distortions in the BBIR is widely accepted in the BBIR literature. Many studies are now focused on decomposing the BBIR such that 'bias-adjusted' BBIR estimates may be obtained. However, caution is required in the consideration of these decomposed BBIR estimates:

(a) The scale and even sign of estimated liquidity premia, inflation risk premia and other biases and distortions are unlikely to be robust to different BBIR decomposition study parameters. This is because these estimates may be sensitive to different term structure models, datasets, estimation methods, sample periods and choice of proxies (among other study parameters). The resulting uncertainty over the scale and sign of biases, premia and distortions makes it difficult to robustly estimate the 'net effect' of these various influences on the BBIR.

The choice of different study parameters and the consequent variability of decomposition estimates may reflect the relatively nascent area of bond market research and the limited understanding of the determinants of bond prices. Zarazaga (2010) draws a similar conclusion:

'current understanding of the determinants of government bond prices is too limited to establish with any confidence which fraction of the relatively large variations in inflation expectations indicators based on forward rates [implied from bond prices] can be attributed to actual changes in long-run inflation expectations and which to time-varying risk premia.'[303]

While there may be sound arguments for the different study approaches adopted, a potential lack of robust estimates of biases, premia and distortions across studies introduces considerable ambiguity over the scale and sign of these effects. The result may be considerable uncertainty over which decomposed BBIR estimates of expected inflation are relatively unbiased.

(b) The requirement of decomposed BBIR estimates is also likely to reduce the transparency of the BBIR method. The modelling and estimation required for the bias-adjusted BBIR estimates may be complex, contentious and difficult to scrutinise. The decomposed BBIR estimates may be difficult to replicate if the modelling and estimation is complex and if the study parameters chosen have varying degrees of influence on the decomposed estimates. The lack of simplicity of decomposed estimates may claim considerable regulatory resources without necessarily reducing the contentiousness of such estimates.

(c) Decomposition estimates of the Australian BBIR may be considerably difficult because of the relative scarcity of Australian bond data. Limited data availability may preclude an assessment of whether or not the estimates are robust to different study parameters chosen. The absence of such an assessment may also result in uncertainty over whether or not decomposed BBIR estimates are congruent with inflation expectations.

[303] *ibid*., p. 38.

However, even if the relevant bond market data are readily available and robust decomposition estimates could be obtained, the decomposed estimates may not necessarily be more congruent with inflation expectations. A decomposition of the BBIR for the purpose of estimating inflation expectations may be based on the tenuous assumption that the 'net effects' of the historically estimated biases are the same whenever BBIR estimates are obtained. This is an unlikely scenario given the findings that biases are volatile and/or time varying.

The aforementioned difficulties of using decomposed BBIR estimates as estimates of expected inflation also readily apply to those studies which find no biases/premia.[304] Before the biases/premia can be considered to be historically insignificant, the estimated biases/premia should be robust to different study parameters chosen. And even if historically robust estimates are achieved, this does not rule out the presence of significant and time-varying premia whenever the BBIR is used for the purpose of prediction.

214. Therefore, raw and decomposed BBIR estimates are likely to be relatively less congruent with 10 year market expectations of inflation when compared to the AER's current method. The AER's current method is also ranked above the BBIR in terms of relative congruence because there are studies which find that long term inflation expectations are relatively stable and are anchored within the RBA inflation target band. Because BBIR estimates may be sensitive to phenomena that are unrelated to market expectations of inflation, they may be less robust than AER estimates. The potential complexity and difficulty of forming both raw and decomposed BBIR estimates rank the BBIR method below the AER's current method in terms of transparency, replicability and simplicity.

215. Compared to BBIR estimates, the swap-implied expected inflation rate may produce relatively congruent estimates of long term inflation expectations. There are several studies which find that inflation swap rates may be less affected by distortions, premia biases compared to the BBIR. Indeed, many researchers demonstrate considerable confidence in the relative unbiasedness of inflation swaps by using this method as a benchmark to estimate the size of liquidity premia in the BBIRs.

216. Compared to BBIR estimates, the 10 year swap-implied expected inflation rate is relatively stable over time. The relative stability of swap-implied estimates is more consistent with findings of the relative stability of long term inflation expectations. The relative stability of swap-implied estimates also suggests that this method is more robust to phenomena that have little influence on long term inflation expectations.

217. The swap-implied forward inflation curve is calculated from many more tenors compared to indexed CGS. And over a 20 business day averaging period each swap tenor is likely to include many traded swap price observations. The result may be that:

- the swap-implied forward inflation curve may more closely reflect the decomposition of market-implied forward inflation rates, and
- the swap-implied inflation term structure may more closely reflect mark-to-market expectations of inflation at each whole year up to 10 years ahead.

