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EXTRACTING INFLATION EXPECTATIONS AND RISK PREMIA FROM THE BREAKEVEN INFLATION RATE IN ICELAND

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Extracting inflation expectations and risk premia from the breakeven inflation rate in Iceland

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Abstract

The yield spread between a conventional nominal bond and a corresponding inflation-indexed bond – the so-called breakeven inflation rate – is a common measure of investors' inflation expectations. But the spread also includes two risk premia that can distort the breakeven rate as a measure of inflation expectations. I use a signal-extraction approach to jointly estimate underlying inflation expectations and the inflation and liquidity risk premia from Icelandic data on 2-year breakeven inflation rates. The estimated 2-year inflation expectations are much smoother than the breakeven rate and remain above the official 2.5% inflation target for most of the sample period. The two risk premia are found to be large and time-varying, highlighting the need for caution when interpreting the breakeven rate as a direct measure of inflation expectations. Finally, I find that the three subcomponents of the breakeven rate react differently to an unanticipated monetary tightening. The tightening leads to a gradual and persistent decline in inflation expectations and the inflation risk premium partly offset by a temporary increase in the liquidity premium, consistent with the "risk-taking" channel of monetary policy.

JEL classification: C32, E31, E43, E44, G12.
Keywords: Breakeven inflation, inflation expectations, inflation risk premia, liquidity risk premia, state-space model, Iceland.

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1 Introduction

The analysis and monitoring of inflation expectations is of central importance in any monetary framework focusing on stabilising the nominal economy. But inflation expectations are not directly observable. One approach is to use surveys where economic agents (such as households, firms, or financial market participants) are asked what they think inflation will be over a given horizon. But surveys have their drawbacks, including sampling issues and the sensitivity of responses to the exact wording of the survey questions and in what order they are posed. An alternative widely used measure of inflation expectations is therefore a market-implied measure obtained from the yield spread between a conventional nominal bond and a corresponding inflation-indexed bond that compensates the bondholder for inflation over the maturity of the bond. This yield spread, commonly called the breakeven inflation rate or inflation compensation, is a closely watched measure of inflation expectations among financial market participants and central banks alike and has the benefit of being observable in real time and reflecting the views of investors putting their own money on the line.

But this market-derived measure of inflation expectations is subject to two potentially important distortions. First, the breakeven inflation rate contains an inflation risk premium that is required to compensate risk-averse investors in nominal bonds for bearing the associated inflation risk over the investment horizon. Second, the market for inflation-indexed bonds is typically less liquid than the corresponding market for nominal debt. The breakeven inflation rate will therefore also reflect a compensation risk-averse investors demand for bearing this liquidity risk when buying inflation-indexed bonds.

Just as inflation expectations themselves, neither of these risk premia are directly observable. Furthermore, both are likely to vary over time and can be large, especially at times of high and volatile inflation and in times of financial distress. Using the breakeven inflation rate as a direct measure of inflation expectations can therefore be problematic. This is particularly true in countries like Iceland with a legacy of high and volatile inflation and a small bond market, notwithstanding its long history of issuing inflation-indexed bonds.

The aim of this paper is to try to estimate the true underlying inflation expectations and the two risk premia embedded in the breakeven inflation rate. To do this, I follow Gürkaynak, Sack and Wright (2010) and compensate the data on the breakeven inflation rate with surveys of inflation expectations in a state space framework estimated using the Kalman filter. Gürkaynak, Sack and Wright (2010) use a two-step approach where they first regress the breakeven rate on various liquidity risk proxies to obtain a liquidity-adjusted breakeven rate that is then used in a state space framework to estimate inflation expectations and the inflation risk premium. Here, however, I jointly estimate all the three unobservable components of the breakeven rate in a state space framework with survey data on inflation expectations and proxies of liquidity and inflation risk to identify the three components. The focus is on the 2-year horizon as that is the longest horizon for survey-based inflation expectations which stretch the furthest back in time. It is also the maturity that is usually argued to be the most relevant horizon for the conduct of monetary policy as it coincides with the commonly found time lag of peak monetary policy impact.

The resulting estimate of the risk-adjusted breakeven inflation rate should give a more accurate estimate of the true underlying inflation expectations than the raw data on the breakeven rate. I find that the estimated 2-year inflation expectations remain above the official 2.5% inflation target for most of the sample period, except for a relatively short period in the late 2010s when inflation expectations are broadly in line with the target. The estimated inflation expectations are, however, much less volatile than the breakeven inflation rate itself, reflecting significant time-variation in the two risk premia which are found to be just as important for explaining the variation in the breakeven rate as inflation expectations. The 2-year inflation risk premium has averaged around 160 basis points since 2006, rising even higher during periods of inflation scares such as in the financial crisis in 2008 and following the 2021 economic rebound after the Covid-19 pandemic and the Russian invasion of Ukraine in early 2022. The 2-year liquidity premium is similarly found to average close to 160 basis points since 2006, rising even higher in periods of financial distress. Although the literature has produced a wide range of estimates of these two premia, my estimates of the two risk premia are in the higher end of these estimates.

The two risk premia push the breakeven inflation rate in the opposite direction: the inflation risk premium introduces an upward bias in the breakeven rate as a measure of inflation expectations, while the liquidity premium distorts the breakeven rate downwards. The fact that the two risk premia are of similar size on average therefore implies that although there are periods when the breakeven rate deviates markedly from the estimated underlying inflation expectations, the breakeven rate is consistent with underlying inflation expectations on average as the two premia largely offset each other. Note also that the fact that the liquidity premium is on average of similar size to the inflation risk premium implies that the reduction in the cost of funding for the government from saving on paying the inflation risk premium by issuing inflation-indexed debt is largely cancelled out by the lower liquidity in the inflation-indexed market – at least over the period analysed here. Government issuing of inflation-indexed bonds may still prove valuable, however, as it provides an asset that investors can use as a hedge against inflation risk – a characteristic that other financial assets generally lack (cf. Bekaert and Wang, 2010).

Finally, I use the decomposition of the breakeven inflation rate to analyse how inflation expectations and the two risk premia respond to an unanticipated monetary policy tightening using the monetary policy shocks identified in Pétursson (2023). I find that an unanticipated monetary tightening leads to a gradual and persistent decline in inflation expectations and the inflation risk premium, while the liquidity premium increases temporarily on impact as investors shift to the safer real returns of inflation-indexed bonds as risk aversion increases and risk-taking becomes more costly. This liquidity effect, through the Borio and Zhu (2012) "risk-taking" channel of monetary policy, leads to a temporary increase in the breakeven inflation rate following a monetary tightening, but this effect is short-lived, and the breakeven rate soon starts to decline in line with the reduction in inflation expectations and the inflation risk premium. The VAR analysis also suggests that monetary policy shocks account for most of the medium-term fluctuations in inflation expectations. The proportion of the medium-term variability in the two risk premia accounted for by monetary policy shocks is smaller but is still economically and statistically significant.

The remainder of the paper is structured as follows. Section 2 discusses some stylised facts about the Icelandic bond market and how the breakeven inflation rate can be separated into inflation expectations and risk premia for inflation and liquidity risk. Section 3 reports estimates of a simple state space model where the data on the breakeven rate is supplemented with various survey-based measures of 2-year inflation expectations to obtain an estimate of the aggregate risk premium that is used in Section 4 to explore the information content of the observable proxies that I use to identify the two unobservable risk premia. In Section 5 I use these proxies together with survey-based measures of inflation expectations to jointly estimate the unobservable inflation expectations and the two risk premia. Section 6 analyses the dynamic relationship between monetary policy and these different subcomponents of the breakeven inflation rate and Section 7 concludes. Appendix 1 documents the data, while Appendices 2 and 3 document the robustness of the key results. Finally, Appendix 4 uses the decomposition of the breakeven rate to explore the key drivers of the nominal 2-year bond rate.

2 Inflation-indexed bonds and the breakeven inflation rate

2.1 Some stylised facts about the Icelandic bond market

Iceland has a long history of issuing marketable inflation-indexed government bonds, with the first bond issued in the mid-1960s – almost twenty years before its introduction in the UK and some thirty years before the first TIPS issuance in the US.[1] In fact, issues of inflation-indexed bonds dominated the Icelandic government bond market for long periods; for example, of the 22 government bonds outstanding at the start of 1997, 20 were inflation-indexed (see the top panel of Figure 1). The nominal market, however, gradually gained prominence and by the start of the sample period in the early 2000s, the number of nominal and inflation-indexed government bonds was roughly equal, although the inflation-indexed bonds continued to dominate the longer end of the market with a maximum maturity almost twice as long as nominal bonds. This was especially true for the so-called HFF-bonds which were bonds with maturity of up to 40 years, issued by the Housing Finance Fund (HFF), a government run entity which issued government-backed bonds to fund its mortgage lending to households. These HFF bonds were originally issued in 2004 and sustained until 2012 when their issuing ceased. These bonds dominated trading in inflation-indexed bonds in the first decade of the 2000s as can be seen in middle panel of Figure 1. The figure also shows how trading activity in the early part of the decade was dominated by the inflation-indexed market, with the trading share of nominal bonds as low as 25% in 2005. But by the middle of the following decade, the share of nominal bond trading had risen to more than 80%, and although it fell somewhat again in the latter half of the decade – especially following the outbreak of the Covid-19 pandemic – it has remained above 70% since. Thus, by the end of the sample period there are 7 actively traded nominal bonds outstanding with a maximum maturity of 20 years and 4 actively traded inflation-indexed bonds with a maximum maturity of 15 years.

While none of the inflation-indexed bonds currently traded on the secondary market are HFF-bonds, they continue to weigh heavily in the market value of outstanding debt as can be seen in Figure 1: in 2022 the market value of HFF bonds was about 0.8 trillion ISK (22% of GDP in 2022) or 44% of the total market value of government and HFF bonds, while the market value of the central government indexed debt was an additional 0.4 trillion ISK (11% of GDP) or 22% of the total market value. The market value of nominal debt therefore remained as low as a third of the total market value by the end of the sample or 0.6 trillion ISK (17% of GDP). This high share of inflation-indexed debt instruments in the total outstanding market value of domestic government debt is in the higher range among OECD countries as can be seen in the bottom panel of Figure 1. It remains below the share in Chile – another country with a long history of issuing indexed debt – but is similar to the share in Israel, closely followed by Brazil, the UK and Turkey.

[1] The history of issuance of inflation-indexed bonds stretches much further back, however, with the Commonwealth of Massachusetts in the US first experimenting with such bonds during the Revolutionary War in 1780 (see Deacon, Derry and Mirfenderski, 2004).

Figure 1 The Icelandic bond market. Individual bonds outstanding in the period 1997-2023 are plotted against their remaining maturity (in years) on the vertical axis. Trading volume and market value are in trillion of ISK. Trading share is the ratio of trading volume to market value. The international comparison shows inflation-indexed central government debt as a ratio of total domestic central government debt. Turnover rate is the ratio of trading volume to the outstanding market value.

With most of the issuance of inflation-indexed bonds being bought by long-term buy-and-hold investors, such as pension funds and life insurers, the turnover rate in these bonds tends to be lower than that for nominal bonds. This lower liquidity of the inflation-indexed market suggests that yields on indexed bonds are likely to trade at a premium relative to nominal bond yields as investors will demand a compensation for holding this liquidity risk. The bottom panel in Figure 1 shows that although the turnover rate of nominal bonds has declined (perhaps reflecting greater demand of domestic banks for high-quality government debt due to stricter Basel-related liquidity rules), the turnover rate of inflation-indexed bonds has also declined, and the relative turnover rate therefore remained broadly stable. This is explored in greater detail below when I attempt to identify this liquidity premium from the data on the yield spread between nominal and inflation-indexed bonds, i.e. the breakeven inflation rate (sometimes also called inflation compensation).

2.2 The breakeven inflation rate

The h-period breakeven inflation rate, $\pi^e_{b,t}(h)$, is defined as the spread between the yield on a conventional h-period nominal bond, $y_{n,t}(h)$, and a corresponding inflation-indexed bond, $y_{r,t}(h)$ (for simplification, the h-period notation is discarded in what follows):

$$\pi^e_{b,t} = y_{n,t} - y_{r,t} \tag{1}$$

The nominal yield can be decomposed as follows:[2]

$$y_{n,t} = r_t + \pi^e_t + \theta^\pi_t + \lambda_{n,t} \tag{2}$$

where r_t is the unobservable risk-free real interest rate, π^e_t is the expected inflation rate over the maturity of the bond, θ^π_t is an inflation risk premium, and $\lambda_{n,t}$ is a liquidity premium for the nominal bond. The yield on the inflation-indexed bond can also be decomposed in a similar way, where a corresponding liquidity premium, $\lambda_{r,t}$, introduces an upward bias in the inflation-indexed yield as a measure of the risk-free real rate:

$$y_{r,t} = r_t + \lambda_{r,t} \tag{3}$$

The breakeven inflation rate is therefore given by a generalised Fisher equation (with the simple Fisher equation, $y_{n,t} = y_{r,t} + \pi^e_t$, as a special case):

$$\pi^e_{b,t} = y_{n,t} - y_{r,t} = \pi^e_t + \theta^\pi_t + \theta^\lambda_t \tag{4}$$

where $\theta^\lambda_t = (\lambda_{n,t} - \lambda_{r,t})$ denotes the *relative* liquidity premium.[3]

[2] To simplify the exposition, I abstract from possible risk premia reflecting investor compensation for counterparty risk and unexpected variations in real interest rates as both cancel out when calculating the breakeven inflation rate. I also abstract from a possible inflation risk premium in the inflation-indexed rate due to indexation lags as these bonds are indexed to prices measured some time prior to the indexation date. This premium is typically thought to be very small (cf. D'Amico, Kim and Wei, 2018), particularly in Iceland given its short indexation lag (Breedon, 2012).

