DISCUSSION PAPER SERIES

DP14207

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FINANCIAL ECONOMICS

ISSN 0265-8003

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Discussion Paper DP14207
Published 17 December 2019
Submitted 11 December 2019

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JEL Classification: N/A

Keywords: N/A

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Acknowledgements
We gratefully acknowledge the useful comments and suggestions of Stefan Nagel, an Associate Editor, two anonymous referees, Tobias Adrian, Mikhail Chernov, Anna Cieslak, John Cochrane, Arvind Krishnamurthy, Augustin Landier, Giorgia Piacentino, Monika Piazzesi, David Thesmar, Dimitri Vayanos as well as seminar participants at Kellogg, Princeton, the University of Michigan, Stanford, the Federal Reserve Bank of New York, the UNC Junior Faculty Roundtable, the NBER Summer Institute, CITE, the MFS meeting, the Adam Smith Conference, and the SED Annual Meeting. We have no relevant or material financial interests that relate to the research described in this paper.

The Banking View of Bond Risk Premia *

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Abstract

Banks' balance-sheet exposure to fluctuations in interest rates strongly forecasts excess Treasury bond returns. This result is consistent with optimal risk management, a banking counterpart to the household Euler equation. In equilibrium, the bond risk premium compensates banks for bearing fluctuations in interest rates. When banks' exposure to interest rate risk increases, the price of this risk simultaneously rises. We present a collection of empirical observations supporting this view, but also discuss several challenges to this interpretation.

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Banks are large sophisticated intermediaries in the market for interest rate risk, but are absent from standard studies of the yield curve.[1] This paper shows that banks' balance-sheet exposure to fluctuations in interest rates strongly forecasts excess Treasury bond returns. We interpret this result through the lens of banks' risk management decisions, which tightly connect their exposure to interest rate risk with the price of this risk. This connection represents a banking counterpart to the classic household Euler equation. In equilibrium, an increase in future bond returns compensates any increase in banks' exposure to interest rate risk.[2] This paper establishes this relationship empirically, presents a collection of facts further supporting this view and highlights challenges to this interpretation.

We start by constructing a measure of the average bank exposure to interest rate risk. At the bank-level, we follow Gomez, Landier, Sraer, and Thesmar (2017) and use the *income gap* as our measure of interest rate risk exposure. The income gap of a financial institution corresponds to the difference between the book value of all assets that either reprice or mature within one year and the book value of all liabilities that mature or reprice within a year, normalized by total assets. This measure, commonly used by both banks and bank regulators, is readily available at the quarterly frequency for the 1986-2014 period through FR Y-9C filings of Bank Holding Corporations (BHC) to the Federal Reserve. The income gap provides a relevant quantification of the *net* exposure of banks' income to interest rate risk. Gomez et al. (2017)

[1]In 2014, private depository institutions (U.S.-chartered depository institutions, foreign banking offices, banks in U.S.-affiliated areas and credit unions) held 3.2% of all outstanding Treasuries, 25% of agency and GSE backed securities, 12.3% of municipal securities, 33.6% of mortgages and 49.5% of all consumer credit.

[2]Importantly, this statement describes an equilibrium relation rather than a causal relationship. The price and quantity of interest rate risk are jointly determined in equilibrium. However, we sometimes follow the tradition of the literature on the household Euler equation, which tends to describe equilibrium relations using a more causal language.

show that the sensitivity of banks' profits to interest rates increases significantly with their income gap.[3] We use the average income gap across banks with more than $1bn of total assets as our measure of interest rate risk exposure of financial intermediaries.

We run regressions of one-year excess returns on Treasuries — borrow at the short rate, buy a long-term bond — on the average income gap available at the beginning of the period. The estimated coefficient is significant for all bond maturities. With this single predictor, we find R^2 values of 20% on average across maturities. Through a battery of robustness checks, we show that this result does not spuriously derive from the persistence of our forecasting variable in a small sample. Additionally, the forecasting power of the average income gap for Treasuries' excess returns is not affected by the inclusion of macroeconomic factors known to predict bond returns (Ludvigson and Ng, 2009). Represented in Figure 1, the robust correlation between bonds' excess returns and the average income gap is the main contribution of the paper. It offers *prima facie* evidence of the role of financial intermediaries in asset pricing (e.g., Brunnermeier and Sannikov (2014), He and Krishnamurthy (2013)).

We interpret this finding through the lens of a simple equilibrium restriction on the yield curve following Greenwood and Vayanos (2014). This equilibrium restriction must hold in a large family of economies. In the model, banks trade assets of different maturities to maximize their expected profits while managing their risk. When banks hold more long-term assets, they must absorb additional interest rate risk. They do so only if the market compensation for this risk increases. This compensation

[3] Purnanandam (2007), Begenau, Piazzesi, and Schneider (2015) and English, den Heuvel, and Zakrajsek (2012) also document that financial intermediaries do not fully hedge out their exposure to interest rate risk. Di Tella and Kurlat (2017) build a model to explain why bank optimally expose their balance sheets to movements in interest rates.

materializes itself for instance in Treasury bond returns.[4] In equilibrium, banks' income gap, i.e., the sensitivity of banks' profits to variations in the short-rate, is negatively correlated with bond risk premia. Since long-term Treasuries are more sensitive to the interest rate than short-term Treasuries, this correlation between banks' income gap and risk premia is larger, in absolute value, for bonds of longer maturities. These qualitative predictions echo our main findings. We confirm they hold quantitatively as well. Fitting the model to the data also allows us to estimate banks' willingness to take risk, a key input for our theory and more generally for macroeconomic models with financial intermediation.

Our analysis departs from the classic, frictionless view of the market for interest rate risk. This view has received mitigated empirical success so far.[5] In contrast, several recent papers provide convincing evidence that not all investors are marginal in Treasury markets.[6] In such a setting, understanding the investment decisions of marginal investors is key to the determination of asset prices. Banks are natural candidates for this role. They hold a sizable share of assets exposed to interest rates. Their modest holdings of Treasuries understates their prominence in the broader fixed income markets (mortgages, consumer credit, agency-backed securities). Banks are also likely sophisticated in managing their interest rate risk exposure (e.g., Drechsler, Savov, and Schnabl (2018)). The tight empirical relationship between banks' bal-

[4]While a large share of the exposure of banks to interest rate risk comes from non-Treasury assets, Treasuries constitute a simple and stable way to measure this price of risk. Hanson (2014) and Malkhozov, Mueller, Vedolin, and Venter (2016) follow a similar measurement approach in the context of MBS supply.

[5]See Duffee (2018), Gürkaynak and Wright (2012), Beeler and Campbell (2012), and Schneider (2017) for discussions on these issues.

[6]For example, Greenwood and Vayanos (2014) provides such evidence at low frequency, while Gagnon, Raskin, Remache, Sack, et al. (2011) Krishnamurthy and Vissing-Jorgensen (2011), Swanson (2011), Hamilton and Wu (2012), and D'Amico and King (2013) document such effects around quantitative easing interventions.

ance sheet exposure and bond excess returns provides supports the view that banks are marginal investors in Treasury markets. The remainder of the paper brings additional evidence to test this hypothesis further.

We present a collection of evidence consistent with this “banking view” of bond risk premia. First, we show that by itself, the average exposure of banks’ *assets* to interest rate risk does not forecast bond risk premia in a significant way. The same result holds for the average exposure of banks’ *liabilities* to interest rate risk. Only the overall holding of interest rate risk by financial institutions, i.e., the average income gap, significantly predicts future bond excess returns. This finding is consistent with our interpretation, whereby bond risk premia only appear in banks’ *overall* portfolio holdings. Second, we document that, over our sample period, standard measures of liquidity risk do not forecast bond risk premia, in contrast to our measure of interest rate risk exposure. Third, we show that the average income gap responds, in the time-series, to several measured changes in the supply and demand for interest rate risk in the economy, such as the total amount of fixed-rate mortgages net of adjustable-rate mortgages, the total supply of Treasuries or the amount of non-interest bearing deposits. However, these shocks to the demand and supply of interest rate risk add no forecasting power for bond risk premia above and beyond the income gap. This result is again consistent with our interpretation since bond risk premia should be entirely captured by the net position of banks, measured in our analysis by the average income gap, and not by any particular components. Finally, we exploit our bank-level data to provide evidence consistent with interest-rate risk-sharing among heterogeneous banks. We split our sample of banks into ten size-sorted groups and compute the time-series of the average income gap for these ten groups. Despite their heterogeneity, we show that these ten groups share a very similar evolution of their average income gap over time. We find similar evidence of risk-sharing among banks with different leverage or among banks located in different geographic areas. All these results support our simple theory.

However, we also highlight challenges to our preferred interpretation. In our theory, banks suffer when they hold significant balance sheet exposures and interest rates increase. This assumption underlies banks' risk management motive and drives the relation between banks' average income gap and excess returns on Treasury bonds. Using banks' equity returns, we fail to find empirical support for this assumption. In the data, periods of low-income gaps are not positively related to the correlation of banks' equity returns with bond returns. Relatedly, our mean-variance framework implies that bond risk premia should be proportional to the expected covariance of banks' equity returns with bond returns. Yet, in the data, there is no significant relationship between bond excess returns and the predicted covariance of daily excess returns on long-term bonds and banks' stock returns. Finally, our model predicts that banks' balance sheet exposure should command a higher risk premium in periods of high interest-rate risk. Using the realized variance of bond returns as a source of variation in interest-rate risk beyond changes in balance sheet composition, we do not find support for this prediction. All these results challenge an interpretation where potential valuation losses drive the reluctance of financial institutions to bear risk, a standard feature of intermediary asset pricing models (e.g., He and Krishnamurthy (2014a), Brunnermeier and Sannikov (2014)).

Related Literature. Our paper relates to the literature trying to understand the pricing of interest rate risk. One strand of the literature investigates how the price of interest rate risk relates to the information contained in the yield curve[7]. Another strand of this literature has explored the role of macroeconomic variables in explaining excess returns on Treasuries[8]. Finally, a third strand of this literature emphasizes the role of segmentation in Treasury markets and show that supply factors forecast bond risk premia[9]. Relative to this literature, our contribution is to shift the focus on financial institutions, which are major participants in the market for interest rate risk, and to use information on financial institutions' exposure to interest rate risk to forecast future bond returns.

In doing so, our paper also relates to the recent literature that emphasizes the crucial role of intermediaries for asset prices. Several theoretical contributions emphasize the role of intermediaries' balance sheets for equilibrium risk premia[10]. Empirically, the importance of financial intermediaries on the determination of asset prices has been mostly investigated in the context of equity markets (e.g., Adrian, Etula, and Muir (2014), Adrian, Moench, and Shin (2013b) and He, Kelly, and Manela (2017)). Relative to this literature, our contribution shifts the focus away from equity markets to the market for Treasuries. Furthermore, our approach uses the actual underlying risk-exposure of intermediaries as a forecasting variable, instead of the standard

[7]See, e.g., Fama and Bliss (1987), Campbell and Shiller (1991), Cochrane and Piazzesi (2005), Duffee (2011), Adrian, Crump, and Moench (2013a), and Cieslak and Povala (2015).

[8]See, e.g., Piazzesi (2005), Ang and Piazzesi (2003), Ludvigson and Ng (2009), and Cooper and Priestley (2009)

[9]See, e.g., Greenwood and Vayanos (2014),Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), Swanson (2011), Hamilton and Wu (2012), D'Amico and King (2013), Baker, Greenwood, and Wurgler (2003), Hanson (2014) and Malkhozov et al. (2016).

[10]Prominent papers include, among others, Brunnermeier and Pedersen (2009), He and Krishnamurthy (2013) or Brunnermeier and Sannikov (2014)

focus on leverage as a proxy for this exposure. Finally, while our paper highlights several empirical facts consistent with an intermediary asset-pricing interpretation, we also present several challenges to this interpretation.

The rest of the paper is organized as follows. Section 1 describes the data we use for our empirical study and discusses our main empirical results. Section 2 presents the model underlying our interpretation of this evidence. Section 3 offers a structural estimation of our model to quantify the risk management motive of banks. Section 4 provides further tests consistent with this banking view of bond risk premia. Section 5 concludes.

1 Banks' Income Gap and Bond Returns

1.1 Data

1.1.1 Income Gap

Income gap definition. The central object of our analysis is the net exposure of banks to interest rate risk. Our main empirical counterpart to this quantity is the income gap, a standard measure of interest rate sensitivity used by banks and regulators. Our definition of the income gap follows the definition in Mishkin and Eakins (2009):

$$\text{Income Gap} = (\text{RSA} - \text{RSL}) \,/\, \text{Total Assets}, \tag{1}$$

where RSA is a measure of the dollar amount of assets that either reprice or mature within one year and RSL is a measure of the dollar amount of liabilities that mature or reprice within a year. A high income gap, therefore, corresponds to a low exposure to long-term fixed-rate assets. Concretely, we construct the income gap using variables from schedule HC-H of form FR Y-9C, which specifically focuses on the interest sensitivity of the balance sheet. RSA is directly provided (item bhck3197). RSL consists of four elements: long-term debt that reprices within one year (item bhck3298); long-term debt that matures within one year (bhck3409); variable-rate preferred stock (bhck3408); interest-bearing deposit liabilities that reprice or mature within one year (bhck3296), such as certificates of deposits. Empirically, the latter is by far the most important determinant of the liability-side sensitivity to interest rates. All these items are available quarterly from 1986 to 2014. We scale these variables by total assets and report summary statistics in Appendix Table IA.1. On average, RSL (interest rate-sensitive liabilities) mostly consists of variable rate deposits, that either mature or reprice within a year. Long term debt typically has a fixed rate. Gomez et al. (2017) validate this measure in the cross-section of banks: they document that when the Fed Funds rate rises, banks with a larger income gap generate stronger earnings and contract their lending by less than other banks.

Our primary forecasting variable for bond risk premia is the average income gap, which we compute across all banks with more than $1bn in consolidated assets. This variable is available quarterly from 1986 to 2014. Figure 1 shows the time-series evolution of the average income gap over this period (thick dark line). The average income gap exhibits pro-cyclical variations. The income gap peaks during expansions, and banks accumulate interest rate risk — lower values of the gap — ahead of recessions. We favor this simple variable for most of our analysis because a) it captures the forces of our theory, b) it has a transparent construction, and c) it reflects how market participants measure interest rate sensitivity in practice. The remainder of this section discusses some benefits and limitations of this measure.

Measurement issues. A first dimension is the treatment of deposits. In the BHC data, the item corresponding to short-term deposit liabilities (bck3296) does not include transaction or savings deposits.[11] Interest rates on these "core" deposits, while having a zero contractual maturity, are known to adjust sluggishly to changes in short-term market rates (Hannan and Berger (1991), Neumark and Sharpe (1992)). Therefore, despite their short maturity, it is natural to exclude these deposits from our measure, as they will not induce direct cash-flow changes when interest rates change. However, if these "core" deposits adjust slightly to changes in the Fed Funds rate, the average income gap will over-estimate the real income gap.[12] To investigate the role of deposits, we make the alternative assumption that all non-interest bearing deposits have short maturity as in English et al. (2012). This change results in a lower mean for the average income gap: 0% versus 12% in our baseline. However, this modified income gap exhibits a correlation of 91% with our baseline measure.

A second dimension is that we do not observe holdings of interest rates derivatives. If banks hedge their interest rate risk exposure through derivatives, the income gap may over-estimate banks exposure to interest rate risk. To assess the extent of this issue, we exploit the fact that, since 1995, banks report on form FR Y-9C the notional amounts of interest derivatives they contract.[13] We compute the average income gap for banks that never report any notional amounts of interest rates derivatives and

[11]See `http://www.federalreserve.gov/apps/mdrm/data-dictionary`.

[12]More recently, Drechsler, Savov, and Schnabl (2016) investigate the price and quantity response of deposits to changes in the Fed Funds rate and find a somewhat larger elasticity of deposits to interest rates.

