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Banks' exposure to interest rate risk and the transmission of monetary policy

Matthieu Gomez[a], Augustin Landier[b], David Sraer[c,*], David Thesmar[d]

[a] Columbia University, United States
[b] HEC, France
[c] UC Berkeley, NBER and CEPR, United States
[d] MIT – Sloan and CEPR, United States

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ABSTRACT

The cash-flow exposure of banks to interest rate risk, or *income gap*, is a significant determinant of the transmission of monetary policy to bank lending and real activity. When the Fed Funds rate rises, banks with a larger income gap generate stronger earnings and contract their lending by less than other banks. This finding is robust to controlling for factors known to affect the transmission of monetary policy to bank lending. It also holds on loan-level data, even when we control for firm-specific credit demand. When monetary policy tightens, firms borrowing from banks with a larger income gap reduce their investment by less than other firms.

1. Introduction

Bank profits are exposed to fluctuations in interest rates. Banks that issue a large share of interest-bearing deposits will see their earnings shrink when interest rates rise. Similarly, banks that tend to lend predominantly through floating rates will experience an increase in net interest income when monetary policy tightens. The difference between the interest rate sensitivities of a banks' assets and liabilities defines its *income gap*. This gap is a standard measure of the overall exposure of a bank's income to changes in interest rates (Flannery, 1983). If the Modigliani–Miller proposition does not hold for banks, banking profits matters for lending activity (Kashyap and Stein, 1995), giving a central role to banks income gap in the transmission of monetary policy to the real economy (Brunnermeier and Koby, 2016). This paper shows that when the Fed Funds rate rises, banks with a higher income gap generate larger earnings and contract their lending by less than other banks. This, in turn, allows their corporate borrowers to invest more than other firms.

We first document the heterogeneity in the exposure of banks' cash-flows to fluctuations in interest rate risk. Using US Bank Holding Company (BHC) data, available quarterly from 1986 to 2013, we measure a bank's income gap as the difference between the dollar amount of a bank's assets that reprice or mature within a year and the dollar amount of liabilities that reprice or mature within a year, normalized by total assets. We find substantial variations in income gap across banks and time. Banks do not fully hedge this exposure to interest rates: instead, when the Fed Funds rate increases, banks with larger income gap generate significantly larger earnings. This finding echoes earlier work by Flannery and James (1984), who document the role of the income gap in explaining S&L stock returns around changes in interest rates. It is also consistent

* Corresponding author.
E-mail addresses: mg3901@columbia.edu (M. Gomez), landier@hec.fr (A. Landier), sraer@berkeley.edu (D. Sraer), thesmar@mit.edu (D. Thesmar).

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with Begeneau et al. (2012), who show that for the four largest US banks, net derivative positions tend to amplify, not offset, balance sheet exposure to interest rate risk. This result also accords with English et al. (2018), who find that unexpected increases in interest rates cause bank share prices to drop, especially for banks with a low maturity mismatch.

We then document the role of banks' income gap in the transmission of monetary policy. When the Fed Funds rate increases by 100 basis point (bps), a BHC at the 75th percentile of the income gap distribution contracts total lending over the following year by 0.25 percentage point (ppt) less than a bank at the 25th percentile. This estimate must be compared to average quarterly loan growth, which equals 1.7% in our sample. The estimated effect is thus large despite potential measurement error in our income gap measure. It is also robust to controlling for a number of factors known to affect the transmission of monetary policy to bank lending: size (e.g., Kashyap and Stein, 1995), leverage (e.g., Kishan and Opiela, 2000), local deposit concentration (e.g., Drechsler et al., 2017), the share of adjustable-rate mortgages in local mortgage issuance (e.g., Di Maggio et al., 2017), the share of liquid assets held on banks balance sheet (Kashyap and Stein, 2000) or the repricing/maturity gap of English et al. (2018). We confirm the robustness to the inclusion of these control variables in a covariate-balancing propensity score matching approach.

This bank-level analysis is cross-sectional. Despite the extensive set of controls, our inference may be biased due to omitted variables: banks with higher income gap may share common unobserved characteristics that also determine how their lending responds to changes in interest rates. While we do not have a valid instrument for banks' income gap, we provide several analyses to attenuate endogeneity concerns. First, we show, in a placebo analysis, that banks' *non-interest income*[1] is *not* more sensitive to interest rates fluctuations for banks with a larger income gap. Second, we exploit internal capital markets within BHCs in the spirit of Lamont (1997) or Campello (2002). We estimate a specification that directly controls for a BHC's commercial banks income gap. This regression allows us to rule out an interpretation whereby local customers with specific characteristics match with commercial banks with a higher income gap. Third, we present sample splits that are consistent with our preferred interpretation, a bank lending channel. We show that our estimate becomes larger for banks that are more likely to be financially constrained: smaller banks, younger banks, and banks with a lower payout ratio. It is also stronger for banks that report no hedging of interest rate risk, for which the income gap is likely more precisely measured.

Perhaps the most pressing endogeneity concern is the matching of BHCs and customers: similar findings could spuriously obtain if banks with a higher income gap tend to attract borrowers whose credit demand is more sensitive to changes in interest rates. We alleviate this concern using corporate loan-level data (Gan, 2007; Khwaja and Mian, 2008): we focus on firms borrowing from multiple banks and identify the effect of the credit supply shock induced by banks' income gap by controlling for credit demand through borrower-year fixed effects. This fixed-effect analysis provides results qualitatively similar to those obtained in the cross-section of banks. Additionally, the inclusion of borrower-year fixed effects does not significantly change the magnitude of the estimated impact of banks' income gap on credit supply. This result is suggestive of random matching between banks and firms (Khwaja and Mian, 2008). It is also reminiscent of earlier findings in the literature (Iyer et al., 2014; Jiménez et al., 2012).

Our analysis shows that the response of banks' credit supply to fluctuations in interest rates depends on their income gap. To analyze whether these variations in credit supply lead to real effects, we aggregate our loan-level dataset at the firm-year level. We find that when the Fed Funds rate rises, firms borrowing from banks with a larger income gap borrow and invest more than other firms.[2] This result is in line with the relationship banking literature: firms cannot easily find new sources of outside financing to substitute for their existing lenders.

Our results highlight a novel and potentially important channel of transmission of monetary policy. In the data, the average income gap is positive: an increase in the Fed Funds rate implies an increase in net interest income for the average US BHC. In this context, our cross-sectional estimates suggest that the banking sector's exposure to interest rate movements may dampen the effect of monetary policy on lending and real activity.

The recent economics literature has shown renewed interest in the study of interest rate risk. Our study is part of that agenda. Papers in the banking and corporate finance literatures focus on interest rate risk-management and its implication for profits and returns of both banks and non-financial firms (Begeneau et al., 2012; Chava and Purnanandam, 2007; Flannery and James, 1984; Purnanandam, 2007; Vickery, 2008). Our paper shifts the focus to bank lending and its effect on real activity. A related macro-finance literature highlights the redistributive implications of monetary policy when economic agents differ in their exposure to interest rate risk. Brunnermeier and Sannikov (2016) develop a theory of money where monetary policy serves as a redistributive tool across heterogeneous economic agents. Brunnermeier and Koby (2016) emphasize the existence of a "reversal interest rate" below which accommodative monetary policy becomes contractionary: in low-interest rate environment, banks net income *increase* with interest rates. Auclert (2016) builds a model where redistribution across agents with different exposure to interest rate risk is part of the transmission mechanism. We contribute to this literature by documenting the heterogeneity in banks' income exposure to interest rate risk and how it affects the transmission of monetary policy. Our paper also relates to Ippolito et al. (2018) who show that firms that borrow using floating

[1] Non-interest income consists in servicing fees, securitization fees, management fees, and trading revenue.

[2] As is standard in the credit supply literature (Khwaja and Mian, 2008), the firm-level analysis relies on a stronger identifying assumption than the loan-level analysis: since we can no longer control for borrower-year fixed effects in firm-level data, firms and banks need to be randomly matched. In support of this assumption, our loan-level analysis shows no significant difference between the OLS and the fixed-effect estimator. Besides, we find that *observable* borrower characteristics are not significantly correlated with their banks' income gap.

Table 1
Summary statistics: dependent and control cariables.

	Mean	sd	p25	p75	Count
Log of assets	14.909	1.385	13.919	15.551	38,117
Equity to assets ratio	0.088	0.032	0.070	0.099	38,117
Local % ARM	20.487	14.760	9.000	28.000	38,117
Local HHI	0.156	0.085	0.093	0.204	38,117
Fraction liquid assets	0.224	0.119	0.142	0.285	28,051
Repricing/maturity gap	3.975	2.120	2.439	5.202	20,597
Δ Interest	0.000	0.001	−0.000	0.000	37,610
Δ Non-interest	0.000	0.001	−0.000	0.000	36,256
Δ Earnings	0.000	0.001	−0.000	0.000	35,820
Δ Market value	0.004	0.022	−0.007	0.015	19,602
Δ log(C&I)	0.013	0.083	−0.027	0.053	37,568
Δ log(Total loans)	0.017	0.044	−0.006	0.036	38,117

Note: Summary statistics are based on the quarterly Consolidated Financial Statements (Files FR Y-9C) between 1986 and 2013 restricted to US bank holding companies with total consolidated assets of $1Bil or more in 2010 dollars. All variables are quarterly and are described in detail in Appendix A.

rates display a stronger sensitivity of their investment to monetary policy. We use the entire balance sheet exposure of US banks to interest rate risk and document how bank *lending* responds to change in the Fed Funds rate as a function of this exposure.

Our paper is also related to the literature on the bank lending channel and its effect on the transmission of monetary policy. The bank lending channel rests on a failure of the Modigliani–Miller proposition for banks. Consistent with this argument, monetary tightening has been shown to reduce lending by banks that are smaller (Kashyap and Stein, 1995), unrelated to a large banking group (Campello, 2002), hold less liquid assets (Kashyap and Stein, 2000), have higher leverage (Gambacorta and Mistrulli, 2004; Kishan and Opiela, 2000) or operate in more concentrated deposit markets (Drechsler et al., 2017). Our results hold even when we control for these factors that affect the transmission of monetary policy to bank lending. Consistent with the bank lending channel, our estimates are larger for banks that are more likely to be financially constrained. Finally, we follow the recent literature on credit supply shocks and show that the endogenous matching of banks and borrowers does not drive our findings (Iyer et al., 2014; Jiménez et al., 2012; Khwaja and Mian, 2008).

The rest of the paper is organized as follows. Section 2 describes the data we use in our analysis. Section 3 examines the link between income gap, profits, and lending policy, using bank-level data. Section 4 estimates credit supply regressions using loan-level data and investigates the real effects of the credit supply shocks induced by banks' income gap. Section 5 discusses the interpretation of our results. Section 6 concludes.

2. Data and descriptive statistics

2.1. Data construction

2.1.1. Bank-level data

We use quarterly Consolidated Financial Statements for Bank Holding Companies (BHC) available from WRDS (form FR Y-9C). These reports have to be filed with the Federal Reserve by all US bank holding companies with total consolidated assets of $500 million or more. Our data covers the period going from 1986:1 to 2013:4. We restrict our analysis to all BHCs with more than $1bn of assets in 2010 dollars. The advantage of BHC-level consolidated statements is that they report measures of banks' income gap every quarter from 1986 to 2013 (see Section 2.2.1). Commercial bank-level data do not have a consistent measure of income gap over such a long period.

For each BHC, we construct six dependent variables: (1) quarterly change in net interest income normalized by lagged total assets (Δ Interest) (2) quarterly change in non-interest income normalized by lagged total assets (Δ Non-interest) (3) quarterly change in earnings normalized by lagged total assets (Δ Earnings) (4) quarterly change in total market value normalized by lagged total assets (Δ Market Value) (5) quarterly change in log commercial & industrial loans (Δ log(C&I)) (6) quarterly change in log total loans (Δ log(Total Loans)). We describe in details the construction of these variables in Appendix A. We also use the following control variables: (1) Log of assets (2) Equity to assets ratio (3) the average adjustable-rate share in mortgage issuance in markets where the BHC operates branches (Local % ARM) (4) the average deposit Herfindahl index in markets where the BHC operate branches (Local HHI) (5) the share of liquid securities defined as the ratio of available-for-sale securities to total assets (Fraction liquid assets) (5) the repricing/maturity gap defined in English et al. (2018). All ratios are trimmed by removing observations that are more than five interquartile range away from the median. Appendix A describes the construction of these variables in detail.

We report summary statistics for these variables in Table 1. Over our sample period, the average quarterly growth in C&I and total lending is 1.3 and 1.7% respectively. Changes in interest income, non-interest income, and total earnings are small relative to banks' total assets. The control variables have the same order of magnitude as previous studies using commercial banks data on similar sample periods. For instance, the average equity-to-asset ratio is 8.8% in our data, compared to 9.5% in Campello's (2002)) sample, which covers 1981 to 1997; the share of liquid assets is 22% in our sample compared to 32% in his sample. Local HHI is 0.16 in our sample while at the commercial bank-level, Drechsler et al. (2017) report a bank HHI of 0.24.

2.1.2. Loan-level data

We use loan-level data from Dealscan (see, e.g., Chava and Roberts, 2008 for a detailed description of this dataset). Dealscan contains publicly available information on over 100,000 corporate loans issued since 1987. The dataset provides detailed information on the size, maturity, and terms (fees, rates) of loan deals. Dealscan also reports the identity of borrowers and lenders. For the majority of loans, the data contain the syndicate structure but not the actual loan shares. However, for the sample of syndicates with non-missing loan shares, we find in unreported regressions that the syndicate structure explains most of the variations in lender shares, with an explanatory power of 94.15%. For observations with missing loan shares, we follow Chodorow-Reich (2014) and impute this variable from the average lender shares of syndicates with a similar structure (i.e., same number of lead lenders and participants).

We combine information on loan amounts, year of origination, and year of termination with loan shares to construct a yearly panel of outstanding loans for each active borrower-lender pair, i.e., for which there is at least one outstanding loan. We drop lenders with a different top-holder BHC in year t and $t+1$. Our key dependent variable is the symmetric loan growth measure $\Delta L_{i\rightarrow j,t}$: this corresponds to the change, from year t to t+1, in firm *j*'s outstanding loan amount from bank *i*, normalized by the average loan amount across both years (see Appendix A for details). This measure is bounded between -2 and +2, and it is defined even when a firm initiates or terminates a lending relationship.

We merge this loan-level dataset to BHCs in two steps. We first use the Dealscan Lender Link Tables from Schwert (2018) to match public lenders. This crosswalk allows us to match public lenders to Compustat. Using the CCM Linktable and the CRSP-FRB link, we then match these lenders to their respective BHCs. This first step allows us to match 490 Dealscan lenders to 79 BHCs. Second, we manually match the remaining large private lenders in Dealscan to their Call Reports using name and location. We then assign each US commercial bank to a BHC using the top-holder BHC reported in the Call Reports (`rssd9348`). This manual approach provides us with an additional 99 Dealscan lenders that we can match to 69 BHCs.

2.1.3. Interest rates

We use three time-series of interest rates. The first is the time-series of the Fed Funds rate, available monthly from the Federal Reserve's website. We then define quarterly interest rates as the Fed Funds rate prevailing in the quarter's last month. The second is the time-series of yields on the 10-year Treasury bond, also available from the Federal Reserve's website. Finally, we construct a measure of expected changes in the Fed Funds rate for year t using the price on the twelve months Fed Funds future's contract (FF12) in January. We then define the surprise change in the Fed Funds rate for year t as the difference between the realized change in the Fed Funds rate over the course of the year and the expected change in the Fed Funds rate. We use a similar methodology to define the surprise change in the Fed Funds rate at the quarterly level.

2.2. Exposure to interest rate risk

2.2.1. Income gap: definition and measurement

We use the definition of a bank's income gap in Mishkin and Eakins (2009):

$$\text{Income Gap} = \text{RSA} - \text{RSL} \tag{1}$$

where RSA is the $ amount of assets that either reprice or mature within a year and RSB is the $ amount of liabilities that mature or reprice within a year. The income gap measures the extent to which a bank's net interest income is sensitive to changes in interest rates. Mishkin and Eakins (2009) proposes to assess the impact of a potential change in short rates Δr on bank's income by calculating: $\text{Income Gap} \times \Delta r$.

However, this relation has no reason to hold exactly. The income gap measures a bank's exposure to interest rate risk imperfectly. First, the cost of debt rollover may differ from the short rate. New short-term lending/borrowing will also relate to the improving/worsening position of the bank on financial markets (for liabilities) and in the lending market (for assets). This introduces noise in the relationship between the change in a bank's net income and $\text{Income Gap} \times \Delta r$. Second, depending on repricing frequency, repricing assets or liabilities may reprice in a quarter when the short rate is constant. This will weaken the correlation between the change in interest income and $\text{Income Gap} \times \Delta r$. To see this, imagine that a bank holds a $100 loan, financed with fixed-rate debt, that reprices every year on June 1. This bank has an income gap of $100 (RSA=100, RSL=0). Assume now that the Fed Funds rate increases by 100 bps on February 20. In the first quarter of the year, the bank has a $100 income gap, the Fed Funds rate have risen by 100 bps, and yet, the bank's interest income is constant. During the second quarter, the Fed Funds rate is constant, yet, the bank's interest income increases by $\$1 = 1\% \times \$100$. For these two consecutive quarters, the correlation between gap-weighted Fed Funds rate changes and interest income is, in fact, negative. Finally, banks might be partially hedging their interest rate exposure. This hedging would also weaken the link between change in income and $\text{Income Gap} \times \Delta r$. Despite these sources of measurement error, we believe that the income gap measure remains attractive, given its simplicity and direct availability from regulatory data.