[3] The nominal liquidity premium is typically thought to be close to zero in advanced economies given the high liquidity of their nominal bond markets, which gives (if $\lambda_{n,t} = 0$) $\theta^\lambda_t = -\lambda_{r,t}$ and $\pi^e_{b,t} = \pi^e_t + \theta^\pi_t -$

Thus, although the breakeven inflation rate is the rate of inflation that *ex post* will make the nominal yield on both bonds equivalent, it can differ from actual *ex ante* inflation expectations due to the two (possibly time-varying) risk premia. The first reflects the extra yield demanded by risk-averse investors when investing in nominal bonds to compensate for bearing the risk that actual inflation deviates from the inflation they expected over the investment horizon. Although the inflation risk premium, θ_t^{π}, can in theory be negative as discussed below, it is typically found to be positive, therefore introducing an upward bias in the breakeven rate as a measure of inflation expectations.

The second reason why the breakeven inflation rate can deviate from actual inflation expectations reflects the fact that the market for inflation-indexed bonds is typically found to be less liquid than the corresponding market for nominal bonds. Risk-averse investors would therefore face greater risk in investing in the relatively less liquid inflation-indexed market than in the nominal bond market where they can resell their investment with relative ease. In this case $\theta_t^{\lambda} < 0$, which would lead the breakeven inflation rate to underestimate actual inflation expectations. This downward bias will therefore weigh against the upward bias due to the inflation risk premium and might, if $\theta_t^{\pi} + \theta_t^{\lambda} = 0$, exactly offset the upward bias due to the inflation risk premium.

The upper panel of Figure 2 shows the nominal and inflation-indexed 2-year yields on government bonds from 2003Q3 to 2023Q3, with the corresponding 2-year breakeven inflation rate shown in the lower panel of the figure. The 2-year yields are obtained from fitted zero coupon yield curves using the Nelson-Siegel approach (further detail on the data and its sources can be found in Appendix 1). The data are quarterly averages of daily data to match the sampled frequency of the survey-based measures of inflation expectations also shown in the lower panel of Figure 2. The data sample starts in 2003 as the fitted yield curves are less reliable prior to that date due to a scarcity of a sufficient number of actively traded bonds (especially nominal bonds as highlighted in the top panel of Figure 1). I focus on the 2-year horizon for yields and the breakeven inflation rate as that is the longest horizon for survey-based inflation expectations which stretch the furthest back in time. It is also the maturity that is usually argued to be the most relevant horizon for the conduct of monetary policy as it coincides with the commonly found time lag of peak monetary policy impact. In Appendix 2, I repeat part of the analysis for the 5-year breakeven rate, for which survey data for households and firms is

$\lambda_{r,t}$. It is not clear whether that assumption applies in Iceland, implying that the relative risk premium $\theta_t^{\lambda} = (\lambda_{n,t} - \lambda_{r,t})$ can only be identified. Note also that the two liquidity premia not only capture the liquidity of each bond market segment, but also various technical and institutional factors and market imperfections, such as trading costs, funding constraints, and demand imbalances (e.g. flight-to-safety demand) between the two types of bonds (see D'Amico, Kim and Wei, 2018).

only available from 2018. As shown in the Appendix, the key results reported here continue to hold at the 5-year horizon as well.

As Figure 2 shows, the breakeven rate rose sharply following a large depreciation of the exchange rate and the near collapse of the domestic financial system during the financial crisis in Iceland in 2008. The breakeven rate eased back below the 4% upper threshold of the Central Bank of Iceland inflation target in early 2010 and remained largely within the 1-4% threshold range until 2022 (and close to the 2.5% target on average from mid-2014 to 2021).[4] But by 2021 the breakeven rate started to creep up again, breaching the 4% upper threshold in 2022 and peaking at 6.8% in early 2023. The breakeven rate has eased slightly again recently but remains above 5% by the end of the sample period.

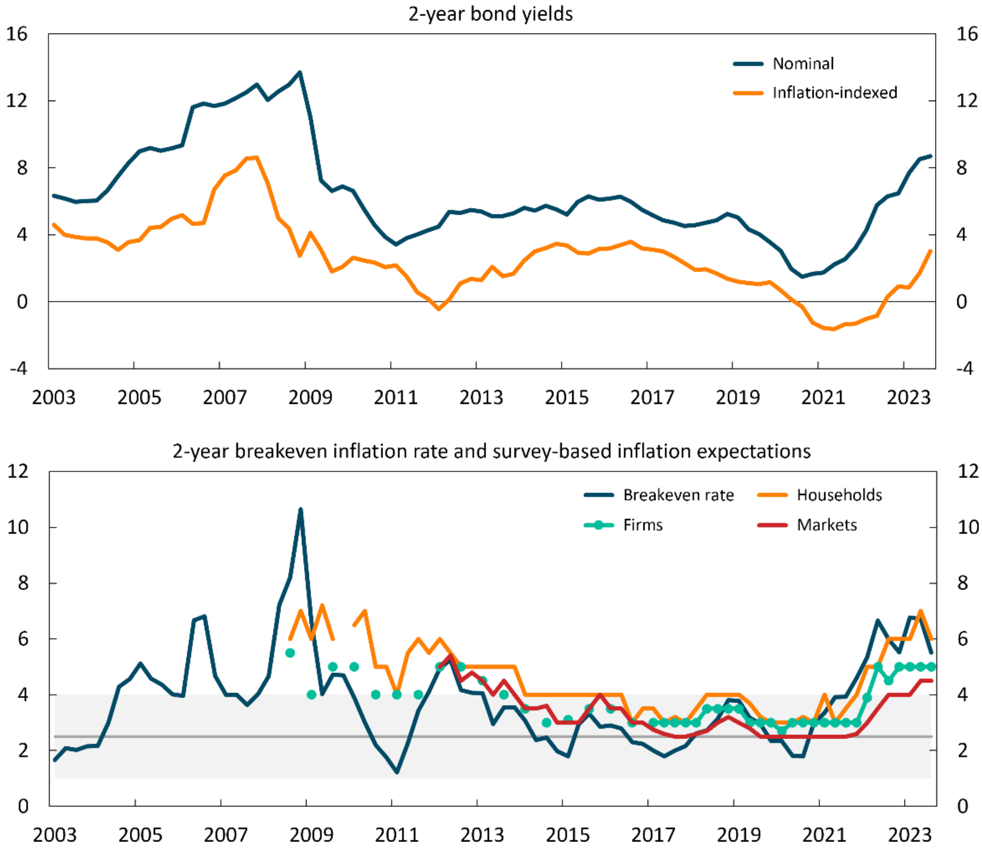

Figure 2 Bond yields, breakeven inflation, and survey-based inflation expectations. The horizontal line shows the official 2.5% inflation target and the shaded area the 1-4% threshold range of the target.

If the liquidity premium is relatively small and stable and the inflation risk premium is positive, one would expect the breakeven rate to consistently be above the survey measures of inflation expectations (given that the latter is on average a reasonably

[4] The breach of the threshold range simply serves to trigger a special public report to the Government explaining the threshold breach.

accurate measure of inflation expectations). But it is clear from the lower panel of Figure 2 that this is seldom the case: the breakeven rate remains below the survey measures for most of the period after the financial crisis and until late 2010s – suggesting (in the absence of a deeply negative inflation risk premium) a significant liquidity premium that has pushed the breakeven rate below the survey measures of inflation expectations.

The greater volatility of the breakeven rate compared to the survey measures and the large and frequent deviations between these measures also suggests that the two risk premia are sizeable and vary over time, and that both are needed to explain the movements in the breakeven rate. In what follows, I attempt to extract the true underlying inflation expectations and the two risk premia from the breakeven rate using the signal-extraction approach similar to that suggested by Gürkaynak, Sack and Wright (2010).

3 A simple state space model of the breakeven inflation rate

Gürkaynak, Sack and Wright (2010) combine data on the breakeven inflation rate with survey-based measures of inflation expectations in a signal extraction setup and use the Kalman filter to estimate the true underlying inflation expectations and the inflation risk premium.[5] Here, I use a similar approach to obtain an estimate of the aggregate risk premium that is used in the preliminary regression in the next section to analyse the information content of the risk premium proxies used in Section 5.

I start by defining the aggregate risk premium as $\theta_t = \theta_t^{\pi} + \theta_t^{\lambda}$, which gives Eq. (4) as:

$$\pi_{b,t}^e = \pi_t^e + \theta_t \tag{5}$$

To identify these two unobservable variables, I use a survey of 2-year inflation expectations among market participants. Although these expectations should be the one most relevant to the analysis given that the participants in the survey most closely match those trading in the bond market, the data is only available since 2012 and involves a relatively small sample of survey respondents. Survey-based measures of 2-year inflation expectations of households and firms that extend further back and include a much larger sample of respondents are therefore also included. The three surveys of inflation

[5] They pre-filter the data of a regression-estimated liquidity premium and use this liquidity-adjusted breakeven rate in the state space setup. See Kim and Orphanides (2012) and Chernov and Mueller (2012) for a discussion of how survey data can improve estimates of term structure models and the underlying components of the breakeven inflation rate.

expectations are all assumed to be a noisy measure of the true underlying inflation expectations that correctly capture these expectations *on average*:[6]

$$\pi^e_{j,t} = \pi^e_t + u_{j,t} \tag{6}$$

where $\pi^e_{j,t}$ $(j = h, f, m)$ are 2-year inflation expectations of households, firms, and market participants and $u_{j,t}$ are independently and identically distributed, mutually uncorrelated measurement errors with mean zero and variance $\sigma^2_{u,j}$.

Following Gürkaynak, Sack and Wright (2010), I assume that the underlying 2-year inflation expectations can be approximated by a random walk (capturing the high persistence typically found in inflation rates, cf. Stock and Watson, 2007):[7]

$$\pi^e_t = \pi^e_{t-1} + \varphi_t \tag{7}$$

while the unobserved risk premium is given as an AR(1) process:

$$\theta_t = \gamma\theta_{t-1} + \varepsilon_t \tag{8}$$

where φ_t and ε_t are independently and identically distributed, mutually uncorrelated random variables with mean zero and variances σ^2_φ and σ^2_ε, respectively.

Eqs. (5) and (6) give the measurement equation of the system:

$$\begin{pmatrix} \pi^e_{b,t} \\ \pi^e_{h,t} \\ \pi^e_{f,t} \\ \pi^e_{m,t} \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 1 & 0 \\ 1 & 0 \\ 1 & 0 \end{pmatrix} \begin{pmatrix} \pi^e_t \\ \theta_t \end{pmatrix} + \begin{pmatrix} 0 \\ u_{h,t} \\ u_{f,t} \\ u_{m,t} \end{pmatrix} \tag{9}$$

while Eqs. (8) and (9) define the state equation of the system:

$$\begin{pmatrix} \pi^e_t \\ \theta_t \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & \gamma \end{pmatrix} \begin{pmatrix} \pi^e_{t-1} \\ \theta_{t-1} \end{pmatrix} + \begin{pmatrix} \varphi_t \\ \varepsilon_t \end{pmatrix} \tag{10}$$

or in state space form:

[6] This is extended in Appendix 3 to allow a time-varying bias in the survey measures – which is periodically found to be statistically significant in the household surveys but not in the other two survey measures. As documented in the Appendix, the key results of the paper are robust to this extension.

[7] This implies that inflation expectations are a slow-moving unit root process. This specification is general enough to capture other forms of non-stationarity, such as structural breaks, and estimating the process freely supports the near-unit root assumption. Judging from the statistical properties of the difference between the breakeven rate and the survey measures of inflation expectations – a simple measure of the risk premium – the AR(1) specification in Eq. (8) also seems a reasonable approximation of the aggregate risk premium.

$$\boldsymbol{x}_t = \boldsymbol{\Phi z}_t + \boldsymbol{u}_t \tag{11}$$

$$\boldsymbol{z}_t = \boldsymbol{\Gamma z}_{t-1} + \boldsymbol{v}_t \tag{12}$$

where $\boldsymbol{x'}_t = (\pi^e_{b,t}, \pi^e_{h,t}, \pi^e_{f,t}, \pi^e_{m,t})$ is the measurement vector, $\boldsymbol{z'}_t = (\pi^e_t, \theta_t)$ is the state vector, and $\boldsymbol{u'}_t = (0, u_{h,t}, u_{f,t}, u_{m,t})$ and $\boldsymbol{v'}_t = (\varphi_t, \varepsilon_t)$ are error terms.