[13]Banks report five types of derivative contracts: Futures (bhck8693), Forwards (bhck8697), Written options that are exchange-traded (bhck8701), Purchased options that are exchange-traded (bhck8705), Written options traded over the counter (bhck8709), Purchased options traded over the counter (bhck8713), and Swaps (bhck3450).

report its time-series evolution on Appendix Figure IA.1 (dark dashed line). The time-series correlation of this series with the time-series for the average income gap computed across all banks is 93%.

The lack of data on interest rates derivatives also explains why we do not use the *aggregate* income gap as our main forecasting variable, i.e., the *asset-weighted* average income gap. Indeed, since large banks hold significant positions in interest rates derivatives, their income gap likely suffers from substantial measurement error. Given the fat-tailed distribution of banks' assets, this bank-level measurement error would translate into a significant aggregate measurement error. Figure IA.1 plots the time-series evolution of the asset-weighted average income gap (orange line), as well as the average income gap computed across the ten largest banks (blue line). These two series are almost identical – the top ten banks are so large that they account for most of the variations in the asset-weighted average gap. Any mismeasure in the gap for some of these ten banks will significantly garble our forecasting variable.

Despite these limitations, our income gap measure represents a significant contribution to the intermediary asset pricing literature. In this literature, financial intermediaries' risk exposures are typically summarized by their leverage (Adrian et al. (2013b), Adrian et al. (2014), He et al. (2017)). This approach fails to account for the differential exposure of different assets and liabilities to aggregate sources of risk. In contrast, using banks' average income gap allows for some risk-weighting of assets and liabilities.

Income gap and exposure g_t. In the model we develop in Section 2, we show that the relevant measure of banks' exposure, g_t, can be constructed from our basic income gap measure as:

$$g_t = 1 - \text{Income Gap}_t \times \frac{A_t}{E_t}, \tag{2}$$

where E_t is equity value at date t. There are several reasons to favor the standard income gap measure over g_t in our empirical analysis. First, it lies between -1 and 1, is defined for banks with negative equity, and its distribution has fewer outliers. Second, this measure corresponds to the one used in Gomez et al. (2017), who shows that the income gap forecasts banks' net income reaction to changes in interest rates. Importantly, $-g_t$ has a correlation of 94% with the baseline average income gap. Appendix Figure IA.2 reports the four versions of the income gap (including deposits or not, scaling by assets or equity). We standardize the measures, so they have mean zero and unit standard deviation. When considering the quantitative properties of the model in Section 3, we define g_t using equation (2) and include deposits. Thus constructed, g_t has a mean of 1.00 and a standard deviation of 0.41. Banks typically have positive exposure to long-term assets, on average equal to their equity and roughly varying between 0 and twice their equity. This exposure constitutes a sizable amount of risk, but much less than a naive approach that would assume that all their assets are long-term, and all their liabilities are short-term.[14]

1.1.2 Bond Prices and other time-series variables

We are interested in relating banks' exposure to interest rate risk with the price of this risk. A natural way to measure this price is to consider Treasury bond risk

[14]Echoing the typical bank leverage, this would give rise to an interest risk exposure of around 10, an order of magnitude larger than what we observe.

premia. Bond return data are constructed from the Gurkaynak, Sack, and Wright (2007) dataset of interpolated yield curves. These curves are computed by fitting Treasury transaction prices daily using the extension by Svensson (1994) of Nelson and Siegel (1987). We compute time series of bond prices of maturity n years, $P_t^{(n)}$, and the yield of these bonds as: $y_t^{(n)} = -\frac{1}{n}\ln(P_t^{(n)})$. The log-forward rate at time t for contracts between time $t+n-1$ and $t+n$ is $f_t^{(n)} = \ln(P_t^{(n-1)}) - \ln(P_t^{(n)})$. The log holding period return from buying an n-year bond at time t and selling it a quarter later as an $n-1/4$ year bond is $r_{t\to t+1}^{(n)} = \ln(P_{t+1}^{(n-1/4)}) - \ln(P_t^{(n)})$. Quarterly bond excess returns are then defined as $rx_{t\to t+1}^{(n)} = r_{t\to t+1}^{(n)} - y_t^{(1/4)}$. Our analysis focuses on a 1-year return horizon, and maturities from 2 to 5 years, $rx_{t\to t+4}^{(n)} = \sum_{i=0}^{3} rx_{t+i\to t+i+1}^{(n)}$.

We also use several macroeconomic variables known to forecast bond risk premia. The output gap consists in the difference between the real seasonally adjusted GDP (GDPC96 from the FRED database) and the real potential GDP (GDPPOT from FRED), normalized by the real seasonally adjusted GDP (Cooper and Priestley, 2009). Industrial production growth is the 1-year growth rate in industrial production (INDPRO in FRED). Inflation is the 1-year growth rate of the CPI, taken from the FRED database. Table 1 presents descriptive statistics for these variables.

1.2 Income Gap and Excess Bond Returns

1.2.1 Main Results

We estimate the following linear equation using quarterly data:

$$rx_{t\to t+4}^{(n)} = a^{(n)} + b^{(n)} \times \text{Income Gap}_t + \epsilon_{t+4}^{(n)}, \quad \text{for n=2, 3, 4 and 5.} \tag{3}$$

$rx^{(n)}_{t\to t+4}$ is the excess return of a zero-coupon bond of maturity n from quarter t to quarter $t+4$, defined in Section 1.1.2. Income Gap$_t$ is the average income gap available at the beginning of quarter t, which corresponds to the average income gap of quarter $t-2$. To account for the overlapping nature of our return variable, we use the reverse regression approach of Hodrick (1992) to compute standard errors for our coefficient estimates. Additionally, we account for potential small sample bias, such as the Stambaugh (1999) bias, by computing p-values from a parametric bootstrap procedure. Precisely, we first estimate a restricted VAR for quarterly excess returns and the income gap under the null of no return predictability by the income gap.[15] We assume the joint distribution of innovations in the VAR corresponds to their empirical distribution. Then, we draw 5,000 samples from this estimated process to obtain a distribution of reverse regression t-statistics. We report the p-value of our estimated t-statistic relative to this bootstrapped distribution. Both the asymptotic standard error and the p-value are informative: the asymptotic standard error is robust to the specifics of the data-generating process, while the p-value handles finite-sample issues conditional on a parameterized data-generating process.[16]

The estimation of Equation (3) is presented in Table 2. The average income gap significantly predicts future bond excess returns. For bonds with a 2-year maturity, $b^{(2)}$ is equal to -.23 and is statistically significant with a p-value of 2.3%. This effect is economically significant. A one standard deviation increase in the average income gap is associated with smaller future excess returns of 2-year maturity zero-coupon

[15] When we add additional controls to the regression, such as in Tables 3 and 5, we allow these other variables to predict returns in the VAR estimation.

[16] We report in Table IA.2 estimates of Equation (3) using Newey-West standard errors allowing for eight quarter lags. However, this procedure has been found to over-reject the null hypothesis in small samples (see, e.g., Ang and Bekaert (2006)).

bonds by about 97 basis points, which represents 44% of the volatility of these bond returns. A one standard deviation increase in the average income gap represents a 4.2 percentage point increase in the fraction of net short-term or variable rate assets, which, given an average income gap of 12.8% corresponds to a 32% increase in the average bank's exposure to interest rate risk.

This correlation increases almost linearly with the maturity of the bond. For bonds with a 5-year maturity, $b^{(5)}$ is equal to -.55, so that a one standard deviation increase in the average income gap corresponds to a 231 basis points reduction in 5-year bond excess returns. This decrease represents about 44% of the volatility of these bonds. $b^{(3)}$, $b^{(4)}$ and $b^{(5)}$ are all statistically different from 0 at the 5% confidence level. $b^{(5)}$ is statistically different from $b^{(2)}$ at the 1% confidence level. The adjusted R^2s we obtain from these forecasting regressions with a single forecasting variable are high: they range from 17% using 2-year maturity bonds up to 20% for bonds with a longer maturity.

Figure 1 highlights the strong forecasting power of the average income gap for future bond returns. This figure plots the value of the average income gap available in quarter t and the excess bond returns from quarter t to quarter $t+4$, $rx^{(n)}_{t\to t+4}$ for zero-coupon bonds of maturity n. Figure 1 displays a striking and robust negative correlation between the income gap series and the excess return series throughout the sample period. In summary, we find that: (1) a smaller average income gap predicts larger bond risk premia (2) this effect is stronger for long-maturity bonds.

In Table 3, we augment Equation (3) by including macroeconomic variables that forecast bond risk premia: the inflation rate and growth in industrial production between $t-4$ and t, and the current output gap. Table 3 shows that the effect of the average income gap on future bond excess returns is left unaffected by the inclusion of these variables. The estimated $b^{(n)}$ and the predictive power of the regressions are similar to those estimated in Table 2, albeit less strongly statistically significant.

1.2.2 Further Analysis

Longer maturities. In Figure IA.3, we estimate Equation 3 for bonds of longer maturities.[17] Panel (a) of Figure IA.3 reports the coefficients $b^{(n)}$, for $n = 1 \ldots 10$, as well as their 95% confidence intervals. The coefficients $b^{(n)}$ decrease for maturities from 2 to 10 years until reaching a level of about -.6. For the longest maturities, the estimates become more imprecise. Panel (b) of Figure IA.3 reports the corresponding adjusted R^2 for each of these regressions. The forecasting power of the income gap is the highest for bonds of maturity 3 to 5 years and then decreases with the bonds' maturity.

Across horizons. We investigate the predictive power of the income gap at various horizons. While one year is the standard horizon considered in the literature predicting bond returns, banks might make risk management decisions at a different horizon. We confirm that our results are robust across horizons. In Table IA.3, we replicate our baseline regression at the 1-quarter horizon. Estimated coefficients are about a quarter of the annual estimates, therefore of similar economic significance. The p-values range from 2.1% to 7.6%. We also construct 1-month returns using the Fama constant maturity portfolios obtained from CRSP. These portfolios are formed every month from bonds of maturity ranging in a one-year interval. Table IA.4 reports

[17] The original data covers the range of maturities regularly until 10 years, but is more sparse above that point, making estimates less reliable.

these estimates, with results again consistent with our baseline.

Real-time prediction. The predictive power found in the full sample may not be observable to economic agents in real-time. To understand whether this is a concern for our analysis, we construct a real-time version of our predictor. At each date t, we estimate a regression of bond excess returns using all data available up to that point. We use the estimated coefficients of this regression in conjunction with the gap at date t to construct a real-time predictor of returns between t and $t+1$. We start the estimation after eight years of data are available. Table 4 reports the estimation of regressions of bond excess returns on this real-time predictor. As the sample period grows large, the coefficient estimate should become 1. In a finite sample, however, the limited amount of data generates measurement error, which biases the estimate toward 0. Despite the short sample period used in our case, we report coefficient estimates that are away from 0, ranging from .69 for 4-year bonds to .81 for 2-year bonds. The coefficients for maturities two and four years are significant at the 10% level and for 3-year bonds at the 5% level. The adjusted R^2 range from 8.3% to 11.2%. While more moderate than the full sample estimates, these results indicate a significant predictive power of the income gap in real-time.

1.2.3 Relation with Yield-Based Predictors

We now turn to an alternative, more indirect, approach to study how much of the variations in bond risk premia are captured by the income gap. Of course, we can never fully characterize these expected returns because the set of potential predictors is arbitrarily large. However, in a large family of models — including the one we present in Section 2 — spanning holds for most parameter combinations: yields at date t capture all the information necessary to predict bond excess returns. Predictability by yields is, therefore, a useful benchmark to consider.

We first ask whether the income gap captures *additional* information about bond risk premia relative to the yield curve. We augment Equation (3) by including 3 and 5 principal components (PC) of yields of maturity 1 to 10 years from the Gurkaynak et al. (2007) data. Table 5 presents the regression estimates. The average income gap appears to have significant forecasting power for bond excess returns, even after controlling for yields. *However*, as crucially emphasized by Bauer and Hamilton (2017), conventional statistics are misspecified to test the spanning hypothesis. Therefore, we use Bauer and Hamilton (2017) bootstrap procedure with three and five PCs to test whether the average income gap is a spanned factor.[18] The bottom row of Table 5 reports p-values for this test and shows that we strongly reject the spanning hypothesis.

Given these results, it is natural to ask how the information captured by banks income gap relates to the information contained in yields. We compare the predictive power of the various forecasting variables. In our sample, the first three PC predict bond returns with an R^2 around 5%, whereas five PC achieve an R^2 around 20%. This latter value is of similar magnitude to what we obtain with the income gap. We also examine the evidence visually to understand better the relationship between various risk premium forecasts (Appendix Figure IA.4). We report forecasts of 5-year Treasury bond excess returns using four different methods: the income gap (thick line), Cochrane and Piazzesi (2005) (dotted line), and three and five PC of yields (dashed

[18] This procedure is similar to the bootstrap we described above in Section 1.2.1, except that the data-generating process for the PC of yields automatically generates return dynamics.

and solid line respectively). All four forecasts exhibit broadly similar cyclical variations. The measure based on three PC are remarkably similar in this sample (a similarity also present in their predictive R^2) and seem to depart significantly from the income gap. However, going up to five PC brings yield forecasts much closer to the average income gap. The main difference between the two measures is the smoother pattern of the average income gap, reflecting the sticky nature of balance sheet quantities relative to asset prices. Echoing our regression results, it seems difficult to argue that one measure is much more informative than the other for forecasting bond excess returns. These results further support both the importance of these additional PC, advocated, for example, by Duffee (2011) and Adrian et al. (2013a), and the economic relevance of the income gap.

2 Theoretical Framework and Predictions

We provide a simple framework to interpret the empirical results presented in Section 1.2. In particular, we consider a setting that abstracts away from many relevant activities and risks banks engage with, such as credit risk, to focus solely on interest rate risk.

2.1 Model and Predictions

Assets. We assume that there are two main assets on the balance sheet of banks. Short-term risk-free assets provide an instantaneous rate of return r_t. Long-lived assets provide a stream of payments $\theta e^{-\theta\tau}dt$ at each date $\tau \geq t$ like a console bond. The parameter θ controls the maturity of long-lived assets: the promised coupons add up to 1, and their average maturity is $1/\theta$.

These two types of assets represent the available saving and borrowing instruments to the economy: productive assets, loans, corporate bonds, deposits, commercial paper, etc. This separation in two categories allows us to consider heterogeneity between short-term and long-term fixed-rate instruments. Also, and this is of empirical relevance, the model allows us to consider variable-rate assets. These instruments are equivalent to rolling over short-term assets and, therefore, can be counted jointly with the short-term assets in our model.

Finally, agents can also trade zero-coupon Treasury bonds of all maturities.[19] Since bonds of all maturities trade, the long-lived asset is redundant: a portfolio consisting of $\theta e^{-\theta\tau}$ bonds of each maturity τ replicates a unit long position in the long-lived asset. We denote by $P_t^{(\tau)}$ the price of the zero-coupon bond with maturity τ. We define the yield on this bond as $y_t^{(\tau)} = -\log(P_t^{(\tau)})/\tau$. Importantly, these Treasury bonds need not constitute a large part of the balance sheet of banks. We include them and use them for measurement because, as will become clear with this model, they are a simple instrument to measure the price of interest rate risk.