Table 2
Income gap and its components.

	Mean	sd	p25	p75	Count
Income gap =	0.122	0.186	0.010	0.239	38,117
Assets maturing/resetting $<$ 1 year	0.423	0.150	0.322	0.521	38,117
− Liabilities maturing/resetting $<$ 1 year =	0.301	0.157	0.191	0.386	38,117
Interest-bearing deposits maturing/resetting $<$ 1 year	0.290	0.157	0.180	0.375	38,117
+ Variable rate long-term debt	0.009	0.026	0.000	0.008	38,117
+ Long-term debt maturing $<$ 1 year	0.001	0.005	0.000	0.000	38,117
+ Variable rate preferred stock	0.000	0.002	0.000	0.000	38,117

Note: Summary statistics are based on the quarterly Consolidated Financial Statements (Files FR Y-9C) between 1986 and 2013 restricted to US bank holding companies with total consolidated assets of $1Bil or more in 2010 dollars. The variables are all scaled by total consolidated assets (bhck2170) and are defined as follows: Assets maturing/resetting $<$ 1 year $= \frac{\text{bhck3197}}{\text{bhck2170}}$; Liabilities maturing/resetting $<$ 1 year $= \frac{\text{bhck3296+bhck3298+bhck3409+bhck3408}}{\text{bhck2170}}$; Interest-bearing deposits maturing/resetting $<$ 1 year $= \frac{\text{bhck3296}}{\text{bhck2170}}$; Variable rate long-term debt $= \frac{\text{bhck3298}}{\text{bhck2170}}$; Long-term debt maturing $<$ 1 year $= \frac{\text{bhck3409}}{\text{bhck2170}}$; Variable rate preferred stock $= \frac{\text{bhck3408}}{\text{bhck2170}}$.

Table 3
Summary statistics: derivatives hedges of interest rate risk.

	Mean	sd	p25	p75	Count
Futures	0.021	0.146	0.000	0.000	28,063
Forward contracts	0.035	0.267	0.000	0.002	28,073
Written options (Exchange traded)	0.007	0.068	0.000	0.000	28,061
Purchased options (Exchange traded)	0.009	0.074	0.000	0.000	28,058
Written options (OTC)	0.026	0.179	0.000	0.003	28,066
Purchased options (OTC)	0.026	0.168	0.000	0.000	28,079
Swaps	0.164	1.363	0.000	0.033	37,694
At least some I.R. hedging	0.583	0.493	0.000	1.000	28,057

Note: Summary statistics are based on Schedule HC-L of the quarterly Consolidated Financial Statements (Files FR Y-9C) between 1995 and 2013 restricted to US bank holding companies with total consolidated assets of $1Bil or more in 2010 dollars. Schedule HC-L is not available prior to 1995. The variables report notional amounts for each type of derivatives at the BHC-quarter level. They are all scaled by total consolidated assets (bhck2170). Futures Contracts $= \frac{\text{bhck8693}}{\text{bhck2170}}$; Forward Contracts $= \frac{\text{bhck8697}}{\text{bhck2170}}$; Written Options (Exchange traded) $= \frac{\text{bhck8701}}{\text{bhck2170}}$; Purchased Options (exchange traded) $= \frac{\text{bhck8705}}{\text{bhck2170}}$; Written Options (OTC) $= \frac{\text{bhck8709}}{\text{bhck2170}}$; Purchased Options (OTC) $= \frac{\text{bhck8713}}{\text{bhck2170}}$; Swaps $= \frac{\text{bhck3450}}{\text{bhck2170}}$. "At least some I.R. hedging" is a dummy variable equal to one if a bank has a positive notional amount in any of the seven types of interest hedging derivatives in a given quarter.

Empirically, we construct a BHC's income gap using variables from schedule HC-H of form FR Y-9C. This schedule is specifically dedicated to interest sensitivity. RSA is provided directly through bhck3197 (Earning assets that are repriceable within one year or mature within one year). RSL is decomposed into four elements: (1) long-term debt that reprices within one year (bhck3298) (2) long-term debt that is scheduled to mature within one year (bhck3409) (3) variable-rate preferred stock (bhck3408) (4) interest-bearing deposit liabilities that reprice or mature within one year (bhck3296). The last element is by far the most important determinant of RSL: on average, it represents 29% of banks' assets, while the three first elements combined represent only 1%. All these items are available every quarter from 1986 to 2013. We scale all these variables by total assets. We report summary statistics in Table 2. The average income gap is 12.2% of total assets: for the average bank, an increase in the Fed Funds rate by 100 bps should approximately increase net interest income by 0.122 percentage points of assets. Importantly for our empirical analysis, Table 2 shows significant cross-sectional dispersion in income gap across banks. The standard deviation of banks' income gap is 18.6%. In unreported analysis, we find that cross-sectional variations in income gap come primarily from two sources: the share of C&I lending in total loans and the share of short-term deposits in total liabilities.

Table 4 reports the correlation of banks' income gap with the four main control variables introduced in Section 2.1.1. The income gap is strongly correlated with size: banks in the top quartile of the income gap distribution are ten times larger than banks in the bottom quartile; a univariate regression of banks' average income gap on size yields a p-value lower than 0.01. Similarly, banks with a large income gap tend to operate in local deposit markets that are more concentrated, and that see a larger share of adjustable rates mortgages (ARM) in mortgage issuance. Both correlations are statistically significant at the 5% confidence level. The income gap is not significantly correlated with leverage. These correlations confirm the importance of controlling for these additional channels to avoid potential omitted variable bias.

Table 4
Balance of covariates.

	Obs.	Income gap quartile				Overall	
		1	2	3	4	Std. dev.	p-value
Log of assets	38117	14.46	14.71	15.00	15.47	1.38	0.00***
Equity to assets ratio (%)	38117	8.80	8.79	8.71	8.80	3.22	0.19
Local % ARM	38117	18.61	19.71	20.83	22.79	14.76	0.00***
Local HHI (%)	38117	16.40	16.74	15.57	13.84	8.46	0.00***

Note: This table shows average bank-level covariates across four quartiles of banks' income gap. Each bank *in the whole sample* is assigned to one of four quartiles of income gap based on their average in-sample income gap. We then compute the in-sample average of covariates for banks in each of these four quartiles (columns 1–4 under income gap quartile). Obs. provides the number of observations used to compute these average. Std. dev. reports the standard deviation of the variable summarized in each row, while p-value reports the p-value for the regression of the row variable on the income gap, where standard errors are two-way clustered at the bank and quarter level. Log of assets is defined as log (total assets (bhck2170)); Equity to asset ratio is defined as 1 − [total liabilities (bhck2948)/total assets (bhck2170)]; Local %ARM corresponds to the average ARM share in markets where the BHC operates; Local HHI corresponds to the average HHI in markets where the BHC operates. Appendix A provides details on the construction of these variables.

A common view of the banking sector is that it engages in maturity transformation, borrowing short and lending long. However, the average income gap is positive (12.2% of total assets).[3] Additionally, 78% of banks exhibit a *positive* income gap. One potential explanation for this surprising fact lies in our treatment of non-interest bearing and savings deposits. In the BHC data, item bck3296 – interest-bearing deposit liabilities that reprice or mature within one year – does not include savings deposits or non-interest bearing deposits.[4] Thus, these deposits are treated as liabilities that reprice or mature in more than one year, despite their zero contractual maturity. There are two justifications for this treatment. First, the banking literature has shown that interest rates on savings deposits adjust slowly in response to changes in short-term market rates (Hannan and Berger, 1991, Neumark and Sharpe, 1992, Drechsler et al., 2017). These findings motivate the choice to treat savings deposits as longer-term fixed-rate liabilities. Second, non-interest bearing deposits, by definition, do not induce direct changes to banks' net interest income in response to changes in Fed Funds rate.[5] Importantly, even if we assume that all non-interest bearing and savings deposits mature or reprice within a year, the average income gap is zero and not negative.

Additionally, a positive average income gap is not necessarily inconsistent with maturity transformation. The income gap is a cash-flow concept. Maturity transformation is about duration, and is, therefore, better captured through *the duration gap*. The duration gap measures the extent to which a bank's equity *value* is sensitive to fluctuations in interest rates. Income gap and duration gap can be of opposite sign, if, for instance, the maturity of long-term assets is substantially longer than that of long-term deposits. English et al. (2018) shows that a 100 basis point increase in interest rates increases the median bank's net interest income relative to assets by almost nine basis points and decreases its market value of equity by 7%. These numbers are very much in line with the observed average income gap of 12.2%.

2.2.2. Direct evidence on interest rate risk hedging

Do banks use derivatives to hedge their "natural" exposure to interest rate risk? Schedule HC-L of form FR Y-9C reports, starting in 1995, the notional amounts of interest derivatives held by banks for Futures (bhck8693), Forwards (bhck8697), exchange-traded written options (bhck8701), exchange-traded purchased options (bhck8705), over-the-counter written options (bhck8709), over-the-counter purchased options (bhck8713), and Swaps (bhck3450). We scale all these variables by assets, and report summary statistics in Table 3. Swaps are the most prevalent form of hedging used by banks: on average, their notional amount accounts for 17.6% of total assets. However, large outliers distort this number: between 10 and 20 banks have a notional amount of swaps greater than their assets. These banks are presumably dealers. In contrast, the median bank has no interest-rate swap. More generally, 41.7% of banks report no derivative exposure. Unfortunately, the data only provide us directly with notional exposures, which may conceal offsetting positions (see Begeneau et al., 2012 or Vuillemey, 2019 for an inference of net exposure using public data). To deal with this issue, we directly estimate the sensitivity of banks' income to fluctuations in interest rates and show how it relates to banks' income gap, for all banks as well as for the subset of banks that do not report any hedging (Section 3.3).

[3] In its seminal contribution, Flannery (1981) also reports a positive average income gap for large banks. Flannery (1983) extends the result to small banks.

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

[5] Indirectly, non-interest bearing deposits may generate a sensitivity of banks' net interest income to changes in Fed Funds rate if their quantity is sensitive to changes in Fed Funds rate. In unreported regressions, however, we estimate that the average sensitivity of non-interest bearing deposits to changes in Fed Funds rate is negative, but not statistically significant. In any case, we show in Section 3.6 that our results are robust to alternative assumptions for the maturity of these deposits.

The figures in Table 3 are consistent with recent papers showing limited hedging of interest-rate risk by financial institutions (e.g., Purnanandam, 2007 or Vuillemey, 2019 for the US and Hoffmann et al., 2018 for banks in the Eurozone). Imperfect hedging is typically interpreted through the lens of financial constraints. Early theories of risk management argue that financially constrained institutions are effectively risk-averse and have incentives to hedge (Froot et al., 1993b and Froot and Stein, 1998). Recent theories highlight that, since both financing and hedging requires pledging collateral, the cost of hedging at the margin is higher for more constrained institutions, who hedge less in equilibrium (Rampini and Viswanathan, 2018 and Rampini et al., 2017). As a result, under these modern theories of hedging, restricting the sample to non-hedging banks would over-estimate the role of banks' income gap, since non-hedging banks would be more financially constrained.

3. Bank-level evidence

This section exploits BHC-level data to provide evidence on the role of banks' income gap in the transmission of monetary policy to bank lending.

3.1. Methodology

Our main specification mimics closely the existing literature (Kashyap and Stein, 1995; Kashyap and Stein, 2000 or Campello, 2002). We estimate the following linear model for bank i in quarter t:

$$\Delta Y_{it} = \sum_{k=0}^{k=4} \alpha_k (\text{gap}_{it-1} \times \Delta \text{Fed Funds}_{t-k}) + \sum_{x \in Control} \sum_{k=0}^{k=4} \gamma_{x,k} (x_{it-1} \times \Delta \text{Fed Funds}_{t-k}) + \sum_{k=1}^{k=4} \eta_k \Delta Y_{it-k} + \phi.\text{gap}_{it-1} + \sum_{x \in Control} \mu_x . x_{it-1} + \delta_t + \epsilon_{it} \quad (2)$$

Standard errors are two-way clustered at the BHC and quarter level. ΔY_{it} is one of the outcome variables introduced in Section 2.1.1. $\sum_{k=0}^{k=4} \alpha_k$ is the coefficient of interest in Eq. (2). It measures how a bank with income gap gap_{it-1} responds to current and past changes in the Fed Funds rate, relative to a bank with an income gap of zero. If the income gap contains information on the interest-rate exposure of banks' net income and if banks do not fully hedge this risk, we expect $\sum_{k=0}^{k=4} \alpha_k > 0$ when ΔY_{it} is the quarterly change in net interest income or total earnings. Under the bank lending channel, we expect $\sum_{k=0}^{k=4} \alpha_k > 0$ when ΔY_{it} is the quarterly change in log C&I lending or log total lending: if banks are financially constrained, the positive income shock induced by a change in the Fed Funds rate should allow banks to expand lending.

Eq. (2) will provide unbiased estimates of α_ks under the identifying assumption that the correlation between banks lending opportunity (ϵ_{it}) and variations in Fed Funds rate (ΔFed Funds_{t-k})) is not systematically related to banks' income gap. There are two main threats to the identification of $\sum_{k=0}^{k=4} \alpha_k$.

First, Eq. (2) may suffer from an omitted variable bias: banks' income gap may be correlated with other characteristics x_i, which may themselves explain how banks' income or lending responds to changes in the Fed Funds rate. We do not have a valid instrument for banks' income gap, which is a limitation of our analysis. However, to alleviate omitted variable concerns, we include an extensive set of control variables to Eq. (2). Importantly, these controls are not only included directly, *but also interacted with current and four lags of interest rate changes* ($x_{it-1} \times \Delta$Fed Funds_{t-k} in Eq. (2)). These controls include important determinants of the transmission of monetary policy to bank lending that have been emphasized in the literature: size (e.g., Kashyap and Stein, 1995), leverage (e.g., Kishan and Opiela, 2000), local deposit concentration (e.g., Drechsler et al., 2017), the share of adjustable-rate mortgages in local mortgage issuance (e.g., Di Maggio et al., 2017), the share of liquid assets held on banks balance sheet (Kashyap and Stein, 2000) or the repricing/maturity gap of English et al. (2018). All specifications include the first four control variables. Because of data limitation, we include the last two controls (share of liquid assets and repricing/maturity gap) in separate tables. To assess the robustness of our findings, we supplement the linear model in Eq. (2) with a covariate-balancing propensity score matching approach (Section 3.6).

The second threat to identification is the endogenous matching of BHCs and customers: $\sum_{k=0}^{k=4} \alpha_k$ could be biased if banks with higher income gaps tend to attract borrowers whose credit demand is more sensitive to changes in interest rates. To alleviate this concern, we exploit internal capital markets within BHCs in the spirit of Lamont (1997) or Campello (2002). We estimate a specification that directly controls for a BHC's commercial banks income gap. This specification allows us to rule out an interpretation whereby local customers with specific characteristics match with commercial banks with a higher income gap. In Section 4, we tackle this endogeneity concern by using corporate loan-level data (Gan, 2007; Khwaja and Mian, 2008), which allows us to control for borrower-date fixed effects.

3.2. Interest rate fluctuations and interest income

We first estimate Eq. (2) using quarterly changes in net interest income (interest income minus interest expenses) normalized by lagged assets as our first explanatory variable. We report the estimation results in Table 5, columns (1)–(5). The bottom panel reports the coefficient of interest, $\sum_{k=0}^{k=4} \alpha_k$, i.e. the cumulative effect of a change in interest rate on the change in net interest income, as well as the p-value of the F-test for $\sum_{k=0}^{k=4} \alpha_k = 0$. Column (1) provides estimation results over the

Table 5
Income gap, interest rates, and interest income.