The model is estimated using maximum likelihood with quarterly data from 2003Q1 to 2023Q3. As shown in Table 1, the risk premium appears quite persistent, with the point estimate of the AR(1) parameter above 0.8. As expected, the household survey of inflation expectations appears to be the noisiest measure of inflation expectations, while the market survey gives the most precise signal.

Table 1 State space model for estimating inflation expectations and the aggregate risk premium

Parameter	Estimate	Standard error	p-value
γ	0.820	0.093	0.000
$\sigma_{u,h}$	1.014	0.030	0.000
$\sigma_{u,f}$	0.524	0.110	0.000
$\sigma_{u,m}$	0.154	0.086	0.077
σ_{φ}	0.283	0.037	0.000
σ_{ε}	0.832	0.113	0.000
$\log L$	-261.89		

The table reports maximum likelihood estimation results for the state space model in Eqs. (5)-(8). The standard errors are computed using the Huber-White method.

Figure 3 gives the smoothed Kalman filter estimates of the two state variables. The pre-2008 estimates are found to be relatively unprecise due to the lack of survey-based data (the figure therefore omits the period before 2006) but from 2012, the state variables become more tightly estimated. The top panel shows that the estimated 2-year inflation expectations remain stuck at around 5% from 2006 until late 2010 when they start to gradually ease towards the official 2.5% inflation target, reaching it in late 2017 and remaining there until late 2021 when they start to creep up again, reaching 4.5% by the end of the sample period.

The estimated aggregate risk premium ($\theta_t = \theta^\pi_t + \theta^\lambda_t$) in the middle panel of Figure 3 tends to be negative during the early part of the period (suggesting that the negative distortion in the breakeven rate from the relative liquidity premium dominated the positive distortion from the inflation risk premium) but is close to zero for most of the last decade. There are two episodes where θ_t turns significantly positive, however. The first one is during the financial crisis in 2008 where most of the increase in the breakeven inflation rate is attributed to a sharp rise in the aggregate risk premium, as can be seen in the bottom panel of Figure 3. The second episode is the post-Covid-19 period since 2021 where an increase in the aggregate risk premium is driving most of the initial increase in the breakeven rate, while a pickup in inflation expectations plays a larger role from 2022 onwards.

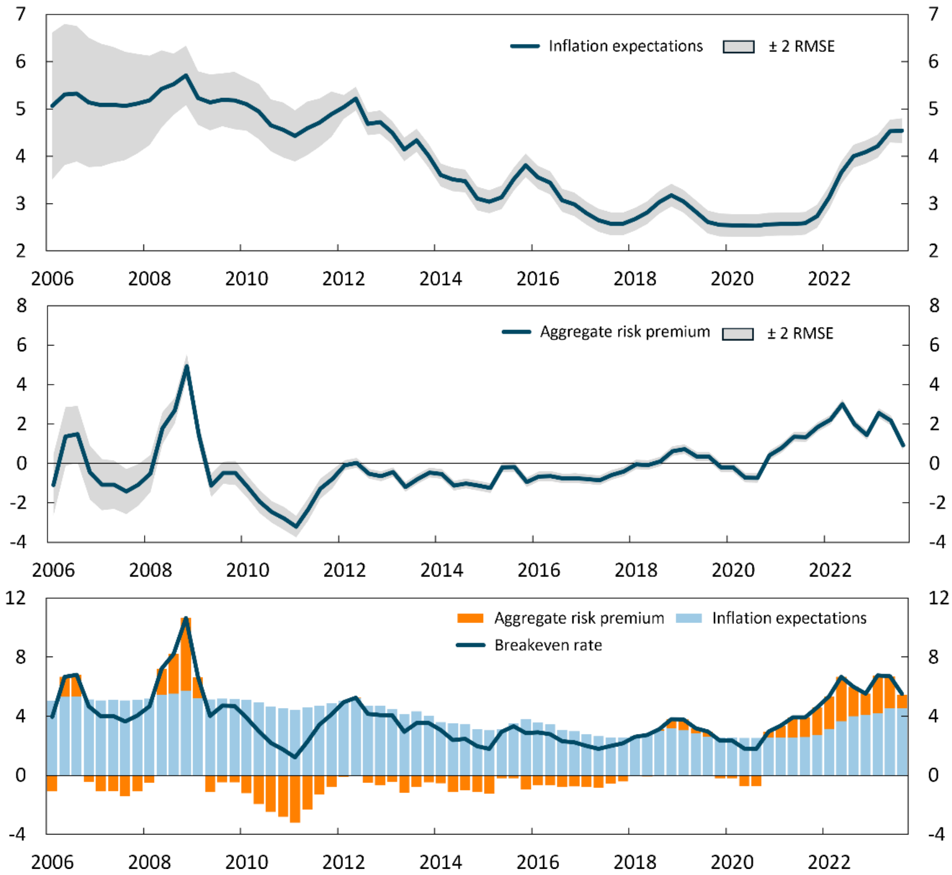

Figure 3 Smoothed Kalman estimates of 2-year inflation expectations and the aggregate risk premium and their contribution to the breakeven inflation rate obtained from the state space model in Eqs. (5)-(8).

It seems likely that these two episodes of a rising aggregate risk premium reflect, at least to some extent, a rising inflation risk premium due to the increase in uncertainty about future inflation coinciding with the large increase in inflation during both these episodes. But they could also reflect fluctuations in the liquidity premium given the market turmoil following the financial crisis in 2008 and the Covid-19 pandemic in 2020. In the next section, I explore this issue further and attempt to separate the aggregate risk premium into these two risk premia using observable proxies of liquidity and inflation risks.

4 Proxies for liquidity and inflation risk

In this section I delve deeper into the analysis of the aggregate risk premium estimated above from the breakeven inflation rate and attempt to identify proxies that can help separate the aggregate premium into its two subcomponents. I first discuss the proxies and then report some preliminary regression results showing how much of the variation in the aggregate risk premium appears to be captured by the proxies.[8]

4.1 A proxy for liquidity risk

The bid-ask spread is used as a measure of bond market liquidity, with the difference between the bid-ask spread in the nominal bond market and its inflation-indexed counterpart used as an observable proxy for relative liquidity risk (see D'Amico, Kim and Wei, 2018, and Andreasen, Christensen and Riddell, 2021). This data is shown in the upper panel of Figure 4. Note that the bid-ask spread is not based directly on actual trading for specific bonds but is calculated from a Nelson-Siegel estimation of the bid and ask zero-coupon curves, respectively. The estimated bid-ask spreads can therefore become negative, especially during periods when the yield curve fitting is based on a small number of bonds or when there are extended periods when no trades take place (this is indeed what happens on three occasions for the inflation-indexed bid-ask spread early in the sample period: in 2003Q2, 2004Q4 and between 2006Q4-2007Q2). I also tried using the relative trading volume from Figure 1 as an additional proxy for liquidity risk, but it turned out to be statistically insignificant.[9]

The relative bid-ask spread tends to fluctuate between -10 to 10 basis points but there is a large spike around the financial crisis in late 2008 when the spread increases to 50 basis points. The crisis led to a large sell-off of domestic financial assets. With buyers of domestic bonds hard to find, bond liquidity virtually dried up and bid-ask spreads blew up. The spike in the nominal bid-ask spread is much larger than in its indexed counterpart, however, reflecting the much greater exit of foreign investors from the nominal market compared to the indexed market where these foreign investors had a much smaller presence (see also the relative fall in the turnover rates in Figure 1).

[8] As shown in Appendix 3, the estimated inflation expectations from the simple state space model in the previous section that is used to generate the aggregate risk premium closely mirrors the market survey-based inflation expectations ($\pi^e_{m,t}$). An alternative approach that gives very similar results (but is only available from 2012) would therefore be to use $\pi^e_{b,t} - \pi^e_{m,t}$ as a preliminary proxy for the aggregate risk premium.

[9] Kajuth and Watzka (2011) and Andreasen, Christensen and Riddell (2021) similarly find that the relative trading volume is a poor proxy for liquidity risk in the US.

There are also some fluctuations in the bid-ask spread around the Covid-19 pandemic, which are mainly attributed to the spread in the inflation-indexed market.

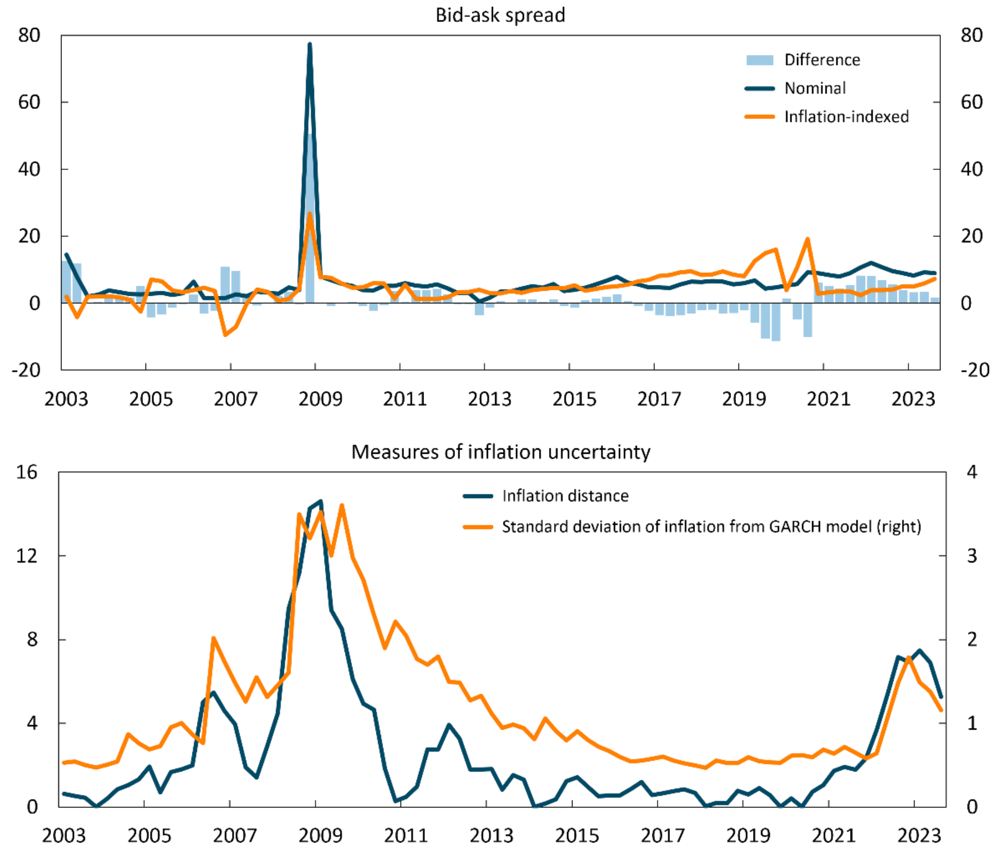

Figure 4 Bid-ask spread in bond market (in basis points) and two measures of inflation uncertainty: the absolute deviation of inflation from target (in percentage points) and the standard deviation of inflation from a GARCH model (in percentages).

4.2 A proxy for inflation risk

The inflation risk premium should be related to the level of inflation uncertainty, which is often estimated using various measures of inflation volatility (cf. Kajuth and Watzka, 2011).[10] It is, however, well established that inflation volatility and uncertainty increases with the level of inflation. Thus, an alternative measure of inflation uncertainty used here is the absolute deviations of inflation from the official 2.5% inflation target. This

[10] The theoretical interpretation of the inflation risk premium is a bit more subtle, however. Standard equilibrium asset price models indicate that the inflation risk premium is determined by the correlation of inflation and wealth (or consumption). When this correlation is negative (positive), an unanticipated rise in inflation that erodes the real return on nominal bonds will coincide with bad (good) states of the world, thus requiring a positive (negative) compensation to invest in nominal bonds rather than in its inflation-protected counterpart (see, for example, Bekaert and Wang, 2010, Campbell, Shiller and Viceira, 2009, and Piazzesi and Schneider, 2007). This correlation can vary over time and lead to a negative inflation risk premium, especially during periods of low inflation and deflation (cf. D'Amico, Kim and Wei, 2018).

measure of inflation uncertainty is shown in the lower panel of Figure 4. Worth highlighting are two episodes of a sharp increase in this measure of inflation uncertainty: first, at the onset of the financial crisis in 2008 and, second, following the 2021 economic rebound after the Covid-19 pandemic and the Russian invasion of Ukraine in early 2022 – episodes that can both be labelled as "inflation scares" (Goodfriend, 1993). Inflation uncertainty is much lower in between these two episodes, however. An alternative measure of inflation uncertainty, based on the conditional volatility of inflation from a GARCH model, shows a very similar pattern.[11] I also tried using the 2-year and 5-year rolling window standard deviation of inflation and the dispersion of inflation expectations survey responses (using data from the survey of market participants from 2012 but extending the data further back by using regression back-casting with data from surveys among households and firms).

