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Changing Perceptions of Maturity Mismatch in the U.S. Banking System: Evidence from Equity Markets

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We use the sensitivity of bank holding company equity returns to market interest rates as an indicator of perceived maturity mismatch. Based on data from 1990 to 2009, there is only weak evidence that market participants perceived banks to be effectively short-funded. However, looking at 1990–1996 and 1997–2009 subsamples separately, our results suggest that U.S. commercial banks were perceived as short-funded during the earlier time period but not the later. During this time of changing perceptions of maturity mismatch, banks were increasing their holdings of real estate loans as a share of total assets. We present evidence that, subsequent to 1996, market participants perceived real estate loans as having become effectively shorter-term.

JEL Classification: G21, G01, E44, E02

1. Introduction

Maturity mismatch refers to the generally longer times to maturity of bank assets relative to their liabilities. This mismatch may be a source of fragility in the banking system. Liabilities (e.g., deposits) are typically short-term claims to bank funds that are tied up in longer-term investments that cannot be liquidated quickly, such as commercial loans and residential mortgages. Maturity mismatch may create the potential for liquidity crises that disrupt financial intermediation and, ultimately, real economic activity.[1]

Starting in the late 1990s, real estate loans as a percentage of U.S. commercial bank assets began to increase rapidly from around 25% to around 35% in 2006–2007 (Figure 1). Given that mortgage loans are long-term contracts, often with stated terms of 30 years, one would expect that market participants perceived, during this time, an increase in maturity mismatch on bank balance sheets. However, in this article we present evidence from U.S. equity markets that

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[1] There are clearly other sources of financial rigidity as well, for example, currency mismatch and nonperforming loans (Penas and Tümer-Alkan 2009). Indeed, Skeie (2008) suggests that maturity mismatch is not itself sufficient for multiple-equilibria bank runs to occur. We simply posit that maturity mismatch is a potential source of instability and move forward.

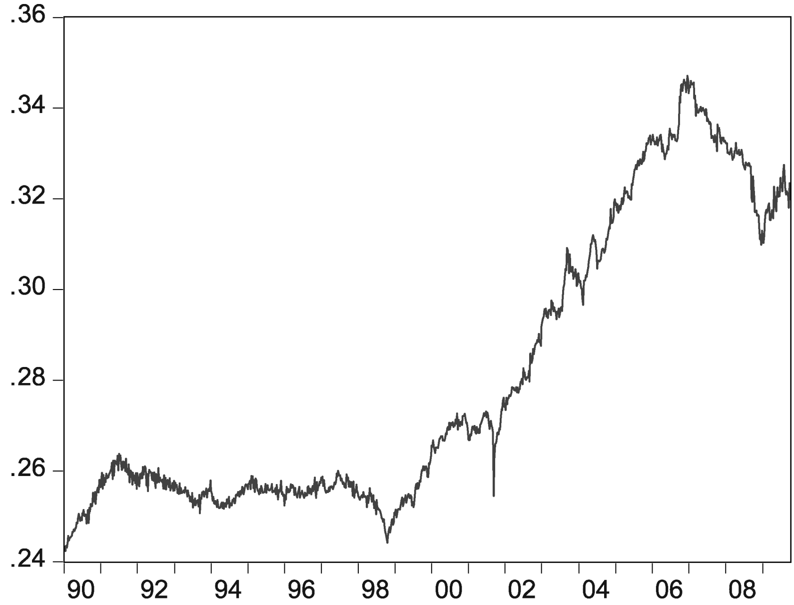

Figure 1. Real Estate Loans as a Share of Bank Assets
Note: Source is Federal Reserve, H.8 Assets and Liabilities of Commercial Banks in the United States. Dates are weekly from 1/3/1990 to 10/7/2009. Horizontal axis tracks year dates; vertical axis tracks shares.

banks' assets were, starting around 1996, perceived as having become shorter-term relative to their liabilities. In particular, mortgage loans and mortgage-backed securities (MBSs) were perceived as having become shorter-term. This is puzzling and, in retrospect, troubling given the relatively long stated maturities of the underlying loans.

Why did perceptions of maturity mismatch decrease at this time? While the stated term of the typical bank asset appears to have increased, it is still possible that *effective* times to maturity of bank assets decreased. Effective maturity is a function of the (expected) time to repricing of an asset. This reflects, among other things, secondary-market sale opportunities open to creditors.[2] Given that we estimate the change in perceptions as having occurred in the mid-1990s, we argue that a plausible underlying cause was a variety of innovations to the mortgage market, for example, the automation of Freddie Mac's underwriting procedures and the Department of Housing and Urban Development's (HUD's) increasing of low- and moderate-income housing goals in 1995. All of these innovations likely increased secondary-market opportunities and decreased expected times to repricing on mortgages.

Flannery and James (1984) were the first to infer perceptions of maturity mismatch from the sensitivity of bank equity returns to market interest rates. To our knowledge, we are the first researchers to use their methodology to empirically examine perceptions of maturity mismatch both before and after these innovations to the mortgage market. We examine the holding period returns of an equally weighted index of all publicly traded U.S. bank holding companies from 1990 to 2009. Using endogenous structural break tests, we present evidence that the interest sensitivity of these returns decreased around 1996. We then relate the changing interest sensitivity of returns to changes in the holdings of particular categories of bank assets.

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[2] Schrand (1997) finds that reductions in maturity mismatch in the 1980s corresponded to increased prepayments of residential loans.

This analysis suggests that changing perceptions of maturity mismatch are linked to changes in the perceived effective terms of real estate loans and consumer loans.

The article is organized as follows. Section 2 reviews the literature regarding maturity mismatch on financial balance sheets. Section 3 briefly describes the theory underlying our analysis. Section 4 describes the structure and intuition behind our empirical framework. The data used in this analysis are also described in section 4. Our empirical results are presented in section 5. Section 6 elaborates on the hypothesis that mid-1990s innovations in the U.S. mortgage market contributed importantly to the changing perceptions of maturity mismatch in the U.S. commercial banking system; we also discuss the potential role of the 1999 Financial Services Modernization Act. A concluding discussion and implications for further research are found in section 7.