	ΔInterest$_{it}$					ΔNon interest income$_{it}$				
	All	Small	Large	No hedge	Some hedge	All	Small	Large	No hedge	Some hedge
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$Gap_{it-1} \times \Delta FedFunds_t$	0.017**	0.018**	0.018	0.03***	0.017	−0.0034	−0.0039	−0.0028	−0.011*	0.0049
	(2.4)	(2.4)	(1)	(3.3)	(1.5)	(−0.79)	(−0.81)	(−0.32)	(−1.8)	(0.56)
$Gap_{it-1} \times \Delta FedFunds_{t-1}$	0.039***	0.038***	0.04***	0.037***	0.044***	−0.0032	−0.0036	0.0022	−0.0011	0.0052
	(6.3)	(6)	(3.7)	(4.2)	(4)	(−0.74)	(−0.76)	(0.23)	(−0.14)	(0.59)
$Gap_{it-1} \times \Delta FedFunds_{t-2}$	0.0034	0.0058	−0.011	0.0081	0.0026	−0.0021	−0.00095	−0.0095	0.0017	−0.0073
	(0.73)	(1.3)	(−0.74)	(1)	(0.43)	(−0.44)	(−0.19)	(−0.73)	(0.17)	(−0.93)
$Gap_{it-1} \times \Delta FedFunds_{t-3}$	0.007	0.005	0.032	−0.005	0.014*	0.011*	0.011	0.0056	0.0039	0.012
	(1.2)	(0.75)	(1.4)	(−0.5)	(1.8)	(1.7)	(1.6)	(0.6)	(.37)	(1.2)
$Gap_{it-1} \times \Delta FedFunds_{t-4}$	−0.0056	−0.0058	0.0018	−0.000076	−0.022***	−0.0018	−0.0048	0.015	0.0078	−0.0048
	(−0.9)	(−0.93)	(0.081)	(−0.0052)	(−2.9)	(−0.33)	(−0.86)	(1.6)	(1.3)	(−0.43)
Obs.	37,649	33,855	3794	11,557	16,454	34,839	31,241	3598	11,092	14,252
Adj. R^2	0.11	0.11	0.16	0.13	0.10	0.16	0.16	0.19	0.17	0.15
Sum of gap coefficients	0.06	0.06	0.08	0.07	0.05	0	0	0.01	0	0
p-value of gap coefficients	0	0	0	0	0	0.98	0.7	0.23	0.87	0.35
p-value of equality test	.	.	0.24	.	0.33	.	.	0.25	.	0.44

Note: This table estimates
$\Delta Y_{it} = \sum_{k=0}^{k=4} \alpha_k (\text{gap}_{it-1} \times \Delta \text{Fed Funds}_{t-k}) + \sum_{x \in Control} \sum_{k=0}^{k=4} \gamma_{x.k} (x_{it-1} \times \Delta \text{Fed Funds}_{t-k}) + \sum_{k=1}^{k=4} \eta_k \Delta Y_{it-k} + \phi.\text{gap}_{it-1} + \sum_{x \in Control} \mu_x . x_{it-1} + \delta_t + \epsilon_{it}$
ΔY is the quarterly change in interest income normalized by lagged total assets (Interest$_{it}$-Interest$_{it-1}$)/(Assets$_{it-1}$) in columns (1)–(5) and change in *non*-interest income normalized by lagged total assets in columns (6)–(10). Columns (1) and (6) report estimates for the entire sample. Columns (2)–(3) and (6)–(7) break down the sample into small and large banks. Columns (4)–(5) and (9)–(10) break down the sample into banks reporting some positive notional exposure to interest rate derivatives and banks with no such exposure. The controls x are log of assets$_{it-1}$, equity to asset ratio$_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$. See Appendix A for details on the construction of these variables. The regression also includes quarter fixed effects. Standard errors are two-way clustered at the BHC and quarter level. "Sum of gap coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4} \alpha_k$. We also report the p-value of a test of significance for $\sum_{k=0}^{k=4} \alpha_k$, as well as a test of equality of these sums across subsamples (large vs. small banks, hedged vs. unhedged banks). These equality tests use the SURE procedure for nesting the two equations in a single model.

whole sample. $\sum_{k=0}^{k=4}\alpha_k = 0$ is significantly different from 0 at the 1% confidence level (p-value < 0.01). Quantitatively, a \$1 increase in $Gap_{it-1} \times \Delta FedFunds_t$, raises interest income over the next five quarters by about 0.06 dollars. The income gap captures the exposure of a BHC's net interest income in a statistically meaningful way.

The effect uncovered in column (1) of Table 5 is observed across bank sizes and is unaffected by the use of hedging by BHCs. Columns (2) and (3) split the sample into large and small banks. "Large banks" are defined as the 50 largest BHCs each quarter in terms of total assets. The estimate of $\sum_{k=0}^{k=4}\alpha_k$ is 0.06 for small banks and 0.08 for large banks. Both estimates are statistically different from 0 at the 1% confidence level. A test of equality of $\sum_{k=0}^{k=4}\alpha_k$ across the two groups yields a p-value of 0.24 so that we cannot reject the null hypothesis that these coefficients are equal at standard confidence level. Columns (4) and (5) split the sample into banks that report some notional exposure to interest rate derivatives and banks that report no interest rate derivative exposure. Because of data availability, this sample split reduces the estimation period to 1995–2013. The sample size drops accordingly from 37,649 BHCs-quarter to 28,011 BHCs-quarter. The estimate of $\sum_{k=0}^{k=4}\alpha_k$ is similar for both group of banks: 0.06 (resp. 0.05) for banks with (resp. without) derivative exposure. The p-value of a test of equality for these two coefficients is 0.33 so that we cannot reject the null hypothesis that these two coefficients are equal.[6]

If our measure perfectly captured a BHC's income exposure to changes in interest rates, we would expect $\sum_{k=0}^{k=4}\alpha_k \approx 0.25$, since interest rates are annualized, but income is measured quarterly. Instead, Table 5 reports a coefficient estimate of 0.06. As mentioned in Flannery (1981) and explained in Section 2.2.1, beyond measurement error, there are several reasons to expect a coefficient estimate below 0.25. Explicit or implicit commitments to renew existing loans without a full pass-through of rate changes to customers might add noise to the relation between net interest income and changes in the Fed Funds rate. Additionally, reset dates of variable rate loans do not exactly occur at the beginning of each quarter. ARMs, which make up a big fraction of banks' interest rate exposure, have lifetime and periodic caps and floors that reduce the sensitivity of their cash-flows to interest rates. All these effects dampen the elasticity of net interest income to interest rates and probably explain why our estimate of $\sum_{k=0}^{k=4}\alpha_k$ is significantly lower than 0.25.

To further assess the validity of our approach, we run a "placebo" test in columns (6)–(10) of Table 5. We use quarterly changes in non-interest income (normalized by lagged assets) as a dependent variable in Eq. (2). Non-interest income includes servicing fees, securitization fees, management fees, and trading revenue. While non-interest income may be sensitive to interest rate fluctuations, there is no reason why this sensitivity should depend on a BHC's income gap. Columns (6)–(10) of Table 5 reproduce the analysis of columns (1)–(5) using non-interest income as a dependent variable. In all these specifications, the estimated $\sum_{k=0}^{k=4}\alpha_k$ is lower than 0.01 and not statistically different from 0.

3.3. Interest rate fluctuations, earnings and value

We now estimate Eq. (2) but use quarterly changes in total earnings scaled by lagged assets as the dependent variable. Columns (1)–(5) of Table 6 report the coefficient estimates. $\sum_{k=0}^{k=4}\alpha_k$ is positive and significantly different from 0 at the 1% confidence level across all specifications. Quantitatively, column (1) implies that a \$1 increase in $Gap_{it-1} \times \Delta FedFunds_t$ raises total earnings over the next five quarters by about \$0.07. This result is similar to the effect on net interest income estimated in column (1) of Table 5, which is not surprising given the result on non-interest income obtained in column (6), Table 5. The estimated $\sum_{k=0}^{k=4}\alpha_k$ takes approximately the same value and remains statistically significant when we restrict the sample to large banks (column (2)), small banks (column (3)), banks with no notional exposure to interest-rate derivatives (column (4)) and banks with some notional exposure (column (5)). These results on BHCs' total earnings indicate that, for most banks in our sample, hedging does not significantly reduce banks' balance sheet exposure to interest-rate risk. This conclusion seems to hold even for the largest banks, which is consistent with Vickery (2008) and Begeneau et al. (2012).

We also estimate Eq. (2) using quarterly changes in equity market value scaled by lagged assets as a dependent variable. Columns (6)–(10) of Table 6 report the coefficient estimates. $\sum_{k=0}^{k=4}\alpha_k$ is positive and significantly different from 0 at the 1% confidence level in all specifications, except when we only include large banks. Quantitatively, a \$1 increase in $Gap_{it-1} \times \Delta FedFunds_t$ increases the market value of banks equity over the next five quarters by about \$1.6. The same increase in $Gap_{it-1} \times \Delta FedFunds_t$ raises total earnings by \$0.07. These results imply an earnings multiple of approximately 25. The estimated $\sum_{k=0}^{k=4}\alpha_k$ is smaller when estimated over the sample of large banks (column (8), $\sum_{k=0}^{k=4}\alpha_k = 0.84$ with a p-value of 0.3): this result is consistent with the notion that small banks are more likely to be financially constrained, so that a given income shock may translate into a higher valuation. The estimate of $\sum_{k=0}^{k=4}\alpha_k$ remains otherwise comparable to its full sample value when estimated on the sample of small banks (column (7)), banks with no derivatives exposure (column (9)) and banks with derivative exposure (column (10)).[7]

[6] In non-reported regressions, we further restrict the sample to BHCs whose notional interest rate derivative exposure exceeds 10% of total assets (some 4000 observations): even on this smaller sample, the income gap effect remains strongly significant and has the same order of magnitude.

[7] Table 6 also shows that banks market values respond not only to contemporaneous changes in Fed Funds rate but also to the previous quarter changes. One possible interpretation is that the market is inattentive to the information contained in the income gap and is pricing actual net income, which, as the first columns of the table show, also respond to both contemporaneous and previous quarter fluctuations in interest rates. Additionally, information about a BHC's income gap may not be contemporaneously observable due to publication lags.

Table 6
Income gap, interest rates, earnings, and market value.

	$\Delta Earnings_{it}$					$\Delta MarketValue_{it}$				
	All (1)	Small (2)	Big (3)	No hedge (4)	Some hedge (5)	All (6)	Small (7)	Big (8)	No hedge (9)	Some hedge (10)
$Gap_{it-1} \times \Delta FedFunds_t$	0.026***	0.028***	0.026	0.03***	0.034**	0.42	0.39	0.99	0.72**	0.75*
	(3.7)	(3.4)	(1.4)	(2.7)	(2.2)	(1.1)	(0.9)	(1)	(2.2)	(1.7)
$Gap_{it-1} \times \Delta FedFunds_{t-1}$	0.033***	0.035***	0.0006	0.058***	0.029*	0.71**	0.8**	0.042	1.2***	0.77
	(3.4)	(3.6)	(0.026)	(4.3)	(2)	(2.5)	(2.3)	(0.045)	(3.6)	(1.5)
$Gap_{it-1} \times \Delta FedFunds_{t-2}$	0.0043	0.00039	0.039*	−0.012	0.023**	0.14	0.16	0.22	0.35	−0.03
	(0.51)	(0.042)	(1.7)	(−0.7)	(2)	(0.52)	(0.51)	(0.24)	(0.77)	(−0.071)
$Gap_{it-1} \times \Delta FedFunds_{t-3}$	0.0091	0.0062	0.013	0.014	−0.000041	0.13	0.21	−0.59	−0.65*	0.71*
	(0.97)	(0.54)	(0.75)	(0.87)	(−0.0031)	(0.51)	(0.71)	(−0.6)	(−1.8)	(1.9)
$Gap_{it-1} \times \Delta FedFunds_{t-4}$	0.0012	0.0014	0.012	0.008	−0.012	0.19	0.15	0.21	0.71	−0.43
	(0.12)	(0.14)	(0.68)	(0.47)	(−0.75)	(1)	(0.68)	(0.32)	(1.5)	(−1)
Obs.	35,080	31,534	3546	11,014	15,113	19,338	18,062	1276	6090	9726
Adj. R^2	0.21	0.21	0.25	0.23	0.22	0.31	0.32	0.22	0.31	0.35
Sum of gap coefficients	0.07	0.07	0.09	0.09	0.07	1.6	1.7	0.88	2.3	1.8
p-value of gap coefficients	0	0	0	0	0	0	0	0.3	0	0
p-value of equality test	.	.	0.39	.	0.24	.	.	0.29	.	0.42

Note: This table estimates:
$\Delta Y_{it} = \sum_{k=0}^{k=4} \alpha_k (\text{gap}_{it-1} \times \Delta \text{Fed Funds}_{t-k}) + \sum_{x \in Control} \sum_{k=0}^{k=4} \gamma_{x,k} (x_{it-1} \times \Delta \text{Fed Funds}_{t-k}) + \sum_{k=1}^{k=4} \eta_k \Delta Y_{it-k} + \phi.\text{gap}_{it-1} + \sum_{x \in Control} \mu_x . x_{it-1} + \delta_t + \epsilon_{it}$
ΔY is the quarterly change in earnings divided by lagged total assets (Earnings_{it}-Earnings_{it-1})/(Assets_{it-1}) in columns (1)–(5) and the quarterly change in equity market value normalized by lagged assets in columns (6)–(10). Columns (1) and (6) report estimates for the entire sample. Columns (2)–(3) and (6)–(7) break down the sample into small and large banks. Columns (4)–(5) and (9)–(10) break down the sample into banks reporting some positive notional exposure to interest rate derivatives and banks with no such exposure. The controls x are log of assets_{it-1}, equity to asset ratio_{it-1}, Local % ARM_{it-1} and Local HHI_{it-1}. See Appendix A for details on the construction of these variables. The regression also includes quarter fixed effects. Standard errors are two-way clustered at the BHC and quarter level. "Sum of gap coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4} \alpha_k$. We also report the p-value of a test of significance for $\sum_{k=0}^{k=4} \alpha_k$, as well as a test of equality of these sums across subsamples (large vs. small banks, hedged vs. unhedged banks). These equality tests use the SURE procedure for nesting the two equations in a single model.

3.4. Interest risk and lending

When the Fed Funds rate increases, banks with a larger income gap generate larger earnings. In the presence of financial constraints, we would expect these banks to expand lending. To test this bank lending channel, we estimate Eq. (2) using quarterly change in log-C&I and log total lending as dependent variables (Kashyap and Stein, 2000). We report the results in Table 7. Columns (1)–(5) use quarterly change in log C&I loan as a dependent variable. Columns (6)–(10) use quarterly change in log total lending as a dependent variable. Columns (1) and (6) use the whole sample. Columns (2) and (7) limit the sample to small banks, columns (3) and (8) to large banks, columns (4) and (7) to banks that report no notional exposure to interest rate derivatives, and columns (5) and (8) to banks reporting no interest rate derivatives exposure. Over the whole sample, the estimate of $\sum_{k=0}^{k=4} \alpha_k$ is 1.1 for total lending and is statistically significant at the 1% confidence level. This estimate is also economically significant. If the Fed Funds rate increases by 100 bps, a bank at the 75th percentile of the income gap distribution expands lending over the following five quarters by 0.27 percentage points more than a bank at the 25th percentile. This effect is large relative to the sample average quarterly total loan growth of about 1.7%. Consistent with the bank lending channel, the estimate of $\sum_{k=0}^{k=4} \alpha_k$ is larger for smaller banks (1.2 with a p-value lower than 0.01) than for the top 50 BHCs (0.79 with a p-value of 0.47).[8] The estimate of $\sum_{k=0}^{k=4} \alpha_k$ is also larger for banks with no notional exposure (1.7 with a p-value of 0.01) than for banks with some exposure (0.92 with a p-value of 0.06), for which the income gap is more likely mismeasured. Qualitatively, the results obtained using C&I lending as a dependent variable are essentially similar with two notable differences: the estimate on hedging banks is insignificant (column (5)); the estimate on large banks is negative and insignificant (column (3)).

Appendix Table C.1 reports estimates for the control variables used in the estimation of Eq. (2). More precisely, in Panel A, we first estimate Eq. (2) using log total lending as a dependent variable and including only one control variable: column (1) uses only Log of assets, column (2) the Equity to assets ratio, column (3) % Local ARM, column (4) Local HHI and column (5) the income gap. Panel A reports each $\gamma_{x,k}$ estimate, as well as an estimate for $\sum_{k=0}^{k=4} \gamma_{x,k}$ and a p-value for the significance of $\sum_{k=0}^{k=4} \gamma_{x,k}$. To ease comparison, we standardize all these control variables by subtracting the in-sample mean and dividing by the in-sample standard deviation. In our BHC-level dataset that covers the 1986–2013 period, banks' income gap is the only variable that affects the transmission of monetary policy to bank lending significantly. Size is marginally significant in univariate regressions (p-value of 0.12 in column (1), Panel A) but the estimate is twice smaller than the estimate of income gap ($\sum_{k=0}^{k=4} \gamma_{x,k}$ is 0.11 for size vs. 0.23 for income gap). In the multivariate regressions of Panel B, for all these control variables, $\sum_{k=0}^{k=4} \gamma_{x,k}$ is lower than 0.15 with p-values greater than 0.19. In contrast, the sum of coefficients for banks' income

[8] See also the discussion in Section 5.1 on the bank lending channel.

Table 7
Income gap, interest rates and lending.