There are two reasons I opt to use the absolute distance of inflation from target as a measure of inflation uncertainty. First, preliminary regression results (discussed in the next section) show that the preferred measure explains a larger share of the variation in the aggregate risk premium than the alternative measures. Second, as reported below, the long-run effect of the preferred inflation uncertainty measure on the risk premium is estimated to be positive as expected *a priori* but is found to be negative (albeit not statistically significant) for the other measures (Kajuth and Watzka, 2011, run into similar issues with some of their proxies for inflation risk). The absolute inflation distance measure is therefore used as the proxy for inflation uncertainty in what follows.

4.3 Preliminary regression analysis

Table 2 reports results from regressing the aggregate risk premium, θ_t, estimated from the state space model in Eqs. (5)-(8) on the chosen liquidity (the relative bid-ask spread) and inflation (absolute inflation distance from target) risk proxies for the period 2003Q1-2023Q3. The risk premium is regressed on a constant and the contemporaneous value and four lags of each proxy. Breedon, Pétursson and Vitale (2023) find that the introduction of capital controls after the financial crisis in 2008 had a significant effect on the efficiency and pricing behaviour of the foreign exchange market in Iceland and I therefore add a dummy variable accounting for the capital controls period to the liquidity risk regressions. I follow Breedon, Pétursson and Vitale (2023) and assume that the capital controls remained from November 2008 until they were gradually phased out in March 2017 when the final restrictions on domestic residents and on foreign investors

[11] The GARCH measure of inflation volatility is the conditional standard deviation of inflation obtained using a GARCH(1,1) model for year-on-year inflation with a Generalised Error Distribution (GED) to account for possibly non-conditional normally distributed errors.

were lifted. The dummy variable is therefore assumed to equal one from 2008Q4 to 2017Q1 and zero otherwise.

The first two columns of Table 2 show the results of regressing θ_t on the liquidity risk proxy and the inflation risk proxy, respectively. Both proxies have a positive effect on the risk premium as expected *a priori* and the sum of the estimated coefficients is found to be statistically significant from zero based on Newey-West adjusted standard errors. The null hypothesis that each of the current and lagged coefficients is separately zero is strongly rejected as well. The proxies are found to explain about 40-60% of the variation in θ_t over the estimation period. The final column of Table 2 similarly reports the results for the joint regression of the risk premium on these two risk proxies. The sum of the current and lagged coefficients continues to carry the expected sign but is now found to be insignificant from zero. However, the joint significance test continues to suggest that both variables are statistically significant and explain about two-thirds of the total variation in θ_t.

Table 2 Preliminary regression results for the aggregate risk premium

			Joint regression	
Parameter	Bid-ask spread	Inflation distance	Bid-ask spread	Inflation distance
Sum of coefficients	0.191	0.140	0.053	0.098
Standard error	0.047	0.060	0.061	0.078
p-value	0.000	0.022	0.387	0.210
Joint significance (p-value)	0.003	0.000	0.000	0.000
R^2	0.410	0.569	0.663	
S.E. of regression	1.197	1.016	0.935	

The table reports results from regressing the estimated aggregate risk premium (θ_t) from the state space model in Eqs. (5)-(8) on a constant and the contemporaneous value and 4 lags of proxies of liquidity and inflation risks, respectively, with standard errors computed using the Newey-West method. The first column reports the outcome of regressing the risk premium on the relative bid-ask spread. The second column reports outcome of regressing the risk premium on the absolute distance between inflation and the inflation target. The final column reports the outcome of regressing the risk premium jointly on both proxies. The regressions involving the bid-ask spread include a dummy variable for the capital controls period (equal to one from 2008Q1-2017Q1 and zero otherwise). Reported are the sum of the coefficients for each proxy variable and a Wald test for the null hypothesis that this sum is zero. Also reported is a F-test for the joint hypothesis that each of the explanatory variable coefficients is separately zero.

5 A state space model of inflation expectations and the two risk premia

5.1 Estimation results

Now that I have found what appear to be two useful instruments to separate the aggregate risk premium into its two subcomponents, the state space model in Section 3 can be expanded to estimate the three unobserved variables simultaneously using the two proxies from the previous section to help us identify the two risk premia:

$$\pi^e_{b,t} = \pi^e_t + \theta^\pi_t + \theta^\lambda_t \tag{13}$$

As in Section 3, the three survey-based measures of inflation expectations are assumed to give a noisy measure of the true underlying inflation expectations (with $j = h, f, m$):

$$\pi^e_{j,t} = \pi^e_t + u_{j,t} \tag{14}$$

which again are approximated by a random walk:

$$\pi^e_t = \pi^e_{t-1} + \varphi_t \tag{15}$$

Instead of modelling the aggregate risk premium as a simple AR(1) process as in Section 3, the inflation risk premium is now approximated by a constant plus the contemporaneous and four lagged values of the inflation distance variable, π^{dist}_t. Also included is a lagged value of the inflation risk premium to capture any remaining autocorrelation in the premium:

$$\theta^\pi_t = \mu_\pi + \gamma_\pi \theta^\pi_{t-1} + \sum_{k=0}^{4} \beta_{\pi,k}\, \pi^{dist}_{t-k} + \varepsilon_{\pi,t} \tag{16}$$

Similarly, the liquidity premium is approximated by a constant plus the contemporaneous and four lagged values of the relative bid-ask spread, b_t, and its own lag. Also included is the dummy variable, D_t, for the capital controls period from 2008Q4 to 2017Q1:

$$\theta^\lambda_t = \mu_\lambda + \delta_\lambda D_t + \gamma_\lambda \theta^\lambda_{t-1} + \sum_{k=0}^{4} \beta_{\lambda,k} b_{t-k} + \varepsilon_{\lambda,t} \tag{17}$$

The error terms, $\varepsilon_{\pi,t}$ and $\varepsilon_{\lambda,t}$ (for example capturing measurement errors in the risk proxies and curve-fitting errors from the zero coupon curves estimation) are assumed to be independently and identically distributed, mutually uncorrelated random variables with mean zero and variances $\sigma^2_{\varepsilon,\pi}$ and $\sigma^2_{\varepsilon,\lambda}$, respectively.

Table 3 State space model for joint estimation of inflation expectations and liquidity and inflation risk premia

Parameter	Coefficient estimate	Standard error	p-value
μ_π	0.783	0.414	0.059
γ_π	0.442	0.003	0.000
μ_λ	-0.599	0.441	0.173
δ_λ	-0.697	0.338	0.039
γ_λ	0.442	0.003	0.000
$\sigma_{u,h}$	0.933	0.117	0.000
$\sigma_{u,f}$	0.292	0.353	0.411
$\sigma_{u,m}$	0.393	0.289	0.179
σ_φ	0.301	0.102	0.004
$\sigma_{\varepsilon,\pi}$	0.493	0.066	0.000
$\sigma_{\varepsilon,\lambda}$	0.406	0.069	0.000
$\sum_{k=0}^{4} \beta_{\pi,k}$	0.017	0.051	0.742
$\sum_{k=0}^{4} \beta_{\lambda,k}$	0.009	0.030	0.767
Joint significance test for $\beta_{\pi,k}$			0.000
Joint significance test for $\beta_{\lambda,k}$			0.034
$\log L$	-244.98		

The table reports maximum likelihood estimation results for the state space model in Eqs. (13)-(17). The joint significance test is a F-test for the joint hypothesis that each of the $\beta_{\pi,k}$ and $\beta_{\lambda,k}$ $(k = 0, \dots, 4)$ coefficients is separately zero. The standard errors are computed using the Huber-White method.

Table 3 summarises the results. As in Table 1, the household survey of inflation expectations is found to be the least informative measure of inflation expectations, with the two other surveys now found to be similarly informative. As in the preliminary regression analysis in the previous section, the long-run effects of each of the risk proxies are found to be insignificant from zero, but the null hypothesis that each of the current and lagged coefficients are separately zero is strongly rejected by the data. The dummy variable for the capital controls period is found to be significantly negative, suggesting that θ_t^λ was more deeply negative during this period, which would be consistent with capital controls pushing both liquidity premia up but having larger effects on the inflation-indexed liquidity premium, $\lambda_{r,t}$, – thus making θ_t^λ more negative. Finally, the coefficients on the two lagged premia are found to be highly significant. The point estimate of both is roughly 0.4, which is lower than found for the aggregate risk premium in Section 3, indicating that some of the inherent persistence in the two risk premia is now captured by the persistence in the two risk proxies.

Figure 5 shows the smoothed Kalman filter estimates of the three state variables. Inflation expectations gradually increase from roughly 4% in early 2006 to more than 5% in late 2008 and fluctuate between 4% and 5% until mid-2012 when they start to ease again, falling below the 4% upper threshold in early 2014 and below 3% in early 2017. They remain close to or below 3% until late 2021, when they start rising again and reach almost 5% by the end of the sample period.

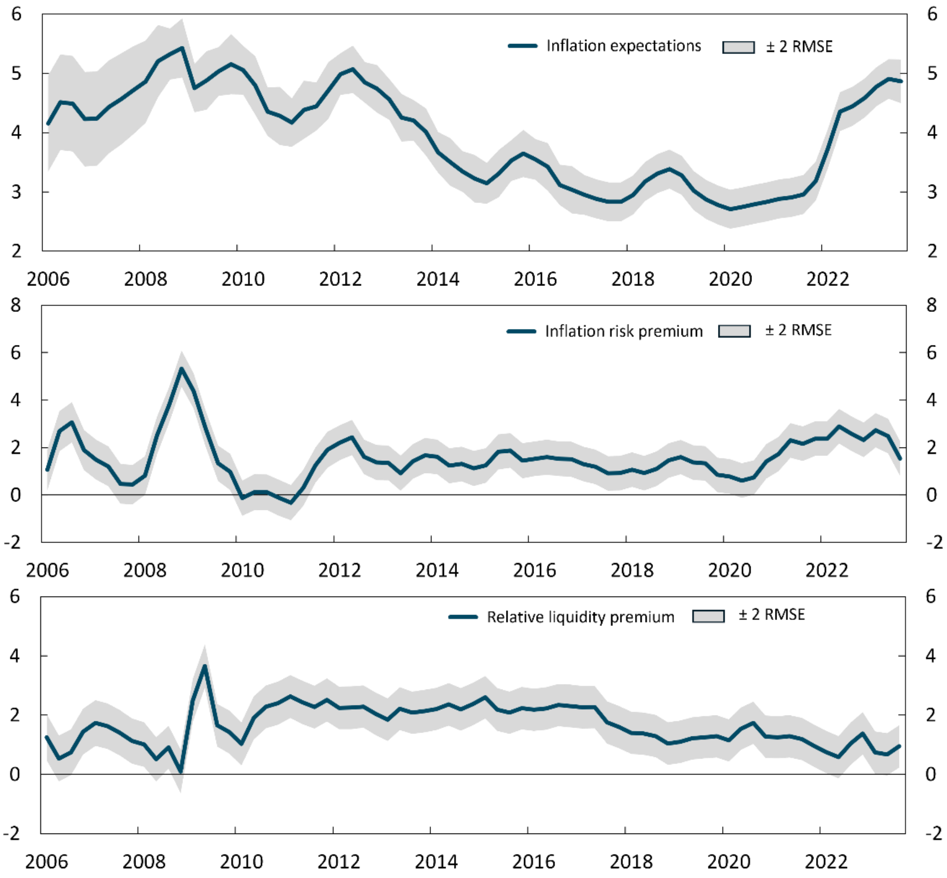

Figure 5 Smoothed Kalman estimates of 2-year inflation expectations and inflation and liquidity risk premia obtained from the state space model in Eqs. (13)-(17). To ease interpretation, the figure shows the negative of the relative liquidity premium, i.e. $-\theta_t^\lambda = \lambda_{r,t} - \lambda_{n,t}$.

There is a sharp increase in the inflation risk premium during the financial crisis, with the risk premium peaking at 532 basis points in 2008Q4 following the collapse of the currency. The risk premium falls back again in 2009 and remains close to zero from 2010 to mid-2011 – even becoming slightly negative for part of the period, presumably reflecting rising deflation concerns following the sharp economic contraction after the financial crisis (with output contracting by close to 15% from 2008Q4 to 2010Q1). This deflationary fear would push investors to accept investing in nominal bonds without a compensation for future inflation risk or even at a small discount.[12] This is consistent with a number of other studies that have found a low or even negative inflation risk premium (especially for shorter maturities) during periods of low inflation and, in particular, during periods of financial turmoil such as the Global Financial Crisis (GFC) in the late 2000s (see the discussion in Section 5.3). But as Figure 5 shows, the inflation risk premium gradually picks up again and remains relatively stable and close to 100-150 basis points from late 2011 to late 2019 when it starts to ease below 100 basis points. However, it starts rising again as inflation picked up following the 2021 economic rebound after the Covid-19 pandemic and the Russian invasion of Ukraine in early 2022. The premium peaks at 289 basis points in mid-2022 before gradually easing to 154 basis points by the end of the sample period.