218. Swap-implied expected inflation rates are relatively transparent and simple to estimate compared to the BBIR. The swap-implied term structure of inflation expectations of any whole year up to 10 years can be readily calculated from the implied forward inflation swap rates by using IPART's approach. IPART's approach to

[304] One study finds that historical biases/premia in the BBIR are not significant: Banco Central do Brasil, 'Breaking the Break-even Inflation Rate', Inflation Report, pp. 18-21.

estimating swap-implied expected inflation rates is publicly available and can be easily replicated and scrutinised. In contrast, the calculation of the BBIR-implied term structure of inflation expectations may be considerably less simple. Complex yield curve models may be required to obtain raw whole year BBIR estimates – and this is even before consideration of the complexity of decomposition estimates of the BBIR.

219. However, inflation swaps may rank below the AER's current method in terms of relative congruence with inflation expectations and robustness of the estimator. Zero coupon inflation swap prices are volatile relative to the AER's current method. While the volatility of zero coupon inflation swap prices may reflect changes in mark-to-market expectations of inflation, swap prices may also be affected by some potential biases such as hedging costs and inflation risk premia. The potential biases may be volatile over time such that, if they are significant, they may drive a variable wedge between inflation swap prices and inflation expectations. There are also mixed findings on the liquidity of the Australian zero coupon inflation swap market. Lower liquidity may result in inflation estimates implied from daily swap prices diverging from mark-to-market inflation expectations.

220. There are studies of US and UK inflation swaps which find that potentially the largest biases, including hedging costs, counterparty default risk premia and liquidity premia, may be small or insignificant. Some of the potentially largest biases, such as counterparty default risk premia and liquidity premia, are also likely to be negligible for Australian zero coupon inflation swaps. However, there is some uncertainty whether other biases such as hedging costs in Australian inflation swaps are insignificant. There are no known decomposition studies of Australian inflation swap prices which may resolve this uncertainty.

221. One potential reason for the lack of these decomposition studies is that biases such as hedging costs are difficult to estimate. The difficulty may partly arise because the hedging cost data are proprietary to the hedger. However, difficulties may remain even if decomposition studies are available and that biases are found to be negligible, or can be robustly estimated and removed. There is the required and tenuous assumption that the historical sample period from which biases (or absence of biases) are observed is representative of the conditions prevailing in the swap market when estimates are obtained.

222. It is considered that the raw swap-implied expected inflation rate may not result in best estimates of expected inflation because there remains uncertainty surrounding some potential biases in inflation swaps. This consideration, combined with the findings that long term expectations of inflation are anchored within the inflation target band, suggest that the AER's current method estimates may be considered better estimates of expected inflation. The AER's current method is also considered relatively transparent, replicable and simple to employ because of the possibility that swap price decomposition estimates may still be required.

223. Survey estimates of expected inflation over a 10 year horizon are also considered in this paper. Many studies of inflation expectations consider survey-based estimates of inflation expectations as reasonable or even superior proxies for market expectations of inflation. However, long term survey estimates of expected inflation for Australia are not available for this comparative assessment. Therefore a comprehensive assessment of this method could not be conducted. Consideration may be given to obtaining and analysing longer term survey-based inflation expectations since this method may be a standalone alternative to the methods considered in this paper.

224. Publicly available survey estimates of market economists' inflation expectations up to 2 years ahead are available from the RBA. There are some limited uses for these estimates. The short term survey estimates may be used to cross-check RBA

forecasts in the AER's current method. Since the volatility of short term survey estimates may be considered near the upper bound of the volatility expected for long term market-based estimates, they may be used to assess the relative congruence and robustness of long term market-based estimates.

225. In this comparative assessment, a ranking of the four methods is now conducted. The available survey estimates of expected inflation are considered to result in 'least-best' estimates of expected inflation because of the limited forecast horizon.

226. Against the criteria of assessment, raw and decomposed BBIR estimates are considered third best estimates of expected inflation. The BBIR method ranks above survey estimates because BBIR data are available in which to form 10 year estimates. However, because there are many issues with BBIR estimates, 10 year survey estimates may rank above the BBIR method (and possibly other methods) if an assessment of these survey estimates can be conducted in future.

