Best estimate of inflation: revaluations and revenue indexation

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1 Introduction

1. I have been asked by Aurizon Network (henceforth referred to as “Aurizon”) to provide a report advising on the appropriate treatment of forecast and actual inflation as an input into revenue modelling and also as an input into the roll forward of the regulatory asset base between regulatory periods.

2. The remainder of this report has the following structure:

   - Section 2 describes how forecast and actual inflation interact within the regulatory regime to deliver compensation – both in revenues in the immediate regulatory period and in the form of a higher RAB in the next period. This section explains that the current treatment of inflation means that the level of nominal compensation received by Aurizon is affected by inflation forecast error. This section also describes potential amendments that would reduce or remove any role for inflation forecast error to affect the nominal compensation for the cost of capital;
   - Section 3 discusses whether there is any justification for making the nominal return received by Aurizon dependent on the level of inflation forecast error by the QCA. It concludes that there is no justification for this exposure as applied to the cost of debt but that the answer is more ambiguous for the cost of equity;
   - Section 4 explains why we believe that the regulatory regime should give more weight to market-based estimates of expected inflation – in particular “break-even” inflation measured as the difference in yields between nominal and indexed Commonwealth Government Security (CGS) yields. Break-even inflation estimates are currently much lower than the QCA’s previous[1] default assumption of 2.5% (even in the long term).; and
   - Section 5 provides a literature review of potential sources of bias in break-even inflation estimates.

[1] We note that, immediately prior to finalising this report the QCA signalled, in its final decision for DBCT, its intention to change its inflation forecast methodology to rely on RBA inflation forecasts where they are available and to assume 2.5% beyond that forecast horizon. We have not had time to amend our report to address this change in policy. However, our key conclusions are not affected by this change in policy. We still regard break-even inflation as a superior method for arriving at an estimate of inflation expectations over the relevant horizon. Amongst the other reasons provided in this report this is because: a) the RBA inflation forecast band is a measure of ‘most likely’ inflation and not ‘expected’ inflation and there is a material difference between these when the risks to inflation are asymmetric as they are at the time of writing; b) the midpoint of that band is not necessarily even the RBA’s estimate of the most likely inflation outcome; and c) the assumption of 2.5% inflation beyond the RBA forecast range is not in any manner an RBA forecast and is not necessarily consistent with inflation expectations – especially in current market circumstances as detailed in this report.

1.1 Summary of conclusions

1.1.1 A nominal cost of debt should be targeted

3. A key conclusion of this report is that the regulatory framework should be designed to deliver a target nominal cost of debt. This is because corporate debt is most efficiently raised using nominal debt instruments (and it is these same instruments that the QCA uses to estimate the cost of debt). Businesses that borrow in nominal terms must meet repayment in nominal terms irrespective of whether actual inflation turns out to be higher or lower than expected at the time they entered into the debt contract. For this reason, the regulatory regime should be designed to deliver target nominal compensation for the cost of debt irrespective of the actual outturn inflation. The same is not necessarily true for the cost of equity, since some investors may instead demand a target real return on equity.

4. The QCA regulatory regime can deliver a target nominal return on debt and either a target real return or target nominal return on equity with some relatively simple amendment. Specifically, the debt component of the RAB should be rolled forward using the same forecast of inflation that is adopted in the regulatory modelling. This will deliver a total nominal compensation equal to the nominal cost of debt used in the revenue modelling. This will mean that the amount of nominal compensation that is 'taken out' of revenues during the regulatory period in anticipation of future RAB indexation will, by definition, be the same as that which is actually provided.

5. The roll forward method that should be applied to the equity component of the RAB will depend on the type of return that investors are assumed to target. If it is assumed that investors target nominal returns on equity, then using the same reasoning argued above for the debt component of the RAB, the equity component should also be rolled forward using forecast inflation.

6. On the other hand, if investors are assumed to target real returns, then the equity component of the RAB can continue to be rolled forward using actual inflation (irrespective of whether this is different to forecast inflation used to determine revenues over the same period). This will deliver a real return on equity equal to the nominal cost of equity determined in the revenue modelling less expected inflation used in the revenue modelling.

1.1.2 Expected inflation should be proxied by break-even inflation

7. Reform to indexation of the debt and equity components of the RAB will have the effect that the level of forecast inflation will have no impact on the overall compensation for the cost of debt and equity received. However, an accurate estimate of expected inflation would still be desirable in order to not front/back load cashflows. If the suggested reform is not applied to the equity component of RAB

then an accurate inflation forecast is important in NPV terms (i.e. will affect the total value of compensation provided).

8. This report surveys the overwhelming evidence that medium term expected inflation is well below 2.5% (being the QCA's standard assumption regarding expected inflation). In our view, the most reliable estimate is provided by break-even inflation – which is obtained by applying the Fisher equation to the difference in yields between inflation indexed Commonwealth Government Securities (CGS) and nominal CGS. This is termed 'break-even' inflation because that is the inflation rate at which investors expect the same nominal return from either asset. This should be measured over the same horizon as Aurizon's regulatory period (4 years).

9. Four-year breakeven inflation was, in the month of June 2016, 1.22% (less than half 2.5%). This is consistent with very low historical inflation outcomes in recent years. Over the last two years (July 2014 to June 2016) CPI inflation has averaged 1.5%. It is also consistent with the fact that RBA forecasts of inflation are 2.0% or below out to December 2018 (the longest forecast horizon).

10. We note that break-even inflation is below the midpoint of the RBA forecast interval at the end of the RBA forecast horizon (which is 2.0%). Incorporating this into the QCA estimate of inflation expectations would result in an estimate lower than 2.5%.

11. However, the correct estimate of expected inflation to use in the QCA revenue model is investors' actuarially expected inflation (i.e., the probability weighted average of all possible inflation outcomes). As a market based measure, break-even inflation captures all of the possible inflation outcomes weighted by the probability investors assign to these outcomes. The RBA forecast, by contrast, represents an interval containing a 'most likely' forecast and not an actuarially expected forecast. As is explained in this report, the risks to the downside on inflation are materially higher than the risks to the upside. Consequently, market-based measures of expected inflation are lower than 'most likely' forecasts.

12. Finally, a review of the literature on inflation forecasts estimated by the break-even approach suggests that the potential sources of bias are small and just as likely to result in an over-estimate of expected inflation as an underestimate. Certainly, it is not plausible that these account for the current 70bp difference between break-even inflation and the QCA's estimate of expected inflation.

2 Compensation for inflation in the regulatory framework

13. The QCA's current regulatory framework for Aurizon uses forecast inflation as an input in order to model an assumed path of the nominal RAB over the regulatory period. That is, forecast inflation is used to forecast revaluations in the QCA's revenue model. The higher the inflation forecast used in the revenue model the higher will be the assumed growth in the nominal value of the RAB and, consequently, the lower the level of compensation provided for in modelled revenues during the regulatory period.

14. In other words, the role of forecast CPI revaluations in the revenue model is to reduce the amount of monetary compensation allowed in revenues over the 4-year undertaking by the amount of forecast CPI revaluations. The rationale for doing so is that Aurizon will expect to receive compensation for rising CPI in the form of a higher opening RAB at the beginning of the next regulatory period (via the RAB roll forward provisions in the IMs). In effect, the revenue model:

   - forecasts the level of the compensation expected to be provided at the beginning of the next regulatory period via the RAB roll-forward provisions; and
   - removes this amount from revenues during the immediate regulatory period in order to avoid double compensation for inflation.

15. However, only if actual and forecast inflation are the same will the amount of revenue removed in the immediate regulatory period be equal in value to the amount added to the RAB at the beginning of the next regulatory period (via the RAB roll-forward provisions of the current approach to inflation compensation). This is because the RAB roll-forward provisions will provide revaluations based on actual inflation at the end of the regulatory period rather than revaluations based on forecast inflation at beginning of the period (with the latter being what is used to forecast revaluations in the revenue model).

16. A simple example illustrates the calculations. Let there be a one-year regulatory period and a perpetual (non-depreciating) asset in the RAB with a value of $100. Let the nominal WACC be 8% and let forecast inflation be 2% over the regulatory period and let the tax rate be zero. In this stylised example, allowed revenues generated by this asset will be $6 – comprised of 8% return on $100 less 2% ($2) forecast revaluation.

17. If inflation turns out to be 2% then the asset owner will receive an actual $2 revaluation of their asset at the end of the one year regulatory period. Consequently, their total return comprising both revenues within the regulatory period and revaluation at the end of it will be equal to the 8% estimated cost of capital at the

beginning of the regulatory period (6% in the form of revenues and 2% in the form of revaluation).

18. However, if actual inflation turns out to be 0% then the asset owner will receive 0% actual revaluation at the beginning of the next regulatory year. Consequently, the asset owner's nominal return will be 6% and not the estimated 8% at the beginning of the previous regulatory year. Similarly, if actual inflation turns out to be 4% then the asset owner will receive nominal compensation of 10% (6% in revenues and 4% in revaluations).

2.1 The current framework delivers a real (not nominal) cost of capital

19. This example highlights the fact that the current arrangements deliver a return on capital that is equal to the real cost of capital estimated at the beginning of a regulatory period - with actual nominal compensation arrived at by adding actual outturn inflation over the regulatory period to the estimated real cost of capital at the beginning of the regulatory period.

20. In summary, the current structure of the inflation compensation arrangements is as follows:

    i. Take a nominal input for the cost of debt and equity;

    ii. Deduct **forecast inflation** to arrive at a real return which is then embedded in the real regulated revenue path;

    iii. Provide nominal compensation that is equal to:

        a. The real return derived in step ii); plus

        b. In the RAB roll forward, compensate for the inflation that **actually occurs** over the regulatory control period.[2]

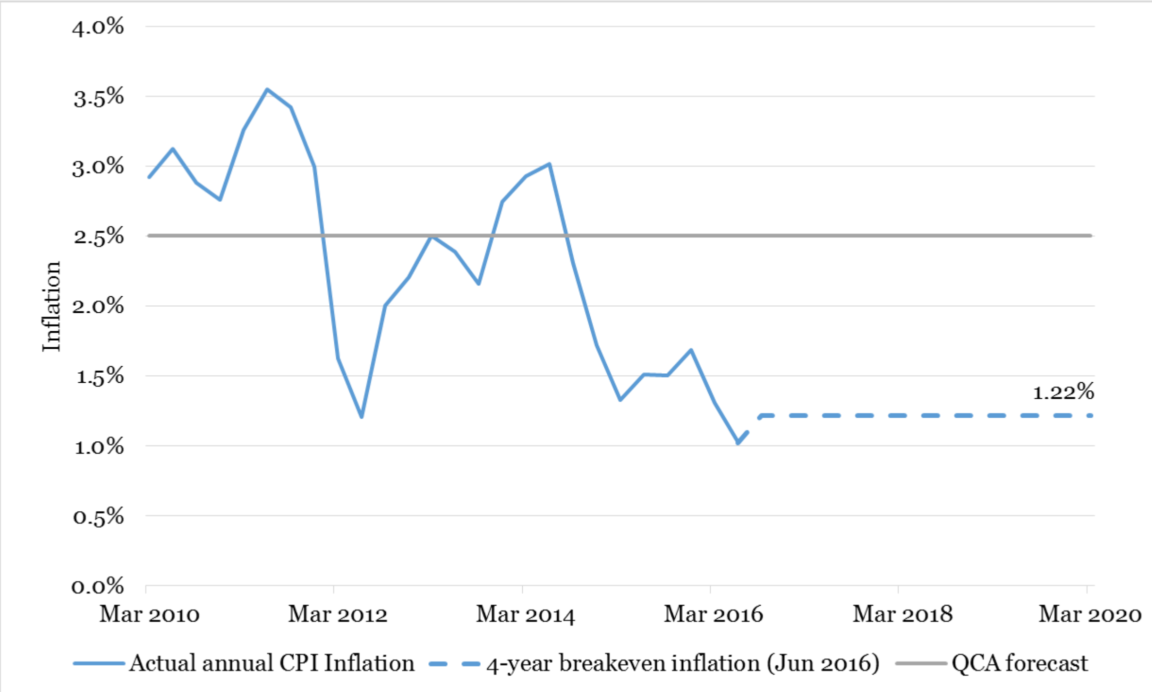
21. The real revenue path in step ii) is the final output of the QCA's revenue model.

22. This creates a potential for material mismatch between the nominal cost of capital inputted into the QCA's revenue model in step i) above and the final nominal compensation provided in step iii), specifically in cases where **actual** inflation over the regulatory period turns out to be different from inflation **forecasts** made at the beginning of the regulatory period.

[2] This is compensated primarily in the RAB roll forward used to set the opening RAB at the beginning of the next regulatory period but also (to a small extent) in the form of price escalation for inflation during the regulatory period.

23. Our analysis of the Aurizon experience under UT4 suggests that this mismatch has been significant and that Aurizon will not been compensated for the estimated nominal cost of capital over that period. Moreover, it appears very likely that this experience will be repeated in the upcoming UT5 period. Figure 1 compares our understanding of forecast vs actual inflation.

Figure 1: Forecast inflation in UT4 vs actual inflation



Source: ABS, QCA, RBA, CEG analysis; Breakeven inflation calculated by applying the Fisher equation to the difference between semi-annual nominal CGS yields and semi-annual inflation-indexed CGS yields

24. Based on Figure 1 Aurizon will have, due to forecast error, suffered material loss relative to the QCA's nominal cost of capital estimates. Moreover, unless inflation rises sharply, Aurizon will continue to suffer inflation forecast losses over UT5 unless the QCA alters either its framework (to remove inflation forecast error) or its inflation forecast methodology.

2.2 Framework reform to target a nominal cost of capital

25. An alternative to the current approach is to amend the framework to deliver a return equal to the QCA's nominal cost of capital with zero forecasting error. This could be achieved by simply not applying any CPI related revaluations in the QCA's revenue model nor in the RAB roll forward provisions of the IMs. This is the standard practice of US regulators. However, such a change would also change the time profile of cost

recovery (allowing earlier cost recovery than the current framework under which CPI revaluations have the effect of back-loading compensation).[3]

26. This change in the profile of cost recovery may, or may not, be appropriate. However, it is not necessary to change the profile of compensation in order to target nominal (rather than real) compensation. An alternative that would retain the current cost recovery profile would be to amend the framework as follows:

   i. Take a nominal input for the cost of debt and equity;

   ii. Deduct **forecast inflation** to arrive at a real return which is then embedded in the real regulated revenue path that is the output of the QCA revenue model;

   iii. Provide nominal compensation that is equal to:

      a. The real return derived in step ii); plus

      b. In the RAB roll forward, compensate for revaluations based on the same **forecast inflation** used in step ii) (i.e., not actual inflation).

27. That is, the framework could be amended to target a nominal return on capital simply by rolling forward the RAB between regulatory periods using the same CPI forecast values used in the QCA's revenue model at the beginning of the regulatory period. Similarly, a real return on capital could be targeted, but with the profile of cost recovery brought forward in order to match that associated with applying a no revaluations policy (as set out in paragraph 25 above).[4]

28. The options described above are summarised Table 1 below.

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3 Reducing revenues in the current regulatory period for the impact of inflation on the RAB over that regulatory period but increasing the RAB over all future regulatory periods.

4 The way that this would be achieved would be to estimate a real return at the beginning of the regulatory period (equal to a nominal return less a forecast of inflation over the regulatory period). The revenue model would then use the nominal return estimates and not apply any revaluations for expected inflation within the regulatory period. The RAB roll forward model would apply revaluations but instead of being based on the actual CPI over the regulatory period the revaluations would be based on the actual CPI less the forecast CPI. The effect of which is that the profile of compensation is shifted forward but the real compensation (revenues plus actual revaluations) continues to be deliver the same real return set at the beginning of the regulatory period.

Table 1: Approaches to CPI compensation

Nominal or real target return	Backloaded or contemporaneous CPI compensation	Revaluations in revenue model*	Revaluations in RAB roll forward for CPI
Nominal.	Backloaded	Yes	Yes, based on forecast CPI
Nominal	Contemporaneous	No	No
Real	Backloaded	Yes	Yes, based on actual CPI
Real	Contemporaneous	No	Yes, based on actual less forecast CPI

* Based on forecast CPI.

29. The key point here is that it is not necessary to link the profile of compensation for inflation to whether the target return is nominal or real. Either immediate or delayed compensation for inflation can be accommodated in both a nominal and a real framework.

3 Is it appropriate to target a real or a nominal return?

30. The appropriateness of any amendment to the role of forecast inflation in the regulatory framework depends on whether the objective is to deliver a target real or a target nominal return to Aurizon. In our view this, in turn, depends on how businesses are assumed to efficiently fund their investments. Moreover, the answer may be different for that part of the RAB funded by debt compared to that part of the RAB funded by equity.

3.1 Efficient debt funding practices

31. If the benchmark efficient debt management practice involves the issuance of plain nominal debt then, at least for the debt component of Aurizon's RAB, the objective should be to deliver nominal compensation to match Aurizon's nominal interest costs. The current regulatory framework does not do this. Instead, it only delivers the target nominal return if there is zero inflation forecast error.

32. This is inappropriate because the potential for forecast error compromises the ability of the businesses to meet the QCA's estimated costs of contractually binding promises to pay nominal interest payments. This might be justified if there was no way to design a regulatory system to avoid the potential for such forecast error. However, as explained above this is not the case. The framework can be modified in a simple and straightforward manner so that a target nominal rate of return is delivered rather than a real rate of return.

33. Alternatively, it may be determined that benchmark efficient debt management practices involve issuing only inflation indexed debt (or, equivalently, issuing plain nominal debt but also trading in CPI swap instruments to create a synthetic CPI indexed portfolio). In this case, the current the treatment of CPI will provide appropriate inflation compensation that is aligned with this benchmark strategy.

34. However, if the benchmark debt management strategy involves issuing CPI indexed bonds (or trading in CPI swaps) then other aspects of the framework would need to be altered to reflect this benchmark. In particular, the nominal cost of debt would need to be:

- built up from the yield on inflation indexed debt plus forecast inflation; or

- based on the nominal cost of debt less the net cash flows (including transaction costs)[5] from a receive fixed/pay floating CPI swap portfolio that matches the issue dates, amounts and maturity of the benchmark nominal debt portfolio.

3.2 Efficient equity funding practices

35. When raising equity, unlike when raising debt, a business does not enter into any binding contract to deliver a specified return (real or nominal) to investors. Consequently, there are no assumed contractual obligations for the model of regulatory compensation to mirror. It is therefore arguable what the compensation for the cost of equity should target; real or nominal return.

36. That is, it may be argued that equity investors care about the real (inflation adjusted) return on their investment.[6] If this is accepted then the current framework (narrowly applied to only the equity component of the RAB) will deliver this provided that the QCA's estimate of the real cost of equity[7] at the beginning of the regulatory period is accurate. On the other hand, if it is assumed that equity investors actually target nominal returns on investment, then the reform suggested in section 2.2 should also be applied to the equity component of the RAB.

37. Ultimately, it is reasonable to assume that the firm itself understands investors' expectations and, therefore, the decision should be left to the firm. It is also worth noting that, choosing a nominal target return eliminates any gaming from the regulated firm (ore the regulator) deliberately proposing a lower (higher) inflation forecast than they truly expect. If a nominal return is targeted there is no expected advantage from such a strategy.

3.3 A weighted average approach

38. If, as appears likely, the benchmark debt management strategy involves issuing nominal bonds, then the current treatment of inflation forecast error should be

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5 We understand that the transaction costs of large trades in inflation swaps may be material. We also understand that the accounting treatment of such swaps would not allow them to be included as hedging instruments – with the effect that changes in their value would add to volatility in reported profits.

6 Of course, this is not always, or necessarily generally, true especially if equity investors as a class have a different consumption bundle (or are saving to finance a different consumption bundle) to that measured in the CPI. Even putting the consumption habits of equity investors aside they may still have a preference for some stability in nominal equity returns in some circumstances if their cash-flow from equity is being used to balance stable nominal debt liabilities etc.

7 The nominal cost of equity less the forecast inflation rate. Or, more precisely, using the Fisher equation which states that the nominal yield (n) on an asset is equal to the real yield (r) plus inflation (p) plus inflation multiplied by the real yield. That is: $n=r+p+r*p$. Solving for r givers $r=(n-p)/(1+p)$.

amended to compensate based on the estimated nominal cost of debt.[8] If, however, the benchmark cost of equity should continue to be treated as a real cost, then the regulatory target return should be a real return. In the latter case, no change to the framework is required in the treatment of inflation on the equity component of the RAB.

39. If this was the view arrived at, then the appropriate approach would be to apply a weighted average of the two approaches. This is summarised in the below table – with the two left hand quadrants reflecting two proposed reforms depending on the assumed target for equity reforms, while the bottom right hand quadrant reflects current QCA practice.

Table 2: Weighted average approaches to CPI compensation

	Nominal target for debt	Real target for debt
Nominal target for equity	Apply revaluations within the revenue model based on forecast inflation but use the same inflation forecast values (not actual inflation) to roll forward the RAB to its new value at the start of the next regulatory period.	Apply approach in top left hand quadrant to the proportion of the RAB that is assumed to be equity funded and the approach in the bottom right hand quadrant to the proportion of the RAB that is assumed to be debt funded.
Real target for equity	Apply approach in top left hand quadrant to the proportion of the RAB that is assumed to be debt funded and the approach in the bottom right hand quadrant to the proportion of the RAB that is assumed to be equity funded	Forecast CPI revaluations in the revenue model and actual CPI revaluations in roll forward (current IMs)

8 That is, to remove the unnecessary potential for inflation forecast error to cause a deviation in compensation from the nominal target.

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4 Methodology for arriving at an inflation forecast

40. In our view, the best estimate of prevailing inflation expectations over a given horizon is given by the difference in yields between CPI indexed and nominal CGS; where the maturity dates for those CGS are consistent with the horizon in question.

41. The QCA's past practice has been to set forecast inflation based on the midpoint of the Reserve Bank of Australia's (RBA) target inflation range (i.e., 2.5%). This approach may be broadly reasonable in 'normal' market circumstances where inflation has, in the immediate prior period, been tracking within the RBA range and investors expect that monetary policy can be relied on to maintain inflation at the midpoint of the central bank's target range. In those circumstances we would expect an estimate of 2.5% to be broadly consistent with break-even inflation.

42. However, current circumstances are such that an estimate of 2.5% is manifestly too high and is wildly inconsistent with: break-even inflation; RBA forecasts of inflation; and recent actual inflation (in Australia and globally). We note that:

- The RBA itself is forecasting inflation out to December 2018 to be below the bottom of its target range (2.0%);[9]
- Australian (and global) inflation rates have been persistently below target, with instances of deflation in Australia (March quarter CPI), US, Japan, the UK and the Eurozone;
- Market based forecasts of inflation are well below 2.5% over a four year horizon;
- A 2.5% inflation forecast would imply a materially negative real risk free rate (assuming nominal CGS are adopted as the proxy for the nominal risk free rate as is QCA practice); and
- The balance of risks to inflation is on the downside (both domestically and globally) – which strengthens the case for the use of market based forecasts that can provide an accurate reflection of asymmetrical expectations of outcomes.

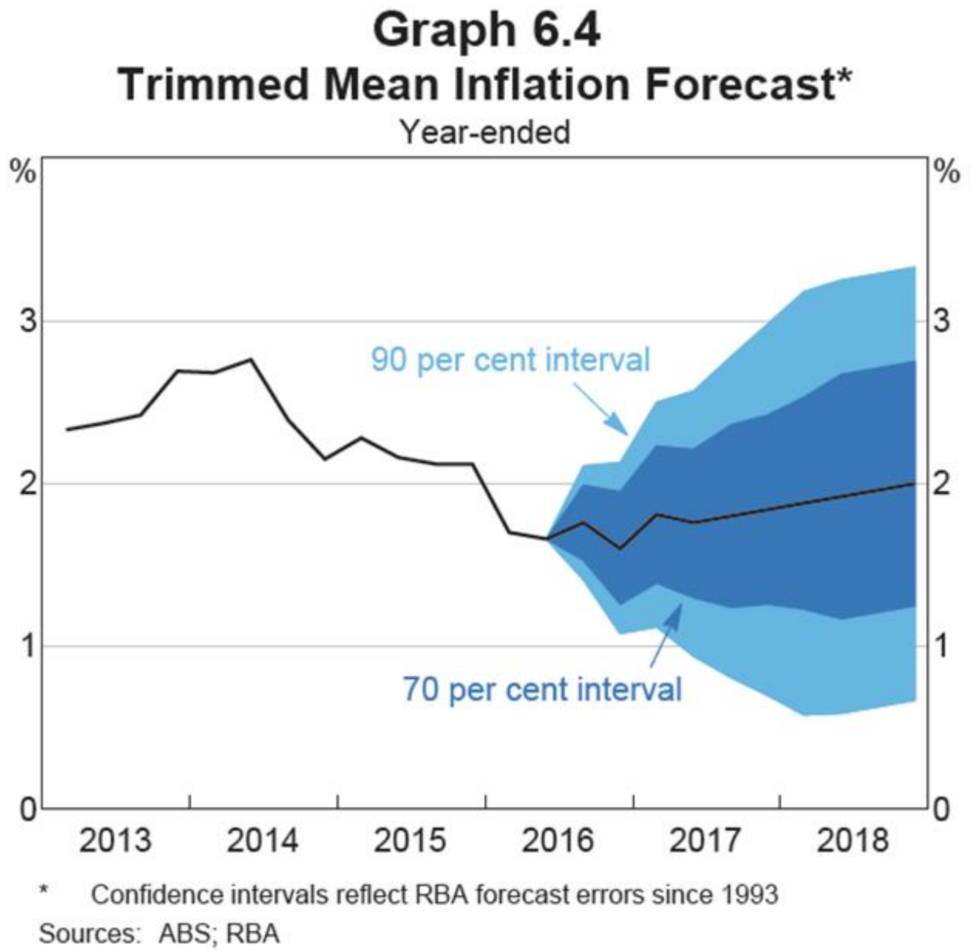
4.1 RBA forecasts of underlying inflation are below 2.0% over the maximum forecast period

43. The QCA's past practice to inflation forecasting, if applied today, would result in forecast inflation above the RBA's own forecasts out to the horizon of its forecast range (December 2018).