As expected, the inflation-indexed liquidity risk premium is found to be larger than its nominal counterpart. The relative liquidity premium therefore tends to be negative (displayed as positive in Figure 5, which shows the negative of the relative liquidity premium to ease the discussion, i.e. $-\theta_t^\lambda = \lambda_{r,t} - \lambda_{n,t}$). There are large fluctuations in the relative liquidity premium around the financial crisis, with the premium falling to close to zero in 2008Q4 as the nominal bond market dried up following the exit of foreign investors discussed earlier which led to an increase in $\lambda_{n,t}$ (and therefore a decline in $-\theta_t^\lambda$ towards zero), followed by large fluctuations in the premium in the aftermath of the crisis. The liquidity premium gradually settles at around 230 basis points from mid-2010 until after the capital account liberalisation in mid-2017 when it starts to decline to 100-150 basis points and further to below 100 basis points from 2022, reaching 95 basis points by the end of the sample period.

Finally, note that there is a relatively modest and short-lived increase in the liquidity premium following the Covid-19 pandemic in early 2020 which wreaked havoc in bond markets around the world, probably reflecting the effectiveness of the measures announced by the Central Bank of Iceland in June that year that the Bank stood ready if needed to act as a market-maker of last resort in the bond market. The announcement appeared to calm the market, and in the end the Bank bought a limited amount of bonds in the secondary market (and much less than it initially said it would be ready to buy). See Andreasen, Christensen and Riddell (2021) for a discussion of the effects of the pandemic on the liquidity premium in the US.

[12] Although year-on-year inflation never fell below 2% following the crisis and the survey-based measures of 2-year inflation expectations remained well above zero throughout (see Figure 2), quarter-on-quarter inflation did become negative in late 2010 and corporate expectations of inflation 1 year ahead fell to zero in the first half of 2009. This fear of deflation may also have been better reflected in survey measures among market participants, but these surveys are unfortunately not available for the period right after the financial crisis and the collapse of the banking system.

5.2 Decomposing the breakeven inflation rate

The upper panel of Figure 6 shows that the estimated inflation expectations are much smoother than the breakeven rate. This is also reflected in the lower panel of the figure, which shows that the two risk premia tend to have offsetting effects on the breakeven rate. There are periods, however, when the breakeven rate deviates markedly from the estimated inflation expectations, such as during the financial crisis and the more recent period from 2021, when the breakeven rate has significantly overestimated the true level of inflation expectations.

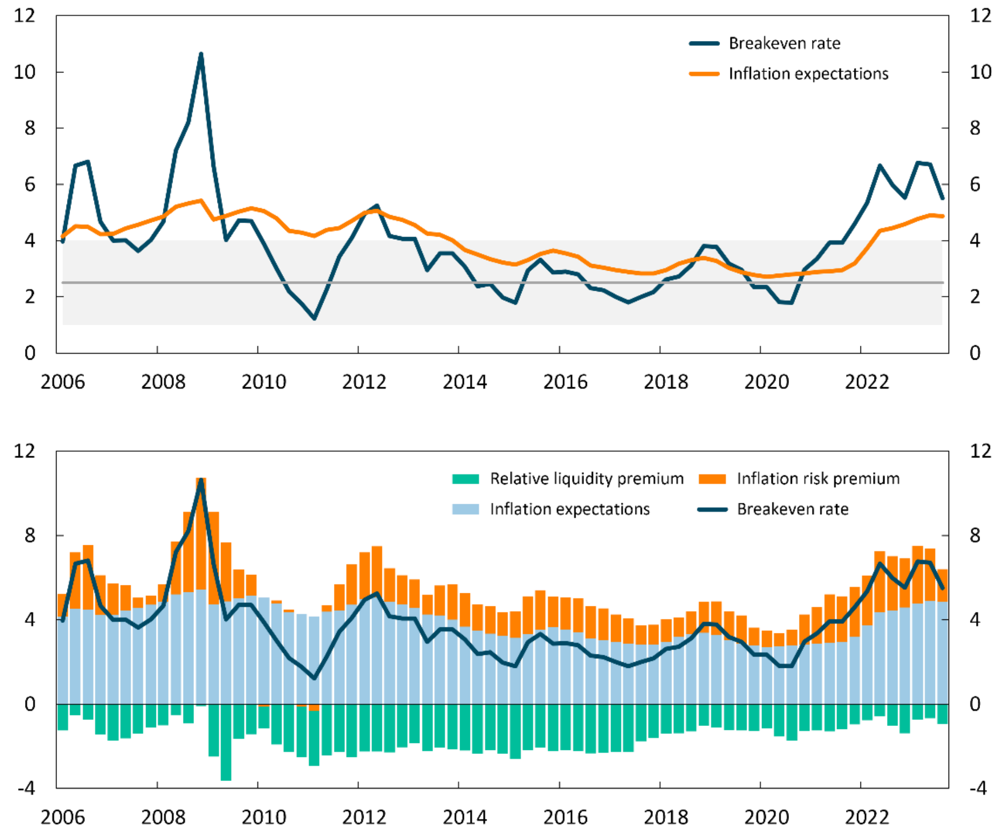

Figure 6 The breakeven inflation rate and its subcomponents. The horizontal line shows the official 2.5% inflation target and the shaded area the 1-4% threshold range of the target.

The figure also highlights the importance of taking account of movements in the two risk premia when interpreting changes in the breakeven rate. For example, much of the sharp increase in the breakeven rate during the financial crisis reflects an increase in the inflation risk premium and most of the fluctuations in the breakeven rate just after the financial crisis are largely due to fluctuations in the two risk premia (especially the liquidity premia). There is also a sizeable contribution from the inflation risk premium to the pickup in the breakeven rate in 2021, which also explains most of the decline in the breakeven rate towards the end of the sample period rather than a significant reversal of inflation expectations.

Finally, Table 4 reports the in-sample variance decomposition of the breakeven rate based on:

$$var(\pi^e_{b,t}) = cov(\pi^e_{b,t}, \pi^e_t) + cov(\pi^e_{b,t}, \theta^\pi_t) + cov(\pi^e_{b,t}, \theta^\lambda_t) \quad (18)$$

Over the period including the financial crisis, it appears that the inflation risk premium explains the largest share of the variation in the breakeven rate (45%), with the smallest contribution to the variation explained by the liquidity premium (23%). However, the contributions of inflation expectations and the inflation risk premium are roughly equal over the last decade, with a slightly smaller contribution from the liquidity premium. The component reflecting inflation expectations and inflation risk is therefore found to explain more than 70% of the variation in the breakeven rate, with the remainder explained by the relative liquidity premium.[13]

Table 4 In-sample variance decomposition of the breakeven inflation rate

Period	Inflation expectations	Inflation risk premium	Liquidity premium
2006-2023	0.318	0.453	0.229
Last 10 years	0.360	0.351	0.289

In-sample variance decomposition of the breakeven inflation rate for two different periods using $cov(\pi^e_{b,t}, \pi^e_t)/var(\pi^e_{b,t}) + cov(\pi^e_{b,t}, \theta^\pi_t)/var(\pi^e_{b,t}) + cov(\pi^e_{b,t}, \theta^\lambda_t)/var(\pi^e_{b,t}) = 1$ from Eq. (18).

5.3 Comparison with other studies

Table 5 summarises the key statistical properties of the breakeven rate and its three subcomponents. Both the breakeven rate and inflation expectations average 3.9% since 2006 (declining to 3.4% during the last decade), with the two risk premia averaging roughly 160 basis points and therefore cancelling each other out.[14] The breakeven rate has therefore been close to the estimated true inflation expectations on average although there are periods of large differences between the two as previously discussed. Fluctuations in inflation expectations and the two risk premia are also of similar size and all are less volatile than the breakeven rate itself. There is also a significant excess kurtosis and positive skewness in the breakeven rate over the period that includes the

[13] This exercise is repeated for the 2-year nominal yield in Appendix 4, where I find that fluctuations in the nominal yield can mostly be explained by the risk-free real interest rate.

[14] It is worth noting, however, that the confidence bands for the two risk premia are quite wide. Based on the 95% confidence band, the sample average from 2006 ranges from 82 to 232 basis points for the inflation risk premium and 94 to 238 basis points for the liquidity premium.

financial crisis which appear to be mostly coming from the inflation risk premium. However, this excess kurtosis and skew largely disappear when the financial crisis period is excluded.

The inflation risk premium fluctuates between -30 and 530 basis points over the period since 2006 but the range narrows to 60-290 basis points when the financial crisis is excluded. The range therefore remains wide, even during relatively normal times. This is consistent with the literature, which reports a wide range of estimates of the inflation risk premium depending on the sample period and the modelling approach applied (for a literature survey, see Bekaert and Wang, 2010, and Kupfler, 2018, and the references therein). Many studies report an inflation risk premium in the range of 50 to 100 basis points with some reporting a sharp increase to 100-200 basis points during the GFC (for example, Kajuth and Watzka, 2011, Adrian and Wu, 2009, Abrahams et al., 2016) before turning very low and even negative right after the crisis (for example, Christensen and Gillan, 2012, Chernov and Mueller, 2012, Haubrich, Pennacchi and Ritchken, 2012, and Hördahl and Tristani, 2014).

Table 5 Summary statistics

Statistic	Breakeven inflation	Inflation expectations	Inflation risk premium	Liquidity premium
		Period 2006-2023		
Average	3.855	3.947	1.568	1.660
Maximum	10.645	5.425	5.321	3.654
Minimum	1.223	2.710	-0.319	0.101
Standard deviation	1.761	0.828	0.979	0.668
Skewness	1.250	-0.016	1.086	0.076
Kurtosis	4.970	1.555	5.559	2.708
Jarque-Bera test (p-value)	0.000	0.045	0.000	0.852
		Last 10 years		
Average	3.356	3.386	1.565	1.595
Maximum	6.764	4.904	2.893	2.602
Minimum	1.791	2.710	0.610	0.582
Standard deviation	1.447	0.624	0.582	0.582
Skewness	1.111	1.188	0.575	0.069
Kurtosis	3.194	3.368	2.521	1.653
Jarque-Bera test (p-value)	0.016	0.008	0.275	0.217

The table reports summary statistics for the 2-year breakeven inflation rate and the smoothed Kalman estimates of the underlying 2-year inflation expectations and the corresponding inflation and liquidity risk premia (the latter shown here as the negative of the relative liquidity premium, i.e. as $-\theta_t^{\lambda} = \lambda_{r,t} - \lambda_{n,t}$). The Jarque-Bera test is a χ^2-test for the null hypothesis that the variable is normally distributed.

The inflation risk premium is therefore found to be in the higher end of the range for Iceland compared to other advanced economies, which is not surprising given Iceland's higher and more volatile inflation rate and more fragile anchoring of inflation expectations (see, Pétursson, 2022). This is also consistent with the findings in Ang, Bekaert and Wei (2008) who use a Markov switching model and find that the inflation risk premium in the US is higher in regimes where inflation is high and volatile than in regimes where inflation is low and stable. In fact, studies focusing on a longer data sample that includes the higher inflation period of the 1980s typically report higher estimates of the risk premium. For example, Buraschi and Jiltsov (2005) report an inflation risk premium in the US that peaks at 140 basis points in the early 1980s, while Ang, Bekaert and Wei (2008) and Chernov and Mueller (2012) estimate the risk premium rising as high as 200-250 basis points during the same period.

As Table 5 reports, the liquidity premium ranges from roughly 10 to 360 basis points for the period since 2006 but from 50-260 basis points when looking at the last decade (thus, excluding the financial crisis). The literature finds a similarly wide range of estimates for the liquidity premium (again, see Bekaert and Wang, 2010, and Kupfer, 2018, for a survey). For example, Kajuth and Watzka (2011) find a liquidity premium that is below 50 basis points before the GFC but rises above 100 basis points during the crisis. Gürkaynak, Sack and Wright (2010), Christensen and Gillan (2012), Hördahl and Tristani (2014), Abrahams et al. (2016) and D'Amico, Kim and Wei (2018) all report a similar increase in the liquidity premium during the GFC, while Andreasen, Christensen and Riddell (2021) report an even larger spike of 300 basis points. Just as with the inflation risk premium, the liquidity premium therefore appears to be larger on average in Iceland than in other advanced economies – presumably reflecting the small and relatively illiquid domestic bond market.

The studies cited above focus almost exclusively on the US bond market. There are, however, a few papers that report results for other countries. For example, Hördahl and Tristani (2014) find a lower liquidity risk premium for the Euro Area than the US, while several studies find a lower liquidity premium for the US compared to the UK and Canada (Pflueger and Viceira, 2016, and Auckenthaler, Kupfer and Sendlhofer, 2015). Hördahl and Tristani (2014) also find that the inflation risk premium is broadly similar in the US and the Euro Area for most of their estimation period, while Pflueger and Viceira (2016) report a lower average inflation risk premium for the UK than the US.

