Inflation and Revaluation of Bank Balance Sheets

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Abstract

This paper quantitatively assesses the gains and losses caused by unanticipated higher inflation to U.S. commercial banks through their exposure to fixed-income instruments. Due to the mismatch of maturity between assets and liabilities, a persistent increase in inflation rate causes a larger decline in bank asset value than in liability value. We find that a one percent permanent increase in inflation rate leads to an average 15 percent loss of Tier 1 capital to U.S. commercial banks. The amount of loss is similar for banks that do not hold interest rate derivatives and thus do not hedge this risk, and for large banks that are systemically important.

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1 Introduction

Since the onset of the 2008 financial crisis, higher inflation target has been advocated by many economists.\footnote{For example, see Blanchard et al. (2010), Krugman (2013), and Rogoff (2008). There are many reasons why higher inflation target is desirable: to address wage rigidity, reduce household and public debt, and reduce the real interest rate when the nominal interest reaches its zero lower bound.} However, higher inflation target reduces the net worth of commercial banks. As expectation of higher future inflation is priced into yield curves by the market, interest rates, especially long-term interest rates rise. Due to the well-known maturity mismatch phenomenon of commercial banks, the value of nominal fixed-income assets drops faster than that of nominal fixed-income liabilities. Commercial banks play an important role in financial intermediation; because of financial frictions, losses borne by banks hamper credit supply and dampen real economic activity (e.g. Gertler and Kiyotaki, 2010).

In this paper we quantify the effect of higher inflation target on U.S. commercial banks’ balance sheets. We first document the size and maturity of nominal fixed-income positions on both sides of bank balance sheets. We then perform a simple experiment. Suppose that the inflation target is increased by 1% permanently and unexpectedly, and is perfectly priced into yield curves, what would be the effect on the value of banks’ nominal fixed-income positions, if the only real effect of inflation were to revalue nominal contracts?

To document the size and maturity of bank nominal positions, we use data from the Bank Reports of Conditions and Income (usually referred to as the call reports) filed quarterly by U.S. commercial banks. The advantage of the call reports is the availability of maturity breakdowns of key nominal instruments on bank balance sheets. On average, at least 70% of bank assets and liabilities are nominal fixed-income instruments. The gap between the average maturity of assets and liabilities is about 5 years.

Combining the call reports data with estimated yield curves, we construct streams of future nominal payments generated by bank nominal positions, and use them to conduct the aforementioned experiment and gauge the valuation effect of a higher inflation target.

Our main result is that even a moderate increase in the inflation target by 1% causes a sizable loss to U.S. commercial banks. The asset-weighted-average capital loss remains quite stable in our sample periods from 1997 to 2009, fluctuating between 10-15%. We also estimate the gains and
losses contributed by each major class of nominal positions. Two thirds of the overall capital losses are contributed by loans and leases to the household and the corporate sectors, which constitute more than half of bank balance sheets. Some banks bear larger losses than others. In 2009Q4, 23.3% of banks would bear a capital loss larger than 20%, suppose inflation were to increase by 1% permanently.

It is possible for banks to hedge this risk by trading interest rate derivatives. To investigate this possibility, we perform the same analysis to a subgroup of banks with no exposure to interest derivatives. Since these banks do not hedge interest rate risk, the results are most clean for this group. We find that the size of loss born by this group of banks is also around 10-15% of Tier 1 capital.

We also perform the experiment to large banks with total assets larger than $50 billion, which are more systemically important. The size of loss incurred to these banks is very similar to that to smaller banks.

**Related literature.** This paper directly relates to some recent works that document the maturity mismatch of commercial banks and evaluate their exposure to interest rate risk, using bank balance sheets data. Sher and Loiacono (2013) estimate the effect of a two percent parallel shift in the yield curve on loan portfolios held by a sample of large European banks. Bank of Japan (2013) performs a similar analysis using data on Japanese commercial banks. To our best knowledge, our work is the first to perform this analysis to U.S. commercial banks. Our work also features a more rigorous implementation in constructing future nominal payment streams used in evaluating the effect of inflation. For example, we construct payment streams of held-to-maturity claims (e.g. loans) using a recursive method and taking into account loan refinancing. In comparison, Sher and Loiacono (2013) simply assume that loans are all newly issued.

This paper also relates to the literature studying the link between banks’ interest rate risk exposure and their stock returns and credit supplies. Flannery and James (1984) find that stock prices of publicly traded commercial banks and savings and loan associations react negatively to increases in the general level of interest rates, and that this reaction is stronger for institutions with larger maturity gap of their assets over their liabilities. Consistent with Flannery and James (1984), English et al. (2014) also find that unanticipated increases in both the level and slope of the
yield curve associated with FOMC announcements have large negative effects on bank stock prices. However, the effects are attenuated by larger maturity gap. Regarding credit supply, Landier et al. (2013) show that banks’ exposure to interest rate risk predicts the sensitivity of bank lending to changes in interest rates.