	Δlog(C&I)					Δlog(Total Loans)				
	All (1)	Small (2)	Big (3)	No Hedge (4)	Some Hedge (5)	All (6)	Small (7)	Big (8)	No Hedge (9)	Some Hedge (10)
$Gap_{it-1} \times \Delta FedFunds_t$	−0.34	−0.078	−2	−0.17	−1	−0.42	−0.57	0.55	−0.34	−0.2
	(−0.49)	(−0.11)	(−1.3)	(−0.14)	(−0.94)	(−1.3)	(−1.6)	(0.64)	(−0.63)	(−0.52)
$Gap_{it-1} \times \Delta FedFunds_{t-1}$	0.76	0.87	−0.17	0.47	1.8*	0.26	0.52	−1.8**	1*	0.12
	(0.95)	(0.98)	(−0.077)	(0.44)	(1.8)	(0.81)	(1.5)	(−2.1)	(1.9)	(0.32)
$Gap_{it-1} \times \Delta FedFunds_{t-2}$	0.87	1.5**	−3.9	−0.39	0.85	0.72**	0.78**	0.42	0.42	0.55
	(1.3)	(2.1)	(−1.4)	(−0.28)	(1.1)	(2.1)	(2.1)	(0.59)	(0.69)	(1.2)
$Gap_{it-1} \times \Delta FedFunds_{t-3}$	2***	1.8**	3.8	3.8***	1.8**	0.63*	0.59	1	0.99	0.48
	(3.1)	(2.4)	(1.4)	(3.1)	(2.1)	(1.9)	(1.6)	(1.2)	(1.5)	(0.96)
$Gap_{it-1} \times \Delta FedFunds_{t-4}$	−1.6**	−1.8***	0.39	−1.2	−2.8***	−0.043	−0.12	0.59	−0.41	−0.023
	(−2.4)	(−2.7)	(0.14)	(−1.2)	(−3.5)	(−0.15)	(−0.39)	(0.74)	(−0.85)	(−0.053)
Obs.	38,436	34,625	3811	11,809	16,711	38,117	34,307	3810	11,689	16,368
Adj. R^2	0.09	0.09	0.07	0.07	0.11	0.21	0.21	0.24	0.24	0.21
Sum of gap coefficients	1.7	2.2	−1.9	2.5	0.68	1.1	1.2	0.79	1.7	0.92
p-value of gap coefficients	0.03	0	0.35	0.04	0.52	0	0	0.47	0.01	0.06
p-value of equality test	.	.	0.08	.	0.24	.	.	0.72	.	0.35

Note: This table estimates
$\Delta Y_{it} = \sum_{k=0}^{k=4} \alpha_k (\text{gap}_{it-1} \times \Delta\text{Fed Funds}_{t-k}) + \sum_{x \in Control} \sum_{k=0}^{k=4} \gamma_{x,k} (x_{it-1} \times \Delta\text{Fed Funds}_{t-k}) + \sum_{k=1}^{k=4} \eta_k \Delta Y_{it-k} + \phi.\text{gap}_{it-1} + \sum_{x \in Control} \mu_x . x_{it-1} + \delta_t + \epsilon_{it}$
ΔY is the quarterly change in log C&I loans in column (1)–(5) and the quarterly change in log total loans in columns (6)–(10). Columns (1) and (6) report estimates for the entire sample. Columns (2)–(3) and (6)–(7) break down the sample into small and large banks. Columns (4)–(5) and (9)–(10) break down the sample into banks reporting some positive notional exposure to interest rate derivatives and banks with no such exposure. The controls x are log of assets$_{it-1}$, equity to asset ratio$_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$. See Appendix A for details on the construction of these variables. The regression also includes quarter fixed effects. Standard errors are two-way clustered at the BHC and quarter level. "Sum of gap coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4} \alpha_k$. We also report the p-value of a test of significance for $\sum_{k=0}^{k=4} \alpha_k$, as well as a test of equality of these sums across subsamples (large vs. small banks, hedged vs. unhedged banks). These equality tests use the SURE procedure for nesting the two equations in a single model.

gap is 0.21 and has a p-value lower than 0.01. These results contrast with previous findings in the literature. The difference comes from our different sample period, as well as our focus on BHC-level data as opposed to commercial bank-level data used in previous banking papers.

We also compare our cross-sectional estimates with results obtained in the literature using aggregate time-series on the transmission of monetary policy. Using a VAR methodology, Bernanke and Blinder (1992) find that, in response to a one s.d. change in the Fed Funds rate, aggregate bank loans decrease by 0.5% after 12 months. Because the average income gap is positive, our cross-sectional estimates imply a dampening of this baseline effect. Using the result in column (6) of Table 7 for a bank at the average income gap, we find that a one s.d. increase in the Fed Funds rate ($\approx$ 50 bps) lead to a 0.07% increase in total loans. This effect represents, in absolute value, about 15% of the aggregate response estimated in Bernanke and Blinder (1992). This comparison, however, is suggestive at best as it ignores any general equilibrium effects, which may change the aggregate effect arising from banks' income gap. It suggests, however, that the income gap channel has the potential to dampen the transmission of monetary policy to bank lending significantly.

3.5. Internal capital markets

A pressing identification concern is that banks with a higher income gap may be matched endogenously to customers with a high sensitivity of loan demand to Fed Funds rate. In this section, we address this issue by exploiting the existence of internal capital markets within BHC. As we showed in Section 3.2, a BHC with a higher income gap receives a larger net income shock following an increase in Fed Funds rates. Through internal capital markets, this liquidity shock will propagate to the BHC's divisions (Rosengren and Peek, 2000, Gilje et al., 2013, Cetorelli and Goldberg, 2012). Using commercial bank-level data, we can then investigate whether, *controlling for the commercial bank own income gap*, this liquidity shock leads to increased lending. This strategy is valid under the identifying assumption that, conditional on a commercial bank own income gap, a BHC's income gap is unrelated to the sensitivity of the commercial bank lending opportunities to interest rates. This identification strategy is analogous in spirit to that used in the seminal contribution of Lamont (1997), who uses shocks to oil-divisions in conglomerates as an exogenous source of variation in internal financing available to non-oil divisions, and in the context of bank conglomerates by Campello (2002). This identifying assumption is also weaker than the one we make in our baseline specification.

We estimate the following equation for commercial bank i, belonging to a BHC j in quarter t:

$$\begin{aligned}\Delta Y^{CB}_{i,j,t} = &\sum_{k=0}^{k=4}\alpha_k(\text{BHC gap}_{jt-1}\times\Delta\text{Fed Funds}_{t-k})+\sum_{k=0}^{k=4}\zeta_k(\text{CB gap}_{i,j,t-1}\times\Delta\text{Fed Funds}_{t-k})\\ &+\phi.\text{BHC gap}_{jt-1}+\psi.\text{CB gap}_{i,j,t-1}+\sum_{x\in CBControl}\sum_{k=0}^{k=4}\left(\mu_x.x_{i,j,t-1}+\gamma_{x,k}(x_{i,j,t-1}\times\Delta\text{Fed Funds}_{t-k})\right)\\ &+\sum_{k=0}^{k=4}\eta_k\Delta Y_{i,j,t-1-k}+\delta_t+\epsilon_{i,j,t},\end{aligned} \tag{3}$$

where Y^{CB}_{it} is C&I lending growth (Panel A) or total lending growth (Panel B) for commercial banks with more than \$500 m in total assets. One issue with estimating Eq. (3) is that we need to compute the income gap at the commercial bank-level, which restricts the sample period to 1997–2013. All specifications include double-clustered standard errors at the BHC and quarter level. Table 8 presents the estimation of Eq. (3).

Column (1) includes our commercial bank controls (log of assets, Equity to assets ratio, % Local ARM and Local HHI) and the commercial bank-level income gap, all interacted with changes in the Fed Funds rate: the commercial bank-level income gap has little explanatory power on the sensitivity of commercial bank lending to interest rates. Column (2) includes the same controls as in column (1), but uses the BHC level income gap: in contrast to column (1), we see that the BHC-level income gap is a significant driver of how commercial bank's lending responds to changes in the Fed Funds rate. These two results validate our approach, which assumes that BHCs make capital budgeting decisions. Columns (3)–(5), which include both the BHC and commercial-bank level income gap and restricts the sample to BHCs with at least 2, 3 or 4 commercial banks, confirms that *even controlling for a commercial bank income gap and additional controls*, the sensitivity of lending to changes in Fed Funds rate for a commercial bank significantly depends on its BHC-level income gap. This result is not consistent with the interpretation that banks with higher income gap tend to match with borrowers with a higher sensitivity of loan demand to the Fed Funds rate.

3.6. Robustness

First, we show that our results are not sensitive to the treatment of non-interest bearing deposits. In our main specifications, we assume that all non-interest bearing deposits mature/reprice in more than one year (Section 2.2.1). In Table 9, we construct our BHC-level income gap measure using alternative assumptions for the duration of non-interest bearing deposits (item `bhdm6631` in files FR Y-9C). We then estimate Eq. (2) using this alternative income gap measure. Column (1) of Table 9 corresponds to our baseline assumption. Column (2) (resp 3, 4 and 5) corresponds to the alternative assumption that

Table 8
Internal capital markets.

	(1)	(2)	(3)	(4)	(5)
Panel A: Total loans					
Sum of CB gap coefficients	1.2	.	−1	−1.9	−2.4
p-value	0.22	.	0.66	0.46	0.49
Sum of BHC gap coefficients	.	2.5	6.5	8.4	9
p-value	.	0	0	0	0.01
Observations	20,844	25,334	8127	5907	4374
Panel B: C& I Loans					
Sum of CB gap coefficients	−0.57	.	−1.5	−2.2	−3
p-value	0.51	.	0.21	0.07	0.02
Sum of BHC gap coefficients	.	1.3	2.9	3.8	5.8
p-value	.	0	0.04	0.02	0
Observations	20,374	24,821	7827	5741	4207

Note: This table estimates
$\Delta Y_{i,j,t} = \sum_{k=0}^{k=4} \alpha_k (\text{BHC gap}_{jt-1} \times \Delta\text{Fed Funds}_{t-k}) +$
$\sum_{k=0}^{k=4} \zeta_k (\text{CB gap}_{i,j,t-1} \times \Delta\text{Fed Funds}_{t-k}) + \phi.\text{BHC gap}_{jt-1}$
$+ \psi.\text{CB gap}_{i,j,t-1} + \sum_{x \in Control} \sum_{k=0}^{k=4} \left(\mu_x . x_{i,j,t-1} + \gamma_{x,k} (x_{i,j,t-1} \times \Delta\text{Fed Funds}_{t-k}) \right) +$
$\sum_{k=0}^{k=4} \eta_k \Delta Y_{i,j,t-1-k} + \delta_t + \epsilon_{i,j,t}$,
where i is a commercial bank, j is the BHC it belongs to and t is a quarter. ΔY is the quarterly change in log C&I loans (Panel A) and the quarterly change in log total loans (Panel B). The sample corresponds to commercial banks with total assets above \$500m in 2010 dollars, and that belong to a BHC. The controls x are log of assets$_{it-1}$, equity to asset ratio$_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$ at the commercial bank-level. See Appendix A for details on the construction of these variables. Standard errors are two-way clustered at the BHC and quarter level. Columns (1) includes only the commercial-bank level income gap. Column (2) includes only the BHC-level income gap. Columns (3)–(5) include both. In column (3) (resp. (4) and (5)), the sample is limited to BHCs with more than one commercial bank (resp. 2 and 3).

Table 9
Different assumptions on non-interest bearing deposits.

Assumption on non-interest bearing deposits with duration >1 yr	100% of all (1)	75% of all (2)	50% of all (3)	25% of all (4)	0% of all (5)
Panel A: C& I Loans					
Sum of CB gap coefficients	1.7	1.7	1.7	1.6	1.5
p-value	0.03	0.03	0.03	0.04	0.04
Observations	384,36	38,435	38,435	38,435	38,435
Panel B: Total loans					
Sum of gap coefficients	1.1	1.2	1.2	1.2	1.1
p-value	0	0	0	0	0
Observations	38,117	38,116	38,116	38,116	38,116

Note: This table reports the estimate (sum of gap coefficient) and a test of significance (*p*-value) for $\sum_{k=0}^{4} \alpha_k$ in Eq. (2). The specification used in each column corresponds to column (1), Table 7 (Panel A) and column (6), Table 7 (Panel B). Each column corresponds to a different assumption about the maturity/repricing of non-interest bearing deposits. In column (1), we assume all deposits mature/reprice in more than one year (our baseline assumption). In column (2), we assume that this fraction is 75%; in column (3), 50%; in column (4), 75% and in column (5), 100%.

75% (resp. 50%, 25%, and 0%) of non-interest bearing deposits mature/reprice in more than one year. Panel A (resp. Panel B) uses quarterly changes in log C&I loans (resp. log total loans) as a dependent variable. Both panels confirm that our results are not sensitive to the assumption on the duration of non-interest bearing deposits and savings deposits. This robustness is not surprising: non-interest bearing deposits are a small fraction of liabilities (about 12% of total liabilities); additionally, there are little cross-sectional variations in the ratio of non-interest bearing deposits to total liabilities.

Second, we estimate our regressions controlling for bank asset liquidity interacted with interest rates movements, in the spirit of Kashyap and Stein (2000). We do not have this control in our main specification because it restricts the sample period to 1993–2013. Table 10 contains the estimation results. Despite the smaller sample size, the estimate of $\sum_{k=0}^{k=4} \alpha_k$ are similar to those obtained in our main analysis of Table 7. In our sample, asset liquidity does not significantly predict how BHCs' lending react to changes in interest rates. If anything, the estimated effects have the "wrong" economic sign: banks with more liquid assets tend to reduce their lending more when interest rates increase. The discrepancy with Kashyap and Stein (2000) originates from the different sample period we use in our analysis: Kashyap and Stein's (2000)) analysis use data from 1977 to 1993, while our sample period runs from 1986 to 2013.

Table 10
Robustness: controlling for liquidity.

	Δlog(C&I)					Δlog(Total loans)				
	All (1)	Small (2)	Big (3)	No hedge (4)	Some hedge (5)	All (6)	Small (7)	Big (8)	No hedge (9)	Some hedge (10)
$Gap_{it-1} \times \Delta FedFunds_t$	−0.13	−0.083	0.56	0.41	−0.94	0.002	−0.15	1.1	0.044	0.053
	(−0.19)	(−0.12)	(0.29)	(0.33)	(−0.85)	(0.008)	(−0.52)	(0.88)	(0.09)	(0.13)
$Gap_{it-1} \times \Delta FedFunds_{t-1}$	0.79	1.1	−2	−0.11	2*	0.28	0.62*	−2.4**	0.64	0.12
	(0.99)	(1.3)	(−0.95)	(−0.1)	(1.9)	(0.87)	(1.8)	(−2)	(1.3)	(0.31)
$Gap_{it-1} \times \Delta FedFunds_{t-2}$	0.45	1	−4	0.0032	0.61	0.57	0.51	1.4	.4	0.45
	(0.46)	(1.1)	(−1.5)	(0.0023)	(0.65)	(1.6)	(1.4)	(1.5)	(0.64)	(1)
$Gap_{it-1} \times \Delta FedFunds_{t-3}$	2.7***	2.6***	3.5	3.3**	1.7**	0.55*	0.69*	−0.2	0.74	0.31
	(3.5)	(3.3)	(1.4)	(2.5)	(2)	(1.7)	(2)	(−0.21)	(1.2)	(0.63)
$Gap_{it-1} \times \Delta FedFunds_{t-4}$	−2***	−2.6***	2.4	−1	−2.9***	−0.11	−0.31	1.2	−0.044	−0.089
	(−3.5)	(−4.9)	(1)	(−0.95)	(−3.4)	(−0.41)	(−1.2)	(1.4)	(−0.091)	(−0.21)
Obs.	28,459	25,628	2831	11,674	16,498	28,051	25,255	2796	11,557	16,163
Adj. R^2	0.09	0.10	0.07	0.08	0.11	0.23	0.22	0.30	0.25	0.21
Sum of gap coefficients	1.8	2.1	0.49	2.6	0.59	1.3	1.4	1.1	1.8	0.84
p-value of gap coefficients	0.06	0.03	0.86	0.05	0.6	0	0	0.46	0	0.09
p-value of equality test	.	.	0.56	.	0.19	.	.	0.83	.	0.25
Sum of liquid assets coefficients	−0.39	−0.76	0.77	0.62	−1.3	−0.35	−0.24	−1.9	−0.1	−0.59
p-value of liquid assets coefficients	0.79	0.67	0.86	0.77	0.53	0.7	0.81	0.49	0.92	0.63

Note: This table estimates
$\Delta Y_{it} = \sum_{k=0}^{k=4}\alpha_k(\text{gap}_{it-1}\times\Delta\text{Fed Funds}_{t-k}) + \sum_{x\in Control}\sum_{k=0}^{k=4}\gamma_{x,k}(x_{it-1}\times\Delta\text{Fed Funds}_{t-k}) + \sum_{k=1}^{k=4}\eta_k\Delta Y_{it-k} + \phi.\text{gap}_{it-1} + \sum_{x\in Control}\mu_x.x_{it-1} + \delta_t + \epsilon_{it}$
ΔY is the quarterly change in log C&I loans in columns (1)–(5) and the quarterly change in log total loans in columns (6)–(10). Columns (1) and (6) report estimates for the entire sample. Columns (2)–(3) and (6)–(7) break down the sample into small and large banks. Columns (4)–(5) and (9)–(10) break down the sample into banks reporting some positive notional exposure to interest rate derivatives and banks with no such exposure. The controls x are log of assets$_{it-1}$, equity to asset ratio$_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$ and Fraction liquid assets. See Appendix A for details on the construction of these variables. The regression also includes quarter fixed effects. Standard errors are two-way clustered at the BHC and quarter level. "Sum of gap coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4}\alpha_k$. We also report the p-value of a test of significance for $\sum_{k=0}^{k=4}\alpha_k$, as well as a test of equality of these sums across subsamples (large vs. small banks, hedged vs. unhedged banks). These equality tests use the SURE procedure for nesting the two equations in a single model.

