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Working Paper 22-039

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Funding for this research was provided in part by Harvard Business School.

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November 2021

Abstract

Claims about the market power of bank deposits in the banking literature are numerous and far reaching. Recently, a causal narrative has emerged in the banking literature: market power in bank deposits, measured as imperfect pass-through of short-term market rates on deposit rates, allows banks to eliminate their asset interest rate exposure and to achieve near constant net interest margin (NIM). We show that the empirical evidence does not support these conclusions. We show that neither deposits nor market power are essential for achieving stable NIM in long-short fixed income portfolios. We show that matching interest income and interest expenses sensitivities to market rate movements is a consequence of achieving stable NIM, not necessarily the mechanism that allows it. Stable NIM does not imply near zero interest rate risk according to standard risk measures. Common measures of imperfect pass-through of market rates to bank deposit rates commingle two distinct mechanisms: (1) intentional rate setting and (2) mechanical consequence of comparing the changes in the periodic interest earned on positive maturity fixed coupon portfolios to changes in a short-term interest rate. The mechanical maturity consequence dominates the measured imperfect pass-through of market rates on time deposits.

*We thank Darrell Duffie, Mark Egan, Samuel Hanson, Victoria Ivashina, Hanno Lustig, Arvind Krishnamurthy, Teodora Paligorova, Amit Seru, Adi Sunderam, and seminar participants at the Federal Reserve Board, the FRB New York, Harvard Business School, Princeton, Stanford GSB, and the 4th Bank of Canada FSRC Macro-Finance Conference for helpful comments and discussions.

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1 Introduction

Claims about the market power of bank deposits in the banking literature are numerous and far reaching. The literature has associated bank market power with the transmission of monetary policy,[1] relationship banking,[2] and banks' interest rate risk exposure.[3] Our focus is on recent claims that deposit market power allows banks to eliminate their interest rate risk exposure. This conclusion is consequential for assessing the overall performance of banks since a maturity term risk premium is one of the best performing risk premia available to US investors over the past forty years.[4] A traditional view of banks that has banks bearing several units of this risk premium through their high leverage and the maturity mismatch between their assets and liabilities is quite different from the recent view of near 0 units of this risk premium. This striking difference in views can generate an economically large benchmark performance difference. The quantity of net interest rate risk exposure in banks is also relevant for assessing overall stability of the banking sector. The Federal Reserve and FDIC researchers viewed the large interest rate increases in the US around 1980 as instrumental in creating an incentive for many banks to gamble their way out of their effective insolvency, created by the large gap between the accounting values and the market values of bank asset portfolios, through high risk loan origination that materialized as losses years later (Federal Reserve, 2013; FDIC, 1997).

This paper reexamines the evidence to reach recent conclusions that (a) banks bear no interest rate risk; (b) market power and the deposits-taking activity are instrumental in allowing for asset and liability spread beta matching, which in turn allows banks to achieve stable net interest margin; and (c) the robustness of the imperfect pass-through of deposit rates as a measure of deposit market power. Our findings show that these conclusions are not robustly supported by the data.

Three empirical properties of bank income and expense rates, summarized in Figure 1, form the recent narrative that banks have used their deposit market power to intentionally hedge their interest

[1] E.g., Drechsler, Savov, and Schnabl (2017); Wang (2018); Wang, Whited, Wu, and Xiao (Forthcoming)
[2] E.g., Granja, Leuz, and Rajan (2018)
[3] E.g., Hoffmann, Langfield, Pierobon, and Vuillemey (2019); Drechsler, Savov, and Schnabl (2021)
[4] A 5-year US Treasury term factor has earned an annualized return of 7.3% over our sample period, 1995 to 2020.

rate risk exposure, achieving stable net interest margin and no net interest rate risk. First, banks pay interest rates on their deposits that do not reflect current market conditions as the top panel in Figure 1 illustrates. In periods of increasing short-term interest rates, deposit rates increase at a substantially slower rate, which suggests imperfect pass-through of market rates to deposit rates.[5] Additionally, bank deposit rates are generally below the short-term market rate. In conjunction with the assumption that banks with different pass-through rates face identical incremental operating costs, this failure of marginal cost pricing suggests that banks have substantial deposit market power.

Second, in a series of influential papers, Drechsler, Savov, and Schnabl (2017, 2021) document a strong pattern of asset (interest income) and liability (interest expense) spread beta matching in the cross section of US commercial banks, illustrated in the middle panel in Figure 1. The spread beta of bank deposits is statistically equivalent to the imperfect pass-through coefficient of the earlier literature. Both are estimated from the same regression of the difference between a short-term market interest rate, say the Federal funds rate (FFR), and the interest paid on bank deposits, on changes in the short-term market interest rate. The relabelling of the pass-through coefficient to spread beta connotes a risk measure that suggests banks have hedged their asset risk by having equivalently risky liabilities.

The strong empirical relation of asset and liability spread beta matching forms the basis for interpreting the third empirical regularity. Banks have highly stable net interest margins (NIM), as illustrated in the bottom panel of Figure 1.[6] The NIM of the aggregate banking sector is remarkably stable through time, fluctuating substantially less than the short-term market interest rate, proxied here by the FFR. At the individual bank level, NIM is also stable through time. The average time series standard deviation of the quarterly change in NIM for all US commercial banks is 0.15%, with the 95th percentile equaling 0.27%, while the standard deviation of the quarterly change in the FFR is 0.70%. Viewing the spread betas as risk measures, Drechsler, Savov, and Schnabl (2021) are

[5] Early papers in the empirical literature examining the relation between deposit rates and market interest rates include Ausubel (1992); Berger and Hannan (1989); Diebold and Sharpe (1990); Hannan and Liang (1993); Hannan and Berger (1997); Neumark and Sharpe (1992); Driscoll and Judson (2013).

[6] NIM is defined as interest income minus interest expense, scaled by book assets.

able to interpret the stable NIM as evidence of banks engaging in maturity transformation without bearing interest rate risk, enabled by the market power derived from their deposit franchise.[7]

We examine the joint interpretation of the three basic properties illustrated in Figure 1 to assess how well-identified are the conclusions in the literature. We begin with two basic observations. First, as long as NIM is stable, banks' interest income and interest expense betas must match. Consider $Y = A - B$, to represent NIM equaling an interest income rate minus an interest expense rate. In the limit of zero variance of Y, any random variable, X, that is correlated with A must be identically correlated with B. For example, the income and expense betas from a regression of bank income and bank expense on the quarterly returns of Amazon stock will match as well. Hence, asset and liability spread beta matching is a consequence of banks achieving nearly constant NIM. As such, it cannot cleanly identify the mechanism that leads to constant NIM. This is important because it means that asset and liability spread matching represents a transformation of the known fact that banks have stable NIM, not an additional piece of evidence to support a causal narrative.

Second, interest income and interest expense betas are incomplete measures of interest rate risk relative to the standard measures used in textbooks (Berk and DeMarzo, 2019; Cochrane, 2009), used by bond investors, and in the asset pricing literature (e.g., Fama and French, 1989); and therefore the fact that they offset at the bank level conveys little about a bank's actual exposure to interest rate risk. Interest spread betas measure the sensitivity of portfolio income and expense to interest rate changes (i.e. coupon payments), while traditional interest rate risk measures quantify the sensitivity of portfolio *value* to interest rate changes. This important distinction allows for the possibility that substantial interest rate risk resides in portfolios that appears to have none according to income based metrics.

We propose two tests of the causal narrative. First, if "two essential properties of the deposit franchise drive this result" (market power and fixed non-interest costs of deposits)[8] then a price

[7] Other recent papers relying on net interest income fluctuations as a measure of interest rate risk exposure include Hoffmann et al. (2019); Jiang and Zhang (2021); Gomez et al. (2021).

[8] Drechsler, Savov, and Schnabl (2021) state, "In this paper we show that despite having a large maturity mismatch banks do not take on significant interest rate risk. Rather, because of the deposit franchise, maturity transformation actually reduces the amount of interest rate risk banks take on. Two essential properties of the deposit franchise drive this result. First, the deposit franchise gives banks market power over retail deposits, which allows them to borrow

taking long-short portfolio strategy in US Treasuries cannot achieve a stable NIM. Second, in a cross section of price-taking portfolio strategies that achieve stable NIM and that produce matching (i.e. offsetting) income and expense betas, the interest rate exposure of these portfolios will be zero. We can reject both of these hypotheses.

We design various long-short portfolios of US Treasury securities that are as successful as banks in generating constant NIM despite operating under a number of constraints. These portfolios have neither banks' price-setting power over loans and deposits nor banks' range of investment and funding options at their disposals. These results reject the notion that market power and bank deposits are necessary for achieving stable NIM.

Additionally, we examine the asset and liability spread betas of these US Treasury portfolios that achieve stable NIM and find a strong pattern of asset and liability beta matching. Because these stable NIM UST portfolios are designed to have positive mean NIM targets, they have positive maturity mismatches between their assets and liabilities. Consistent with basic fixed income valuation, we find that there is a very tight link between the maturity mismatch and both model-implied duration risk exposure and regression based duration risk exposure estimates. In other words, these portfolios carry substantial interest rate risk exposures while also featuring near constant NIMs and matching asset and liability betas. These results reject the notion that portfolios achieving constant NIM combined with asset and liability spread beta matching imply near zero interest rate exposure.

While our UST portfolios are not designed to mimic banks' portfolios, this analysis clarifies that the existing evidence is uninformative about banks' interest rate risk exposure. It also casts doubt on using spread betas or imperfect pass-through coefficients as a measure of bank deposit market power. Specifically, passive US Treasury portfolios with positive maturity, which clearly do not have market power, exhibit substantial imperfect pass-through because the methodology does not properly control for maturity.

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at rates that are both low and insensitive to market interest rates. Second, while running a deposit franchise incurs high operating costs (branches, salaries, marketing, technology), these costs do not vary much over time and hence are also insensitive to interest rates. Thus, even though deposits are short-term, funding via a deposit franchise resembles funding with long-term fixed-rate debt."

Carrying these insights to banking data, We show that what is measured as low sensitivity of bank rates to market rates arises for two reasons: (1) intentional rate setting decisions enabled by market power and (2) the mechanical consequence of comparing the periodic interest earned or paid on a positive maturity portfolio with changes in a short-term interest rate. A substantial portion of bank deposits are time deposits, which we show to exhibit low sensitivity largely due to the mechanical reason. This challenges the notion that imperfect pass-through is a reliable proxy for market power in bank deposits, instead much more a measure of the relative composition of time and non-time deposits.

Scale and incremental operating cost differences between banks that operate in different competitive environments are two additional limitations for using impartial rate pass through coefficients as a proxy for a bank's deposit market power. Concentrated markets tend to be 12 to 14 times smaller in terms of population, aggregate personal income, and aggregate employment compared to the most competitive markets. We provide suggestive evidence for incremental cost differences associated with operating in more concentrated markets. Using HHI as a measure of bank deposit market power, we estimate a 3 basis point lower annual deposit rate, given a one standard deviation increase in bank market power. This rate advantage is offset by a 23 basis point increase in annual operating expenses, which clearly pushes against the notion of a positive net benefit to banks operating in the most concentrated markets.

The paper is structured as follows. We begin with a brief description of the data in Section 2 and of the properties of NIM, interest betas, and the relationship between income betas and standard measures of duration risk in Section 3. In Section 4, we show that stable NIM and asset and liability spread beta matching can be a property of a price-taking US Treasury portfolio that remains exposed to interest rate risk. Section 5 re-examines the robustness of partial rate adjustment as a measure of bank market power. In Section 6, we discuss the implications of our results for an empirical perspective on banks. The last section concludes.

2 Data

There are several sources of data used in this analysis. We obtain detailed bank-level data from quarterly regulatory filings of commercial banks collected in multiple forms, most recently forms FFIEC 031 and FFIEC 041. The quarterly bank data used for this analysis begin in 1985. For this analysis, we rely only on assets, non-equity liabilities, interest income, and interest expense, from which we can calculate NIM and the interest income and interest expense returns. To calculate bank and county level HHI as well as bank and county level deposit amounts, we rely on the branch office deposit data provide by the FDIC.[9]

We obtain economic statistics at the county level from the Regional Economic Accounts of the Bureau of Labor Statistics.[10] The annual data series begin in 2000 and end in 2019. Our analysis uses county level population, employment, and nominal personal income.

We also use monthly yields and returns for US Treasury bonds. We obtain monthly yields on US Treasuries (UST) for various maturities from the Federal Reserve, monthly returns on a 5-year constant maturity bond portfolio from CRSP, monthly returns on the value-weighted stock market and the one-month US Treasury bill, as calculated by Ken French and available on his website. To calculate interest income and expense sensitivities as well as spread betas we also use the effective Federal Funds rate (converted to a monthly frequency) published by the Federal Reserve H.15 release.

3 Properties of Interest Income and Expense Betas

Net interest margin (NIM) is a widely referenced operating and interest rate risk metric in bank financial reports and press releases, the academic banking literature, bank stock analyst reports, and Federal Reserve reports. NIM is defined as:

[9] https://www7.fdic.gov/sod/dynaDownload.asp?barItem=6

[10] https://apps.bea.gov/regional/downloadzip.cfm

$$\begin{aligned} \text{NIM}_t = & \frac{\text{Interest Income}_t - \text{Interest Expense}_t}{\text{Book Assets}_{t-1}}. \\ = & R_t^{\text{Inc}} - R_t^{\text{Exp}}, \end{aligned} \tag{1}$$

where R_t^{Inc} is the interest income return and R_t^{Exp} is the interest expense return. We examine several important properties of NIM as a risk metric with a special interest in comparing it to interest rate risk metrics used in textbook and practitioner bond valuation and in academic asset pricing research. The goal is to evaluate how much the empirical characteristics of NIM warrant the interpretation of NIM as a measure of interest rate risk exposure.

3.1 Stable NIM and Matching Income and Expense Betas

In line with views expressed in bank annual reports, Drechsler, Savov, and Schnabl (2021) argue that stable NIM implies that banks succeed in hedging the interest rate risk embedded in standard retail banking activities. In particular, they propose that banks rely on the deposit franchise to offset interest rate risk exposure by intentionally matching the sensitivity of interest income R_t^{Inc} to changes in the market rate (income beta) to that of interest expenses R_t^{Exp} (expense beta).[11] Indeed, at the bank level, a regression of the quarterly change of R_t^{Inc} on the quarterly change of the Federal Funds Rate (FFR) delivers nearly the same OLS coefficient as a regression of the quarterly change of R_t^{Exp} on the quarterly change of FFR. Hence, in the cross-section income and expense betas match neatly.

In this section, we first show that the causality plausibly goes the other way – stable NIM implies asset and liability beta matching. We provide an empirical example showing that asset and liability interest spread betas measured against Amazon stock returns instead of the Federal funds rate also match neatly. Second, we compare income and expense betas to standard interest rate risk

[11] Spread betas, also known as imperfect pass-through coefficients in the banking literature, are regression coefficients of changes in interest income rate (or expense rate) spreads on changes in a short-term market interest rate. Interest income (expense) rate spreads are measured as a short-term market rate minus the income (expense) rate. Spread betas are related to income (expense) betas as follows: income (expense) beta = 1 − spread beta.

exposure measures such as DV01 and bond excess return regression betas to assess the robustness of inferences about interest rate exposure gleaned from these measures.