Banks. In each period, there is a continuum of banks indexed by i. Denote $E_{i,t}$ the initial net worth of bank i at date t and $X_{i,t}^{(\tau)}$ its net dollar position in bonds of maturity τ. As it will be useful later on, we write $x_{i,t}^{(\tau)} = X_{i,t}^{\tau}/E_{i,t}$ the same position relative to the net worth of the bank. We drop the index i for aggregate quantities. A bank's net worth evolves according to:

[19]All quantities are real. It is straightforward to include an exogenous process for inflation in the model.

$$dE_{i,t} = \int_0^\infty X_{i,t}^{(\tau)} \frac{dP_t^{(\tau)}}{P_t^{(\tau)}} d\tau + \left(E_{i,t} - \int_0^\infty X_{i,t}^{(\tau)} d\tau \right) r_t dt \tag{4}$$

Banks select their net holdings $X_t^{(\tau)}$ so as to maximize an instantaneous mean-variance criterion:[20]

$$\max_{\left\{X_{i,t}^{(\tau)}\right\}_\tau} \mathbb{E}(dE_{i,t}) - \frac{\gamma}{2E_{i,t}} var(dE_{i,t}), \tag{5}$$

where γ is a risk-aversion coefficient. This objective can be rationalized in a setting where banks form overlapping generations, living for an infinitesimal interval dt, and maximize expected utility of final wealth as in Greenwood and Vayanos (2014).[21]

With this objective function, we capture the risk management decisions of banks without taking a particular stance on their origin. One interpretation of the risk-aversion parameter γ is that it comes from the actual risk aversion of the bank's manager, or emanates from her career concerns. Another interpretation is that γ is the Lagrange multiplier on a no-default condition for the bank or a regulatory risk constraint like value-at-risk limits.[22] Irrespective of its origin, risk-aversion by banks is key in our theoretical framework. The fundamental underlying force for our results to hold is that banks trade-off expected profits and risk in a *stable* way over time. This assumption appears legitimate: banks and regulators often explicitly express their concerns over interest rate risk. As an illustration, Bank of America states in its 2016 annual report: "Our overall goal is to manage interest rate risk so that movements in interest rates do not significantly adversely affect earnings and capital."

[20]Note that given the redundancy of the long-lived asset and the zero-coupon bonds, banks simply maximize their holdings of the bonds without loss of generality.

[21]An alternative foundation would be to assume that banks are long-lived and their myopia comes from log utility.

[22]He and Krishnamurthy (2013), Brunnermeier and Sannikov (2014), or Adrian and Shin (2013) are examples of more complete models of the risk appetite of banks.

The FDIC (FDIC (2005)), in its Supervisory Insights, expresses the view that "Interest rate risk is fundamental to the business of banking." The presence of such a risk management motive is also supported by existing evidence coming from the cross-section of banks, see e.g. Drechsler et al. (2018), Kirti (2017), Rampini, Viswanathan, and Vuillemey (2017), or Vuillemey (2017). In Section 4.2, we investigate this risk management motive directly in the data. In particular, our risk-management theory implies that banks suffer when they hold significant balance sheet exposures and interest rates increase. Using banks' equity returns, we do not find empirical support for this assumption. This result constitutes a challenge to the model and interpretation we introduce in this section.

Equilibrium yield curve. Rather than completely specifying the model, we derive relations between the short rate, investment decisions of banks, and the yield curve that must hold in the equilibrium of any economy where banks make risk-management decisions as specified above. The relationships we derive this way are the banking counterpart of household Euler equations for bonds of various maturities.

First, note that, scaled by their equity, all banks solve the same problem. Therefore, the optimal holdings per dollar of equity, $x_{i,t}^{(\tau)} = \frac{X_{i,t}^{(\tau)}}{E_{i,t}}$ are constant across banks. Define g_t the net amount of long-term assets held by banks, divided by their equity. This quantity maps into holdings of the form:

$$\forall \tau > 0, \quad x_{i,t}^{(\tau)} = g_t \theta e^{-\theta \tau}. \tag{6}$$

We study equilibria where the joint dynamics of the short rate and the net position are of the form:

$$dg_t = -\kappa_g (g_t - \bar{g})\, dt + \sigma_g dW_{g,t}, \tag{7}$$
$$dr_t = -\kappa_r (r_t - \bar{r})\, dt - \kappa_{g\to r} (g_t - \bar{g})\, dt + \sigma_r dW_{r,t}.$$

These simple processes capture some key properties of the dynamics we observe empirically. We assume $\kappa_g, \kappa_r > 0$: both the exposure of banks to long-term assets and the short-rate exhibit mean-reversion. The term in $\kappa_{g\to r}$ allows the exposure g_t to predict future changes in the short rate. However, this is not a causal statement: we simply entertain the possibility that there is, in the data, a relationship between changes in the short rate dr_t and banks exposure g_t. Note additionally, that the insights we derive hereafter hold for a larger family of specifications, for example including other determinants of the short-rate dynamics.[23]

As in Greenwood and Vayanos (2014), we guess that yields are linear in the variables we specified, the short-rate r_t and the net exposure to long-lived assets g_t:

$$-\log\left(P_t^{(\tau)}\right) = y_t^{(\tau)} = A_r(\tau) r_t + A_g(\tau) g_t + C(\tau), \tag{9}$$

where $A_r(\tau)$ (resp. $A_g(\tau)$) is the exposure of the yields of bonds with maturity τ to the short-term rate r_t (resp. to the net exposure to long-lived assets g_t). These coefficients are an endogenous outcome of the model that we compute in equilibrium. Plugging in

[23]Consider more state variables z_t to capture the dynamics of interest rates and the income gap (e.g., inflation, employment, ...). As long as this joint system follows a continuous-time VAR(1), that is the vector $\zeta_t = (r_t, g_t, z_t)$ follows

$$d\zeta_t = -K(\zeta_t - \bar{\zeta})dt + \Sigma_\zeta dW_t, \tag{8}$$

Proposition 1 will hold.

the law of motions of r_t and g_t, we obtain an expression for the expected bond returns that we note $\mu_t^{(\tau)}$.

Given this form for yields, we can easily write down the first-order conditions of banks with respect to their holdings in bonds of maturity τ:

$$\mu_t^{(\tau)} - r_t = A_r(\tau)\lambda_{r,t} + A_g(\tau)\lambda_{g,t}, \tag{10}$$

$$\text{where } \lambda_{j,t} = \gamma\sigma_j^2 \int_0^\infty x_{i,t}^{(\tau)} A_j(\tau) d\tau, \text{ for } j = g, r. \tag{11}$$

This condition is akin to a standard Euler equation. The first line tells us that for a bond of a given maturity, the bank requires a risk premium proportional to the exposures ($A_j(\tau)$) of the bond to the fundamental shocks of the economy. The second line characterizes how much compensation is asked for bearing each of these risks: it is proportional to the product of the risk aversion γ, the risk σ_j^2, and the total exposure accumulated through positions in bonds of various maturities.

Plugging the equilibrium portfolio positions into the first-order condition of banks, we obtain the equilibrium risk premia. We provide the details of calculations and proofs as well as verify the conjecture on the form of prices in Appendix A.

Proposition 1. *Consider an equilibrium where the balance sheet position of banks and the short rate are given by Equation (7). The expected excess returns $\mu_t^{(\tau)}$ on the τ-maturity bond is proportional to the net position of banks in long-term assets g_t:*

$$\mu_t^{(\tau)} - r_t = g_t \times (c_r A_r(\tau) + c_g A_g(\tau)) = g_t \times \phi(\tau), \tag{12}$$

where c_r and c_g are two constants determined in equilibrium and $\phi(\tau) > 0$.

Proposition 1 shows that the risk premium on a bond of maturity τ is positively correlated with banks net exposure to long-term assets g_t. When banks hold more long-term assets, they stand to lose more if interest rates increase. As a consequence, they are less willing to hold zero-coupon bonds of various maturity as they lose value at the same time. In an equilibrium where banks do not decide to change their positions in these bonds, the expected return must have adjusted to compensate this lower willingness to bear risk. Thus, in equilibrium, a higher net exposure is correlated with a more significant bond risk premium.

We can further characterize the relationship between bond risk premia and banks' net exposure across maturities.

Proposition 2. *Consider an equilibrium where Equation (7) describes the relationship between the balance sheet position of banks and the short rate. The expected excess returns of bonds of longer maturity are more sensitive to the net exposure of banks:* $\phi(\tau)$ *is strictly increasing in* τ*.*

Proposition 2 shows that a more significant exposure to long term assets predicts a higher risk premium for bonds with longer maturities. Indeed, longer maturity bonds are riskier: their exposure to variations in interest rates is higher than the exposure of short maturity bonds. As a result, following an increase in the net exposure to long-term assets, holding risk premia constant, banks are relatively less willing to hold bonds of longer maturity. Thus, as the net exposure of banks increases, the equilibrium risk premium on bonds of longer maturity will increase more than the risk premium on shorter maturity bonds.

Our model thus makes two direct testable predictions: (1) a larger average net exposure of banks to long-term assets should predict higher bond risk premia, (2) this effect should be stronger for long-maturity bonds. These predictions correspond to the empirical results established in Section 1.

2.2 Additional Considerations

Excess returns versus yields. Our main predictions link bond risk premia $\mu_t^{(\tau)} - r_t$ and the balance sheet of banks g_t. Equation (9) suggests other testable implications, linking banks' balance sheets and yields directly. However, the sign and magnitude of this relation between banks' net position and yields depend on the joint dynamics of rates and positions. This result is in contrast to the relationship between banks' net position and bond excess returns, whose sign is unambiguous in our model. The following proposition illustrates this property.

Proposition 3. *Consider an equilibrium where the balance sheet position of banks g_t and the short rate r_t are given by Equation (7). Then the exposure of bond prices to the net position g_t, $A_g(\tau)$, is of the same sign as $\gamma\sigma_r^2 \frac{1}{\theta+\kappa_r} - \kappa_{g\to r}$. g_t is an unspanned factor if and only if $\kappa_{g\to r} = \gamma\sigma_r^2 \frac{1}{\theta+\kappa_r}$.*

In equilibrium, yields depend not only on current risk premia but also expectations of future rates. Additionally, risk management by banks creates a link between risk premia and their balance sheet composition. Periods of large holdings of risk by banks correspond to periods of large risk premia and high yields. However, risk management by banks does not constrain the relation between short rate expectations and their balance sheet. If periods of high long-term holdings g_t happen to coincide with periods where the short rate decreases (a positive $\kappa_{g\to r}$), then yields should be lower when banks net position increases to reflect expectations of future rates. Proposition 3 characterizes which of the two effects dominate. For one particular parameter value, $\kappa_{g\to r} = \gamma\sigma_r^2 \frac{1}{\theta+\kappa_r}$, the two effects cancel each other and yields of all maturities do not depend on g_t. The net exposure g_t is then an unspanned factor. Close to this knife-edged case, $\kappa_{g\to r} \approx \gamma\sigma_r^2 \frac{1}{\theta+\kappa_r}$, the role of the income gap in explaining yield dynamics remains quantitatively limited. This situation echoes our empirical finding that while not outperforming yields, the information contained in the income gap about bond risk premia reflects the information contained in the higher-order component of yields (Table 5 and Figure IA.4).

Completing the model. We outline a particular economy in which Equation 7 describes the joint dynamics of the short rate r_t and banks net position g_t. To do so, we specify the supply of other assets as well as the behavior of other market participants.

We first assume the existence of an instantaneous risk-free asset that is in perfectly elastic supply at rate r_t, now a primitive of the model. We also assume that long-lived assets are in finite supply, while zero-coupon bonds are in zero net supply. We introduce a second group of agents in addition to banks: households. Households are considered here in an extended sense: we pool them together with non-financial firms and the government. They are endowed with the entire supply of long-lived assets. Additionally, households borrow from banks at date t an exogenous amount B_t of long-lived asset and lend to banks an exogenous amount L_t of long-term assets.[24] We define the net imbalance $-g_t$ as the difference between the ratio of long-term savings to total bank equity $l_t = L_t/E_t$ and long-term borrowing to total bank equity $b_t = B_t/E_t$. Now g_t is also a primitive of the model. Then, as long as the exogenous

[24] We can easily relax the exogeneity assumptions and allow borrowing and lending by households to be price-elastic: this does not change the qualitative predictions we derived so far.

laws of motion for r_t and g_t are given by Equation (7), we obtain the equilibrium yield curve in Equation (9).

The assumption of exogenous changes in households and firms portfolios is a simplification of a more complicated decision problem: households and firms savings and borrowing decisions. Exogenous shocks to l_t and b_t are meant to capture the fact that factors other than simple risk-return trade-offs influence those decisions. For instance, changing liquidity needs, the use of incorrect heuristics or hedging demands can affect those decisions. We come back to potential empirical counterparts of these shocks in Section 4.1.2.

3 Model Estimation

In this section, we take the model presented in Section 2 to the data. This exercise allows us to consider the ability of our theory to quantitatively rationalize the relationship between banks' balance sheets and expected returns throughout the yield curve. Besides, we obtain an estimate of banks' willingness to take risk, γ, a key parameter of our model, which is also central to many macroeconomic models with intermediaries.

To define the state variable g_t, we use equation (2) and construct the bank-level gap g_{it}, which corresponds to $1 - \text{Income Gap}_{it} \times \frac{\text{Assets}_{it}}{\text{Equity}_{it}}$ (see Section 1.1.1). Table IA.6 confirms that the predictive results of Section 1.2 hold for this measure as well. To estimate the dynamics of the model's state variables, we discretize the model using 1 year as the time unit. Concretely, if t is a year, we estimate the following equations, which correspond to the discrete-time version of Equation (7):

$$\begin{cases} y_{t+1}^{(1)} - y_t^{(1)} = -\kappa_r y_t^{(1)} - \kappa_{g\to r} g_t + \epsilon_{r,t} \\ g_{t+1} - g_t = -\kappa_g g_t + \epsilon_{g,t} \end{cases}$$

where g_t is the exposure measure defined above measured in the first quarter of the year. We use a parametric bootstrap to correct the estimates of κ_r, κ_g and $\kappa_{g\to r}$ for small sample bias. σ_r and σ_g are estimated as the empirical standard deviation of ϵ_r and ϵ_g respectively. We estimate $\phi(\tau) = (c_r A_r(\tau) + c_g A_g(\tau))$ defined in Proposition 1 by regressing bond the one-year holding excess returns of bonds of maturity τ on g_t at the yearly frequency. We calibrate $\frac{1}{\theta}$, the time-to-maturity of the long term asset, to 10 years.[25] We use these estimated coefficients and the calibrated θ to compute $\hat{I}_r = \frac{1}{\hat{\kappa}_r}\left(1 - \frac{\theta}{\theta+\hat{\kappa}_r}\right)$ and $\hat{A}_r(\tau) = \frac{1-e^{-\hat{\kappa}_r\tau}}{\hat{\kappa}_r}$.

Finally, γ, the risk-aversion coefficient is estimated by minimizing the squared distance between the average $\phi(\tau)$ across maturities ($\frac{1}{4}\sum_{\tau=2}^{5}\hat{\phi}(\tau)$) and their theoretical counterpart. Table 6 presents the coefficient estimates. The estimated risk-aversion is about 19. Given banks optimization problem in Equation 5, this risk-aversion coefficient corresponds to a relative-risk aversion coefficient. The model reveals a much larger risk-aversion than the typical calibration in macroeconomic models with a financial sector. He and Krishnamurthy (2014b) use a relative-risk aversion coefficient of 2; Brunnermeier and Sannikov (2014) use log-utility. This number is within the range of the estimates of Greenwood and Vayanos (2014), who use variations in Treasury supply to identify the *absolute* risk-aversion of *all* arbitrageurs in fixed income

[25] To assess the importance of this calibration, we provide a sensitivity analysis below using a range of alternative values for θ.

markets. Because their method does not observe the arbitrageurs directly, they must make assumptions on their total wealth, giving rise to a wide range of plausible estimates. We can obtain point estimates without such assumptions because we directly measure the portfolios of banks. If we assume that banks constitute the whole group of arbitrageurs in the market for interest rate risk, their estimates are a third of ours.[26] The literature on quantitative easing interventions reports estimates of risk aversion that are about 85% of what we find here.[27] The other interpretation of this difference is that banks are only a subset of arbitrageurs in this market. Under this view, banks constitute a sizable part of this group, between a third and 85% depending on the supply-response estimates.

We confirm the model's ability to fit risk premium dynamics across maturities. Figure IA.5 shows the model's goodness of fit by comparing the empirical estimates $\hat{\phi}(\tau)$ – the coefficient estimates obtained when regressing bond excess returns of maturity τ on g – with their model-implied counterpart. For the 2-year bond, the model slightly overestimates the sensitivity of bond risk premia to the income gap; at all other horizons, the model-implied estimates and the empirical estimates are very close. Figure IA.6 investigates robustness relative to our calibration for θ. Our baseline estimation uses an average time-to-maturity for the long term asset of 10 years ($\theta = .1$). Figure IA.6 re-estimates our model using different values of $1/\theta$ ranging from 2 to 50. For high values of θ ($\approx$ 50), the risk aversion coefficient is estimated at 10, while a time-to

[26] Greenwood and Vayanos (2014) have a point estimate for the absolute risk aversion of arbitrageurs of 57. To obtain a relative risk aversion, assuming arbitrageurs are only banks, one needs to multiply this number by the total banking sector's capital as a fraction of GDP. In 2015, the U.S. GDP was $18tn, banks' total assets were $17tn, and banks' capital to assets ratio was 11.7%. These numbers imply a relative risk aversion of 6.3.