Most studies also focus on the 10-year bond maturity. Studies that also report results for shorter maturities typically find that the inflation risk premium is higher for longer maturities (as risk-averse investors typically demand a higher compensation for holding inflation risk over longer maturities), but that the opposite holds true for the liquidity premium (as markets for longer-term inflation-indexed debt tend to be more liquid than their shorter-maturity counterparts). Papers finding an upward-sloping term structure of inflation risk include Buraschi and Jiltsov (2005), Ang, Bekaert and Wei

(2008), Chen, Liu and Cheng (2010) and Hördahl and Tristani (2014). Papers finding a lower liquidity premium for longer maturities include Gürkaynak, Sack and Wright (2010), Christensen and Gillan (2012), Abrahams et al. (2016), and Andreasen, Christensen and Riddell (2021).

6 The breakeven rate and monetary policy

The final part of the analysis explores the dynamic relationship between monetary policy and the individual subcomponents of the breakeven inflation rate. More specifically, I want to analyse whether monetary policy only affects inflation expectations, together with the usual macroeconomic effects on inflation and real economic activity, or whether it also affects how investors price risk.

To do this, I use the monetary policy shocks identified in Pétursson (2023). There, I use a structural VAR model to identify monetary policy shocks through alternative identification schemes but the one chosen here is a non-recursive identification scheme that allows monetary policy to react contemporaneously to exchange rate shocks while, at the same time, allowing the currency to react contemporaneously to monetary policy shocks. The monetary policy authority is also assumed to observe inflation contemporaneously but output only with a lag. As is typically assumed in VAR models of monetary policy, monetary policy is assumed to impact output only with a lag, but the identification scheme allows for a possible contemporaneous indirect effect on inflation through the exchange rate.

Here, these monetary policy shocks are included in a VAR model together with the inflation expectations and the two risk premia identified in the previous section. The monetary policy shocks represent the non-systematic component of monetary policy where the systematic feedback component has been stripped out from the policy rate. The VAR is therefore restricted to be block exogenous so that the monetary policy shocks do not respond to the other three variables (see Paul, 2020, and Camara, Christiano and Dalgic, 2024, for a similar approach). This restriction is easily accepted by the data (p-value = 0.936). The VAR model is estimated with one lag (as chosen by the Schwarz criterion) for the period 2009Q1-2022Q4 used in Pétursson (2023) and allows the monetary policy shocks to affect the other variables contemporaneously (the model also includes constants ignored here without loss of generality):

$$\begin{pmatrix} \mathbf{I} & -\boldsymbol{\kappa}_0 \\ \mathbf{0} & 1 \end{pmatrix} \begin{pmatrix} \boldsymbol{Y}_t \\ mp_t \end{pmatrix} = \begin{pmatrix} \boldsymbol{A} & \boldsymbol{\kappa}_1 \\ \mathbf{0} & \psi \end{pmatrix} \begin{pmatrix} \boldsymbol{Y}_{t-1} \\ mp_{t-1} \end{pmatrix} + \begin{pmatrix} \boldsymbol{\epsilon}_t \\ \epsilon_t^{mp} \end{pmatrix} \tag{19}$$

where $\boldsymbol{Y'}_t = (\pi_t^e, \theta_t^\pi, \theta_t^\lambda)$, mp_t are the cumulative monetary policy shocks from Pétursson (2023) and ϵ_t^{mp} are the structural monetary innovations. The three other structural innovations are contained in $\boldsymbol{\epsilon}_t$, while ψ is a scalar, $\mathbf{0}$ is a 1×3 vector of zeros, $\mathbf{I}$ is a 3×3 identity matrix, and $\boldsymbol{A}$, $\boldsymbol{\kappa}_0$ and $\boldsymbol{\kappa}_1$ are appropriately dimensioned coefficient matrices.

Figure 7 shows the responses of the three subcomponents of the breakeven inflation rate to an unanticipated 100 basis points increase in the monetary policy rate over a 5-year horizon. As expected, a monetary tightening leads to a gradual and persistent decline in 2-year inflation expectations, with a peak effect of 20 basis points reduction 11 quarters later. The effect gradually fades out and becomes statistically insignificant after 14 quarters.

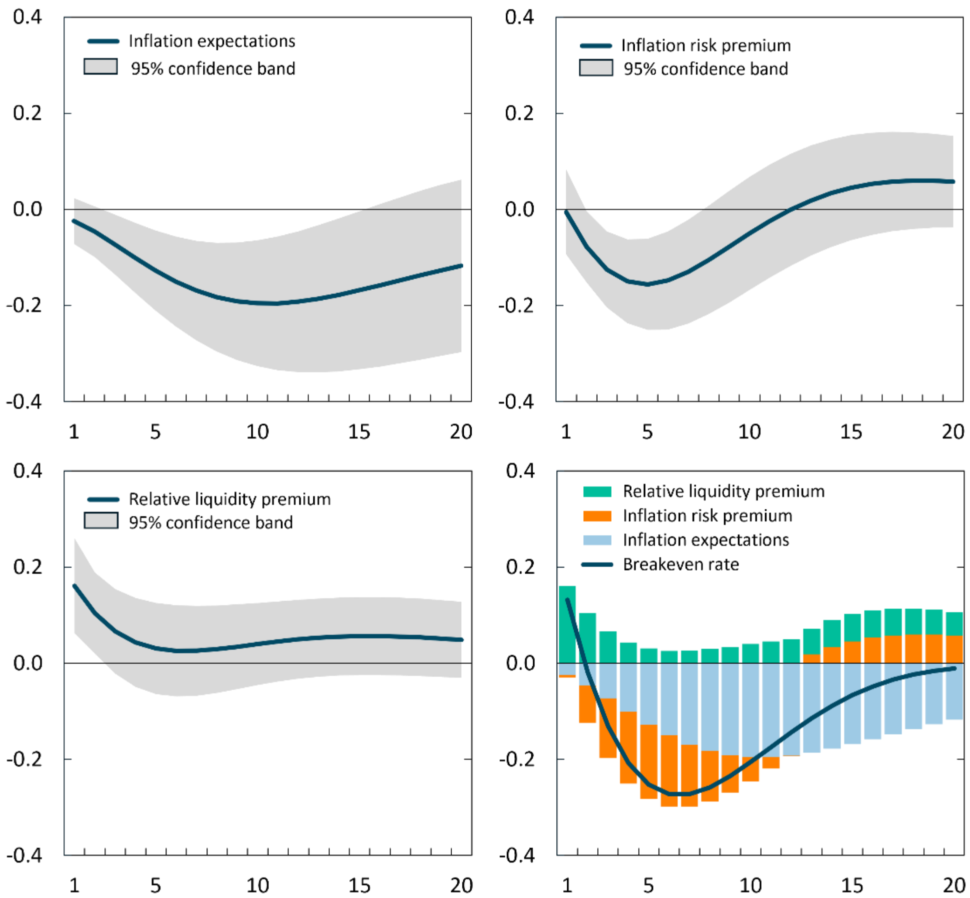

Figure 7 Impact of an unanticipated 100 basis points monetary policy tightening on the 2-year breakeven inflation rate and its three subcomponents over a 20 quarters period.

But the monetary policy tightening also affects the two risk premia. The inflation risk premium gradually declines as economic activity slows and inflation pressures ease with a peak effect after 5 quarters when the risk premium has declined by 16 basis points. The effect gradually fades out and becomes insignificant after 7 quarters. The impact of the monetary policy tightening on the inflation risk premium is therefore similar in size to the impact on inflation expectations, but the effect peaks earlier and fades out faster.[15]

Contrary to the impact on the inflation risk premium, the unanticipated monetary tightening leads to an immediate increase in the relative liquidity premium, which rises by 16 basis points at impact but becomes insignificant after 2 quarters. One way to interpret this is that the surprise monetary tightening raises investors' risk aversion (cf. Bekaert, Hoerova and Lo Duca, 2013, Kekre and Lenel, 2022, Pflueger and Rinaldi, 2022, and Zhang, 2024). The cost of liquidity increases as well, which makes leveraged investments and risk taking more costly (see Drechsler, Savov and Schnabl, 2018). Investors therefore shift from nominal bonds towards the safer real returns of inflation-indexed bonds through the Borio and Zhu (2012) "risk-taking" channel of monetary policy (see Abrahams et al., 2016). This shift in the relative bond demand pushes the nominal liquidity premium, $\lambda_{n,t}$, upwards while squeezing the real liquidity premium, $\lambda_{r,t}$, leading to an increase in the relative liquidity premium, $\theta_t^{\lambda} = (\lambda_{n,t} - \lambda_{r,t})$.

As seen in the final panel of Figure 7, this impact on the liquidity premium leads to an increase in the breakeven inflation rate by roughly 13 basis points at impact but the effect quickly fades out and the breakeven rate starts to decline from the first quarter after the shock as inflation expectations and the inflation risk premium start to fall with a peak effect after 7 quarters when the breakeven rate has fallen by 27 basis points from its pre-shock level.

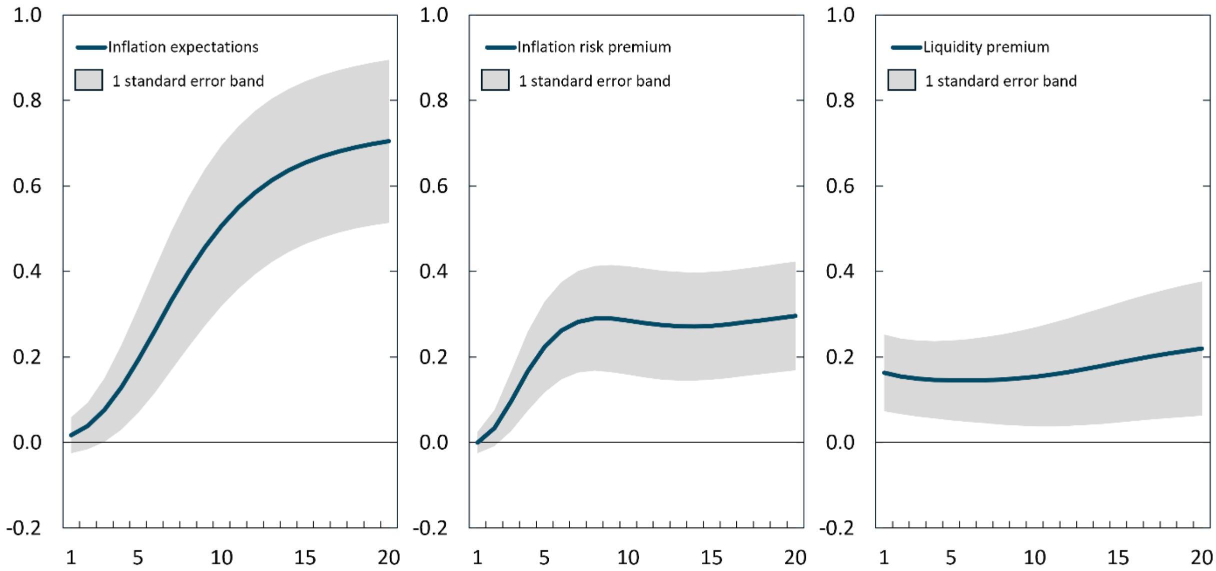

Figure 8 The percentage share of k-step-ahead (with k ranging from 1 to 20 quarters) forecast error variance of the three subcomponents of the breakeven inflation rate due to monetary policy shocks. The standard error bands are calculated using 1,000 Monte Carlo replications.

[15] This is similar to the findings in Abrahams et al. (2016) and is consistent with equilibrium models of the term structure, such as Piazzesi and Schneider (2007).

Finally, Figure 8 shows what share of the forecast error variance of the three subcomponents of the breakeven inflation rate can be attributed to monetary policy shocks at a horizon up to 20 quarters. The role of monetary policy in explaining variations in inflation expectations appears limited at short horizons but it accounts for most of the medium-term fluctuations in inflation expectations (70%). The contribution of monetary policy shocks to the medium-term variation in the two risk premia is smaller (20-30%) but still economically and statistically significant.

7 Concluding remarks

I formulate a state space model to estimate inflation expectations and the inflation and liquidity risk premia embedded in the breakeven inflation rate using the Kalman filter, complimenting data on the 2-year breakeven inflation rate with survey data on inflation expectations of different economic agents and observable proxies for inflation and liquidity risk.

I find that the estimated true underlying inflation expectations remain above the official 2.5% inflation target for most of the sample period, except for a relatively short period in the late 2010s when inflation expectations become broadly consistent with the target. The results suggest that the inflation risk premium has averaged around 160 basis points since 2006, rising even higher during periods of inflation scares such as in the financial crisis in 2008. The liquidity premium is similarly found to average close to 160 basis points, rising even higher in periods of financial distress. As anticipated, both premia are in the higher end of what is typically found in other countries. The estimated inflation expectations are also found to be much more stable than the breakeven rate and that variations in the two risk premia are just as important for explaining the variation in the breakeven rate as fluctuations in inflation expectations. These results therefore highlight the difficulty in interpreting the breakeven rate directly as a measure of inflation expectations. The fact that the two premia largely offset each other over the period analysed, suggests that the breakeven rate has *on average* been an unbiased estimator of inflation expectations but there are periods when the breakeven rate deviates markedly from the estimated inflation expectations.