We begin by assuming that the bank has achieved stable NIM. Perfectly stable NIM means that NIM is a constant:

$$\mathrm{NIM}_t = R_t^{Inc} - R_t^{Exp} = R_{t-1}^{Inc} - R_{t-1}^{Exp} = \mathrm{NIM}_{t-1} \;\; \forall t \in \{1,...,T\}. \tag{2}$$

As a result of constant NIM, any variation in R_t^{Inc} needs to match the variation in R_t^{Exp}. Since NIM is a constant, its covariance with any random variable is 0, $\mathrm{COV}(NIM_t, X) = 0$, for any X. Writing out the components of NIM_t and recognizing that $\mathrm{COV}(X, Y+Z) = \mathrm{COV}(X,Y) + \mathrm{COV}(X,Z)$, we can write

$$\mathrm{COV}\left(R_t^{Inc}, X\right) - \mathrm{COV}\left(R_t^{Exp}, X\right) = 0. \tag{3}$$

We again make use of covariance properties and the fact that Eq. 3 has to hold for $\forall t$ to write

$$\mathrm{COV}\left(R_t^{Inc} - R_{t-1}^{Inc}, X\right) - \mathrm{COV}\left(R_t^{Exp} - R_{t-1}^{Exp}, X\right) = 0.$$

Finally, divide by the variance of $VAR(X)$ to derive the coefficients of any regression of changes in interest income and changes in interest expense on some random variable X:

$$\underbrace{\frac{\mathrm{COV}\left(\Delta R_t^{Inc}, X\right)}{VAR(X)}}_{:=\beta^{\mathrm{Inc},X}} - \underbrace{\frac{\mathrm{COV}\left(\Delta R_t^{Exp}, X\right)}{VAR(X)}}_{:=\beta^{\mathrm{Exp},X}} = 0. \tag{4}$$

Eq. (4) simply says that as long as a bank has achieved stable NIM, the interest income and interest expense regression coefficients must satisfy

$$\beta^{\mathrm{Inc},X} = \beta^{\mathrm{Exp},X}$$

regardless of the independent variable X in the regression. In the specific case when $X = \Delta FFR_t$, the coefficients defined by a regression on the federal funds rate (and lags therefore) satisfies the property that $\beta^{\text{Inc},FFR} = \beta^{\text{Exp},FFR}$.

This highlights that conditional on banks achieving a stable time series of NIM, matching interest income and interest expense betas at the bank level is a necessary consequence. Figure 2 illustrates this point with asset and liability spread betas measured against Amazon stock returns instead of the Federal funds rate over the period Q3 1997 to Q4 2020, where Amazon is a publicly traded firm. The asset and liability Amazon-beta matching is nearly perfect, essentially recreating the result based on the Federal funds rate. It seems implausible that bank managers intentionally managed their exposure to Amazon stock, as the causal narrative requires of this evidence.

3.2 Interest Rate Risk Exposure Measures

The sensitivity of NIM and its components, R_t^{Inc} and R_t^{Exp}, to changes in short-term market interest rates is sometimes used to assess the interest rate risk exposure of banks (e.g., Hoffmann et al., 2019; Haddad and Sraer, 2020; Drechsler, Savov, and Schnabl, 2021). To reach conclusions about the net interest rate exposure of long-short portfolios that have matching interest income and interest expense betas, these betas must be good measures of interest rate exposure. This section describes the properties of income betas and compares them to standard interest rate risk exposure measures.

In this method, the change in NIM, or the change in R_t^{Inc} and R_t^{Exp}, is regressed on changes in the Federal Funds Rate (FFR), resulting in coefficients β^{FFR}. In contrast, standard asset pricing theory defines interest rate risk, or duration risk, as the change in the *value* of a portfolio to a change in interest rates. For example, DV01 defines duration as the change in the asset value for a 1 basis point change in the interest rate. Another related way to measure interest rate risk is to regress the periodic excess returns of a portfolio on an interest rate factor, say the 5-year UST market return in excess of the one-month US T-bill rate. The resulting regression coefficient, β^{TERM}, captures how much a portfolio value moves with a 1% movement in the interest rate factor.

Income Betas. To see the difference in these two methods for assessing interest rate risk, we focus first on income betas (or equivalently expense betas). Take a simple example. Assume that the bank holds a fixed-income portfolio that invests each period the same amount into a bond with characteristics m_s and holds this bond to maturity. The subscript s denotes the period during which the bond was bought. Bond characteristics can include the maturity and credit risk of the bond. For simplicity, we assume that each period the bank buys default-free bonds of the same maturity. Denote with $y_s^{m_s}$ the associated income (coupon) earned each period until its maturity. Abstracting from default, the income stream for each bond $y_s^{m_s}$ is fixed. Hence, the income rate on the portfolio and the quarterly change in the income rate are simply:

$$R_t^{\text{Inc}} = \frac{1}{J} \sum_{j=1}^{J} y_{t-j}^{m_{t-j}}. \tag{5}$$

$$\Delta R_{t+1}^{\text{Inc}} = \frac{1}{J} (y_t^{m_t} - y_{t-J}^{m_{t-J}}). \tag{6}$$

This simple portfolio example clarifies that the change in the income of the simple fixed income portfolio only captures the difference between the income of the most recently purchased bond and the income of the oldest bond in the portfolio, since the coupons associated with all other bonds purchased in between those dates are fixed and therefore contribute zero to the difference. Consider attempting to measure interest rate risk using a regression of the change in income to a change in FFR:

$$\beta^{\text{Inc}} = \frac{\text{COV}(\Delta R_{t+1}^{\text{Inc}}, \Delta\text{FFR}_t)}{\text{VAR}(\Delta\text{FFR}_t)} \tag{7}$$

$$= \frac{\frac{1}{J}\text{COV}(y_t^{m_t}, \Delta\text{FFR}_t)}{\text{VAR}(\Delta\text{FFR}_t)}, \tag{8}$$

where the second line of Eq. (8) follows from the first because $y_{t-J}^{m_{t-J}}$ is uncorrelated with ΔFFR_t for $J > 1$. Adding lags of FFR up to $t - J$ to the regression will measure the covariance of $y_{t-J}^{m_{t-J}}$ with ΔFFR_{t-J}. But since the coupons of all other bonds are differenced, the additional lags will not improve this regression. Additionally, notice that the coefficient is declining in the portfolio strategy maturity, J, as the portfolio weights will be decreasing in maturity for any realistic strategy that maintains relatively stable exposure.

For example, a portfolio strategy that each month buys a 5-year bond will have 60 holdings and the difference in interest income returns will be, $\Delta R^{\text{Inc}}_{t+1} = \frac{1}{60}(y^{60}_t - y^{60}_{t-60})$. Note that the interest income from just 2 of 61 positions are affecting this calculation and that the covariance is being heavily down-weighted by the average position weight, 1/60. Suppose that market yields can be characterized by the short rate plus a term premium, $y^{60}_t = y^0_t + \phi^{60}_t$. If ϕ^{60}_t is constant through time, then

$$\text{COV}(\Delta R^{\text{Inc}}_{t+1}, \Delta \text{FFR}_{t+1}) = \frac{1}{60}\text{COV}\left((y^0_t - y^0_{t-60}), (\text{FFR}_t - \text{FFR}_{t-1})\right).$$

In this simplified example, the income beta would just be 1/60 of the contemporaneous covariance between the change in Federal funds rate and y^0_t (depending on the definition of y^0_t, y^0_t may simply be FFR_t).

Duration and Term Exposure. Interest rate risk is typically measured via duration (Cochrane, 2009; Berk and DeMarzo, 2019). Duration is the sensitivity of a bond's j value V^j_t to a parallel shift in the current yield curve y_t, hence $d^j_t \equiv \frac{\delta V^j_t}{\delta y_t}$. It is well-known that individual bond sensitivities tend to be increasing in maturity. The interest rate sensitivity of a bond portfolio is simply the weighted average duration of the portfolio's individual bonds d^j_t, i.e., $d^p_t = \sum_{j=1}^{J} w^j d^j_t$.

Another way to express duration is via excess bond return regressions relative to some benchmark bond portfolio, say the constant H-maturity portfolio constructed as in Section 4 that earns the portfolio return R^H_{t+1} as follows

$$R^H_{t+1} = \frac{c^H_{t+1} + \Delta V^H_{t+1}}{V^H_t} = \sum_{j=1}^{J} w^j_t R^j_{t+1}, \tag{9}$$

where w^j_t are the portfolio weights of bond j in portfolio H, c^H_{t+1} is the sum of all coupons on the portfolio, and ΔV^H_{t+1} is the change in the value of the bond portfolio H.

To see the relationship between this duration measure and an empirical duration measure based on regressions for a bond k, define first the periodic excess bond k return by subtracting the riskfree rate from bond's k return, so

$$XR_{t+1}^{k} = R_{t+1}^{k} - R_{t+1}^{F} = exc_{t+1}^{k} + d_t^k \Delta y_{t+1} + e_{t+1}^{k},$$

where $exc_{t+1}^{k} = c_{t+1}^{k} - R_{t+1}^{F}$ is coupon on bond k in excess of the riskfree rate R_{t+1}^{F}, $d_t^k \Delta y_{t+1}$ uses the fact that the change in the bond value to a shift in the yield curve Δy_{t+1} equals d_t^k, and e_{t+1}^{k} was introduced to allow for return shocks that are uncorrelated with Δy_{t+1}. We can then calculate the empirical duration as the regression coefficient of the fitted periodic excess return of bond k on the fitted constant H-maturity portfolio excess return, which can be expressed as

$$\begin{aligned} \frac{\mathrm{COV}(XR_{t+1}^{k}, XR_{t+1}^{H})}{\mathrm{VAR}(XR_{t+1}^{H})} &= \frac{\mathrm{COV}(exc_{t+1}^{k} + d_t^k \Delta y_{t+1}, exc_{t+1}^{H} + d_t^H \Delta y_{t+1})}{\mathrm{VAR}(exc_{t+1}^{H} + d_t^H \Delta y_{t+1})} \\ &= \frac{d^k d^H \mathrm{VAR}(\Delta y_{t+1})}{(d^H)^2 \mathrm{VAR}(\Delta y_{t+1})} \\ &= \frac{d^k}{d^H}, \end{aligned} \tag{10}$$

where the second line follows from the first because removing the risk-free rate from the cash income means removing the only time varying element from c_{t+1}^{x} from the perspective of t.[12] All other cash flows are known ex-ante and uncorrelated with Δy_{t+1}. Note, that we dropped time scripts on d_t^x to denote time series averages. Eq. (10) says that under our assumptions the empirical duration regression coefficient is simply the ratio of bond k's duration to the duration of the constant H-maturity portfolio.[13] As a result, the portfolio regression beta of a portfolio of bonds is simply the weighted average of the relative durations, $\sum_j^J w_t^j \frac{d^j}{d^H}$.

Comparing the interest rate risk measures implied by duration or term regressions coefficient Eq. (10) with the income beta Eq. (8), we can immediately see how fundamentally different these

[12]For a more detailed derivation, please refer to Appendix A.

[13]With unfitted excess returns in the regression, the regression coefficient would include an additional term related to the covariance of the e^k's with the e^H's.

two measures are. While the income beta of Eq. (8) measures the covariance of the current market rate with a single coupon weighted by the longest maturity of the underlying portfolio, the term regression coefficient implied by Eq. (10), $\sum_j^J w_t^j \frac{d^j}{d^H}$, measures the weighted average exposure of the market returns of all components of the bond portfolio. These two equations also clarify that income betas will never recover the duration exposure of a portfolio, unless the portfolio consists only of floating rate bonds in which case the duration is zero. Adding more lags or more data to the regression behind (8) does not resolve the fundamental issue that changes in fixed interest income exposures are a different notion of interest rate risk from the standard asset repricing risk notion – income sensitivity vs. value sensitivity.

In Appendix B and Tables 8 and 9 we present detailed results on how duration and portfolio return term exposure coefficients differ from income and expense betas for the purpose of measuring interest rate risk exposure.

4 Stable NIM without a Deposit Franchise or Market Power

The popular narrative emphasizes the essential role of deposits and market power for generating stable NIM and for eliminating interest rate exposure.[14] We first investigate the claim that a deposit franchise and market power are essential to generate stable NIM. Next, we show that stable NIM is not informative about a portfolio's interest rate risk exposure. To empirically evaluate the first claim, we develop and evaluate a rule-based portfolio strategy that invests only in US Treasury securities, thereby restricting its access to deposits and any notion of market power. Assessing the validity of the basic premise will primarily involve a comparison of the time series variation in actual bank NIM with the time series variation in the UST portfolio NIM. We can then also

[14] Drechsler, Savov, and Schnabl (2021) compare the smooth NIM of banks with the more volatile NIM of a Treasury portfolio they constructed. They state "while banks' interest expense is low and smooth with respect to the Fed funds rate, the interest expense of the Treasury portfolio closely tracks the Fed funds rate. This is why the NIM crashes whenever the Fed funds rate rises. Thus, Figure 4 makes clear why the deposit franchise allows banks to engage in maturity transformation without exposing their bottom lines to interest rate risk". This statement implies (a) that the deposit franchise is necessary to generate a stable NIM, and (b) that stable NIM means banks are not exposed to interest rate risk.

evaluate to what extent a stable NIM portfolio has near zero interest rate risk.

4.1 A US Treasury Portfolio Strategy for Stable NIM

We develop a range of variants of a long-short UST portfolio strategy that target different levels of constant NIM over the 1967 to 2020 period. We compare the time series volatility of the resulting UST portfolio NIM time series with that of banks.

Each month, the strategy selects cash amounts, asset maturity, debt maturity, leverage, and repurchasing amounts of assets and debt to target a constant level of NIM, NIM*. We initially endow the strategy with an asset portfolio comprised of a fraction, ω_t^{Cash}, in cash (1-month US T-bill) with the remainder invested equally across a seasoned allocation to UST bonds purchased at previous dates each with an initial maturity of H_A. This portfolio is initially funded with a fraction, $1-D/A$, of investor's equity with the remainder funded with an equally weighted allocation of UST bonds sold at previous dates with an initial maturity of H_D. At the end of each month, the portfolio accounting and market equity and asset values are updated and then decisions about asset reinvestment, liability refinancing, and rebalancing of assets and liabilities are made. The portfolio decision are constrained by the evolution of the balance sheet, a maximum book value leverage ratio, D_t/A_t, of 0.9, a maximum rebalancing of 20% of assets and 20% of debt in any period, and no further access to external equity capital. The updating of the portfolio occurs for the book and market value balance sheets.