Banks could use interest rate derivatives, which are off-balance sheet instruments, to offset their on-balance sheet exposure to interest rate risk. However, empirical evidence shows that there has been very limited success, if any. Begenau et al. (2013) replicate both on- and off-balance sheet items of several largest U.S. banks with two factors. They find that during 1999-2004 and 2007-2011, net derivative positions tend to amplify, not offset, balance sheet exposure to interest rate risk. Landier et al. (2013) also find that interest rate hedging is a minor force for most banks.

Finally, this paper is related to a recent literature studying the redistribution effect of monetary policy, both empirically and theoretically. Doepke and Schneider (2006) quantifies the gains and losses born by various sectors (household, government and foreigners) and age groups under several hypothetical inflation scenarios. Gomes et al. (2014) develop a general equilibrium model with financial frictions to study the effect of inflation on the value of nominal corporate debt and its macroeconomic consequences.

Roadmap. The rest of the paper is organized as follows. Section 2 discusses the data on banks nominal positions and maturity mismatch. Section 3 presents the conceptual framework used in our empirical analysis and describes the procedures to construct streams of future payments. Section 4 presents the main results. Section 5 concludes.

2 Nominal Positions and Maturity Mismatch of U.S. Commercial Banks

2.1 Data on commercial banks’ fixed income portfolios

We use the Bank Reports of Conditions and Income, generally referred to as the call reports, filed quarterly by U.S. commercial banks (FFIEC 031 and 041).2 The call reports contain detailed breakdowns of the key items on an institution’s income statement and balance sheet. There are two

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2We acquire data from Wharton Research Data Services.
major advantages of the call reports comparing with alternative sources of data, such as banks’ SEC filings. First, call reports provide information of the maturity distribution of banks’ balance sheet items, such as loans, bonds and mortgage backed securities (MBS). Such information is crucial to evaluate banks’ risk exposure to changes in the long-run inflation target. Second, the call reports are filed by all banks, not only those that are publicly traded.

We use the reports filed by commercial banks, and aggregate bank-level data for all commercial banks owned by the same bank holding company (BHC). We perform this aggregation because common ownership ties could foster risk sharing among bank subsidiaries. Bank holding companies also file regulatory reports (form FR Y-9C). We do not directly use the reports filed by BHCs because detailed information on maturity distribution is only available in commercial banks’ reports.

We build panel data for the sample period 1997 Q2-2009 Q4, when information of maturity distribution is available. During this period, there is considerable amount of mergers and acquisitions among banks and bank holding companies. We address this issue using data on merger and acquisition activities from the Federal Reserve Bank of Chicago, which contain the date of merger, the identity number of the non-surviving and the acquiring bank or BHC.\(^3\) If institution A is acquired by institution B in date \(t\), we add A’s balance sheet positions to B and treat them as one institution prior to date \(t\).

We drop from our sample banks with asset value smaller than $500 million in 2009 Q4 and restrict our attention to relatively large banks.\(^4\) We drop banks whose observations are not continuous in the sample. This is because we adopt a recursive method to construct future payment streams of some asset classes on banks’ balance sheet, as described in Section 3.3. For this purpose, it is important that a bank has continuous observations over the sample period.\(^5\)

Table 1 lists the distribution of sample banks in the fourth quarter of each sample year. We segregate banks into three size groups according to their total assets in 2009Q4: large banks have assets greater than $50 billion, medium banks have assets between $10-$50 billion, and small banks.

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\(^3\)Data are obtained from [https://www.chicagofed.org/webpages/publications/financial_institution_reports/merger_data.cfm](https://www.chicagofed.org/webpages/publications/financial_institution_reports/merger_data.cfm).

\(^4\)$500 million is threshold above which a BHC needs to file regulatory report FR Y-9C (after March 2006).

\(^5\)Only 20 banks are dropped due to discontinuous observations, which constitute less than 3% of the total number of banks.
have assets less than $10 billion. In total there are around 800-1100 banks in the sample each year, among which more than 90% are small banks. Since larger banks have greater systemic importance in the financial system, we will evaluate the effect of higher inflation target separately for these three size groups in Section 4.1.

### 2.2 Information of maturity breakdowns

Crucial to our analysis are the maturity breakdowns of key items on bank balance sheets. The call reports provide maturity breakdowns for banks’ holding of securities, loans, time deposits and other borrowed money. The remaining maturity or the time to next repricing date of each item is categorized in the form of buckets: less than three months, over three months through 12 months, etc. (see Table A.1 for a complete summary).

Importantly, time to the next repricing date, rather than the contractual maturity, is recorded for variable rate contracts. This information greatly simplifies our analysis, because we can treat a variable-rate contract as a fixed-rate contract maturing on the next repricing date.

Maturity breakdowns are available for most items on bank balance sheet, as shown in Figure 1. For most sample periods, maturity information is known for more than 70% of bank assets and liabilities. Items for which maturity information are not reported include stocks, trading assets and liabilities, and securities purchased (sold) under agreements to resell (repurchase), etc. Without this information, we do not consider these items when we evaluate the effect of higher inflation target.