Table 11
Balance of covariates (matched sample).

	Obs.	Income gap quartile				Overall	
		1	2	3	4	Std. dev.	*p*-value
Log of assets	38,117	14.91	15.18	14.97	14.96	1.38	0.86
Equity to assets ratio (%)	38,117	8.83	8.72	8.72	8.71	3.22	0.82
Local % ARM	38,117	19.99	18.92	19.40	20.54	14.76	0.96
Local HHI (%)	38,117	15.60	17.19	16.04	15.13	8.46	0.85

Note: The sample is reweighted using the covariate balancing propensity score methodology (Fong et al., 2018; Imai et al., 2014), which allows us to rebalance the sample for the covariates log of assets$_{it-1}$, equity to asset ratio$_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$ with respect to a treatment taking a continuum of value (gap_{it}). The table displays the average of bank-level covariates after splitting banks into four quantiles of income gap. Obs. provides the number of observations used to compute these average. Std. dev. reports the standard deviation of the variable summarized in each row, while *p*-value reports the *p*-value for the regression of the row variable on the income gap, where standard errors are two-way clustered at the bank and quarter level. Appendix A provides details on the construction of the covariates.

Table 12
Regressions on matched sample.

	ΔInterest income (1)	ΔMarket value (2)	Δlog(C&I) (3)	Δlog(Total loans) (4)
$Gap_{it-1} \times \Delta FedFunds_t$	0.018**	0.41	−0.06	−0.62*
	(2.2)	(1.1)	(−0.089)	(−1.8)
$Gap_{it-1} \times \Delta FedFunds_{t-1}$	0.033***	0.63	0.76	0.5
	(3.5)	(1.6)	(0.83)	(1.3)
$Gap_{it-1} \times \Delta FedFunds_{t-2}$	0.0075	−0.088	0.4	0.8*
	(1.4)	(−0.2)	(0.5)	(1.9)
$Gap_{it-1} \times \Delta FedFunds_{t-3}$	0.0093	0.4	3***	0.59*
	(1.2)	(1.4)	(3.4)	(1.7)
$Gap_{it-1} \times \Delta FedFunds_{t-4}$	−0.0026	0.16	−2**	0.015
	(−0.32)	(0.6)	(−2.6)	(0.05)
Obs.	36,221	18,072	36,381	38,117
Adj. R^2	0.11	0.33	0.10	0.21
Sum of gap coefficients	0.06	1.5	2.1	1.3
p-value of gap coefficients	0	0	0	0

Note: This table estimates:
$\Delta Y_{it} = \sum_{k=0}^{k=4} \alpha_k (\text{gap}_{it-1} \times \Delta \text{Fed Funds}_{t-k}) + \sum_{k=0}^{k=4} \eta_k \Delta Y_{it-1-k} + \phi.\text{gap}_{it-1} + \delta_t + \epsilon_{it}$
ΔY is the quarterly change in net interest income divided by lagged total assets (column (1)), quarterly change in market value divided by lagged total assets (column (2)), quarterly change in log C&I lending (column (3)), quarterly change in log total lending (column (4)). *The sample is reweighted using the covariate balancing propensity score methodology* (Fong et al., 2018; Imai et al., 2014), which allows us to rebalance the sample for a set of covariates (log of assets$_{it-1}$, equity to asset ratio$_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$) with respect to a treatment taking a continuum of value (gap_{it}). The regression also includes quarter fixed effects. Standard errors are two-way clustered at the BHC and quarter level. "Sum of gap coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4} \alpha_k$. *p*-value corresponds to the *p*-value of a test of significance for the estimated coefficients.

Third, in Appendix B, we use the methodology in Kashyap and Stein (2000). This alternative estimation procedure proceeds in two steps. First, each quarter t, we estimate the sensitivity of ΔY_{it} to banks' income gap in the cross-section of banks. Second, we correlate the quarterly time-series of this slope coefficient with the quarterly change in the Fed Funds rate. Appendix Tables B.1 and B.2 show that this alternative methodology delivers similar results to our baseline estimation.

Fourth, we assess the robustness of our main findings to a matching approach. Given the continuous nature of our treatment variable (income gap), we use a generalized propensity score method, which extends the propensity score matching methodology to continuous treatments. Precisely, we implement the covariate-balancing propensity score matching of Fong et al. (2018), which directly estimates the propensity score weights as the ones that minimize the correlation between the value of the income gap and the value of the control variables. Table 11 shows that, on the reweighted sample, banks' income gap is no longer significantly correlated with the covariates we use as controls in our main specification. Table 12 reproduces our baseline analyses on the reweighted sample. With this alternative methodology, we confirm that, following an increase in the Fed Funds rate, banks with a higher income gap exhibit a relative rise in net interest income, market value, C&I lending, and total lending. These estimates from the matching procedure are all significant at the 1% confidence level.

Fifth, in Appendix Table C.2, we show that our results are virtually similar if we exclude the years that follow the financial crisis from our sample (i.e., 2009–2013). This result is not surprising since there are no movements in Fed Funds rate post-2008 so that pre-2008 variations in Fed Funds rate naturally identify our main coefficient estimates. 'Sixth, we address a particular endogeneity concern. Anticipating an increase in the Fed Funds rate, banks facing a loan demand with a high sensitivity to interest rates expect an increase in loan demand. If banks are financially constrained, they may decide to increase their income gap. As a result, banks with a larger income gap may end up lending to firms whose loan demand is more sensitive to interest rates. This selection would create an upward bias in the estimation of the effect of banks' income gap. While Section 4 below deals with this issue by using loan-level data, we implement here a simple test to assuage this concern. Precisely, we re-estimate our baseline regression but consider variations in net interest income that are created by *surprise* quarterly changes in the Fed Funds rate. By focusing on the surprise component of changes in the Fed Funds rate, we know that banks cannot adjust their balance sheet anticipating these shocks. Table 13 shows that the results of this analysis are broadly consistent with our baseline results in Tables 5 and 7. An *unexpected* increase in the Fed Funds rate generates a relative increase in net interest income for banks with a larger income gap. This increase in net interest income leads to an increase in lending. The main difference with our baseline estimation is that the effect on C&I lending, while of similar magnitude, is no longer significant (columns (7)–(9), Table 13. In contrast, the effect on total lending have similar magnitudes than our baseline estimates and are statistically significant.'

4. Loan-level evidence

A fundamental issue with the approach in Section 3 relates to omitted variable bias. In particular, banks with a larger income gap may endogenously match with firms whose loan demand is more sensitive to changes in the Fed Funds rate (Froot et al., 1993a,Vickery, 2006). We follow Khwaja and Mian (2008) and exploit loan-level data from Dealscan to address this potential issue.

4.1. Testing for sorting

Our first approach is descriptive. Using the loan level dataset described in Section 2.1.2, we show that banks' income gap is unrelated to borrowers characteristics and in particular, the sensitivity of loan demand to interest rates. We start from the exhaustive set of loans in Dealscan and aggregate them at the industry-year level and the state-year level.[9] We then regress total loan growth on changes in the Fed Funds rate for each sector or each state. The estimated coefficient measures either the sensitivity of loan demand to the Fed Funds rate at the industry level (SIC code $\beta_{\text{Debt/Int. rate}}$) or the state level (Zip code $\beta_{\text{Debt/Int. rate}}$). We then assign these βs to each borrower in the Dealscan sample. We also construct additional borrowers' characteristics that may capture how their loan demand responds to changes in the Fed Funds rate. For each bank, we compute the loan-share weighted-average of its borrowers' total sales, debt, age (i.e., number of years since entering Dealscan), public status, and loan maturity. Table 14 investigates the correlation of banks' income gap and borrowers characteristics. In the first four columns, we split the sample into four quartiles of banks' income gap and report average borrowers' characteristics for each of these quartiles. In column (6), we run univariate cross-sectional regressions of banks' average income gap on the average characteristics of their borrowers and report the *p*-value on the coefficient estimates. Banks' average income gap is not significantly related to any of the observable characteristics described above.

The previous analysis relies on observable measures of borrowers characteristics to test for the matching of banks and borrowers. We can improve on this analysis by focusing on the income gap of banks lending *to the same firm*. If banks with a higher income gap lend to a particular type of firms, two banks lending to the same firm should, on average, have correlated income gap. We test this hypothesis in two ways. First, for firms with multiple lenders in the same year, we regress the income gap of the firm's largest lender on the income gap of the firm's *second* largest lender (Greenstone et al., 2020). Second, for firms issuing loans in multiple years, we regress the income gap of their *future* main lenders on the income gap of their current main lenders. Appendix Table C.4 shows that both tests fail to reject the null hypothesis that banks lending to the same firms have uncorrelated income gap. Overall, we do not find any empirical evidence that banks and firms endogenously match based on banks' income gap.

4.2. Income gap, interest rates and credit supply

Our second approach follows Khwaja and Mian (2008). To address the endogeneity bias that may arise from the matching of banks and firms, we estimate a credit supply equation that includes firm-year fixed effects to control for loan demand. These fixed-effects are identified thanks to firms who borrow from multiple banks in a given year. We use the following linear model for bank i, firm j in year t:

$$\begin{aligned}\Delta L_{i\to j,t} &= \alpha(\text{gap}_{it-1} \times \Delta\text{Fed Funds}_t) + \sum_{x\in Control} \gamma_x(x_{it-1} \times \Delta\text{Fed Funds}_t) \\ &\quad + \phi.\text{gap}_{it-1} + \mu.\text{ttm}_{ijt} + \delta_{jt} + \epsilon_{it} \end{aligned} \tag{4}$$

where $L_{i\to j,t}$ denotes the outstanding loans from bank i to firm j in year t, $\Delta L_{i\to j,t}$ is the symmetric growth rate of $L_{i\to j,t}$ (see Section 2.1.2). tttm$_{ijt}$ is the average time to maturity, in year, of all outstanding loans from bank i to firm j in year t.

[9] Precisely, we use 3-digit SIC codes and 3-digit ZIP Codes for this aggregation. We also remove all ZIP Codes and industries with less than ten borrowers.

Table 13
Surprise changes in Fed Funds rate.

	ΔInterest			ΔNon-interest			Δlog C&I			Δlog total loans		
	All	Small	No hedge	All	Small	No hedge	All	Small	No Hedge	All	Small	No Hedge
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$Gap_{it-1} \times \text{Surprise}\Delta FedFunds_t$	0.025*	0.023*	0.042***	−0.0033	−0.0014	0.004	−0.41	−0.24	0.39	0.031	−0.05	0.68
	(1.9)	(1.8)	(3.2)	(−0.44)	(−0.16)	(0.38)	(−0.39)	(−0.23)	(0.17)	(0.052)	(−0.087)	(0.81)
$Gap_{it-1} \times \text{Surprise}\Delta FedFunds_{t-1}$	0.046***	0.045***	0.039**	−0.0051	−0.0094	−0.0097	1.1	1.5*	1.8	0.081	0.51	.2
	(5.2)	(5.1)	(2.6)	(−0.58)	(−1)	(−0.93)	(1.3)	(1.7)	(0.86)	(0.16)	(0.92)	(0.31)
$Gap_{it-1} \times \text{Surprise}\Delta FedFunds_{t-2}$	0.027**	0.03**	0.045***	0.0069	0.011*	0.011	1.2	1.6*	1.4	1.2**	1.4**	1.7
	(2)	(2.3)	(2.6)	(0.99)	(1.8)	(0.79)	(1.4)	(1.7)	(1.2)	(2.3)	(2.6)	(1.5)
$Gap_{it-1} \times \text{Surprise}\Delta FedFunds_{t-3}$	0.027***	0.026***	0.028**	0.0079	0.0068	−0.0088	2.3*	2.5**	4.3**	0.95	0.97	1.4*
	(2.9)	(2.9)	(2.6)	(1.1)	(0.8)	(−0.8)	(1.9)	(2)	(2.5)	(1.6)	(1.4)	(1.9)
$Gap_{it-1} \times \text{Surprise}\Delta FedFunds_{t-4}$	0.011	0.0089	0.022	−0.00098	−0.0063	0.01	−1.7*	−2.2**	−3.1**	0.25	−0.13	.8
	(1.4)	(1.1)	(1.5)	(−0.15)	(−1)	(0.81)	(−1.7)	(−2.3)	(−2.3)	(0.39)	(−0.19)	(1)
Obs.	37,684	33,891	12,344	36,346	32,664	12,091	37,818	34,033	12,430	37,997	34,183	12,490
Adj. R^2	0.06	0.06	0.08	0.03	0.03	0.03	0.06	0.06	0.05	0.11	0.11	0.12
Sum of gap coefficients	0.13	0.13	0.17	0	0	0	2.5	3.1	4.8	2.5	2.7	4.8
p-value of gap coefficients	0	0	0	0.62	0.96	0.66	0.25	0.16	0.12	0.02	0.01	0.01

Note: This table estimates
$\Delta Y_{it} = \sum_{k=0}^{k=4} \alpha_k (\text{gap}_{it-1} \times \Delta FedFunds_{t-k}^{\text{surprise}}) + \sum_{x \in Control} \sum_{k=0}^{k=4} \gamma_{x,k} (x_{it-1} \times \Delta FedFunds_{t-k}^{\text{surprise}})$
$+ \sum_{k=0}^{k=4} \eta_k \Delta Y_{it-1-k} + \phi.\text{gap}_{it-1} + \sum_{x \in Control} \mu_x . x_{it-1} + \delta_t + \epsilon_{it}$
ΔY is the quarterly change in net interest income divided by lagged total assets (columns (1)–(3)), quarterly change in non-interest income divided by lagged total assets (columns (4)–(6)), quarterly change in log C&I lending (columns (7)–(9)) and quarterly change in log total lending (columns (10)–(12)). We estimate the regression above on the whole sample (columns (1), (4), (7) and (10)), on the sample of small banks (columns (2), (5), (8) and (11)) and on the sample of firms who do not report any notional exposure to interest rate derivatives. The controls x are log of assets$_{it-1}$, equity to asset ratio$_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$. $\Delta FedFunds_{t-k}^{surprise}$ corresponds to the surprise change in the Fed Funds rate in quarter $t-k$. See Appendix A for details on the construction of these variables. The regression also includes quarter fixed effects. Standard errors are two-way clustered at the BHC and quarter level. "Sum of gap coefficients" report the coefficient estimate for $\sum_{k=0}^{k=4} \alpha_k$.

Table 14
Testing for sorting along observable characteristics.

	Income gap quartile				overall	
	1	2	3	4	std. dev.	p-value
Income gap	−0.0207	0.0829	0.188	0.34	0.148	
SIC code $\beta_{\text{Debt/Int. rate}}$	3.65	3.81	3.72	3.64	1.13	0.476
Zipcode $\beta_{\text{Debt/Int. rate}}$	3.7	3.81	3.9	3.56	2.23	0.246
Share public	0.464	0.502	0.535	0.525	0.185	0.24
Sales at close (millions)	6610	7786	7693	7870	9290	0.934
Total debt (millions)	1430	1757	1853	1808	1476	0.741
Loan maturity (months)	48.1	47.1	46.8	45.7	13	0.132
Age	6.34	6.56	6.83	6.88	2.25	0.427

Note: We construct characteristics at the bank level by averaging the characteristics of all its borrowers (weighted by loan shares) for each bank-year observation in our loan-level data. Columns (1)–(4) report the average of these bank-level covariates for four quantiles of banks' income gap. All variables are demeaned with respect to the year of observation. The fifth column reports the standard deviation of the variable summarized in each row. We also estimate univariate regressions of each of these covariates on banks' income gap. The sixth column reports the p-value on the income gap estimate. Standard errors are clustered at the bank level.

Table 15
The impact of income gap on lending within borrowers.

	$\Delta L_{i\to j,t}$					
	All loans			Loans maturing during the year		
	All firms	Firms with multiple banks		All firms	Firms with multiple banks	
	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Gap}_{it-1} \times \Delta\text{FedFunds}_t$	2.9**	2.9*	3.7***	7.3**	8.1**	10***
	(2.1)	(1.9)	(2.7)	(2.1)	(2.1)	(2.9)
Observations	478,955	435,496	435,496	159,347	141,013	141,013
Borrowers	23,147	15,404	15,404	20,495	12,748	12,748
Lenders	543	525	525	521	487	487
BHC top-holders	136	134	134	133	132	132
FE	Year	Year	Firm × Year	Year	Year	Firm × Year
Adj. R^2	0.54	0.53	0.68	0.08	0.07	0.40

Note: This table estimates
$\Delta L_{i\to j,t} = \alpha(\text{gap}_{it-1} \times \Delta\text{Fed Funds}_t) + \sum_{x\in Control} \gamma_x (x_{it-1} \times \Delta\text{Fed Funds}_t)$
$+ \phi.\text{gap}_{it-1} + \mu.\text{ttm}_{ijt} + \delta_{jt} + \epsilon_{it}$
where $L_{i\to j,t}$ denotes the outstanding loans from bank i to firm j in year t, $\Delta L_{i\to j,t}$ is the symmetric growth rate of $L_{i\to j,t}$ (see Section 2.1.2). tttm$_{ijt}$ is the average time to maturity, in years, of all outstanding loans from bank i to firm j in year t. x_{it-1} corresponds to the bank-level controls used in our BHC-level analysis (Log of assets, Equity to assets ratio, % Local ARM and Local HHI). δ_{jt} are firm-year fixed effects. Standard errors are two way clustered at the bank and firm level. Columns (1)–(3) include all loans. Columns (4)–(6) restrict the sample to loans with a remaining maturity lower than one year. Columns (1) and (4) do not include the firm-year fixed effects (δ_{jt}). Columns (2) and (5) are similar to (1) and (4), but restrict the sample to firms borrowing from multiple banks. Columns (3) and (6) include firm-year fixed effects.

x_{it-1} corresponds to the bank-level controls used in our BHC-level analysis (Log of assets, Equity to assets ratio, % Local ARM and Local HHI). δ_{jt} are firm-year fixed effects. In the presence of these fixed-effects, α is effectively identified by comparing how loan supply responds to changes in the Fed Funds rate for two banks with different income gap *lending to the same firm*.