[27] D'Amico and King (2013) find supply effects two and a half as large as Greenwood and Vayanos (2014), and Hamilton and Wu (2012) report an absolute risk aversion twice as large.

maturity of 5 years leads to a relative-risk aversion for banks of 25.

4 Interpretation

The model developed in Section 2 provides a simple interpretation of our results. In this section, we first present a collection of empirical observations supporting this view and then discuss several challenges to this interpretation.

4.1 Supporting Evidence

4.1.1 The Income Gap or Other Balance Sheet Quantities?

Our theory relates the quantity of interest rate risk borne by banks with the market price of this risk. Empirically, the predictive power of the income gap may come from specific features of banks' average balance sheets that happen to correlate with bond risk premia for reasons unrelated to banks risk management of interest rate risk. If this were the case, we should observe similar or higher predictability using dimensions of the balance sheets that do not focus on the net exposure to interest rate risk. In what follows, we consider two particular dimensions.

The income gap and its components. Our first tests estimate separately the ability of the asset and liability components of the income gap to forecast bonds' excess returns. Figure IA.7 shows these two components: "Non-exposed assets" correspond to the average bank-level ratio of assets that either reprice or mature within a year normalized by total consolidated assets (in blue); "Non-exposed liabilities" is the opposite of the average bank-level ratio of liabilities that either reprice or mature within a year normalized by total consolidated assets (in red). If the forecasting power of the income gap comes only from, say, its asset side (the blue line), then our interpretation cannot be valid: in our theory, only banks' total portfolio exposure should forecast bonds' excess returns. Since the liability side of the gap varies significantly in the time-series, such a result would invalidate our interpretation.

To implement this test, we simply replace the Income Gap in Equation (3) by its two components: "Non-exposed assets" and "Non-exposed liabilities". Table 7 reports the results. For brevity, we only show the estimated coefficients when the dependent variable is the excess return on 5-year maturity bonds. Column (1) replicates the results of Column (4), Table 2. Column (2) and (3) show that taken individually, each of the two components of the average income gap does not forecast robustly future bond excess returns. The estimated coefficients have low statistical significance and are small in magnitudes. In Column (4), we include the two components simultaneously in the regression. Both coefficients then become statistically significant and of a magnitude close to that of the income gap alone. Thus, consistent with our interpretation, only the overall exposure of the average financial intermediary explains bond risk premia.

Interest rate risk versus liquidity risk. Similarly, we ask whether balance sheet aggregates focusing on *liquidity risk* predict bond returns. We consider the liquidity mismatch index (LMI) of Bai, Krishnamurthy, and Weymuller (2018), the bank liquidity creation index of Berger and Bouwman (2009), which we equal-weight or value-weight by total gross assets across banks (BB), and the Basel Committee's liquidity coverage ratio (LCR) as constructed by Choi and Choi (2016).[28]

[28]We thank the authors of this work who graciously shared their data with us.

The measures of liquidity risk behave differently from banks average income gap. Figure IA.8 plots these four measures jointly with the income gap, standardized to have a unit standard deviation. We flip the sign of the BB measure so that low values correspond to high liquidity risk, like LMI and LCR. The time-series behavior of liquidity risk differs from the income gap in at least three ways. First, while the average income gap evolves smoothly around the crisis, LMI experiences a sharp drop and rebounds right after the financial crisis.[29] Second, the liquidity measures all exhibit strong growth in the post-crisis period. Third, in the earlier part of the sample, these measures depict a slow secular increase in liquidity risk while there are substantial cyclical variations in the average income gap.

The measures of liquidity risk do not predict bond returns. Table IA.7 reports our baseline predictive regressions, replacing the income gap by the value-weighted BB index, which features an extended sample and echoes the behavior of the other measures in the late part of the sample. None of the coefficients are statistically significant, and the adjusted R^2 are all well below 1%. Interestingly these results also dispel the idea that it would be enough to exhibit somewhat of a downward trend to capture bond risk premia.[30]

4.1.2 Demand Shocks and Bond Risk Premia

We consider three measures of the "demand" for savings and borrowing instruments and ask whether they forecast excess bond returns: (1) the aggregate demand for

[29] Bai et al. (2018) argue this feature reflects the superiority of their measure, which also leads to a better ability to capture how cross-sectional differences in liquidity risk are related to bank lending.

[30] We reproduced this analysis for the equal-weighted measure and also found no significant coefficients and all R^2 below 1%. The shorter sample measures, LMI and LCR, do not perform better, with no coefficients distinct from 0 and low R^2 of about 2% even in the short sample.

adjustable-rate mortgages (2) the aggregate demand for deposits (3) the aggregate supply of government bonds. These measures correspond to the supply/demand shocks of long-lived assets in the model of Section 2. In particular, none of these shocks should have a significant forecasting power for bond risk premia above and beyond the average income gap. Indeed, as per our model, a sufficient statistic for bond risk premia is the net interest rate risk held by banks, captured by the income gap. Empirically, we consider three such observable shifts in quantities:

Households' choice of fixed-rate vs. adjustable-rate mortgages (ARM) depends on multiple determinants, which can change over time.[31] Using the Monthly Interest Rate Survey, we compute the quarterly ratio of ARM issuance to total mortgage issuance. To the extent that shifts in households' demand are the source of some of these variations, as in our model, an increase in the share of ARM in total mortgage issuance forces banks to hold more ARM. Everything else equal, banks' average income gap should decrease. Figure IA.10(a) shows that there is, in fact, a positive correlation (59%) between the share of ARM in mortgage issuance and the average income gap, at least until 2006.[32]

We also consider the average quarterly bank-level ratio of non-interest-bearing deposits normalized by total consolidated assets. When households increase their relative demand for non-interest-bearing deposits, banks end up in equilibrium with more interest rate sensitive liabilities. Thus, everything else equal, their income

[31]This choice involves a risk-return trade-off and households may use simple imprecise heuristics to make decisions (Koijen, Hemert, and Nieuwerburgh, 2009). This choice also partly reflects the desire of households to manage their liquidity, which may depend on aggregate factors (Chen, Michaux, and Roussanov, 2013).

[32]Of course, this unconditional positive correlation does not have to be present, since other shifts in the demand for other components of banks' balance sheets may force them to adjust their income gap in an opposite direction.

gap increases. There are several time-varying determinants of the demand for non-interest-bearing deposits. Depositors have a choice between many stores of wealth, which, beyond a standard risk-return trade-off, will be determined by liquidity considerations (Tobin (1956), Baumol (1952)) or demand for safety (Krishnamurthy and Vissing-Jorgensen, 2012).[33] Figure IA.10(b) shows the time-series evolution of non-interest-bearing deposits and its positive correlation (64%) with the average income gap.

Finally, we consider the aggregate supply of government bonds. We use the maturity-weighted supply of treasuries, normalized by GDP, as in Greenwood and Vayanos (2014). By varying the supply of long-term bonds in the economy, the government may shift the availability of interest rate risk. For instance, to fund an expansionary fiscal policy, the government will increase the Treasury supply, and, in equilibrium, the income gap of banks should decrease. Figure IA. 10(c) show the time-series evolution of the maturity-weighted Treasuries supply measure. Given the low-frequency fluctuations in Treasuries supply, this series does not exhibit much correlation with the average income gap.

We investigate whether these measured fluctuations in the supply/demand for interest rate risk predict bond risk premia. We start by replacing the average income gap by each of these "demand" factors in Equation (3). We then add the average income gap to the forecasting regression. The estimated coefficients are presented in Table 8. Column (1) and (5) show that the share of adjustable-rate mortgages and the maturity-weighted Treasury supply measure of Greenwood and Vayanos (2014) do not significantly correlate with future bonds excess returns. Thus, unsurprisingly,

[33]For instance, the fraction of non-interest-bearing deposits exhibits a correlation of 46% with the HP-filtered monetary aggregate M1.

Column (2) and (6) of Table 8 show that the forecasting power of the average income gap is not affected by the inclusion of these two variables in Equation (3). Column (3) shows an R^2 of 8.7% when using the average ratio of non-interest-bearing deposits normalized by consolidated assets to predict returns on 5-year bonds. However, Column (4) shows that once we control for the average income gap, non-interest-bearing deposits do no longer correlate with bond risk premia, while the income gap remains a statistically significant predictor with an economic magnitude similar to our baseline specification.

All these results are consistent with our interpretation: the net exposure to interest rate risk borne by banks, as measured by the average income gap, appears to better capture variations in expected excess bond returns than quantities of particular types of financial assets.

4.1.3 Risk-Sharing Evidence

We exploit information on income gap at the bank level to study the time-series behavior of the income gap across heterogeneous banks. In our model, the equilibrium risk premium adjusts so that banks are collectively willing to bear the interest rate risk supplied by other agents in the economy. Even if banks face customers with heterogeneous demand, they can use financial markets to share interest rate risk. To the extent that banks have similar risk preferences, they would end up with the same net exposure. Therefore, even across heterogeneous banks, one would expect to find common variations in their income gap, close to the average income gap. We find evidence supporting this risk-sharing view using three sources of heterogeneity across banks: size, geography, and leverage.

Panel (a) of Figure 2 represents the time series of the 10th, 25th, 50th, 75th, and 90th percentile of the cross-sectional distribution of the gap each quarter. There are substantial cross-sectional variations in income gap across banks: the interquartile range is about 20%. However, the whole distribution appears to shift up and down over time, suggesting common variations. Panel (b) reinforces this point: it presents the demeaned time series of the various percentile. Those series are all strongly positively correlated.

The first dimension of bank heterogeneity we consider is size.[34] We split banks into ten groups based on decile of total assets. Figure 3 represents the average income gap for each size group. All series are remarkably similar to the average income gap except for the largest size group, for which we do not capture the income gap accurately, most likely because of their use of interest rate derivatives. The correlation with the average income gap is about 85% for each size group except the fourth (72%) and the tenth (18%).

We repeat this comparison across nine geographic regions of the United States. Because of heterogeneity in local economic conditions, one would expect banks in different regions to face different demand for interest rate exposure. However, Figure 4 shows that across these nine regions, banks share similar net exposure to interest rates. The local average income gaps all exhibit a strong correlation with the national average income gap. All correlations are between 80% and 90% except for the South-West Center (Panel 8, 63%) and the Mountain region (Panel 4, 45%).[35]

Finally, we compare banks that vary directly in the composition of their balance

[34]For example, Kashyap and Stein (2000), document variation in bank balance sheet composition across the size distribution.

[35]The latter is the only substantial deviation, likely caused by individual measurement error as the Mountain region has the lowest number of banks in our sample, between 7 and 23 per quarter.

sheets. For each bank, we compute the equity-to-assets ratio and deposits-to-assets ratio. Book leverage consists of the ratio of book equity over consolidated assets. The fraction of deposits is the ratio of checking deposits to total assets. For each of those characteristics, we split our sample into two groups. Panel (a) of Figure 5 presents the average income gap of banks sorted on equity-to-assets. The top group has an average ratio of 10% and the bottom one of 7%. The average income gap for each group does not exhibit any substantial deviation from each other. Panel (b) compares the two groups based on deposits-to-assets. The average level for the ratio for the two groups is 8% and 17%, a distinction reflecting the likely exposure to interest rate risk of deposits. Over time, the two series also exhibit a strong positive correlation.

4.2 Challenges to Interpretation

We now discuss several challenges to the interpretation of our results described in Section 2. These challenges all pertain to a particular assumption that is central to the banking view of bond risk premia. Our model builds on a risk management objective for banks: when banks hold significant balance sheet exposures and the interest rate increases, banks' value should decrease. This assumption underlies banks' risk management decisions, which, in turn, drive the relationship between the average income gap and excess returns on Treasury bonds. In this section, we use banks' equity returns to test this assumption and its implications.

Our first test investigates the empirical relationship between banks' equity returns and Treasury returns and how this relationship depends on the average income gap. In the simple framework of Section 2, when banks' average income gap is low, banks' value should decrease when interest rates increase. Measuring banks' value through banks' equity returns, we expect the correlation of realized banks' returns with realized bond returns to be significantly lower when banks' average income gap is low. We test this hypothesis on quarterly data from 1986 to 2014. We measure banks' returns as the excess 1-quarter return of the Fama-French industry portfolio for banks. We measure bond returns as the excess 1-quarter return of the Fama portfolio of bonds with maturities ranging from five to ten years. We then estimate the following equation:

$$rx_{banks,t} = b_0 + b_1 r_{Tbond,t} + b_2 Gap_{t-1} + b_3 Gap_{t-1} \times r_{Tbond,t}. \quad (13)$$

Table 9 presents the estimation results. Periods of low-income gap appear to be *negatively*, rather than positively, related to banks' exposure to bond returns (i.e., $b_3 > 0$). This result suggests that when banks' balance sheet exhibit significant exposure, a rise in interest rate increases, rather than decreases, banks' equity value. This result is inconsistent with the risk management motive for banks highlighted in our model. Note, however, that once we control for the equity market returns (Column (2)), b_0, b_1 and b_2 become insignificant.[36] With this added control, the relation between banks' income gap and the covariance between banks and bond returns is neither economically nor statistically significant.

We can also construct a more specified test that builds on the particular mean-variance framework used in Section 2. In our model, banks aim to limit the volatility of their equity value. This particular specification of banks' risk management objective implies that bond risk premia should be proportional to the expected covariance

[36] While not a direct consequence of the theoretical model of this paper, controlling for market exposures to understand intermediary risk is a frequent feature of intermediary asset pricing models, adopted for instance by Adrian et al. (2014) and He et al. (2017).

of banks' equity returns with bond returns. Table 10, Column (2) tests this prediction empirically. Each quarter, we compute the covariance of excess daily returns from the Fama portfolio of Treasuries with maturities ranging from five to ten years and the Fama-French industry index for banks. We then construct a forecast of this quantity using an AR(1) model and use this forecast as a predictor of bond returns. The coefficient is small and insignificant. The regression's adjusted R^2 is negative. There is no meaningful relationship between bond excess returns and the predicted covariance of daily excess returns on long-term bonds and banks stock returns. This analysis rejects the mean-variance framework that we use to motivate banks' risk management decisions at the heart of the model in Section 2.

Another, related, view of banks' objective function is that banks consider risk in a segmented way. In particular, banks may care *specifically* about the volatility created by their interest rate exposure. In this case, banks are reluctant to hold large *total* quantity of interest rate risk, so that bond risk premia should be proportional to the product of their net quantity of exposed assets and the current variance of long-term bond returns. Table 10, Column (6) shows this is not the case empirically. Using the Fama portfolio returns, we construct a quarterly measure of expected variance similar to the measure of covariance described above. The interaction of banks' income gap and bond variance does not significantly forecast bond risk premia: the predictability of bond excess returns arising from banks' income gap is not higher when interest rate risk is larger. This result is not surprising since the variance of bond returns itself does not forecast bond risk premia (Table 10, Column (4)).[37]

[37]The fact that a strong predictor of return does not significantly correlate with return volatility and that return volatility does not predict future returns is not unique to our setting. For example, Moreira and Muir (2017) find similar evidence for equities

These analyses, together with the evidence of predictability in Section 1 and the evidence in Section 4.1, constitute an exciting puzzle: banks' balance sheet exposures strongly and robustly forecast bond risk premia (Section 1); a natural interpretation of these results relies on banks' risk management: banks try to limit their interest rate exposure, and only take on significant exposures when bond risk premia provide appropriate compensation (Section 2); this interpretation is consistent with the collection of evidence presented in Section 4.1; yet, this interpretation relies importantly on banks' risk management motives, a motive that remains elusive in the data.