Figure 1 also shows the size of key balance-sheet items for which maturity breakdowns are available. On the asset side of bank balance sheets, loans and leases (mortgage, commercial and industrial, etc.) exceed 50% of bank total assets. Mortgage-backed securities, including both pass-through securities and structured products (e.g., CMOs) account for 7% to 10% of total assets. The holdings of securities issued by U.S. Treasury and government agencies decrease from more than 8% of total assets in 1997Q2 to less than 5% before the 2008 financial crises. They grow back to 8% thereafter, consistent with flight-to-liquidity and flight-to-quality theories. On the liability side

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6Pass-through securities are securities of which interest and principal payments from the borrower or homebuyer are directly passed through to holders of the MBS.
of bank balance sheets, deposits (time deposits, transaction deposits, and savings accounts) cover more than half of bank total liabilities. Since 2001Q1, maturity breakdowns for “other borrowed money” become available, which includes Federal Home Loan Bank advances and other borrowings. Other borrowed money accounts for 9-12% of bank total liabilities.

The maturity of transaction deposits and savings accounts deserves special attention. These deposits have zero contractual maturity, and in principal interest rates paid on these deposits can adjust instantly. However, it has been shown that interest rates on these claims are de facto very sticky (Hannan and Berger, 1991). As a result, the effective maturity of these claims can be very long. Bearing this caveat in mind, we proceed by assuming that transaction deposits and savings accounts have zero maturity.

2.3 Maturity mismatch between bank assets and liabilities

We now document the degree of maturity mismatch between bank assets and liabilities. The first two panels of Figure 2 plot the average maturity/repricing period of the key items on both sides of bank balance sheets. In our calculations, we set the average maturity/repricing period within each bucket to the midpoint of that buckets’ range.\(^7\)

On the asset side, pass-through mortgage-backed securities have the longest maturity, increasing from ten years at the beginning of sample period to 15 years at the end of sample period. Treasury and agencies securities have maturity of around 5 years. Loans and leases, as well as structured mortgage-backed securities, have shorter maturity of around three to four years. On the liability side, time deposits and other borrowed money both have very short maturity of one to two years. The maturities of these items remain relatively stable over time.

[Insert Figure 2 here.]

To gauge the degree of maturity mismatch, we define maturity gap as the difference between the weighted-average maturity/repricing period of bank assets and liabilities, as in English et al. (2014). We plot cross-sectional asset-weighted mean and median maturity gap in the third panel of

\(^7\)For example, U.S. Treasury securities with remaining maturity or time to the next repricing date of more than one years but less than or equal to three years are assumed to have a maturity/repricing period of two years, the midpoint of the \((1, 3]\) interval. Claims with remaining maturity or time to the next repricing date of over 15 years are assumed to have a maturity/repricing period of 20 years; claims with remaining maturity or time to the next repricing date of over three years are assumed to have a maturity/repricing period of five years.
Figure 2. Both measures of maturity gap fluctuate around three to five years over the entire sample period.

Although contractual maturity/repricing periods and maturity gap are useful to describe maturity mismatch as a first pass, they are insufficient and imprecise to characterize the entire distribution of cash payments over future periods. For zero coupon bonds, it is true that the contractual maturity coincides with the effective duration. But for long-term coupon bonds or amortized mortgages with sizable cash payments before the contractual maturity date, effective durations can be much shorter than the contractual maturities.\(^8\) Therefore, when evaluating bank losses in a higher inflation scenario, it is important to know future cash payments of long-term bonds and mortgages. In the next section, we describe our methods to construct future cash payment streams for various balance sheet items, and propose an asset pricing framework to price the future payments under high inflation scenarios.

### 3 Inflation and Bank Gains and Losses: Methods

In this section we assess the gains and losses to the U.S. commercial banks induced by an unanticipated arrival of a moderate inflation episode. Suppose that, starting from a benchmark date, inflation target is increased by one percentage point permanently and unexpectedly. The goal is to estimate the present-value gains or losses caused by such an inflation episode for the U.S. commercial banks.

To proceed, we first propose an asset pricing framework to price the future payments under high inflation scenarios. One key assumption we adopt is that the only real effect of higher inflation is revaluing nominal fixed-income claims. More specifically, the real stochastic discount factor and credit risks associated with the financial claims are assumed not to be affected by higher inflation. We then describe our methods to estimate yield curves and construct payment streams generated by bank portfolios.

\(^8\)One way to characterize the effective duration is the Macaulay duration, which is a weighted average of the maturities of the cash payments (see Mishkin and Eakins, 2010, chapter 3).
3.1 Conceptual Framework

We first discuss the pricing of zero coupon bonds. A more general fixed-income claim with coupon payments can be viewed as a portfolio of zero-coupon bonds with different maturities. Therefore, the price of this claim is a linear combination of the prices of zero-coupon bonds.

**Pricing nominal zero-coupon bonds.** We assume the exogenous fundamentals of the economy are functions of a shock $s_t$. We let $s_t = (s_0, ..., s_t)$ denote a history of shocks.