9 RBA, Statement on Monetary Policy, August 2016, p. 67.

44. The RBA's central forecast of underlying inflation (trimmed mean inflation)[10] increases only gradually over the next two and a half years as evidenced from Graph 6.4 of the August SoMP (reproduced below).

Figure 2: RBA forecast path for underlying inflation



45. That is, the RBA's central forecast features gradual increases in underlying inflation[11] over the next two and a half years, with inflation only just reaching 2.0% at the end of the forecast period. In order for inflation to average 2.5% over a 4 year horizon

10 The RBA's standard measure of underlying inflation is trimmed mean inflation. See RBA Bulletin, Measures of Underlying Inflation, March Quarter 2010 which states "Given that CPI inflation is quite volatile, most of the models and equations used in the Bank to explain inflation use some measure of underlying inflation (often 15 per cent trimmed-mean inflation) as the dependent variable."

11 Noting that underlying inflation has the same forecast range in Table 6.1 of the SoMP as "headline" CPI inflation.

then, if the RBA's forecasts to 2018 are accepted, actual inflation would need to jump above 3.0% in 2019 and beyond.

46. Low Australian inflation is entirely consistent with international experience across western developed countries, with inflation persistently at or below the bottom end of central bank targets.[12] RBA Governor Glenn Stevens has made the same point in a 3 May 2016 speech when announcing a further cut in the official cash rate by 25bp to 1.75%.

> *Inflation is quite low. Recent information has confirmed that growth in labour costs remains quite subdued. Given this, and with inflation also restrained elsewhere in the world, inflation in Australia* ***is likely to remain low over the next year or two.*** [13]

> *Inflation has been quite low for some time and recent data were unexpectedly low. While the quarterly data contain some temporary factors,* ***these results, together with ongoing very subdued growth in labour costs and very low cost pressures elsewhere in the world, point to a lower outlook for inflation than previously forecast****.*[14] [Emphasis added]

47. The statement following its August 2016 RBA further rate reduction from 1.75% to 1.50% echoed the same logic[15]

> *Recent data confirm that inflation remains quite low. Given very subdued growth in labour costs and very low cost pressures elsewhere in the world,* ***this is expected to remain the case for some time****.*

4.2 Actual inflation has been persistently below 2.0% in recent years

48. The annual rate of CPI inflation to the June quarter 2016 was 1.0% year-on-year. This reflects an intensification of a pre-existing trend whereby over the nearly five-year period beginning 1 July 2011, the arithmetic average annual inflation has been 2.1%. Over the last two years (July 2014 to July 2016) inflation has averaged 1.5%.

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[12] See IMF, World Economic Outlook (WEO), April 2016. "*Headline inflation in advanced economies in 2015, at 0.3 percent on average, was the lowest since the global financial crisis, mostly reflecting the sharp decline in commodity prices, with a pickup in the late part of 2015 (Figure 1.2). Core inflation remained broadly stable at 1.6–1.7 percent but was still well below central bank targets*."

[13] RBA, Statement by Glenn Stevens Governor: Monetary Policy Decision, 2016-08, April 2016.

[14] RBA, Statement by Glenn Stevens Governor: Monetary Policy Decision, 2016-10, 3 May 2016.

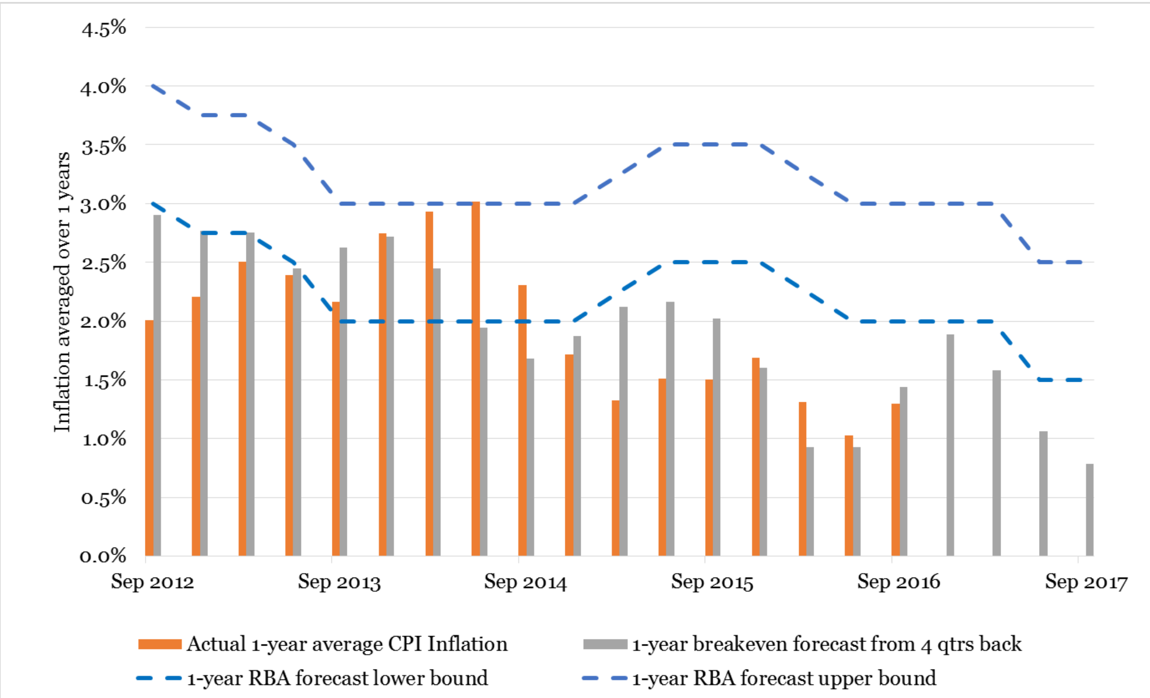
[15] RBA, Statement by Glenn Stevens Governor: Monetary Policy Decision, 2016-18, 2 August 2016.

49. In terms of forecast accuracy, actual inflation over the year to June 2016 of 1.0% can be compared to the year-ahead forecast of these values using:

- the one-year ahead midpoint of the RBA forecast interval of 2.6%,[16] which overestimated the actual inflation outcome by 1.6%, and
- the one-year-ahead break-even forecast of 0.9% [17] which underestimated the year to June 2016 inflation by only 0.1%.

50. Figure 3 provides the same comparison for 5 years from September 2012 to September 2017 – with break-even inflation more accurately predicting low and falling inflation in the subsequent 12 months than the midpoint of RBA forecasts from September 2012 onwards.

Figure 3: RBA and breakeven forecast versus actual inflation (1 year horizon)



Source: ABS, QCA, RBA, CEG analysis

51. It can be seen that:

16 The RBA's SoMP for February 2015 featured a one-year ahead midpoint forecast of 2.75%, while the May 2015 SoMP featured a one-year ahead midpoint forecast of 2.50%. The one-year ahead midpoint forecast averaged over 1 April 2015 to 30 June 2015 is therefore 2.6%.

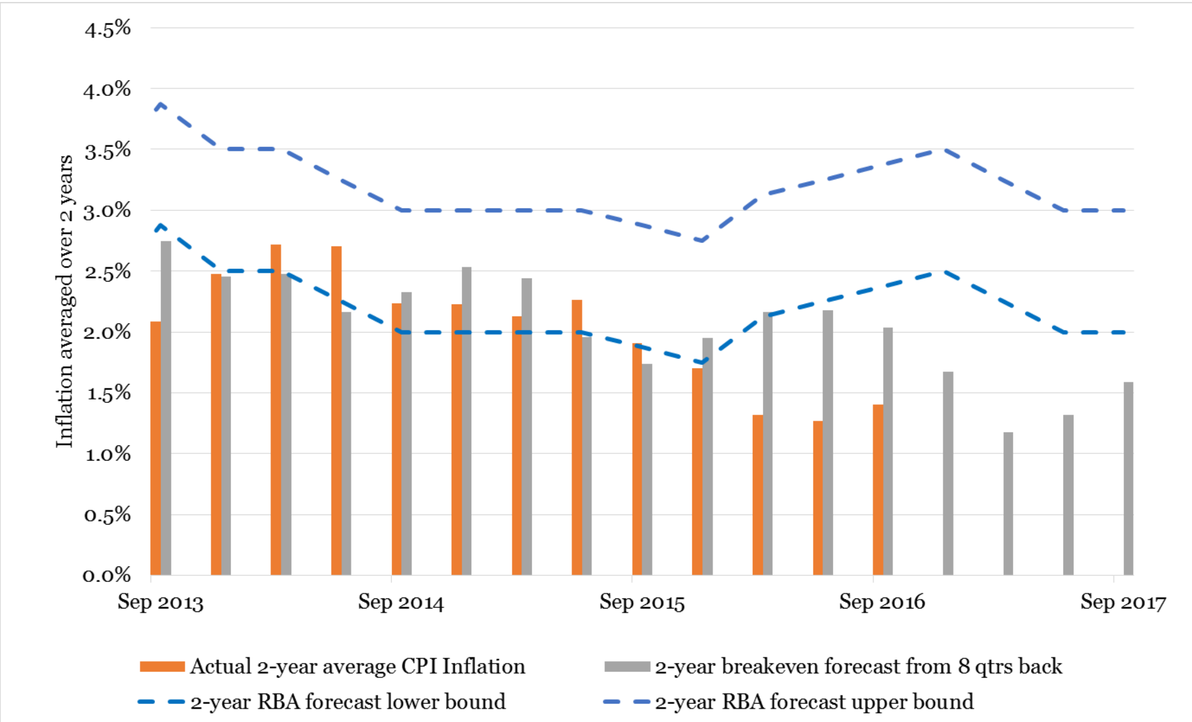
17 These are taken as the average break-even inflation rates (interpolated to one year) over the June quarter of 2015 (1 April 2015 to 30 June 2015).

- the midpoint of the RBA one year forecast range has underestimated actual inflation for the year ended September 2014 and for the year ended every subsequent quarter up to and including the most recent quarter (September 2016); but
- actual inflation has been below the lower bound of the RBA forecast range in more than two thirds of the time and in every year since the year ended December 2014 (i.e., the year beginning January 2013).

52. We note that this may be of particular interest to the QCA given that the QCA's has signalled in its recent DBCT decision that it proposes to adopt the midpoint of the RBA forecast range as its estimate of expected inflation. Had the QCA previously adopted this approach, the QCA inflation expectation estimate for the next year would have been below actual inflation at all times since September 2013. (Note that the "September 2014" in Figure 3 represents the year ended that date and the forecasts associated with that inflation outcome were made one year earlier(i.e., in September 2013).

53. The same analysis is repeated below but, this time, with a 2 year horizon for both inflation and inflation forecasts.

Figure 4: RBA and breakeven forecast versus actual inflation (2 year horizon)



Source: ABS, QCA, RBA, CEG analysis

54. When the horizon is increased to two years, it can be seen that actual inflation in every two year period ending September 2013 and later (i.e., beginning post September 2011 and later) has been below the midpoint of the RBA two year forecast. On this measure, actual inflation has been at or below the bottom end of the RBA forecast range more than half of that time.

55. Treating the midpoint of the RBA forecast and the break-even expectations as forecasts of actual inflation we can calculate the root mean square error of these forecasts over the period since September 2011 (i.e. the last 5 years).[18] The following table makes this comparison.

Table 3: Root mean square error – inflation forecasts since September 2011

Forecast	RMSE
1 year horizon	
Midpoint of RBA forecast range	1.102%
Breakeven inflation	0.542%
2 year horizon	
Midpoint of RBA forecast range	0.864%
Breakeven inflation	0.510%

Source: RBA, ABS, CEG analysis. Break even inflation is averaged over the corresponding quarter 1 (or 2) years prior to the average actual 1 (2) inflation ending in a given quarter. The midpoint of RBA inflation forecast is similarly taken from RBA Statement of Monetary Policy in the same quarter (interpolated where necessary as set out in footnote 16).

56. It can be seen that root mean square error has been materially lower for breakeven inflation over the most recent period.

4.3 Market based forecasts of inflation are well below 2.5% over 4 years

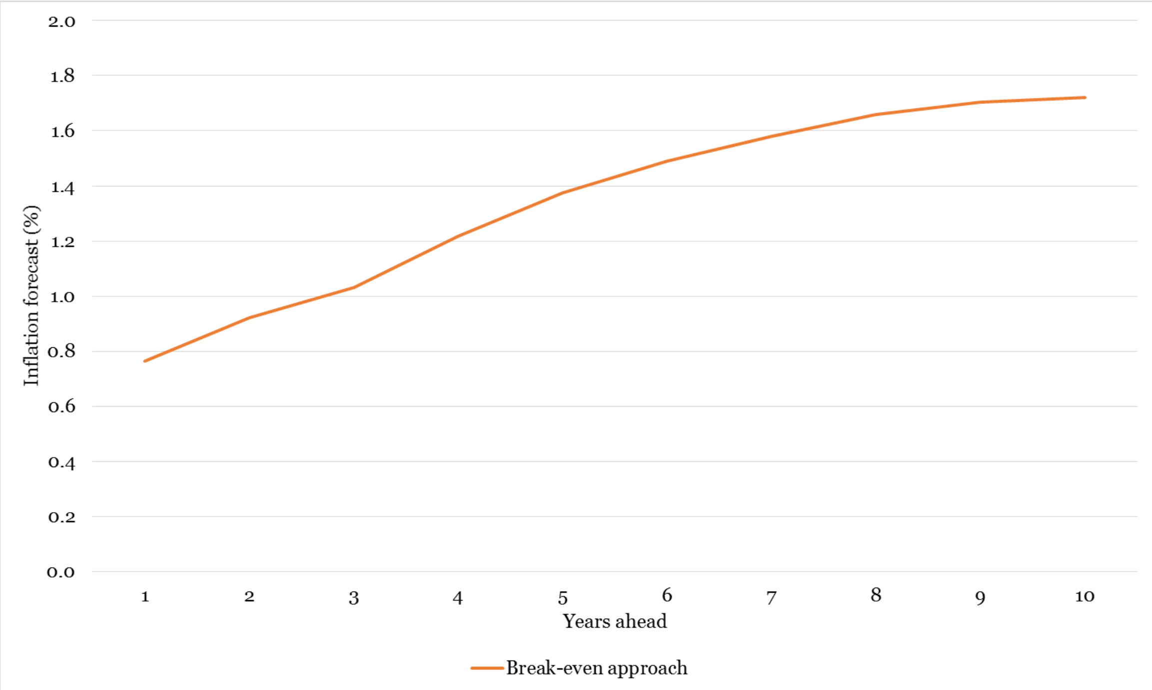
4.3.1 Breakeven inflation is our preferred estimate of inflation expectations

57. Adopting break-even inflation expectations is equivalent to adopting the indexed CGS yield as the best estimate of the real risk free rate. This is because the real risk free rate in the QCA's modelling is equal to the nominal risk free rate less the estimate of inflation expectations. Given that break-even inflation is simply the difference between nominal and CPI indexed CGS rates, deducting this from nominal CGS rates gives a real rate of return equal to the CPI-indexed CGS yield.

18 Using data since September 2011 implies that this is when the first forecasts are made and the first one/two year actual inflation figure is available in September 2012/13.

58. Over June 2016 the annualised 4-year indexed CGS yield was 0.40%. By contrast, the annualised 4 year nominal CGS yield was 1.62% (implying break-even inflation of 1.22% (applying the Fisher equation). Break-even inflation by maturity is summarised in the figure below.

Figure 5: Implied (breakeven) inflation term structure from nominal and indexed CGS yields



Source: RBA, CEG analysis

59. By contrast, if a 2.5% inflation forecast is adopted then this would imply that the real risk free rate was -0.86%. Not only is this estimate of the real risk free rate materially negative, implying that investors expect to pay in real terms for the privilege of lending to the Commonwealth Government, but it is 1.3% lower than the real (inflation protected) return that can be earned with certainty by lending to the Commonwealth Government. If this really was the case then a number of implications would have to follow.

60. First, the Commonwealth Government would, in our view irrationally, be simultaneously borrowing in a very expensive form (indexed CGS) and a much cheaper form (nominal CGS). With an expected interest cost of indexed CGS that is 2.9% (2.5% inflation plus a real cost of 0.4%) being considerably higher (1.3%) than the interest cost on nominal CGS (1.6%). In our view, were borrowing in indexed CGS really so relatively inefficient compared to borrowing in nominal CGS, the Commonwealth would cease to do it.

61. Second, and by a similar logic, lenders would have to be simultaneously lending to the Commonwealth with very different interest rates. The only reason for doing so would be if the higher yielding indexed CGS were higher risk in the eyes of investors. While it is possible that small differences, such as in liquidity, might have a small effect on relative perceived risk (in the single digits of bppa)[19] it is simply not credible that this could explain a 2.9% vs 1.6% expected return. We return to this issue in section 5.

62. Notably, indexed CGS were in short supply prior to 2009 due the Government's then policy of ceasing new issuance (in the face of a then low borrowing requirement). The general consensus, including by the RBA, was that this short supply this led to lower indexed CGS yield (such that break-even inflation *overestimated* actually expected inflation). For example, as noted in a report that I co-authored,[20] in its February 2006 Statement on Monetary policy (pages 48 to 49) the RBA states:

> *"…Other investors, such as hedge funds, are said to have recognised that this process is likely to continue for some time and have added to demand. These developments, against a background of a small, tightly-held domestic supply of indexed bonds, have seen their prices rise (yields fall) significantly. As a consequence, and despite having fallen a little in February, the current spread between yields on nominal and indexed government bonds overstates the market's expectations of inflation."*

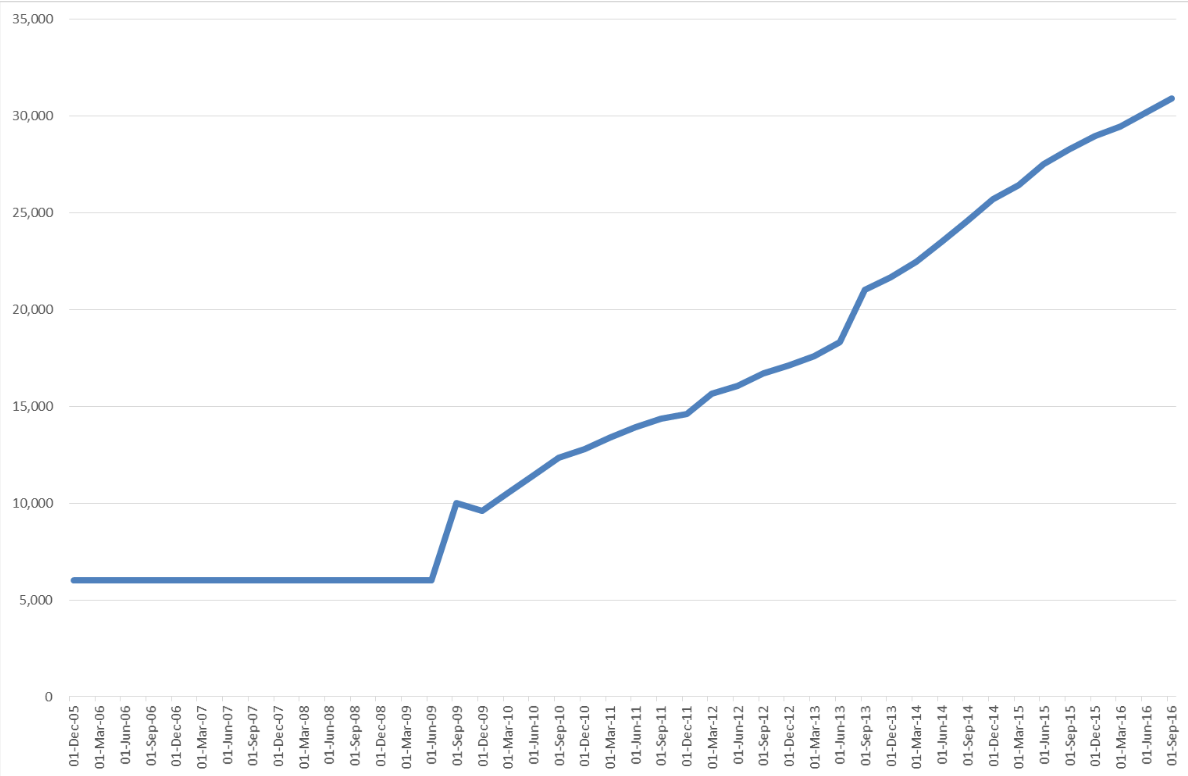
63. However, there has been a sixfold increase in indexed CGS on issue post the global financial crises (see such that any effect of shortage in supply on pricing can be assumed to have been largely ameliorated or eliminated.

---

19 Both the indexed and nominal CGS markets are highly liquid. Turnover in the nominal CGS market is around one million million (trillion) dollars and turnover in the indexed CGS markets is around 50 thousand million (50 billion) (AFMA, Australian Financial Markets Report, 2015). While the former is roughly 20 times larger than the latter both markets are extremely liquid. Beyond a certain point turnover becomes sufficiently large that increases in turnover do not provide any benefit in terms of ease of transaction. The indexed CGS market is sufficiently liquid that any benefit of additional liquidity from the nominal CGS market must be severely limited. In this context, we note that Grishchenko and Huang (2012) use an estimate of 5.6bppa for the relative liquidity premium in nominal and indexed US government bonds. Moreover, their core conclusion is that break-even rates will tend to (modestly) overstate inflation by around 8 to 13bp. That is, while differential liquidity risk implies a 5.6bp underestimate from breakeven inflation, other factors, such as the premium paid for guaranteed inflation protection, imply a 14bp to 19bp overestimate. See Olesya Grishchenko and Jing-zhi Huang, *Inflation Risk Premium: Evidence from the TIPS market*, 2012. An alternative explanation of relatively low nominal CGS yields is that nominal CGS have a more strongly negative beta than indexed CGS. However, this would be a further argument for adopting indexed CGS as the real risk free rate (because it would have a beta closer to zero).

20 NERA, Relative Bias in Indexed CGS Bonds as a Proxy for the CAPM Risk Free Rate March 2007.

Figure 6: Indexed CGS on issue



AOFM data, CEG analysis

64. In our view, expected inflation by investors and borrowers cannot deviate far from break-even inflation for precisely the above reasons. If expected inflation did vary materially from break-even inflation then some lenders would be suffering avoidable losses – losses that could be avoided by switching their investment between indexed and nominal CGS. This would cause those investors to do precisely that – causing break-even inflation to track expected inflation. Moreover, even if investors failed to do so, the Commonwealth Government would have a strong incentive to cease borrowing in one or the other of the instruments if expected inflation departed materially from break-even inflation. The academic literature on the potential magnitude of bias in break-even inflation estimates is discussed in section 5 below.