The decomposition of the breakeven inflation rate into its three subcomponents makes it possible to explore the reaction of each component to monetary policy shocks. I use the monetary policy shocks identified in Pétursson (2023) using a non-recursive structural VAR model. The results suggest that an unanticipated monetary tightening leads to a gradual and persistent decline in 2-year inflation expectations, with a peak effect almost three years after the shock. A surprise monetary tightening also suppresses the inflation risk premium as economic activity slows and inflation pressures ease. Furthermore, a monetary tightening is found to lead to an immediate increase in the liquidity premium as investors' risk aversion rises and risk-taking becomes more costly – pushing investors towards the safer real returns of inflation-indexed bonds. This liquidity effect, through the "risk-taking" channel of monetary policy, leads to an increase in the breakeven rate at impact following the monetary policy shock, but the effect is short-lived, and the breakeven rate starts to decline from the first quarter after the shock in line with the declining inflation expectations and inflation risk premium. Moreover, monetary policy shocks are found to account for most of the medium-term fluctuations in inflation expectations. The proportion of the medium-term variability in the two risk premia accounted for by monetary policy shocks is smaller but is still economically and statistically significant.

The 2-year breakeven inflation rate has persistently been above 3% since early 2021 and above 5% since early 2022. The analysis shows that the rise in the breakeven rate is mainly driven by an increase in inflation expectations, which have risen well above the official 2.5% inflation target. The deterioration of nominal stability is also reflected in a rising inflation risk premium that reached almost 300 basis points in mid-2022. This rise in the inflation risk premium increased the upward distortion in the breakeven rate as a measure of inflation expectations, which was distorted further by a smaller offsetting effect from the liquidity premium which gradually declined from late 2020. Thus, by mid-2022, the breakeven rate was overstating the estimated inflation expectations by more than 2 percentage points, highlighting the need for caution when interpreting the breakeven rate as a simple measure of inflation expectations. The inflation risk premium has declined again recently and the upward bias in the breakeven rate has therefore fallen again, reaching 0.6 percentage points by the end of the sample period. The inflation risk premium remains elevated, however, at 150 basis points and together with expectations of inflation two years ahead still close to 5% highlight the continued challenge of regaining monetary stability in Iceland after the disinflation program following the financial crisis that succeeded in re-anchoring of expectations in the latter half of last decade.

Appendix 1 The data

Bond market data in Figure 1

The Icelandic bond market data comes from the Iceland Stock Exchange and the Central Bank of Iceland (the data on outstanding market value is only available since 2008).

The international data on the share of indexed central government debt comes from the Bank of International Settlements (BIS) data portal. The data is from 2022, except for Chile, where the data is from 2015.

Data on bond yields and breakeven inflation

The data on yields and the breakeven inflation rate are obtained from the Central Bank of Iceland database. The yields are obtained from fitted zero coupon yield curves using the Nelson-Siegel approach. The data are quarterly averages of daily data from 2003Q3-2023Q3.

The relative bid-ask spread is calculated as $b_t = b_{n,t} - b_{r,t}$, where $b_{n,t}$ is the nominal bid-ask spread and $b_{r,t}$ is the inflation-indexed bid-ask spread. The estimated bid-ask spreads are calculated from a Nelson-Siegel estimation of the nominal and inflation-indexed bid and ask zero-coupon curves, respectively. The data was kindly provided by my colleague, Magnús F. Gudmundsson. The data are quarterly averages of daily data from 2003Q3-2023Q3.

Data on inflation and survey-based inflation expectations

Headline year-on-year CPI inflation is used to calculate the inflation distance measure, $\pi_t^{dist} = abs(\pi_t - \pi^T)$, where π_t is inflation and π^T is the official 2.5% inflation target. The data are quarterly averages of monthly data from 2003Q3-2023Q3.

The quarterly survey-based inflation expectations for households and firms are from Gallup while the survey on market participants inflation expectations is conducted by the Central Bank of Iceland (each survey asks what rate of year-on-year inflation participants expects in two years' time). The survey data for households and firms starts in 2008Q3 (there are gaps in the early part of the data on corporate expectations as the survey are only conducted semi-annually until 2017, while there is one missing observation for household expectations in 2007Q1). The survey data for market participants starts later, or in 2012Q1.

Appendix 2 The 5-year breakeven inflation rate

The analysis in the main text focuses on the 2-year breakeven inflation rate due to the lack of data on longer-horizon survey measure of inflation expectations: data on 5-year inflation expectations of market participants is available from 2012, just as for 2-year expectations, but survey measures of households' and firms' 5-year expectations are only available from 2018.

As shown in Figure A.1, the 5-year breakeven rate moves closely with the 2-year rate, although its rise during the two inflation scares in the financial crisis and the post-Covid-19 period is less pronounced. The recent increase in the survey-based 5-year inflation expectations is also broadly similar to that of 2-year expectations.

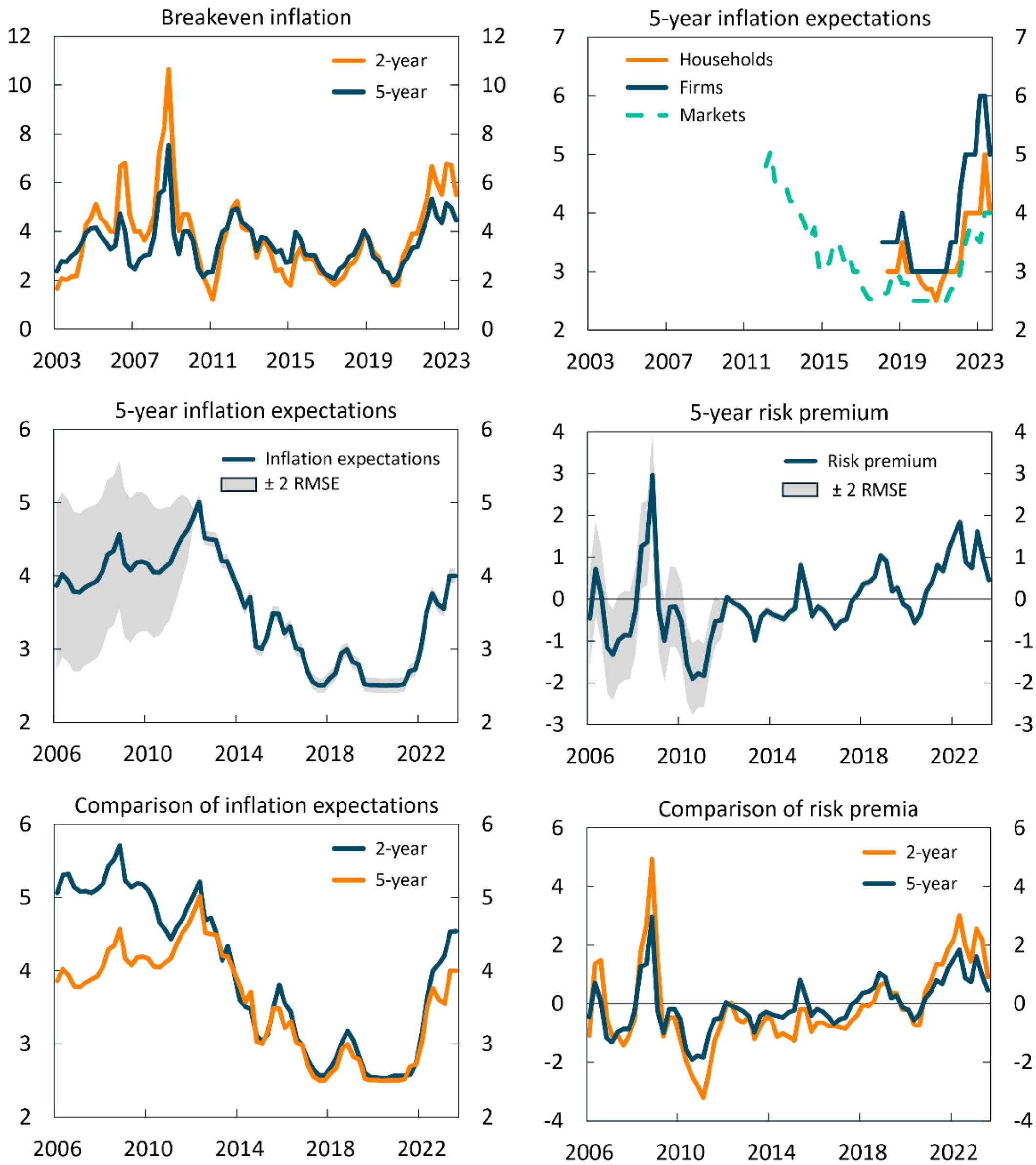

Figure A.1 Comparison of results for 2-year and 5-year breakeven inflation rates.

Figure A.1 also shows the estimates of the latent 5-year inflation expectations and the risk premium from the state space model in Eqs. (5)-(8). The estimated 5-year inflation expectations are significantly below the 2-year rate for the early part of the sample period but are very similar across these two horizons from 2011 until recently when the 2-year rate rises again above the 5-year rate. The 5-year aggregate risk premium remains broadly similar to the 2-year premium throughout – which could be consistent with the findings from term structure models discussed in the main text that show an upward sloping term structure of inflation risk premia being broadly offset by a downward sloping term structure of liquidity premia.

Appendix 3 Allowing for a time-varying bias in survey measures of inflation expectations

Although survey measures of inflation expectations are useful, they have their drawbacks. There are the typical issues with sampling a representative part of the population being surveyed. Survey responses are also found to be sensitive to the exact wording of the survey question and they can be sensitive to how the question is framed and in what order they are posed. Repeated participation in surveys is also known to lead to what is commonly known as panel conditioning, which reduces their reliability as a true representative of the broader population (see, for example, Weber et al., 2022).

If the survey measures of inflation expectations are not only a noisy measure of the true underlying inflation expectations as assumed in the main text, but also include a systematic (and possibly time-varying) bias, the Kalman smoother could, presumably, lead to biased estimates of the latent inflation expectations and risk premium. To explore this issue further I therefore expand the state space model to allow for a time-varying systematic bias in the survey measures by re-writing the measurement equations for the survey-based measures of inflation expectations (Eq. (6) in the main text) as:

$$\pi^e_{j,t} = \alpha_{j,t} + \pi^e_t \tag{A3.1}$$

with the unobserved bias $\alpha_{j,t}$ $(j = h, f, m)$ approximated by a random walk:

$$\alpha_{j,t} = \alpha_{j,t-1} + u_{j,t} \tag{A3.2}$$

where $u_{j,t}$ are, as before, independently and identically distributed, mutually uncorrelated measurement errors with mean zero and variance $\sigma^2_{u,j}$.

Figure A.2 shows the estimated five state variables for the 2-year data (with the estimated biases shown from 2008 when the household and firm survey data starts). The estimated biases in firms' and market's survey responses show very little time variation and are found to be insignificant from zero throughout the estimation period. The bias in household survey responses is, however, periodically found to be statistically significant, particularly around periods of greater inflation uncertainty such as during the financial crisis and the period after the Covid-19 pandemic and the war in Ukraine.

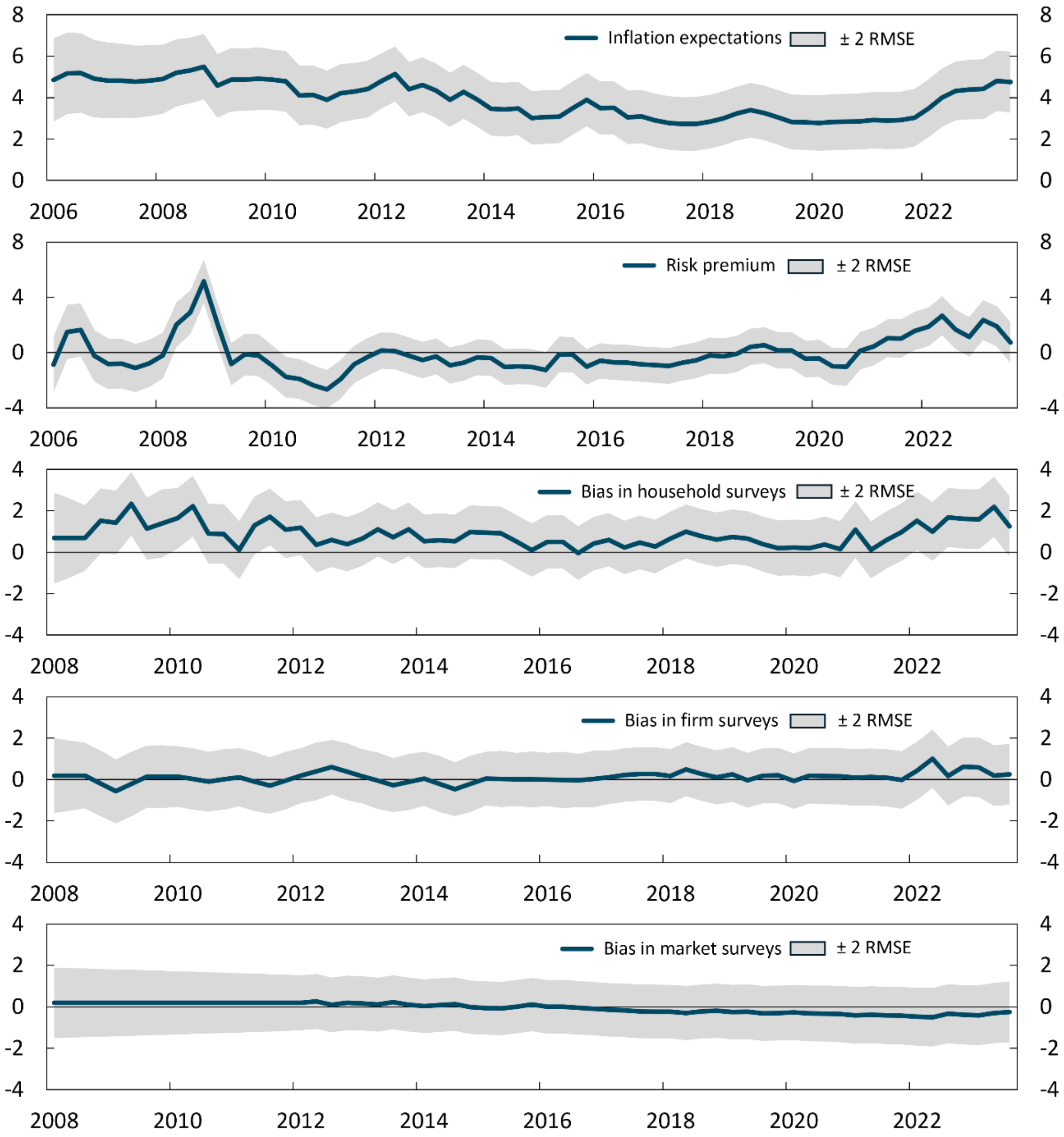

Figure A.2 Smoothed Kalman estimates of 2-year inflation expectations and the risk premium obtained from the Kalman smoother allowing for a time-varying bias in survey-based inflation expectations.