5 Conclusion

While banks are central intermediaries in the market for interest rate risk, they are notably absent of the standard empirical analyses of bond risk premia. Our paper fills this gap in the literature. We show that the net exposure of the banking sector to interest rate risk, as measured through banks' average income gap, strongly forecasts future bond excess returns. The economic magnitude of this forecastability is significant: an increase of banks holding of short-term or variable rate assets by 4.2 percentage points (as a fraction of their total assets) is associated with a 231 basis points decrease in the 1-year excess returns of 5-year maturity bonds. This relationship is stronger for bonds with longer maturities and survives a battery of robustness checks.

A natural interpretation of these findings considers banks as large marginal investors in the market for interest rate risk. In our term-structure model, the price of interest rate risk adjusts so that banks are collectively willing to bear this interest rate risk and banks' holdings forecast bond risk premia. We document a collection of empirical findings consistent with this interpretation. We show that only the average income gap forecasts bond risk premia, and not its liability or asset components. We also find that standard measures of liquidity risk do not forecast bond risk premia, in contrast to our measure of banks' balance sheet exposure. Additionally, isolated shocks to the realized net demand and supply of interest rate risk do not bring additional forecasting power to our income gap measure. Finally, we present evidence consistent with interest rate risk-sharing among heterogeneous banks.

This interpretation, however, faces a significant challenge: the banking view of bond risk premia we highlight in this paper requires that banks suffer when they hold significant balance sheet exposures and interest rates increase. This risk management motive remains elusive in the data. Solving this apparent puzzle is a challenge we hope to tackle in future research.

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Tables

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	P25	P50	P75
Income Gap	109	.128	.042	.092	.122	.163
$y^{(1)}$	111	.041	.026	.015	.046	.059
$y^{(2)}$	111	.043	.025	.018	.047	.063
$y^{(3)}$	111	.046	.025	.023	.048	.063
$y^{(4)}$	111	.048	.024	.027	.05	.066
$y^{(5)}$	111	.05	.023	.03	.051	.069
$rx^{(2)}$	108	.014	.022	-.001	.013	.027
$rx^{(3)}$	108	.02	.033	-.002	.021	.042
$rx^{(4)}$	108	.026	.043	-.008	.026	.057
$rx^{(5)}$	108	.03	.052	-.012	.031	.069
IP Growth	107	.021	.042	.01	.028	.045
Inflation	111	.028	.013	.02	.028	.036
Output Gap	111	-.015	.017	-.027	-.013	-.001

Note: Quarterly data over the 1986-2014 period. The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. $y^{(n)}$ is the yield of GSW zero-coupon bonds of maturity n. $rx^{(n)}$ is the excess 1-year return of GSW zero-coupon bonds of maturity n. IP growth is the 1-year growth rate in industrial production (INDPRO in FRED). Inflation is the 1-year growth rate of the CPI, taken from the FRED database. Output gap corresponds to the difference between the real seasonally adjusted GDP (GDPC96 from the FRED database) and the real potential GDP (GDPPOT from FRED), normalized by the real seasonally adjusted GDP.

Table 2: Income Gap and Bond Excess Returns

	(1) $rx^{(2)}$	(2) $rx^{(3)}$	(3) $rx^{(4)}$	(4) $rx^{(5)}$
Income Gap	-0.23**	-0.36**	-0.47**	-0.55**
	(0.10)	(0.15)	(0.21)	(0.27)
Constant	0.04**	0.07**	0.09**	0.10**
	(0.01)	(0.02)	(0.03)	(0.04)
Bootstrapped p-value	0.023	0.024	0.035	0.048
Observations	106	106	106	106
Adjusted R^2	0.172	0.200	0.201	0.189

Sample period: 1986-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. $rx^{(n)}$ is the excess 1-year return of GSW zero-coupon bonds of maturity n. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance, where the p-values are computed using the bootstrap approach described in Section 1.2.1.

Table 3: Income Gap and Bond Excess Returns : Controlling for Macroeconomic Conditions

	(1) $rx^{(2)}$	(2) $rx^{(3)}$	(3) $rx^{(4)}$	(4) $rx^{(5)}$
Income Gap	-0.21*	-0.34*	-0.44*	-0.52*
	(0.10)	(0.16)	(0.22)	(0.28)
Inflation	0.49	0.58	0.61	0.60
	(0.34)	(0.53)	(0.71)	(0.87)
IP Growth	-0.10	-0.10	-0.07	-0.01
	(0.07)	(0.13)	(0.20)	(0.27)
Output Gap	0.06	-0.02	-0.14	-0.27
	(0.24)	(0.38)	(0.53)	(0.68)
Constant	0.03	0.05	0.07	0.08
	(0.02)	(0.03)	(0.04)	(0.04)
Bootstrapped p-value	0.061	0.051	0.055	0.071
Observations	104	104	104	104
Adjusted R^2	0.223	0.210	0.189	0.166

Sample period: 1986-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. $rx^{(n)}$ is the excess 1-year return of GSW zero-coupon bonds of maturity n. IP growth is the 1-year growth rate in industrial production (INDPRO in FRED). Inflation is the 1-year growth rate of the CPI, taken from the FRED database. Output gap corresponds to the difference between the real seasonally adjusted GDP (GDPC96 from the FRED database) and the real potential GDP (GDPPOT from FRED), normalized by the real seasonally adjusted GDP. NBER recession is a dummy equal to 1 for quarters flagged as a recession by the NBER. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance, where the p-values are computed using the bootstrap approach described in Section 1.2.1.

Table 4: Income Gap and Bond Excess Returns : In Real Time

	(1) $rx^{(2)}$	(2) $rx^{(3)}$	(3) $rx^{(4)}$	(4) $rx^{(5)}$
Predicted Excess Return	0.81*	0.72**	0.69*	0.71
	(0.41)	(0.36)	(0.38)	(0.43)
Constant	0.00	0.00	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.02)
Bootstrapped p-value	0.052	0.050	0.076	0.112
Observations	71	71	71	71
Adjusted R^2	0.083	0.112	0.106	0.097

Sample period: 1991-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. Predicted return is computed using the current value of the income gap and the coefficients from a regression of realized excess returns on the income gap using all data available until that point. $rx^{(n)}$ is the excess 1-year return of GSW zero-coupon bonds of maturity n. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance, where the p-values are computed using the bootstrap approach described in Section 1.2.1.

Table 5: Income Gap and Bond Excess Returns : Testing the Spanning Hypothesis

	3 Principal Components				5 Principal Components			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$rx^{(2)}$	$rx^{(3)}$	$rx^{(4)}$	$rx^{(5)}$	$rx^{(2)}$	$rx^{(3)}$	$rx^{(4)}$	$rx^{(5)}$
Income Gap	-0.39***	-0.60***	-0.77***	-0.89***	-0.36***	-0.55***	-0.71***	-0.83***
	(0.11)	(0.18)	(0.25)	(0.31)	(0.11)	(0.18)	(0.25)	(0.31)
PC1	0.09	0.12	0.15	0.16	0.09	0.12	0.14	0.15
	(0.03)	(0.05)	(0.06)	(0.08)	(0.03)	(0.05)	(0.06)	(0.08)
PC2	0.17	0.34	0.53	0.72	0.17	0.34	0.52	0.72
	(0.17)	(0.28)	(0.38)	(0.47)	(0.17)	(0.28)	(0.38)	(0.47)
PC3	-0.46	-1.05	-1.61	-2.11	-0.38	-0.93	-1.46	-1.94
	(0.82)	(1.34)	(1.81)	(2.24)	(0.82)	(1.33)	(1.80)	(2.23)
PC4					-1.95	-2.45	-2.47	-2.07
					(2.15)	(3.39)	(4.51)	(5.49)
PC5					-4.27	-7.14	-10.06	-12.68
					(3.39)	(5.57)	(7.65)	(9.57)
Constant	0.03	0.06	0.08	0.09	0.05	0.08	0.11	0.13
	(0.02)	(0.03)	(0.05)	(0.06)	(0.03)	(0.04)	(0.05)	(0.07)
Spanning p-value	0.003	0.003	0.007	0.015	0.005	0.009	0.012	0.020
Observations	106	106	106	106	106	106	106	106
Adjusted R^2	0.417	0.428	0.426	0.414	0.442	0.451	0.447	0.433

Sample period: 1986-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and is defined as the difference between the amount of assets that either reprice, or mature, within one year, and the amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. $rx^{(n)}$ is the excess 1-year return of GSW zero-coupon bonds of maturity of maturity n. PC1 to PC5 are the principal components of GSW yields of maturity 1 to 10 years, divided by 100. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance, where the p-values are computed using the bootstrap approach described in Section 1.2.1. The last row reports the p-value of a test of the spanning hypothesis using the parametric bootstrap of Bauer and Hamilton (2017).

Table 6: Model Estimation

Parameters	Estimates	90% CI
κ_r	0.146	[-0.033, 0.295]
κ_g	0.062	[-0.164, 0.263]
κ_{gr}	0.019	[0.012, 0.029]
σ_r	0.0001	[0.0001, 0.0002]
σ_g	0.071	[0.037, 0.093]
$\hat{\phi}(2)$	0.016	[0.008, 0.026]
$\hat{\phi}(3)$	0.030	[0.016, 0.047]
$\hat{\phi}(4)$	0.042	[0.023, 0.064]
$\hat{\phi}(5)$	0.051	[0.026, 0.079]
γ	19.221	[1.767, 75.995]

This table presents the model's parameter estimates. The estimation procedure is described in details in Section 3. 90% CI corresponds to bootstrapped 90% confidence intervals.

Table 7: Asset and Liability Risk Exposure and Bond Excess Returns

	(1) $rx^{(5)}$	(2) $rx^{(5)}$	(3) $rx^{(5)}$	(4) $rx^{(5)}$
Income Gap	-0.55**			
	(0.27)			
Non-Exposed Assets		-0.10		-0.50*
		(0.18)		(0.27)
- Non-Exposed Liabilities			-0.36	-0.78**
			(0.23)	(0.34)
Constant	0.10**	0.07	-0.08	0.01
	(0.04)	(0.08)	(0.07)	(0.08)
Observations	106	106	106	106
Adjusted R^2	0.189	0.001	0.081	0.233

Sample period: 1986-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. $rx^{(n)}$ is the excess 1-year return of GSW zero-coupon bonds of maturity n. Non-exposed Assets is the average bank-level ratio of assets that either reprice or mature within a year normalized by total consolidated assets. - Non-exposed liabilities is the opposite of the average bank-level ratio of liabilities that either reprice or mature within a year normalized by total consolidated assets. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance,where the p-values are computed using the bootstrap approach described in Section 1.2.1.

Table 8: Changing Asset Quantities and Bond Excess Returns

	(1)	(2)	(3)	(4)	(5)	(6)
	$rx^{(5)}$	$rx^{(5)}$	$rx^{(5)}$	$rx^{(5)}$	$rx^{(5)}$	$rx^{(5)}$
Income Gap		-0.83**		-0.51*		-0.60**
		(0.32)		(0.27)		(0.26)
ARM Fraction of Issuance	-0.02	0.09				
	(0.06)	(0.07)				
Non Int.-Bearing Deposits			-0.94	-0.15		
			(0.63)	(0.64)		
Mat.-Weighted Debt/GDP					-0.00	0.01
					(0.01)	(0.01)
Constant	0.04	0.11*	0.15*	0.12	0.04	0.09
	(0.03)	(0.04)	(0.08)	(0.08)	(0.04)	(0.05)
Observations	98	98	106	106	106	106
Adjusted R^2	-0.004	0.269	0.087	0.182	-0.007	0.194

Sample period: 1986-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. $rx^{(5)}$ is the excess 1-year return of GSW zero-coupon bonds of 5-year maturity. ARM fraction of issuance is the quarterly share of adjustable-rate mortgages in total mortgage issuance, from the Monthly Interest Rate Survey. Non int. bearing deposits is the average of the quarterly bank-level ratio of non-interest-bearing deposits normalized by total consolidated assets. Mat.-weighted Debt / GDP is the maturity-weighted Treasuries supply measure of Greenwood and Vayanos (2014). Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance, where the p-values are computed using the bootstrap approach described in Section 1.2.1.

Table 9: Banks' Stock Return Exposure to Treasuries

	(1)	(2)
	$rx_{banks,t}$	$rx_{banks,t}$
Income Gap_{t-1}	0.06	0.10
	(0.26)	(0.19)
$rx_{Tbond,t}$	-4.35***	-0.17
	(1.08)	(0.78)
Income $\text{Gap}_{t-1} \times rx_{Tbond,t}$	28.13***	3.65
	(8.22)	(5.74)
$rx_{mkt,t}$		1.09***
		(0.09)
Constant	0.02	-0.01
	(0.04)	(0.03)
Observations	109	109
Adjusted R^2	0.124	0.620

Sample period: 1986-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. rx_{banks} is the excess 1-quarter return of the Fama-French industry portfolio for banks. rx_{Tbond} is the excess 1-quarter return of the Fama portfolio of bonds with maturities ranging from five to ten years. rx_{mkt} is the excess 1-quarter return of the CRSP value-weighted index. Newey-West standard errors with a bandwidth of 2 years are reported in parentheses. *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance.

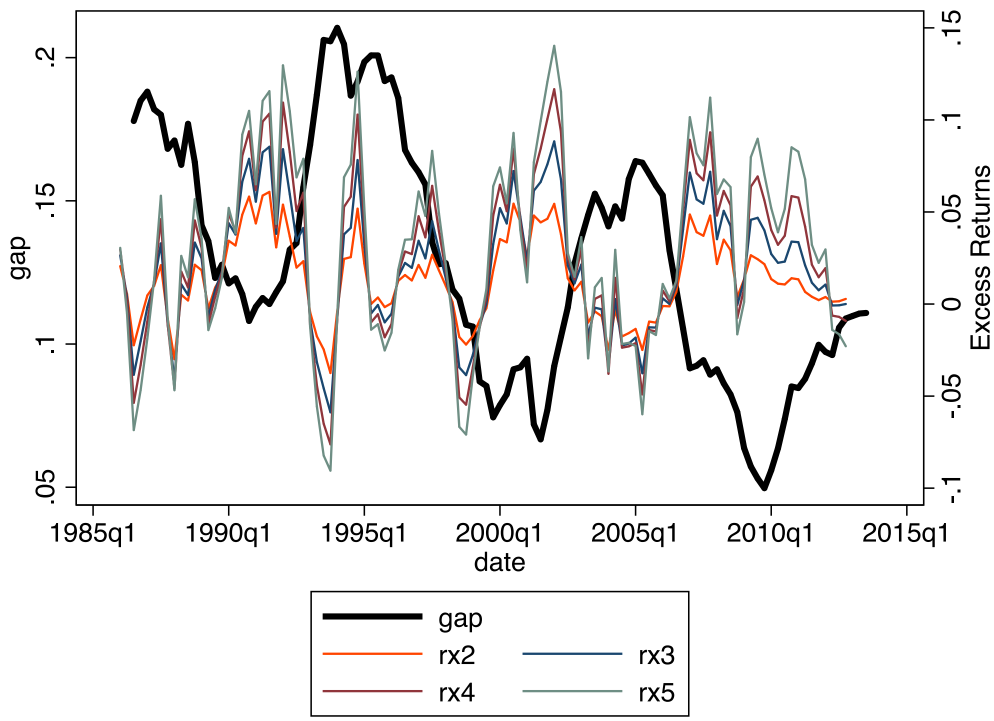
Table 10: Alternative Risk Measures and Bond Excess Returns

		$X = \text{Cov}_t(r_{banks}, r_{Tbond})$		$X = \text{Var}_t(r_{Tbond})$		
	(1)	(2)	(3)	(4)	(5)	(6)
	$rx^{(5)}$	$rx^{(5)}$	$rx^{(5)}$	$rx^{(5)}$	$rx^{(5)}$	$rx^{(5)}$
Income Gap	-0.55**		-0.68**		-0.59**	-1.04*
	(0.27)		(0.29)		(0.27)	(0.53)
X		-0.01	0.03	-0.03	-0.10	-0.33
		(0.03)	(0.03)	(0.10)	(0.10)	(0.28)
Income Gap $\times$ X						2.00
						(1.93)
Constant	0.10**	0.03	0.12**	0.04	0.13**	0.18**
	(0.04)	(0.01)	(0.04)	(0.03)	(0.05)	(0.08)
Observations	106	106	106	106	106	106
Adjusted R^2	0.189	-0.008	0.218	-0.008	0.202	0.211

Sample period: 1986-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. $rx^{(n)}$ is the excess 1-year return of GSW zero-coupon bonds of maturity n. The conditional variance and covariance forecasts are constructed in two steps: first compute realized values using daily returns for each month, then create a forecast by estimating an AR(1) in the full sample. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance,where the p-values are computed using the bootstrap approach described in Section 1.2.1.