Given the number of choices and the target of constant NIM, there are potentially many solution methods to this problem. We are simply looking for a method that achieves a relatively stable NIM, not necessarily the best strategy for this objective. As illustrated in Section 3 and with Eq. 5, the income or expense on any historical position implies largely predetermined cash flows. That is, at each point in time, conditional on portfolio holdings being chosen, the next period NIM is known with certainty since all holdings are fixed income securities. The practical challenge is having enough slack to make adjustments, given the current market yield curve. For example, if the entire current yield curve is relatively flat and offering low market interest rates relative to the

NIM target, then leverage will need to be low, and leverage will need to have been moving lower beforehand to satisfy the constraints that limit portfolio rebalancing and restrict access to external equity. Thus, the algorithm must choose an appropriate forward looking target leverage depending on the perceived challenge of being able to achieve the constant target NIM in the forward period where existing assets have yet to mature, but after existing debt matures (i.e. H_D to H_A). It also has to take into account what reinvestment asset amounts and refinancing liability amounts generate the forward looking target leverage and how much rebalancing of assets and liabilities is allowed. These decisions generate a pro forma NIM for the next period that we can then compare against the constant target NIM. The strategy then chooses the period t decisions that bring the pro forma NIM closest to the target. We generate a cross-section of UST portfolios where each is defined by a set of initial parameter conditions $H_A, H_D, D/A, w^{Cash}$ and a stable NIM^* target.

4.2 Stable NIM and Spread Beta Matching in UST Portfolios

We explore the properties of a constructed sample of stable NIM portfolios that use the same set of above mentioned portfolio rules, but differ in their strategy parameters. Specifically, we consider all permutations of the following strategy parameters: $H_A \in$ {48, 54, 60, 66}, $H_D \in${18, 24, 30}, $\omega_t^{Cash} \in${0.10, 0.15, 0.20, 0.25, 0.30}, $D/A \in${0.50, 0.55, 0.60, 0.65, 0.70, 0.75, 0.80}, and $NIM^* \in${1.0%, 1.5%, 2.0%, 2.5%, 3.0%}, resulting in 2,100 portfolio strategies.

Table 2 and Figure 3 compare the NIM stability and interest rate sensitivity matching of US commercial banks to the sample of stable NIM UST portfolios. Panel A of Table 2 summarizes the mean and time series variation of NIM for the aggregate banking sector and for a similarly constructed aggregate of the considered UST portfolios. Over the period 1985-2020, bank NIM has a quarterly standard deviation of 0.090 and the standard deviation of quarterly changes in bank NIM is 0.031. Over this same period, the quarterly standard deviation of NIM of the UST portfolios is 0.068 and the standard deviation of quarterly changes in UST portfolio NIM is 0.020. Interestingly, over the longer sample from 1965-2020 that includes the interest rate spike around 1981, the UST portfolio NIM continues to have a lower standard deviation than bank NIM. The top panel of Figure 3 displays the annualized quarterly NIM for banks and the average UST portfolio, along with the Federal funds rate. While not the focus of this analysis, it is natural to compare the mean levels of NIM between the UST portfolios and actual banks. The average annualized NIM for commercial banks is 3.24% and is 1.57% for UST portfolios. It is helpful to recall that the interest expense component of deposits is only a portion of the full cost of deposits, since operating expenses are excluded from NIM; and that the issuance yield on loans is what banks earn in the absence of losses, but not what they actually earn after losses are realized. It is also important to note that these UST portfolios are not designed to mimic the maturity composition of banks, merely to evaluate whether stable NIM can be achieved without deposits.[15]

A central element in the causal narrative of how banks achieve stable NIM is their asset and liability interest beta (or spread beta) matching. To evaluate the hypothesis that deposit market power is essential to the interest beta matching, we explore whether there is any evidence of asset and liability interest beta matching within the sample of UST portfolios targeting stable NIM. The bottom panel of Figure 3 shows that there is near perfect interest beta matching within the sample of UST portfolios. The second and third panels of Table 2 confirms this relation with cross sectional regressions of income spread betas on expense spread betas (panel B) and income betas on expense betas (panel C) using the same specifications as in Drechsler, Savov, and Schnabl (2017, 2021). For comparison, we also include the cross sectional regressions for the banks. The first column essentially reproduces the results in Drechsler, Savov, and Schnabl (2017, 2021) over a slightly updated sample period, with nearly identical regression coefficients and R^2. The regressions from the sample of UST portfolios show that the spread beta matching in the sample of UST portfolios is even stronger than it is in banks, with similar regression coefficients and higher R^2. This result holds over the longer sample period that begins in 1965. The beta matching is consistent with the analysis in Section 3, showing that conditional on achieving stable NIM approximate beta

[15] Begenau and Stafford (2020) construct passive capital market portfolios based on the reported maturity and credit risk holdings of banks and compare the cash flows and returns of these benchmark portfolios to banks. Interpreting their results relies on whether bank deposits effectively offset the duration risk of bank assets. Without a near complete offset of the duration risk of bank assets, Begenau and Stafford find that bank cash flows and returns underperform their passive capital market benchmarks.

matching is a consequence, not the unique causal mechanism. The finding that both stable NIM and interest beta matching (and spread beta matching) are achievable in UST portfolios illustrates that neither deposits nor market power are essential for achieving stable NIM.

4.3 Interest Rate Risk of Stable NIM UST Porfolios

An important recent inference in the banking literature is that banks are able to engage in activities that create a maturity mismatch between their assets and their liabilities without bearing interest rate risk (see Drechsler, Savov, and Schnabl, 2017, 2021).[16] We now examine the claim that stable NIM and asset and liability spread beta matching are indicative of near zero interest rate exposure. We test this hypothesis directly with our sample of stable NIM UST portfolios that exhibit strong asset and liability interest beta matching.

As in Section 3, we calculate interest rate risk in two standard ways, using a simple fixed income valuation model and from regressions of market excess returns on a interest rate term factor, TERM (i.e. the excess return on a constant maturity 5-year UST bond portfolio). At each point in time, the asset and liability positions in each UST portfolio are known and a simple fixed income bond valuation model is used to map the fixed coupon, remaining maturity, and current yield curve into a market value for each position. This same valuation model can be used to calculate a sensitivity to a constant shock to all current yields, a sensitivity commonly referred to as duration risk. As we showed in Section 3, the net portfolio duration is the weighted sum of individual holding durations across both assets and liabilities. Additionally, we can calculate the market value of the equity of each UST portfolio each quarter, with the quarterly percentage changes in equity being quarterly returns. The quarterly returns, in excess of the one-month US T-bill rate are regressed on a TERM factor as an alternative means of measuring interest rate risk exposure (e.g. Fama and French, 1993). Thus, we can explore the time series and cross sectional relation between maturity mismatch, model-based estimates of duration risk, and equity excess return regression estimates of TERM exposure.

[16] In contrast, many other studies argue that banks bear interest rate risk (e.g., Begenau, Piazzesi, and Schneider, 2015; English, Van den Heuvel, and Zakrajšek, 2018; Paul, 2020; Williams, 2020).

By construction, the UST portfolios that target a positive stable NIM have a maturity mismatch between their asset maturity and their liability maturity, given the generally upward sloping US Treasury yield curve from 1954 to 2020. Figure 4 shows the time series behavior of the aggregate UST portfolio strategies in terms of leverage and cash share of assets (panel A), asset and liability maturity per dollar of assets (panel B), and model-based duration risk estimates of assets and liabilities per dollar of assets (panel C). Each quarter, the aggregate UST portfolio has an economically large maturity mismatch, which coincides with a large duration risk mismatch between assets and liabilities.

Table 3 summarizes the relation between duration risk and maturity composition of the portfolios with cross sectional regressions. We refer to duration risk as "Delta," measuring the average value change of a security given a 1% shock to the entire yield curve. Consequently, deltas are negative, reflecting the negative relation between interest rate shocks and fixed income values. The dependent variable is the time series average of the quarterly asset or debt delta per dollar assets. Independent variables are the associated maturity in years for debt, the associated maturity in years and the cash share for assets, and net delta per dollar of equity regressions include leverage. The cross sectional relation between duration risk and maturity mismatch are very strong across all specifications with R^2 values ranging from 0.80 to 0.99.

Duration risk is the major risk that fixed income investors worry about. Figure 5 illustrates why this risk matters. Figure 5 displays the quarterly time series of the Federal funds rate and the total return index of the aggregate stable NIM UST portfolios and the quarterly drawdowns (measured as the quarterly total return index measured as a percentage return relative to the previous maximum price level). In the period leading up to June 1981, US short-term interest rates increased substantially and the total return index experienced a drop in market value approaching -40%. The figure also highlights the strong tailwinds that a levered maturity mismatched portfolio experienced from June 1981 through 2011, as interest rates generally declined, but longer-term yields were such that this realized trend was unlikely to have been anticipated (Fama, 2006). Table 4 reports results from a time series regression of the aggregate equity return, in excess of the one-month US T-bill rate, on the 5-year TERM factor. The coefficient is 1.7 (t-statistic = 56.4) and the R^2 is 0.89, highlighting the strong evidence that this maturity mismatched portfolio has substantial interest rate risk, despite achieving both stable time series NIM and cross sectional spread beta matching between assets and liabilities. Table 4 also reports results from a cross sectional regression of portfolio-level TERM exposures on that portfolio's average net duration risk per dollar equity. The cross sectional relation between TERM exposures and average net duration risk is highly statistically reliable with almost all of the variance well explained with an R^2 of 0.94.

From a standard valuation perspective, there is little that is surprising in the interest rate exposure analysis, given the transparent nature of the stable NIM UST portfolio strategies. Maturity mismatch is tightly linked to duration risk, which is tightly linked to equity TERM exposure. The surprising result is that stable NIM and spread beta matching can coincide with these economically large interest rate exposures. These results strongly reject the notion that evidence of stable NIM and spread beta matching can be used to infer that interest rate exposure is near zero.

5 Imperfect Pass-Through as Evidence of Bank Market Power?

Deposit rates appear to imperfectly pass-through market interest rate shocks, even though a large fraction of deposits are demandable and therefore have zero contractual maturity. This is an important component of the evidence on bank's market power in deposits. The idea is that banks exploit their market power over depositors to set rates optimally instead of setting deposit rates in lockstep with current market rates. The analyses in this section are organized around two main observations. First, what is measured as imperfect pass-through or partial adjustment can occur both because of intentional rate setting and because there is a maturity component to many deposits. To see the maturity mechanism easily, recall that there is "imperfect pass-through" in the income return of a rule-based portfolio strategy that buys-and-holds 5-year US Treasury bonds. This is clearly not because of intentional rate setting by the portfolio manager, but simply the mechanical consequence of the imperfect pass-through measurement methodology when applied to positive maturity portfolios. We explore how important this mechanical maturity component is in time deposits, which can directly affect inferences for total deposits. Second, beyond the maturity mechanism, the imperfect pass-through measure remains an incomplete proxy for market power by implicitly assuming no incremental cost differences and no capital scaling differences across banks operating in concentrated vs competitive deposit markets. We explore whether these implicit assumptions are likely to be benign or meaningful for inferences.

5.1 Time Deposits are Different

5.1.1 Market power versus Maturity as Mechanisms for Imperfect Pass-Through

We build on the simple bank portfolio example from Section 3.2, where Eq. (7) defines β^{Inc} in the context of the income return or equivalently expense rate defined by Eq. (5). Recall that spread betas are simple transformations of expense or income betas (e.g., $\beta^{Inc} = 1 - \beta^{\text{spread,Inc}}$). In this section, we study two mechanisms that affect β^{Inc}: maturity in fixed income portfolio dynamics and intentional rate setting behavior of banks. We begin with a benchmark case of β^{Exp} in the context of a price taking portfolio composed of floating rate bonds, where β^{Exp} refers to an expense rate defined as the interest expense over last period's assets. For this reason, the expense beta is affected by the debt-to-asset ratio of banks, $\frac{D}{A}$, through $\frac{\text{\$Expense}}{\text{\$Assets}} = \frac{D}{A}\frac{\text{\$Expense}}{\text{\$Debt}} = \frac{D}{A}R^L$. For simplicity and without loss of generality, we set $\frac{D}{A} = 1$.

Price taking portfolio with floating rate bond We first develop intuition for the income beta behavior in the case when funding occurs at short-term capital market rates. That is, we assume the bank funds itself with floating rate debt, where the rate is $R_t^L = 1 + FFR_t + \phi$, i.e. the Fed Funds rate (reference rate) plus a constant spread. This means

$$\beta^{\text{Exp}} = \frac{\text{COV}\left(\Delta FFR_t, \Delta FFR_t\right)}{VAR\left(\Delta FFR_t\right)} = 1. \tag{11}$$

With $\beta^{\text{Exp}} = 1$, any market rate change is perfectly passed through to a bank's interest expense rate.

Market power Suppose banks use their market power to set R_t^L for $\forall t$ such that the desired expense rate sensitivity to the Federal Funds Rate $\beta^{\text{Exp}} = \frac{\text{COV}(\Delta R_t^L, \Delta FFR_t)}{VAR(\Delta FFR_t)}$ is achieved. For instance, β^{Exp} could be set to a fraction $\psi < 1$ of the current market rate: $R_t^L = 1 + \psi FFR_t$, then:

$$\beta^{\text{Exp}} = \frac{\text{COV}\left(\Delta\left(\psi FFR_t\right), \Delta FFR_t\right)}{VAR\left(\Delta FFR_t\right)} = \psi. \tag{12}$$

Hence, β^{Exp} reflects banks ability to pay below market rates. The comparison of the price taking portfolio with floating rate bonds with the market power cases leads to the standard empirical tests to determine whether interest expense betas are less than one, or whether spread betas are greater than zero.

Price taking portfolio with *M* period bond portfolio held to maturity Finally, consider the case where the expense rate evolves analogously to Eq. (5) in 3. As a result, the expense beta is defined analogously to Eq. (8). Only the longest maturity in the portfolio and the contemporaneous covariance between the federal funds rate and the most recently issued yield factor into the β^{Exp} measure:

$$\begin{aligned}
\beta^{\text{Exp}} &= \frac{1}{J}\frac{\text{COV}\left(y_t^M, \Delta FFR_t\right) - \text{COV}\left(y_{t-J}^M, \Delta FFR_t\right)}{VAR\left(\Delta FFR_t\right)} \\
&= \frac{1}{J}\frac{\text{COV}\left(y_t^M, FFR_t\right) - \text{COV}\left(y_t^M, FFR_{t-1}\right)}{VAR\left(FFR_t - FFR_{t-1}\right)}
\end{aligned} \tag{13}$$

Note that Eq. (13) is equivalent to Eq. (8) if past yields are uncorrelated with the current realization of the FFR. With a specific term structure model in mind, we could explicitly solve Eq. (13) in terms of the parameters that determine factor dynamics and the term structure. Eq. (13) clarifies that $\beta^{Exp/A}$ will be smaller the larger J and the more autocorrelated the federal funds rate is. Thus, either Eq. (12) or Eq. (13) deliver $\beta^{\text{Exp}} < 1$. An interest expense beta coefficient less than

1 cannot be purely attributed to market power if the deposits include some notion of maturity. The clearest practical example is time deposits, and therefore also total deposits, which include time deposits.

