Bank Failures, Capital Buffers, and Exposure to the Housing Market Bubble*

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Abstract

We empirically document that banks with greater exposure to high home price-to-income or price-to-rent ratio regions before the financial crisis of 2007–2009 have higher mortgage delinquency and charge-off rates and significantly higher probabilities of failure during the crisis even after controlling for standard bank characteristics and local economic conditions. While high house prices relative to fundamentals present a greater likelihood of house price correction, we find no evidence that banks managed this risk by building stronger capital buffers. The bank level mortgage risk measures we develop could be used to improve risk management.

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1 Introduction

In the lead up to the financial crisis of 2007–09, mortgage credit expanded tremendously in the U.S. economy, especially in areas that experienced the largest house price growth. Due to the size of that market, the unwinding of mortgage risk became systemic. The large decline in residential housing prices led to extensive short sales, foreclosures, and ultimately, to many bankruptcies and a global recession. The first signs of this crisis emerged in financial institutions heavily exposed to the U.S. mortgage market, especially to the subprime segment. As housing market began to cool in late 2005 and 2006 and house prices reversed trend, a series of financial companies struggled with solvency, including the mortgage giants of Washington Mutual, Countrywide, and New Century. As the crisis deepened, financial institutions issuing and holding mortgages and even agencies insuring mortgage-backed securities also experienced distress. The result was the collapse or near collapse of several investment banks and insurance companies, most notably AIG, Bear Stearns, and Lehman Brothers.

The high profile distress of large financial institutions, which were highly exposed to the mortgage market, led to a widespread belief in the public sphere that these exposures were the primary culprit underlying the troubles of the broader financial industry, including commercial banks which were also hit hard by the crisis. Delinquency and charge-off rates skyrocketed, and over 300 commercial banks failed in the U.S. during and in the immediate aftermath of the crisis. Despite the apparent consensus that the mortgage credit boom was at the center of the last crisis, some studies that examined the large number of commercial bank failures during the crisis found no evidence that these failures were driven in part by banks’ residential mortgage exposures.

In this paper, we revisit this question of what role did mortgage loans play in commercial bank losses and, ultimately, in failures. Our analysis contributes to these debates on two
dimensions. First, we offer a novel approach by utilizing loan level data from the Home Mortgage Disclosure Act (HMDA) to create better bank level mortgage risk measures. We find that banks with more mortgage exposures in counties with overvalued housing markets performed worse during the crisis, where performance is measured by delinquent loans, loan charge-offs, and likelihood of bank failure. Second, we show that banks with larger exposures to these overvalued counties did not manage their increased risk by building capital buffers. We argue that the latter result is driven in part by the invariance of bank capital regulations to the different risk characteristics of mortgage loans.

For the first contribution, we measure the riskiness of underlying mortgages using forward-looking measures of housing overvaluation, primarily using price-to-income (PTI) and price-to-rent (PTR) ratios. These are good indicators of risk across markets and through time because they link the asset value to fundamentals. The value of a house should be related to the stream of housing services it provides. Davis and Ortalo-Magne (2011) document that housing services tend to be a constant fraction of household income. If prices grow faster than household income, housing becomes more unaffordable. PTI captures this risk, because it will increase as house prices deviate away from household incomes. Similarly, PTR measures the extent to which house prices are disconnected with a close substitute: rental property.

We first demonstrate that exposure to counties with high PTI and PTR ratios captures banks’ mortgage risk. Using a difference-in-differences regression design, we show that banks which originated and retained loans in such overvalued counties in the years leading up to the crisis have higher mortgage delinquencies and, ultimately, charge-offs during and in the early aftermath of the financial crisis. With this relationship between PTI/PTR exposure and residential real estate (RRE) asset quality established, we then examine the relationship between exposure to overvalued counties in 2005 and 2006 and bank failures in the 2008–11 period. In particular, we run probabilistic regressions of a failure indicator on common bank
performance measures, and focus on the interaction term between PTI/PTR exposure and residential mortgages. We show that banks with large exposures to counties with high house prices relative to incomes or rents are more likely to fail. Therefore, we argue that accounting for the riskiness of a mortgage portfolio is essential for establishing a link between residential mortgage exposures and bank performance. Most studies on bank failures use RRE loans as a percent of assets to control for mortgage exposures, but this measure only accounts for the size of a bank’s mortgage business and is invariant to the riskiness of underlying mortgages. Our results confirm that this measure is not positively related to mortgage delinquency rates, charge-offs, and bank failures in the crisis episode. Similar to the findings in existing studies, we also document that high commercial real estate (CRE) exposure and low regulatory capital were also significant drivers of bank failures during the last crisis.