2. Literature Review

There are several lines of research on the implications of maturity mismatch. The model of Diamond and Dybvig (1983) formalizes the problem of bank runs due to maturity mismatch, and many subsequent articles consider the possibilities for bank-run equilibria in Diamond–Dybvig-type models.[3] By contrast, other models suggest that maturity mismatch can actually increase bank stability. Morgan and Smith (1987) and Niinimäki (2001) show that a mismatch of asset and liability maturities may be an optimal consequence of risk aversion and can create a stable equilibrium as banks continually renew their long-term loans.

While the theoretical literature discusses whether maturity mismatch leads to instability or stability, there are empirical studies documenting situations where maturity mismatch may or may not increase. Several empirical studies find that developing countries are exposed to maturity mismatch from the potential withdrawal of foreign capital (Sachs, Tornell, and Velasco 1996; Chang 1999; Rajan and Bird 2003).[4] Other works specifically link the recent financial crisis to problems of illiquidity created by maturity mismatch (Adrian and Shin 2008; Diamond and Rajan 2009; Farhi and Tirole 2012). Notably, these latter articles address the liquidity crisis of 2008 but do not explicitly explore the relationship between maturity mismatch and the massive quantities of real estate loans that accumulated in the banking system since the 1990s.

Flannery and James (1984) pioneer the inference of perceived maturity mismatch from the interest sensitivity of bank stock returns.[5] They also relate that interest sensitivity to balance-sheet composition to determine the effective maturity of specific asset categories. While Flannery and James examine U.S. data, subsequent studies apply their methodology to savings and loan banks (Schrand 1997) and Turkish banks (Penas and Tümer-Alkan 2010).

Of particular interest to the present study, Schrand (1997) finds that reductions in maturity mismatch in the 1980s corresponded to increased prepayments of residential loans. Prepayment implies that the assets are not held through their stated terms. Increased incidence of prepayment therefore reduces the time to repricing and the effective maturity of mortgage

[3] For examples, see Green and Lin (2000), Goldstein and Pauzner (2005), and Skeie (2008).

[4] For an argument rejecting the evidence from these studies, see Bleakley and Cowan (2010).

[5] Several works—such as Unal and Kane (1988), Kwan (1991), and Fraser, Madura, and Weigand (2002)—study the impact of interest rates on bank stock returns using methods other than maturity mismatch.

loans. However, there was no similar increase in prepayments to explain this phenomenon in the 1990s. For this reason, we argue that the changing perceptions of maturity mismatch in the U.S. commercial banking system more plausibly arose from mortgage-market innovations that increased secondary-market opportunities.

3. Theory

Grove (1974) derives conditions for optimality in regards to the term composition of bank balance-sheet items. His contribution is an extension of the Hicks–Samuelson *duration theorem*.[6] The Hicks–Samuelson duration theorem suggests that investors can either hedge or increase their net worth by altering the weighted durations of their asset and liability streams. Specifically, investors who wish to increase their wealth as interest rates rise (fall) should adjust the structure of their balance sheet so that the weighted duration of the liability stream is greater (less) than that of the asset stream. It follows that risk-averse investors wishing to hedge their investment against interest-rate fluctuations will adjust their portfolio to set these weights equal.

More relevant to the present article, Grove demonstrates that the effect of a change in the interest rate on a balance sheet will be dependent on the value-weighted duration of assets relative to liabilities. In Grove's model the durations of the asset and liability streams, m_A and m_L, are choice variables for an investor planning a current balance-sheet structure over T periods:

$$\begin{array}{l} m_A = (1/A)\int_0^T tA(t)\exp[-R(t)t]dt \\ m_L = (1/L)\int_0^T tL(t)\exp[-R(t)t]dt \end{array}, \tag{3.1}$$

where A and L are the present values of the investor's asset and liability streams $A(t)$ and $L(t)$ and $R(t)$ is the market yield curve,

$$\begin{cases} R(t) = r(t) = \text{constant} & \text{for } t = 0 \\ R(t) = \left(\frac{1}{t}\right)\int_0^t r(x)dx & \text{for } t > 0 \end{cases}. \tag{3.2}$$

The investor's wealth can then be stated (approximately) as a function of the durations (Eqn. 3.1):

$$w = W + h(Lm_L - Am_A), \tag{3.3}$$

where h is a parameter associated with a general increase or decrease in interest rates, $R(t) + h$ for $0 \leq t \leq T$. The approximation (Eqn. 3.3) formally captures the result that "[a]n increase (decrease) in interest rates will increase net worth if the weighted duration of the liability stream is greater than (less than) the weighted duration of the asset stream" (Grove 1974, p. 697).

Intuitively, assets and liabilities represent, respectively, future streams of payments due and owed. Net worth (equity), being the difference between the two, is increasing (decreasing) in the value of assets (liabilities). When interest rates change, this indicates that the payment streams of both assets and liabilities must be discounted differently and will be repriced in the same direction.

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[6] See Hicks (1946) and Samuelson (1945).

The effect on net worth, then, is determined by the change in asset values *relative to* the value of liabilities. In the simplest case of a shift in the entire market term structure (h from the previous model), payments occurring further in the future will be subject to a larger (in absolute value) repricing: If FV is some future payment (T period from now) and P is its present value, then

$$P = \frac{FV}{(1 + R(t) + h)^{T}} \tag{3.4}$$

and

$$\frac{\partial P}{\partial h} < 0 \quad \text{and} \quad \frac{\partial^2 P}{\partial h \partial T} < 0. \tag{3.5}$$

An immediate implication for banks, or any institution characterized by the issue of short-term liabilities to acquire longer-term assets, is that we would expect their equity values to be negatively related to market interest rates. This expectation would be based on an assumption that banks are *short-funded* (i.e., the average effective maturity of bank assets is greater than that of bank liabilities). If, on the other hand, a bank were to be *long-funded* (i.e., the average effective maturity of assets is less than that of liabilities), then we would expect that its net worth is positively related to market rates.