4.3.2 CPI swaps are upward biased estimates of expected inflation

65. Implied inflation measured from inflation swap markets is also a market measure of inflation. However, this measure will tend to be biased upwards to account for risk premiums and capital costs for the banks providing these products. This is because the inflation swap market is one-sided in the sense that there is more demand for the fixed leg of an inflation swap than the floating leg. That is, there are more investors wanting to hedge long-term inflation than who want to be exposed to long term inflation (by taking on floating rate exposure). The costs associated with a bank issuing inflation swaps are discussed by Campbell, Shiller, and Viceira (2009):

> *The figure shows that the two breakeven rates track each other very closely up to mid-September 2008, with the synthetic inflation breakeven rate being about 35-40 basis points larger than the cash breakeven inflation rate on average.*
>
> *This difference in breakeven rates is typical under normal market conditions. According to analysts, it reflects among other things the cost of manufacturing pure inflation protection in the US. Most market participants supplying inflation protection in the US inflation swap market are levered investors such as hedge funds and banks proprietary trading desks. These investors typically hedge their inflation swap positions by simultaneously taking long positions in TIPS and short positions in nominal Treasuries in the asset swap market. A buying position in an asset swap is functionally similar to a levered position in a bond. In an asset swap, one party pays the cash flows on a specific bond, and receives in exchange LIBOR plus a spread known as the asset swap spread. Typically this spread is negative and its absolute magnitude is larger for nominal Treasuries than for TIPS. Thus a levered investor paying inflation - i.e. selling inflation protection - in an inflation swap faces a positive financing cost derived from his long-short TIPS-nominal Treasury position.*[21]

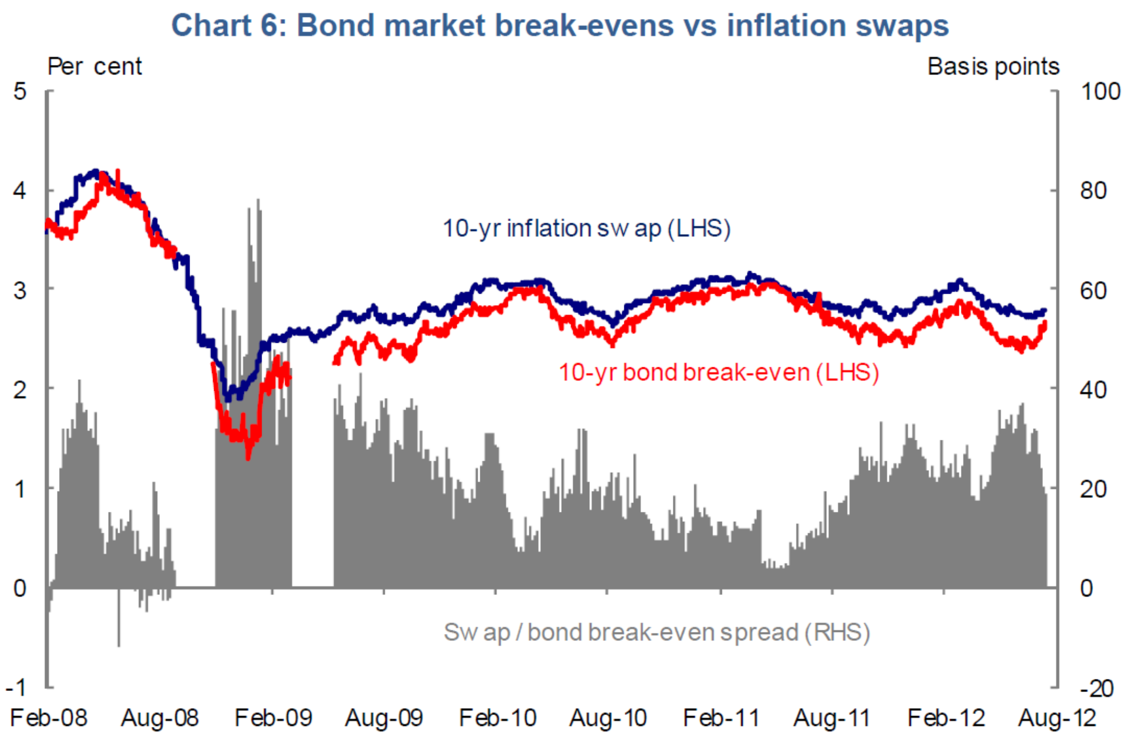
66. In this example the dealer is promising to pay the floating leg of the swap and then attempting to hedge the floating inflation risk that they have incurred. (If the swap market was evenly balanced the dealer would just take the floating side of another swap rather than buy indexed bonds.) Therefore, it is to be expected that inflation swap data will be above breakeven inflation because breakeven inflation defines the base rate of inflation that the dealer can use to hedge its exposure. Thus, the fixed rates offered by dealers must be above breakeven inflation if the dealer is to cover their costs and risks.

67. A Treasury Roundup paper[22] illustrates the persistently higher inflation in CPI swap markets than in breakeven markets as illustrated in the following figure from that paper.

21 Campbell, Shiller, and Viceira, Understanding Inflation-Indexed Bond Markets, NBER Working Paper No. 15014, (2009), p. 21.

22 W. Devlin and D. Patwardha, Measuring market inflation expectation, Economic Roundup, Issue 2, 2012.

Figure 7: Chart 6 from Treasury round up



Source: Bloomberg and Treasury.

68. Consistent with this, inflation swap rates remain well above breakeven inflation – in June 2016 the average 4-year inflation swap was 1.89% vs break-even inflation of 1.43%. It is notable that the period in early 2009 and late 2008 has the greatest difference between breakeven and inflation swap rates. This is an exceptional period where the opportunity cost of capital was very high for financial firms, suggesting that the costs of providing inflation swaps would be high.[23]

69. The bias in CPI Swap inflation is illustrated out by examining the future implied inflation rate that is consistent with the CPI swap term structure. For example, it is possible to back out the implied expected 5 year inflation rate in 5 years' time by comparing the 5 and 10 year spot CPI swap rates. If CPI swaps were an unbiased

23 W. Devlin and D. Patwardha, Measuring market inflation expectation, Economic Roundup, Issue 2, 2012.

23 However, it is also the case that this was a period of extremely high liquidity premiums which likely depressed breakeven inflation rates. (Noting that nominal CGS tend to be more liquid than indexed CGS and indexed CGS were in limited supply in that period and Government policy was not to issue new indexed CGS. However, as noted earlier, since the GFC the Commonwealth Government has significantly expanded issuance on indexed CGS and committed to maintaining new issuance). In such exceptional circumstances it is difficult to be sure what the best estimate of expected inflation was. However, in more normal periods outside of financial crisis circumstances the best estimate will tend to be break-even inflation given that the no-arbitrage condition means that the CPI swap market tends to reflect breakeven inflation rate plus a premium for the hedging costs of swap dealers.

estimate of inflation expectations then the difference between the 5 and 10 year CPI swap rates today (t=0) would provide an estimate of expected inflation over the period t=5 to t=10 years in the future.

70. The formula for estimating the implied x-year expected inflation in y-years is:

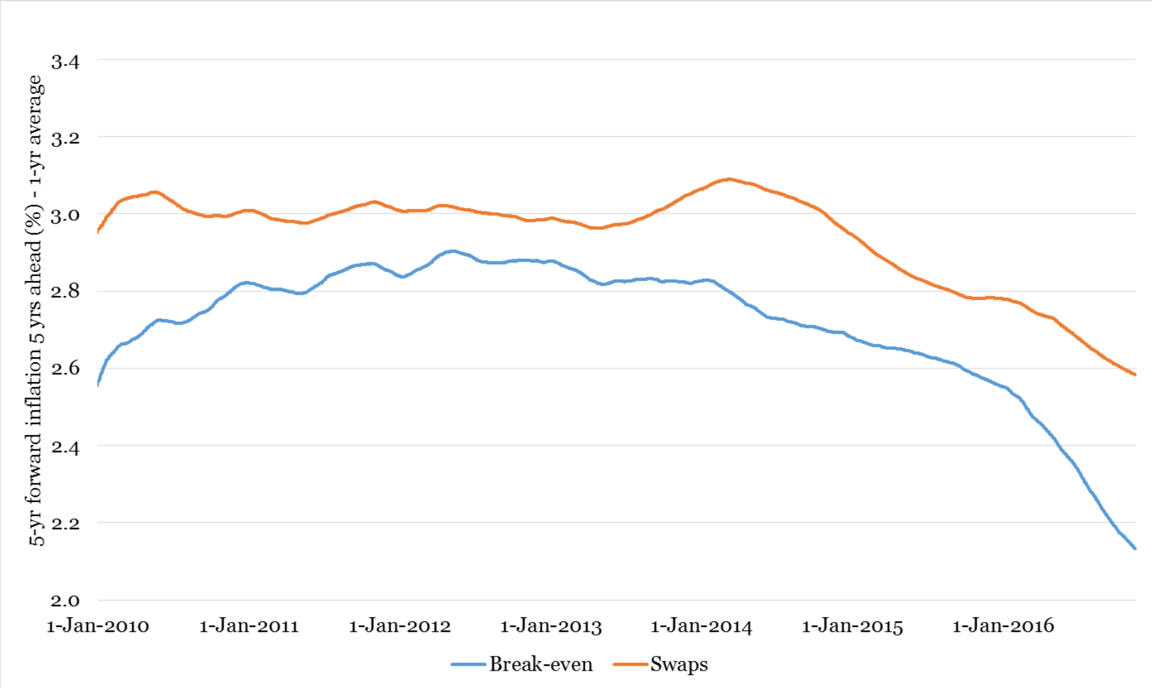
$$\sqrt[x]{\frac{\left(1+\pi_{x+y}\right)^{x+y}}{\left(1+\pi_{y}\right)^{y}}}-1$$

where π_x and π_y refer to the inflation rates in years x and y respectively. The above formula is a simple variation of the well-known Fisher equation that is commonly used to convert nominal interest rates into real interest rates.

71. Five-year inflation five years ahead is a useful measure because it abstracts from short run influences that might influence inflation expectations over the next five years. Rather, it focuses on long run average inflation expectations in the future (beyond the short run horizon). This is, therefore, a useful measure of inflation expectations to compare with the RBA's target range. If investors expect the RBA to deliver inflation within the target range in the long run and if the inflation measure is unbiased then implied 5-year inflation 5 years ahead should also fall within the target range.

72. When we perform these calculations we estimate the following time series for the implied 5-year inflation 5 years ahead from the CPI swap data.

Figure 8: Implied 5-year inflation 5 years ahead



Source: Bloomberg, RBA

73. When interpreting this chart it is useful to keep in mind that, as described in section 4.5, there is a fundamental asymmetry in how monetary policy can be used to target inflation outcomes. Central banks can always raise interest rates in order to lower inflation but they cannot, due to the existence of the zero lower bound, always lower interest rates. Therefore, if investors believes that, true to the RBA's policy, it will target inflation in the range 2.0% to 3.0% in the long run then:

- one should not expect to see 5 year forward 5 year inflation expectations above the top of the 2.0% to 3.0% range.
- in periods when there is little perceived risk of interest rates hitting the zero lower bound one should expect to see 5 year forward five year inflation expectations broadly towards the middle of the RBA range;
- one might expect to see inflation expectations below that range in periods when interest rates are low and approaching the zero lower bound (such that investors perceive a risk that the RBA will not be able to raise inflation via cutting interest rates).

74. With these considerations in mind. it can be seen that, prior to 2015, the 5-year inflation 5 years ahead as implied from the CPI swap curve is consistently at, or above, the top of the RBA's target range. Only in the recent extremely low inflation environment, with interest rates approaching the zero lower bound, has this measure of forward inflation expectations come in materially below 3.0% and, even so, it is

still above 2.5%. By contrast, 5 year forward 5 year inflation is typically much closer to the midpoint of the RBA target range in the pre-2016 period and has fallen below the midpoint of the RBA range in 2016 – as one would expect in a scenario where there is positive probability of monetary policy being constrained by the zero lower bound in the future.

75. Two possible implications can be drawn from these observation. First, it is possible that CPI swaps generate inflation estimates that are biased upwards. The second possibility is that the RBA's commitment to maintaining long-run inflation within the target band is not sufficiently credible. There does not appear to be any evidence of a loss of credibility on the RBA's part. In our view, it is more likely that CPI swaps tend to overestimate future inflation, especially at longer tenors.

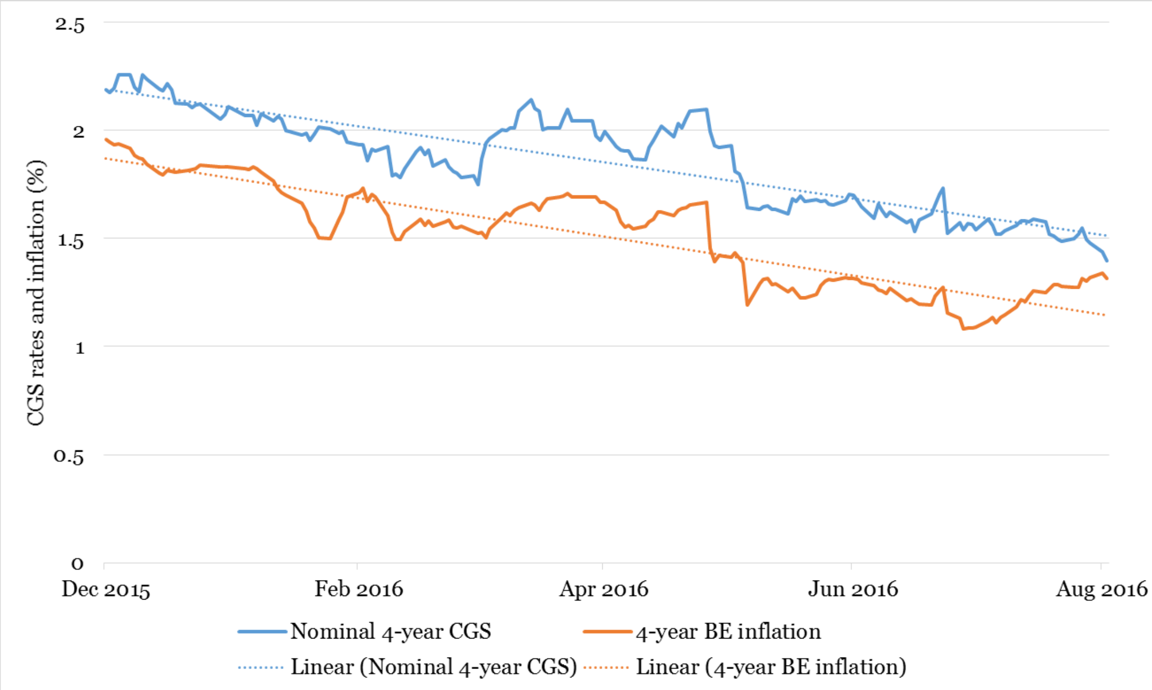
4.4 Forecast inflation of 2.5% implies strongly negative real risk free rate

76. There has been a material fall in nominal CGS returns in recent years. The fall in 4-year nominal CGS yields has been associated with a similar fall in break-even inflation estimates.[24] If one believes, as we do, that break-even inflation estimates are an accurate measure of expected inflation, then this implies that most of the fall in nominal CGS yields has been due to a fall in inflation expectations – rather than falls in real yields.[25] This would imply that the real yield on 4-year CGS has been relatively stable over this period.

[24] Inflation is the link between nominal and real returns on assets. Other things equal, a rise/fall in expected inflation implies a rise/fall in nominal yields as investors demand more/less compensation for the erosion of the purchasing power of money.

[25] This does not imply that changes in inflation expectations are the only cause of changes in nominal interest rates or that they are always the dominant cause. It may also be that real interest rates change (as they have dramatically since the GFC). However, over the period from December 2015 it is apparent that changes in inflation expectations have been the dominant driver of changes in nominal yields.

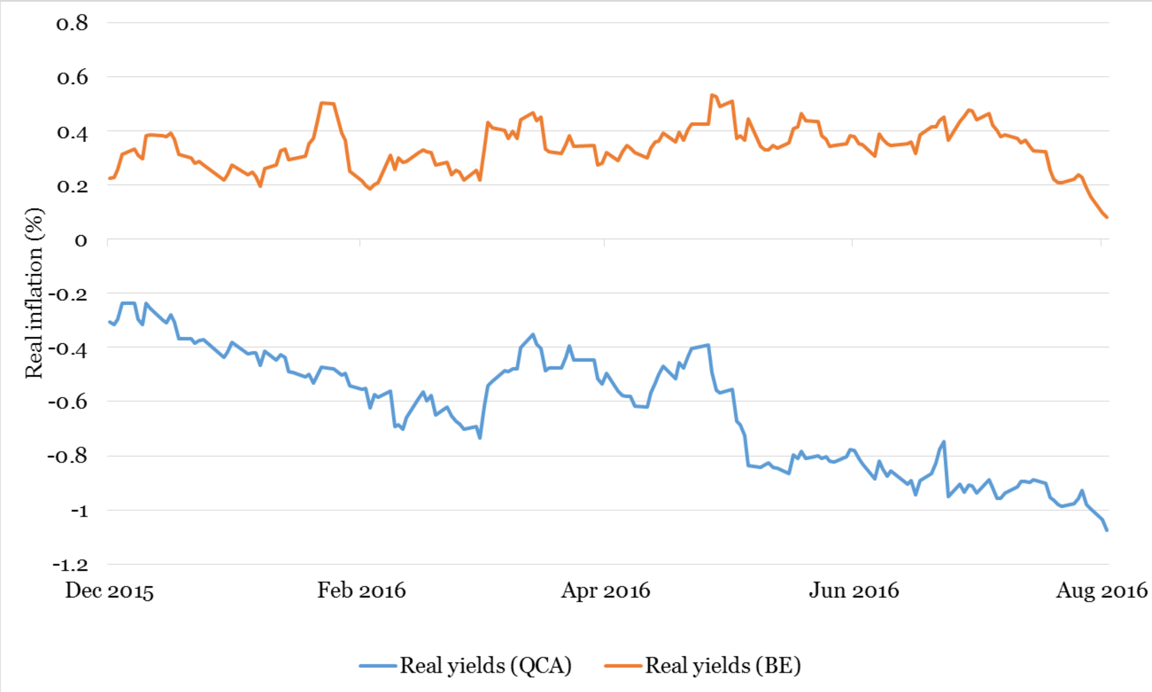
Figure 9: 4-year nominal CGS rates and 4-year breakeven inflation



Source: RBA, CEG analysis

77. By contrast, if, as is the case with the QCA's approach, inflation is assumed to have remained constant at 2.5% over the December 2015 to March 2016 period, this would imply that real CGS yields have fallen by the same magnitude as nominal CGS yields. Indeed, it would imply that real yields have been negative over the entire period from December 2015 onwards – implying that investors were happy to invest in nominal CGS in the expectation that the purchasing power of their investment in 4 years' time would be lower than it was at the time of their investment.

Figure 10: Real 4-year CGS yields using QCA vs break-even inflation expectations



Source: Bloomberg, RBA, CEG analysis.

78. It is not impossible for investors in nominal CGS to buy them in the expectation of receiving a negative real return (i.e. it is not impossible for investors to save in order to have lower future consumption options than if they did not save and instead consumed now). However, this is an anomalous result and one that would, in our view, require investigation and justification before being accepted. This is especially so in the context where the investor could have bought inflation indexed CGS at a guaranteed positive real return.

79. We believe that the anomaly (negative estimated real returns to risk free saving in nominal assets) is a result of the QCA's assumed inflation rate of 2.5% being inappropriate for the economic environment in the near future rather than a true anomaly in investor required returns.

80. This conclusion is supported by the fact that, over the course of 2016, daily changes in 4 year break-even inflation have reasonable explanatory power in explaining daily changes in nominal 4 year CGS yields (as one would expect of an accurate measure). From 31 December 2016 to 2 August 2016 regression of daily changes in CGS yields on daily changes in break-even inflation results in an estimated coefficient of 0.56, suggesting that, on average, one-unit changes in inflation expectations are reflected in changes in nominal yields by 0.56 units, as shown in Table 4 below. This coefficient is highly statistically significantly different to zero (significant at the 99% confidence level, with the standard errors of each parameter shown in parentheses).

Table 4: Regression of nominal CGS yields against inflation

	Constant	Slope
Change in 4 year nominal CGS vs change in 4 year breakeven inflation	-0.00 (0.00)	0.56 (0.08)

Source: Bloomberg, RBA, CEG analysis

4.5 The balance of inflation risks is to the downside when policy rates approach the "zero lower bound"

81. With the RBA cash rate at record low levels of 1.5%, the policy interest rates are dangerously close to the 'zero lower bound'. Monetary policy's most direct effect on the economy and, therefore, inflation is through lower interest rates. However, the RBA cannot set a cash rate below zero (or at least not materially below zero) because at such levels, businesses and households will prefer to hold cash – which delivers a zero rate of interest. Thus, the potential for monetary policy to stimulate economic activity diminishes as policy interest rates approach zero, thereby creating the potential for a low inflation trap, which monetary policy may be ineffective at extracting the economy from.

82. This is not a theoretical prospect but is the actual experience of many countries in recent history (consistent with the global low returns on government debt). At the time of writing, the United States, the Eurozone and Japan have all had policy interest rates at the zero lower bound for extended periods and have all suffered from below target inflation (and deflation in much of the Eurozone and in Japan). While the US, after five years at the zero lower bound, has recently raised policy interest rates, but this is not the case in the Eurozone or Japan. As noted by the IMF recently:

> *"... with the United States expecting to exit the zero lower bound this year, but with no such prospects for the euro area or Japan."*[26]

83. In the same document, the IMF pointedly refers to the risk that a number of other countries, including Australia, will fall into the same low inflation trap.[27]

> *However, in economies in which output gaps are currently negative (Australia, Japan, Korea, Thailand), policymakers may need to act to prevent a persistent decline in inflation expectations.*

84. In a low interest rate environment, the risks associated with inflation outcomes in the current environment are asymmetric – with greater risk of below target inflation than above target inflation. The essential point is that monetary policy is constrained in

[26] International Monetary Fund, "World Economic Outlook", April 2015, p. xiii.

[27] Ibid, p. 56.

how low interest rates can go in order to raise inflation (the 'zero lower bound') with no similar constraint on raising interest rates in order to reduce inflation. This creates the potential for a 'low inflation/interest rate trap' that has no symmetrical opposite. Following the RBA's May 2016 rate cut, the financial press reported that:

> *Australians must urgently confront the danger that the Reserve Bank of Australia is nearing the very limits of its powers and risks stumbling into the same zero-interest rate trap that has neutered European and Japanese central banks, say two high-profile economists. …*
>
> *"The evidence is that even aggressive monetary policy action doesn't seem to be driving up inflation, so far," Mr Yetsenga told* AFR Weekend.[28]

85. It is the potential to fall into such a trap that is, naturally, an important factor for bond investors when valuing nominal bond yields. Low nominal bond yields may still offer reasonable real returns in the event that an economy falls into such a low inflation 'trap'.

86. It is difficult to over-emphasise the importance of these considerations in the context of arriving at an estimate of expected inflation built into nominal bond yields. Even if investors attribute a low probability of Australia falling into a low inflation trap this will have a material impact on their expected inflation and, therefore, the compensation for inflation they require to be priced into nominal bond yields.

87. Bloomberg also reported that the May SoMP inflation forecasts are built on an assumption that the RBA will reduce interest rates in line with market expectations.[29] This implies that the RBA's inflation forecasts are based on the RBA reducing interest rates again at least once in the near term which would imply cash-rates fall to 1.5% or lower.[30]

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28 AFR Weekend, RBA joins race to the interest rate bottom, 6 May 2016 at 11.45pm. Available at this link: http://www.afr.com/news/economy/monetary-policy/rba-joins-race-to-the-interest-rate-bottom-20160506-gooblo#ixzz47xFNhJoE . See also Bloomberg, RBA's New Head Seen Facing Risk of Rate Cuts to 1% by JPMorgan May 9, 2016 (Available at http://www.bloomberg.com/news/articles/2016-05-08/rba-s-new-head-seen-facing-risk-of-rate-cuts-to-1-by-jpmorgan.) which reports:

> *The central bank's focus Friday on inflation expectations was notable given the phrase appeared 16 times in a document that rarely mentions it, said Joseph Capurso, a senior currency strategist in Sydney at Commonwealth Bank of Australia. "It is very hard to lift inflation expectations when they are low and Japan is a good example of this," he said*

29 RBA, May 2016 SoMP, p. 60. "*In preparing the domestic forecasts, a number of technical assumptions have been employed. The forecasts are conditioned on the assumption that the cash rate moves broadly in line with market pricing as at the time of writing.*"

30 Bloomberg, *Reserve Bank of Australia Cuts Core Inflation Forecast to 1-2%,* May 6, 2016. (Available at http://www.bloomberg.com/news/articles/2016-05-06/rba-cuts-core-inflation-forecast-unlikely-to-hit-target-in-16.)

> *"If after cutting once and factoring in another rate cut, as per market pricing, you are still only getting to the bottom half of your target band by the end of the forecast horizon, that's giving a clear signal you feel quite concerned about underlying inflation pressures and the outlook," said James McIntyre, head of economic research at Macquarie Group Ltd.*

88. Similar sentiments were expressed following the August 2016 RBA rate cut:

> *"With 50 basis points of easing since May 2016, we now believe the RBA has delivered the first increment of its likely policy response to lower than expected inflation outcomes," JPMorgan chief economist Sally Auld said.*
>
> *"**Our bias is to think that Australia risks a more protracted - period of low inflation**, and as such, we continue to forecast a further 50 basis points of easing from the RBA in the first half of 2017."*
>
> …
>
> *ANZ senior economist Kieran Davies agreed that the path of the currency and the extent of the pass-through of the cash rate to lending rates would affect the RBA's thinking on interest rates from here, although he expected rates to bottom at 1.5 per cent.*
>
> *"Our central case is unchanged and we see rates on hold at this point, albeit with a clear risk of further easing given we think that **the RBA's forecast outlook of persistently low inflation** is consistent with an easing bias," he said.*

89. This is not a peculiarly Australian predicament. In the IMF's October 2015 World Economic Outlook publication, the IMF has projected inflation to continue to be generally below central bank targets.[31]

> *In advanced economies, inflation is projected to rise in 2016 and thereafter, but to remain generally below central bank targets.*

90. This projection was revised down by the IMF in the April 2016 World Economic Outlook with the IMF stating: [32]

> *With the December 2015 declines in oil prices mostly expected to persist this year, consumer price inflation has been revised downward across almost all advanced economies and is projected to remain below central bank targets in 2016.*

---

[31] IMF, World Economic Outlook, October 2015, p. 16

[32] IMF, World Economic Outlook, April 2016, p. 21

91. Most recently, the IMF's October 2016 World Economic Outlook report, also found that inflation expectations have recently become more sensitive to negative inflationary shocks, particularly in countries where monetary policy is constrained by the zero interest rate lower bound, resulting in asymmetric inflation risks [emphasis added]:[33]

> *An analysis of the response of inflation expectations to positive and negative inflation shocks also points to constrained monetary policy as the underlying cause of a possible unanchoring of expectations. If constraints on monetary policy are the source of the increased sensitivity of inflation expectations, this sensitivity should be higher for negative shocks than for positive ones—a central bank constrained by the effective lower bound on policy rates can always respond to higher inflation by raising the policy interest rate, but has little scope to reduce it when inflation is declining.* ***This creates an unavoidable asymmetry in the ability of the monetary authority to handle downward and upward inflation shocks****.*
>
> *Indeed, most of the increased sensitivity for countries with constrained monetary policy seems to stem from negative inflation shocks (Figure 3.21).* ***After 2009, when policy rates approached their effective lower bounds, the response of medium-term inflation expectations to negative shocks exceeded the response to positive shocks, while the response to positive shocks was larger before 2009****. The estimates imply that if countries with policy rates currently at the effective lower bound faced inflation surprises comparable to those observed over the past two years, long-term inflation expectations would on average drift further down by about 0.15 percentage point. This is not particularly large in absolute terms but still three times larger than if their sensitivity had remained unchanged—while under well-anchored expectations, there should be no impact at all.*

92. In the same report, the IMF further warned about the downside risk of low inflation periods possibly leading to a deflationary spiral [emphasis added]:[34]

> ***In periods of low inflation, even small disinflationary shocks can lead to a fall in the level of prices of goods and services.*** *If economic agents expect prices to continue to fall, they can become less willing to spend—particularly on durable goods whose purchases can be postponed—since the ex-ante real interest rate increases and holding cash generates a positive real yield. Consumption and investment would be deferred farther into the future,* ***leading to a contraction in aggregate demand that***

[33] IMF, World Economic Outlook (WEO), October 2016, pp. 139-140.