We first consider the pricing of a one-period bond issued in date $t$, that is, a financial claim in date $t$ which pays $1$ in date $t+1$, in all histories $s^t+1|s^t$. When considering the credit risk associated with the bond, we assume that it is a pool on many independent borrowers, and therefore the law of large numbers applies. We denote the fraction of borrowers who default in history $s^t+1$ by $h(s^t+1)$. The dollar value of this financial claim in state $s^t$ is

$$w_1(s^t) = \sum_{s^t+1|s^t} \Pr(s^t+1|s^t) \frac{(1 - h(s^t+1)) m_{t,t+1}(s^t+1)}{\pi_{t,t+1}(s^t+1)},$$

where $\pi_{t,t+1}(s^t+1)$ denotes the gross inflation rate between state $s^t$ and $s^t+1$, $m_{t,t+1}(s^t+1)$ denotes the real stochastic discount factor in state $s^t$ for a payoff in state $s^t+1$, and $\Pr(s^t+1|s^t)$ is the conditional probability. This pricing equation has the following interpretation. The bond pays $1 - h(s^t+1)$ dollars in state $s^t+1$. For each dollar paid in $s^t+1$, its dollar value in $s^t$ is $\frac{1}{\pi_{t,t+1}(s^{t+1})}$, and should be discounted by the real discount factor $m_{t,t+1}(s^t+1)$.

We next consider a zero-coupon bond without restricting its maturity to one period. Specifically, a $j$-period bond that pays $1$ in all states $s^t+j|s^t$, for a given $j \geq 1$. It is priced by

$$w_j(s^t) = \sum_{s^t+j|s^t} \Pr(s^t+j|s^t) \prod_{m=0}^{j-1} \frac{(1 - h(s^t+m+1)) m_{t+m,t+m+1}(s^t+m+1)}{\pi_{t+m,t+m+1}(s^t+m+1)}$$

$$\equiv \frac{1}{(1 + i_{t,t+j}(s^t))^j} \quad (1)$$

The second equality is simply the definition of the $j$-period zero-coupon yield $i_{t,t+j}(s^t)$. It depends on the expected inflation, the default risk and the real stochastic discount factor.

Now consider an unanticipated one-time announcement by the central bank in state $s^t$ to increase
the inflation target by $\Delta \pi$ in all histories after $s^t$. We assume that this scenario is a surprise to agents in the market, and the expectation of higher future inflation rate is immediately formed after the announcement. The value of the $j$-period zero-coupon bond after the announcement becomes

$$
\tilde{w}_j(s^t) = \sum_{s^{t+j}|s^t} \text{Pr}(s^{t+j}|s^t) \prod_{m=0}^{j-1} \frac{1 - h(s^{t+m+1})}{\pi_{t+m,t+m+1}(s^{t+m+1}) + \Delta \pi} m_{t+m,t+m+1}(s^{t+m+1})
$$

The underlying assumption is that the only real effect of higher inflation is to revalue nominal financial claims. More specifically, we assume that the credit risk, characterized by the state-contingent haircut $h(s^{t+m})$, and the real stochastic discount factor $m_{t+m,t+m+1}(s^{t+m+1})$ are both unaffected by the change in the inflation target. In making these assumptions, we essentially restrict our attention to the partial equilibrium effect of inflation. In a general equilibrium model, changes in the inflation target will endogenously affect the default risk, the real stochastic discount factor, and therefore the price of bonds.

When zero coupon yields $i_{t,t+j}(s^t)$ and the change in inflation rate $\Delta \pi$ are small, we can approximate $\tilde{w}(s^t)$ by

$$
\tilde{w}_j(s^t) \approx \frac{1}{(1 + i_{t,t+j}(s^t) + \Delta \pi)^j}
$$

Intuitively, this equation states that expectations of higher inflation target are priced into the nominal yield curve, when real interest rates remain unaffected. This is the formula commonly adopted in studies of the redistribution effects of higher inflation rate (e.g., Doepke and Schneider, 2006).

It follows that the value of the $j$-period zero-coupon bond drops by

$$
\Delta w_j(s^t) = \tilde{w}_j(s^t) - w_j(s^t) = \frac{1}{(1 + i_{t,t+j}(s^t) + \Delta \pi)^j} - \frac{1}{(1 + i_{t,t+j}(s^t))^j}.
$$

**Pricing more general nominal fixed-income claims.** Now consider a more general financial claim which pays $\nu_j$ dollars in all states $s^{t+j}|s^t$ for $\forall j \geq 1$. By linearity, the decline in its value in
a higher inflation scenario of $\Delta \pi$ is

$$\Delta V(s^t) = \sum_j \left[ \frac{1}{(1 + i_{t,t+j}(s^t) + \Delta \pi)^j} - \frac{1}{(1 + i_{t,t+j}(s^t))^j} \right] \nu_j. \quad (3)$$

In the rest of the paper, we estimate $\Delta V(s^t)$ for bank portfolios, in a scenario of a one percent increase in the inflation target ($\Delta \pi = 0.01$). The estimation involves three steps. First, we estimate the zero-coupon yield curves $\{i_{t,t+j}\}_{j \geq 1}$, for different types of financial claims held by banks. Second, we construct payment streams $\{\nu_j\}_{j \geq 1}$ generated by these financial claims, using information on their size and maturities. Third, we estimate banks’ gains and losses according to Equation (3).