Table 15 reports estimates of α in Eq. (4). Columns (1)–(3) include all loans. Columns (4)–(6) restrict the sample to loans with a remaining maturity lower than one year. It is natural to focus on these loans: these firms are likely to need to roll over these loans in the coming year and therefore constitute a natural sample to study the transmission of monetary policy to bank lending. Columns (1) and (4) do not include the firm-year fixed effects (δ_{jt}). Columns (2) and (5) are similar to (1) and (4), but restrict the sample to firms borrowing from multiple banks. Columns (3) and (6) include firm-year fixed effects. Standard errors are two way clustered at the bank and firm level.

The estimate of α is statistically significant at the 10% confidence level in columns (2), at the 5% level in columns (1), (4) and (5) and at the 1% in column (3) and (6), when we include firm-year fixed effects. Quantitatively, the magnitude of the estimated α is similar to the BHC-level estimate in Table 7. When we focus on firms more likely to have high loan demand (columns (4)–(6) where we restrict the sample to loans maturing within the coming year), the estimated α becomes larger (OLS estimate of 8.1; fixed effect estimates of 10). Interestingly, when restricting the sample to the same set of firms with multiple banks, the inclusion of the firm-year fixed effects lead to a small increase in the estimated coefficient relative to the OLS estimate: from 2.9 to 3.7 when using all loans in the sample; from 7.3 to 10 when restricting the sample to loans maturing during the year. This result is standard in the banking literature (Iyer et al., 2014; Jiménez et al., 2012; Khwaja and Mian, 2008). It rejects the hypothesis that banks with larger income gap tend to lend to firms whose loan demand is more sensitive to changes in the Fed Funds rate.

4.3. Real effects

In the presence of frictions in the credit market, credit supply shocks may have real effects on banks' customers: when credit from a bank dries out, the bank's customers may not be able to find alternative sources of funding in the short-run, which may impair their ability to invest. The findings in Sections 3.4 and 4.2 establish that when the Fed Funds rate decreases, banks with a larger income gap are unable to expand lending as much as other banks. In this section, we exploit our loan-level dataset to investigate whether these credit supply shocks lead to such real effects.

We start from a standard linear investment equation and augment it to include the credit supply shock faced by firm i in year t:

$$\frac{\text{capex}_{it}}{\text{assets}_{it-1}} = \omega_i + \delta_t + \sum_{k=0}^{1} \alpha_k (\text{gap}_{it-1} \times \Delta \text{Fed Funds}_{t-k}) + \beta . \frac{\text{cash-flows}_{it}}{\text{assets}_{it-1}} + \gamma \frac{\text{ME}_{it-1}}{\text{BE}_{it-1}} + \rho . \text{size}_{it-1} + \sum_{k=0}^{1} \theta_{xk} (x_{it-1} \times \Delta \text{Fed Funds}_{t-k}) + \sum_{x \in \text{Bank Control}} \mu_x . x_{it-1} + \phi . \text{gap}_{it-1} + \epsilon_{it} \tag{5}$$

Banking relationships are mostly built on information exchange between borrowers and their lead arranger. As a result, we define gap_{it-1} as the income gap of firm's i lead arranger. Similarly, the bank controls we include (Log of assets, Equity to assets ratio, % Local ARM and Local HHI) correspond to the controls for firm's i lead arranger and are described in Appendix A. We use three firm-level controls: cash-flows to lagged assets, the ratio of market equity value to book equity value ($\frac{\text{ME}}{\text{BE}}$), and 10 deciles of lagged assets (size)). Eq. (5) includes both year and firm fixed-effects. Standard errors are two way clustered at the firm and year level. To estimate Eq. (5), we restrict the sample to firms with accounting information in Compustat. To match the reporting schedule of their banks, we only include firms with fiscal year end in December. Appendix Table C.5 confirms the evidence of Section 4.2 on this restricted sample of borrowers. Finally, note that Eq. (5) allows for a one year lag in the response of investment to the credit supply shock induced by banks' income gap.

As is standard in the credit supply literature, the identification of real effects (Eq. (5)) requires an assumption stronger than the identification of credit supply shocks (Eq. (4)): Eq. (5) can only be estimated on firm-level data, which prevents the inclusion of firm-year fixed effects as in Eq. (4). The assumption required for the identification of $\alpha_0 + \alpha_1$ is that firms with investment opportunities sensitive to changes in the Fed Funds rate do not borrow from banks with a systematically different income gap. Sections 4.1 and 4.2 offered evidence consistent with such an absence of sorting. Besides, Eq. (5) controls for standard determinants of corporate investment (market-to-book ratio, cash-flows, and size deciles) and include both year and firm fixed-effects.

Columns (1)–(3) of Table 16 reports estimates of Eq. (5) when we use change in total debt divided by lagged assets as a dependent variable. These regressions test whether the credit supply shock experienced by a firm's lead arranger has a significant effect on the firm's total borrowing. Column (1) does not include any control beyond the year and firm fixed-effects. Column (2) includes the firm controls. Column (3) adds controls for lead arranger's characteristics. The last two rows of Table 16 reports the point estimate for $\alpha_0 + \alpha_1$, as well as a p-value for a test of significance of $\alpha_0 + \alpha_1$. Across these three specifications, $\alpha_0 + \alpha_1$ is positive and statistically significant at the 1% confidence level: when the Fed Funds rate increase, a firm borrowing from a lead arranger with a larger income gap will typically experience a relative increase in total debt. This finding is consistent with the hypothesis that firms cannot easily substitute loans from their main lender with other sources of financing, at least in the short-run (e.g. Khwaja and Mian, 2008 or Iyer et al., 2014). Quantitatively, consider two identical firms: firm 1 borrows from a bank whose income gap is higher than the income gap of firm2's bank by 0.18 (the in-sample standard deviation in income gap). Following a 100 bps increase in the Fed Funds rate in year t, the ratio of change in total debt to lagged assets of firm 1 will be higher than that of firm 2 by about 0.0036 at the end of year $t+1$. This effect corresponds to about 5% of the in-sample standard deviation of this ratio.

Column (4)–(6) are similar to column (1)–(3), but use the ratio of capital expenditures to lagged assets as a dependent variable. Again, across all specifications, $\alpha_0 + \alpha_1$ is positive and statistically significant at the 5% confidence level: the increase in debt levels documented in column (1)–(3) leads to a significant increase in investment. This finding is consistent with the hypothesis that firms are financially constrained: in the short-run, firms can only imperfectly substitute loans from their lead arrangers with other sources of financing so that the credit supply shocks experienced by their main lender affects their investment behavior. Quantitatively, consider two identical firms again: firm 1 borrows from a bank whose income gap is higher than the income gap of firm2's bank by 0.18. Following a 100 bps increase in the Fed Funds rate, the ratio of capital expenditures to lagged assets of firm 1 will be higher than that of firm 2 by about 0.0014 at the end of year $t+1$. This effect corresponds to approximately 2% of the in-sample standard deviation of this ratio.

One notable difference between our approach and Khwaja and Mian (2008) is that the aggregate shock we consider (yearly changes in Fed Funds rate) is partially anticipated. To make our analysis closer to Khwaja and Mian (2008), we estimate Eq. (5) but replace the realized change in Fed Funds rate (ΔFed Funds_{t-k}) with its surprise component defined in Section 2.1.3. Table 17 shows that our results are qualitatively similar when using the surprise components of changes in the Fed Funds rate. Quantitatively, the effect on corporate investment is three times larger in this specification relative to the specification in columns (4)–(6) of Table 16.

Table 16
Real effects.

	$\frac{\Delta\text{Debt}_{it}}{\text{Assets}_{it-1}}$			$\frac{\text{capex}_{it}}{\text{Assets}_{it-1}}$		
	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Gap}_{it-1} \times \Delta\text{FedFunds}_t$	0.53**	0.89***	0.83**	0.43***	0.35*	0.39*
	(2.3)	(3.6)	(2.3)	(2.7)	(2)	(1.8)
$\text{Gap}_{it-1} \times \Delta\text{FedFunds}_{t-1}$	1.2***	1.3***	1.2***	0.44**	0.46	0.4
	(5.1)	(2.8)	(2.8)	(2.2)	(1.5)	(1.2)
Gap_{it-1}	−0.00098	0.018**	0.01	−0.00094	−0.002	−0.0036
	(−0.14)	(2.2)	(0.98)	(−0.24)	(−0.68)	(−0.76)
$\text{Cash-flows}_{it}/\text{assets}_{it-1}$		0.045*	0.045*		0.092***	0.091***
		(1.7)	(1.7)		(13)	(13)
$\text{ME}_{it-1}/\text{BE}_{it-1}$		0.0039***	0.0039***		0.0039***	0.004***
		(4.1)	(4.1)		(5.5)	(5.8)
Bank controls	No	No	Yes	No	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	38,318	23,379	23,161	38,318	23,379	23,161
Adj. R^2	0.15	0.17	0.18	0.67	0.77	0.77
Sum of gap coefficients	1.7	2.1	2	0.86	0.81	0.78
p-value of gap coefficients	0	0	0	0	0.01	0.02

Note: This table estimates for firm i in year t
$\frac{Y_{it}}{assets_{it-1}} = \omega_i + \delta_t + \sum_{k=0}^{1} \alpha_k (\text{gap}_{it-1} \times \Delta\text{Fed Funds}_{t-k}) + \beta . \frac{\text{cash-flows}_{it}}{assets_{it-1}} + \gamma \frac{\text{ME}_{it-1}}{\text{BE}_{it-1}} + \rho.\text{size}_{it-1}$
$+ \sum_{k=0}^{1} \theta_{xk} (x_{it-1} \times \Delta\text{Fed Funds}_{t-k}) + \sum_{x \in \text{Bank Controls}} \mu_x . x_{it-1} + \phi.\text{gap}_{it-1} + \epsilon_{it}$
Y_{it} is either the yearly change in total debt from year $t-1$ to t (columns (1)–(3)) or capital expenditures in year t (column (4), (5) and (6)). The bank controls x are measured for firm i's lead arranger and correspond to log of assets, the equity to asset ratio, local % ARM, and local HHI. Size is defined as ten deciles of lagged assets. $\frac{ME}{BE}$ corresponds to the market value of equity divided by the book value of equity. All specifications include year and firm fixed-effects. Columns (1) and (4) do not include any controls except for year and firm fixed-effects; columns (2) and (5) include the firm-level controls; columns (3) and (6) include bank-level controls x. Standard errors are two-way clustered at the firm and bank level. "Sum of gap coefficients" reports the estimate for $\alpha_0 + \alpha_1$. p-value of gap coefficients corresponds to the p-value of a test of significance for $\alpha_0 + \alpha_1$.

Table 17
Real effects: surprise changes in the Fed Funds rate.

	$\frac{\Delta\text{Debt}_{it}}{\text{Assets}_{it-1}}$			$\frac{\text{capex}_{it}}{\text{Assets}_{it-1}}$		
	(1)	(2)	(3)	(4)	(5)	(6)
$\text{Gap}_{it-1} \times \Delta\text{FedFunds}_t^{\text{surprise}}$	2.6***	2.7***	2.5**	0.53	0.48	0.95*
	(3.1)	(2.9)	(2.1)	(1.2)	(0.96)	(1.7)
$\text{Gap}_{it-1} \times \Delta\text{FedFunds}_{t-1}^{\text{surprise}}$	1.9*	3.8***	4.2**	2.5***	2.8***	3.5***
	(1.9)	(3)	(2.5)	(5.2)	(3.9)	(3)
Gap_{it-1}	0.011	0.021**	0.021	0.0095***	0.0095***	0.014**
	(1.6)	(2.5)	(1.7)	(3)	(3.4)	(2.2)
$\text{Cash-flows}_{it}/\text{assets}_{it-1}$		0.034	0.034		0.078***	0.077***
		(1)	(1)		(8.9)	(8.8)
$\text{ME}_{it-1}/\text{BE}_{it-1}$		0.0024	0.0024		0.0034***	0.0034***
		(1.5)	(1.5)		(3.6)	(3.8)
Bank controls	No	No	Yes	No	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	20,848	16,413	16,349	20,848	16,413	16,349
Adj. R^2	0.21	0.22	0.22	0.78	0.81	0.81
Sum of gap coefficients	4.4	6.5	6.7	3	3.3	4.4
p-value of gap coefficients	0	0	0	0	0	0

Note: This table estimates for firm i in year t
$\frac{Y_{it}}{assets_{it-1}} = \omega_i + \delta_t + \sum_{k=0}^{1} \alpha_k (\text{gap}_{it-1} \times \Delta\text{Fed Funds}_{t-k}^{\text{surprise}}) + \beta . \frac{\text{cash-flows}_{it}}{assets_{it-1}} + \gamma \frac{\text{ME}_{it-1}}{\text{BE}_{it-1}} + \rho.\text{size}_{it-1}$
$+ \sum_{k=0}^{1} \theta_{xk} (x_{it-1} \times \Delta\text{Fed Funds}_{t-k}^{\text{surprise}}) + \sum_{x \in \text{Bank Controls}} \mu_x . x_{it-1} + \phi.\text{gap}_{it-1} + \epsilon_{it}$
Y_{it} is either the yearly change in total debt from year $t-1$ to t (columns (1)–(3)) or capital expenditures in year t (columns (4), (5) and (6)). The bank controls x are measured for firm i's lead arranger, and correspond to log of assets, the equity to asset ratio, local % ARM and local HHI. Size is defined as ten deciles of lagged assets. $\frac{ME}{BE}$ corresponds to the market value of equity divided by the book value of equity. $\Delta\text{Fed Funds}_{t-k}^{\text{surprise}}$) is the difference between the realized Fed Funds rate in the last month of year $t-k$ and the predicted rate for that month in the first month of year $t-k$, calculated using the 12 months Fed Funds future. All specifications include year and firm fixed-effects. Columns (1) and (4) do not include any controls except for year and firm fixed-effects; columns (2) and (5) include the firm-level controls; columns (3) and (6) include bank-level controls x. Standard errors are two-way clustered at the firm and bank level. "Sum of gap coefficients" reports the estimate for $\alpha_0 + \alpha_1$. p-value of gap coefficients corresponds to the p-value of a test of significance for $\alpha_0 + \alpha_1$.

Table 18
Sample splits based on size, age and payout ratio.

		ΔInterest income (1)	ΔMarket value (2)	Δlog(C&I) (3)	Δlog(Total loans) (4)
Small	Sum of gap coefficients	0.05	1.6	3	1.5
	p-value of gap coefficients	0	0	0	0
	N	18,817	8222	19,031	19,099
Big	Sum of gap coefficients	0.06	1.6	0.14	0.65
	p-value of gap coefficients	0	0	0.88	0.25
	N	18,832	11,116	19,405	19,018
	Test of equality	0.84	0.96	0.029	0.22
Young	Sum of gap coefficients	0.05	2	1.7	1.3
	p-value of gap coefficients	0	0	0.1	0
	N	17,552	7459	18,077	17,776
Old	Sum of gap coefficients	0.05	0.85	0.87	0.6
	p-value of gap coefficients	0	0	0.36	0.28
	N	19,948	11,806	20,187	20,173
	Test of equality	0.97	0.037	0.53	0.36
Low dividend policy	Sum of gap coefficients	0.05	1.7	2.6	1.4
	p-value of gap coefficients	0	0	0.01	0.02
	N	18,999	8374	19,111	19,038
High dividend policy	Sum of gap coefficients	0.07	1.3	0.53	0.82
	p-value of gap coefficients	0	0	0.59	0.11
	N	18,424	10,882	19,078	18,864
	Test of equality	0.19	0.45	0.11	0.41

Note: This table estimates, on various sub-samples, the equation
$\Delta Y_{it} = \sum_{k=0}^{k=4} \alpha_k (\text{gap}_{it-1} \times \Delta\text{Fed Funds}_{t-k}) + \sum_{x \in Control} \sum_{k=0}^{k=4} \gamma_{x,k} (x_{it-1} \times \Delta\text{Fed Funds}_{t-k})$
$+ \sum_{k=0}^{k=4} \eta_k \Delta Y_{it-1-k} + \phi.\text{gap}_{it-1} + \sum_{x \in Control} \mu_x . x_{it-1} + \delta_t + \epsilon_{it}$
ΔY is the quarterly change in net interest income divided by lagged total assets (column (1)), quarterly change in market value divided by lagged total assets (column (2)), quarterly change in log C&I lending (Column (3)), quarterly change in log total lending (column (4)). The controls x are log of assets$_{it-1}$, equity to asset ratio $_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$. See Appendix A for details on the construction of these variables. The regression also includes quarter fixed effects. Standard errors are two-way clustered at the BHC and quarter level. "Sum of gap coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4} \alpha_k$. "Sum of repricing gap coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4} \tilde{\alpha}_k$. *p*-value corresponds to the *p*-value of a test of significance for the estimated coefficients. Small (resp. Big) corresponds to the sample of firms with total assets below (resp. above) the in-sample mean total assets. Young (resp. old) corresponds to the sample of firms whose age is below (resp. above) the in-sample mean age, where age is defined using a BHC opening date `rssd9950`. Low dividend policy (resp. high dividend policy) corresponds to the sample of firms whose payout ratio (defined as the sum of end of year `bhck4598` (total preferred dividend) and `bhck4460` (total cash dividend) normalized by the BHC annual net income) is below (resp. above) the in-sample mean payout ratio.