4. Empirical Framework

Flannery and James (1984) propose a method of studying the perceived maturity mismatch on bank balance sheets. They use data on a sample of 67 banks and bank holding companies from 1976 through 1981 and assume that, for a given bank j,

$$R_{jt} = \beta_{0j} + \beta_{mj} R_{mt} + \beta_{lj} R_{lt} + \beta_{jt}, \tag{4.1}$$

where R_{jt} = the holding period return on j's stock over t, R_{mt} = the holding period return on some stock index over t, and R_{lt} = the holding period return on a constant maturity index of default risk-free bonds over t.

R_{jt} is the growth in j's equity; R_{lt} proxies (inversely) for market interest rates;[7] and R_{mt} is a control for other factors affecting firms' net worth generally. The parameter of interest is β_{lj}. The effect of changes in market interest rates on a bank's equity should be larger (smaller) when its balance sheet is relatively longer-funded (shorter-funded). Since R_{lt} is related inversely to interest rates, β_{lj} should be larger (smaller) when j's balance sheet is relatively shorter-funded (longer-funded).

In this article we focus on balance-sheet data representative of the U.S. commercial banking industry as a whole from 1990 through the earlier part of 2009. Flannery and James' regression model (Eqn. 4.1) can be straightforwardly adapted to aggregate data:

$$R_t = \beta_0 + \beta_m R_{mt} + \beta_l R_{lt} + \beta_t, \tag{4.2}$$

where R_t = the holding period return on commercial bank stocks over t, R_{mt} = the holding period return on a general stock index over t, and R_{lt} = the holding period return on a constant maturity index of default risk-free bonds over t.

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[7] Prices and yields (i.e., implied rates of interest) have an inverse relationship for any financial asset.

In this article our dependent variable of interest, R_t, will be a value-weighted index of all publicly traded U.S. bank holding companies (BHCs).[8] For general stock returns, we employ a value-weighted index of all publicly traded U.S. firms in the Center for Research in Security Prices (CRSP) data ($R_{m,t}$).[9] Since β_I is our parameter of interest, we employ three alternative indicators of risk-free market interest rates: 1-year, 7-year, and 10-year U.S. treasury constant maturity rates.[10] To convert these interest-rate series (y_t) into (approximate) holding period returns ($R_{I1,t}$, $R_{I2,t}$, and $R_{I3,t}$, respectively), we compute $-(y_t - y_{t-1})/y_{t-1}$. The returns move inversely with market yields. We have 989 weekly observations on R_t from October 31, 1990, through October 7, 2009.

Table 1 presents summary statistics for the variables we have described. Also, augmented Dickey–Fuller (ADF) unit-root test statistics are reported. The top grouping of statistics is associated with the full 1990–2009 sample. There are also statistics provided for both a 1990–1996 subsample and a 1997–2009 subsample. This anticipates evidence on a structural break that is reported later and subsequent analysis of the two subsamples separately. Here we merely note that, in all cases and subsamples, the unit-root null hypothesis is easily rejected by the ADF tests.

In addition to estimating β_I from Equation 4.2, we will also be interested in estimating how this parameter changed over time in the lead-up to the crisis. To do so, we perform "rolling regressions" with a moving window of 201 weekly observations. We compute β_I estimates centered on dates starting from September 30, 1992, and ending with a β_I estimate centered on November 11, 2007. By "centered on," we mean that the regression includes that date's observation and both the 100 observations before and the 100 observations after. By plotting these rolling regression β_I we can get an indication of how market perceptions of maturity mismatch evolved over time.

Additionally, we can use the rolling regression estimates as time series with which to examine how bank holdings of various asset categories affected perceived maturity mismatch. Using Federal Reserve aggregate commercial bank balance-sheet data, we estimate regressions of the form

$$\begin{aligned}\hat{\beta}_{It} = \alpha_0 + \alpha_1 \times \left(\frac{\text{Real Estate Loans}}{\text{Equity}}\right) + \alpha_2 \times \left(\frac{\text{Cash Assets}}{\text{Equity}}\right) + \\ \alpha_3 \times \left(\frac{\text{Commercial and Industrial Loans}}{\text{Equity}}\right) + \alpha_3 \times \left(\frac{\text{Consumer Loans}}{\text{Equity}}\right)\end{aligned}.^{11} \qquad (4.3)$$

Estimates of the α_i coefficients from Equation 4.3 indicate whether, on the margin, increases in the proportion of a bank's balance sheets composed by a given asset category were associated with increases ($\alpha_i > 0$) or decreases ($\alpha_i < 0$) in perceived maturity mismatch.

[8] This value-weighted index was created using a list of all publicly traded BHCs with price data available from the Center for Research in Security Prices. The BHC list is available from the Federal Reserve Bank of New York at http://www.newyorkfed.org/research/banking_research/datasets.html (accessed 17 July 2012).

[9] Analysis using the S&P 500 index and the NASDAQ Bank index (IXBK) yield similar results.

[10] The source is the Board of Governors of the Federal Reserve; 7-year and 10-year rates can be found at, respectively, http://research.stlouisfed.org/fred2/data/WGS7YR.txt (accessed 17 July 2012) and http://research.stlouisfed.org/fred2/data/WGS10YR.txt (accessed 17 July 2012).

[11] Federal Reserve commercial bank balance-sheet data are available at http://www.federalreserve.gov/releases/h8/current/default.htm (accessed 17 July 2012). The data series used are "Real Estate Loans; All Commercial Banks; SA," "Cash Assets; All Commercial Banks; SA," "Consumer Loans; All Commercial Banks; SA," "Commercial and Industrial Loans; All Commercial Banks; SA," and "Residual (assets less liabilities" (assets less liabilities; equity).