5.1.2 Maturity and the Imperfect Pass-through of Time Deposit Rates

Given that time deposits account for a large share of total deposits, and that these accounts by definition are positive maturity, we investigate the extent to which the maturity mechanism affects measures of partial adjustment in time deposit rates. Table 5 reports cross sectional regressions of various deposit partial rate adjustment coefficients on the average market concentration, average natural log bank size, weighted-average county employment where a bank has deposits (log), the share of non-time deposits to total deposits, and maturity composition variables. The maturity composition variables are the average share of deposits within quarterly reported maturity categories. We separately analyze these relations for transaction deposits, time deposits, and total deposits. To the extent that transaction deposits have no maturity, then the partial rate adjustment coefficients for these accounts should properly reflect intentional rate setting. In a univariate regression of transaction deposit spread betas (i.e. a cross section of estimated bank-level partial rate adjustment coefficients) on HHI, there is a reliably positive relation, although the R2 of 0.02 shows that the fraction of variance explained is small. A regression that excludes HHI, but includes the bank control variables has an R2 of 0.11. The specification with HHI and the control variables finds that HHI continues to be reliably positive.

The second panel of Table 5 shows regressions for time deposits. In addition to the previous set of bank-level control variables, we also include three variables describing the maturity distribution of time deposits for each bank, the fraction of time deposits with maturity 3-months to 1-year, 1-year to 3-years, and more than 3-years, with 0 to 3-months being the omitted category. Again, a univariate regression finds that HHI is reliably positively related to spread beta with essentially zero R2. The specification with controls, excluding the maturity variables has an R2 of 0.04. A specification with the maturity variables has an R2 of 0.42, with reliably positive coefficients, suggesting that there is a strong relation between measured partial adjustment coefficients for time deposits and the maturity of these deposits, as anticipated from equations 8 and 13. Adding all of the bank controls increases R2 to 0.47. The final specification adds HHI and finds that the coefficient is indistinguishable from zero. These regressions suggest that what is measured as partial adjustment for time deposits is mostly describing the maturity composition of these deposits and reflecting essentially no intentional rate setting behavior by banks. This would be consistent with time deposits, on average, being competitive, paying equivalent rates to US Treasuries of equivalent maturity (Fama, 1985).

The third panel of Table 5 shows regressions for bank total deposits. These results blend those from transaction deposits and time deposits. We include the transaction deposit share of deposits as an additional independent variable. Consistent with the previous regressions, the relation between the partial adjustment coefficients of deposits and HHI is statistically reliable, but small with an R^2 of 0.006 in a univariate regression. Again, the control variables, especially the maturity variables explain substantially more of the cross sectional variation.

The regressions in Table 4 highlight that time deposits are different from the non-time deposits and should be analyzed separately. Figure 6 plots the time series of annualized quarterly transaction deposits rates, time deposit rates, and total deposit rates for US commercial banks. All three rates are grouped into value-weighted portfolios based on their deposit HHI, along with the Federal funds rate. High HHI is defined as the top tercile of the HHI distribution across banks, which roughly coincides with the US Department of Justice definition of high market concentration (HHI above 0.25 on a 0 to 1 scale). Low HHI is defined as the bottom tercile, which roughly coincides with the FTC's threshold for medium market concentration (HHI above 0.15 is considered moderately concentrated).[17] There are several things to notice. The imperfect pass-through of market rates for time deposits can now be understood to reflect their increased maturity as opposed to intentional rate setting. Consistent with this interpretation, time deposits, on average, pay higher interest rates than the Federal funds rate. The annual average rate paid on time deposits

[17] https://www.justice.gov/atr/herfindahl-hirschman-index

is 3.1%, while the Federal funds rate averages 2.4% over this sample period. Only transaction deposits (non-time deposits) exhibit the tell tale signs of market power – imperfect pass-through and average rates lower than short-term market rates. Additionally, within the non-time deposits, the difference in rates between high and low market concentration is inconsequential relative to the difference between the non-time deposit rate and the Federal funds rate. The average non-time deposit rate for all banks is 1.02%, which is 1.38% below the average Federal funds rate; while the average difference in transaction deposit rates for banks operating in concentrated versus non-concentrated markets is only 0.10%. This will be important for assessing whether operating in concentrated markets provides banks with a net benefit over banks operating in non-concentrated markets if doing so leads to positive incremental costs or requires limiting their scale.

5.2 Net Benefits to Operating in Concentrated Deposit Markets

The imperfect pass-through of short-term market rates to bank deposit rates is an imperfect proxy for market power for reasons beyond the maturity mechanism documented above. A stylized description of the incremental profits banks earn by operating in concentrated deposit markets relative to competitive deposit markets would consider an empirical relation like the following:

$$\begin{aligned}\text{Incremental Profit} = &\left(R_t^M - R_t^{\text{D,high MP}} - C_t^{\text{high MP}}\right) D_t^{\text{high MP}} - \\ &\left(R_t^M - R_t^{D\text{,low MP}} - C_t^{\text{low MP}}\right) D_t^{\text{low MP}},\end{aligned}$$

where R_t^M denotes the short term market rate, $R_t^{\text{D,X MP}}$ is the deposit rate in markets with "X" deposit market power, X being either high or low, $C_t^{\text{X MP}}$ is the operating cost associated with deposit funding in markets with X market power, $D_t^{\text{X MP}}$ is the quantity of deposit funding in markets with X market power. The interest rate spread is only a portion of the net benefit and therefore only provides an accurate assessment of the benefits of operating in a concentrated market if incremental costs and incremental scale are inconsequential (for a detailed discussion see (Weyl and Fabinger, 2013)). These are strong assumptions that we investigate in this section.

We characterize the incremental spread benefit to operating in a relatively concentrated market via regressions of a panel of deposit rates on various measures of market concentration. The market concentration measures include a bank-level HHI (measured as the weighted average of county HHI where the bank has deposits), the transaction spread beta, and a residual deposit spread beta estimated by controlling for the maturity variables (i.e. specification 3 from Panel 3 of Table 5). It is useful to note that HHI and the transaction spread beta are not highly correlated and that HHI and the residualized deposit spread beta are essentially uncorrelated with HHI, so these variables do indeed measure different things. The panel regressions include time fixed effects and standard errors are calculated with clustering by time and bank.

Table 1: Net benefits

	HHI	Trans. Spread Beta	Resid. Spread Beta
Std	0.119	0.105	0.080
Rate Coef x Std (bps)	-2.6	-8.9	-7.8
Cost Coef x Std (bps)	23.0	8.9	4.9
Net Benefit	-20.4	0.0	2.9

Table 6 reports results from these regressions and Table 1 provides a simple calculation of the net-benefit based on the estimated coefficients from Table 6. The first specification simply includes the time and bank fixed effects to provide a baseline as context for the adjusted R2, which is 0.85. The second specification adds the bank-level control variables, which are the same ones used in Table 5, increasing adjusted R2 to 0.93. Each of the coefficients on the three proxies for bank deposit market power are reliably negative, with minimal improvement in adjusted R2. The coefficients multiplied by one standard deviation of the associated variable are used to interpret economic magnitudes and are summarized at the bottom of the panel. A one standard deviation increase in market power is associated with a 3 to 9 basis point improvement in deposit funding rates.

We turn now to whether the incremental 3 to 9 basis points improvement in funding rate is large enough to offset the potential cost and scale differences that arise for banks operating in concentrated markets. We run similar regressions of operating expense rates (non-interest rate expense scaled by bank assets) on bank characteristics and the market concentration proxies to measure incremental cost differences. The bank controls continue to include bank size and the average county size in which the bank operates, but now also include real estate loans and business loans as a share of deposits. The coefficients on the three proxies for market power tend to be reliably positive, although the coefficient on the residual deposit spread beta is only marginally significant. A one standard deviation increase in market power is associated with a 5 to 23 basis point increase in non-interest expenses. The net benefits (i.e. marginal funding benefit - marginal operating expense) range from +3 basis points to -20 basis points per year, with the most negative net benefit associated with the most direct proxy for market power, HHI.

A final analysis investigates the characteristics of counties with high deposit market concentration. We summarize the average county level population, employment, and personal income conditional on deposit market concentration level in Table 7. There is a strong tendency for highly concentrated deposit markets to be relatively small places based on either population, employment, or personal income, consistent with results in Drechsler, Savov, and Schnabl (2017).

Overall, these results cloud the picture of banks benefiting from operating in the most concentrated deposit markets. There may be a local market power benefit to transaction deposits that essentially all banks are able to benefit from based on the partial adjustment analysis of transaction deposits that shows that even banks operating in the most competitive markets exhibit highly imperfect interest rate pass through. However, this inference is constrained by not considering costs. It is not at all clear that the spread is large enough to cover the costs associated with running the deposit-taking activity, especially when interest rates are low and the rate paid appears to be constrained to be non-negative, resulting in essentially a zero spread (or benefit). In a very low interest rate environment with positive costs, the deposit-taking activity may well be generating economic losses.

6 Discussion

Interpreting the UST portfolio analysis The key result is that long-short fixed income portfolios can achieve stable NIM, and as a consequence exhibit asset and liability spread beta matching, without having access to deposits or market power. This requires a dynamic portfolio strategy that adjusts leverage and strategically rebalances the portfolio based on the relative yields available in the market via the yield curve and those available inside the portfolio. As a consequence of constructing a sample of transparent UST portfolio strategies that, on average, have a maturity mismatch between assets and liabilities, the interest rate risk exposures can be measured with standard methods. While these portfolios share the same properties that have been used in the literature to conclude that interest rate risk is near zero, they in fact have statistically reliable and economically large interest rate risk exposure. Thus, our analysis shows that substantial interest rate risk may reside in portfolios that according to industry-standard performance metrics suggest no risk exposure at all.[18]

This main result is simple and intuitive once the distinction between income (expense) betas and duration risk is recognized. Even though we have shown that interest income or expense do not reveal the interest rate exposure of banks, our results do not establish that banks do have interest rate exposure. We only show that the evidence used to conclude that they do not bear interest rate risk cannot support that conclusion. In order to measure banks' interest rate risk exposure the duration risk of deposits must be estimated. There is an earlier literature that estimates the duration risk of bank deposits and finds that these risks are difficult to empirically measure, requiring a structural valuation model of bank deposits Hutchison and Pennacchi, 1996; Jarrow and Van Deventer, 1998; Janosi, Jarrow, and Zullo, 1999; Bolton et al., 2021). An alternative is to outsource the assessment of banks' interest rate exposure to the stock market and to estimate these implied assessments from stock returns. We discuss these inferences below.

There are many important components to the valuation of bank deposits. Two important ones

[18]During the US interest rate spike in 1981, the average equity value of the UST portfolios loses approximately -40% of its value, while maintaining near constant net interest margin.

are operating costs and forecasts of the level of future interest rates. To the extent that time deposits are approximately competitive (Fama, 1985), the allocation of bank operating costs to transaction deposits must be high. Additionally, since banks cannot sell short deposits and the stickiness of deposit customers is likely to be related to the spread between short-term market rates and transaction deposit rates, and the interest rate appears to be bounded at zero, it is not clear that the value of deposits is positive when interest rates are low and expected to remain low for a while.[19] These are issues to be sorted out with a structural valuation model of bank deposits that allows for these economic properties as well as the potential for market power. A valuation model of bank deposits also allows for the estimation of the duration risk of bank deposits, which is a big step towards a conceptually valid assessment of the net interest rate risk of banks.

Connecting the Results to Banks The focus on US Treasury portfolios can seem detached from the operations of US commercial banks. It is helpful to recall from Section 5 that in the absence of market power and operating and regulatory costs, the interest rate paid by banks on time deposits will resemble US Treasury securities. Additionally, US Treasury securities directly account for a small portion of the aggregate asset portfolio and underlie the pricing of most other assets that banks hold.

The analysis shows that a fairly dynamic portfolio strategy is required to achieve stable NIM in UST securities. It is natural to consider whether banks are likely to be more or less constrained than the UST portfolio strategies, given their mix of activities. Access to transaction deposits and loans represent the most unique differences from the UST portfolios. For banks, rebalancing within existing loans is constrained and short selling of deposits is completely restricted. However, all else equal, access to more non-redundant activities adds slack to the optimization. Additionally, the unique properties, in terms of NIM contribution, of loans and transaction deposits add considerable flexibility. Loans add flexibility because they contribute a credit yield spread without subtracting losses from NIM, while also contributing zero marking-to-market as market conditions evolve. This is a significant source of stable interest income, but also clearly an allocation that bears risk.

[19] Bolton et al. (2021) propose a theory where involuntary deposit inflows lower bank valuations.

Additionally, loans offer an easy means for "disposing" of excess NIM, as banks can extend credit at below market rates if stable NIM optimization is the agreed upon objective. Transaction deposits add a stable interest expense to NIM, but importantly also a relatively low amount of interest expense, which leads to a higher level of NIM. The interest paid on transaction deposits is likely a small portion of the full cost of supplying transaction services to customers and therefore offers a substantial advantage over a strategy that must report its full cost of funding.

This highlights a few important points. First, banks are likely to face a less constrained stable NIM optimization than the one implemented in UST securities because of the way their unique activities contribute to the measure. Both loans and deposits contribute stable net income to NIM and both also exclude substantial associated costs, losses, and risks (i.e. covariance of unexpected costs and losses with economic states of nature) that are in fact being borne by the equity investors. The UST portfolio strategies are constrained to trade within a set of assets that do not allow for similar omissions of costs, losses, and risks. A second related point is that from an economic perspective, NIM seems to be a highly unusual metric to receive so much practitioner interest. NIM does appear to be, at least somewhat, optimized to be stable through time. It would be a remarkable coincidence for an optimized stable NIM strategy to be equivalent to value maximization, given that the measure omits costs, losses, and systematic risks and essentially makes no use of market values. Third, to the extent that bank managers view interest income sensitivity to interest rate shocks as opposed to market value sensitivity to interest rate shocks and make decisions on this basis there may be some inconsistent pricing of bank and market pricing of related products. This would lead a bank lender and a non-bank market lender to require different returns on the same loan, simply because of different definitions of risk.

Comparing to Inferences from the Stock Market It is common to infer risk properties about firms and sectors from the stock returns of publicly traded firms. Implicit in this analysis is the assumption that stock market valuations, and importantly changes in valuation, accurately reflect the fundamentals of the firms being analyzed. In general, this is viewed to be a robust empirical design, but in the case of banks there are a few causes for concern about relying too completely on this methodology. Bank valuation multiples appear to be very strongly related to accounting ROE (net income divided by Tier 1 capital). Stock market valuations do not distinguish between accounting ROE that is generated by attractively selected risks (positive risk-adjusted performance) and simply increased risk premia (zero or even negative risk-adjusted performance). In other words, the stock market will pay more for dollar of earnings from a highly levered underperforming bank than for a low levered outperforming bank. Additionally, stock return implied risk measures for banks predict realized risks substantially worse than simple rankings based on risk-weighted assets to tier 1 capital (Begenau and Stafford, 2020). The risks implied from bank stock returns suggest that banks have little interest rate risk, have little credit risk, and strongly resemble the risks of ordinary non-bank corporations. At the same time, the level and time series patterns of bank cash flows are well described by portfolios constructed to mimic the reported duration and credit risk of bank activities (Begenau and Stafford, 2020).