[34] IMF, World Economic Outlook, October 2016, p. 124-125.

> ***would in turn exacerbate deflation pressures. A deflation cycle would then emerge, with weak demand and deflation*** *reinforcing* ***each other, and the economy could end up in a deflation trap.*** *In this context, the behavior of prices and output could become unstable if monetary policy is constrained by the effective lower bound on interest rates (see, for instance, Benhabib, Schmitt-Grohé, and Uribe 2002; Cochrane 2016).[7] These difficulties are aggravated if fiscal policy cannot be readily and efficiently deployed to stimulate demand.*

93. With the RBA cash rate at record low levels of 1.5%, the policy interest rates are dangerously close to the 'zero lower bound'. Monetary policy's most direct effect on the economy and, therefore, inflation is through setting interest rates. However, the RBA cannot set a cash rate below zero (or at least not materially below zero) because at such levels, businesses and households will prefer to hold cash – which delivers a zero rate of interest. The potential for monetary policy to stimulate economic activity diminishes as policy interest rates approach zero, thereby creating the potential for a low inflation trap, for which monetary policy may be ineffective at extracting the economy from.

94. Governor Brainard of the US Federal Reserve released the text of a speech made on 12 September 2016 which made precisely this point:[35]

> *The four features just discussed that define the new normal make it likely that we will continue to grapple with a fifth new reality for some time: the ability of monetary policy to respond to shocks is* ***asymmetric****. With policy rates near* ***the zero lower bound*** *and likely to return there more frequently even if the economy only experiences shocks similar in magnitude to those experienced pre-crisis, due to the low level of the neutral rate, there is an asymmetry in the policy tools available to respond to adverse developments. Conventional changes in the federal funds rate, our most tested and best understood tool,* ***cannot be used as readily to respond to downside shocks to aggregate demand as it can to upside shocks****.*
>
> …
>
> *Indeed, it is striking that despite active and creative monetary policies in both the euro area and Japan, inflation remains below target levels.* ***The experiences of these economies highlight the risk of becoming trapped in a low-growth, low-inflation, low-inflation-expectations environment*** *and suggest that policy should be oriented*

35 Governor Lael Brainard, At the Chicago Council on Global Affairs, Chicago, Illinois, September 12, 2016, *The "New Normal" and What It Means for Monetary Policy,* available at http://www.federalreserve.gov/newsevents/speech/brainard20160912a.htm

> *toward minimizing the risk of the U.S. economy slipping into such a situation.* [Emphasis added.]

4.5.1 Asymmetric risks cause expected and "likely" inflation to diverge

95. The difference between the probability weighted assessment of inflation outcomes compared to the most likely outcome can be illustrated by imagining a highly simplistic scenario where investors believe that there is:

    - a 2/3rd probability that Australia will escape the "low inflation trap". In this state of the world, 10 year inflation may be expected to fall within the RBA target range (centred on, say, 2.5%);
    - a close to 0% probability of inflation being above the RBA target range; but
    - a 1/3rd probability of being, at least for a time, stuck in a "low inflation trap". In this state of the world 10 year inflation might be expected to average only 1.0%.

96. Faced with these perceived probabilities an investor's (actuarially) expected inflation will be 2.0% (=0.67*2.5% + 0.33*1.0%). This is the additional return that they will demand to compensate them for the probability weighted expected level of inflation. This is notwithstanding the fact that the most likely outcome may well be that inflation is around 2.5%. The QCA methodology automatically takes lower nominal CGS yields resulting from asymmetrical inflation expectations into account and reflects this in a lower nominal risk free rate as observed in bond markets. However, the QCA does not automatically reflect the same lower probability weighted inflation expectations in its inflation forecast. This is in spite of the fact that this can also be directly observed from bond markets in the form of break-even inflation estimates.

97. The IMF April 2016 World Economic Outlook provides a cogent summary of the difference between central forecasts and probability weighted forecasts where the distribution of possible outcomes is tilted to the downside. This discussion, while focussed on global forecasts and risks is, as we shall show, effectively mirrored in the RBA February SoMP and explanatory statements by the RBA. Notable also is the fact that the IMF continues to express concern about low inflation outcomes in a world where low interest rate environments limit central banks' scope to raise inflation expectations.[36]

> *WEO [(World Economic Outlook)] growth forecasts form a **central, or modal, scenario**—growth rates that the IMF staff estimates to be the **most likely** in each year of the forecast horizon. The weakening in global growth in late 2015 and the escalation of threats to global economic activity*

[36] IMF, World Economic Outlook (WEO), April 2016, p. 24.

> *since the start of this year have led the staff to reduce the projected growth rates under the central scenario.*
>
> *Alongside these reduced central projections, the staff views* ***the likelihood of outcomes worse than those in the central scenario as having increased****. Put differently, not only is the central WEO scenario now less favorable and less likely;* ***in addition, the even weaker downside outcomes have become more likely****.*
>
> *… Over the near term, the main risks to the outlook revolve around (1) the threat of a disorderly pullback of capital flows and growing risks to financial stability in emerging market economies, (2)* ***the international ramifications of the economic transition in China****, …* ***Perceptions of limited policy space to respond to negative shocks, in both advanced and emerging market economies, are exacerbating concerns about these adverse scenarios.*** *In the euro area,* ***the persistence of low inflation*** *and its interaction with the debt overhang is also a growing concern. Beyond the immediate juncture, the danger of secular stagnation* ***and an entrenchment of excessively low inflation in advanced economies,*** *as well as of lower-than-anticipated potential growth worldwide, has become more tangible.*
>
> [Emphasis added.]

98. RBA Assistant Governor Christopher Kent, in a speech made on 6 April 2016, has used precisely the same example to illustrate the difference between central forecasts of what is most likely to occur and probability weighted consideration of all possible outcomes.[37]

> *One can also imagine scenarios that are unlikely to occur but may have far more substantial implications for the economic outlook if realised. These scenarios can be difficult to quantify but may be worth discussing nonetheless.* ***An example that we discussed in our most recent*** **Statement** ***which was the potential for financial instability in China to lead to a sharp slowdown in economic activity there and in the Asian region more broadly.***

99. The "Statement" referred to above is the February 2016 SoMP where there is a long discussion of downside risks to the forecasts associated with negative development in

37 Christopher Kent, Assistant Governor (Economic), Address to the Economic Society of Australia (Hobart), University of Tasmania, Hobart – 6 April 2016. See also section 5.3 of RBA Research Discussion Paper, Estimates of Uncertainty around the RBA's Forecasts, Peter Tulip and Stephanie Wallace, 2012-07. This article is referenced by Assistant Governor Kent in his 6 April 2016 speech.

China which mirrors the IMF's own discussion.[38] This is repeated in the May SoMP in which the RBA states under the heading of "uncertainties":[39]

> *The forecasts are based on a range of assumptions about the evolution of some variables, such as the exchange rate, and judgements about how developments in one part of the economy will affect others. One way of demonstrating the uncertainty surrounding the central forecasts is to present confidence intervals based on historical forecast errors (Graph 6.3, Graph 6.4 and Graph 6.5).*
>
> ***It is also worth considering the consequences that different assumptions and judgements might have on the forecasts and the possibility of events occurring that are not part of the central forecast.*** *One of the key sources of uncertainty continues to be the outlook for growth in China and the implications of high levels of debt there.*

100. Put simply, the midpoint of the RBA's forecast range cannot be assumed to be the probability weighted mean inflation expectation that is perceived by investors (and which will be reflected in nominal CGS yields).[40] The best way to ensure that this is the case is to use inflation forecasts derived from financial market prices which automatically reflect investors' mean actuarial expectations across all possible outcomes.

101. In this context, break-even inflation has a critical advantage over simple analyst forecasts of the most likely inflation outcomes. This is because, in the presence of asymmetry, the most likely inflation outcome (which is, as is discussed below, typically what published forecasts are predicting) will not equal the mean expected

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38 See RBA, Statement On Monetary Policy, February 2016 pp. 63-64.

39 RBA, Statement On Monetary Policy, May 2016 p. 63.

40 In this context it is also relevant to note that the biggest challenge the RBA faces is avoiding a low inflation trap. However, the greatest risk in this regard is the self-fulfilling prophecy of low inflation expectations. In the words of Nobel Prize winning economist Paul Krugman, "…if nobody believes that inflation will rise, it won't" (Paul Krugman, Rethinking Japan, 20/10/2015, New York Times, The Opinion Pages (online, available at: http://krugman.blogs.nytimes.com/2015/10/20/rethinking-japan/?_r=0)). If the RBA does forecast inflation to continue to be below its target range then this very act may make its task of returning inflation expectations, and ultimately actual inflation, back to within its target range more difficult.* One way the RBA could deal with this issue is to adopt a very wide range for its forecasts (which it has done). Similarly, the RBA can ameliorate this tension by discursively dealing with downside risks to its forecast range rather than embedding these in its central estimate (which it is also apparent that it has done – see discussion at paragraphs 98 to 100 above).

* Consistent with this, break-even inflation forecasts fell materially following the release of the RBA's downgraded inflation forecast in its 5 May 2016 SoMP. In that publication the midpoint of the RBA forecast range for inflation was 2.0%; at the bottom of, but still within, the target range of 2.0% to 3.0%. This would appear to have shifted market expectations of inflation - with the 10 year break-even rate falling from 1.84% on 4 May to 1.64% on 6 May (noting that in the 5 days after the ABS release of the March quarter CPI deflation (i.e., 28 April to 4 May) the 10 year break-even rate had traded at between 1.80% and 1.84%).

inflation outcomes (which is what prices in financial markets reflect). That is, break-even inflation reflects the market's probability weighted assessment of all possible inflation outcomes – not just the most likely outcome.

102. In its World Economic Outlook October 2016 report, the IMF also observes that the break-even inflation estimate reflects the expected inflation rate [emphasis added]:[41]

> *Market-based measures of inflation expectations can be extracted from inflation compensation embedded in long-maturity inflation-linked and nominal bonds or from inflation-linked swaps.30* ***The break-even inflation rate measured by the yield spread between conventional bonds and comparable inflation-linked bonds provides an estimate of the level of expected inflation at which a (risk-neutral) investor would be indifferent between holding either type of bond.*** *It is widely used as a timely measure of investors' inflation expectations, although it is effectively based on the pricing of the marginal investor and includes a liquidity premium and an inflation risk premium.*
>
> *This contrasts with other sources of inflation forecasts, such as surveys of consumers, unionists, economists and government agencies. Most survey forecasts report the median forecast instead of the probability weighted average forecast, and* ***even if the mean of a survey forecast were to be reported, it would not have the same statistical interpretation as market-based estimates.*** *This is because the distribution of survey estimates represents variation in beliefs about future inflation, and do not reflect the probability of a particular forecast. For example, if all survey respondents predicted the same inflation forecast, this can only be interpreted to mean that the respondents were in agreement, and does not suggest that there was zero uncertainty in the forecast estimate.*

103. The IMF made the same observation in its World Economic Outlook for October 2016 [emphasis added]:[42]

> *Survey-based and market-based measures of inflation expectations measure somewhat different concepts and have different statistical properties. Surveys collect one measure of central tendency—the mean, median, or mode—of the believed distribution of individual professional*

41 IMF, World Economic Outlook, October 2016, p. 135. We note that empirical literature suggests that liquidity premium and inflation risk premium have an offsetting effect on each other, with the net effect being that break-even inflation is a reasonable approximation of the probability weighted inflation forecast. We discuss the empirical literature further in section 6.

42 IMF, World Economic Outlook, October 2016, p. 134.

forecasters or households, and different individuals may report a different measure of their believed distribution.

5 Quantification of potential sources of bias in break-even inflation

104. This section provides a review of literature on three issues related to break-even inflation forecasts (these being the major potential sources of bias identified in the literature):

- Liquidity premium;
- Inflation risk premium; and
- Convexity bias.

105. The overwhelming conclusion of this literature survey is that the above potential sources of bias are small and more likely to result in an over-estimate of expected inflation than an underestimate. Certainly, it is not plausible that these account for the current 128bp difference between 4-year break-even inflation (1.22%) and the QCA's estimate of expected inflation (2.5%).

106. The literature covered in this section is summarised in Table 5.

Table 5: Summary of literature on bias in break-even inflation

Paper	Actual findings	CEG Comments
Tulip and Wallace (2012)	No significant difference between RBA and private sector forecasts	RBA only provides forecast intervals up to 2 years ahead. These are currently lower than the QCA's 2.5% estimate.
D'Amico, Kim and Wei (2010)	Excluding the GFC, break-even inflation has mostly been similar to, or above, inflation expectations	The paper's conclusion suggests that if any adjustment to break-even inflation is needed, it would be a downward adjustment. Given that break-even inflation is already lower than the QCA's forecasts, this suggests that the former is a more accurate estimate.
Scholtes (2002)	The possibility of convexity bias was stated but not estimated.	Ang, Bekaert and Wei (2008) find that convexity bias amounts to less than 1 bp, even at longer maturities
Grishchenko and Huang (2012)	Over 2000-2008, inflation risk premium, including liquidity adjustment, ranges from -16 to 10. Over 2004-2008, the range is 14 to 19.	The risk premium in the longer sample has a range with a midpoint close to zero, while the shorter more recent sample has a range that suggests break-even inflation overestimates expected inflation. The earlier period in the longer sample reflects a period when TIPS was still new, and may not reflect current conditions. The authors also explicitly state that they consider the second set of estimates (14-19) as more reasonable. The paper uses its own inflation forecast and survey inflation as a proxy for inflation expectation.
Shen and Corning (2001)	Breakeven inflation calculated from TIPS is lower than estimates from surveys by 87 basis points. The difference is attributed to be inflation risk and liquidity premium. Given, TIPS was new at the time of the study, the paper states that the liquidity premium is likely to decline, allowing closer approximations of market inflation expectations.	Shen and Corning (2001) assume that survey inflation is an accurate predicator of market inflation expectation and uses it to back out liquidity premium. The difference between breakeven inflation and survey inflation is assumed to be inflation risk and liquidity premium. Of course, for the reasons discussed in section 4 and, in particular, section 4.5, survey inflation is a 'most likely' estimate and cannot be assumed to reflect actuarial inflation expectations. The difference between the two estimates may simply reflect the fact that they aren't measuring the same measure of expectation.
Paper	**Actual findings**	**CEG Comments**
Ang, Bekaert and Wei (2008)	Convexity bias amount to less than one basis point, even for longer maturities. Inflation risk premium is 114 bp on average over the period studied.	If anything, this paper suggests breakeven inflation overestimates expected inflation.

Pflueger and Viceira (2015)	TIPS liquidity premiums fell below 50 bp from 2012 onwards. Liquidity premium is lower in the UK than the US.	The study was carried out by regressing breakeven inflation on variables related to liquidity. However, the sample includes periods when TIPS was first introduced, which is likely to bias the results. The results also suggest that there may be instability in their estimates.
Lehman Brothers (2006)	For the 3-year forward rate, convexity bias is 4 bp, inflation risk premium is 35 bp, liquidity premium is 15 bp.	The net bias is an overestimation of expected inflation by 16 bp, even after including liquidity premium in indexed bonds.
Banco Central do Brasil (2014)	Liquidity premium for Brazilian indexed bonds is not statistically different from zero. Inflation risk premium is positive for all bonds majority of the time.	The net effect of liquidity premium and inflation risk premium is that break-even inflation is more likely to over-estimate expected inflation.
Coroneo (2016)	Using a dynamic factor model, the liquidity premium has been close to zero since 2005, aside from the GFC. During the quantitative easing period, "liquidity premium" was negative.	This implies that the "liquidity premium" results in break_even inflation overestimating expected inflation since the GFC. This highlights that care must be taken when interpreting references to the term 'liquidity premium' in the literature. Many authors simply use this term as the 'residual' for their model – (i.e., the unexplained element is called a 'liquidity premium'). In this context we note that Corneo (2016) does not take inflation risk premium into account separately which suggests that the estimated "liquidity premium" may be the net effect across all factors (inflation risk premium and liquidity premium etc). This still implies that the breakeven inflation has either matched closely with inflation expectations or lain above inflation expectations during the quantitative easing period.
Celasun, Mihet and Ratnovski (2012)	The liquidity premium is approximately 0.5 for 10-year TIPS.	Celasun, Mihet and Ratnovski (2012) use the same approach as Gürkaynak, Sack and Wright (2010) to decompose breakeven inflation. Their estimates should be interpreted as estimates of liquidity premium if, and only if survey inflation is assume to reflect actuarially expected inflation. For the reasons discussed in section 4 and, in particular, section 4.5, survey inflation is a 'most likely' estimate and cannot be assumed to reflect actuarial inflation expectations. In any event, the estimated liquidity premium of 0.5 is offset by inflation risk premium, which Ang, Bekaert and Wei (2008) estimate to also be 0.5.

Gürkaynak, Sack and Wright (2010)	Liquidity premium was elevated in 2001 when the Treasury Advisory Committee recommended the end of the TIPS program. The premium also spiked during the GFC, but eventually settled by 2014.	Gürkaynak, Sack and Wright (2010) relies on trading volume and inflation expectation to be proxies for liquidity premium and inflation expectation respectively in order to calculate inflation compensation. Given that survey inflation is a 'most likely' estimate and cannot be assumed to reflect actuarial inflation expectations the estimates will 'pick up' divergences between actuarially expected and most likely inflation (as well as other sources of bias in survey data) Their findings support those found by Shen and Corning (2001), which stated that the high liquidity premium in their study mostly arose because TIPS was still new at the time of their study, and that the premium would likely decline. As with our comments for Shen and Corning (2001), we note that a high liquidity premium during the GFC cannot be generalised as applying broadly to "periods of uncertainty".
Abrahams, Adrian, Crump and Moench (2015)	Breakeven inflation decomposed into liquidity premium, inflation risk premium, and expected inflation. Breakeven inflation has been above the calculated inflation and survey inflation for majority of the period since sometime after 2002 other than during the GFC.	Result by Abrahams, Adrian, Crump and Moench (2015) goes against the claim that breakeven inflation underestimates inflation expectations due to liquidity premium. Abrahams, Adrian, Crump and Moench (2015) supports findings in other papers that show liquidity premium is less than inflation risk premium over majority of the past decade except during the GFC.
Christensen, Lopez Rudebusch (2010)	For majority of the period after 2014, the inflation risk premium is above the liquidity premium. After the Lehman Brothers bankruptcy, expected inflation fell sharply while survey inflation was unchanged. Inflation risk premium also fell in that period.	The fact that inflation risk premium exceeds liquidity premium for majority of the period after 2014 suggests that breakeven inflation has been overestimates the level of inflation expectations in the past two years. This pattern is also observed in the European TIPs market where Garcia and Werner (2010) finds that the liquidity premium is exceeded by the inflation risk premium. This result corresponds to Shen and Corning's (2001) claim that the liquidity premium in U.S. TIPS will fall to a level seen in European market as U.S. TIPS mature.
Garcia and Werner (2010)	Breakeven inflation is greater than inflation expectation for the European market. Survey inflation was more volatile than the inflation expectations estimated by the model.	The study is also reliant on survey inflation as a proxy for inflation expectation. It calls the difference between breakeven inflation and survey inflation, inflation risk premium. Therefore the inflation risk premium estimated in this study takes into account liquidity premiums. The fact the estimated 'inflation risk' is positive suggests that breakeven inflation overestimates the level of inflation expectations, and thus represent conservative estimates.

Finlay and Wende (2012)	The net bias in 5- and 10-year breakeven estimates caused by inflation risk premium and liquidity premium has historically fluctuated around zero, but was usually positive.	A positive net bias implies that the true level of inflation expectations is likely to be lower than the breakeven estimates. The study was carried out on a sample that that runs from July 1992 to December 2010. Since the quantity of indexed CGS on issue has increased greatly since then, it is likely that any net bias would have., if anything, become even more positive, causing the overestimation to be even larger in magnitude.

*Source: Articles and CEG analysis; *The RBA's does not derive its forecast interval in a manner that sets its point estimate as the midpoint of the interval. Instead, the interval is obtained by taking the closest 25 bp unit and then placing the interval at ±50 bp around it.*

5.1 Liquidity premium

5.1.1 The term 'liquidity premium' does not mean the same thing in all studies

107. Before proceeding with a discussion of each individual paper it is useful to make a few observations about the existence or otherwise of a 'liquidity premium'. The first point to note is that in much of the literature the reported 'liquidity premium' is, in reality, an error term in the analysis. It is the term given to the amount of the difference between nominal and indexed government bonds that is not explained by the other factors in the researchers' models. For example, D'Amico, Kim and Wei (2016) estimate a TIPS[43] liquidity premium that has historically been negative (i.e., associated with breakeven inflation underestimating expected inflation) but has recently been positive (i.e., associated with breakeven inflation overestimating expected inflation). This is despite the fact that TIPS are generally acknowledged to have been less liquid (or, at least, not more liquid) than nominal US Treasuries over the entire period.

108. There is no reason to believe that investors pay more for index linked Treasuries bonds on the grounds that these bonds are more liquid than nominal Treasuries bonds. Therefore, there is no reason to find a 'negative liquidity premium' if the 'liquidity premium' is truly a measure of the value of relative liquidity of the instruments. However, if the liquidity premium is simply the name given to an error term (residual) in the researcher's model then this, naturally, can be negative. Given that many of the papers surveyed use surveys of inflation expectations as the benchmark against which break-even inflation is measured what is really being measured are potential explanations for why break-even inflation is different to the average of survey information.

43 US Treasury Inflation Protected Securities.

5.1.2 Bias identified in the studies is likely bias in surveys as a measure of actuarially expected inflation

109. In section 4.5 we explain that surveys of inflation forecasts are measures of 'likely' inflation while market based measures reflect actuarially expected inflation. We also explain that the expected inflation that must be used in a regulatory revenue model (and which is built into observed bond yields) is actuarially expected inflation. Actuarially expected and most likely inflation can, and do, diverge. Therefore, when a research paper identifies a 'bias' in a market based measure of inflation expectations (such as break-even inflation) relative to survey inflation expectations this is not necessarily (or even likely) a measure of bias relative to the inflation expectation that the QCA should be targeting. Rather, it is just as likely a measure of bias in survey inflation relative to the measure that the QCA should be targeting.

5.1.3 Potential for 'true' liquidity premium is small

110. The theoretical reason for the existence of a liquidity premium is that investors will have a preference for assets that are more liquid because those assets allow them to optimise their portfolios at lowest cost. Specifically, a 'liquid' market is one where an individual investor can expect to be able to buy or sell into the market without their personal transaction having a significant impact on the price paid/received in the transaction.

111. In reality, both indexed and nominal CGS are highly liquid. This means that the value investors place on any differential in liquidity is likely to be trivial. Both the nominal and indexed CGS markets are highly liquid with turnover of around $1,000bn and $50bn respectively. While the turnover in nominal bonds is around 20 times larger, both are very large in absolute magnitude.

112. Moreover, liquidity is a function of the ability of an investor to divest their holding without moving the market and, given that investors' holdings on nominal CGS tend to be larger, the absolute turnover must be adjusted for the average holding of these bonds in an investor's portfolio. The standard way to do so is to divide turnover rates by total outstanding stock in order to provide the 'turnover ratio'. The Australian Financial Markets Association produces this metric for nominal CGS and it has fallen from 5.2 in 2007/08 to 3.2 in 2014/15.[44] A similar metric for indexed CGS was around 1.2 in 2007/08 and 2.0 in 2014/15.[45] On this metric, liquidity in nominal CGS is only modestly higher than for indexed CGS.

44 AFMA, 2008 and 2015 Australian Financial Markets Report.

45 AFMA does not explicitly present this ratio but it can be calculated as total turnover in index linked CGS (e.g., $51bn in 2014-15) divided by total bonds outstanding available from AOFM ($25.5bn average of beginning and end of year outstanding in 2014-15).

113. Moreover, it is important to note that investors valuation of additional liquidity falls to zero as soon as they are confident that their own trading will not move the market against themselves. That is, if I am already confident that I will not move the CGS market against myself when trading, then I receive no advantage, and will not value CGS any higher, if the turnover in the market doubles or quadruples. Both nominal and indexed CGS are a homogenous product that are very easy to value. This means that there are not the same 'inside information issues' that arise with trading corporate equity and debt. This fact, when combined with the very large in size (and turnover relative to size) means that it is therefore reasonable to assume that the potential value of incremental increases in turnover/liquidity ratio when moving from indexed CGS to nominal CGS are very small. That is not to say that there might be a more material liquidity premium when moving from CGS to less liquid assets (such as corporate debt/equity or real-estate). However, there is no reason to believe that a material liquidity premium exists when moving from indexed to nominal CGS – at least not in normal market circumstances.