5. Discussion

5.1. Further evidence of a bank lending channel

Our main results are consistent with a standard bank lending channel, whereby external financing for banks is costly, and positive income shocks alleviate constraints on lending. In this section, we offer further evidence consistent with this interpretation. We follow the empirical corporate finance literature and split our sample based on ex-ante characteristics that likely correlate with financial constraints. We then show that the effect estimated in Table 6, Table 5, and Table 7 are stronger for banks that are more likely to be financially constrained.

Precisely, we re-estimate Eq. (2) separately for banks that are above/below the in-sample (1) median size (defined as total banking assets) (2) median age (defined as the bank's opening date `rssd9950`) (3) median dividend payout ratio. Table 18 reports these sample splits. Across all specifications, the sum of gap coefficients for interest income is strikingly similar (at about 0.06): when the Fed Funds rate increases, banks with a higher income gap experience a relative increase in net interest income, irrespective of their size, age or payout ratio. Table 18 also shows that, following an increase in the Fed Funds rate, the increase in lending for banks with higher income gap is larger for smaller banks, younger banks, or banks that pay fewer dividends. For instance, the estimated sum of gap coefficients for lending is (a) 1.5 for small banks (*p*-value < 0.01) vs. 0.65 for large banks (*p*-value of 0.25) (b) 1.3 for young banks (*p*-value of 0.01) vs. 0.6 for old banks (*p*-value of 0.28 for large banks) (c) 1.4 for banks with low payout ratios (*p*-value of 0.02) vs. 0.82 for banks with higher payout ratios (*p*-value of 0.11) (last column of Table 18). Note that these differences in coefficients between the various subgroups are not statistically significant: tests for equality of the coefficients fail to reject the null of equality in most cases. Qualitatively, however, Table 18 provides a consistent finding: to the extent that small banks, young banks and banks with low payout ratios are more likely to be financially constrained, this table is consistent with the estimated effect of income gap emanating from a bank lending channel.

Table 19
Short vs. long-term rates.

	ΔInterest income (1)	ΔMarket value (2)	Δlog(C&I) (3)	Δlog(Total loans) (4)
$Gap_{it-1} \times \Delta FedFunds_t$	0.021***	0.28	−0.19	0.39
	(2.6)	(0.7)	(−0.23)	(0.97)
$Gap_{it-1} \times \Delta FedFunds_{t-1}$	0.039***	0.88***	0.12	0.1
	(6)	(2.8)	(0.15)	(0.31)
$Gap_{it-1} \times \Delta FedFunds_{t-2}$	−0.001	0.39	0.61	0.59
	(−0.21)	(1.3)	(0.77)	(1.4)
$Gap_{it-1} \times \Delta FedFunds_{t-3}$	0.0044	0.16	2.5***	0.39
	(0.75)	(0.67)	(3.5)	(1.1)
$Gap_{it-1} \times \Delta FedFunds_{t-4}$	−0.0027	0.039	−1.5*	0.13
	(−0.46)	(0.19)	(−1.9)	(0.38)
$Gap_{it-1} \times \Delta 10years_t$	−0.0013	0.21	−0.5	−1.2***
	(−0.3)	(1)	(−0.69)	(−3.4)
$Gap_{it-1} \times \Delta 10years_{t-1}$	−0.0063	0.025	0.54	−0.9**
	(−1.4)	(0.088)	(0.72)	(−2.4)
$Gap_{it-1} \times \Delta 10years_{t-2}$	0.0027	−0.28	0.74	−0.3
	(0.58)	(−1.1)	(1.1)	(−0.94)
$Gap_{it-1} \times \Delta 10years_{t-3}$	0.0039	−0.34	0.13	−0.18
	(0.86)	(−1)	(0.18)	(−0.43)
$Gap_{it-1} \times \Delta 10years_{t-4}$	0.002	−0.12	−0.4	0.34
	(0.44)	(−0.57)	(−0.6)	(0.97)
Obs.	34,141	17,581	34,922	34,625
Adj. R^2	0.11	0.32	0.09	0.21
Sum of coefficients: Fed Funds	0.06	1.8	1.5	1.6
p-value	0	0	0.12	0
Sum of coefficients: 10 years	0	−0.5	.5	−2.3
p-value	0.93	0.55	0.79	0.04

Note: This table estimates
$\Delta Y_{it} = \sum_{k=0}^{k=4} \alpha_k (\text{gap}_{it-1} \times \Delta \text{Fed Funds}_{t-k}) + \sum_{x \in Control} \sum_{k=0}^{k=4} \gamma_{x,k} (x_{it-1} \times \Delta \text{Fed Funds}_{t-k}) +$
$\sum_{k=0}^{k=4} \sigma_k (\text{gap}_{it-1} \times \Delta 10years_{t-k})$
$+ \sum_{x \in Control} \sum_{k=0}^{k=4} \theta_{x,k} (x_{it-1} \times \Delta 10years_{t-k}) + \sum_{k=0}^{k=4} \eta_k \Delta Y_{it-1-k} + \phi . \text{gap}_{it-1} + \sum_{x \in Control} \mu_x . x_{it-1} + \delta_t + \epsilon_{it}$
ΔY is the quarterly change in net interest income divided by lagged total assets (column (1)), quarterly change in market value divided by lagged total assets (column (2)), quarterly change in log C&I lending (column (3)), quarterly change in log total lending (column (4)). The controls x are log of assets$_{it-1}$, equity to asset ratio$_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$. See Appendix A for details on the construction of these variables. $\Delta 10years_{t-k}$ corresponds to the quarterly change in the 10-year yields in quarter t-k. The regression also includes quarter fixed effects. Standard errors are two-way clustered at the BHC and quarter level. "Sum of gap coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4} \alpha_k$. We also report the p-value of a test of significance for $\sum_{k=0}^{k=4} \alpha_k$.

5.2. Credit multiplier

We can also use our bank-level analysis to recover the credit multiplier faced by BHCs in our sample. We re-estimate Eq. (2) using the quarterly *increase* in total loans divided by lagged assets as our dependent variable. This dependent variable allows us to directly interpret the sum of the interacted coefficients, $\sum_{k=0}^{k=4} \alpha_k$, as the \$ effect on lending of a \$1 increase in interest-sensitive income, i.e. gap $\times \Delta r$. This specification leads to an estimate for $\sum_{k=0}^{k=4} \alpha_k$ of 0.76. This estimate is significantly different from 0 at the 1% confidence level. Thus, a \$1 increase in gap $\times \Delta r$ leads to an increase in total loans by \$.76. At the same time, Table 5 shows that the same \$1 increase in gap $\times \Delta r$ generates an increase in total earnings of about \$0.06. Under our identifying assumption, these findings imply a credit multiplier of 0.76/0.06=12.6: a \$1 increase in income leads to an increase in lending by \$12.6. This credit multiplier is slightly lower than what bank leverage suggests. In our sample, the average asset-to-equity ratio is 13.1. Given that net income also represents additional reserves, the credit multiplier we obtain is consistent with existing reserve requirements in the US, which are around 10 for large banks.

5.3. Cash flow vs. balance sheet channel

An alternative interpretation of our results is that the income gap acts as a noisy measure of the *duration gap*. The duration gap measures how *the value* of banks' assets responds to changes in the Fed Funds rate, relative to *the value* of their liability. When the duration gap is not zero, changes in the Fed Funds rate affect the value of a bank's equity, which may, in turn, affect the bank's financing capacity. For a bank with a positive duration gap, an increase in the Fed Funds rate increases equity value, which may allow this bank to raise more funds and lend more. This interpretation also relies on a failure of the Modigliani–Miller theorem for banks, but it goes through banks' *value* as opposed to banks' cash-flows. This mechanism is akin to a balance sheet channel, à la Bernanke and Gertler (1989), but for banks.

Table 20
Controlling for the repricing gap.

	ΔInterest income (1)	ΔMarket value (2)	Δlog(C&I) (3)	Δlog(Total loans) (4)
$Gap_{it-1} \times \Delta FedFunds_t$	0.01	0.25	0.57	−0.48
	(1.4)	(0.64)	(0.67)	(−1.1)
$Gap_{it-1} \times \Delta FedFunds_{t-1}$	0.026***	1.2***	0.47	0.49
	(3.5)	(4.5)	(0.49)	(1.4)
$Gap_{it-1} \times \Delta FedFunds_{t-2}$	0.0082*	0.041	0.048	0.25
	(1.9)	(0.14)	(0.04)	(0.64)
$Gap_{it-1} \times \Delta FedFunds_{t-3}$	0.01	0.41	3***	1.1***
	(1.3)	(1.3)	(3.7)	(2.9)
$Gap_{it-1} \times \Delta FedFunds_{t-4}$	−0.0064	0.019	−1.7**	−0.43
	(−0.67)	(0.072)	(−2.3)	(−1.1)
$RepricingGap_{it-1} \times \Delta FedFunds_t$	−0.0022**	−0.025	0.16**	0.022
	(−2.1)	(−0.84)	(2)	(0.41)
$RepricingGap_{it-1} \times \Delta FedFunds_{t-1}$	−0.003***	0.028*	−0.06	−0.027
	(−2.7)	(1.7)	(−0.65)	(−0.76)
$RepricingGap_{it-1} \times \Delta FedFunds_{t-2}$	0.00071	−0.069*	−0.1	−0.036
	(1.1)	(−1.8)	(−1.6)	(−0.6)
$RepricingGap_{it-1} \times \Delta FedFunds_{t-3}$	0.00063	0.011	0.051	−0.0064
	(1)	(0.5)	(0.72)	(−0.14)
$RepricingGap_{it-1} \times \Delta FedFunds_{t-4}$	0.00031	0.032	−0.0012	−0.003
	(0.45)	(1.3)	(−0.018)	(−0.067)
Obs.	20,319	12,430	20,610	20,414
Adj. R^2	0.13	0.32	0.09	0.26
Sum of gap coefficients	0.048	1.970	2.317	0.981
p-value of gap coefficients	0.000	0.000	0.030	0.058
Sum of repricing gap coefficients	−0.004	−0.023	0.052	−0.051
p-value of repricing gap coefficients	0.003	0.435	0.586	0.416

Note:
$\Delta Y_{it} = \sum_{k=0}^{k=4} \alpha_k(\text{gap}_{it-1} \times \Delta\text{Fed Funds}_{t-k}) + \phi.\text{gap}_{it-1} + \sum_{k=0}^{k=4} \tilde{\alpha}_k(\text{repricing gap}_{it-1} \times \Delta\text{Fed Funds}_{t-k}) + \tilde{\phi}.\text{repricing gap}_{it-1}$
$+ \sum_{x\in Control} \sum_{k=0}^{k=4} \gamma_{x,k}(x_{it-1} \times \Delta\text{Fed Funds}_{t-k}) + \sum_{k=0}^{k=4} \eta_k \Delta Y_{it-1-k} + \sum_{x\in Control} \mu_x.x_{it-1} + \delta_t + \epsilon_{it}$
ΔY is the quarterly change in net interest income divided by lagged total assets (column (1)), quarterly change in market value divided by lagged total assets (column (2)), quarterly change in log C&I lending (column (3)), quarterly change in log total lending (column (4)). The controls x are log of assets$_{it-1}$), equity to asset ratio $_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$. See Appendix A for details on the construction of these variables. The regression also includes quarter fixed effects. Standard errors are two-way clustered at the BHC and quarter level. "Sum of gap coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4} \alpha_k$. "Sum of repricing gap coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4} \tilde{\alpha}_k$. p-value corresponds to the p-value of a test of significance for the estimated coefficients.

We offer two ways to disentangle these interpretations. Our first approach exploits the fact that the effect of interest rates on banks' value partly comes from long-term rates. The present value at date t of a safe cash-flow C at time $t+T$ is $\frac{C}{(1+r_{t,T})^T}$, where $r_{t,T}$ is the risk-free yield between t and $t+T$. As long as there are shocks to long-term yields that are not proportional to shocks to short-term yields, we can identify the balance sheet channel separately from the cash-flow channel we emphasize in the paper. Consider, for instance, an increase in long-term rates, holding short-term rates constant. If our income gap measure affects lending through asset values and not through cash-flows, firms with lower income gap should lend relatively less following this long-term interest rates increase. By contrast, if cash-flows drive our results, this increase in long-term interest rates should not have a differential effect on loan growth of high vs. low-income gap BHCs.

We test this hypothesis by adding to our benchmark specification, Eq. (2), additional interaction terms between banks' income gap and five lags of changes in long-term interest rates, measured as yields on ten years treasuries. Table 19 reports the estimation results for different dependent variables (interest income in column (1)), market value of equity in column (2), C&I lending growth in column (3) and total lending growth in column (4)). The sum of coefficients on the interaction of banks' income gap and lags of changes in long-term interest rates is insignificant in column (1)–(3), and significant at the 5% confidence level in column (4), but *negative* (−2.3). In contrast, the sum of coefficients on the interaction of banks' income gap and lags of changes in the Fed Funds rate remains significant and quantitatively similar to our baseline results. These findings are not consistent with the hypothesis that these baseline results capture a balance sheet channel.

Our second approach exploits the measure of BHC repricing/maturity gap developed in English et al. (2018). The repricing/maturity gap is the mismatch between the maturity or repricing time of bank assets and that of their liabilities. The measure is based on granular information on the maturity and repricing time of assets and liabilities that are available in the Call Reports starting in 1997:Q2.[10] While the repricing/maturity gap is not the duration gap, it should have a stronger

[10] We follow closely (English et al., 2018) (Section 3.1.1 and Appendix C in the online appendix) to construct the maturity/repricing gap at the BHC level. Precisely, let j indexes the 26 interest-earning asset categories reported on the Call Report by remaining maturity or next repricing date. A^j_{ibt} is the dollar

correlation with the duration gap than the income gap. As a result, if banks income gap affects lending through shocks to equity value, we expect that controlling for the interaction of the repricing/maturity gap and changes in Fed Funds rate would drive our main effect to 0.

We implement this test in Table 20. We add to our benchmark Eq. (2) interaction terms between the repricing/maturity gap – our proxy for the duration gap – and five lags of changes in Fed Funds rates. The bottom part of Table 20 reports the *p*-value on the sum of these interactions as well as the *p*-values on the sum of the interactions between banks' income gap and changes in the Fed Funds rate. Again, we use as dependent variables interest income (column (1)), market value of equity (column (2)), C&I lending growth (column (3)) and total lending growth (column (4)). Table 20 confirms the interpretation of our main results in terms of a cash-flow channel. Over the 1997–2013 period, the sum of gap coefficients remains significantly different from 0 in all specifications (*p*-values lower than 0.01 in column 1 and 2, 0.03 in column 3 and 0.058 in column 4); in addition, the estimated sum of gap coefficients are quantitatively close to our baseline estimates (1.7 vs. 2.3 for C&I lending and 1.1 vs. 0.98 for total lending). In contrast, over this sample period, the repricing-gap is not strongly predictive of how lending responds to changes in Fed Funds rate (*p*-values on sum of repricing gap coefficients in columns 3 and 4 for C&I and total lending is 0.58 and 0.41).

6. Conclusion

This paper builds on the fact that banks retain significant exposure to interest rate risk through their asset and liability composition. Our sample consists of quarterly data on US bank holding companies from 1986 to 2013. We measure a bank's income exposure to changes in the Fed Funds rate through its income gap, which is defined as the \$ amount of a bank's assets that reprice or mature within year minus the \$ amount of liabilities that reprice or mature within a year. The average income gap in our sample is 12.5% of total assets (28% in asset-weighted terms), but it exhibits significant cross-sectional variations. Unsurprisingly, banks' income gap strongly predicts how their profits respond to changes in the Fed Funds rates.