### 3.2 Estimating Yield Curves

To price a given payment stream generated by banks’ portfolio at each date, we need to know the zero-coupon yield curve. In principal, asset classes differ in safety, liquidity and other features, and we want to estimate the yield curve for each asset class. Due to limitations on interest rate data, we estimate two yield curves: that of Treasury securities and that of swap contracts.\(^9\) We use the yield curve of Treasury securities to discount banks’ holding of safe assets and liabilities, e.g., Treasury and agencies securities, and consumer deposits. We use the swap yield curve to discount privately issued securities, such as loans and leases.

We adopt parametric formulations of the yield curves in our estimation. In general, parametric formulations impose smoothness assumptions on the curve, and therefore is more suitable to study the macroeconomic forces that influence the shape of the curve. In contrast, Spline-based method is suited to better capture local behaviors of the yield curve.

We follow the standard approach proposed by **Svensson (1994)** and assume the following parametric form for the instantaneous forward curve at date $t$:

$$f_{t}(t + j) = \beta_{0,t} + \beta_{1,t}e^{-\frac{j}{\tau_{1,t}}} + \beta_{2,t}\frac{j}{\tau_{1,t}}e^{-\frac{j}{\tau_{1,t}}} + \beta_{3,t}\frac{j}{\tau_{2,t}}e^{-\frac{j}{\tau_{2,t}}}$$

where $f_{t}(t + j)$ denotes instantaneous forward rate $j$ years ahead. Under the expectation hypothesis, the zero-coupon yield curve is given by $i_{t,t+j} = \frac{1}{j} \int_0^j f_{t}(t + u)du$. At a given point of time $t$, the

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\(^9\)Swap interest rate is the rate of the fixed leg of a swap contract, calculated to make the net present value of the contract equal zero.
zero-coupon yield curve \( \{ i_{t,t+j} \}_j \) is characterized by six parameters \( \{ \beta_0,t, \beta_1,t, \beta_2,t, \beta_3,t, \tau_1,t, \tau_2,t \} \).

The Svensson yield curve is the most commonly used parametric form in central banks (Reppa, 2008). It is flexible enough to produce curves with two extrema, one maximum and one minimum.

**Treasury yield curve.** We directly use the result of Gürkaynak et al. (2007), who estimate the Svensson yield curve for the entire maturity range spanned by outstanding Treasury securities from 1961 to present.\(^{10}\) They show that their estimation is accurate for the entire maturity range, and the prediction error of bond yields lie within one basis point.

**Swap yield curve.** We use middle rate quotes of the UK-based inter-dealer broker ICAP, accessed through the Reuters database. The maturities of the contracts are 1-10, 12, 15, 20, 25 and 30 years.

In our estimation, we use the fact that a hypothetical bond paying a coupon rate equal to the swap interest rate is priced at par (Lesniewski, 2008). For each quarter of the sample period, we estimate \( \{ \beta_0,t, \beta_1,t, \beta_2,t, \beta_3,t, \tau_1,t, \tau_2,t \} \) by minimizing the weighted sum of squared deviations between actual bond prices and predicted bond prices. The weights are the inverse of the duration of each individual securities.\(^{11}\)

The success at fitting the swap yields is repeated throughout the sample. Table 2 shows the time-average absolute yield prediction error in different maturities. As can be seen, all of the errors are quite small over the entire sample, within several basis points.

[Insert Table 2 here.]

As an example, we report estimated Treasury and swap yield curve at the beginning of the sample period (1997Q2) and before the crisis (2007Q4) in the appendix (Figure A.1). Two observations are worth noting. First, the Svensson parametric form is flexible enough to capture two humps in the Treasury yield curve in 2007Q4. Second, our sample period features a large decline in the overall level of interest rate. This pattern of data suggests that when constructing payment streams of long term loans, it is important to distinguish loans issued at earlier and later dates, since their yields may

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\(^{11}\)Since a given change in the yield corresponds to a larger change in the price of a bond with a longer duration, fitting prices of each bond given an equal weight irrespective of its duration will lead to over-fitting of the long-term bond prices at the expense of the short-term prices. Therefore we follow the literature by weighting the price error of each bond by a value derived from the inverse of its duration (Bank for International Settlements, 2005). This procedure is approximately equivalent to minimizing the unweighted sum of squared deviations between the actual and predicted yields of securities.
differ a lot. Therefore in the spirit of Doepke and Schneider (2006), we adopt a recursive method to construct payment streams for long-term loans and mortgage backed securities, as described in the next subsection.

3.3 Constructing Payment Streams

We now describe the methods to construct payments streams of major categories of fixed-income instruments on bank balance sheet. In the construction we use size and maturity data on balance sheet positions, and yield curves estimated from the previous subsection.

For long-term fixed-income claims, it is important to distinguish between book value and fair value accounting. According to the guidelines of the call reports, most loans are recorded at face value, while most securities (Treasury or agency securities, or privately issued MBS) are recorded at fair value.

Since maturity data in the call reports are in the form of buckets. We assume that within each bucket the maturity is uniformly distributed, and that the maximal maturity is 20 years.

Loans and leases. We assume that all loans and leases are amortized according to the straight-line schedule, which features equal monthly payment until the maturity.