Table 1. Summary Statistics for Regression Variables

	R_t	$R_{m,t}$	$R_{l1,t}$	$R_{l2,t}$	$R_{l3,t}$
1990–2009					
Mean	0.0023	0.0004	0.0023	0.0007	0.0007
Standard deviation	0.0264	0.0051	0.0394	0.0235	0.0272
Maximum	0.1694	0.0311	0.2754	0.1536	0.1800
Minimum	−0.1427	−0.0394	−0.3280	−0.1168	−0.1284
ADF1	−33.018***	−32.036***	−11.488***	−25.673***	−26.404***
ADF2	−33.373***	−32.082***	−11.530***	−25.662***	−26.391***
Observations	989	989	989	989	989
1990–1996					
Mean	0.0053	0.0007	0.0007	0.0008	0.0008
Standard deviation	0.0147	0.0029	0.0210	0.0160	0.0176
Maximum	0.0684	0.0126	0.0808	0.0421	0.0485
Minimum	−0.0338	−0.0098	−0.0675	−0.0566	−0.0642
ADF1	−14.550***	−17.848***	−12.753***	−14.801***	−14.977***
ADF2	−14.615***	−17.820***	−12.909***	−14.827***	−15.009***
Observations	321	321	321	321	321
1997–2009					
Mean	0.0009	0.0003	0.0030	0.0006	0.0007
Standard deviation	0.0303	0.0058	0.0457	0.0264	0.0308
Maximum	0.1694	0.0311	0.2754	0.1536	0.1800
Minimum	−0.1427	−0.0394	−0.3280	−0.1168	−0.1284
ADF1	−28.120***	−26.416***	−9.509***	−21.044***	−21.705***
ADF2	−28.229***	−26.415***	−9.566***	−21.028***	−21.688***
Observations	668	668	668	668	668

Full sample period is the week of October 31, 1990, through the week of October 7, 2009. The 1990–1996 sample period is the week of October 31, 1990, through the week of December 28, 1996. ADF1 and ADF2 denote augmented Dickey–Fuller statistics from unit-root tests including, respectively, intercept only and trend with intercept. Lag length in both cases was based on the Schwarz information criterion.

*** Significant at the <0.01 level.

5. Results

Estimated Perceptions of Maturity Mismatch

Results of estimating Equation 4.2 are presented in Table 2. There are three regressions reported on, based on our full weekly time-series sample (October 31, 1990, to October 7, 2009). The dependent variable in each case is our BHC returns index. Each panel then contains the results of three regressions, one for each of the risk-free bond returns that we consider (based on 1-year, 7-year, and 10-year Treasuries, respectively). All standard errors (reported in parentheses) are Newey–West heteroscedastic and autocorrelation consistent.

The coefficient of interest (β_l) is on the bond returns, which is an inverse proxy for market interest rates. This coefficient should be larger (smaller) when bank balance sheets are relatively shorter-funded (longer-funded). Surprisingly, the β_l estimates are statistically insignificant in all three regressions. At best, Table 2 paints an ambiguous picture regarding perceptions of effective maturity mismatch in the U.S. banking system from October 1990 to October 2009.

Table 2. Equity-Weighted BHC Index Returns Regressed on General Stock Market Returns and Risk-Free Bond Returns: Full 1990–2009 Time-Series Sample

Observations: 989	1-Year Treasury (R_{l1})	7-Year Treasury (R_{l2})	10-Year Treasury (R_{l3})
CRSP value-weighted index (R_m)			
β_0	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)
β_m	0.276***	0.277***	0.277***
	(0.018)	(0.019)	(0.019)
β_l	0.010	0.015	0.013
	(0.009)	(0.013)	(0.013)
R^2	0.516	0.516	0.516

Newey–West standard errors are in parentheses. Sample period is the week of October 31, 1990, through the week of October 7, 2009.

*** Significant at the <0.01 level.

A Structural Break in Perceptions?

The lack of significance in our β_l coefficients presented in Table 2 is somewhat surprising, since other studies have found bank performance to be highly sensitive to changes in the interest rate. One potential explanation for this ambiguity is that the perceptions of bank maturity mismatch may have changed in the years leading up to the 2008 financial-markets crisis. To explore this hypothesis, we search for structural breaks in our β_l estimates of interest-rate sensitivity. If we find a structural break, we can test the prebreak and postbreak periods to determine which categories of bank assets may have been responsible for this change in the perceptions of maturity mismatch.

We test for structural breaks using the Quandt likelihood ratio (QLR) to identify significant changes in our β_l estimates of interest-rate sensitivity. To perform this test, we must first specify β_l as an AR(p) process. To specify the number of lags, p, we use the Akaike information criterion (AIC). Based on the AIC, the preferred lag structure is six lags using the 1-year Treasury index and 11 lags for the 7-year and 10-year Treasury indexes. Given this lag structure, we perform QLR tests for an unknown structural break date in β_l for each of the specifications from Table 2. The degrees of freedom are ($p + 1$) based on the inclusion of a constant term as well. (See Stock and Watson 2010, chapter 14, for details.)

Table 3 reports the QLR test statistics associated with the most likely break date for the six combinations of Treasury bonds and lag structures. The specific dates are reported along with the 5% critical test values for each test. It turns out that under all 12 specifications, the QLR test suggests a break point for the β_l coefficient at the end of 1996 (in November or December). The break estimate is, in every case, statistically significant at better than the 5% level.

Figure 2 plots the QLR test statistics computed at the various observations for all three Treasury bonds using a six-lag structure.[12] Five percent critical values are displayed as horizontal lines in each subfigure. In all cases, the large spike in the QLR test statistic value near the end of 1996 indicates a significant structural break. There is also a peak in the

[12] Only graphs based on an assumption of six lags are presented in Figure 2, since the plots are virtually identical based on the 11-lag assumption.