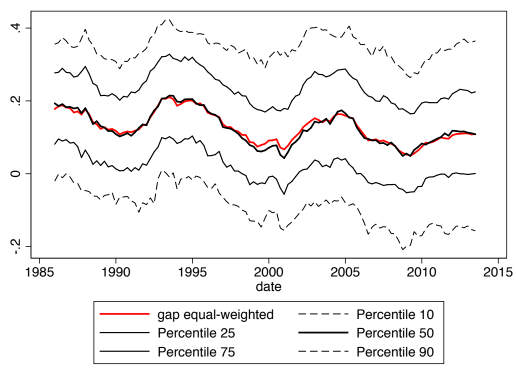
Figures

Figure 1: Average Income Gap and Future Bond Excess Returns

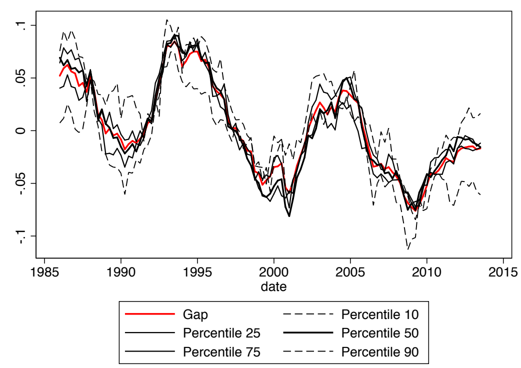


Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. “gap” is the average income gap, computed across all U.S. bank holding companies with total consolidated assets of $1Bil or more. rx$n$ is the excess 1-year return of zero-coupon bonds of maturity n, using data from Gurkaynak et al. (2007).

Figure 2: Cross-Sectional Distribution of the Income Gap



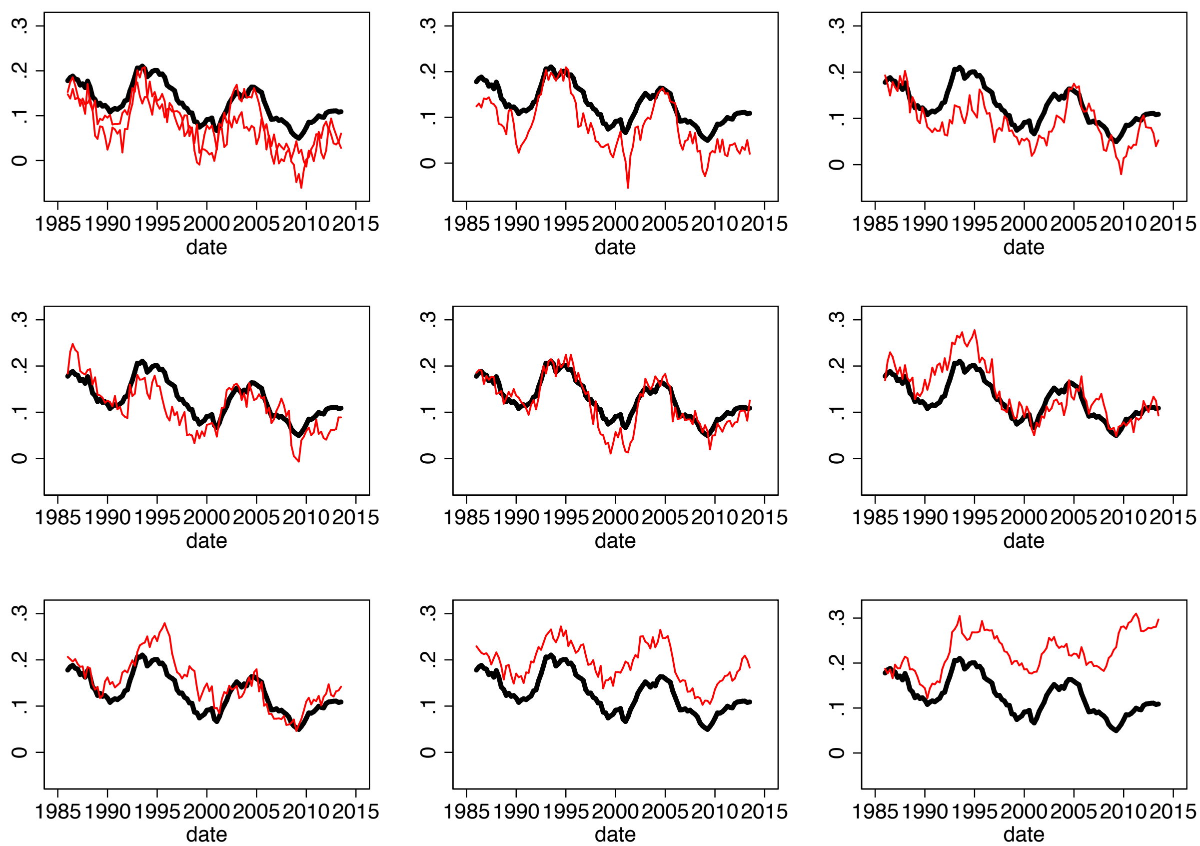
(a) Raw Distribution



(b) Demeaned

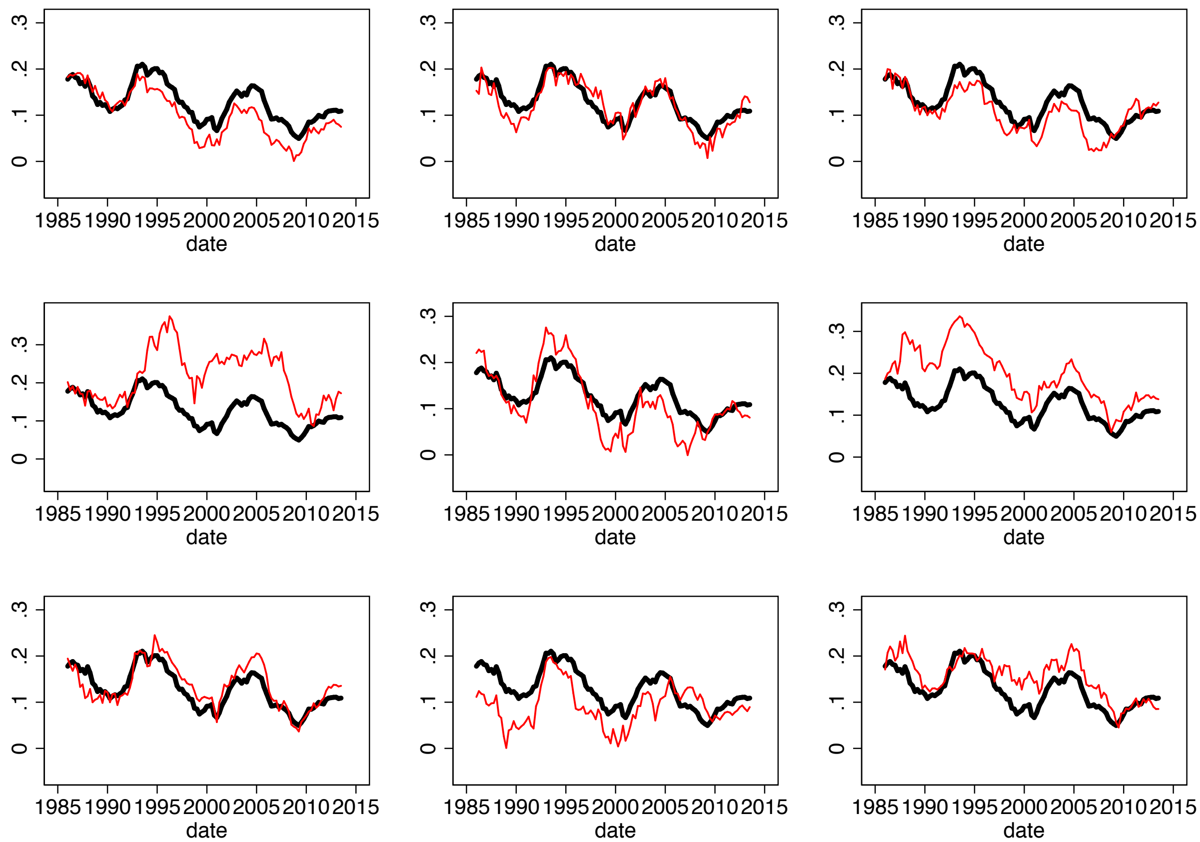
Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and is defined as the difference between the amount of assets that either reprice, or mature, within one year, and the amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. We compute the various percentile of the income gap in each date on the top panel. The bottom panel presents the demeaned time-series.

Figure 3: Income Gap across Bank Sizes



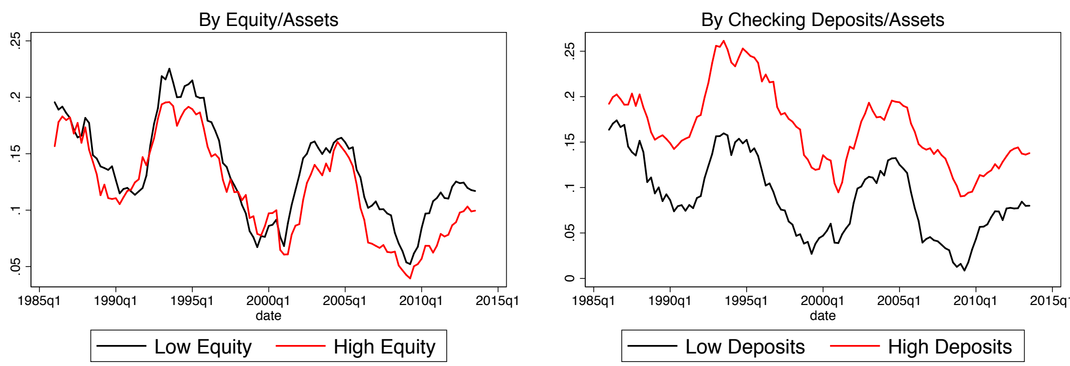
Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. The dark line represents the average income gap, computed across all U.S. bank holding companies with total consolidated assets of $1Bil or more. Each panel corresponds to the average income gap within a decile of total consolidated assets, in increasing order. We represent the first two deciles on the first panel.

Figure 4: Income Gap across U.S. Regions



Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. The dark line represents the average income gap, computed across all U.S. bank holding companies with total consolidated assets of $1Bil or more. Each panel corresponds to the average income gap within one of 9 regions of the US.

Figure 5: Income Gap across Bank Characteristics



(a) Equity/Assets

(b) Checking Deposits/Assets

Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Panel (a) represents the average income gap for banks split into two groups based on the average value of the ratio of book equity to consolidated assets. Panel (b) represents the average income gap for banks split into two groups based on the average value of the ratio of checking deposits to assets.

Internet Appendix (Not for Publication)

A Proofs

The banks' first-order condition is simply:

$$\mu_t^{(\tau)} - r_t = A_r(\tau)\lambda_{r,t} + A_g(\tau)\lambda_{g,t} \tag{IA.1}$$

$$\lambda_{j,t} = \gamma\sigma_j^2 \int_0^\infty x_t^{(\tau)} A_j(\tau) d\tau, \quad \text{for } j = g, r \tag{IA.2}$$

We can also express $\mu_t^{(\tau)}$, the returns on a τ-maturity bond using the law of motions:

$$\begin{aligned} \mu_t^{(\tau)} = {} & A_r'(\tau) r_t + A_g'(\tau) g_t + C'(\tau) + A_r(\tau)\kappa_r (r_t - \bar{r}) + A_r(\tau)\kappa_{g\to r} (g_t - \bar{g}) + A_g(\tau)\kappa_g (g_t - \bar{g}) \\ & + \frac{1}{2} A_r(\tau)^2 \sigma_r^2 + \frac{1}{2} A_g(\tau)^2 \sigma_g^2 \end{aligned} \tag{IA.3}$$

Identifying the terms in g_t, r_t and the constant, we obtain a set of ODEs. In particular A_r and A_g solve the following system, with initial conditions $A_r(0) = A_g(0) = 0$:

$$1 = A_r'(\tau) + \kappa_r A_r(\tau) \tag{IA.4}$$

$$A_r(\tau)\left(\gamma\sigma_r^2 I_r - \kappa_{g\to r}\right) = A_g'(\tau) + \left(\kappa_g - \gamma\sigma_g^2 \int_0^\infty \theta e^{-\theta u} A_g(u) du\right) A_g(\tau) \tag{IA.5}$$

The solutions of these equations are given by

$$A_r(\tau) = \frac{1 - e^{-\kappa_r \tau}}{\kappa_r} \tag{IA.6}$$

$$A_g(\tau) = \frac{Z}{\kappa_r}\left(\frac{1 - e^{-\hat{\kappa}_g \tau}}{\hat{\kappa}_g} - \frac{e^{-\kappa_r \tau} - e^{-\hat{\kappa}_g \tau}}{\hat{\kappa}_g - \kappa_r}\right) \tag{IA.7}$$

$$Z = \gamma\sigma_r^2 \frac{1}{\theta + \kappa_r} - \kappa_{g\to r} \tag{IA.8}$$

$$\tag{IA.9}$$

where $\hat{\kappa}_g$ solves

$$\hat{\kappa}_g = \kappa_g - \gamma\sigma_g^2 \int_0^\infty \theta e^{-\theta u} A_g(u) du \tag{IA.10}$$

$$\hat{\kappa}_g = \kappa_g - \gamma\sigma_g^2 \frac{Z}{\kappa_r}\left(\frac{1}{\theta + \hat{\kappa}_g} - \frac{1}{\hat{\kappa}_g - \kappa_r}\left(\frac{\theta}{\theta + \kappa_r} - \frac{\theta}{\theta + \hat{\kappa}_g}\right)\right) \tag{IA.11}$$

Clearly, A_r is positive and increasing. For A_g, its derivative is:

$$A_g'(\tau) = Z\frac{e^{-\kappa_r\tau} - e^{-\hat{\kappa}_g\tau}}{\hat{\kappa}_g - \kappa_r} \tag{IA.12}$$

The function $e^{-x\tau}$ is decreasing in x, so A_g' is of the same sign as Z. Combined with $A_g(0)$, we obtain that A_g is of the same sign as Z and that $A_g = 0$ when $Z = 0$. This result corresponds to Proposition 3.

Going back to the risk premia, we have:

$$\mu_t^{(\tau)} - r_t = g_t\left(A_r(\tau)\gamma\sigma_r^2\int_0^\infty \theta e^{-\theta u}A_r(u)du + A_g(\tau)\gamma\sigma_g^2\int_0^\infty \theta e^{-\theta u}A_g(u)du\right) \tag{IA.13}$$

$$\mu_t^{(\tau)} - r_t = g_t\phi(\tau) \tag{IA.14}$$

Given that A_g and A_r are monotone of constant sign, both terms in the sum in parentheses are positive and increasing in τ. Therefore, ϕ is positive and increasing, properties that correspond to Propositions 1 and 2 respectively.