Historical evidence from several countries suggests that the PTI ratio and some other price-based indicators such as the growth rate of house prices and the PTR ratio are good forward-looking measures of financial stability risk. In particular, cross-country studies indicate that both the level and the growth rate of PTI ratio typically rise in the years ahead of major financial crises, and signal a build-up of vulnerabilities and imminent distress (BOE, 2016; ESRB, 2014). In addition, during the financial crisis in the United States, our sample of county-level data shows that a large deviation of house prices from fundamentals, such as household income, is associated with bigger corrections in house prices and employment (Figures 1–4).

Data on house prices, rents, and incomes in a given region are available in a fairly timely manner. Using PTI or PTR as a risk characteristic is well known by real estate experts. Thus, it is likely that when a bank is exposed to such overvalued regions, its managers and investors are aware of the risk build-up. From a risk management perspective, one may expect these banks to build stronger capital buffers for the additional risk exposure. However, using data from the pre-crisis episode (2003–2006) in a panel regression, we show
that banks that experienced large increases in their exposure to overvalued counties before the crisis did not increase their capital buffers relatively more to counteract this extra risk. This lack of capital build can partially be attributed to the notion that markets did not anticipate an imminent house price correction in the 2000s. It may also reflect moral hazard: banks expected to be bailed out by the government in case of a downturn and therefore did not voluntarily provision for such a scenario. However, we argue that the lack of prudential behavior during the lead up to the financial crisis was also due in part to the design of bank regulations in the pre-crisis environment.

Basel bank capital regulations are largely invariant to the riskiness of underlying mortgages, thereby allowing banks to participate in the expansion of credit during the boom. Thus, our results suggest that there is scope for improved measures of risks associated with residential mortgage lending, measures that could be considered for regulatory and risk management applications. Such measures could help prevent the formation of vicious cycles of asset price booms and leverage by financial institutions. By incorporating mortgage risk measures such as PTI and PTR ratios, banks and regulators can monitor and address building vulnerabilities in the banking system. One way to achieve this would be to explicitly relate mortgage risk weights to forward-looking risk measures such as PTI and PTR ratios. Alternatively, if banks track PTI/PTR exposure for their mortgage portfolio, they may better monitor risk and be positioned to take appropriate steps to hedge that risk by, for example, building additional capital buffers and diversifying their RRE portfolios along geographic lines.

The next section further discusses related research on real estate risk, systemic risk, and bank failure. Section 3 describes the data used in this paper and explains how to construct our measures of mortgage risk. Section 4 explores the relationship between these risk measures and asset outcomes such as delinquency rates and bank failure. Section 5 contains robustness tests. Section 6 then turns to capital and discusses how macroprudential
policies can improve building capital buffers for mortgage exposures. Section 7 concludes.

2 Related Literature

The U.S. mortgage market is funded by roughly $11 trillion in debt (2019, Financial Accounts of the United States). With such a large market, it is important to monitor mortgage risk in the financial system, and since the financial crisis, there has been renewed focus on the drivers of the mortgage credit cycle. For example, Mian and Sufi (2009) show that mortgage defaults during the 2007–09 crisis in the United States were concentrated in ZIP codes that experienced a much larger growth of mortgage credit between 2002 and 2005 without improving fundamentals such as higher income growth. In contrast, Adelino et al. (2016) use different data to show that mortgage originations increased across all income levels. This paper will not focus on the drivers of the mortgage credit cycle and will instead focus on the performance of banks that had more exposure to mortgage risk as measured by deviations from fundamentals.

A large number of studies focusing on early-warning systems, especially after the financial crisis, show that house price growth is a strong predictor of banking crises historically (Barrell et al., 2010; Borio and Drehmann, 2009; Claessens et al., 2010; Drehmann et al., 2010; Jordà et al., 2015; Mendoza and Terrones, 2008; Reinhart and Rogoff, 2008; Riiser, 2005). Cross country analyses by the European Systemic Risk Board and Bank of England show that both house price growth and PTI are robust predictors of banking crises (ESRB, 2014; BOE, 2016). Detken et al. (2014) using data from 28 European Union countries that span the time period 1970–2012, show that relative house price measures perform better in crisis prediction than other market- or real economy-based indicators. Building upon this work, and Tölö et al. (2018), show that PTI outperforms transformations of the PTR ratio or real house prices as an early warning signal for banking crises. Additionally, using data from
32 advanced and emerging economies, Deghi et al. (2020) show that an increase in house prices relative to incomes presents a greater likelihood of house price correction. Given these findings, we contribute to this literature by adopting county-weighted measures of both PTI and PTR for individual U.S. banks. We confirm that exposure to high PTI or high PTR counties is associated with mortgage risk outcomes such as delinquencies and charge-offs.