227. The 10 year inflation expectations implied from inflation swaps are considered to produce second best estimates of expected inflation. There are many tenors of inflation swaps and 10 year swap-implied inflation expectations are relatively stable over time (compared to the BBIR method). There are studies which find that inflation swaps are better estimates of expected inflation compared to the BBIR and that the largest biases in inflation swap prices may be negligible. Therefore, inflation swaps are considered to rank above the BBIR method on the basis of relative congruence with inflation expectations and robustness. Inflation swaps also rank above the BBIR method on the basis of transparency, replicability and simplicity. Estimates of inflation expectations can be readily obtained from published swap prices. The publicly available method employed by IPART to estimate 10 year swap-implied inflation expectations is also transparent and can be easily replicated.

228. However, against the criteria of assessment, inflation swaps rank below the AER's current method. While there are international studies which find negligible biases in inflation swap prices, there remains some uncertainty over the size of some potential biases in Australian inflation swap prices. There are also mixed findings on the liquidity of the zero coupon inflation swap market. The 10 year inflation expectations implied from inflation swaps are also relatively volatile compared to the AER's current method. The relative volatility of swap-implied estimates is less consistent with the findings that long term inflation expectations are relatively stable over time. Therefore, the AER's current method is considered to rank above inflation swaps against the criteria of relative congruence and robustness (to phenomena that may be unrelated to changes in long term inflation expectations).

229. Inflation expectations can be easily calculated from published inflation swap prices. However, the possibility that swap prices may need to be decomposed into estimates of inflation expectations and biases result in this method ranking below the AER's current method in terms of transparency, replicability and simplicity. On the basis of this comparative assessment, the AER's current method is considered to rank above all other methods against the criteria of assessment. Best estimates of expected inflation are considered to be obtained from the AER's current method.

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Appendix 1: The geometric average in the AER's current method

230. In this paper, expected inflation in 'best estimates of expected inflation' are considered to be market expectations of the percentage growth in the CPI over a 10 year horizon. A method considered to result in best estimates of expected inflation must calculate the expected average annual percentage growth in the CPI over a 10 year horizon. This form is an input into the PTRM and is used to calculate the real WACC from the nominal WACC.

231. The AER's current method provides whole year estimates of the expected inflation rate 1 to 10 years ahead. Whole year estimates include the RBA forecast of inflation 1 and 2 years ahead and the midpoint of the RBA inflation target band from 3 to 10 years ahead. Where RBA forecasts a range of possible inflation outcomes, a simple midpoint of the range is chosen. The AER calculates the geometric annual average of whole year estimates of expected inflation over a 10 year horizon:

$$\pi_{\mathrm{G}}^{\mathrm{e}} = \sqrt[10]{\left(1+\pi_1^{\mathrm{RBA}}\right) * \left(1+\pi_2^{\mathrm{RBA}}\right) * \left(1+\pi_3^{\mathrm{midpoint}}\right) *, \ldots, * \left(1+\pi_{10}^{\mathrm{midpoint}}\right)} - 1 \quad \text{(A1)}$$

where:

π_1^{RBA} is the RBA forecast CPI inflation rate, 1 year ahead.

π_2^{RBA} is the RBA forecast CPI inflation rate, 2 years ahead.

$\pi_3^{midpoint}, \ldots, \pi_{10}^{midpoint}$ are the midpoints of the RBA target inflation band of 2 to 3 per cent, each year from 3 to 10 years ahead.

232. The arithmetic annual average of expected inflation over a 10 year horizon is calculated as follows:

$$\pi_A^e = \frac{1}{10}\left[\pi_1^{RBA} + \pi_2^{RBA} + \pi_3^{midpoint} +, \ldots, +\pi_{10}^{midpoint}\right] \quad \text{(A2)}$$

233. If the expected annual inflation rate is not constant (and trivially assuming $1 + \pi_t^e$ is non-negative), the geometric average of the expected annual inflation rate is always below the arithmetic average. The geometric annual average is considered more appropriate than the arithmetic average for the calculation of 10 year estimates of expected inflation in the AER's current method. An arithmetic average of the expected growth in the CPI will overstate the expected average annual inflation rate as a result of not accounting for the cumulative effect of each year's expected rate of inflation on the base. In other words, the annual compounding effect from year to year is not considered in the calculation of the arithmetic average. This problem is corrected by calculating the geometric average since the geometric average accounts for the compounding effect.[305]

[305] Spizman and Weinstein (2008) consider the geometric and arithmetic average in detail. Vide: Lawrence Spizman and Marc Weinstein (2008), 'A Note on Utilizing the Geometric Mean: When, Why and How the Forensic Economist Should Employ the Geometric Mean', *Journal of Legal Economics*, 15(1), pp. 43-55.