7 Conclusion

The analysis in this paper demonstrates that the evidence used to reach conclusions about bank interest rate risk exposure being near zero does not support that conclusion. We show that in a sample of transparent US Treasury portfolio strategies, sharing the empirical properties that have been used in the literature to conclude that interest rate risk is near zero, that these portfolios have statistically reliable and economically large interest rate risk exposure. For example, during the US interest rate spike in 1981, the average equity value of the UST portfolios loses nearly -40% of its value, while maintaining near constant net interest margin. This evidence does not establish that banks do bear interest rate risk, which requires properly assessing the duration risk offset that transaction deposits may provide (see Hutchison and Pennacchi, 1996; Jarrow and Van Deventer, 1998; Janosi, Jarrow, and Zullo, 1999), but highlights that substantial interest rate risk can reside in portfolios that according to industry-standard performance metrics suggest no risk at all.

The analysis also suggest that the cross-section of market power translates into very small consequences for bank funding rates, which are essentially offset by increased non-interest expenses. To the extent that there is bank deposit market power, all banks appear to have it, with the cross section of bank deposit market power appearing to be relatively inconsequential. This has implications for research relying on a meaningful cross section of bank deposit market power in their empirical design.

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Table 2: Comparing Interest Rate Sensitivity Matching of Banks and UST Portfolios

	Banks 1985-2020	UST 1985-2020	UST 1965-2020
		NIM Stability	
Mean NIM	0.810	0.393	0.424
Std NIM	0.090	0.068	0.072
Mean dNIM	-0.001	-0.001	-0.001
Std dNIM	0.031	0.020	0.027
N	144	144	224
		Spread betas SB $\text{Inc}_i = b_0 + b_1 \times \text{SB Exp}_i + e_i$	
Intercept	0.094	0.059	-0.032
t-stat	(10.62)	(10.11)	(-5.63)
Slope	0.828	0.834	1.014
t-stat	(59.72)	(75.09)	(104.86)
R2	0.30	0.73	0.84
N	8,484	2,100	2,100
		Income betas B $\text{Inc}_i = b_0 + b_1 \times \text{B Exp}_i + e_i$	
Intercept	0.078	0.107	0.018
t-stat	(14.96)	(19.80)	(4.40)
Slope	0.828	0.834	1.014
t-stat	(59.72)	(75.09)	(104.86)
R2	0.30	0.73	0.84
N	8,484	2,100	2,100

Notes: This table reports summary statistics and regression coefficients for US commercial banks and US Treasury (UST) portfolio strategies that target stable NIM. The first column uses data from an aggregate sample of US commercial banks from 1985 Q1 to 2020 Q1. An aggregate sample of stable UST portfolios from 1985 Q1 to 2020 Q1 is presented in the second column and from 1965 Q1 to 2020 Q1 in the third column. The top panel presents the annualized percentage mean and standard deviation of NIM and the quarterly change in NIM for all three samples. The middle panel presents the cross-sectional regression results of asset income spread betas regressed on liability expense spread betas. Spread betas are calculated as bank or UST portfolio-level OLS coefficients from regressions of changes in the spread between the Federal funds rate and bank or UST portfolio interest rates on changes in the Federal funds rate with four lags. The bottom panel displays the cross-sectional regression results of asset income betas regressed on liability expense betas. Income (expense) betas are calculated as bank or UST portfolio-level OLS coefficients from regressions of changes in bank or portfolio income (expense) rates on changes in the Federal funds rate with four lags. Bank data comes from commercial bank call reports (FFIEC 031 and 041).

Table 3: Duration Risk Explained by Maturity Mismatch

	Intercept	Debt Mat.	Asset Mat.	Cash Shr	Leverage	R2 / N
Debt Delta / A	0.00	-0.01				0.99
	(9.42)	(-119.62)				222
Asset Delta / A	-0.02		0.00			0.16
	(-9.23)		(6.65)			222
Asset Delta / A	-0.05		0.00	0.19		0.80
	(-32.40)		(19.23)	(26.39)		222
Net Delta / A	-0.04	0.01	-0.01	0.14		0.96
	(-19.46)	(31.98)	(-25.01)	(13.72)		222
Net Delta / E	0.06	0.04	-0.01	-0.10	-0.14	0.88
	(4.63)	(12.57)	(-10.58)	(-1.45)	(-26.16)	222

Notes: This table summarizes the relation between duration risk and maturity composition of the stable NIM UST portfolio strategies using regression results. The dependent variable is duration risk "Delta" calculated as the average value change of a security given a 1% shock to the entire yield curve. Deltas are calculated for a time series of debt and asset values of each portfolio per dollar of assets. Net Delta are expressed per dollar of assets and equity value, respectively. The independent variables are the associated maturity in years for debt and the associated maturity in years and the cash share for assets to which the net delta regressions add leverage.

Table 4: 5yr TERM Exposure of UST Stable NIM Strategies (Monthly)

	Intercept	MKT-RF	5yr TERM	R2 / N
Total Return Index	0.00	-0.03		0.00
	(3.77)	(-1.05)		399
Total Return Index	0.00		1.74	0.89
	(0.29)		(56.02)	399
Total Return Index	-0.00	0.02	1.75	0.89
	(-0.17)	(2.71)	(56.44)	399

Cross Section of 5yr TERM Exposure Explained by Net Delta / MV Equity

	Intercept	Net Delta	R2 / N
5yr TERM Exposure	-0.31	-30.91	0.94
	(25.95)	(185.88)	2,100

Notes: This table summarizes the interest rate exposures of stable NIM UST portfolio strategies. The top panel presents the results from a monthly time series regression of the aggregate stable NIM UST portfolio equity return, in excess of the one-month US T-bill rate on the market excess return of a 5-year constant maturity portfolio, 5-year TERM factor, controlling for the market excess return provided by Kenneth French's website. The bottom panel shows the result of a cross-sectional regression of portfolio-level TERM exposures on the portfolio-level net delta. The portfolio-level TERM exposure is calculated as a time series regression of the portfolio-level equity excess return on the TERM factor. The portfolio-level net delta is calculated as the average value change of the portfolio in response to a 1% shift of the entire yield curve per portfolio-level market equity value.

Table 5: Cross-Sectional Regressions explaining Imperfect Deposit Rate Pass-Through

Transaction Deposits	Constant	HHI	log Assets	log Emp.	3m-1y	1y-3y	3y+	TrShr	avgR2
1	0.763	0.129							0.018
	(211.04)	(8.77)							4055
2	1.166		-0.026	-0.003				-0.043	0.111
	(69.00)		(-16.85)	(-2.79)				(-3.14)	4055
3	1.125	0.078	-0.027	0.000				-0.04	0.115
	(58.68)	(4.43)	(-17.42)	(0.30)				(-2.93)	4055
Time Deposits	**Constant**	**HHI**	**log Assets**	**log Emp.**	**3m-1y**	**1y-3y**	**3y+**	**TrShr**	**avgR2**
1	0.476	0.048							0.002
	(129.75)	(3.24)							4056
2	0.674		-0.005	-0.01				-0.03	0.041
	(38.15)		(-2.86)	(-9.00)				(-2.12)	4056
3	0.289				0.053	0.652	0.582		0.42
	(20.07)				(2.18)	(30.80)	(16.03)		4056
4	0.547		-0.015	-0.006	-0.035	0.629	0.572	0.069	0.471
	(24.43)		(-12.28)	(-7.18)	(-1.44)	(30.53)	(16.36)	(6.43)	4056
5	0.55	-0.006	-0.015	-0.006	-0.035	0.627	0.573	0.069	0.471
	(22.96)	(-0.43)	(-11.99)	(-6.06)	(-1.45)	(29.98)	(16.36)	(6.38)	4056
Deposits	**Constant**	**HHI**	**log Assets**	**log Empl.**	**3m-1y**	**1y-3y**	**3y+**	**TrShr**	**avgR2**
1	0.615	0.06							0.006
	(203.48)	(4.88)							4056
2	0.763		-0.021	-0.003				0.274	0.197
	(57.25)		(-17.58)	(-3.92)				(25.59)	4056
3	0.71				-0.548	0.206	0.221		0.167
	(169.65)				(-26.63)	(5.00)	(3.14)		4056
4	0.615		-0.024	-0.002	0.007	0.486	0.783	0.455	0.308
	(16.64)		(-21.31)	(-2.73)	(0.13)	(10.34)	(10.51)	(12.38)	4056
5	0.576	0.058	-0.025	0.000	0.012	0.520	0.756	0.466	0.312
	(15.21)	(4.50)	(-21.83)	(0.42)	(0.23)	(10.95)	(10.13)	(12.66)	4056

Notes: This table presents cross-sectional regressions explaining deposit spread betas, a measure of the imperfect pass-through of market rates on deposit rates. The deposit spread beta is calculated as the OLS regression coefficient of a bank's quarterly change in its deposit rate on the quarterly change in the Federal funds rate. The dependent variable in the top panel is the bank-level transaction deposit spread beta, in the middle panel the bank-level time deposit spread beta, and in the bottom panel the total deposit spread beta. The independent variables are HHI as a measure of a bank's market concentration, the average log size of bank assets, and the average log number of employment (in 1000s) of the counties the bank has deposits, weighted by the amount the bank's deposits in each county. The time deposit and total deposit spread beta regressions include the maturity distribution of time deposits. The time deposit maturity information is the share of time deposits maturing in less than 3 months (omitted), between 3 months and 1 year, between 1 year and 3 years, and more than 3 years. The deposit spread beta regression includes the transaction deposit share. Bank deposit rates and maturity data are from commercial bank reports (FFIEC 031 and 041 filings) from 2000 Q1 to 2019 Q1. HHI and deposits at the bank-county level are calculated based on branch-level data provided by the FDIC "Branch Office Deposits". County level employment statistics are from the Bureau of Labor Statistics. T-stats are in parentheses.

Table 6: Benefits and Costs of Market Power

Int	HHI	Trs. Spread β	Res. Spread β	log Asset	log Emp.	3m-1y	1y-3y	3y+	TrD/D	Adj R2
Deposit Rate										
0.834										0.845
(6968.51)										72,594
1.054				0.040	-0.100	1.388	2.127	2.199	-1.199	0.928
(6.27)				(4.15)	(-1.72)	(5.26)	(6.15)	(6.50)	(-4.48)	72,594
1.358	-0.220			0.044	-0.216	1.364	2.064	2.218	-1.229	0.928
(7.04)	(-5.95)			(4.43)	(-3.39)	(5.20)	(5.97)	(6.66)	(-4.59)	72,594
2.174		-0.856		0.018	-0.120	1.340	1.909	2.201	-1.319	0.933
(5.43)		(-3.70)		(3.31)	(-2.12)	(5.09)	(5.07)	(6.63)	(-4.43)	72,594
1.167			-0.974	0.017	-0.120	1.658	2.284	2.469	-0.957	0.931
(6.10)			(-3.41)	(3.49)	(-2.07)	(6.57)	(7.15)	(8.57)	(-4.71)	72,594

Int	HHI	Trs. Spread β	Res. Spread β	log Asset	log Emp.	RE L/D	C&I L/D	TrD/D	Adj R2
Non-interest expense / Deposits									
3.504									0.005
(7199.42)									71,958
1.379				-0.136	1.085	0.638	1.463	1.058	0.032
(2.97)				(-3.89)	(5.33)	(2.57)	(3.64)	(3.08)	71,958
-1.060	1.931			-0.173	2.092	0.691	1.451	1.118	0.045
(-1.81)	(4.23)			(-6.03)	(9.22)	(2.88)	(3.68)	(3.47)	71,958
0.404		0.850		-0.118	1.069	0.697	1.711	1.123	0.035
(0.75)		(3.64)		(-3.36)	(5.25)	(2.86)	(4.33)	(3.21)	71,958
1.223			0.620	-0.124	1.080	0.667	1.617	1.030	0.033
(2.41)			(1.42)	(-4.05)	(5.36)	(2.60)	(3.73)	(3.11)	71,958

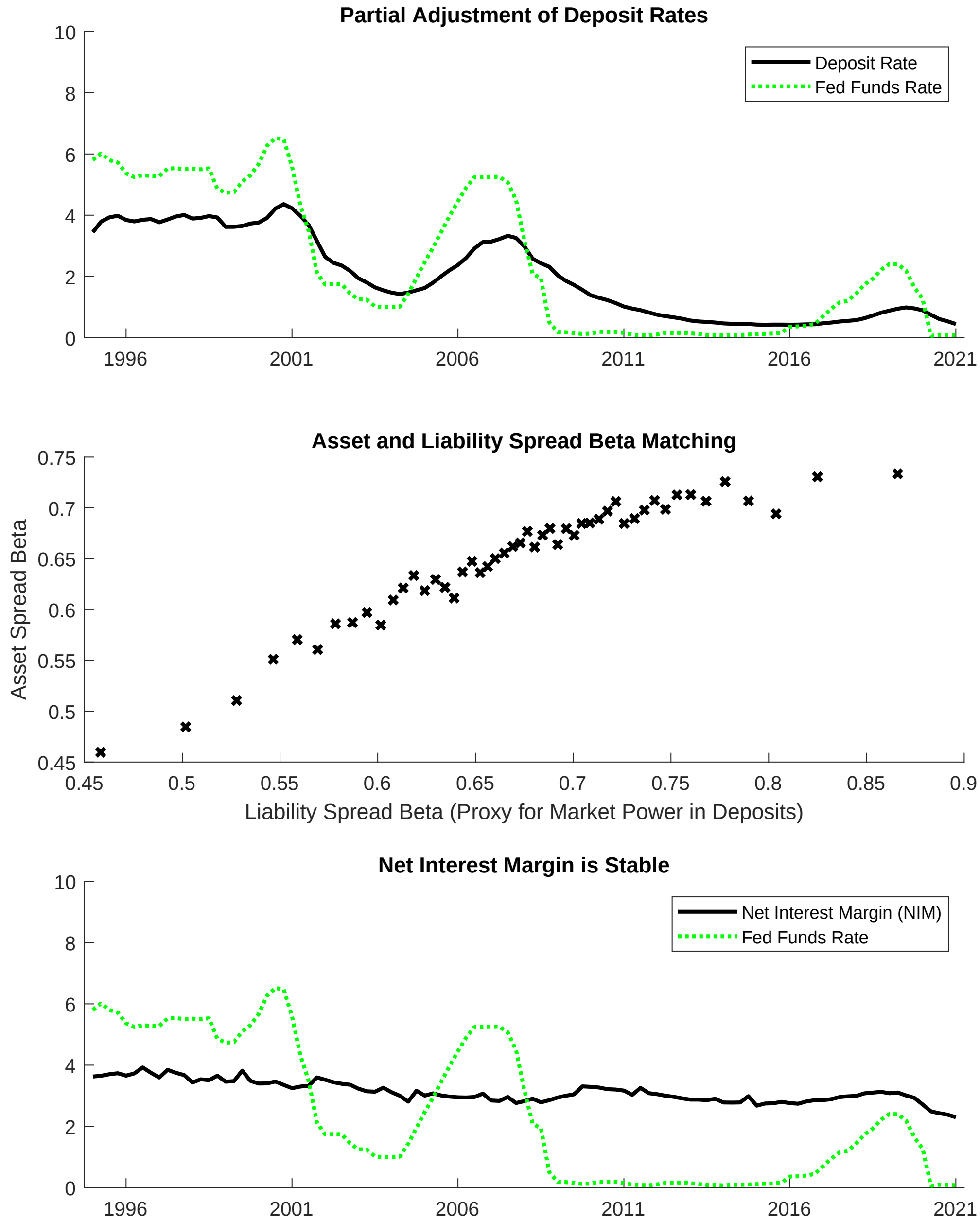
Notes: This table presents results from annual panel regressions explaining the annualized bank deposit rates (top panel) and annualized bank operating expenses (bottom panel). The independent variables include three measures of market power: HHI, the transaction deposit spread beta, and on the time deposit maturity distribution residualized total deposit spread beta. In addition, they include the average log size of bank assets and the average log number of employment (in 1000s) of the counties the bank has deposits, weighted by the amount the bank's deposits in each county. The deposit rate regression in the top panel include the transaction deposit share and the maturity distribution of time deposits measured as the shares maturing in less than 3 months (omitted), between 3 months and 1 year, between 1 year and 3 years, and more than 3 years. The dependent variable in the bottom panel is the annualized non interest expenses as a fraction of deposits. The additional independent variables are the shares of real estate loans, commercial and industrial loans, and transaction deposits in deposits. The annual sample covers the years from 2000 to 2019. Bank deposit rates and maturity data are from commercial bank reports (FFIEC 031 and 041 filings). HHI and county level bank deposits are calculated based on branch-level data provided by the FDIC "Branch Office Deposits". Annual county level employment statistics are from the Bureau of Labor Statistics. T-stats are in parentheses. T-stats are in parentheses.