114. In this regard, and as previously noted in section 4.3.1, in 2007/08 it is accepted that breakeven inflation was *overestimating* expected inflation. This is despite liquidity in the indexed CGS market being much lower then than it is today. That is, when indexed CGS were relatively much less liquid than they are today there was no evidence that a differential liquidity premium was causing break-even inflation to under-estimate expected inflation – in fact the opposite was accepted as being the case.

5.2 Literature review

5.2.1 Tulip and Wallace (2012)[46]

115. Tulip and Wallace (2012) assesses the accuracy of the RBA's inflation forecasts. It concludes that the RBA's *"1 year forecasts of inflation have substantial explanatory power and in the past RBA forecasts have been marginally more accurate than private sector forecasts."*

116. First, we note that the QCA's forecast methodology previously applied to Aurizon[47] assumes that inflation will be at the midpoint of the RBA's target band in all future

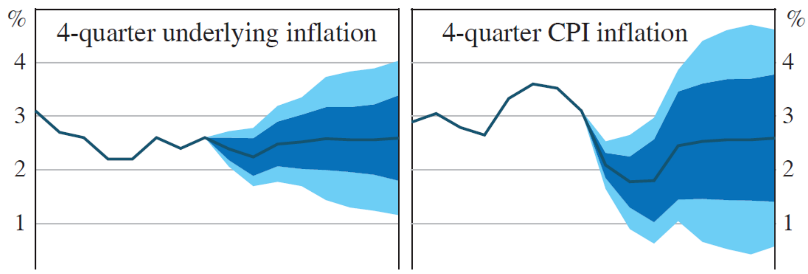
46 Tulip, P., Wallace, S., (2012) "Estimates of uncertainty around the RBA's forecasts", RBA Research Discussion Paper – November 2012, RDP2012-07.

47 As set out in footnote 1, we note that, immediately prior to finalising this report the QCA signalled, in its final decision for DBCT, its intention to change its inflation forecast methodology to rely on RBA inflation forecasts where they are available and to assume 2.5% beyond that forecast horizon. We have not had time to amend our report to address this change in policy. However, our key conclusions are not affected by this change in policy. We still regard break-even inflation as a superior method for arriving at an estimate of inflation expectations over the relevant horizon. Amongst the other reasons provided in this report this is because: a) the RBA inflation forecast band is a measure of 'most likely' inflation and not

years, and does not explicitly use the RBA's short-term forecasts.[48] We note that the point of interest to us is the relative accuracy of break-even inflation expectations versus QCA's future-year estimates of inflation – an issue not addressed by Tulip and Wallace (at the 10 year horizon or any other horizon). We have addressed this issue in section 4 of this report and find break-even inflation is superior, as evidenced by the comparison showed in Figure 3.

117. In any event, Tulip and Wallace (2012) report wide confidence intervals for the RBA forecasts as illustrated in Figure 11. For underlying inflation, actual inflation lies outside a 100bp range 30% of the time. For CPI inflation the actual inflation will lie outside a 200bp range 30% of the time.

Figure 11: 70% and 90% Confidence Interval for RBA forecasts



Source: Tulip and Wallace (2012)

118. Furthermore, comparing the accuracy of RBA forecasts relative to forecasts by the private sector, Tulip and Wallace (2012) states *"the differences are small and not statistically significant"*. That is, the RBA is forecasts are not found to be statistically significantly different to other forecasts.

5.2.2 D'Amico, Kim and Wei (2010)[49]

119. D'Amico, Kim and Wei (2010) assess the inflation forecasts obtained from a breakeven approach and argue that, "*breakeven estimates require adjustment to*

'expected' inflation and there is a material difference between these when the risks to inflation are asymmetric as they are at the time of writing; b) the midpoint of that band is not necessarily even the RBA's estimate of the most likely inflation outcome; and c) the assumption of 2.5% inflation beyond the RBA forecast range is not in any manner an RBA forecast and is not necessarily consistent with inflation expectations – especially in current market circumstances as detailed in this report.

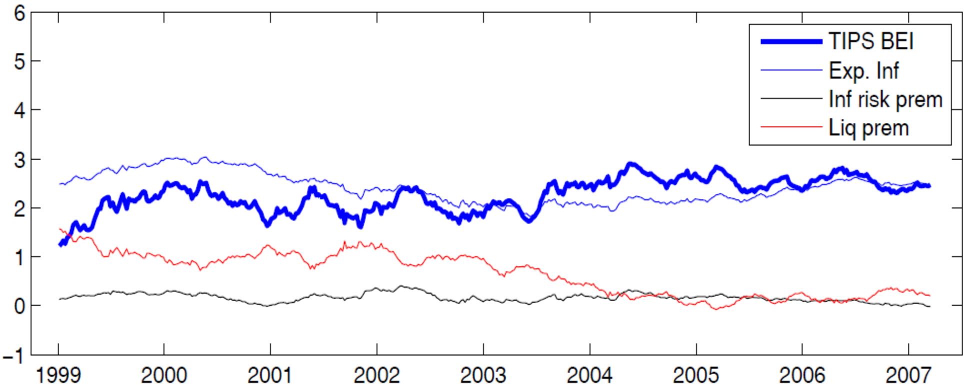
48 The RBA provides forecast intervals up to two years ahead in its quarterly *Statement on Monetary Policy*.

49 D'Amico, S., Kim, D.H., Wei, M., (2010) 'Tips from TIPS: the informational content of Treasury inflation-protected security prices', Federal Reserve Board, 2010-19 (Draft Version December 29, 2009)

account for several different types of bias." In particular, they investigate inflation risk premium, the index lag effect, and the liquidity premium.

120. The result of D'Amico, Kim and Wei (2010) is summarised in Figure 12. This clearly shows break-even inflation at, *or above*, expected inflation from around 2002.

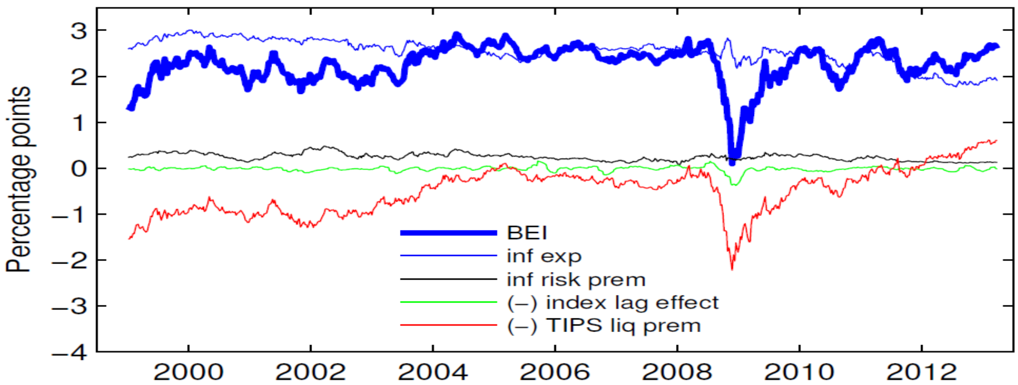
Figure 12: Decomposing 10-year TIPS Breakeven Inflation D'Amico, Kim and Wei (2010)



Source: D'Amico, Kim and Wei (2010)

121. Figure 13 shows an update of the same estimates in a subsequent 2014 paper by the same authors (this time including the index lag effect). The thick blue line is breakeven inflation, the thin blue line is the expected inflation, the black line is the inflation risk premium, the green line is the index lag effect and the red line is the liquidity premium. Once more, since the early 2000s, but with the exception of the GFC, break-even inflation has been very similar to inflation expectations and, most recently, above. The authors estimate that in 2013, there is a negative liquidity premium, indicating a preference for indexed bonds compared to nominal bonds.

Figure 13: Decomposing 10-year TIPS Breakeven Inflation D'Amico, Kim and Wei (2014)



Source: D'Amico, Kim and Wei (2014)[50]

5.2.3 Scholtes (2002)[51]

122. Scholtes (2002) investigates the effect of convexity bias on break-even inflation forecasts, and finds that "the differences in bond convexity bias could bias long-term breakeven inflation rates below inflation expectations." While Scholtes (2002) does not attempt to estimate the impact of the convexity bias, Ang, Bekaert and Wei (2008)[52] has found that the "*convexity bias amount to less than one basis point, even for longer maturities*".[53]

5.2.4 Grishchenko and Huang (2012)[54]

123. Grishchenko and Huang (2012) use their own forecast of expected inflation and survey inflation as a proxy for inflation expectation in order to decompose the breakeven inflation into its components.

124. Grishchenko and Huang (2012) finds "the inflation risk premium to range from -0.16 to 0.10." However, the -0.16 to 0.10 range is not the inflation risk premium in its strictest definition, rather it is the bias after taking into account the liquidity premium, and it can therefore be considered as the net bias. Grishchenko and Huang (2012) states: "*…if we add a monthly average liquidity adjustment to it,…, we obtain the estimates that vary from -16 to 10 basis points.*"[55] That is, an average very close to zero.

125. Furthermore, the analysis is done for the whole sample from 2000 to 2008. If the result is restricted to the sample period from 2004 to 2008, Grishchenko and Huang (2012) finds "*that 10-year inflation risk premium is between 14 and 19 basis points*," after taking into account the liquidity adjustment. That is, when the sample is limited to after 2004, after the TIPS market has matured, Grishchenko and Huang (2012) finds that breakeven inflation lies within the range of 19 basis points above to 14 basis

50 D'Amico, S., Kim, D. H., and Wei, M., (2014) "Tips from TIPS: the Informational Content of Treasury Inflation-Protected Security Prices," FEDS Working Paper 2014-24 (Draft Version February 19, 2016)

51 Scholtes, C., (2002) "On market-based measures of inflation expectations", Bank of England Quarterly Bulletin, Spring 2002

52 Ang, A., Bekaert, G., Wei, M., (2008) "The Term Structure of Real Rates and Expected Inflation," Journal of Finance, Volume 63, No 2, pg 797-849

53 Further discussion of Ang Bekaert and Wei (2008) is in Section 5.2.6 Ang, Bekaert and Wei (2008)

54 Grishchenko, O., Huang, J.Z. (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

55 In Section 5.4 Liquidity correction of Grishchenko and Huang (2012).

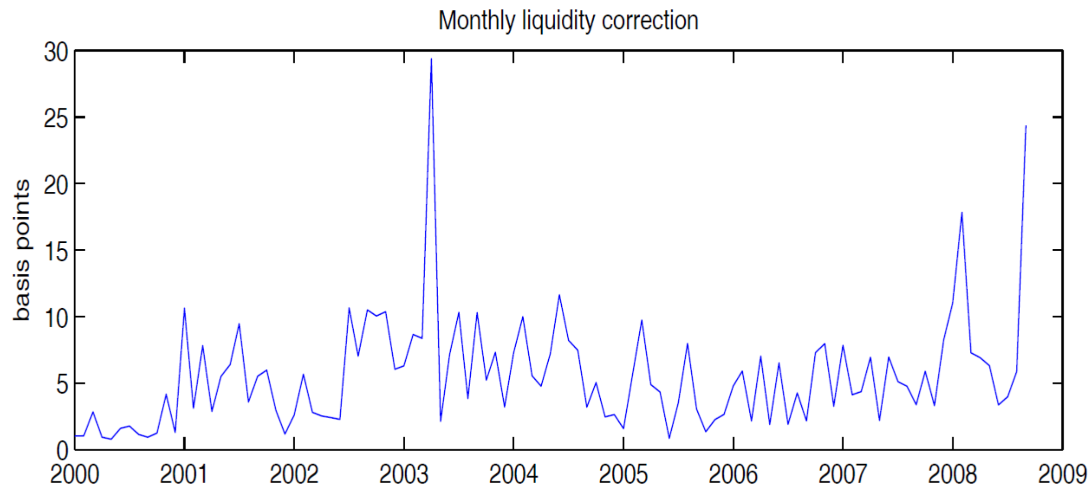
points above expected inflation on average. That is, break even inflation *overestimates* expected inflation by around 14-19 bp.

126. When comparing the two sets of estimates (-16 to 10 bp versus 14 to 19 bp), the authors explicitly noted that they favoured the second set of estimates [emphasis added]:[56]

> *As a result of the above discussion of causes of negative inflation risk premia,* ***we consider the estimates of inflation risk premium obtained over the second half of the sample period to be more reasonable****. Furthermore, we focus on estimates relative to CPI but not core CPI as TIPS are indexed to the former.* ***As such, we conclude that the 10-year inflation risk premium ranges between 14 and 19 b.p.****, depending on the proxy used for expected inflation, based on our empirical analysis and when we correct for liquidity using a liquidity adjustment (28).*

127. Figure 14 reports the monthly average liquidity premium reported by Grishchenko and Huang (2012). It shows that, with the exception of a month in 2003 and the period of the 2008/09 GFC, the liquidity premium is generally around 10 basis points or less.

Figure 14: Liquidity Premium in Grishchenko and Huang (2012)



Source: Grishchenko and Huang (2012)

56 Grishchenko, O., Huang, J.Z. (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. 30.

5.2.5 Shen and Corning (2001)[57]

128. Shen and Corning (2001), published only a few years after the introduction of TIPS, investigates the liquidity premium in TIPS estimates:

> *The liquidity premium has been especially important, causing the yield spread to understate market inflation expectations. The liquidity premium has also been highly volatile, causing the yield spread to vary too widely to reflect only changes in inflation expectations. Nevertheless, if current trends continue, indexed Treasuries should become more liquid and the liquidity premium should gradually decline, allowing the yield spread to more closely approximate market inflation expectations. Even if this happens, though, the yield spread may never be a perfect measure of expected inflation because both the inflation risk premium and the liquidity premium may still vary over time. As a result, it will always be advisable to combine yield spreads with other information to best estimate market expectations of future inflation.*

129. Shen and Corning's (2001) assessment must be tempered somewhat by the fact that Shen and Corning (2001), published in 2001, claim difficulty in assessing the use of TIPS as a forecast for inflation due to the "*short history of TIPS*". Moreover, the method used by Shen and Corning (2001) to arrive at an estimate of the liquidity premium is, in retrospect, highly problematic. Shen and Corning compare the breakeven spread against:

- historical 10-year average consumer price index inflation from 1960 to 2000; and
- survey forecasts of economists.

130. Shen and Corning (2001) find the breakeven inflation to be 87 basis points lower than the (latter) survey on average. Assuming the survey of forecasts by economists is the same as the inflation expectation of investors, Shen and Corning (2001) attributes the difference to liquidity premium. This is a very strong assumption (i.e., unlikely to be true).

131. In any event, Shen and Corning (2001) note that, given the relative newness of TIPS and its uniqueness, its low trade volumes were likely causing liquidity premiums in the yields of TIPS. The high liquidity premium in the first few years after the introduction of TIPS is corroborated in more recent research. In particular, research by D'Amico, Kim and Wei (2016) shows that breakeven inflation is persistently lower than the expected inflation prior to 2004.

132. Shen and Corning (2001) remark that in the UK, where inflation indexed bonds had a longer history and were traded at a higher rate compared to the U.S., "*the liquidity*

57 Shen, P., Corning, J., "Can TIPS Help Identify Long-Term Inflation Expectations?', Federal Reserve Bank of Kansas City, Economic Review, Fourth Quarter 2001, pp. 61–87.

difference there is much smaller", and "*the liquidity premium on indexed debt is smaller than the inflation risk premium on conventional debt*." Shen and Corning (2001) also state that "*if the current trends continue, indexed Treasuries should become liquid and the liquidity premium should gradually decline, allowing the yield spread to more closely approximate market inflation expectations*." In fact this can be seen in Figure 13, where the breakeven inflation has either hovered around or lie above the expected inflation.

5.2.6 Ang, Bekaert and Wei (2008)[58]

133. Ang, Bekaert and Wei (2008) analyse the breakeven spread between nominal bonds and indexed bonds by breaking it down into two components: expected inflation; and inflation risk premium. Regarding convexity, the paper concludes that the "*convexity bias amount to less than one basis point, even for longer maturities*."

134. This is a consistent finding across other papers and our own simulation modelling[59] of this potential source of bias (including surveyed below). That is, it is trivial in magnitude and cannot be expected to make any contribution to explaining the gap between break-even inflation and the QCA's estimates.

135. However, the paper does find a material source of bias in the form of the inflation risk premium. Figure 15 shows its estimated inflation risk premium for a 5 year bond. The grey lines are two standard deviation intervals and the grey bars are periods of recession. The average inflation risk premium calculated is approximately 1.14 percentage points.

136. That is, based on this element of 'bias', break-even inflation would tend to *overestimate* expected inflation by around 1.14% over the period studied. This is the average of the dark line in the below chart. This shows the value is never negative but has been lower since the 1980s (consistent with more stable inflation outcomes in that period). However, even in that period it has averaged around 50bp.

137. This means that any other bias (namely liquidity/index lag effect) would have to make up approximately 50bp in order to make the total bias negative (i.e., lead to an understatement of expected inflation).

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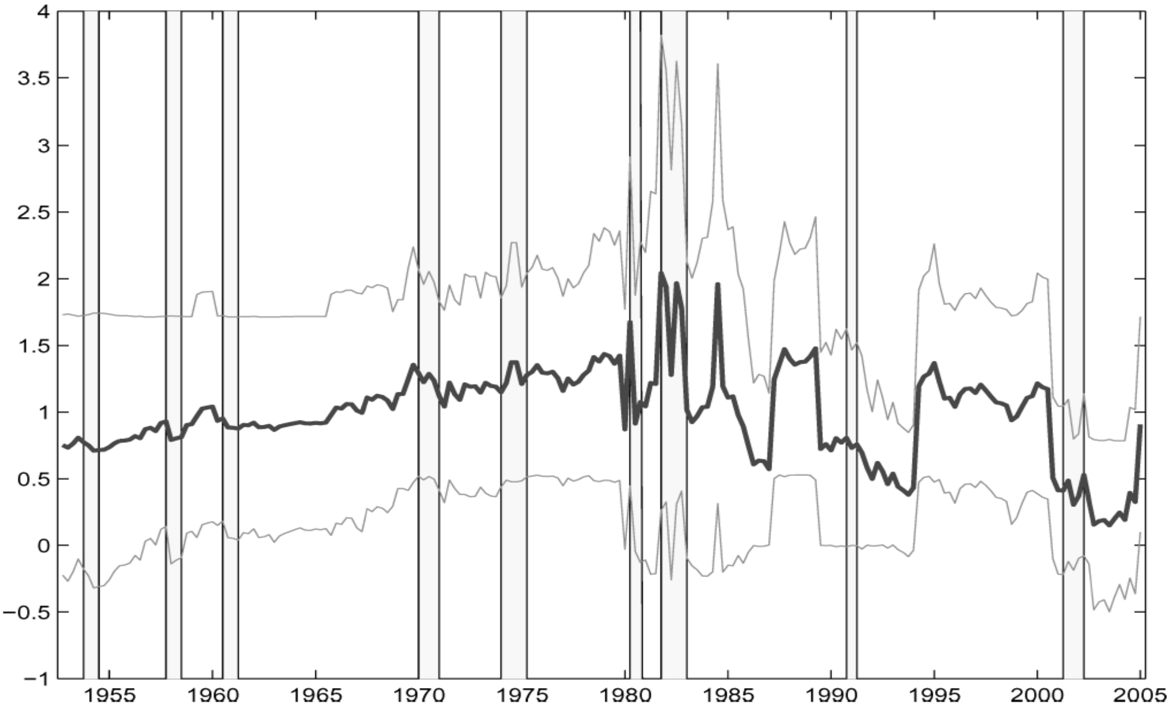
[58] Ang, A., Bekaert, G., Wei, M., (2008) "The Term Structure of Real Rates and Expected Inflation," Journal of Finance, Volume 63, No 2, pg 797-849

[59] See 6.2.3Appendix A Convexity Bias.

Figure 15: Inflation Risk Premium



Source: Ang, Bekaert and Wei (2008)

5.2.7 Pflueger and Viceira (2015)[60]

138. Pflueger and Viceira (2015) calculates the highest liquidity premium for the U.S. TIPS. It adopts a different approach for determining the liquidity premium. Pflueger and Viceira (2015) regresses the breakeven inflation on variables that may indicate liquidity issues[61] and published expected inflation. The component of the regression with variables related to liquidity issues is considered as the liquidity premium. The result is illustrated in Figure 16, it finds the liquidity premium for the U.S. TIPS to be approximately 50 basis points or more up to 2010. After 2012, TIPS liquidity premiums have fallen to below 50 basis points. However, it finds much lower liquidity premium in the U.K. TIPS where it has fallen below 50 basis points since 2006.

139. Since the coefficients on the variables related to liquidity do not change over time, the model utilised by Pflueger and Viceira (2015) assumes a constant relationship between liquidity premium and the explanatory variables. If these variables do not explain all the movements of liquidity premium across time, the liquidity premium

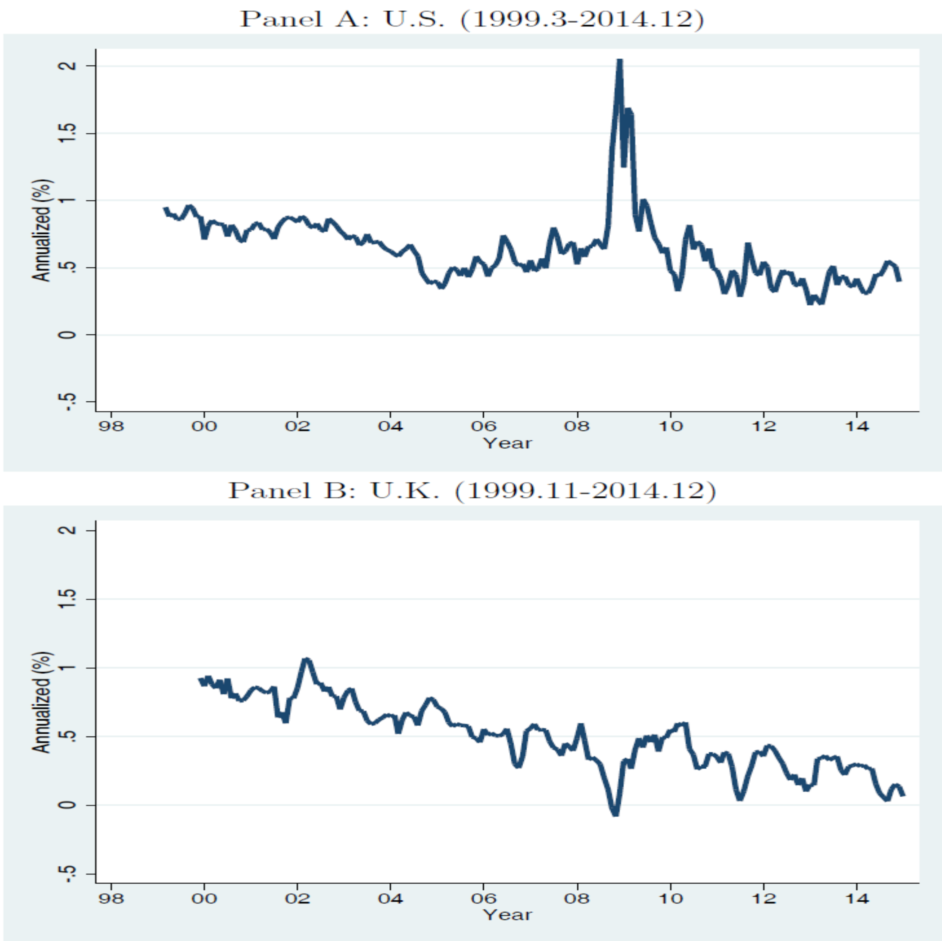
60 Pflueger, C. E. and Viceira, L. M., (2015) “Return Predictability in the Treasury Market: Real Rates, Inflation, and Liquidity”, Working Paper, (Draft Version February 2015)

61 The variables are the spread between on-the-run nominal bonds and off-the-run nominal bonds; synthetic and cash breakeven inflation differential; and transaction volume ratio between nominal bonds and TIPS.

will be over-estimated for some time periods and under-estimated for other time periods. This is because the coefficient is trying to capture the average relationship between the liquidity premium and the explanatory variables. Since Pflueger and Viceira's (2015) sample includes the periods when TIPS are first introduced and the global financial crisis, which exhibits high liquidity premium, the estimation will overestimate the relationship between the liquidity premium and the explanatory variables in other periods.

140. Pflueger and Viceira (2015) do not test the stability of the estimated coefficient or allow for the removal of the impact of the global financial crisis and introductory period of TIPS. Pflueger and Viceira (2015) do run a separate regression for the period prior to the global financial crisis and finds that the estimated coefficient for two of the liquidity indicators is no longer statistically significant, which may indicate instability in the coefficient.

Figure 16: Liquidity premium in Pflueger and Viceira (2015)



Source: Pflueger and Viceira (2015)

5.2.8 Lehman Brothers (2006)[62]

141. Lehman Brothers (2006) discusses how it managed convexity, inflation risk premium and liquidity in its valuation framework. Lehman Brothers (2006) does not report the size of the premiums for a 5 year bond, however it reports the premiums for a 3 year forward rate, two years forward which approximate a 5 year bond. The use of forward rates (rather than spot rates) will exaggerate the impact of convexity. For the 3 year forward rate, two years forward, the convexity bias is 4 basis points, the inflation risk premium is 35 basis points, and the liquidity premium is 15 basis points. Therefore the net bias is an *underestimation* of the expected inflation by 16 basis points – even including any liquidity premium in indexed bonds.