B Additional Tables and Figures

Table IA.1: Income Gap and Its Components

Variable	Obs	Mean	Std. Dev.	P25	P50	P75
Income Gap =	47800	.126	.187	.011	.124	.243
Assets maturing/resetting $<$ 1 year	47800	.425	.153	.323	.433	.525
- Liabilities maturing/resetting $<$ 1year =	47800	.299	.157	.191	.272	.384
Short Term Liabilities	47800	.288	.157	.18	.261	.372
+ Variable Rate Long Term Debt	47800	.01	.027	0	0	.008
+ Short Maturity Long Term Debt	47800	.001	.005	0	0	0
+ Prefered Stock	47800	0	.002	0	0	0

Note: Summary statistics are based on the quarterly Consolidated Financial Statements (Files FR Y-9C) between 1986 and 2014 restricted to US bank holding companies with total consolidated assets of $1Bil or more. The variables are all scaled by total consolidated assets (bhck2170) and are defined as follows: Interest Sensitive Liabilities =(bhck3296+bhck3298+bhck3409+bhck3408)/bhck2170; Interest Sensitive Assets=(bhck3197)/bhck2170; Short Term Liabilities=bhck3296/bhck2170; Variable Rate Long Term Debt=bhck3298/bhck2170; Short Maturity Long Term Debt=bhck3409/bhck2170; Prefered Stock=bhck3408/bhck2170

Table IA.2: Income Gap and Bond Excess Returns: Newey-West Standard Errors

	(1) $rx^{(2)}$	(2) $rx^{(3)}$	(3) $rx^{(4)}$	(4) $rx^{(5)}$
Income Gap	-0.23**	-0.36***	-0.47***	-0.55***
	(0.09)	(0.12)	(0.15)	(0.17)
Constant	0.04***	0.07***	0.09***	0.10***
	(0.01)	(0.02)	(0.02)	(0.02)
Observations	106	106	106	106
Adjusted R^2	0.172	0.200	0.201	0.189

Sample period: 1986-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. $rx^{(n)}$ is the excess 1-year return of GSW zero-coupon bonds of maturity n. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance, where the p-values are computed using the bootstrap approach described in Section 1.2.1.

Table IA.3: Income Gap and Bond Excess Returns: Quarterly

	(1) $rx^{(2)}$	(2) $rx^{(3)}$	(3) $rx^{(4)}$	(4) $rx^{(5)}$
Income Gap	-0.05**	-0.08**	-0.11*	-0.12*
	(0.02)	(0.04)	(0.05)	(0.07)
Constant	0.01**	0.02**	0.02**	0.02*
	(0.00)	(0.01)	(0.01)	(0.01)
Bootstrapped p-value	0.021	0.035	0.054	0.076
Observations	109	109	109	109
Adjusted R^2	0.038	0.035	0.029	0.024

Sample period: 1986-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. $rx^{(n)}$ is the excess 1-quarter holding return of Gurkaynak et al. (2007) zero-coupon bonds of maturity n. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance, where the p-values are computed using the bootstrap approach described in Section 1.2.1.

Table IA.4: Income Gap and Bond Excess Returns: Monthly

	(1) $rx^{(12-24m)}$	(2) $rx^{(24-36m)}$	(3) $rx^{(36-48m)}$	(4) $rx^{(48-60m)}$	(5) $rx^{(60-120m)}$
Income Gap	-0.01**	-0.02**	-0.03*	-0.03*	-0.03
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Constant	0.00**	0.00**	0.01**	0.01**	0.01*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Bootstrapped p-value	0.033	0.032	0.054	0.064	0.145
Observations	327	327	327	327	327
Adjusted R^2	0.011	0.011	0.009	0.008	0.005

Sample period: 1986-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. $rx^{(n)}$ is the excess 1-month holding return of Fama bond portfolios of maturity in the range indicated in superscript. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance, where the p-values are computed using the bootstrap approach described in Section 1.2.1.

Table IA.5: Income Gap and Bond Excess Returns : Controlling for the CP factor

	(1) $rx^{(2)}$	(2) $rx^{(3)}$	(3) $rx^{(4)}$	(4) $rx^{(5)}$
Income Gap	-0.27***	-0.44***	-0.57***	-0.68**
	(0.10)	(0.17)	(0.23)	(0.28)
CP Factor	0.52	0.85	1.16	1.45
	(0.27)	(0.45)	(0.61)	(0.74)
Constant	0.05	0.08	0.10	0.12
	(0.01)	(0.02)	(0.03)	(0.04)
Bootstrapped p-value	0.008	0.005	0.007	0.012
Observations	106	106	106	106
Adjusted R^2	0.299	0.353	0.372	0.372

Sample period: 1986-2014. Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income Gap is the average bank-level income gap. $rx^{(n)}$ is the excess 1-year return of GSW zero-coupon bonds of maturity n. CP factor is the Cochrane and Piazzesi (2005) factor and is constructed as in Cochrane and Piazzesi (2005) over the 1964-2013 period. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance, where the p-values are computed using the bootstrap approach described in Section 1.2.1.

Table IA.6: Exposure g_t and Bond Excess Returns

	(1)	(2)	(3)	(4)
	$rx^{(2)}$	$rx^{(3)}$	$rx^{(4)}$	$rx^{(5)}$
g_t	2.19**	3.52**	4.57**	5.34**
	(0.87)	(1.40)	(1.93)	(2.46)
Constant	-0.01	-0.01	-0.02	-0.02
	(0.01)	(0.02)	(0.02)	(0.03)
Bootstrapped p-value	0.013	0.015	0.017	0.032
Observations	106	106	106	106
Adjusted R^2	0.147	0.171	0.172	0.161

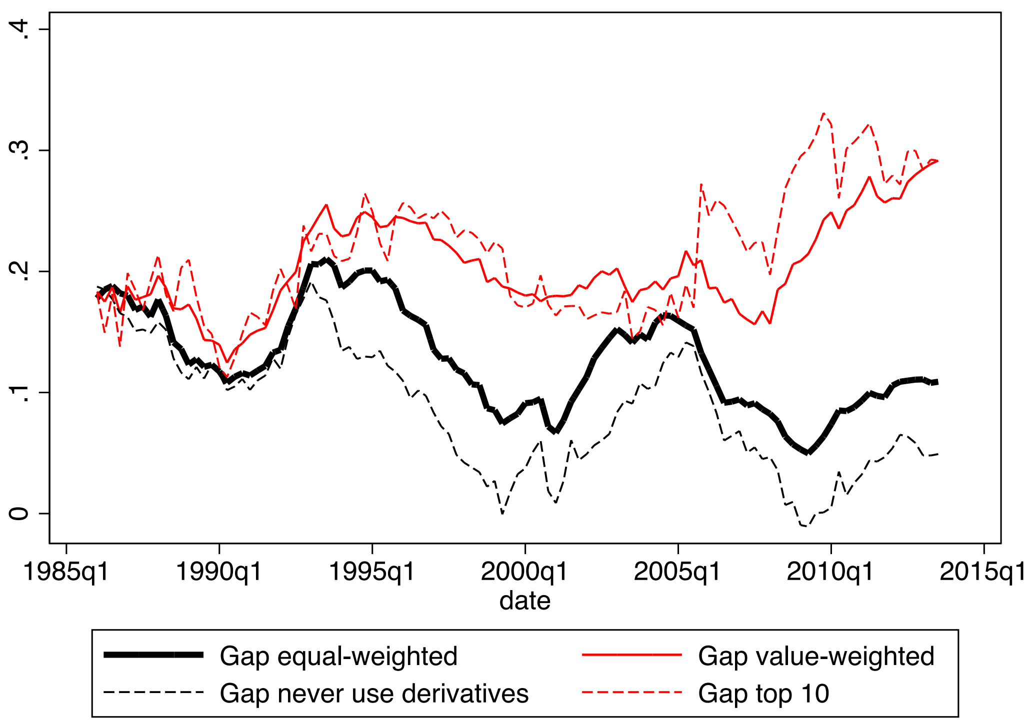
Sample period: 1986-2014. Note: g_t is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C). We compute, at the bank-level: $g_{it} = 1 -$ (\$ amount of rate-sensitive assets-\$ amount of rate-sensitive liabilities$_{it}$)/\$ Book Equity$_{it}$, where the \$ amount of rate sensitive assets corresponds to item bhck3197 and \$ amount of rate-sensitive liabilities corresponds to the sum of long-term debt that reprices within one year (item bhck3298), long-term debt that matures within one year (bhck3409), variable-rate preferred stock (bhck3408) and interest-bearing deposit liabilities that reprice or mature within one year (bhck3296). g_t is then the equal-weighted average of g_{it} across all banks in our sample. $rx^{(n)}$ is the excess 1-year return of GSW zero-coupon bonds of maturity of maturity n. We multiply all coefficients by 100 for readability. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance, where the p-values are computed using the bootstrap approach described in Section 1.2.1.

Table IA.7: Bank Liquidity Risk and Bond Excess Returns

	(1) $rx^{(2)}$	(2) $rx^{(3)}$	(3) $rx^{(4)}$	(4) $rx^{(5)}$
BB (VW)	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.01)	(0.01)	(0.01)
Constant	0.01	0.02	0.03	0.03
	(0.00)	(0.01)	(0.01)	(0.01)
Bootstrapped p-value	0.707	0.708	0.731	0.768
Observations	106	106	106	106
Adjusted R^2	-0.003	-0.002	-0.003	-0.004

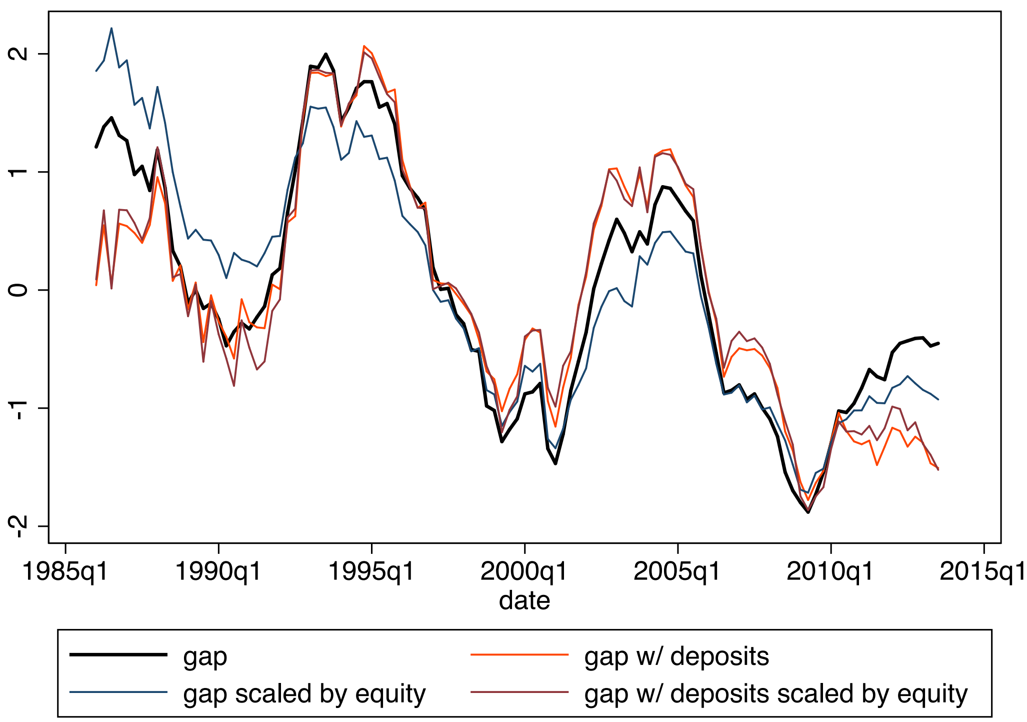
Sample period: 1986-2014. Note: The liquidity risk measure is the bank liquidity creation index of Berger and Bouwman (2009) which we value-weight by total gross assets across banks (BB). We normalize this measure to have standard deviation of 1% in our sample and flip its sign so that a low value reflects high risk. $rx^{(n)}$ is the excess 1-year return of GSW zero-coupon bonds of maturity of maturity n. Standard errors are computed using the reverse regression approach of Hodrick(1992). *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance, where the p-values are computed using the bootstrap approach described in Section 1.2.1.

Figure IA.1: Income Gap: Derivatives and Largest Banks



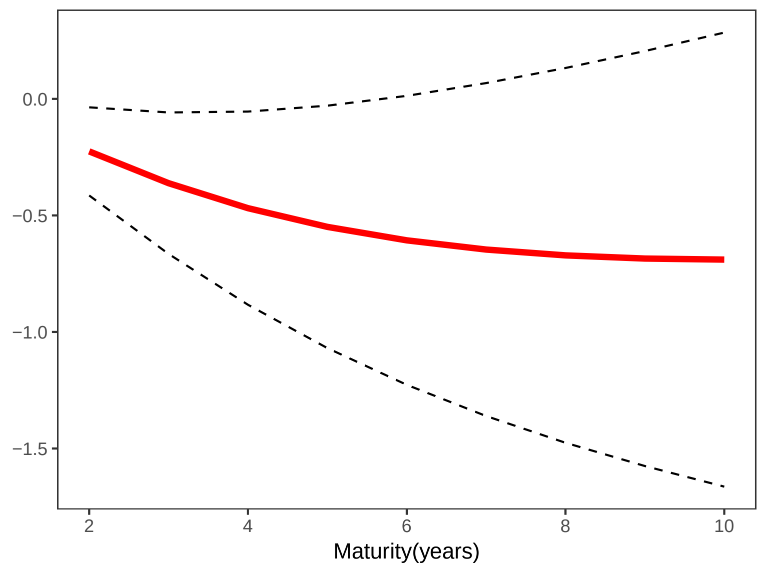
Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. The solid black line represents the average income gap, computed across all U.S. bank holding companies with total consolidated assets of $1Bil or more. The solid red line represents the weighted-average income gap, where we use BHCs' total consolidated assets as weights. The dotted black line represents the average income gap across banks that never reports derivative positions in their financial statements. The dotted red line represents the average income gap across the ten largest banks.

Figure IA.2: Income Gap: Deposits and Leverage

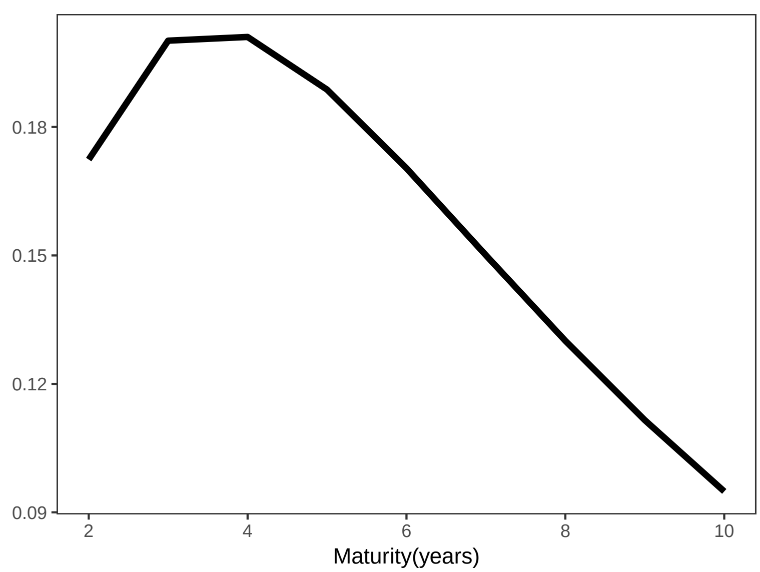


Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. The solid black line represents the average income gap, computed across all U.S. bank holding companies with total consolidated assets of $1Bil or more. The orange line is the average income gap, including core deposits. The blue line scales the gap by equity rather than assets. The red line includes core deposits and scales by equity. All series are standardized to have mean 0 and unit standard deviation.