Appendix 2: Proxies for liquidity and the availability of Australian data

Proxy	Measure of liquidity	Available Australian Data
Average curve fitting error	Dispersion between observed indexed bond yields and benchmark indexed bond yields obtained from a yield curve model is used as a proxy for illiquidity and a liquidity premium. Average fitting error of TIPS individual issues' yields with respect to the Nelson, Siegel and Svensson (NSS) yield curve. This measure of illiquidity is not maturity specific because it is a measure of the whole TIPS market liquidity. However it can be maturity dependent if the benchmark and observed yields are applied to a particular maturity. [306] Grishchenko and Huang (2012) argue that during times when capital is abundant arbitrage smooths out the Treasury yield curve so that average fitting errors are low. However, during times when capital is relatively scarce arbitrage trades are more difficult and this results in large fitting errors of the Treasury yield curve.[307] Grishchenko and Huang's (2012) dispersion measure of TIPS illiquidity is based on the NSS model employed by Hu et al. (2012)[308] for the US nominal Treasury market. Hu et al. have on average 163 US Treasury bonds and Treasury notes (daily) to fit the yield curve and 109 bonds with maturity between 1 and 10 years to construct the noise measure (sample period 1987 to 2011).[309] Hu et al. employ a number of spline based methods to check the robustness of their main dispersion results, and they find that the results are robust to various curve fitting methods.[310]	Unlike the studies of US nominal and indexed bond markets, curve fitting error studies of the indexed CGS market may produce anomalous results because there are too few outstanding indexed CGS. For example, dispersion results may not be robust to yield curve model employed for the Australian market since there are only 7 outstanding indexed CGS in Australia up to 24 years. A lack of robustness may mean that dispersion results are not reasonable indicators of illiquidity.
Spread between on-the-run and off-the-run nominal bonds	A liquidity measure in the US Treasury market is the potential liquidity spread between more and less liquid Treasuries. This is often calculated as the difference between on-the-run and off-the-run US Treasuries (that have similar cash flow characteristics). [311] In their decomposition analysis of the BBIR, Shen and Corning (2001) argue that a lower bound proxy for the liquidity premium on US TIPS is the liquidity spread between on-the-run and off-the-run US Treasuries. There are sizeable differences in yields between	No.

306 Olesya Grishchenko and Jing-zhi Huang (2012), 'Inflation Risk Premium: Evidence from the TIPS market', *Finance and Economics Discussion Series Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C.* 2012-06, pp. 19-20.

307 *ibid.*, p. 3.

308 Grace Hu, Jun Pan and Jiang Wang (2012), 'Noise as Information for Illiquidity', 1 July, pp. 1-46.

309 *ibid.,* p. 7.

310 *ibid.*, p. 9; pp. 38-43.

311 Michael Fleming (2003), 'Measuring Treasury Market Liquidity', *Federal Reserve Bank of New York Economic Policy Review*, September, p. 85.

	newly issued treasuries (on-the-run) and treasuries of similar maturity but already in the market (off-the-run). Shen and Corning identify the spread between these yields as a liquidity premium since these treasuries with similar maturity are almost identical except for liquidity.[312] Shen and Corning find that this proxy for the TIPS liquidity premium varies considerably through time.[313] Pflueger and Viceira (2015) use on-the-run and off-the-run spread as a proxy for the relative liquidity of US TIPS.[314]	
Spread between government backed instruments and government bonds	Gurkaynak et al. (2010) use the spread between the US Resolution Funding Corporation (RefCorp) STRIPS and Treasury STRIPS in addition to transaction data to estimate relative changes in the liquidity premium in the US BBIR.[315] Celasun et al. (2012) also use the spread between nominal Treasury bonds and (RefCorp) bonds as a liquidity proxy to estimate relative changes in the liquidity premium in the US BBIR.[316]	Unknown whether such proxies may be available.
Quote size or trade size	Quote size is the quantity of securities that are bid for or offered for sale at the stated bid and ask prices. However, a drawback of this proxy is that the market makers may not disclose the full quantities for which they are willing to trade at a given price.[317] Trade size is the measure of the quantity of securities that can be traded at bid or offer prices which reflects the negotiation over the quantity. However, the quantity traded is usually less than the quantity that could have been traded at the stated prices. This proxy also does not consider the cost of executing larger trades.[318]	No.
Trading frequency	Trading frequency is the number of trades executed within a specified time interval (normally daily) without reference to trade size. This proxy may	No.

312 STRIPS, 'Separate Trading of Registered Interest and Principal Securities' are financial instruments that have been stripped of their coupon payments so that the coupon and principal components are traded separately. Therefore STRIPS are known as zero coupon securities since the only time an investor receives a payment is at maturity. The Resolution Funding Corporation issued bonds to finance the resolution of the Savings and Loan Crisis. These STRIPS are guaranteed by the government and have the same credit risk as Treasury STRIPS except they are considerably less liquid. Refet Gurkaynak, Brian Sack and Jonathan Wright (2010), 'The TIPS Yield Curve and Inflation Compensation', *American Economic Journal: Macroeconomics*, 2(1), p. 87.