Since most loans and leases are held to maturity, we adopt a recursive method to construct payment streams. In the initial sample period (1997Q2), we assume that all loans were newly issued. For each maturity $j$, we observe the book value of the loan with maturity of $j$ years. We construct the loan’s payment stream $\{\nu_{t,m}\}_m$ according to the fact that, the discounted value of payment stream $\{\nu_{t,m}\}_m$ using the swap yield curve must equal their book value. We also determine the remaining face value of the initial vintage of loans in each subsequent sample period. This recursive method distinguishes between loans issued in earlier sample periods when interest rates were high and loans issued in later periods when interest rates were low.

For each subsequent sample period, we compute recursively the face value of new loans issued, as well as the expected payments and evolution of face value associated with that period’s vintage.

We consider refinancing activities when constructing payment streams. In late 1990s and early 2000s, many homeowners took advantage of relatively low interest rates to refinance their mortgage loans. As shown in Figure A.2, 7-13% of outstanding mortgage loans were refinanced each quarter.\textsuperscript{12}

\textsuperscript{12}To construct the fraction of outstanding mortgage loans being refinanced, we use “mortgage refinance by one- to
Therefore, when constructing payment streams after the initial sample period, we take into account that some existing loans are refinanced. We assume that when a mortgage loan is refinanced, the new loan has the same maturity as the remaining maturity of the old loan.

*Mortgage backed securities.* We assume that all mortgage backed securities are pass-through securities for which principal and interest payments are directly passed on to security holders from mortgage borrowers.\textsuperscript{13} To construct payment streams, we adopt a recursive approach similar to that of loans and leases. The only difference is that mortgage-backed securities are recorded at fair value. Therefore, for each period we compute the fair value of previously issued securities using current interest rates.

*Treasury, agency-bond, other non-MBS.* Because these securities are actively traded on the market instead of held to maturity, the previously mentioned recursive method is not appropriate in constructing payment streams. To proceed, we make two assumptions. First, all securities are newly issued and issued at par; second, a security is a zero-coupon bond if its maturity is less than 1 year, and a coupon bond otherwise. Then we compute coupon payments using the Treasury yield curve.

*Time deposits and Other borrowed money.* We also adopt the previously mentioned recursive method to construct payment streams for time deposits. The only difference is how payments are distributed across future periods. For time deposits, interests are accrued until maturity; for other borrowed money, we assume that it is in the form of coupon bonds, and their face values are not amortized.

*Transaction deposits and savings accounts.* As discussed in the previous session, we assume that these deposits have maturity of a quarter and the interest rates paid on these deposits adjust in a quarter.

### 3.4 Constructed payment streams: examples

As an example, constructed quarterly payment streams for four largest bank holding companies are plotted in Figure 3. On both asset and liability sides of bank balance sheets, future payments are very concentrated on short maturities within 5 years. Consistent with evidence of maturity

\[\text{four-family residences}\] from Mortgage Banker Associations, and “mortgage debt outstanding by one- to four-family residences” from the FRED database.

\textsuperscript{13} As in Figure 1, the majority of MBS is pass-through securities.
mismatch discussed in the previous section, payments of bank assets are less concentrated on short maturities, comparing with payments of bank maturities.

[Insert Figure 3 here.]

4 Inflation and Bank Gains and Losses: Results

In this section, we use the constructed payment streams to evaluate the economic value of each category on bank balance sheets. We then assume that inflation target increases permanently by 1% ($\Delta \pi = 0.01$), and use Equation (3) to gauge the gains or losses of bank balance sheets.

The results are shown in Figure 4. For each sample year (fourth quarter), we compute gains and losses as a percentage of Tier 1 capital for each bank in the sample, and report the asset-weighted average statistics in the figure.

As a result of maturity mismatch, most banks suffer a capital loss after an increase in inflation rate. Overall losses as a percentage of Tier 1 capital fluctuate around 10-15% over the sample period. This estimate is comparable with estimates of Japanese banks provided by Bank of Japan (2013).

As shown in Figure 4, most losses are caused by holdings of loans and leases, which are around 10% of Tier 1 capital. This large loss is driven by the large volume of loans and leases, which amounts to more than half of bank total assets (see Figure 1). The second largest loss is through holdings of mortgage-backed securities (3-5% of Tier 1 capital). As seen in the previous section, although mortgage-backed securities constitute only 10% of bank total assets, they have very long maturities of 10-15 years. Therefore, they contribute a considerable amount of bank loss when inflation rises. Treasury and agencies securities cause a relatively small amount of capital loss, which fluctuates around 1-2%. At the same time, since bank liabilities tend to have very short maturities, they only cause less than 5% of capital gains when inflation rate rises.

[Insert Figure 4 here.]

Capital losses born by some banks are much larger than the average. Figure 5 presents the cross-sectional distribution of capital losses at the beginning and the end of the sample period.

\footnote{This number is considerably smaller than that of Japanese banks, which is around 10-20%. This is because U.S. commercial banks hold much less government bonds on their balance sheet than Japanese banks.}
(1997Q2 and 2009Q4). In 2009Q4, 23.3% of banks would bear a capital loss larger than 20%, suppose inflation were to increase by 1% permanently. The distribution becomes flatter over time. For example, in 1997Q2 only 8.2% of banks would bear a loss larger than 20%.