5.2.9 Banco Central do Brasil (2014)[63]

142. Banco Central do Brasil (2014) analyses breakeven inflation for Brazilian indexed bonds with horizon between 1 to 4 years. It concludes that its convexity bias is close to 1 basis points for these bonds (once more, trivial). It finds that the "*liquidity premium is not statistically different from zero*."

5.2.10 Coroneo (2016)[64]

143. Coroneo (2016) attempts to measure the size of the TIPS liquidity premium using a dynamic factor model. The model separates the TIPS yield into two components, the real interest rate component that causes movements in both the nominal yield and TIPS yield, and the liquidity component that causes movements only in the TIPS. Corneo (2016) also checks the robustness of its result by extrapolating the liquidity premium via inflation swaps. The model obtains the real interest rate via the difference in the nominal yield and inflation swaps, which is then used to generate a proxy for liquidity. The result is presented in Figure 17. It shows that other than the period during the global financial crisis, the liquidity factor calculated based on the dynamic factors model and robustness proxy hovers around zero since 2005. Furthermore during the quantitative easing period, marked by the blue vertical region, the period just prior to the global financial crisis in early 2008 and early 2010, the liquidity factor is below zero. This implies a negative liquidity premium for TIPS bonds.

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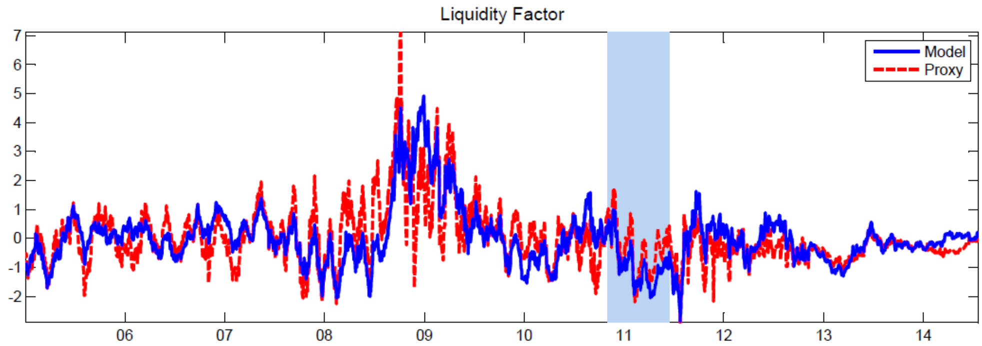
62 Lehman Brothers, (2006) "A TIPS Valuation Framework," U.S. Interest Rate Strategy, Fixed Income Research,

63 Banco Central do Brazil, (2014), "Breaking the Break-even Inflation Rate," Inflation Report, 2016 December

64 Coroneo, L, (2016) "TIPS Liquidity Premium and Quantitative Easing", Working paper (draft version April 2nd 2016)

Figure 17: Liquidity Factor in Coroneo (2016)



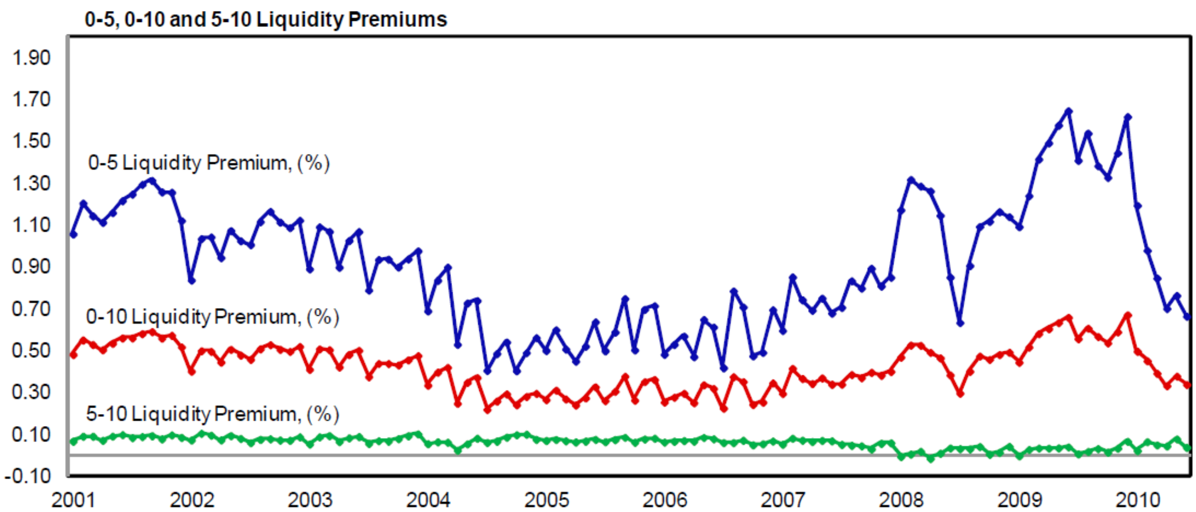
Source: Coroneo (2016)

5.2.11 Celasun, Mihet and Ratnovski (2012)

144. The paper investigates the impact of oil and food prices on market and survey based inflation expectations. The market based inflation is constructed using both breakeven inflation and de-constructed inflation expectation that attempts to remove inflation risk premium and liquidity premium from the breakeven inflation.

145. The liquidity premium is removed by regressing the breakeven inflation on factors that may be related to liquidity. The inflation risk premium is extracted by smoothing the breakeven inflation (without liquidity premium) using survey inflation. The survey results are assumed to be noisy, therefore a Kalman filter approach is used. However the methodology still assumes survey inflation to be systematically accurate.

Figure 18: Liquidity premium for TIPs under different maturity



Source: Celasun, Mihet and Ratnovski (2012)

146. Figure 18 shows the calculated liquidity premium for TIPS of different terms. For TIPS with 10 year maturity, the liquidity premium is approximately 0.5. Celasun, Mihet and Ratnovski (2012) does not report inflation risk premium. However, we note that Ang, Bekaert and Wei (2008) finds the inflation risk premium to be around 0.50 for a 5 year bond, which almost exactly offsets the estimated liquidity premium for 10 year TIPS.

5.2.12 Gürkaynak, Sack and Wright (2010)

147. Gürkaynak, Sack and Wright (2010) provides an overview of TIPS and provides a breakdown of breakeven inflation into various components.

148. As part of the overview, the paper explains that there was a high liquidity premium of TIPS when it is first introduced:

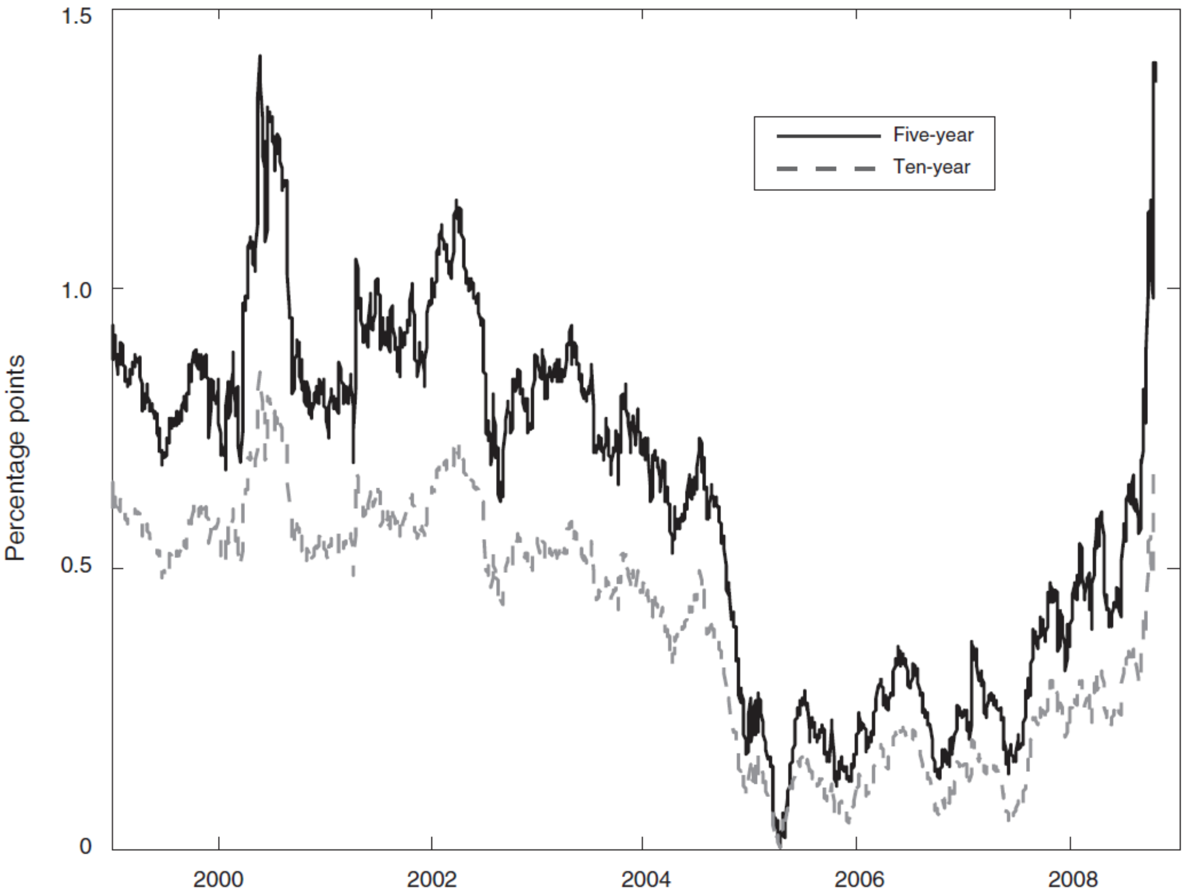
> *Liquidity in TIPS was initially poor, and investor participation in the market was limited, either due to lack of familiarity with the asset class or, in some cases, institutional rules preventing these securities from being held. Another important factor shaping the market was that, for a time, the long-term future of TIPS was unclear. For example, in May 2001, the Treasury Advisory Committee of the Bond Market Association recommended that the TIPS program be discontinued. However, the Treasury subsequently reaffirmed its commitment to the program, and liquidity improved substantially.*

149. In the main section, the paper attempts a deconstruction of breakeven inflation. To capture the liquidity premium component, it regresses the change in breakeven inflation on the change of two liquidity related factors. One factor is the volume of TIPs relative to total Treasury, and the other factor is the spread between two Treasury securities: Resolution Funding Corporation (Refcorp) strips; and Treasury strips. Both securities are guaranteed by the Treasury but the former is much less liquid. Since the regression is based on the change of the variables, the paper normalises the liquidity premium to be zero in April 2005. Although no reason is given for the choice, we note that the calculated liquidity premium is lowest in that month.

150. The calculated liquidity premium is shown in Figure 19. As can be seen, when the Treasury Advisory Committee of the Bond Market Association recommended the end of the TIPS program in May 2001, the liquidity premium increased from below 1 percentage point to above 1 percentage point. The market eventually settled by 2014, after which the liquidity premium decreased below 0.5 to around 0.25. However, the

liquidity premium increased considerably during the GFC due to the large number of TIPS unloaded.[65]

Figure 19: Liquidity premium for 5 and 10 year TIPs



Source: Gürkaynak, Sack and Wright (2010)

151. To extrapolate the inflation risk component, the paper assumes that the consensus forecast is accurate with some noise, and that the inflation risk component acts as a persistent stochastic shock that causes a deviation away from the consensus forecast. The paper uses a Kalman filter to extract the inflation risk component, but does not actually report the size of the inflation risk component.

65 See pg 10 in Abrahams, M., Adrian, T., Crump, R.K., Moench, "Decomposing Real and Nominal Yield Curves", Working Paper, February 2015

5.2.13 Abrahams, Adrian, Crump and Moench (2015)

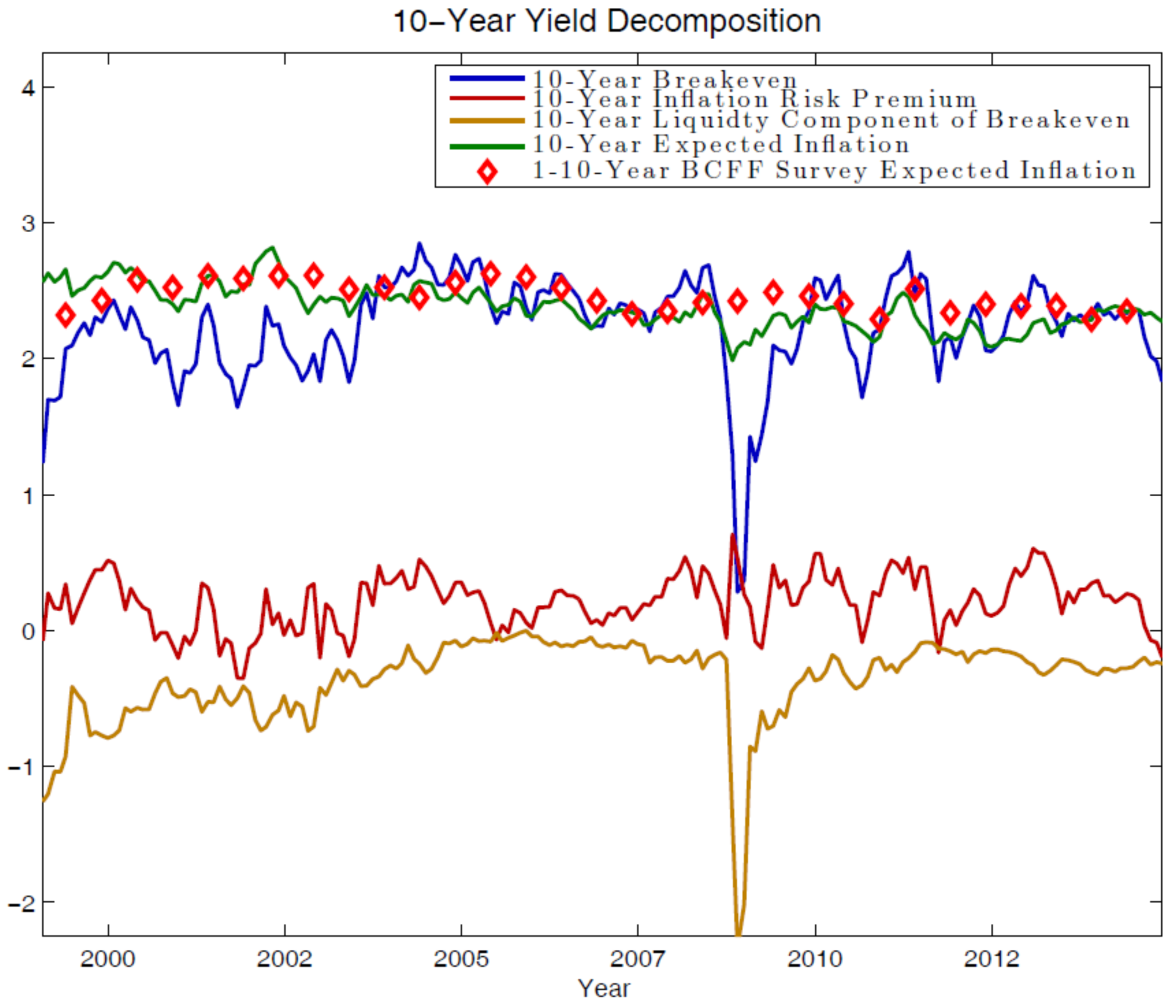
152. Abrahams, Adrian, Crump and Moench (2015) utilises a term structure model to decompose breakeven inflation estimates. The model assumes that the underlying factors that make up the interest rate – such as the real spot rate and liquidity premium – follow a stochastic process. It then constructs the yield curve using the evolution of the various components under no-arbitrage conditions.

153. What sets Abrahams, Adrian, Crump and Moench (2015) apart from many other literature using term structure models is that it uses observables variables to capture the liquidity premium factor in the term structure model. Other papers have either used no additional sources of data, proxies for the short rate, or survey inflation forecast to capture inflation expectations in order to back out inflation and/or liquidity premium[66]. Abrahams, Adrian, Crump and Moench (2015) use two variables to capture the liquidity premium factor. The two factors are the TIPS yield curve fitting errors from the Nelson-Siegel-Svensson model and volume of TIPS relative to overall Treasury transactions.

154. The paper's decomposition of breakeven inflation is shown in Figure 20, in which breakeven inflation is broken down into liquidity premium, inflation risk premium and expected inflation. Also, the calculated expected inflation is compared to survey inflation forecasts. It can be seen that other than the period after TIPs' introduction and the GFC, the breakeven inflation rate has hovered around the calculated expected inflation and survey inflation forecasts.

66 For example see Garcia, J.A. and Werner, T., 2010, " Inflation Risks and Inflation Risk Premia", European Central Bank Working Paper Series, No 1162, March 2010

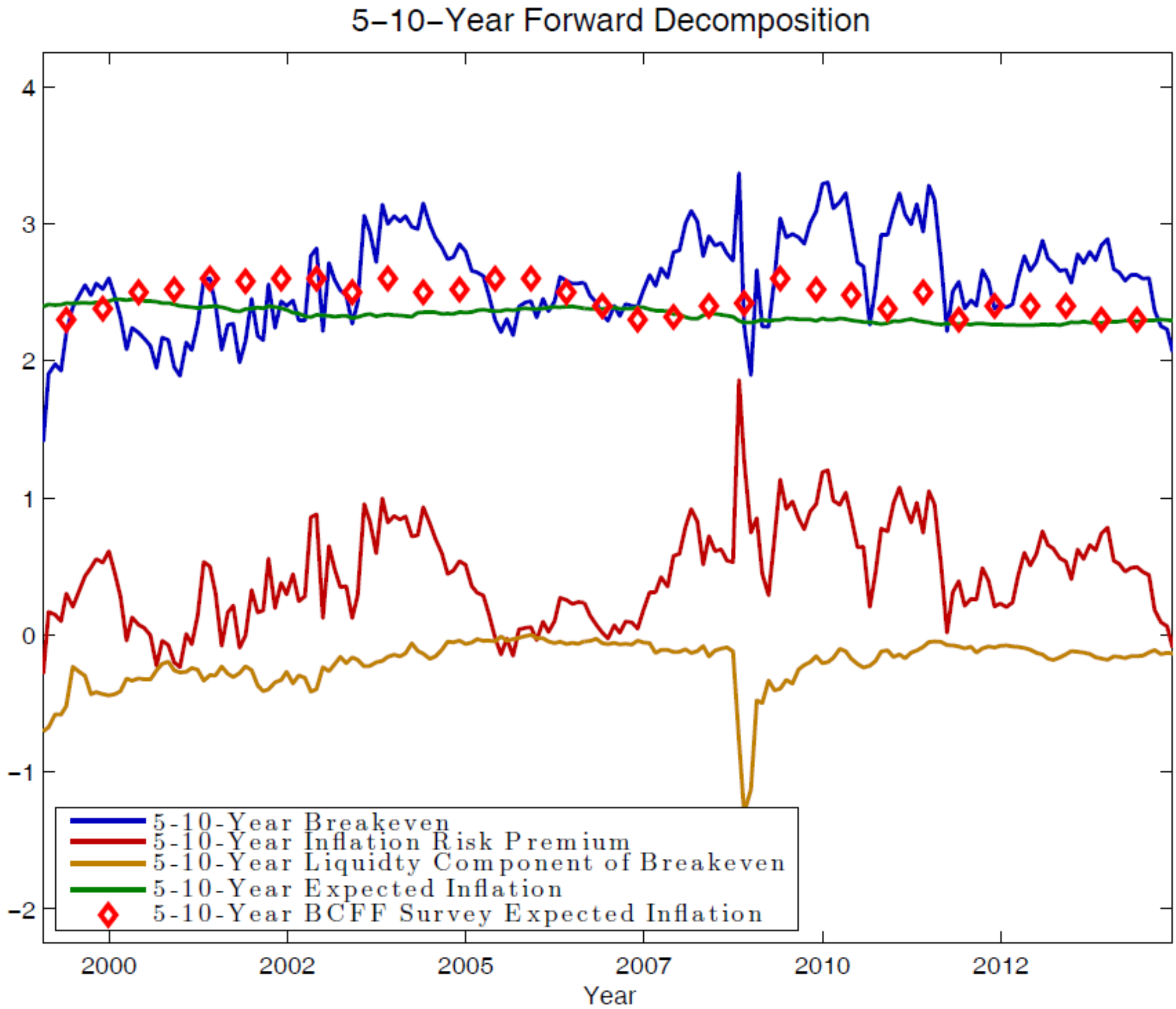
Figure 20: Decomposition of 10 year breakeven inflation



Source: Abrahams, Adrian, Crump and Moench (2015)

155. Figure 21 shows the decomposition for the 5-10 year forward breakeven inflation. It can be seen that breakeven inflation has been above the calculated inflation and survey inflation for majority of the period since sometime after 2002. Furthermore, the paper finds that model-implied inflation expectations track survey forecasts closely.

Figure 21: Decomposition of 5-10 year forward breakeven inflation



Source: Abrahams, Adrian, Crump and Moench (2015)

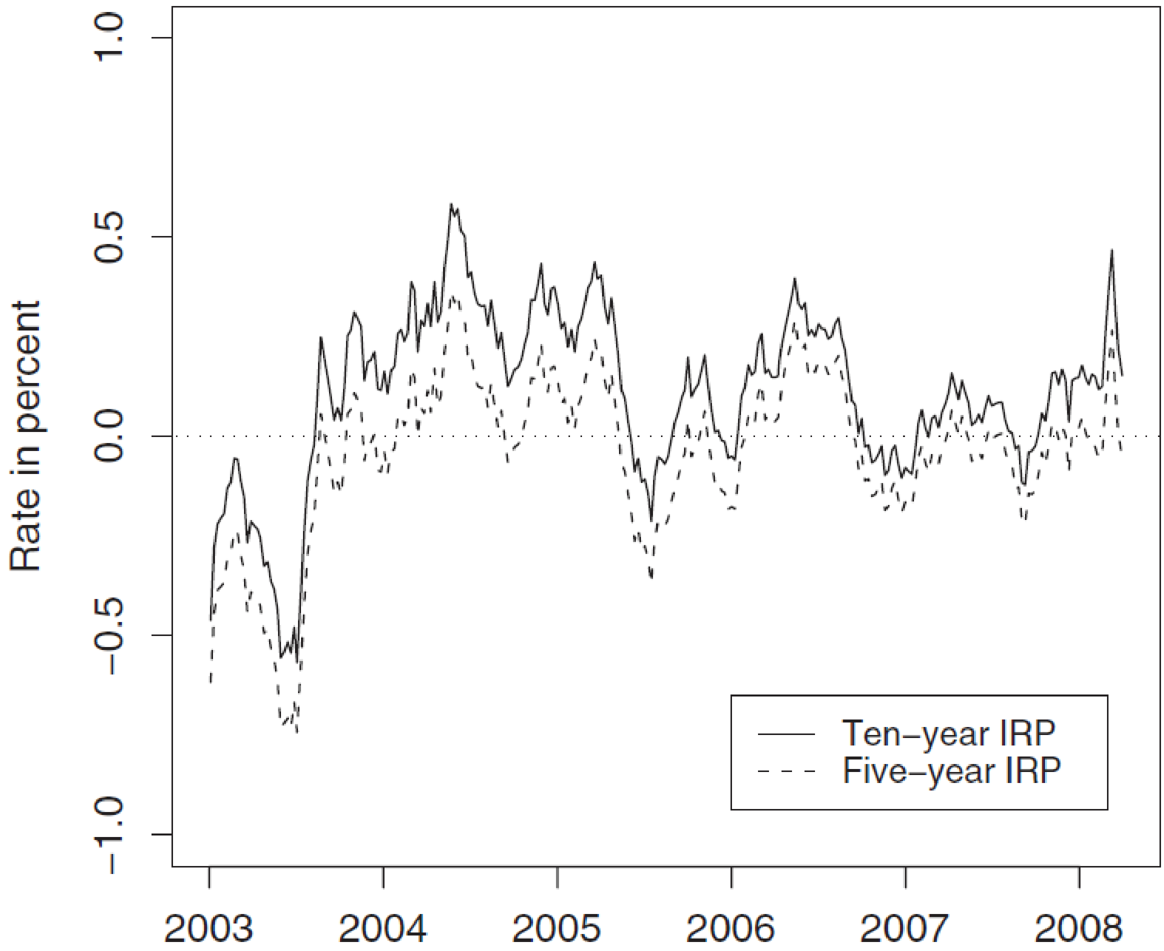
5.2.14 Christensen, Lopez Rudebusch (2010)

156. Christensen, Lopez Rudebusch (2010) is one of the earlier papers that uses an arbitrage-free term structure model to decompose breakeven inflation. It assumes there are three stochastic factors that affect the nominal Treasury yields, which it refers to as: level; slope; and curvature. The real yield is in turn made up of two stochastic components called level and slope. The difference the nominal yield and real yield is assumed to decompose into two components, namely the inflation expectation and the inflation risk premium. Since there is no additional component for liquidity premium, the inflation risk premium estimated in this model therefore consists of both the inflation risk premium and liquidity premium.

157. Figure 22 shows the estimated inflation risk premium. For the period before 2014 and parts of the period after 2014, the estimated inflation risk premium falls below

0. This implies that the estimated liquidity premium is larger than the inflation risk premium during these periods. However for majority of the period after 2014, the inflation risk premium is above the liquidity premium.