Table 3. Test Statistics and Break-Point Dates from QLR Tests of Risk-Free Bond Returns Coefficients

Dependent Variable	BHC Index	1-Year Treasury (R_{l1})	7-Year Treasury (R_{l2})	10-Year Treasury (R_{l3})
		6 lags, critical value (5%): 3.15		
CRSP value-weighted index (R_m)	Date	12/14/1996	11/09/1996	11/09/1996
	QLR statistic	5.83	3.94	5.90
		11 lags, critical value (5%): 2.71		
CRSP value-weighted index (R_m)	Date	12/14/1996	11/09/1996	11/09/1996
	QLR statistic	6.72	3.64	4.94

mid-2000s for the 7-year Treasury specification that is significant at the 5% level. However, a most likely break at the end of 1996 is dramatically evident across the panels of Figure 2.

Based on the QLR test results, we split our time-series data into two time subsamples covering, respectively, roughly 1990–1996 and 1997–2009.[13] We then run regressions based on Equation 4.2 for each of the specifications and for each of the two time-period subsamples. The estimates of the β_l coefficients using the "prebreak" and "postbreak" samples are reported in the top rows of Table 4. For each of the specifications, the prebreak coefficient estimate on risk-free bond returns is positive and significant at the 1% level. This suggests that up to and including 1996, market participants perceived banks to be short-funded; the effective terms of their assets were longer than those of their liabilities. However, the postbreak β_l estimates are not statistically different from 0. Through 1996, banks were perceived as being short-funded, but after 1996, these perceptions were reversed.[14]

Bank Asset Categories and Changes in Perceived Maturity Mismatch

These results indicate a change in perceptions concerning maturity mismatch between 1990 and 2009, our best guess being some time towards the end of 1996. Whereas market participants had previously perceived U.S. commercial banks to be effectively short-funded, after 1996 there is little evidence that market participants perceived bank assets to be effectively longer-term than bank liabilities. Indeed, the only statistically significant estimates that we report suggest the opposite. The question that inevitably follows from these results is: Why? To shed some light on an answer, we carry out, for each of the three specifications, rolling regressions with a moving window of 201 weekly observations and compute β_l estimates centered on dates starting from September 30, 1992, and ending with November 11, 2007. We use the resulting weekly time series of estimated β_l coefficients as dependent variables in regressions based on Equation 4.3 where various bank asset holdings scaled to equity are controls. We estimate six regressions using both prebreak and postbreak subsamples for each of the three specifications.

[13] For each specification, we separate the pre- and postbreak periods based on the dates of the actual break points in November or December of 1996, suggested by the QLR test results in Table 3 and assuming six lags.

[14] In a previous version of this article, we computed β_l estimates for 27 of the largest U.S. BHCs for both the 1990–1996 and 1997–2009 subsamples. While earlier- and later-period β_1 estimates were not often statistically different from one another, whenever they were (in regressions involving five of the BHCs), the later-period β_l estimate was significantly lower.

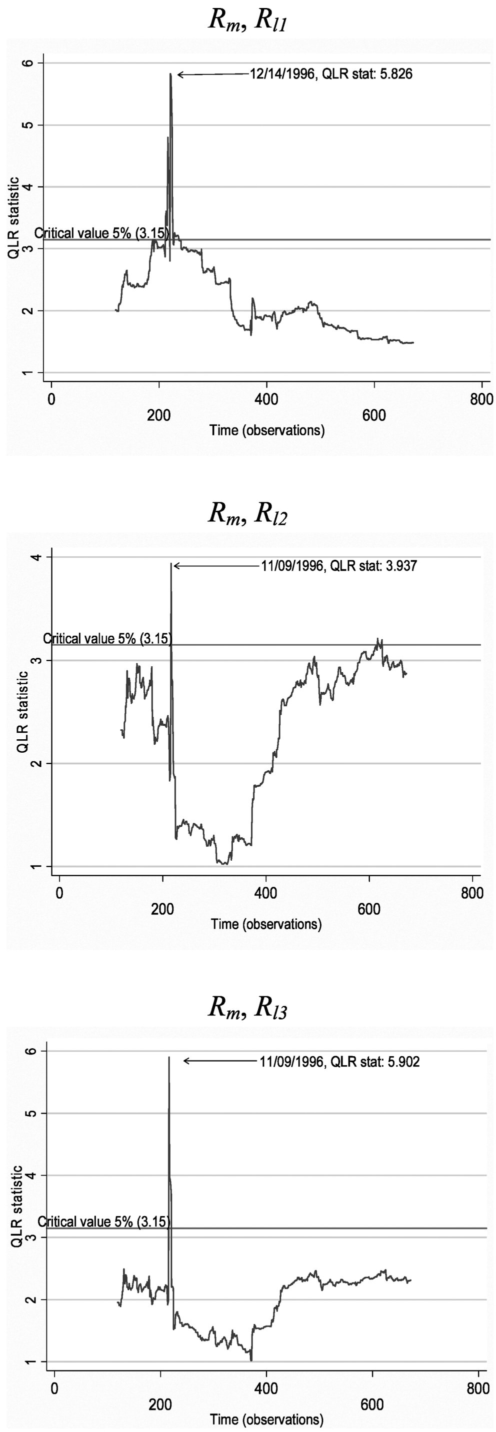

Figure 2. Plots of QLR Test Statistics Associated with Risk-Free Bond Returns Coefficients

Table 4. Equity-Weighted BHC Index Returns Regressed on General Stock Market Returns and Risk-Free Bond Returns: 1990–1996 and 1997–2009 Subsamples