Table 7: Characteristics of Deposit Market Concentration

	2000	**2009**	**2019**	**Average (2000 - 2019)**	**Normalized Average**
Bank Deposits ($MM) by County Deposit Market Concentration					
Bottom Third	2,921	4,103	6,432	4,525	4.8
Middle Third	621	2,030	3,515	2,181	2.3
Highest Third	242	871	1,723	935	1.0
Population (MM) by County Deposit Market Concentration					
Bottom Third	214	221	242	225	11.8
Middle Third	50	63	63	59	3.1
Highest Third	15	20	20	19	1.0
Employment (MM) by County Deposit Market Concentration					
Bottom Third	127	124	150	131	12.8
Middle Third	28	38	41	36	3.5
Highest Third	8	10	11	10	1.0
Personal Income (MM) by County Deposit Market Concentration					
Bottom Third	6,850	8,811	13,863	9,682	14.0
Middle Third	1,328	2,407	3,551	2,404	3.5
Highest Third	359	672	895	693	1.0
Avg Spread Beta (x100) by County Deposit Market Concentration					
Bottom Third	75	75	75	75	1.0
Middle Third	75	74	75	75	1.0
Highest Third	75	75	75	75	1.0
Avg HHI (0-100) by County Deposit Market Concentration					
Bottom Third	16	15	16	15	0.3
Middle Third	29	27	28	27	0.5
Highest Third	63	59	60	59	1.0

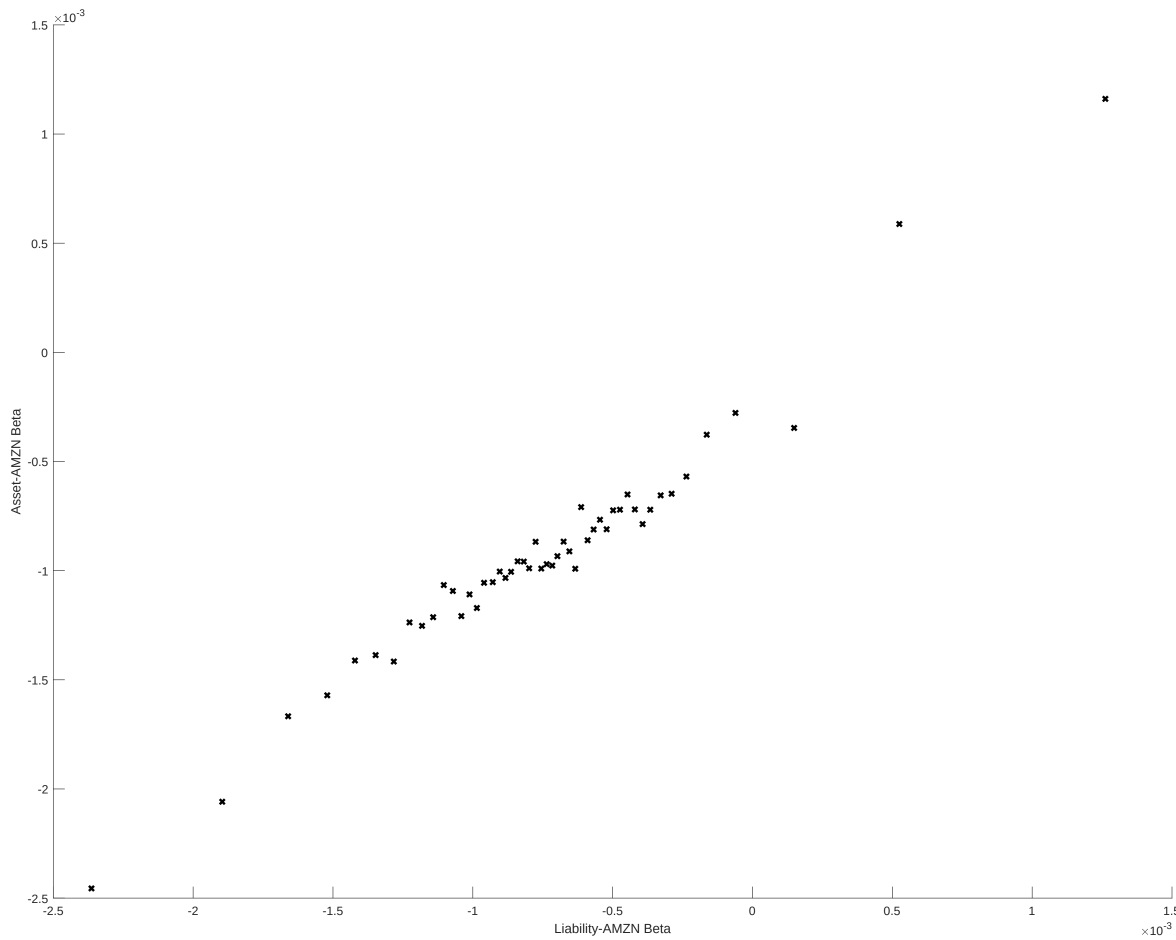
Notes: This table present aggregate statistics based on county deposit market concentration as measured by terciles of the county level HHI distribution. The annual sample covers the years from 2000 to 2019. Bank deposit rates and maturity data are from commercial bank reports (FFIEC 031 and 041 filings). HHI and county level bank deposits are calculated based on branch-level data provided by the FDIC "Branch Office Deposits". Annual county level economic statistics are from the Bureau of Labor Statistics.

Figure 1: Summary of the Literature



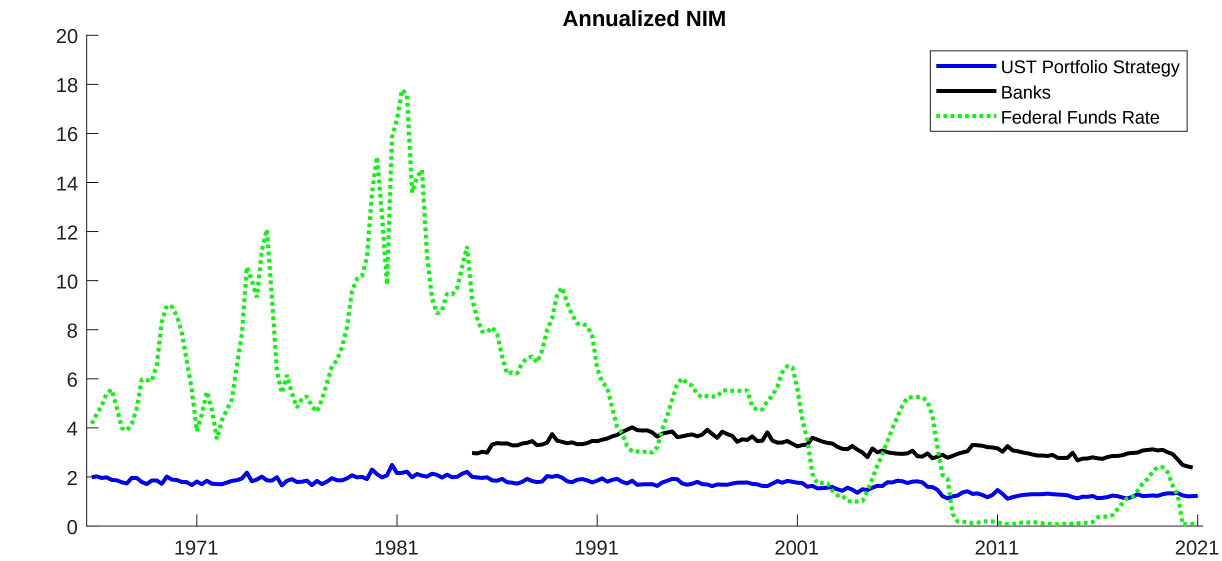
Notes: This figure displays three empirical properties of US commercial bank interest rates. The top panel plots the aggregate interest rate paid on deposits, calculated as the ratio of sums across banks of interest expense on deposits and deposits. The interest rate is annualized by multiplying the quarterly rate by 4. The Federal funds rate is displayed for comparison. The middle panel displays a scatter plot of asset spread betas against liability spread betas. Spread betas are calculated via regressions of changes in the Federal funds rate (FFR) minus the interest income (expense) rate on changes in the FFR and four lags of the changes in FFR. We form 50 equally sized bins based on the distribution of liability spread betas and calculate the average spread beta within each bin. The bottom panel displays the annualized aggregate net interest margin (NIM) and the Federal funds rate. Aggregate quarterly NIM is calculated as the ratio of the sum of interest income minus interest expense divided by the sum of book value of assets.

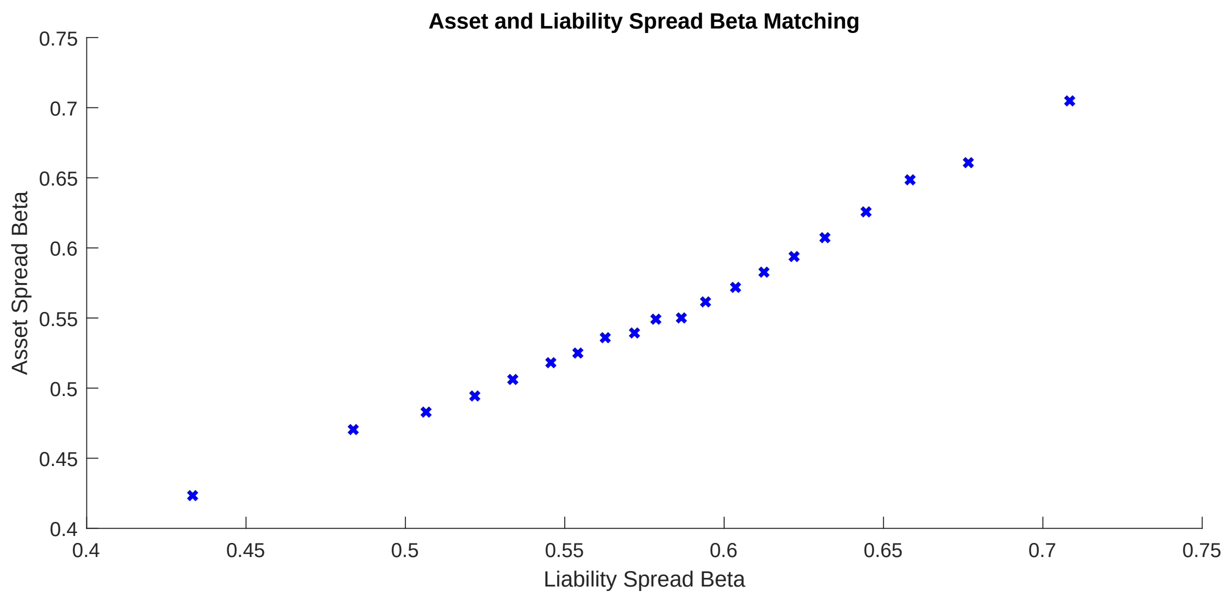
Figure 2: Matching Amazon Stock Return Betas



Notes: This figure presents a scatter plot of asset betas against liability betas calculated via regressions of a bank's quarterly income (expense) rate on changes in the quarterly stock return of Amazon up to four lags. We form 50 equally sized bins based on the distribution of liability Amazon betas and calculate the average asset beta within each bin. Amazon stock return data is from CRSP. The sample is from 1997 Q1 to 2019 Q4.