However, as shown in Figure A.3, the estimates of the underlying inflation expectations and the aggregate risk premium ($\theta_t = \theta_t^\pi + \theta_t^\lambda$) are very similar to those obtained from the two state space specification in the main text, especially to the state space specification from Section 5 which estimates inflation expectations jointly with the two risk premia. This probably reflects the fact that most of the potential bias is found to be in the household survey measure, which the Kalman filter tends to discount in its estimation of the underlying inflation expectations due to the low signal-to-noise ratio in the household survey.

The simple state space specification in Section 3 is also broadly similar but gives a slightly lower estimate of inflation expectations from 2017 onwards and, correspondingly, a slightly higher estimate of the aggregate risk premium. The figure also shows how the estimated inflation expectations from the simple state space specification in Section 3 closely mirrors the market survey measure of inflation expectations, whereas the two others, that either uses a richer data set (specification in Section 5) or allows for a bias in survey expectations (the specification in this Appendix) give a somewhat higher estimate of inflation expectations from 2017.

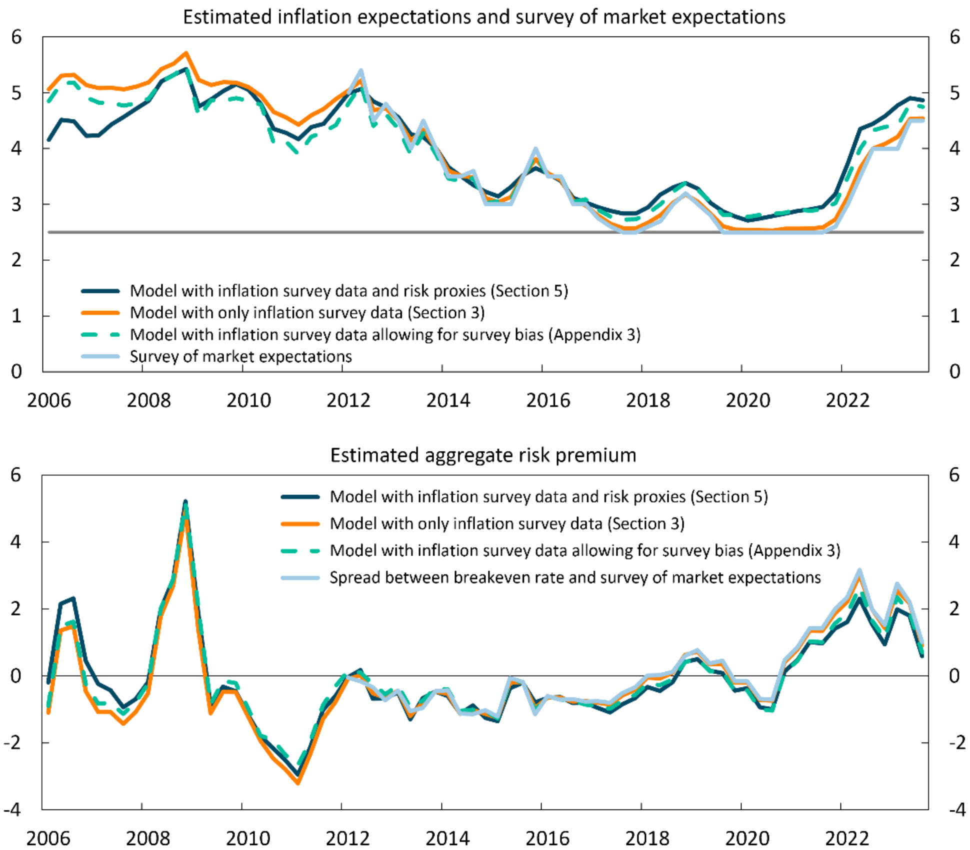

Figure A.3 Comparison of smoothed Kalman estimates of 2-year inflation expectations and aggregate risk premium from alternative state space models. The horizontal line shows the official 2.5% inflation target.

The average values of inflation expectations and the risk premium over the period 2006-2023 across the three models are very similar, however: the estimated inflation expectations range from 3.87% (the specification that allows for a survey bias) to 3.95% (the two other specifications) and the aggregate risk premium from -2 basis points (the specification that allows for a survey bias) to -9 basis points (the two other specifications). Thus, allowing for a possible bias in the survey measures of inflation expectations does not appear to alter the findings reported in the main text, in particular when estimating inflation expectations and the two risk premia jointly as in Section 5.

Appendix 4 Decomposing the 2-year nominal yield

While not a focus of this paper, the decomposition of the breakeven rate can also be used to decompose the nominal yield in a similar way to the breakeven rate, although the risk-free real rate r_t cannot be directly identified from Eq. (2) unless a further assumption on the properties of the liquidity premium is made. The reason is that the relative liquidity premium $\theta_t^\lambda = \lambda_{n,t} - \lambda_{r,t}$ is only estimated and not the two separate liquidity premia. Thus, the real rate cannot be identified unless it is assumed that $\lambda_{n,t} = 0$, which gives $\lambda_{r,t} = -\theta_t^\lambda$ and:

$$r_t = y_{r,t} - \lambda_{r,t} = y_{r,t} + \theta_t^\lambda \tag{A4.1}$$

and the decomposition of the nominal yield as:

$$y_{n,t} = r_t + \pi_t^e + \theta_t^\pi \tag{A4.2}$$

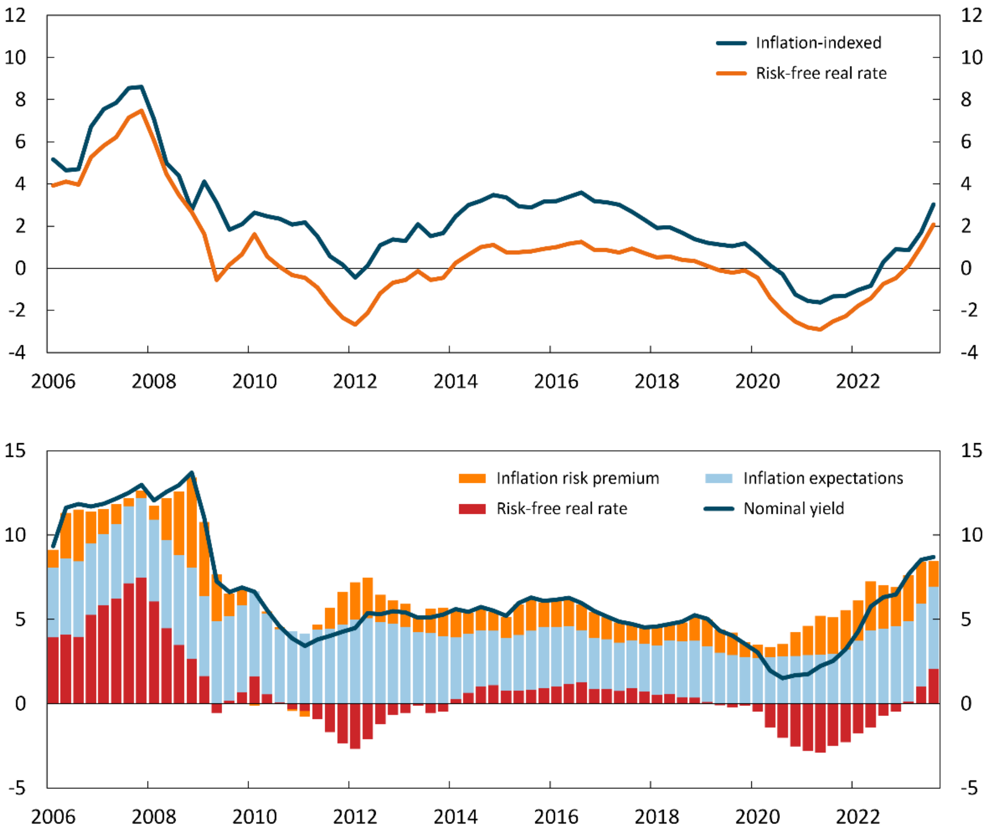

Figure A.4 Decomposition of the 2-year nominal yield. The real rate is obtained assuming that $\lambda_{n,t} = 0$, thus giving $r_t = y_{r,t} - \lambda_{r,t} = y_{r,t} + \theta_t^\lambda$.

The upper panel of Figure A.4 compares the inflation-indexed yield to the estimated risk-free real rate obtained assuming that $\lambda_{n,t} = 0$. A positive real liquidity premium, $\lambda_{r,t} > 0$, implies that the indexed rate overestimates the risk-free real rate. For example, the indexed yield averages 2.3% since 2006 but the estimated risk-free rate (again, assuming that $\lambda_{n,t} = 0$) averages only 0.7%. In fact, the liquidity distortion in the indexed yield increases for a given estimate of θ_t^λ the higher the liquidity premium in the nominal yield is assumed to be (with $\lambda_{r,t} = \lambda_{n,t} - \theta_t^\lambda$). The estimated risk-free real rate shown in Figure A.4 therefore gives an upper estimate of the real rate given the estimated relative liquidity premium θ_t^λ.

The lower panel of Figure A.4 shows the decomposition of the nominal yield from Eq. (A4.2). It shows how the real rate became negative following the Covid-19 pandemic in early 2020, driving down the nominal yield. The nominal has risen again in recent years as the real rate has inched up, pushed further by rising inflation expectations and an increased compensation demanded by investors for rising inflation risk.

The important role of the real rate as a driver of the nominal bond yield can also be seen from the in-sample variance decomposition, where the variance of the nominal yield is decomposed as:

$$var(y_{n,t}) = cov(y_{n,t}, r_t) + cov(y_{n,t}, \pi_t^e) + cov(y_{n,t}, \theta_t^\pi) \qquad \text{(A4.3)}$$

The variance decomposition is reported in Table A.1. The estimated real rate explains 70% of the total variation in the nominal yield over the period since 2006 and 60% of the variation in the last decade. Inflation expectations explain a further 20-30% of the variation in the nominal yield and the inflation risk premium what is remaining. The dominant role of the real rate in explaining the variation in the nominal yield is consistent with the findings in D'Amico, Kim and Wei (2018) but different from Ang, Bekaert and Wei (2008) who find that most of the fluctuations in nominal yields can be attributed to the variation in expected inflation and the inflation risk premium.[16]

Table A.1 In-sample variance decomposition of the nominal yield

Period	Risk-free real rate	Inflation expectations	Inflation risk premium
2006-2023	0.698	0.172	0.130
Last 10 years	0.590	0.288	0.122

In-sample variance decomposition of the breakeven inflation rate for two different periods using $cov(y_{n,t}, r_t)/var(y_{n,t}) + cov(y_{n,t}, \pi_t^e)/var(y_{n,t}) + cov(y_{n,t}, \theta_t^\pi)/var(y_{n,t}) = 1$ from Eq. (A4.3). The real rate is obtained assuming that $\lambda_{n,t} = 0$, thus giving $r_t = y_{r,t} - \lambda_{r,t} = y_{r,t} + \theta_t^\lambda$.

[16] As in Ang, Bekaert and Wei (2008), I find no evidence of the Mundell-Tobin effect, i.e. of a negative correlation between the real rate and expected inflation – consistent with the existence of activist monetary authority that raises real rates in response to an increase in expected inflation.

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