313 Pu Shen and Jonathan Corning (2001), 'Can TIPS Help Identify Long-Term Inflation Expectations?' Federal Reserve Bank of Kansas City, *Economic Review*, Fourth Quarter, p. 77.

314 Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, pp. 9-10.

315 Refet Gurkaynak, Brian Sack and Jonathan Wright (2010), 'The TIPS Yield Curve and Inflation Compensation', *American Economic Journal: Macroeconomics*, 2(1), pp. 86-88.

316 Oya Celasun, Roxana Mihet and Lev Ratnovski (2012), 'Commodity Prices and Inflation Expectations in the United States', *IMF Working Paper*, WP/12/89, p. 7.

317 Michael Fleming (2003), 'Measuring Treasury Market Liquidity', *Federal Reserve Bank of New York Economic Policy Review*, September, p. 85.

318 *ibid*., p. 85.

	reflect a more liquid market, but the proxy is also associated with high volatility and lower liquidity.[319]	
Price impact coefficient Daily bond prices and daily net volume of trades ($ million). Buyer instigated volume of trade net of seller instigated volume of trade.	The price impact coefficient measures the responsiveness of the price of the security to changes in the net trading volume (buyer instigated volume of trades less seller instigated volume of trades). A lower responsiveness of the price to changes net trading volume may indicate a more liquid market.	No.
Spread between the BBIR and inflation swaps prices.	Pflueger and Viceira (2015) and D'Amico et al. (2016) for the US and Liu et al. (2015) for the UK use the spread between the inflation swap rates and the BBIRs as a proxy to estimate liquidity premia in BBIRs.[320]	Data on 10 year zero coupon inflation swaps and the 10 year BBIR are available. However, there remains some uncertainty over the potential biases in Australian zero coupon inflation swap rates.
Other proxies	The spread between nominal CGS and NSW Treasury Corporation 10 year bonds was considered as a crude proxy of the relative liquidity of indexed CGS. The total issue value of NSW Treasury Corporation bonds is considerably greater than indexed CGS. Daily data are available on NSW Treasury Corporation 10 year bonds from July 1998.[321] However, analysis of the spreads between NSW Treasury bonds and nominal CGS reveal possibly other more profound explanations for the spreads beside that of liquidity.[322]	Potentially poor proxy for relative liquidity

319 *ibid*., p. 85.

320 Zhuoshi Liu, Elisabeth Vangelista, Iryna Kaminski and Jon Relleen (2015), 'The informational content of market-based measures of inflation expectations derived from government bonds and inflation swaps in the United Kingdom', *Staff Working Paper No. 551, Bank of England*, p. 2; Carolin Pflueger and Luis Viceira (2015), 'Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity', Working Paper, p. 12, p. 16 and Table IIA; Stefania D'Amico, Don Kim and Min Wei (2016), 'Tips from TIPS: The informational content of Treasury Inflation-Protected Security prices', Finance and Economics Discussion Series, Divisions of Research and Statistics and Monetary Affairs, Federal Reserve Board, 2014-24, pp. 28-29 and p. 59.

321 The NSW Government's credit rating has been AAA each year over the observed period from 1998 to 2016. Evidence of this AAA rating was obtained from Office of Financial Management Annual Reports, NSW Budget Papers, New South Wales Treasury Corporation Annual Reports and New South Wales Treasury Annual Reports.

322 Despite their similar cash flow profiles and the same credit ratings, the differences between the yields on 10 year NSW Treasury Corporation bonds and 10 year nominal CGS may not be solely attributed to a differential liquidity premium. For example, Lancaster and Dowling (2011) attribute the widening of the spreads between nominal CGS and semi-government bonds during the financial crisis to the perceived increase in risk of NSW Treasury bonds due to lack of familiarity of the degree of vertical fiscal integration, where state governments receive a large share of their revenue via redistributions of Commonwealth Government tax receipts. (David Lancaster and Sarah Dowling (2011), 'The Australian Semi-Government Bond Market', *Reserve Bank of Australia Bulletin*, September Quarter, p. 54.) There may also be other influences. Unlike the Commonwealth, State Governments do not possess the (ultimate) ability to engage in seigniorage financing to repay their outstanding obligations. Therefore, it is possible the spread may also be explained by other subtle risk differences between the Commonwealth and NSW Government's ability to repay debt.