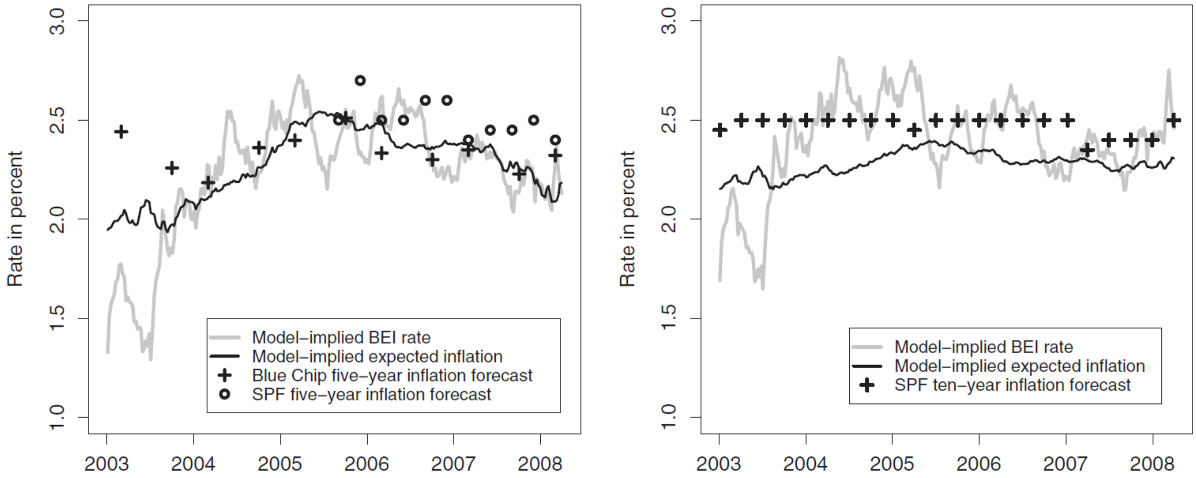
Figure 22: Inflation Risk Premium



Source: Christensen, Lopez Rudebusch (2010)

158. Figure 23 shows the estimated inflation expectation and breakeven inflation for both the 5 year and 10 year maturities. The results show that after 2004, breakeven inflation has either hovered around or lain above the model's estimated inflation expectation. Furthermore, the estimated breakeven inflation also matches the survey inflation forecast.

Figure 23: Model implied expected inflation vs survey



(a) Five-year horizon. (b) Ten-year horizon.

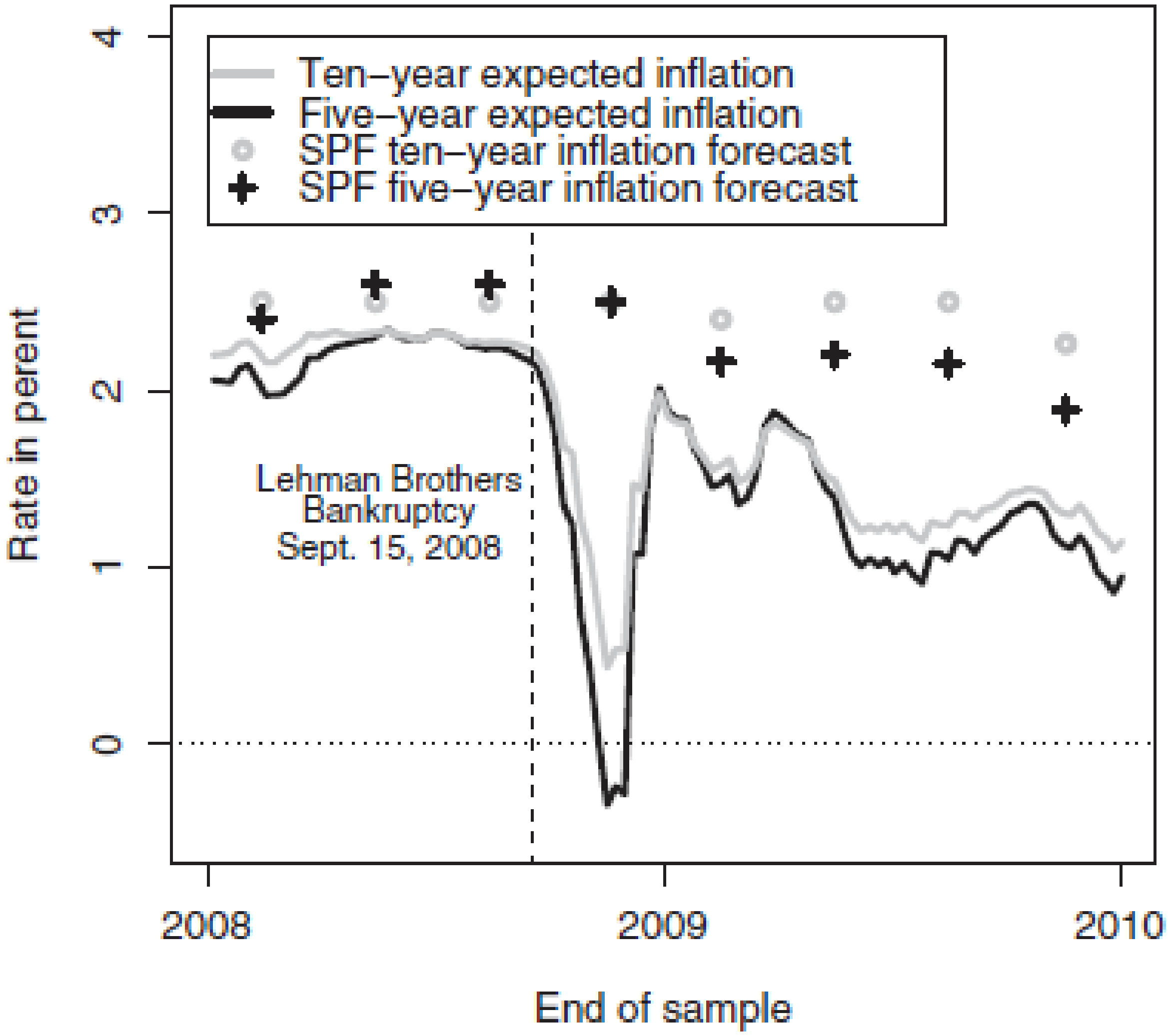
Source: Christensen, Lopez Rudebusch (2010)

159. Christensen, Lopez Rudebusch (2010) also investigates the result of the model during the GFC. They find that after Lehman Brothers' bankruptcy, the calculated expected inflation fell sharply, whereas the survey inflation did not change. It questions whether the market inflation expectation did fall during that period and raises the possibility that liquidity premium is not removed from breakeven inflation estimates. However, the calculated inflation risk premium also fell sharply during that period, reaching -3 in early 2009, shown in Figure 25. This indicates that the extrapolated inflation risk premium did take into account liquidity premium.

160. Furthermore Christensen, Lopez Rudebusch (2010) also compares the calculated inflation expectation against inflation expectation implied by inflation swaps and finds that both inflation expectation estimates fell sharply during that period, as shown in Figure 26. The correlation during that period is 68% for 5 year maturity and 57% for 10 year maturity. This implies that the market's inflation expectation did indeed fall sharply during that period.

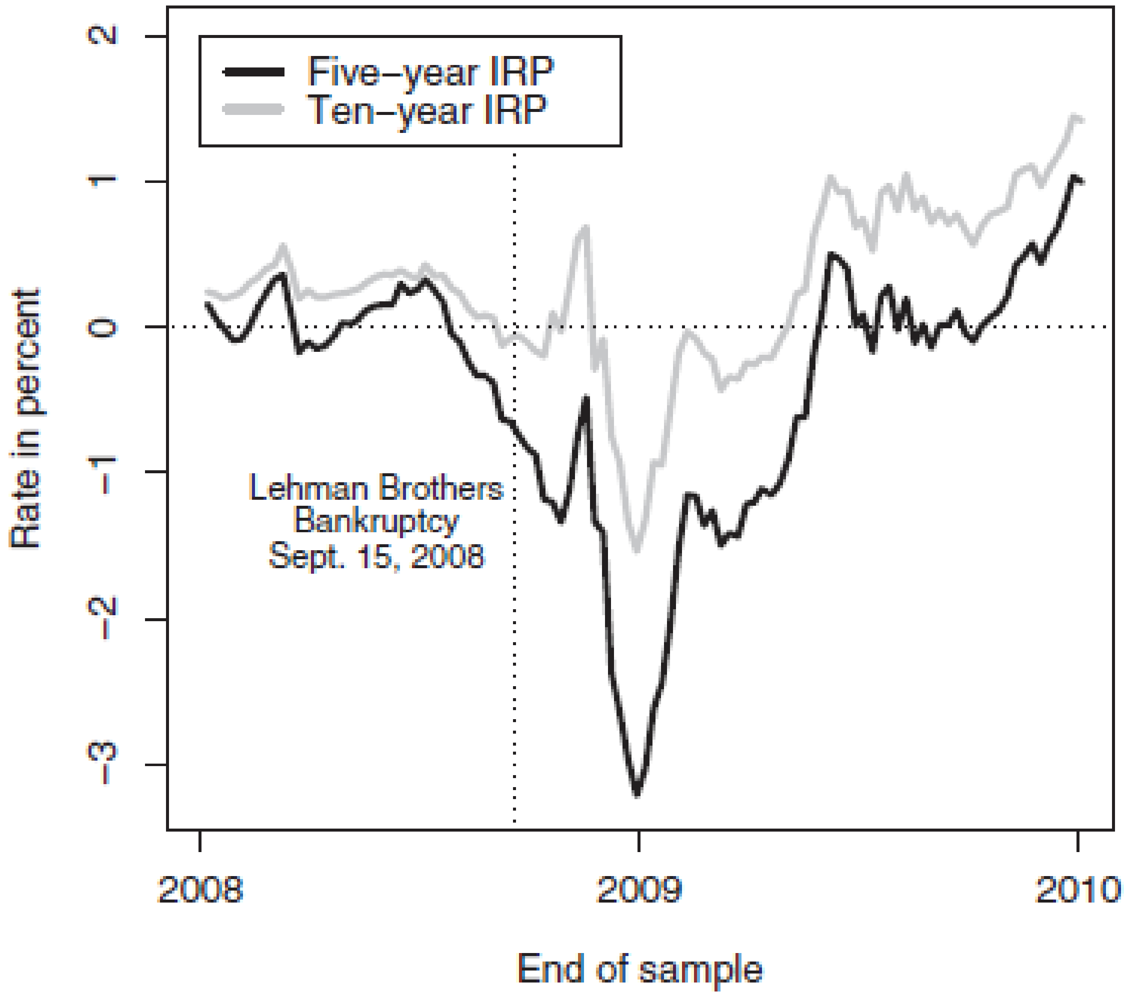
COMPETITION
ECONOMISTS
GROUP

Figure 24: Model implied expected inflation during GFC



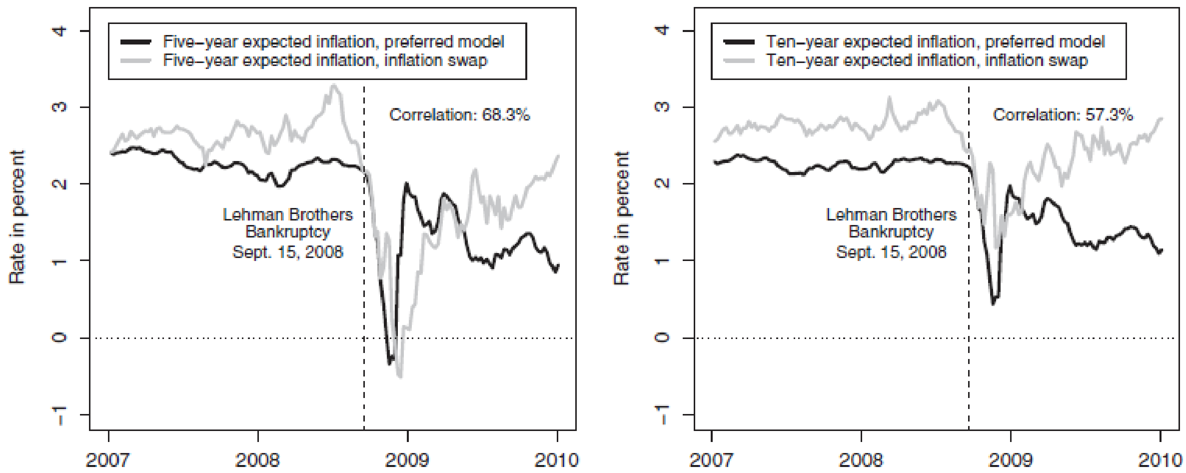
Source: Christensen, Lopez Rudebusch (2010)

Figure 25: Inflation risk premium during GFC



Source: Christensen, Lopez Rudebusch (2010)

Figure 26: Comparison between breakeven inflation and inflation swap



(a) 5-year horizon. (b) 10-year horizon.

Source: Christensen, Lopez Rudebusch (2010)

5.2.15 Garcia and Werner (2010)

161. We review Garcia and Werner (2014)[67] based on its working paper, Garcia and Werner (2010). Similar to Christensen, Lopez Rudebusch (2010), Garcia and Werner (2010) uses the term structure model to analyse breakeven inflation in the European market. It decompose breakeven inflation into two components, expected inflation and inflation risk premium. Therefore the estimated inflation risk premium actually contains both inflation risk premium and liquidity premium. However instead of using a stochastic variable to capture the movement of expected inflation, it relies on an observed variable to represent inflation expectation. The observed variable used here is survey inflation expectation. Therefore the accuracy of survey inflation is a key assumption of this paper.

162. The paper claims that the use of survey inflation expectation is justified because the use of survey information does not decrease the fitting of the model to data, as shown in Figure 27. When survey information is used, it also implies the calculated inflation expectation is closer to survey inflation expectations compared to a model that does not use the survey inflation forecast. This is shown in Figure 28.

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67 Garcia, J.A. and Werner. T. 2014. "Inflation Compensation and Inflation Risk Premia in the Euro Area Term Structure of Interest Rates." Developments in Macro-Finance Yield Curve Modelling, Cambridge University Press

Figure 27: Root mean Square Error for nominal yields

Horizon	Model without surveys	Model including surveys
One year ahead	12	13
Two year ahead	6	7
Five year ahead	10	7

Source: Garcia and Werner (2010)

Figure 28: Difference in calculated inflation expectation and survey inflation forecast (basis points)

Year-on-year rate	Model including surveys	Model without surveys
in one year	19	26
in two years	10	21
in five years	6	9

Source: Garcia and Werner (2010)

163. Figure 29 reports the breakeven inflation, inflation expectation and inflation risk premium for TIPS of different length. In the majority of the scenarios for one year TIPS and for all longer period TIPS, breakeven inflation lies above inflation risk premium. This implies that the inflation risk premium is greater than the liquidity premium in the European market. Furthermore as the maturity of each bond increases, the corresponding inflation risk premium also increases. It also finds that:

> *"volatility of inflation compensation at longer horizon is almost fully driven by the inflation risk premia."*

164. The use of 5 year survey forecast as the basis for long term inflation expectation will generally lead to lower variance in modelled inflation expectation as long term survey forecasts are anchored in inflation targets. However, the paper finds that the volatility of modelled inflation expectations is less than that found in survey data.

Figure 29: Decomposition of breakeven inflation

Forward inflation compensation (BEIR), inflation expectations and risk premia

Figure 1: BEIR ending in one year

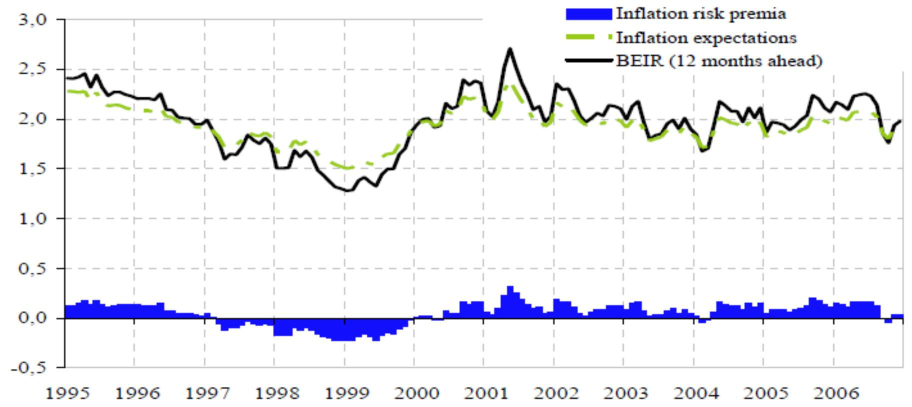


Figure 2: One-year forward ending in two years

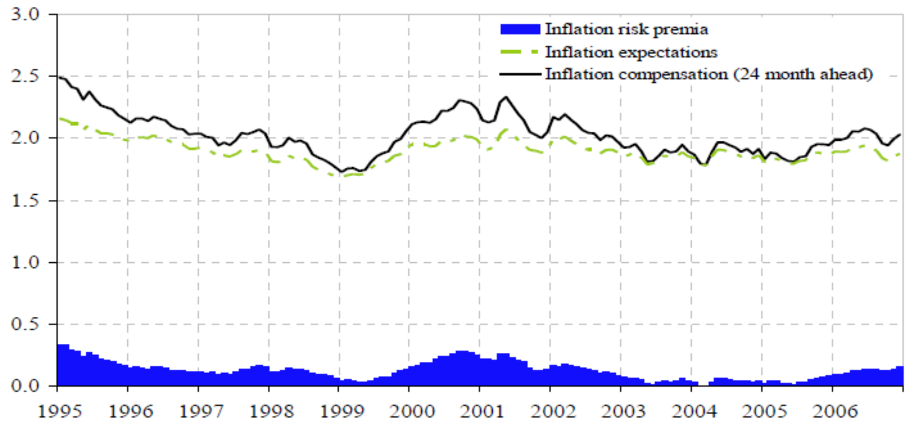
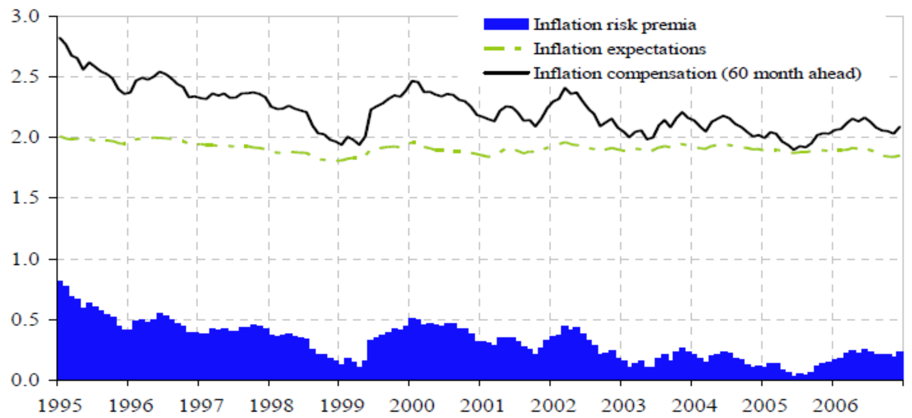


Figure 3: One-year forward ending in five years



Note: The charts depict the decomposition of BEIRs (or inflation compensation) into its two components, namely the expected level of inflation and the inflation risk premium associated with it. Data are in percentage points.

5.2.16 Finlay and Wende (2012)[68]

165. Finlay and Wende (2012) uses an affine term structure model based on survey estimates of inflation expectations to evaluate breakeven inflation estimates in Australia. The assumption underpinning the analysis is that survey data, as manipulated in the author's model, results in an accurate estimate of inflation expectations. The model is estimated using a non-linear Kalman filter.

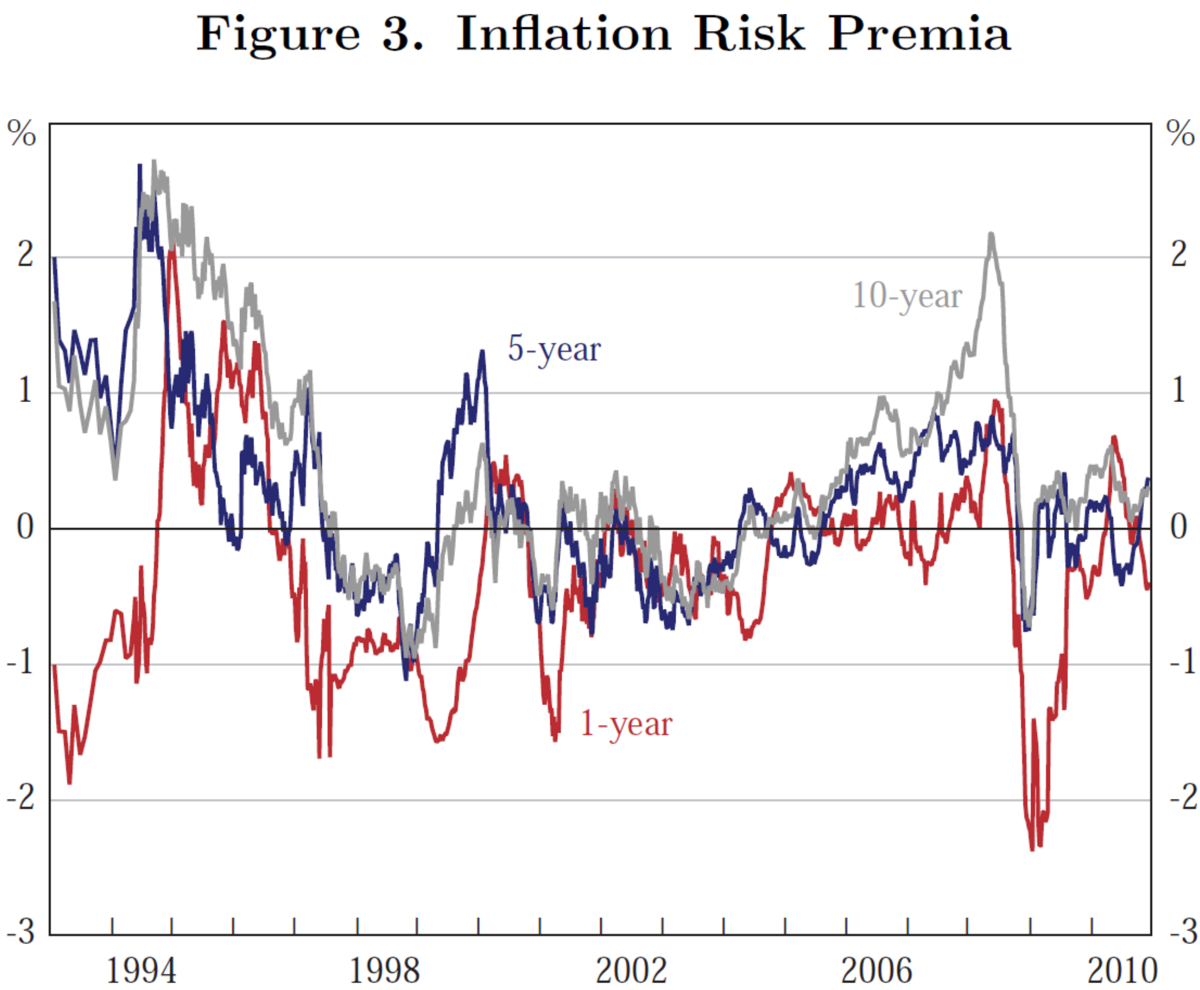
166. Recognising that inflation yields may be affected by factors other than inflation expectations, the authors include a separate parameter in their inflation stochastic discount factor estimates equation, in which the additional λ parameter is assumed to capture all factors aside from inflation expectations. These factors include inflation risk premium and liquidity premium.

167. Figure 30 shows the premium generated by the model, which includes both inflation risk premium and liquidity premium. That is, the series shown represent the overall net bias estimated by the model. It can be seen that the 5- and 10-year series both fluctuate around zero but are usually positive, which implies, that breakeven inflation usually overestimates the expected level of inflation, such that true expected inflation would be even lower than the breakeven inflation estimates. This results corroborates with the findings from Grishchenko and Huang (2012) and Lehman Brothers (2006), both of which observed positive net bias in breakeven inflation estimated from US data.

168. Furthermore, we note that Finlay and Wende (2012) carried out their analysis on a sample that runs from July 1992 to December 2010. As shown inFigure 6, there has been a sixfold increase in indexed CGS on issue post the global financial crises, which would likely lead to a reduction in any liquidity premium associated with breakeven inflation. This suggests that, if anything, any net bias is likely to have become even more positive in the six years since the end of Finlay and Wende's (2012) sample.

[68] Finlay and Wende (2012), "Estimating Inflation Expectations with a Limited Number of Inflation-Indexed Bonds", International Journal of Central Banking, pp. 111-142.

Figure 30: Inflation risk premia, Finlay and Wende (2012)



*Source: Finlay and Wende (2012); *The authors define the risk premia as encompassing all factors (aside from inflation expectations) that may affect the inflation yield.*

6 Estimating the real cost of capital directly

169. This section explains that if the sources of potential bias in break-even inflation addressed in section 5 are material they actually imply that the nominal CGS yield is a biased proxy for the risk free rate. If these sources of bias did exist then the appropriate course of action would be to adopt the indexed CGS yield as the real risk free rate proxy.

170. In this section we explain how this can be done by estimating a real cost of capital directly. The nominal cost of capital inputs to the QCA revenue model can be estimated by adding expected inflation to the real cost of equity and debt. Under this approach, the nominal cost of debt and equity used as inputs into the QCA revenue model are set equal to the estimated real of debt and equity plus expected inflation. This approach has, in our view, the material advantage that it renders the estimate of expected inflation used in the QCA revenue model relatively unimportant to the compensation that will be provided to the regulated entity.