	1-Year Treasury (R_{I1})	7-Year Treasury (R_{I2})	10-Year Treasury (R_{I3})
	R^2 (prebreak): 0.354 Observations: 320 R^2 (postbreak): 0.548 Observations: 669	R^2 (prebreak): 0.353 Observations: 315 R^2 (postbreak): 0.548 Observations: 674	R^2 (prebreak): 0.352 Observations: 315 R^2 (postbreak): 0.548 Observations: 674
CRSP value-weighted index (R_m)			
β_I (prebreak)	0.034***	0.052***	0.045***
	(0.014)	(0.016)	(0.015)
β_I (postbreak)	0.008	0.009	0.008
	(0.010)	(0.016)	(0.015)
	R^2 (prebreak): 0.020 Observations: 315 R^2 (postbreak): 0.146 Observations: 674	R^2 (prebreak): 0.021 Observations: 315 R^2 (postbreak): 0.136 Observations: 674	R^2 (prebreak): 0.021 Observations: 315 R^2 (postbreak): 0.137 Observations: 674
Large BHCs			
β_I (prebreak)	0.109**	0.160***	0.134**
	(0.0477)	(0.060)	(0.054)
β_I (postbreak)	0.019	0.035	0.035
	(0.044)	(0.076)	(0.070)
	R^2 (prebreak): 0.490 Observations: 315 R^2 (postbreak): 0.545 Observations: 674	R^2 (prebreak): 0.491 Observations: 315 R^2 (postbreak): 0.545 Observations: 674	R^2 (prebreak): 0.355 Observations: 322 R^2 (postbreak): 0.546 Observations: 674
Small BHCs			
β_I (prebreak)	0.093	0.363	0.325
	(0.299)	(0.404)	(0.362)
β_I (postbreak)	0.152**	0.133*	0.138**
	(0.043)	(0.072)	(0.062)

Newey–West standard errors are in parentheses. Full sample period is the week of October 31, 1990, through the week of October 7, 2009. "Prebreak" and "postbreak" subsamples correspond to a break point of November 9, 1996, based on a QLR test for the full sample assuming 10 lags and reported in Table 3.

* Significant at the <0.10 level.

** Significant at the <0.05 level.

*** Significant at the <0.01 level.

Before we discuss the results, we pause to comment on the interpretation of coefficients in Equation 4.3. Because each category of bank assets enters relative to bank equity, the correct interpretation of its coefficient is the impact on perceived maturity mismatch of banks shifting funds to or from excluded asset categories (Flannery and James 1984, p. 441). Therefore, a negative coefficient on an asset category is interpreted as perceived maturity mismatch increasing when a greater proportion of funds is put into that category of assets. However, a negative coefficient does not necessarily imply that assets in that category are generally perceived as shorter-term than bank liabilities. Also, all regressions contain constants, and though we do not dwell on their estimates, the constant in Equation 4.3 in part "captures the interest sensitivity of bank equity due to off-balance sheet activities" (Flannery and James 1984, footnote 8).

Table 5 contains the results. The prebreak coefficient estimate on real estate loans is positive and significant at the 1% level in every specification. Remarkably, while the coefficients

Table 5. Regressions of Estimated β_{lt} Time Series from Rolling Regressions on Various Categories of Bank Assets Scaled to Equity

Dependent variable: Equity-weighted BHC β estimates, β_{lt}		1 R_m; R_{l1} R^2: (prebreak): 0.228 (postbreak): 0.437	2 R_m; R_{l2} R^2: (prebreak): 0.385 (postbreak): 0.363	3 R_m; R_{l3} R^2: (prebreak): 0.168 (postbreak): 0.388
Real estate loans	(prebreak)	1.712*** (0.285)	2.045*** (0.335)	1.486*** (0.280)
	(postbreak)	0.508*** (0.069)	0.505*** (0.076)	0.434*** (0.087)
Cash assets	(prebreak)	−0.231 (0.163)	−0.502** (0.195)	0.182 (0.170)
	(postbreak)	1.473*** (0.073)	0.801*** (0.061)	1.054*** (0.075)
Commercial and industrial loans	(prebreak)	−0.571*** (0.168)	−0.854*** (0.191)	−0.802*** (0.164)
	(postbreak)	0.214*** (0.040)	0.624*** (0.041)	0.597*** (0.044)
Consumer loans	(prebreak)	0.029 (0.206)	0.181 (0.246)	0.047 (0.213)
	(postbreak)	−0.825*** (0.224)	−0.617*** (0.216)	−0.638*** (0.259)
Constant	(prebreak)	−0.289*** (0.064)	−0.284*** (0.075)	−0.222*** (0.064)
	(postbreak)	−0.264*** (0.031)	−0.269*** (0.034)	−0.262*** (0.039)

Newey–West standard errors are in parentheses. Sample period is the week of October 31, 1990, through the week of October 7, 2009. Number of observations for specifications 1 and 3: 215 and 575 for the prebreak and postbreak periods, respectively. Number of observations for specification 2: 220 and 570 for prebreak and postbreak periods, respectively. Shaded estimates represent cases where the later-period confidence interval is (i) lower than and (ii) not overlapping the earlier-period confidence interval.

** Significant at the <0.05 level.

*** Significant at the <0.01 level.

of real estate loans are also positive in the postbreak period, the point estimates each fall by more than 65%. Increases in real estate loan holdings were positively related to perceptions of maturity mismatch during the entire 1990–2009 time period. However, subsequent to 1996 they were less positively related. In other words, the perceived effective terms of real estate loans decreased.

The results are similar for consumer loans. Through 1996, changes in holdings of consumer loans do appear to have had a positively significant effect on perceived maturity mismatch. The postbreak coefficients are, when statistically significant, actually negative. This indicates that after 1996, market participants perceived increases in consumer loan holdings as being associated with decreases in U.S. commercial bank maturity mismatch.

Coefficient estimates on commercial and industrial loans and, perhaps more surprisingly, cash assets increase from the prebreak period to the postbreak period. The prebreak estimated effects on commercial industrial loans are always negative and statistically significant (5% level or better). Based on the data subsequent to 1996, the coefficient estimates are always significant (10% level or better) and positive. Whereas consumers began to perceive real estate loans and consumer loans as shorter-term assets, our results suggest that they began to perceive loans to commercial and industrial firms as longer-term assets.