4.1 Do losses caused by inflation depend on bank size?

In this subsection we investigate whether bank size affects losses caused by rising inflation. If larger banks have better management of maturity mismatch, we expect that they suffer smaller capital loss after inflation rises. We perform the same experiment of 1% permanent inflation to three groups of banks categorized according to their total assets in 2009Q4 (see Table 1 for sample description). Results of the experiment are plotted in Figure 6.

Overall, the sizes of losses are robust across three groups of banks, which are around 10-15% percent of Tier 1 capital. If anything, the largest group of banks with assets larger than $50 billion bears slightly larger losses than medium and small-sized banks in the second half of the sample (after 2003). Therefore, inflation causes a substantial loss to big banks which bear more systemic importance.

4.2 Do banks hedge risks through holdings of interest rate derivatives?

In this subsection we investigate whether banks hedge interest rate risks through holdings of interest rate derivatives. The call reports record the notational value of interest rate derivatives (swaps, futures, etc.), and they distinguish between derivatives “held for trading” or “held for purposes other than trading”. According to accounting rules, the majority of positions due to market making activity are recorded as “held for trading”. We assume that all derivatives held “not for trading” are due to trading on one’s own account.

We focus our attention on interest rate derivatives held for purposes other than trading, as we are mostly interested in banks’ behavior to hedge their own interest rate risks. We plot the fraction

\[ \text{Fraction held for trading} \]

Most interest rate derivatives are traded over the counter, and a few large dealers make the market. In particular, dealers intermediate between two parties by initiating, say, a pay-fixed swap with the first party as well as an offsetting pay-floating swap with the second party. Often one of the parties is another dealer.
of banks holding a positive amount of interest derivatives in Figure 7, as well as the size of their holdings as a percentage of total assets, conditional non-zero holding.

[Insert Figure 7 here.]

Banks’ exposure to interest rate derivatives increases drastically during our sample periods, as reflected in the fraction of banks holding interest rate derivatives and the size of their holdings. In 1997, only 5% of banks hold interest rate derivatives, compared to 40% in 2009. Conditional on positive exposure, the average size of exposure also expands quickly from 5% in 1997 to 40% in 2003, and falls gradually to 20% in 2009. However, it is worth noting that even in 2009 more than half of the banks do not hold any interest rate derivatives.

For each sample year, we divide banks into three groups according to their exposure to interest rate derivatives (no exposure, smaller and larger than 20% of total assets). We then repeat our experiment on each group, and report the results in Figure 8.

The overall size of capital loss caused by higher inflation is similar across three groups, which fluctuates around 10-15%. Without any exposure to interest rate derivatives, the first group of banks do not hedge interest rate risk, and therefore results are the most clean for this group.

On the other hand, there is evidence that banks with the largest holding of interest rate derivatives would bear larger loss through on-balance-sheet fixed-income portfolio suppose inflation rate rose. This is particularly the case in the early 2000s before the Great Repression. This result is consistent with the findings of Begenau et al. (2013) that from 2004 to 2007, interest rate swaps and futures were hedging the interest rate risk of on-balance-sheet items.

[Insert Figure 8 here.]

5 Conclusion

Our goal in this paper was to quantitatively assess the effect of inflation to the U.S. commercial banks. We have documented the size and maturity of nominal assets and liabilities on bank balance sheets, and we have used those numbers to compute the capital gains and losses that would be induced by a moderate inflation episode. Our main result is that even moderate inflation leads to a sizable capital loss to banks. We also find a sizable loss to large banks which are more systemically

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important, and to banks that hold no interest rate derivatives and thus do not hedge interest rate and inflation risk.

Our analysis raises questions for future research. Will losses born by banks cause a decline in credit supply and the efficiency of resource allocation? If so, how should a country with a fiscal problem trade off between fiscal and monetary policy? Our results suggests a cost of inflation to banks and therefore a smaller reliance on inflation in the optimal design of fiscal and monetary policy. Some of these questions are addressed in Cao (2017), where we study how a country should adjust fiscal and monetary policy to fiscal expenditure shocks, in the presence of financially constrained banks holding nominal assets and liabilities.
References


Cao, Q. (2017). Optimal fiscal and monetary policy with collateral constraints. 5