6.1 Practical method for building a nominal cost of debt/equity from the real risk free rate

171. Once a real risk free rate has been determined, it is necessary to transform this into a real cost of debt and equity by adding a risk premium to each. However, the QCA revenue model requires nominal (not real) inputs for the cost of debt, the cost of equity and expected inflation. In order to arrive at estimates of the nominal cost of debt and equity that are internally consistent, the expected inflation input into the QCA revenue model the latter must be added to the estimates of the real cost of debt and equity.

172. We set out mechanically how this would be done for equity and debt in the following section. Let us assume, purely for the purpose of illustration, that a risk premium of 4.5500% is applied to the risk free rate. If this is added to a nominal risk free rate (of, say, 2.0000%) we will arrive at a nominal cost of equity of 6.5500% from which, within the QCA revenue model, expected inflation is removed in order to deliver a real rate of return.

173. In the same circumstances our proposal is that the QCA deflate this 4.5500% risk premium by expected inflation in order to turn it into a real risk premium.[69] Let expected inflation be 0.9901% in which case the real risk premium is given by:

69 This risk premium is largely, but not wholly, net of inflation. The risk premium is expressed as a return in excess of the risk free rate it is already in excess of inflation (in the Fisher equation (n=r+p +r*p) it is

Real risk premium = 4.5500%/(1+0.9901%)= 4.5054%

174. This real risk premium is then added to the best estimate of the real risk free rate which, for the purpose of this example, we let be 1.0000%. This gives a real cost of equity of:

Real cost of equity = 5.5054%.

175. This estimate of the real cost of equity is then transformed into a nominal return using the Fisher equation and expected inflation (assumed above to be 0.9901%).

Nominal cost of equity (QCA revenue model input) = 5.5054%+0.9901% +5.5054×0.9901%

= 6.5500%

176. It is useful to note that, in this illustration the nominal risk free rate is 2.0%, the real risk free rate is 1.0% and the estimate of expected inflation is the difference between these values (using the Fisher equation).[70] In this situation we get the same answer whether we start with a nominal or a real risk free rate. This is because our estimate of expected inflation is consistently determined as the difference between these real and nominal rates.

177. By contrast, if the estimate of expected inflation was higher than implied by the Fisher equation (say, 2.00%) then our nominal cost of equity would be higher (7.62)%. Of course, the real return delivered by the QCA revenue model would be unaffected at 5.5054 because the higher expected inflation used to derive the nominal cost of equity would also be removed from revenues within the QCA revenue model – leaving the real return unchanged.

6.2 Why indexed CGS are the best proxy for the real risk free rate

178. Even if the QCA believed that 2.5% was the best estimate of expected inflation (much higher than breakeven inflation due to biases in breakeven inflation (a proposition we do not accept)) then the same logic should lead the QCA to adopt indexed CGS as the best estimate of the real risk free rate.

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in excess of "p". However, it still has r*p embedded in it (i.e., it is the real risk premium plus the real risk premium multiplied by inflation). Therefore, it must be divided by (1+p) in order to remove this element of inflation compensation to transform it into a pure real risk premium.

70 That is, 0.9901% expected inflation is the inflation implied by a 2.0000%/1.0000% nominal/real risk free rate (0.9901%=(2%-1%)/(1+1%))

179. To see why, consider the following sources of potential bias in break-even inflation as a measure of expected inflation.

- Inflation risk premium, whereby investors demand a higher expected real yield from nominal CGS due to the fact that they are exposed to inflation risk when investing in nominal CGS;
- Liquidity premium, whereby investors demand a lower expected real yield from nominal CGS because they place value on the higher liquidity of these instruments; and
- Convexity premium, whereby investors demand a lower expected real yield from nominal CGS in order to compensate for the greater sensitivity of nominal yields to changes in inflation expectations.

180. To the extent that such sources of bias in break-even inflation existed they would imply that the nominal CGS yield requires adjustment to be an idealised risk free rate (not the indexed CGS yield).

181. To see why, note that a conclusion that the difference between indexed and nominal CGS is not the best estimate of expected inflation must be because:

a. Nominal CGS yields are an imperfect proxy for the real risk free rate plus expected inflation;

b. Indexed CGS are an imperfect proxy for the real risk free rate; or

c. Both of the above are true.

182. That is, even if the potential sources of bias in break-even inflation were considered to be material (and negative), that would not justify rejecting indexed CGS as the best proxy for the real risk free rate. In order to arrive at that conclusion, the QCA would also need to believe that the 'bias' manifested in indexed CGS yields being 'too high' rather than nominal CGS yields being 'too low'.

183. The remainder of this section sets out what relevance, if any, the sources of potential bias in break-even inflation have for any attempt to make adjustments to the indexed CGS yield as the best proxy for the real risk free rate.

6.2.1 Convexity bias

184. Nominal CGS prices are sensitive to both changes in real risk free rates and expected inflation. Indexed CGS prices are only sensitive to changes in real yields. Therefore, convexity risk is greater for nominal CGS (their value is more sensitive to potential changes in discount rates). This implies that nominal CGS are more risky than indexed CGS and are a worse starting point for a calculation of the real risk free rate (even if expected inflation was known with certainty).

6.2.2 Inflation risk premium

185. The inclusion of an inflation risk premium in nominal CGS yields is clearly a reason to prefer indexed CGS yields as the best proxy of the real risk fee rate. The logic of an inflation risk premium bias in break-even inflation is that investors will demand an additional risk premium from nominal CGS due to the fact that these bonds do not deliver a guaranteed real risk free return but, instead, will deliver volatile real returns depending on the actual inflation outcome over the investment horizon (in this case 10 years). Clearly, as this is a risk premium built into nominal yields, it is inappropriate for inclusion in the risk free real rate of return.

186. It is worth noting that, in the current environment, inflation risk very likely has a strong systematic element such that if inflation is:

- lower than expected this will tend to be associated with 'bad' economic events (slow growth or recession); or
- higher than expected this will tend to be associated with 'good' economic events (stronger growth and the breaking out from a 'low inflation trap').

187. This means that the inflation risk premium built into nominal CGS at the moment is likely to be negative (have negative beta risk). That is, rather than being 'risk free', nominal CGS are providing an insurance premium to investors against bad economic news such that they will benefit (in the form of higher real returns) if the economy performs poorly and inflation is lower than expected.

188. The IMF considers that the reduction in the asset beta of nominal government bonds to negative levels has been an important contributor to the fall in nominal government bond yields. That is, government bonds now exhibit not just low or zero risk, but have become negative risk in the CAPM sense.

> *"... a change in the relative riskiness of bonds and equities has made bonds relatively more attractive. In particular, the evidence summarized in Figure 3.13 (panel 1) shows that the correlation between bond and equity returns has steadily declined (similar results have been found in Campbell, Sunderam, and Viceira, 2013)..."*[71]

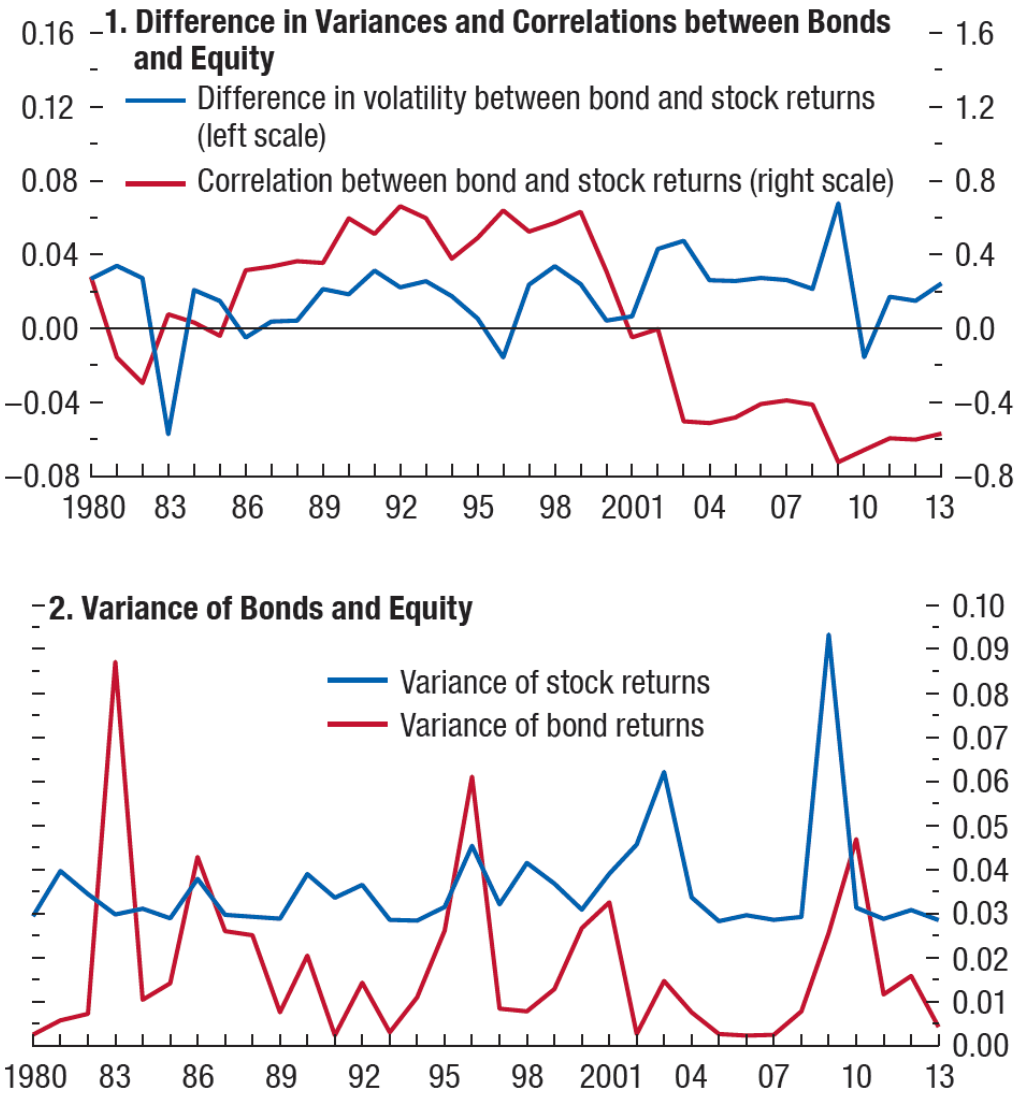
189. The evidence summarised in panel 1 of Figure 3.13 from the IMF (2014) report is reproduced below.

[71] International Monetary Fund World Economic Outlook: April 2014, Chapter 3, Perspectives On Global Real Interest Rates p.13.

Figure 31: IMF estimates of correlation between bond and stock returns

Figure 3.13. Portfolio Shifts and Relative Riskiness of Bonds versus Equity, 1980–2013

(Percent)



Source: IMF

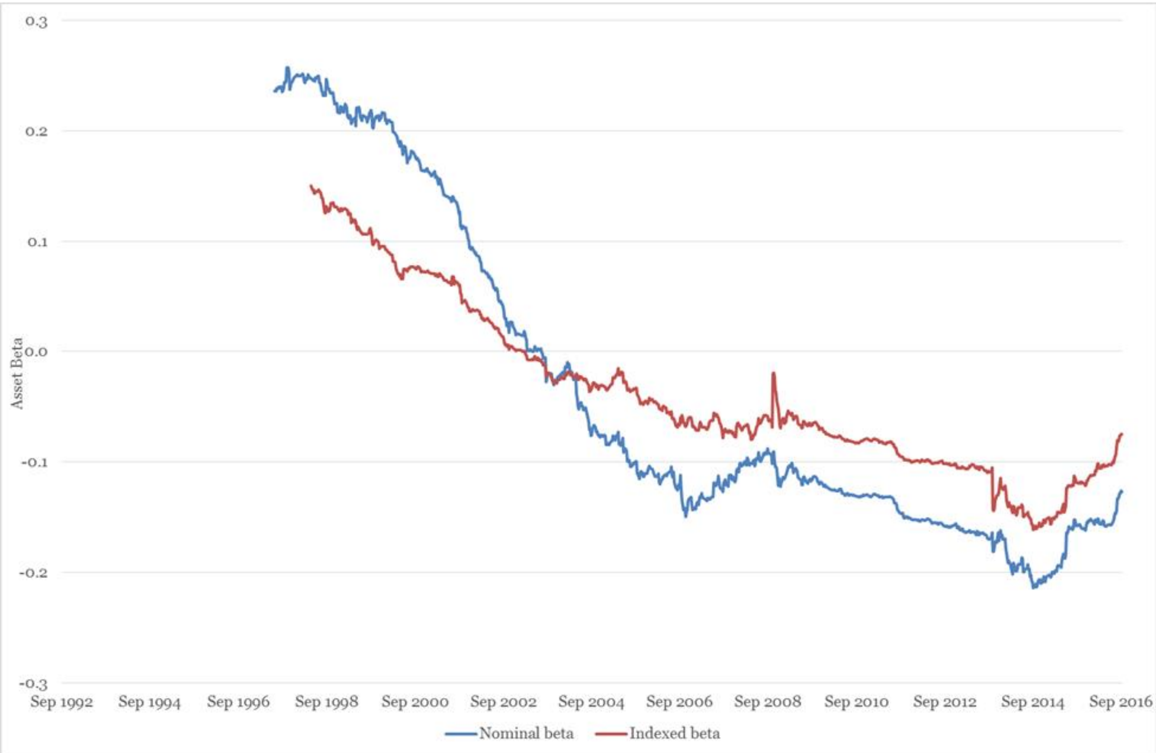
190. The beta on nominal government bonds implied by the above analysis is around negative 0.25.[72] If one believes that the MRP is 6.5% this would imply that whatever

[72] While the IMF does not specifically report the beta for government bonds, the data in the above two panels covers the constituent elements of beta. Specifically, the asset beta is equal to the correlation between stock and government bond returns (shown in the top panel) multiplied by the square root of the ratio of the variance of bond returns to the variance of stock returns (with the variances shown in the bottom

risk exposure is causing negative beta for nominal government bonds is around negative -1.25%.

191. The IMF's estimates are global but are similar to our own for Australian CGS. An examination of the beta for Australian CGS clearly shows the same trend as reported by the IMF. Nominal and indexed 5 and 10 year CGS have had materially negative betas since around 2000. This is apparent in Figure 32 below, which shows weekly asset betas measured over 5 years to the date on the horizontal axis (such that the point at which the time series crosses zero in early 2003 is using data from early 1998 to early 2003). Similarly, the first observations in 1997 use data from 1992 to 1997.

Figure 32: Weekly rolling 5-year betas for 10-year maturity – nominal and indexed CGS



Source: RBA, Bloomberg, CEG analysis

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panel). The ratio of variances will always be positive (as will its square root) and consequently the sign of the beta is determined by the sign of the correlation.

The IMF panel shows, based on a global analysis, that there existed positive betas for government bonds prior to 2000 and strongly negative betas for government bonds since then. Reading off the first panel of the IMF figure the correlation has been at, or below, -0.4 since around 2003. Let us conservatively say that this has been -0.5 on average. Reading off the second panel, the average variance for bonds/stocks appears to be around 0.01/0.04=0.25; such that the square root of this ratio is around 0.5 ($\sqrt{0.25}=0.5$). This implies an asset beta of around -0.25 (=correlation×√ratio of variances= -0.5×0.5=-0.25).

192. Notably, nominal CGS have, since the early 2000s had materially more negative (further from zero) betas than indexed CGS. This is consistent with nominal CGS being exposed to greater (negative beta) inflation risk than indexed CGS.[73]

193. The above result suggests that both indexed and nominal CGS yields may be depressed by virtue of having negative betas. However, indexed CGS yields are likely less depressed and, therefore, are a better proxy of the real risk free rate (as one would expect given zero inflation risk exists for indexed CGS).

6.2.3 Liquidity premium

194. The fact that indexed CGS also have a negative measured beta suggests that there may be other risk factors influencing the riskiness of both real and nominal CGS yields. An obvious explanation is liquidity risk.

195. In the Sharpe-Lintner CAPM, relative liquidity plays no role in determining the required return on an asset. The CAPM is a one-period model in which investors invest once, hold the asset for a single period and then divest and consume the entirety of their wealth. In this model there is no role for 'liquidity' to play a role in determining required returns. Consequently, at least in terms of the mathematics of the derivation of the Sharpe Lintner CAPM, it is not obvious how one should deal with the existence of liquidity risk in the real, multi-period, world.

196. A role for liquidity does exist in a multi-period asset pricing model (such as the inter-temporal CAPM). In multi-period models investors are optimising and altering their investment portfolios in response to unexpected news/shocks. In such models investors will have a preference for assets that are more liquid because those assets allow such optimisation to occur at lowest cost. Specifically, a 'liquid' market is one where an individual investor can expect to be able to buy or sell into the market without their personal transaction having a significant impact on the price paid/received in the transaction.

197. It may, or may not, be the case that nominal CGS are materially more liquid than indexed CGS. However, based on the theory of the Sharpe-Lintner CAPM there is simply no way of inferring whether the existence of a difference in liquidity makes indexed CGS a better or worse proxy for the real risk free rate.

198. In order to reach any conclusion along these lines one must step out of the Sharpe Lintner CAPM and ask, in a world where relative liquidity plays a role in investors' required returns, what is the optimal liquidity of the proxy for the real risk free rate?

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73 However, the fact that both have negative betas suggests that there is some risk factor other than inflation risk affecting both forms of CGS (noting that inflation indexed CGS have no inflation risk). This may have a relationship with interest rate risk (valu with the 'liquidity premium' as discussed in section 6.2.3.

The answer to this is that the real risk free rate should have the same liquidity as the assets being valued (the assets whose required return is being estimated).

199. In which case, both the nominal and indexed CGS are imperfect proxies for the nominal/real risk free rate because both are much more liquid than any other asset in the Australian economy. This means that both nominal and indexed CGS will have negative liquidity premiums relative to other less liquid assets; assets such as equity in a railway infrastructure company.

200. This need not be problematic for the application of the Sharpe-Lintner model if the liquidity premium is constant (i.e., if the higher required return on corporate equity/debt is due to lower liquidity is constant over time). In this case, the liquidity premium will simply be built into the estimate of the historical average market risk premium (MRP) and, at least for assets with betas of around 1.0, will not affect the estimated required return (i.e., depressed risk free rates will be offset by higher MRP estimates of the same magnitude).

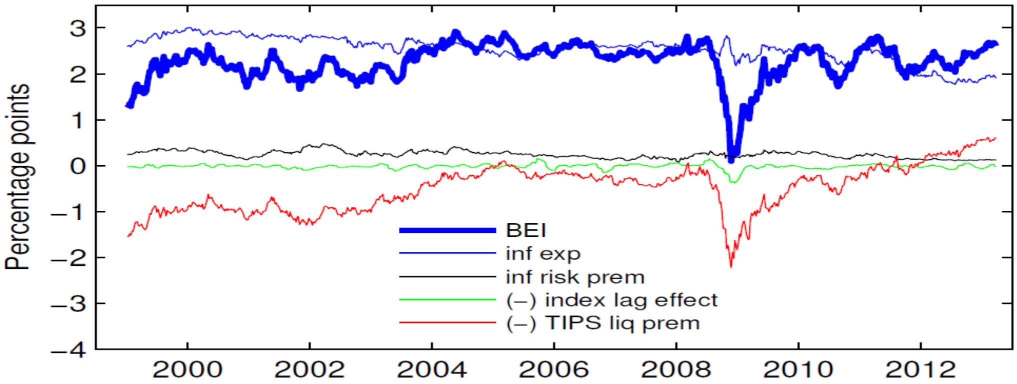
201. However, if there are some periods where investors place an unusually high value on liquidity, such as was the case in the GFC of 2008/09, using either nominal or indexed CGS as risk free rate proxies within the Sharpe-Lintner CAPM will result in:

- estimated risk free rates that are unusually low (unusually depressed by high value placed on liquid assets); and
- market risk premium estimates that are too low (unless they are increased to reflect an unusually high premium (relative to liquid CGS) required for investment in illiquid assets, do not offset the depressed CGS yields). (For low beta stocks (beta less than 1.0), this is true even if the QCA increases the MRP to incorporate the heightened liquidity risk premium).

202. The behaviour of CGS yields in the GFC provides a perfect illustration of this point. During the GFC it is generally accepted that the liquidity premium was exceptionally high. This led to significant falls in both indexed and nominal government bonds – but greater falls for the latter than the former.[74] This event is picked up in the academic literature which suggests that during this period break-even inflation was biased downward as an estimate of expected inflation due to nominal government bond yields being depressed by more than indexed government bond yields. This is illustrated in 2008/09 in the below figure – with the thick blue line falling well below the thick blue line.

74 Note that the events of September 2008 can be seen to have measurable differential impact on betas of nominal and indexed CGS – with the latter spiking up towards zero and the former spiking down further away from zero – see Figure 32 above.

Figure 33: Decomposing 10-year TIPS Breakeven Inflation D'Amico, Kim and Wei (2016)



Source: D'Amico, Kim and Wei (2014)[75]

203. However, the critical point to understand is that in the same period the required return on less liquid assets was increasing dramatically – consistent with the massive sell-off on global stock markets and the unprecedented spike in risk premiums on corporate debt.

204. This, at least in part, reflects the fact that the forces driving down yields on liquid government bonds were the *exact same* forces driving up required returns on less liquid corporate assets. If one applied an assumption, as the QCA indeed does, that the market risk premium is very stable and centred on historical average excess returns, then using a very liquid proxy for the risk free rate in a period of unusually high liquidity premium will tend to result in an underestimate of the true cost of capital. Such a conclusion was ultimately arrived at by the Australian Competition Tribunal in assessing the reasonableness of the AER's use of a risk free rate measured in the midst of the GFC.[76]

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75 D'Amico, S., Kim, D. H., and Wei, M., (2014) "Tips from TIPS: the Informational Content of Treasury Inflation-Protected Security Prices," FEDS Working Paper 2014-24 (Draft Version February 19, 2016)

76 *Application by EnergyAustralia and Others (includes corrigendum dated 1 December 2009)* [2009] ACompT 8 (12 November 2009), paras. 112-114.

> *The Applicants submitted that these facts demonstrated that basing a risk free rate on the AER's specified averaging periods would not achieve the objective of an unbiased rate of return consistent with market conditions at the date of the final decision. They appealed to expert opinion that the market risk premium was far higher than its deemed value while the risk free rate was abnormally low, so that the return required by investors was much higher than the AER's specified averaging period would generate.*
>
> …
>
> *The Tribunal considers that an averaging period during which interest rates were at historically low levels is unlikely to produce a rate of return appropriate for the regulatory period.*

205. On this basis, if there was a materially higher liquidity premium built into nominal CGS yields compared to indexed CGS yields, this would make indexed CGS yields a superior proxy for the risk free rate used to determine the required (real) rate of return on relatively illiquid corporate assets.

206. Of course, the indexed CGS yield would not be a perfect proxy for the risk free rate when valuing illiquid corporate equity. This is because both indexed and nominal CGS are highly liquid.[77] In circumstances where the liquidity premium is so high that it is differentially effecting nominal and indexed CGS yields, the liquidity premium difference between either form of CGS and illiquid corporate equity would dwarf the liquidity premium differential between nominal and indexed CGS.[78] That is, while both nominal and CGS yields will be depressed relative to required returns on risky assets, the indexed CGS yield will be less depressed.

77 Both the nominal and indexed CGS markets are highly liquid with turnover of around $1,000bn and $50bn respectively. While the turnover in nominal bonds is around 20 times larger both are very large in absolute magnitude. Moreover, liquidity is a function of the ability of an investor to divest their holding without moving the market and, given that investors' holdings on nominal CGS tend to be larger, the absolute turnover must be adjusted for the average holding of these bonds in an investor's portfolio. The standard way to do so is to divide turnover rates by total outstanding stock in order to provide the 'turnover ratio'. The Australian Financial Markets Association produces this metric for nominal CGS and it has fallen from 5.2 in 2007/08 to 4.7 in 3.2 in 2014/15. A similar metric for indexed CGS was around 1.2 in 2007/08 and 1.9 in 2014/15. On this metric, liquidity in nominal CGS is only modestly higher than for indexed CGS.

78 Noting that nominal and indexed CGS are likely the most liquid asset classes in Australia with many billions of dollars of turnover each year for a relatively homogenous assets.

Appendix A Convexity Bias

207. The convexity bias is caused by the curvature of the yield to price function and the dispersion of inflation expectation. It can be approximated using the yield to price function of a zero coupon bond based on the present value formula.

208. The model assumes the nominal yield contains two components, the expected real interest rate and the expected inflation. [79] The expected inflation is assumed to follow a log-normal distribution and the period of the bonds is assumed to be 5 years. We find the convexity bias is increasing on the dispersion of the belief on forecast inflation.

209. Table 6 shows the underestimation of expected inflation caused by the convexity bias. It shows than when the range of the 90% confidence interval is 200 basis, (this implies when the annual expected inflation is 2%, the range of the 90% confidence interval for annual inflation is from 1.1% to 3.1%) the impact of the convexity bias is only 2.2 basis points.

Table 6: Simulated Underestimation of Expected Inflation (basis points)

Expected inflation	Range of 90% Confidence Interval Around Mean (bppa)		
	100	150	200
1.5%	-0.5	-1.2	-2.2
2.0%	-0.5	-1.1	-2.0

79 The convexity bias does not depend on the expected real interest rate and its dispersion. Its impact on the price of nominal bond is offset by its impact on the price of the indexed bond. Therefore its effect disappears when the convexity bias is calculated.