These new measures of mortgage risk in the U.S. banking system are then used to improve upon the bank failure literature. Several studies have examined the underlying causes of bank failures in the U.S. during the financial crisis. These studies have generally pointed to CRE as being the primary driver of bank failures, while dismissing any significant contribution from residential mortgage exposures. For example, the Inspector General of the Federal Reserve Board concludes that the main driver of bank failure was rapid loan growth without matching risk management expertise (FRB, 2011). Specifically, asset concentrations in CRE, especially loans to support construction and land development (CLD), are identified as drivers of bank failure.

While FRB (2011) is based on a relatively small sample of banks, similar conclusions are backed by other broad-based research such as Cole and White (2012), DeYoung and Torna (2013), GAO (2013), Antoniades (2020), and Balla, Mazur, Prescott and Walter (2017). Across these studies, CLD loans, commercial mortgages, and multifamily mortgages are consistently associated with a higher likelihood of bank failure, whereas residential single-family mortgages are either neutral or associated with a lower likelihood of bank failure. In particular, Cole and White (2012) argue that exposures to the residential mortgages, especially to “toxic” residential mortgage-backed securities (MBS) and subprime mortgages, were not among the primary culprits for bringing down nearly 300 commercial banks during 2008–10. The measured impact of RRE loans in these and similar bank failure studies is

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1 The general insights from these studies are in line with an earlier literature that examined the bank and thrift failures during the late 1980s and early 1990s (Thomson, 1991; Whalen, 1991; Wheelock and Wilson, 2000; DeYoung, 2003; Oshinsky and Olin, 2006, are some examples).
relatively small for two main reasons: 1) banks offloaded a large amount of RRE risk by selling them into securitization structures (Mian and Sufi, 2009; Loutskina and Strahan; Demyanyk and Hemert, 2011), 2) standard bank mortgage measures do not account for the riskiness of the loans held on balance sheet. The most common measure used by these studies is RRE loans divided by total assets.

Berger and Bouwman (2013) and DeYoung and Torna (2013) construct somewhat similar mortgage risk measures to ours, but there are crucial differences which lead to different conclusions. To control for banks’ exposures to housing markets, they both calculate house price growth rates for each bank using deposits in each state as weights. Berger and Bouwman (2013) analyze bank failures between 1984 and 2010, and they do not find any significant effect of this price index on the survival probability of banks. Unlike our study, their period covers several market crises and normal times where real sector overvaluation is not a particular concern. Meanwhile, DeYoung and Torna (2013) focus on the last crisis and find that stronger home price appreciation tends to reduce the probability of bank failure. Our results differ in part because we do not use price growth but the ratio of house prices to fundamentals such as incomes and rent. Growth is good for collateral values, but unsupported growth is not sustainable and will eventually correct. Second, we use the location of the actual mortgages not the location of a bank’s deposits to calculate bank level exposure. Third, we use data at the more granular county level. In fact, Mian and Sufi (2009) show that using data at the state level instead of at the local level (ZIP code) for the financial crisis can lead to opposite conclusions.

Our results are consistent with the findings of Altunbas et al. (2017) who show that exposure to the real estate sector had a positive impact on the systemic dimensions of bank risk during the last crisis. Their study is based on publicly listed banks from 16 countries. They calculate the exposure of a bank to the real estate market using a CAPM model, whereas we use loan level data to calculate a bank’s balance sheet exposures to overvalued
housing markets. Furthermore, they mainly focus on market-based risk measures while our bank performance measures include delinquencies, charge-off rates, and bank failure.