### Table 1: Number of Bank Holding Companies

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Large</th>
<th>Medium</th>
<th>Small</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>774</td>
<td>22</td>
<td>33</td>
<td>719</td>
</tr>
<tr>
<td>1998</td>
<td>808</td>
<td>23</td>
<td>35</td>
<td>750</td>
</tr>
<tr>
<td>1999</td>
<td>854</td>
<td>23</td>
<td>39</td>
<td>792</td>
</tr>
<tr>
<td>2000</td>
<td>886</td>
<td>23</td>
<td>39</td>
<td>824</td>
</tr>
<tr>
<td>2001</td>
<td>913</td>
<td>24</td>
<td>41</td>
<td>848</td>
</tr>
<tr>
<td>2002</td>
<td>941</td>
<td>24</td>
<td>41</td>
<td>876</td>
</tr>
<tr>
<td>2003</td>
<td>960</td>
<td>24</td>
<td>44</td>
<td>892</td>
</tr>
<tr>
<td>2004</td>
<td>982</td>
<td>24</td>
<td>44</td>
<td>914</td>
</tr>
<tr>
<td>2005</td>
<td>1,005</td>
<td>24</td>
<td>44</td>
<td>937</td>
</tr>
<tr>
<td>2006</td>
<td>1,031</td>
<td>24</td>
<td>44</td>
<td>963</td>
</tr>
<tr>
<td>2007</td>
<td>1,054</td>
<td>25</td>
<td>44</td>
<td>985</td>
</tr>
<tr>
<td>2008</td>
<td>1,075</td>
<td>28</td>
<td>45</td>
<td>1,002</td>
</tr>
<tr>
<td>2009</td>
<td>1,079</td>
<td>29</td>
<td>45</td>
<td>1,005</td>
</tr>
</tbody>
</table>

Note: Large banks have assets larger than $50 billion in 2009Q4, medium banks have assets between $10-$50 billion in 2009Q4, and small banks have assets less than $10 billion in 2009Q4.

### Table 2: Average absolute yield prediction errors by maturity

<table>
<thead>
<tr>
<th>Maturity</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>12</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error (bps)</td>
<td>1.3</td>
<td>3.3</td>
<td>2.2</td>
<td>2.1</td>
<td>2.0</td>
<td>2.4</td>
<td>3.5</td>
<td>2.6</td>
<td>3.4</td>
<td>3.5</td>
<td>4.5</td>
<td>2.7</td>
<td>2.5</td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

Note: Average absolute yield prediction error across time in different maturities.
Figure 1: Fraction of total assets and liabilities of which maturity breakdowns are reported

Note: We compute fractions for each bank in the sample, and report the asset-weighted average statistics in the figure.

Figure 2: Maturity of bank assets and liabilities

Note: We compute statistics for each bank in the sample, and report the asset-weighted average statistics in the figure.
Figure 3: Constructed quarterly payment streams for four largest bank holding companies

Figure 4: Gains and losses caused by 1% permanent increase in inflation rate

Note: We compute gains and losses for each bank in the sample, and report the asset-weighted average statistics in the figure.
Figure 5: Cross-sectional distributions of capital loss

Note: We plot the cross-sectional distributions of capital losses caused by 1% permanent increase in inflation rate.
Figure 6: Gains and losses by bank size (total assets)

Note: We compute gains and losses for each bank in the sample, and report the asset-weighted average statistics in the figure.
Figure 7: Fraction of banks holding interest rate derivatives and the size of their holdings

Note: the dash-dotted line shows the notational amount of interest rate derivatives as a percentage of total assets, conditional on positive holding. We compute the percentage for each bank in the sample, and report the asset-weighted average statistics in the figure.
Figure 8: Gains and losses by bank derivative holdings

Note: We compute gains and losses for each bank in the sample, and report the asset-weighted average statistics in the figure.
Appendix

A Maturity breakdowns in the call reports

Table A.1: Maturity breakdowns in the call reports

<table>
<thead>
<tr>
<th>Category</th>
<th>Breakdowns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treasury and agencies securities,</td>
<td>1. Three months or less.</td>
</tr>
<tr>
<td>Residential pass-through MBS,</td>
<td>2. Over three months through 12 months.</td>
</tr>
<tr>
<td>Loans and leases</td>
<td>3. Over one year through three years.</td>
</tr>
<tr>
<td></td>
<td>4. Over three years through five years.</td>
</tr>
<tr>
<td></td>
<td>5. Over five years through 15 years.</td>
</tr>
<tr>
<td></td>
<td>6. Over 15 years.</td>
</tr>
<tr>
<td>Time deposits,</td>
<td>1. Three months or less.</td>
</tr>
<tr>
<td>Other borrowed money</td>
<td>2. Over three months through 12 months.</td>
</tr>
<tr>
<td></td>
<td>3. Over one year through three years.</td>
</tr>
<tr>
<td></td>
<td>4. Over three years.</td>
</tr>
<tr>
<td>Non pass-through MBS</td>
<td>1. Three months or less.</td>
</tr>
<tr>
<td></td>
<td>2. Over three months.</td>
</tr>
</tbody>
</table>
B Estimated yield curves

We report estimated Treasury and swap yield curve at the beginning of the sample period (1997Q2) and before the crisis (2007Q4) are plotted in Figure A.1. The Svensson parametric form is flexible enough to capture two humps in the Treasury yield curve in 2007Q4. The first hump, which is located at shorter horizon, probably reflects expectation of monetary easing prior to crises; the second hump, which is located at longer horizon, reflects convexity, which tends to bring down long term bond yield.

Figure A.1: Estimated Yield Curve
C  Mortgage rate and refinancing activities

Figure A.2: Mortgage rate and refinancing activities

Note: The red line plots the (quarterly) percentage of existing mortgage loans being refinanced; the blue dash-dotted line plots the 30-year fixed mortgage rate.