Remarkably, the results are similar for cash assets. While the estimated prebreak coefficients are not always significantly different from 0, the coefficient of the 7-year Treasury is significantly negative at the 5% level. Postbreak, the estimated effect is always positive and significant at the 1% level. *Post-1996, the greater the portion of banks' balance sheets composed of cash assets, the greater the perception of maturity mismatch!* This is puzzling. The results contained in Table 5 as a whole suggest to us the possibility that, in the years leading up to the financial crisis, the perceptions of market participants were becoming divorced from the realities of the commercial banking system.

Large versus Small BHCs

What underlying market forces caused these changed perceptions of maturity mismatch after 1996? The mid-1990s featured several major financial regulatory changes and other events (e.g., the Federal Housing Enterprises Financial Safety and Soundness Act of 1992; the Asian financial crisis in 1997). In this section we split our sample of banks into two groups: large and small BHCs. We have data on how large and small banks differed in terms of balance-sheet composition and also how some policies affected them differently. Examining how results differ for the two groups can help to home in on plausible causes.

We define large BHCs as the 100 with the highest average total assets over the sample period.[15] The remaining BHCs (584) are classified as small, and we construct two value-weighted stock indexes based on the large and small subsamples. For 2009 the average large BHC in our sample had total assets of \$105 billion; the average small bank had total assets of \$1.5 billion.[16]

Below the full sample results in Table 4 we report separate prebreak and postbreak estimates of β_l for the small- and large-BHC subsamples.[17] The results associated with large BHCs are qualitatively similar to those using the full sample: Perceived maturity mismatch is positive and statistically significant in the prebreak period but is not significantly different from 0 post-1996. Using the small-BHC index, we get entirely opposite results: insignificant prebreak, positive and significant post-1996. The estimated decrease in perceived maturity mismatch post-1996 appears to clearly be driven by large BHCs.

6. Discussion

In the years following 1996, perceptions of maturity mismatch in the U.S. commercial banking system appear to have changed. Specifically, commercial banks were perceived to be effectively

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[15] Considering that four large BHCs (JPMorgan Chase, Bank of America, Citigroup, and Wells Fargo) control almost 50% of the assets in the U.S. banking system, all major banks are likely to be included in the top 100 BHCs.

[16] On average in 2009, large BHCs held less of their assets as real estate loans than small BHCs (37.8% vs. 47.1%). This is not because large banks are less active in real estate loan originations (Harvey 2009). Rather, the difference reflects the greater tendency of large banks to securitize real estate assets and move them off the balance sheet (Jiangli and Pritsker 2008). Panetta and Pozzolo (2010) report a similar tendency for a cross-country sample of banks.

[17] As before, we conducted QLR tests for both the large-BHC and small-BHC indexes. Regardless of the bond index used, the large-BHC series has a structural break in 1996 that is significant at the 10% level or better. (In each case, this break is also the highest probability break before the mid-2000s.) For the small BHCs, alternatively, while there is evidence for a 1996 break, it is much weaker. (Using the 7-year Treasury rate, the QLR statistic is actually marginally insignificant; using the 1-year or 10-year Treasury rate, it is marginally significant.)

long-funded. As they devoted an increasingly large portion of their funds to real estate loans, this contributed to their being perceived as effectively longer-funded. And cash assets were perceived as effectively longer-term than either the real estate loans or the commercial and industrial loans on banks' balance sheets. These perceptions seem inconsistent with the fractional-reserve commercial banking system that we describe to undergraduates in our money and banking courses.

They also differ from the perceptions that prevailed during the 1990–1996 time period. During that earlier period, commercial banks were perceived as short-funded. Real estate loans were perceived to be effectively longer-term than commercial and industrial loans, consumer loans, or cash assets. What happened around the mid-1990s to change the perceptions of market participants so radically? Answering this question may be critical for understanding developments in the commercial banking system that contributed to the recent financial crisis. Regarding U.S. broker-dealer institutions, Diamond and Rajan (2009, p. 606) note that the "consensus on the proximate causes of the crisis [includes] misallocated resources to real estate, financed through the issuance of exotic new financial instruments [which] were largely financed with short-term debt." Adrian and Shin (2008, p. 3) also stress the importance of maturity mismatch for U.S. broker-dealer institutions:

> The pinch points will be those institutions that are highly leveraged and who hold long-term illiquid assets financed with short-term debt[.] When the short-term funding runs away, the pinch point financial institutions will face a liquidity crisis. Arguably, this is exactly what happened to Bear Stearns[.]

The remarkable increase in real estate loans as a percentage of bank assets (Figure 1) suggests that similar "proximate causes" may have been relevant to the commercial banking system. The changed perceptions of maturity mismatch documented in the foregoing preceded and perhaps played a causal role in the increased holdings of real estate loans.

There were several major financial events in the mid-1990s that could be suspects in the change of perceptions. The Asian financial crisis occurred in 1997, almost precisely where we estimate a break point in perceptions of maturity mismatch. Not long afterwards, in 1998, the Federal Reserve's organized bailout of Long-Term Capital Management occurred. However, we suspect that the cause was something more specific to real estate and mortgage markets. We know that the changed perceptions of maturity mismatch were followed by a period of commercial banks increasing the share of their business made up by real estate loans. We also have presented evidence that real estate loans became perceived as effectively shorter-term. While we also present evidence that consumer loans became perceived as shorter-term, consumer loans decreased on average during the entire 1990–2009 period; furthermore, they are trending downward during the entire post-1996 period.

If we look, then, specifically towards the U.S. housing and mortgage market in the mid-1990s, notable policy developments include the Federal Housing Enterprises Financial Safety and Soundness Act (FHEFSSA) of 1992, the 1995 implementation of the Community Reinvestment Act (CRA), and the encouragement of the Department of Housing and Urban Development (HUD) to stimulate the mortgage and mortgage-backed securities (MBS) secondary market. These policy innovations were complementary and, we argue, could have contributed to changing perceptions of maturity mismatch associated with commercial banks whose balance sheets were increasingly flush with real estate loans.