Finally, our paper is also part of the broader literature on early warning indicators for financial crises. This literature finds that, in addition to house price growth, financial crises are often preceded by financial liberalization, in particular, rapid growth in credit and monetary aggregates, weak macroeconomic environment, and excessive liquidity creation by banks.\(^2\)

3 Data and Measuring Mortgage Risk

In this section, we discuss our main data sources: Home Mortgage Disclosure Act data, bank financial statements, house price data, and household income data. In addition, we use bank failure data from the Federal Deposit Insurance Corporation (FDIC). At the end of the section, we describe how PTI and PTR are constructed. Variable definitions are provided in table 1.

3.1 The Home Mortgage Disclosure Act (HMDA)

The Home Mortgage Disclosure Act of 1975 is a law requiring most banks, savings and loan associations, credit unions, and consumer finance companies to report every mortgage application received. As a result, the data provide substantial coverage of the United States mortgage market. Avery, Brevoort and Canner (2007) estimate that HMDA covers approximately 80 percent of all home lending nationwide in 2006.\(^3\) The mandatory reporting threshold for depository institutions has changed over time but includes almost all commercial banks that originate mortgages. Any bank with assets above $44 million, with a branch in a metropolitan statistical area, and that originated at least one mortgage loan had to file

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\(^2\)See, for example, Demirgüç-Kunt and Detragiache (1998); Kaminsky and Reinhart (1999); Schularick and Taylor (2012), and Berger and Bouwman (2017).

\(^3\)See Avery et al. (2007) for an extensive discussion of HMDA data.
a HMDA report in 2015.

HMDA data include county and state codes to determine the location of the home. For baseline testing, we use only data on originated and purchased loans that are kept by a bank (not sold in the same year). The loan amount is used to weight the risk measures in each geographic area (county). To exclude outliers, individual mortgage loans with amounts that are smaller than $10,000 or larger than $10 million are dropped.

### 3.2 Bank Financial Statements

We also use financial information for commercial banks from the quarterly Reports of Condition and Income (Call Reports). In order to capture risks associated with bank failure, we use Call Report data to construct variables often used in prior research that are also proxies for the CAMELS ratings (Berger and Bouwman, 2013; DeYoung and Torna, 2013; Antoniades, 2020). These variables should control for idiosyncratic causes of bank insolvency or general risk taking at the bank level. In addition, given the findings of prior research, we include controls for on- and off-balance sheet exposures to the CRE market. Table 1 provides more detail on how the control variables are constructed. Call Reports also contain data on asset quality such as delinquency rates and net charge-offs. These variables are used as outcome variables to assess whether PTI and PTR exposure capture mortgage risk. We match annual HMDA data to Call Reports filed by commercial banks every December for the period between 2000 and 2013.

The sample used in our baseline regressions excludes banks that have total assets below $50 million and banks that start filing Call Reports in 2005 or later. We also drop banks

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4During the period we analyze, all commercial banks must file quarterly either the “Consolidated Reports of Condition and Income for a Bank with Domestic and Foreign Offices” (FFIEC 031) or “Consolidated Reports of Condition and Income for a Bank with Domestic Offices Only” (FFIEC 041).

5The CAMELS rating system is used by bank examiners to assess the safety and soundness of a bank. More specifically, CAMELS is an acronym of six measures: 1) capital adequacy, 2) asset quality, 3) management, 4) earnings, 5) liquidity, and 6) sensitivity to market risk.
that do not file a HMDA form, banks that would not have significant mortgage exposure. In baseline bank failure regressions we also exclude banks that stop filing Call Reports before December 2011 but did not fail. These “missing banks” are generally due to mergers and acquisitions or a bank changing its charter. The resulting samples contain about 2,900 unique banks for delinquency and charge-off rate regressions and about 2,450 unique banks for bank failure regressions.

3.3 House Price and Income Data

The baseline results presented in this paper use house price data from Moody’s. Moody’s is slightly preferred to other home price data sources because it has better coverage of counties. We separately test using house price data from CoreLogic and Zillow to confirm our results. We obtain annual median household income data at the county level from the Census Bureau.

3.4 Price-to-Income (PTI)

PTI is calculated at the county level as the median house price divided by the median household income. PTI has the advantage over other measures as being based on good quality data that are available for most housing markets. As discussed above, the ratio ties house prices to asset pricing fundamentals and has been shown to outperform other measures such as the house price-to-rent ratio or real house prices as an early warning signal for banking crises (Tö lö et al., 2018). PTI is also widely used by the real estate industry to assess risk (e.g., Shiller, 2015).