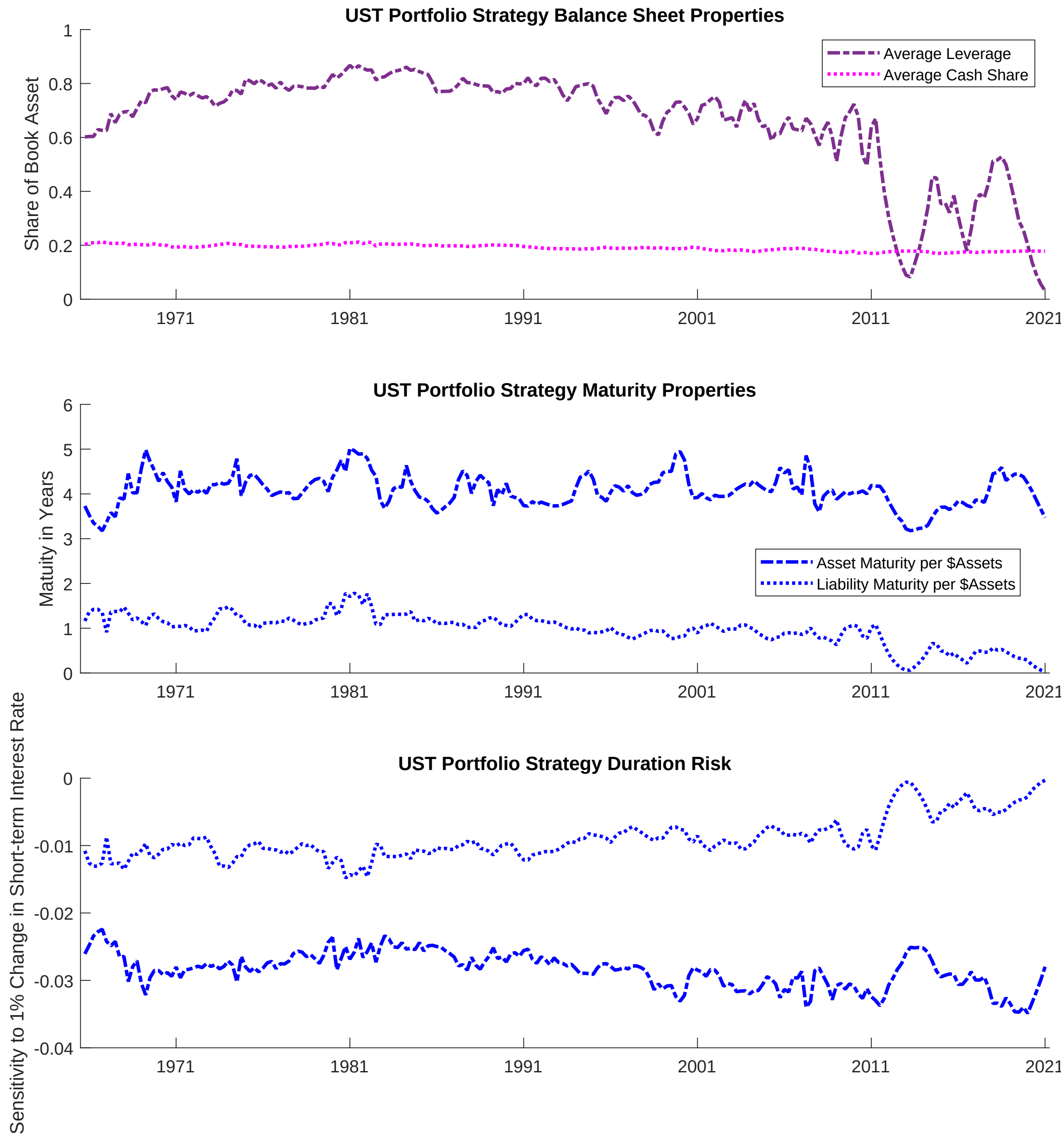
Figure 3: Stable NIM UST Portfolios and Matching Betas





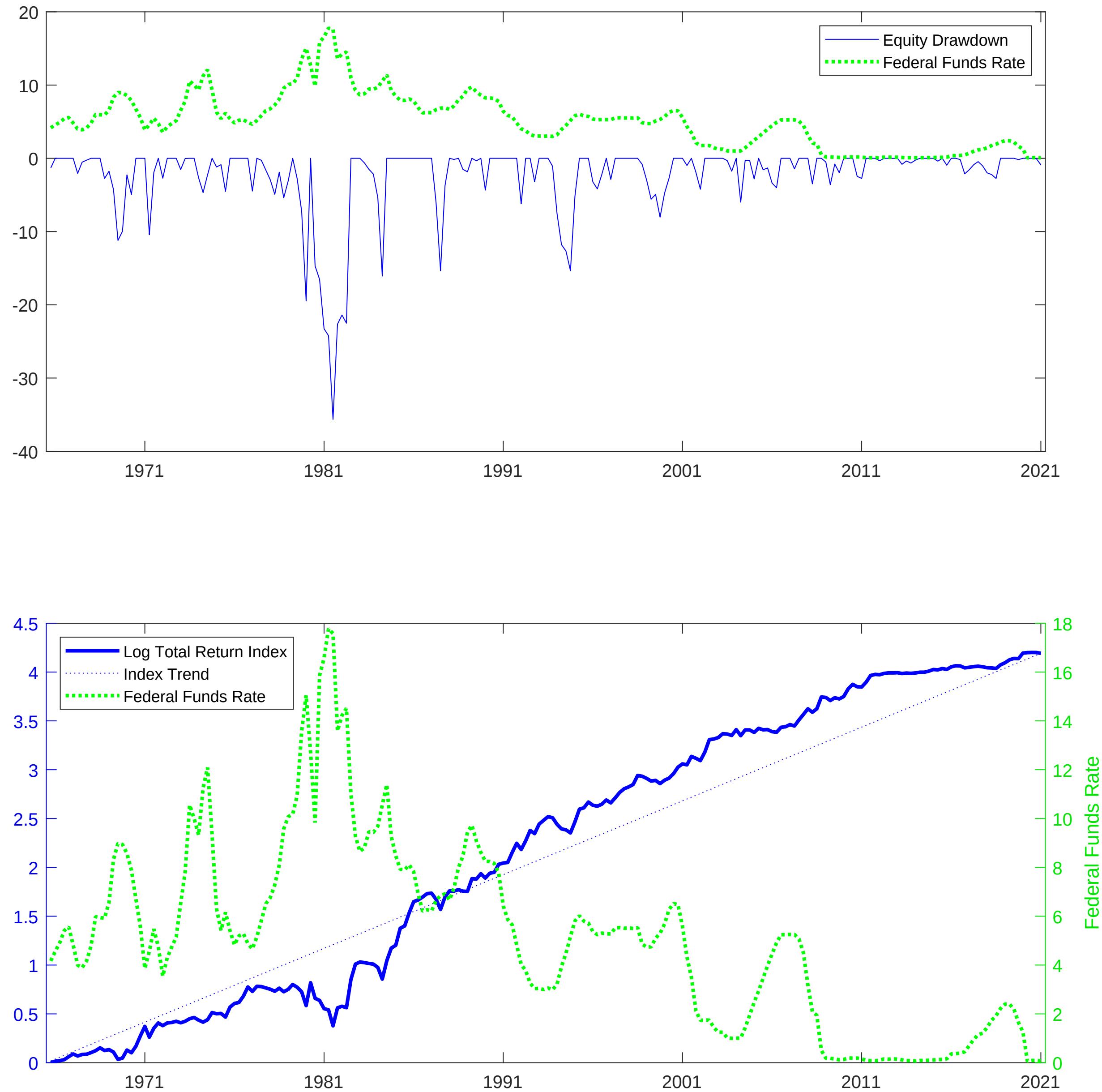
Notes: This figure displays two properties of US Treasury (UST) portfolios that each target stable net interest margins. The top panel plots the annualized aggregate net interest margin (NIM) of a cross-section of stable NIM UST portfolio strategies and the Federal funds rate. Aggregate quarterly NIM is calculated as the ratio of the sum of interest income minus interest expense divided by the sum of book value of assets. The Federal funds rate is displayed for comparison. The bottom panel displays a scatter plot of associated asset spread betas against liability spread betas. Spread betas are calculated via regressions of changes in the Federal funds rate (FFR) minus the UST portfolio interest income (expense) rate on changes in the FFR and four lags of the changes in FFR. We form 20 equally sized bins based on the distribution of liability spread betas and calculate the average spread beta within each bin.

Figure 4: Average Properties of Stable NIM UST Portfolio Strategies



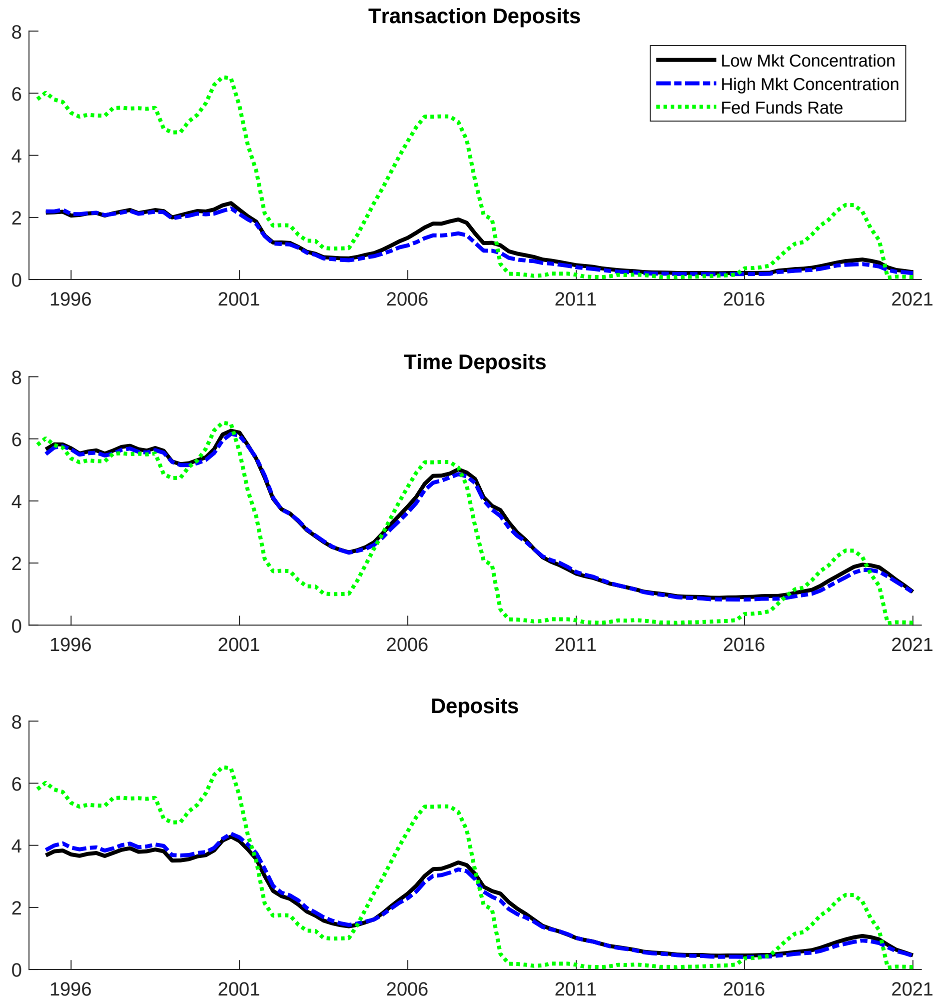
Notes: This figure displays average properties of US Treasury (UST) portfolios that all target stable net interest margins. The top panel plots the time series of average portfolio leverage and cash share. Average leverage is calculated as the average ratio of each UST portfolio's book value of debt divided by the book value of assets. Average cash share is calculated as the average ratio of each UST portfolio's cash holding divided by the book value of assets. The middle panel displays the average maturity in years of assets and liabilities of the stable NIM UST portfolios. The bottom displays the average duration risk of the assets and the liabilities of the stable NIM portfolio strategies. Duration risk is calculated as the average change in the value of assets and liabilities to a 1% change in the short-term market interest rate.

Figure 5: Portfolio Risk



Notes: This figure visualizes the risk embedded in the stable NIM UST portfolios. The top panel presents the equity drawdown calculated as the percentage between a market value peak and the subsequent trough of the aggregate stable NIM UST portfolios. The aggregate stable NIM UST portfolio is simply the sum of all individual portfolios. The Federal funds rate is plotted in green as an annualized percentage rate. The bottom panel presents the log total return index of the aggregate stable NIM UST portfolio along with its trend (left axis). The federal funds rate is plotted in green as an annualized percentage rate (right axis).

Figure 6: Imperfect Pass-Through in Deposits and Market Power



Notes: The figure plots the time series of annualized quarterly transaction deposit rates (top panel), time deposit rates (middle panel), and total deposits (bottom panel) for US commercial banks grouped into portfolios based on their deposit market power as measured by the top (high) and bottom (low) tercile Herfindahl-Hirschman Index (HHI) together with the Federal funds rate (green line). Bank interest rate data is from commercial bank reports (FFIEC 031 and 041 filings) from 1994 Q1 to 2020 Q1. HHI is calculated based on branch-level data provided by the FDIC "Branch Office Deposits".

Appendix A Derivation of empirical duration

In an asset pricing context, the interest rate risk is typically defined as a portfolio value sensitivity to changes in interest rates. With a simple bond valuation model that maps coupons, remaining maturity, and the current term structure of market yields into values, duration-style measures can be calculated for individual holdings and aggregated into a portfolio duration estimate. It is also common to estimate interest rate risk exposure via regressions of portfolio excess returns on the excess returns on a constant maturity bond portfolio.

In this section, we show how analytical duration measures are related to regression based duration measures, and we will contrast these two with the income beta measure defined in the earlier section. Consider the same portfolio strategy defined above, holding equal amounts of J-maturity bonds entered into evenly over the past J-months. Each of these holdings has a portfolio weight, w_{t-1}^{j}, and a market value, V_t^j, such that the portfolio value is, $V_t^p = \sum_{j=1}^{J} w_{t-1}^{j} V_t^j$. We define duration as the sensitivity of V_t^j to a parallel shift in the current yield curve, $d_t^j \equiv \frac{\delta V_t^j}{\delta y_t}$. It is well-known that individual bond sensitivities tend to be increasing in maturity. The portfolio value sensitivity to a parallel shift in the yield curve can be calculated as the weighted sum of the individual d_t^j, i.e., $d_t^p = \sum_{j=1}^{J} w^j d_t^j$.

To see the relationship between this duration measure and an empirical duration measure based on regressions, define the periodic return on the portfolio,

$$R_{t+1}^{p} = \frac{c_{t+1}^{p} + \Delta V_{t+1}^{p}}{V_t^p} = \sum_{j=1}^{J} w_t^j R_{t+1}^{j}, \tag{14}$$

where c_{t+1}^{p} is the sum of coupons collected from all J bonds in the portfolio over the period, and R_{t+1}^{j} denotes the return of bond holding j. The periodic portfolio return is related to a change in the yield curve only through changes in market values, $\frac{\delta R_{t+1}^{p}}{\delta y_{t+1}} = \frac{1}{V_t^p} \frac{\delta V_{t+1}^{p}}{\delta y_{t+1}} \equiv D_t^p$, since the coupons are fixed. D_t^p denotes the sensitivity of the portfolio return with a change in the yield curve. It is useful to note that the portfolio value sensitivity to interest rate changes makes use of all of the holdings.