Figure IA.3: Longer Maturities



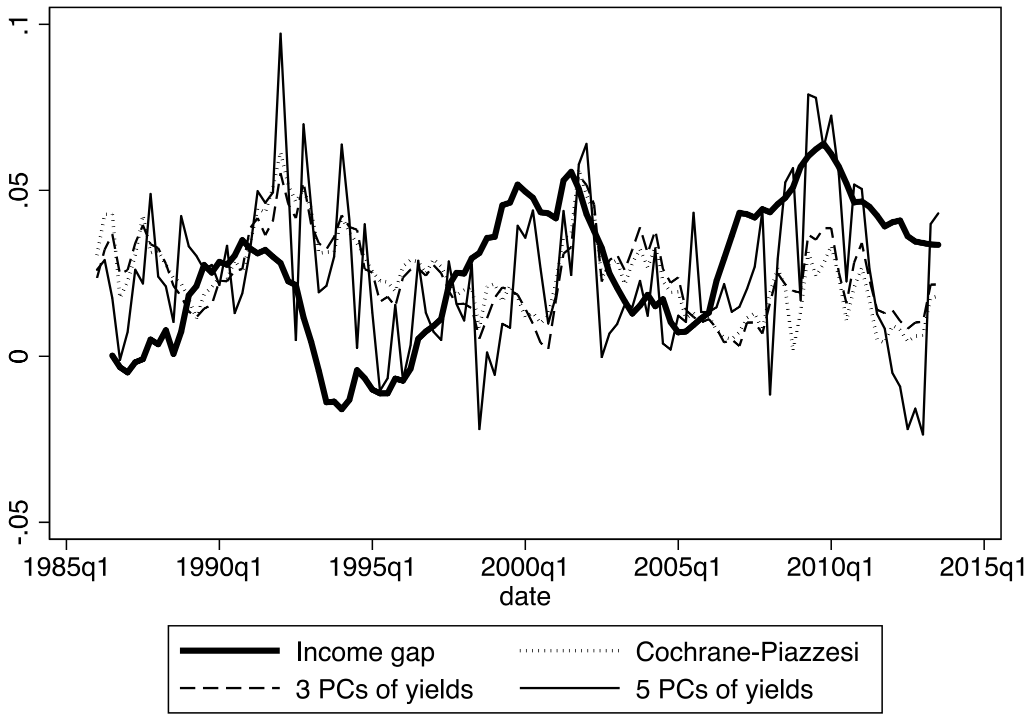
(a) Coefficients



(b) Adjusted R^2

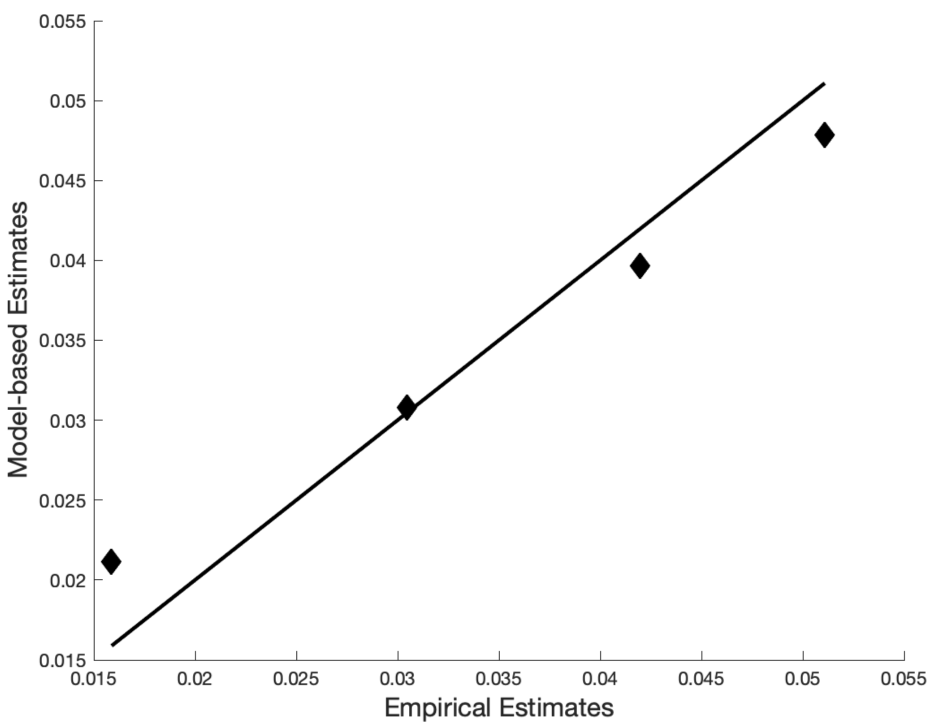
Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. Income gap is the average income gap, computed across all US bank holding companies with total consolidated assets of $1Bil or more. We regress the excess 1-year holding return of zero-coupon bonds of maturity n on the average income gap. We obtain zero-coupon bond series with long maturities from Gurkaynak et al. (2007). Panel (a) of the figure reports, for each maturity n, the coefficient on the average income gap, as well as its 95% confidence interval. Panel (b) reports the corresponding R^2 of each of these regressions.

Figure IA.4: Forecasts of 5-Year Treasury Bond Returns



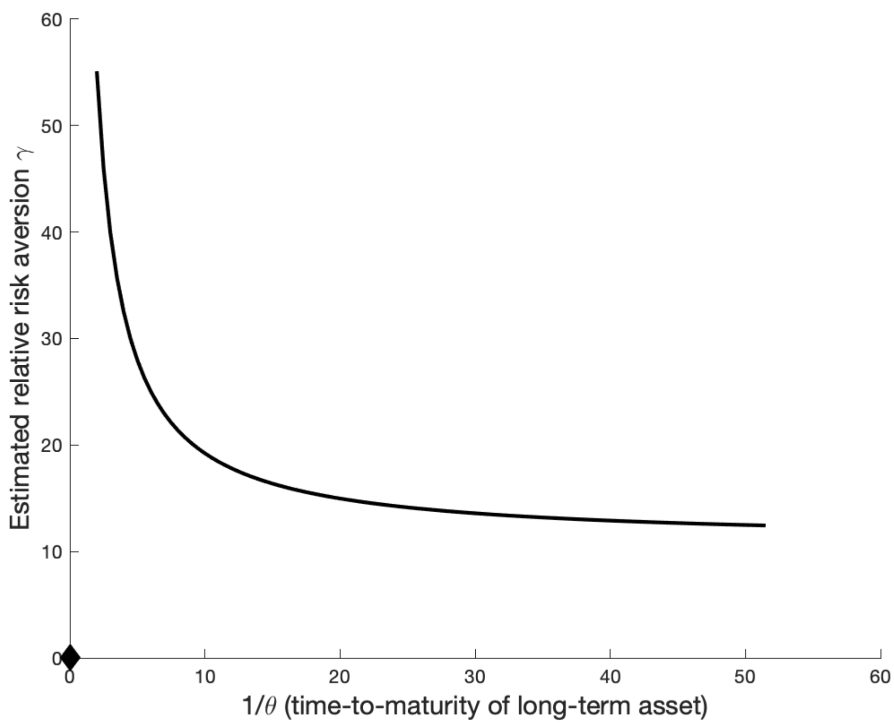
Note: The figure presents best linear forecasts of the 5-year Treasury excess returns using the income gap, the Cochrane and Piazzesi (2005) combination of yields, the first three principal components of yields, and the first five principal components of yields. The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. The solid black line represents the forecast based on the average income gap, computed across all U.S. bank holding companies with total consolidated assets of $1Bil or more. The principal components of yields are extracted from Gurkaynak et al. (2007) yields.

Figure IA.5: Estimated vs. Model-Implied Coefficients



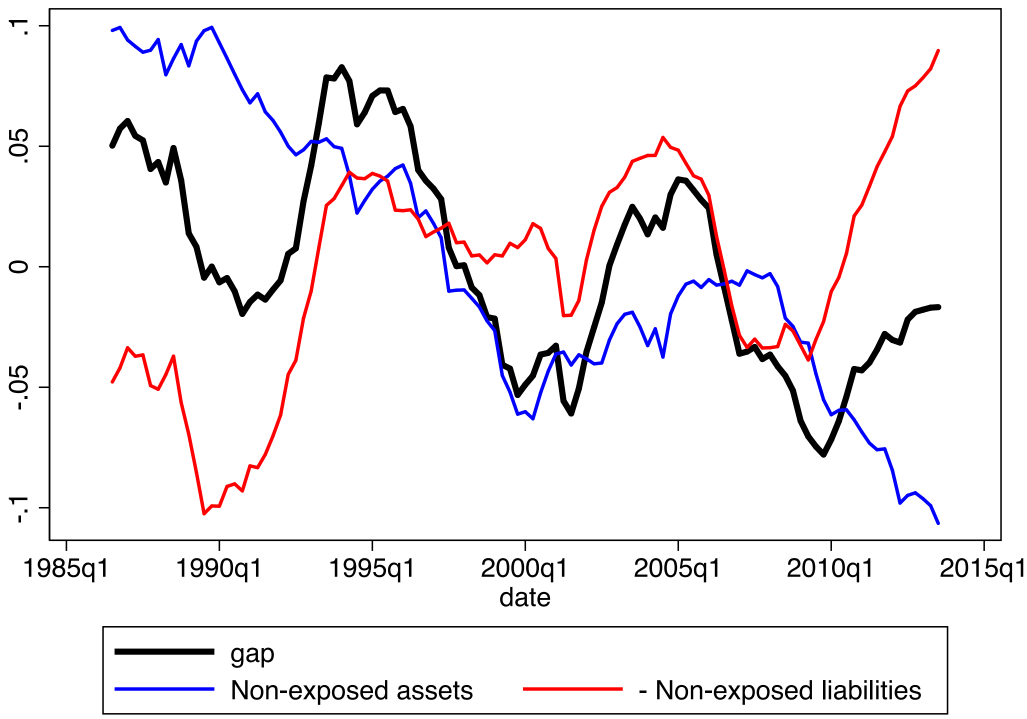
This figure shows the model-implied coefficients of a predictive regression of bond excess returns of maturity τ on banks' average income gap (y-axis) plotted against the empirical coefficients (x-axis). The line corresponds to the 45 degree line.

Figure IA.6: Sensitivity Analysis on Calibration of Duration θ



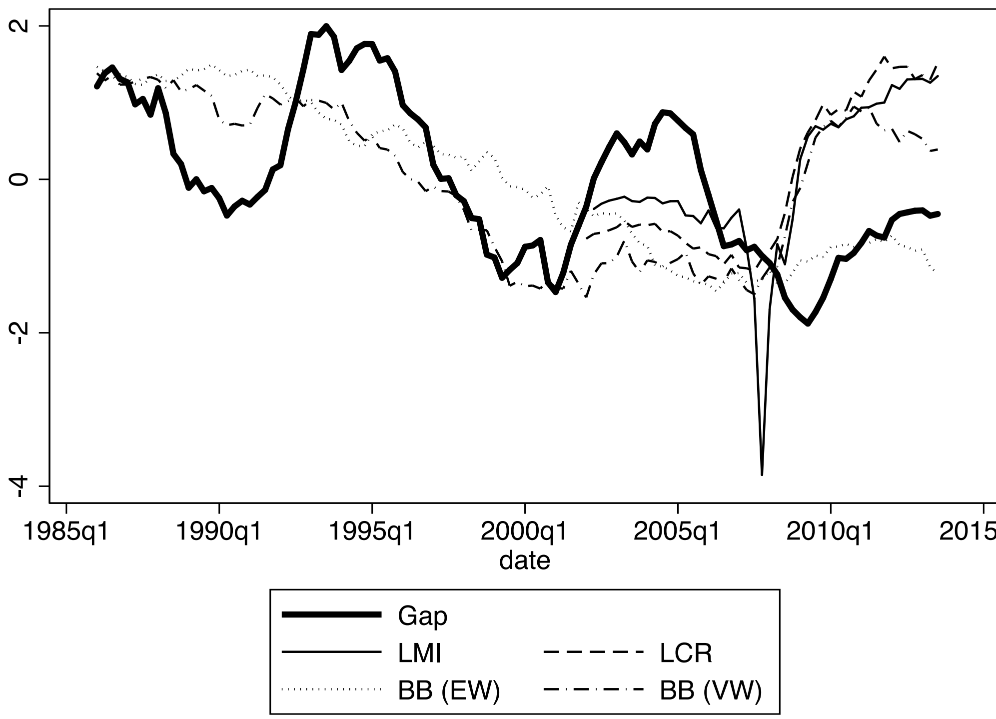
This figure shows estimates of the relative-risk aversion parameter γ for alternative calibration of $1/\theta$, the time-to-maturity of the long-term asset. The model estimation is detailed in Section 6

Figure IA.7: Asset and Liability Components of the Income Gap



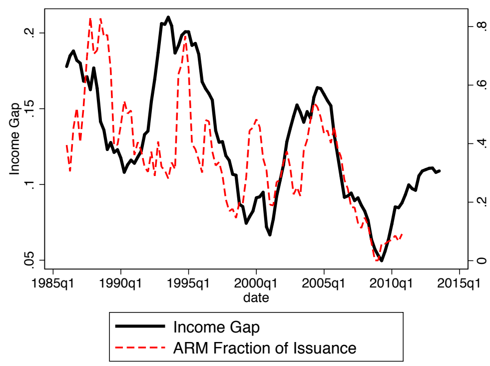
Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. The dark line represents the average income gap, computed across all U.S. bank holding companies with total consolidated assets of $1Bil or more. The blue line represents the average bank-level ratio of assets that either reprice or mature within a year normalized by total consolidated assets. The red line represents the opposite of the average bank-level ratio of liabilities that either reprice or mature within a year normalized by total consolidated assets.

Figure IA.8: Income Gap and Liquidity Risk Measures

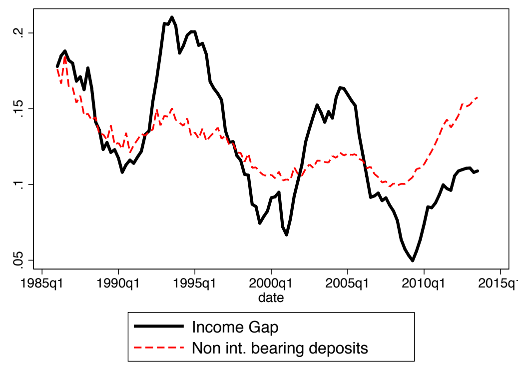


Note: The figure presents the income gap and four bank liquidity risk measures. The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the $ amount of assets that either reprice, or mature, within one year, and the $ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. The thick solid line represents the forecast based on the average income gap, computed across all US bank holding companies with total consolidated assets of $1Bil or more. The thin solid line is the liquidity mismatch index (LMI) of Bai et al. (2018). The dashed line is the Basel Committee's liquidity coverage ratio (LCR) as constructed by Choi and Choi (2016). The dotted and dotted-dashed lines are the bank liquidity creation index of Berger and Bouwman (2009), which we equal-weight or value-weight by total gross assets across banks (BB). All measures are normalized to have unit standard deviation and with sign chosen so that a low value reflects high risk.

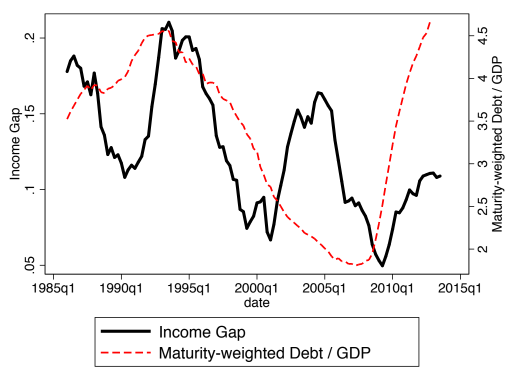
Figure IA.9: Income Gap and Asset Quantities



(a) Share of Adjustable-Rate Mortgages.



(b) Share of Non Interest-Bearing Deposits.



(c) Supply of Treasuries.

Note: The bank-level income gap is computed from the quarterly Consolidated Financial Statements (Files FR Y-9C) and corresponds to the difference between the \$ amount of assets that either reprice, or mature, within one year, and the \$ amount of the liabilities that mature or reprice within a year, all scaled by total consolidated assets. The dark line represents the average income gap, computed across all U.S. bank holding companies with total consolidated assets of \$1Bil or more. In panel (a), the dashed red line represents the quarterly ratio of issuance of adjustable-rate mortgages normalized by total issuance of mortgages. We use the Monthly Interest Rate Survey to compute this ratio. In panel (b), the dashed red line represents the average of the quarterly bank-level ratio of non-interest-bearing deposits normalized by total consolidated assets. In panel (c), the dashed red line is the maturity-weighted Treasuries supply measure of Greenwood and Vayanos (2014).