Our main finding is that banks' income gap also affects the transmission of monetary policy to bank lending. When the Fed Funds rate increases by 100 basis point (bps), a BHC at the 75th percentile of the income gap distribution contracts total lending over the following year by 0.27 percentage point (ppt) less than a bank at the 25th percentile. This estimate must be compared to average quarterly loan growth, which equals 1.6% in our sample. This finding is robust to controlling for other determinants of monetary policy transmission to bank lending. Using loan-level data, we show that the endogenous matching of banks to firms does not drive this result. We also show that the credit supply shock we uncover leads to significant real effects on corporate investment. Further analyses confirm our preferred interpretation: the increase in cash-flows of high-income gap banks that results from an increase in the Fed Funds rate drives the observed growth in lending; the increase in equity value does not. In other words, our results are consistent with a bank lending channel and not with a balance sheet channel.

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Appendix A. Variable definitions

This section describes the construction of all variables. i indexes a bank, t for the quarter.

A1. Bank-level variables

This section gathers the variables constructed using the Consolidated Financial Statements of Bank Holding Companies (form FR Y-9C). Note that flow variables (e.g., interest and non-interest income, earnings) are defined each quarter "year to date". Hence, each time we refer to a flow variable, we mean the *quarterly*, not year-to-date, flow. To transform a year-to-date variable into a quarterly one, we take the variable as it is for the first quarter of each year. For each quarter $q = 2, 3, 4$, we then take the difference in the year-to-date variable between q and $q - 1$.

amount in asset category j reported by commercial bank i, belonging to BHC b, in quarter t. A^{IE}_{ibt} it denotes bank i's total interest-earning assets. m^j_A is the average repricing/maturity period (in months) for asset category j, as defined in English et al. (2018) (midpoint of category j's maturity or repricing range reported on the Call Report). Similarly, L^j_{ibt} is the dollar amount of liability item j, L_{ibt}t are bank i's total liabilities and m^L_j denotes the average repricing/maturity period (in months) for liability item j. We then define the maturity/repricing gap for bank b as:

$$\text{Repricing Gap}_{bt} = \frac{\sum_{i\in b}\sum_j m^j_A A^j_{ibt}}{\sum_{i\in b} A^{IE}_{ibt}} - \frac{\sum_{i\in b}\sum_j m^j_L L^j_{ibt}}{\sum_{i\in b} L_{ibt}}$$

- Δ **Interest**$_{it}$: Change in interest income = [interest income (bhck4107) at t + interest expense (bhck4073) at $t-1$ – interest income (bhck4107) at $t-1$ – interest expense (bhck4073) at t]/(total assets (bhck2170) taken in $t-1$]. Note that bhck4073 and bhck4107 have to be converted from year-to-date to quarterly as explained above.
- Δ **Non interest**$_{it}$: Change in non interest income = [non interest income (bhck4079) at t – non interest income (bhck4079) at $t-1$]/(total assets (bhck2170) taken in $t-1$]. Note that bhck4079 has to be converted from year-to-date to quarterly as explained above.
- Δ **Earnings**$_{it}$: Change in earnings = [earnings (bhck4340) at t – earnings (bhck4340) at $t-1$]/(total assets (bhck2170) taken in $t-1$]. Note that bhck4340 has to be converted from year-to-date to quarterly as explained above.
- Δ **Value**$_{it}$: Change in interest income = [Equity market value at t – equity market value at $t-1$]/(total assets (bhck2170) taken in $t-1$]. Equity market value is obtained for publicly listed banks after matching with stock prices from CRSP. It is equal to the number of shares outstanding (shrout) $\times$ the end-of-quarter closing price (absolute value of prc).
- Δ **log(C&I loans**$_{it}$**)**: commercial and industrial loan growth = log[C&I loans to US addressees (bhck1763) at t + C&I loans to foreign addressees (bhck1764) at t] – log[C&I loans to US addressees (bhck1763) at $t-1$ + C&I loans to foreign addressees (bhck1764) at $t-1$].
- Δ **log(Total loans**$_{it}$**)**: Total loan growth = log [Total loans (bhck2122) at t] – log[Total loans (bhck2122) at $t-1$].
- Δ **Earnings**$_{it}$: Change in earnings = [earnings (bhck4340) at t – earnings (bhck4340) at $t-1$]/(total assets (bhck2170) taken in $t-1$]. Note that bhck4340 has to be converted from year-to-date to quarterly as explained above.
- **Gap**$_{it-1}$: Income gap = [assets that reprice or mature within one year (bhck31970) − interest bearing deposits that reprice or mature within one year (bhck3296) − long term debt that reprices within one year (bhck3298) − long term debt that matures within one year (bhck3409) − variable rate preferred stock (bhck3408)]/total assets (bhck2170)
- **Equity**$_{it-1}$: Equity ratio = 1 − [total liabilities (bhck2948)/total assets (bhck2170)]
- **Size**$_{it-1}$: log (total assets (bhck2170))
- **Liquidity**$_{it-1}$: Liquidity ratio = [Available for sale securities (bhck1773)+ Held to Maturity Securities (bhck1754)]/total assets (bhck2170)
- **HHI**$_{it-1}$: for each US county, we first construct, using FDIC's Summary of Deposits data from 1986 onwards, the deposit HHI as the sum of the square market share of each commercial bank operating in this county; for each commercial bank, we then construct a deposit-weighted average of HHI across branches of this commercial bank; finally, at the BHC level, we construct a deposit weighted-average of the HHI values for the commercial banks that belong to this BHC.
- **Local** % **ARM** $_{it-1}$: we measure the fraction of Adjustable Rate Mortgages (ARM) in state-level mortgage issuances using an ancillary survey (the Monthly Interest Rate Survey (MIRS) – state level ARM share is available here: https://www.fhfa.gov/DataTools/Downloads/Pages/Monthly-Interest-Rate-Data.aspx). We then compute, for each commercial bank, a deposit-weighted average of the ARM share across the bank's branches. Finally, at the BHC level, we compute a deposit-weighted average of the ARM share across the commercial banks within the BHC. Note that MIRS starts in 1986 and that MIRS is missing information for 2008 and 2011. We use the 1986 ARM share for 1985. For 2008 and 2011, we use the ARM share for 2009 and 2011, respectively.
- **Maturity/repricing gap**$_{bt-1}$: we follow English et al. (2018) (Section 3.1.1 and Appendix C in the Online Appendix) to construct the maturity/repricing gap at the BHC level. Precisely, let j indexes the 26 interest-earning asset categories reported on the Call Report by remaining maturity or next repricing date. A^j_{ibt} is the dollar amount in asset category j reported by commercial bank i, belonging to BHC b, in quarter t. A^{IE}_{ibt} denotes bank i's total interest-earning assets. m^j_A is the average repricing/maturity period (in months) for asset category j, as defined in English et al. (2018) (midpoint of category j's maturity or repricing range reported on the Call Report). Similarly, L^j_{ibt} is the dollar amount of liability item j, L_{ibt}t are commercial bank i's total liabilities and m^L_j denotes the average repricing/maturity period (in months) for liability item j. We then define the maturity/repricing gap for bank b as:

$$\text{Repricing Gap}_{bt} = \frac{\sum_{i\in b}\sum_j m^j_A A^j_{ibt}}{\sum_{i\in b} A^{IE}_{ibt}} - \frac{\sum_{i\in b}\sum_j m^j_L L^j_{ibt}}{\sum_{i\in b} L_{ibt}}$$

A2. Times series variables

- ΔFed Funds$_t$: Quarterly change in "effective Federal Funds" rate in quarter t. Fed Funds rates are available monthly from the Federal Reserve's website: each quarter, we take the observation corresponding to the last month in the quarter. Thus, ΔFed Funds$_t$ corresponds to the difference between the effective Fed Funds rate in the last month of quarter t and the effective Fed Funds rate in the last month of quarter $t-1$.
- Δ10yrs$_t$: Change in the yield of the ten year Treasury securities in quarter t, available from the Federal Reserve's website.
- **Expected FF**$_t$: expected Fed Funds rate for end of year t. We measure it using the price on the twelve months Fed Funds future's contract (FF12) in January. We also use a quarterly measure of expected Fed Funds rate for end of quarter t by using the price on the 3 months Fed Funds future's contract (FF3) at the beginning of each quarter.

- ΔFed Funds$_t^{surprise}$: the surprise change in the Fed Funds rate for year t is defined as the difference between the realized change in the Fed Funds rate over the course of the year and the expected change in the Fed Funds rate. The expected change in the Fed Funds rate is defined as the difference between the expected Fed Funds rate at the end of the year (Expected FF$_t$) and the prevailing Fed Funds rate at the end of year $t-1$. We use a similar definition for the quarterly surprise change in the Fed Funds rate for quarter t: it is defined as the realized change in the Fed Funds rate over the course of the quarter and the expected change in the Fed Funds rate at the beginning of the quarter.

A3. Loan level variables

- $L_{i\to j,t}$ is the total outstanding loan amount, in \$, of loans made by bank i to firm j in year t
- $\Delta L_{i\to j,t}$ is the symmetric growth rate of total outstanding loans between t and $t+1$:

$$\Delta L_{i\to j,t} \equiv 2\frac{L_{i\to j,t+1} - L_{i\to j,t}}{L_{i\to j,t+1} + L_{i\to j,t}}$$

  This measure is bounded between -2 and 2. It accommodates initiations and terminations of lending relationships. We have also experimented specifications with changes in logs and obtained similar results.
- ttm$_{ijt}$: weighted-average time to maturity, in years, of all outstanding loans from bank i to firm j in year t. We use loan amounts as weights.

A4. Compustat variables

- Assets$_{it}$: total assets (item `at`).
- Cash-flows$_{it}$: operating cash-flows. It is defined as Income Before Extraordinary Items (item `ib`) plus Depreciation and Amortization (item `dp`).
- ME$_{it}$: market value of equity (item `mkvalt`).
- BE$_{it}$: book value of common equity (item `ceq`).

Appendix B. Time-series regressions

We provide alternative estimates using the methodology in Kashyap and Stein (2000) and Campello (2002).

B1. Methodology

We proceed in two steps. First, we run, *separately for each quarter*, the following regression:

$$\Delta Y_{it} = \gamma_t.gap_{it-1} + \mu_t'.controls_{it} + \epsilon_{it} \quad (6)$$

Table B.1
Time-series approach: profits.

	$\Delta Interest_{it}$					$\Delta Earnings_{it}$				
	All (1)	Small (2)	Big (3)	No hedge (4)	Some hedge (5)	All (6)	Small (7)	Big (8)	No hedge (9)	Some hedge (10)
$\Delta FedFunds_t$	0.013**	0.015**	−0.022	0.01	0.025**	0.031***	0.034***	0.032	0.053***	0.027*
	(2.2)	(2.5)	(−0.89)	(1.2)	(2.2)	(3.7)	(3.8)	(1.2)	(3.7)	(1.9)
$\Delta fedfunds_{t-1}$	0.028***	0.029***	0.024	0.032***	0.022*	0.026***	0.03***	0.019	0.015	0.059***
	(4.2)	(4.3)	(0.86)	(3.4)	(1.9)	(2.7)	(3)	(0.64)	(1)	(4.1)
$\Delta fedfunds_{t-2}$	0.0051	0.0072	−0.039	0.0027	0.013	−0.0087	−0.012	0.017	0.0018	−0.021
	(0.81)	(1.1)	(−1.5)	(0.3)	(1.1)	(−0.96)	(−1.3)	(0.6)	(0.12)	(−1.5)
$\Delta fedfunds_{t-3}$	0.01*	0.007	0.05*	0.013	−0.0038	0.012	0.01	−0.026	0.0038	0.015
	(1.7)	(1.2)	(2)	(1.4)	(−0.33)	(1.4)	(1.1)	(−0.96)	(0.26)	(1.1)
$\Delta fedfunds_{t-4}$	−0.0038	−0.0041	0.0069	−0.017**	−0.0018	0.014*	0.012	0.062**	0.012	0.0064
	(−0.72)	(−0.77)	(0.31)	(−2)	(−0.17)	(1.8)	(1.5)	(2.5)	(0.9)	(0.48)
N	93	93	93	63	63	93	93	93	63	63
ar2										
Sum of coefficients	0.05	0.05	0.01	0.04	0.05	0.07	0.07	0.1	0.08	0.08
p-value	0	0	0.46	0	0	0	0	0	0	0

Each quarter t, we first run the following regression:
$\Delta Y_{it} = \gamma_t.gap_{it-1} + \mu'.controls_{it} + \epsilon_{it}$
where ΔY_{it} is the quarterly change in net interest income divided by lagged total assets (columns (1)–(5)) and the quarterly change in total earnings divided by lagged total assets (columns (6)–(10)). $controls_{it}$ is a vector of control variables that include $\Delta Y_{it-1}, \ldots, \Delta Y_{it-4}$,log of assets$_{it-1}$), equity to asset ratio $_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$. We then estimate:

"Sum of coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4} \alpha_k$. p-value is the p-value from a significance test of the estimate of $\sum_{k=0}^{k=4} \alpha_k$.

Table B.2
Time-series approach: lending.

	Δlog(C&I loans)					Δlog(Total loans)				
	All (1)	Small (2)	Big (3)	No hedge (4)	Some hedge (5)	All (6)	Small (7)	Big (8)	No hedge (9)	Some hedge (10)
$\Delta FedFunds_t$	−0.037	0.21	−2.5	−0.66	0.78	−0.27	−0.4	0.11	−0.16	0.073
	(−0.04)	(0.22)	(−0.93)	(−0.58)	(0.49)	(−0.65)	(−0.87)	(0.1)	(−0.23)	(0.1)
$\Delta fedfunds_{t-1}$	0.55	0.64	−1.1	0.57	−0.036	−0.26	0.038	−1.9	0.082	0.63
	(0.53)	(0.6)	(−0.36)	(0.47)	(−0.021)	(−0.56)	(0.074)	(−1.6)	(0.11)	(0.85)
$\Delta fedfunds_{t-2}$	0.21	0.79	−5.8**	0.37	−1.1	0.82*	0.87*	0.16	0.12	0.79
	(0.22)	(0.77)	(−2)	(0.31)	(−0.64)	(1.8)	(1.8)	(0.14)	(0.17)	(1.1)
$\Delta fedfunds_{t-3}$	1.8*	1.3	7.4***	2.5**	3.6**	0.64	0.47	2.3**	0.44	0.49
	(1.9)	(1.3)	(2.7)	(2.1)	(2.2)	(1.5)	(1)	(2.2)	(0.61)	(0.68)
$\Delta fedfunds_{t-4}$	−1.4*	−1.3	−0.59	−2.8**	−0.34	0.082	0.095	−1.4	0.46	0.092
	(−1.7)	(−1.6)	(−0.24)	(−2.5)	(−0.22)	(0.22)	(0.23)	(−1.4)	(0.68)	(0.13)
N	93	93	93	63	63	93	93	93	63	63
ar2										
Sum of coefficients	1.1	1.6	−2.5	0.01	2.9	1	1.1	−0.67	0.93	2.1
p-value	0.25	0.12	0.37	0.99	0.08	0.02	0.03	0.54	0.2	0

Each quarter t, we first run the following regression:
$\Delta Y_{it} = \gamma_t.gap_{it-1} + \mu'.controls_{it} + \epsilon_{it}$
where ΔY_{it} is the quarterly change in log C&I lending (columns (1)–(5)) and total lending (columns (6)–(10)). $controls_{it}$ is a vector of control variables that include $\Delta Y_{it-1}, \ldots, \Delta Y_{it-4}$,log of assets$_{it-1}$), equity to asset ratio $_{it-1}$, Local % ARM$_{it-1}$ and Local HHI$_{it-1}$. We then estimate:
$\gamma_t = \sum_{k=0}^{k=4} \alpha_k.\Delta FedFunds_{t-k} + \text{quarter FE}_t + \epsilon_{it}$
"Sum of coefficients" reports the coefficient estimate for $\sum_{k=0}^{k=4} \alpha_k$. p-value is the p-value from a significance test of the estimate of $\sum_{k=0}^{k=4} \alpha_k$.

where ΔY_{it} is one of the dependent variable we use in Tables 5–7. $controls_{it}$ is a vector of control variables that include: $\Delta Y_{it-1}, \ldots, \Delta Y_{it-4}$, log of assets$_{it-1}$, equity to asset ratio$_{it-1}$, Local % ARM$_{it-1}$, and Local HHI$_{it-1}$. From this first step, we obtain a time-series for the sensitivity of ΔY to banks' income gap, γ_t.

In our second step, we regress γ_t on changes in the Fed Funds rate (current and last four quarters) and quarter fixed-effects:

$$\gamma_t = \sum_{k=0}^{k=4} \alpha_k.\Delta FedFunds_{t-k} + \text{quarter FE}_t + \epsilon_{it} \tag{7}$$

We expect $\sum_{k=0}^{k=4} \alpha_k > 0$: when the Fed Funds rate increases, banks with a higher income gap generate higher net interest income and lend more.

Tables B.1 and B.2 reports the coefficient estimates for $\sum_{k=0}^{k=4} \alpha_k$, which are of similar magnitudes and statistical significance as our main estimates. The one notable difference is the estimate of $\sum_{k=0}^{k=4} \alpha_k$ for C&I lending on the whole sample, which has now a p-value of 0.12 as opposed to 0.03 with our baseline methodology.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jmoneco.2020.03.011.

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