The empirical duration measure is the coefficient from a regression of portfolio excess returns on the periodic return on a constant H-maturity portfolio, $R^H_{t+1} = \frac{c^H_{t+1}+\Delta V^H_{t+1}}{V^H_t}$. If H = 5yrs, then this is the periodic return on a 5yr bond. Before we derive the relation between the empirical duration measure and d^p_t, note that we can write the periodic return on any bond x as

$$\begin{aligned}
R^x_{t+1} =& \frac{1}{V^x_t}\left(c^x_{t+1}+\Delta V^H_{t+1}\right),\\
=& \frac{1}{V^x_t}\left(c^x_{t+1}+d^x_t\Delta y_{t+1}\right),\\
=& \frac{1}{V^x_t}\left(\tilde{c}^x_{t+1}+\tilde{d}^x_t\Delta y_{t+1}+\tilde{e}^x_{t+1}\right),
\end{aligned} \tag{15}$$

where the second equality used the definition for duration d^x_t and the third equality just follows from allowing for the possibility of shocks e^x_{t+1} to the return that are uncorrelated with shocks to y_{t+1}. In what follows, we will use Eq. (15) to define the empirical duration. To this end, we abuse notation and redefine $\tilde{z}^x = z^x V^x_t$. Then, we calculate an excess return on the bond x by subtracting the riskfree rate from the bond return, so

$$XR^x_{t+1} = R^x_{t+1} - R^F_{t+1} = exc^x_{t+1} + d^x_t\Delta y_{t+1} + e^x_{t+1},$$

where $exc^x_{t+1} = c^x_{t+1} - R^F_{t+1}$. To abstract from potential measurement issues or other forces than duration risk that affect XR^x_{t+1}, we study the regression coefficient of the fitted periodic excess return of bond j on the fitted constant H-maturity portfolio excess return. We can express this regression coefficient as

$$\begin{aligned}
\frac{\mathrm{COV}(XR^j_{t+1}, XR^H_{t+1})}{\mathrm{VAR}(XR^H_{t+1})} =& \frac{\mathrm{COV}(exc^j_{t+1}+d^j_t\Delta y_{t+1}, exc^H_{t+1}+d^H_t\Delta y_{t+1})}{\mathrm{VAR}(exc^H_{t+1}+d^H_t\Delta y_{t+1})}\\
=& \frac{d^j d^H \mathrm{VAR}(\Delta y_{t+1})}{(d^H)^2\mathrm{VAR}(\Delta y_{t+1})}\\
=& \frac{d^j}{d^H},
\end{aligned} \tag{16}$$

where the second line follows from the first because removing the risk-free rate from the cash income means removing the only time varying element from c^x_{t+1} from the perspective of t. All other cash flows are known ex-ante and uncorrelated with Δy_{t+1}. Note, that we dropped time scripts on d^x_t to denote time series averages. Eq. (16) says that under our assumptions the empirical duration regression coefficient is simply the ratio of bond j's duration to the duration of the constant H-maturity portfolio.[20] As a result, the portfolio regression beta is simply the weighted average of the relative durations, $\sum_j^J w^j_t \frac{d^j}{d^H}$.

Comparing the interest rate risk measures implied by duration or term regressions coefficient (Eq. (16)) with the income beta (Eq. (8)), we can immediately see how fundamentally different these two measures are. While the income beta of Eq. (8) measures the covariance of the current market rate with a single coupon weighted by the longest maturity of the underlying portfolio, the term regression coefficient implied by Eq. (16), $\sum_j^J w^j_t \frac{d^j}{d^H}$, measures the weighted average exposure of the market returns of all components of the bond portfolio. These two equations also clarify that income betas will never recover the duration exposure of a portfolio, unless the portfolio consists only of floating rate bonds in which case the duration is zero. Adding more lags or more data to the regression behind (8) does not resolve the fundamental issue that changes in fixed interest income exposures are a different notion of interest rate risk from the standard asset repricing risk notion – income sensitivity vs. value sensitivity.

Appendix B Properties of Interest Rate Risk Measure

We now explore the properties of interest rate risk measures in the context of UST bond portfolios empirically. To design the UST bond portfolios in accordance with the available maturity information on bank deposits and asset portfolios, we modify our UST bond portfolios as follows. For a portfolio that buys each period bonds of maturity H, rather than holding the bond to maturity we sell any bonds in the portfolio that reached $h < H$. The income return includes the sales proceeds

[20] With unfitted excess returns in the regression, the regression coefficient would include an additional term related to the covariance of the e^j's with the e^H's.

from bonds with maturity h.

Table 8 summarizes the properties of UST bond portfolio interest rate risk exposure measures using monthly data from 1996 to 2018. We consider two dimensions of the bond maturity composition – pure maturity and the effect of an increasing cash share while holding the remaining share's maturity constant. Panel A summarizes results for maturity and Panel B summarizes results relating to varying cash share. To explore the variation in interest rate risk exposure inferences from different return measures, we use three return measures. The first return measure is the market return, which is calculated as the change in the value of the portfolio from period $t-1$ to t. The second measure relies on interest income returns, calculated as the income on the portfolio divided by the beginning of period par (or book) value of portfolio. To make our results comparable to the primary measure used in the literature, the third measure is based on interest income spreads, with the spread calculated as the difference between the Federal funds rate (FFR) and the interest income return as defined above.

A model-based measure of duration risk (denoted as Delta) measures the change in the value of a bond portfolio with an increase in interest rates. It is calculated by repricing bonds after a hypothetical 1% increase in all UST bond yields and then determining the percentage change in value. Panel A in Table 1 clearly shows that duration risk (Delta) is increasing in the maturity of the portfolio. The value of portfolios with a maturity or repricing date of at least 15+ years falls by 12%, while the value of portfolios with a maturity between three months and 12 months falls by only 1% with an increase in the interest rate. Consistent with this conceptual relation, when we regress the various UST portfolio market returns in excess of the one-month UST yield on the excess returns of a 5-year TERM factor, calculated as the excess return of the 5-year constant maturity UST bond return series from WRDS, we find that the coefficient on the 5-year TERM factor increases with the maturity of the portfolio, consistent with a strong relation between maturity and TERM risk exposure.

A reliable prediction from standard asset pricing theory is that higher risk exposures are associated with a higher risk premium. Consistent with this prediction, UST portfolios with a longer maturity earn a higher mean returns than UST portfolios of shorter maturity. The mean market return of a UST portfolio with a maturity of less than three months is 2.43% per annum, while a portfolio with a maturity of more than 15 years has earned 7.07% on average over our sample period. As Fama (2006) emphasizes, TERM exposure has been a highly attractive risk premium since 1981.

Interest rate sensitivity measures based on interest income returns suggest very different properties of bond portfolio interest rate risk. Consistent with earning a higher risk premium, longer maturity UST portfolios earn a higher mean income returns than shorter maturity bond portfolios. Table 1 also shows that the volatility of interest income returns on UST portfolios decreases with maturity. This counterfactually suggests a lower interest rate risk exposure of portfolios with longer maturity. When we calculate interest rate risk exposures based on the change in income returns regressed on the change in the Federal funds rate and four quarterly lags, the coefficients decline with maturity of the UST portfolio. In addition, for portfolios with a maturity of more than five-years, the explanatory power declines to zero.

The reason for this pattern is that the fixed income (i.e., the coupon payments) on these portfolios sums coupons of bonds issued at different points in time. The longer the maturity, the more coupons payments from different points in time are included in the sum and the resulting income time series is smoother than from a shorter maturity portfolio. Figure 1, which displays the income return on different bond portfolios with various maturities, shows this clearly. The longer the maturity of the portfolio the smoother the income return. This explains why a regression of a long-maturity bond portfolio income return on changes in the Federal funds rate will deliver a small coefficient and little explanatory power. Figure 1 also illustrates that the mean income return tends to be increasing in portfolio maturity, which will provide the basis for some future analyses.

Another version of the previous regression is based on the interest income spread, i.e., the difference in the Federal funds rate and the income return. This version is more commonly used in the recent literature (e.g., see (Drechsler, Savov, and Schnabl, 2021))) and measures the partial rate adjustments. The coefficients on the change in the Federal funds are equal to 1 minus the coefficient on the equivalent regression coefficient in the income return regression discussed above. As a result, the coefficients, also commonly called spread betas, are now increasing with the maturity and appear to have high explanatory power. Note though that for long maturity UST portfolios, the variation of the dependent variable is almost exclusively coming from the Federal funds rate, which also shows up on the right-hand side of the regression as the explanatory variable, leading to a high R2. Higher income spread coefficients (referred to as spread betas by (Drechsler, Savov, and Schnabl, 2017, 2021)) are interpreted as these portfolios having higher partial rate adjustment in response to changes in market rates. It is important to note that the artificial smoothing of interest income returns caused by the increased maturity does not translate into lower duration risk, and of course, does not reflect a managerial action to "sluggishly" adjust rates in response to changes in market rates. To highlight the role of the cash share ω_t, we vary the cash share from 0% to 100% for a portfolio with its remaining share invested in UST bonds of maturities from three years to five years, results in Panel B of Table 8. Market returns and duration risk exposure, as measured by both delta and the 5-year TERM coefficient, are declining as the cash share increases. The average interest income return is also declining with the cash share, while its volatility is increasing. Importantly, in regressions of the income return the coefficient on the change in the Federal funds rate is increasing with the cash share, consistent with the premise that this coefficient will be strongly related to the the share of (within a year with lags) zero-duration assets in the portfolio. Equivalently, the income spread regressions have coefficients (i.e. spread betas) that are decreasing in the cash share, which would commonly be interpreted as a decrease in the sluggishness in rate adjustment to changes in market rates, despite these clearly being passive portfolio strategies with no such intent.

These results demonstrate that a wide range of duration risks can be created across portfolios that have different combinations of maturity and cash shares and that inferences about these portfolio duration risk exposures will be difficult to identify with income or income spread based measures.

To illustrate how poorly identified duration risk is with income return based measures, we consider six portfolios strategies that seek to increase their portfolio duration risk exposure, while maintaining a target spread beta of 0.5, by investing in constant maturity UST bonds and cash. Table 2 reports the results from this exercise. Table 2 shows that estimated spread betas are essentially constant at their specified target of 0.5, while duration risk as measured by the loading on the 5-year Term factor more than doubles from the lowest to the highest of the considered strategies. To construct this table, we calculate bond portfolios that buy bonds at maturity H and sell them when the remaining maturity goes to h. Moving down the rows of Table 2, both the duration risk as measured by the 5-year TERM factor as well as the cash share of the portfolio increases. Consistent with the portfolio duration risk exposure increasing across these portfolios, the mean returns are also monotonically increasing across these portfolios. Yet the spread beta coefficient remains constant, demonstrating that spread betas are not informative about the extent of duration risk exposure.

To summarize, our UST bond analysis has shown that stable income streams generated by fixed income portfolios do not easily reveal their duration risk exposure with methods that provide the basis for the conclusion that banks do not bear interest rate risk. Thus, these conclusions seem premature. Empirical measures of the in the adjustment of income returns to changes in market rates are strongly related to the maturity composition of passive UST bond portfolios.

Table 8: Properties of UST Portfolio IRE Measures by Maturity

	0-3m	3m-12m	1y-3y	3y-5y	5y-15y	15y+
			Market Returns			
Mean	2.32	2.74	3.70	5.92	6.85	8.50
Std	1.09	1.24	2.20	5.91	8.06	11.20
Delta	0.00	-0.01	-0.02	-0.06	-0.09	-0.12
5y-TERM Coef	0.01	0.07	0.35	1.20	1.58	2.03
5y-TERM t-stat	(3.41)	(8.67)	(18.18)	(26.39)	(20.19)	(14.60)
5y-TERM R2	0.10	0.42	0.76	0.87	0.80	0.68
			Income Rates			
Mean	2.33	2.60	3.13	4.51	5.04	4.83
Std	1.08	1.09	1.01	0.82	0.80	0.80
chgFFR Coef	0.93	0.81	0.46	0.03	0.00	0.01
chgFFR t-stat	(29.30)	(26.89)	(14.19)	(3.43)	(0.36)	(1.02)
chgFFR R2	0.92	0.90	0.68	0.10	-0.01	0.02
			Interest Rate Spreads (FFR - Inc Rate)			
Mean	0.10	-0.18	-0.71	-2.09	-2.62	-2.41
Std	0.09	0.19	0.49	0.73	0.74	0.74
chgSpread Coef	0.07	0.19	0.54	0.97	1.00	0.99
chgSpread tstat	(2.23)	(6.29)	(16.62)	(100.87)	(172.59)	(75.79)
chgSpread R2	0.48	0.82	0.91	0.99	1.00	0.99

Notes: This table reports summary statistics for various portfolios comprised of US Treasury (UST) bonds. The constant maturity UST portfolio invests each month in a $H-$period US Treasury bond and liquidates the bond when the maturity has reached h-periods until maturity, denoted in the headings in the format $(h-H)$. UST portfolio market returns are calculated by repricing all of the bonds in the portfolio each quarter based on the current UST yield curve and the bond coupon and maturity terms. UST portfolio interest income returns are calculated based on hold-to-maturity accounting whereby the periodic portfolio value for each holding is measured at historical cost and periodic cash flows are generated by the interest payments and eventual sale proceeds or repayment of the holdings. Delta is calculated by repricing bonds after a hypothetical 1% increase in all UST bond yields and then determining the percentage change in value. Market returns in excess of the one-month UST yield are regressed on the excess returns of a 5-year TERM factor, calculated from the 5-year constant maturity UST bond return series from WRDS. Interest income return regressions have the change in interest income return as the dependent variable and have the change in the Federal funds rate (FFR) and four quarterly lags as independent variables. Interest income spreads are measured as the FFR minus the interest income return. Changes in interest income spreads are regressed on the change in FFR with four lags.

Table 9: Properties of UST Portfolio IRE Measures by Cash Share

	0-3m	3m-12m	1y-3y	3y-5y	5y-15y	15y+
			Market Returns			
Mean	2.32	2.74	3.70	5.92	6.85	8.50
Std	1.09	1.24	2.20	5.91	8.06	11.20
Delta	0.00	-0.01	-0.02	-0.06	-0.09	-0.12
5y-TERM Coef	0.01	0.07	0.35	1.20	1.58	2.03
5y-TERM t-stat	(3.41)	(8.67)	(18.18)	(26.39)	(20.19)	(14.60)
5y-TERM R2	0.10	0.42	0.76	0.87	0.80	0.68
			Income Rates			
Mean	2.33	2.60	3.13	4.51	5.04	4.83
Std	1.08	1.09	1.01	0.82	0.80	0.80
chgFFR Coef	0.93	0.81	0.46	0.03	0.00	0.01
chgFFR t-stat	(29.30)	(26.89)	(14.19)	(3.43)	(0.36)	(1.02)
chgFFR R2	0.92	0.90	0.68	0.10	-0.01	0.02
			Interest Rate Spreads (FFR - Inc Rate)			
Mean	0.10	-0.18	-0.71	-2.09	-2.62	-2.41
Std	0.09	0.19	0.49	0.73	0.74	0.74
chgSpread Coef	0.07	0.19	0.54	0.97	1.00	0.99
chgSpread tstat	(2.23)	(6.29)	(16.62)	(100.87)	(172.59)	(75.79)
chgSpread R2	0.48	0.82	0.91	0.99	1.00	0.99

Notes: This table reports summary statistics for various portfolios comprised of US Treasury (UST) bonds. The constant maturity UST portfolio invests each month a fraction ω in cash denoted in the headings, and $1-\omega$ into a 5-year US Treasury bond and liquidates the bond when the maturity has reached 3-years until maturity. UST portfolio market returns are calculated by repricing all of the bonds in the portfolio each quarter based on the current UST yield curve and the bond coupon and maturity terms. UST portfolio interest income returns are calculated based on hold-to-maturity accounting whereby the periodic portfolio value for each holding is measured at historical cost and periodic cash flows are generated by the interest payments and eventual sale proceeds or repayment of the holdings. Delta is calculated by repricing bonds after a hypothetical 1% increase in all UST bond yields and then determining the percentage change in value. Market returns in excess of the one-month UST yield are regressed on the excess returns of a 5-year TERM factor, calculated from the 5-year constant maturity UST bond return series from WRDS. Interest income return regressions have the change in interest income return as the dependent variable and have the change in the Federal funds rate (FFR) and four quarterly lags as independent variables. Interest income spreads are measured as the FFR minus the interest income return. Changes in interest income spreads are regressed on the change in FFR with four lags.