The FHEFSSA established the Office of Federal Housing Enterprise Oversight as an independent agency within HUD to monitor the government-sponsored entities (GSEs)

Table 6. GSE Housing Goals, 1993–2006

	Low- and Moderate-Income		Underserved Areas		Special Affordable	
	Fannie Mae	Freddie Mac	Fannie Mae	Freddie Mac	Fannie Mae	Freddie Mac
1993	34.2	29.7	23.6	21.8	9.7	7.0
1994	44.8	37.4	29.5	25.2	15.2	11.3
1995	42.3	38.9	31.9	26.4	14.1	12.8
1996	45.6	41.1	28.1	25.0	15.4	14.0
1997	45.7	42.6	28.8	26.3	17.0	15.2
1998	44.1	42.9	27.0	26.1	14.3	15.9
1999	45.9	46.1	26.8	27.5	17.6	17.2
2000	49.4	49.9	31.0	29.2	19.2	20.7
2001	51.5	53.2	32.6	31.7	21.6	22.6
2002	51.8	50.3	32.8	31.0	21.4	20.5
2003	52.3	51.2	32.1	32.7	21.2	21.4
2004	53.4	51.6	33.5	32.3	23.6	22.7
2005	55.1	54.0	41.4	42.3	26.3	24.3
2006	56.9	55.9	43.6	42.7	27.8	26.4

Goals are stated in terms of percentages of homes financed by the GSE. Source: HUD (2002, 2008).

Freddie Mac and Fannie Mae. The secretary of HUD was tasked with establishing and enforcing goals for the GSEs in terms of financing provided to make housing more affordable—for example, GSEs were required to purchase both mortgages made to low- and moderate-income households and mortgages on properties located in "underserved areas" of the economy.[18] Shortly afterwards, in 1995, the Clinton administration requested that HUD implement the mandates (up until that time, largely toothless) of the 1977 CRA. The FHEFSSA set out transitional goals for 1993 to 1995 and then, under the auspices of the CRA, HUD began steadily increasing the goals, continuing to do so through 2006 (Table 6). Also around 1995, Fannie Mae and Freddie Mac both introduced automated software to loan originators. The statistical analyses carried out by the GSEs' software packages supported the origination of loans that banks would have previously considered too risky (Straka 2000).

These innovations to mortgage-market practice and policy likely signaled increased GSE secondary-market purchases of mortgages and MBSs and less scrutiny of the loans underlying those purchases. This is precisely the sort of development that could have decreased the perceived time to repricing of real estate loans. Our estimates date a break in perception of maturity mismatch at the end of 1996, very soon after these innovations were put into effect. Of course, if these changes in practices and policies were unwise, then the resulting changes in perceptions of maturity mismatch may have been unreasonable; underlying real estate loans may have been more risky and less liquid than market participants were led to believe.

Another likely relevant innovation was the Financial Services Modernization Act (FSMA) of 1999. The FSMA came three years after the estimated break, but it likely had an effect that was complementary to the 1992 FHEFSSA and the 1995 HUD CRA implementation. The FSMA allowed commercial banks to enter markets that were previously the exclusive domain of insurance companies and investment banks. These markets emphasize fees that are a more volatile source of income for banks and can increase the likelihood of financial distress (see,

[18] See DiVenti (2009) for more details on FHEFSSA and the role of HUD.

e.g., Roland 1997; DeYoung and Roland 2001; DeYoung and Rice 2004; Stiroh 2004; Purnanandam 2007). As banks become more dependent on relatively volatile income from fees, this creates incentives for them to more aggressively manage interest-rate risk.[19] This, in turn, could lead to decreased sensitivity of their equity returns to changes in interest rates.

Note that the FHEFSSA, the HUD CRA implementation, and the FSMA would all be expected to have affected large banks to a greater extent than smaller banks. These regulatory and policy innovations encouraged securitization activities (especially in regards to real estate loans) and a shift in business models towards fee income. Both securitization (Jiangli and Pritsker 2008) and fee income (DeYoung and Rice 2004) are predominantly associated with large BHCs. As we reported earlier, it appears to be large BHCs that are primarily associated with the changes in perceptions of maturity mismatch.

7. Conclusions

Farhi and Tirole (2012, p. 61) have called the recent financial crisis "one of wide-scale maturity mismatch." In this article we have explored market participants' perceptions of maturity mismatch in the U.S. commercial banking system during the years leading up to and encompassing the crisis (1990 to 2009).

We use the sensitivity of bank holding company equity returns to market interest rates as an indicator of perceived maturity mismatch. Based on data covering the entire 1990–2009 period, there is only weak evidence that market participants perceived banks to be effectively short-funded. This appears to be due to a break in perceptions near the end of 1996. Breaking the time-series data in two subsamples (roughly 1990–1996 and 1997–2009), our results suggest that banks were perceived as effectively short-funded during the earlier time period. This is consistent with economists' conception of fractional-reserve banking. However, from the latter period (1997–2009) there is no evidence that market participants perceived banks to be short-funded. During a time when U.S. banks became increasingly flush with real estate loans, perceived maturity mismatch decreased.

We present evidence that, subsequent to 1996, market participants perceived consumer loans and real estate loans as having become effectively shorter-term. Alternatively, commercial and industrial loans and cash assets were perceived as having become effectively longer-term. Since it is real estate loans that increased notably as a share of commercial bank assets during this time period, we speculate that innovations to the mortgage market in the mid-1990s contributed to the changed perceptions of maturity mismatch. Specifically, we point to the Federal Housing Enterprises Financial Safety and Soundness Act of 1992 and the subsequent oversight of the government-sponsored mortgage giants Fannie Mae and Freddie Mac by HUD, starting in 1995. These innovations created incentives for banks to discount the risk and illiquidity of real estate loans. Furthermore, the elimination of restrictions on commercial banks associated with the Financial Services Modernization Act of 1999 likely had complementary effects, encouraging securitization and fee-based activities associated with the mortgage market.

[19] Notably, interest rates were also generally lower post-1996, and it is recognized that banks have a stronger tendency to hedge against interest rates when they are low relative to when they are high (Bharati, So, and Nanisetty 2006).

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