Figure 1 is a United States map showing the distribution of PTI across counties. The dark blue regions indicate high PTI counties in 2006, at the onset of the crisis. The map shows that PTI was highest mainly in sand states (California, Nevada, Arizona, Florida), western states such as Oregon and Washington as well as states in the northeast. Figure 2
shows the change in PTI between 2006 and 2010. It is almost a mirror image of the previous map. The biggest declines in house prices relative to incomes during the crisis occurred generally in counties where house prices had shown the biggest deviations from incomes in the pre-crisis period. Figures 3 and 4 show that the same counties were also more likely to have larger increases unemployment rates and bigger declines in household incomes during the crisis. This evidence suggests that PTI is a good predictor of vulnerabilities in the housing market.

To measure PTI exposure precisely at the bank level, one would need to know every mortgage that a bank has on balance sheet. HMDA data just report which mortgages a bank originated and kept in that year. Mortgages can be sold off or repaid in subsequent years. For instance, early prepayments are generally done by refinancing a mortgage. In order to get a good estimate of a bank’s market exposure while controlling for these prepayments, we construct a weighted PTI exposure measure using the last three years of mortgage data in HMDA. In particular, bank $i$’s PTI exposure is calculated as follows:

$$PTI_{i,t} = \sum_{c=1}^{C} w_{i,c,t} \times PTI_{c,t},$$

where $c$ indexes counties, and $t$ indexes year. In this formula, $w_{i,c,t}$ are weights which are the percent of mortgage lending to county $c$ based on the dollar amounts of kept owner-occupied mortgages for the past three years at bank $i$ ($w_{i,c,t} = \frac{\sum_{t-2}^{t} mortgages_{i,c,t}}{\sum_{t-2}^{t} mortgages_{i,t}}$). Finally, $PTI_{c,t}$ is the median home price divided by median household income for county $c$ in year $t$.

### 3.5 Price-to-Rent (PTR)

Alternatively, PTR could be used to capture mortgage risk across geographic markets. This measure also ties house prices to market fundamentals, namely the price of a substitute good: rented housing services. If house prices increase much more than rents, PTR increases,
capturing evidence of miss-pricing in the market. Some may argue that because rental markets are more active, mis-pricing and market imbalances may be evident earlier in PTR than PTI. The weakness of PTR is data comparability. In many markets, the houses that are rented are likely not representative of the houses that are owned through a mortgage. In addition, the FRB (2019) finds that PTR trends up over time. In this paper, we use either PTI or PTR and get similar results. We calculate the PTR exposure in the same way as PTI exposures shown above. In particular,

\[ PTR_{i,t} = \sum_{c=1}^{C} w_{i,c,t} \times PTR_{c,t}, \]

where \( PTR_{c,t} \) is the median home price divided by median rental price for county \( c \) in year \( t \). \( w_{i,c,t} \) has the same definition.

### 3.6 Summary statistics

Table 2 shows the correlations between the two mortgage risk measures and lags of the measures. Panel A shows correlations using data between 2003 and 2010. In general, PTI and PTR seem to capture similar information at the same time. PTI and PTR are strongly correlated, and the correlation falls as they are further away in time. For example, in the first column PTR and PTI have a correlation of 0.86, but PTI and PTR lagged a period have a correlation of 0.80. Panels B and C show correlations for the two subperiods: pre-crisis (2003–2006) and crisis (2007-2010). The same pattern is evident. The crisis does not appear to change the relationships.

Furthermore, in table 3 we show the correlations between our mortgage risk measures at the bank level with other bank level control variables. Overall, our measures have very low to modest levels of correlations with all control variables. Hence, our risk measures provide additional information that is not captured by these comprehensive set of controls. In par-
ticular, our risk measures have a low negative correlation with traditional home mortgages over total assets, and the correlations are negative in all periods, suggesting that banks with large mortgage balances did not necessarily expanded into overvalued markets. This fact helps us to understand why previous research did not find a relationship between residential mortgage book size and bank performance during the crisis. We test this relationship formally in the following sections.

Table 4 shows the summary statistics for our mortgage performance, mortgage risk, and bank control variables for the sample used in our mortgage performance tests, namely delinquency and charge-off rates. The table restricts the panel to the years of 2003 through 2010 as in the regressions. All balance sheet measures are divided by total assets, except nonperforming loans are divided by loans, and size is the natural log of total assets. All variables are winsorized at the 1 percent and 99 percent levels. The first two columns report the mean and standard deviation for 2003–2010. The next four columns report the same statistics for banks for the pre-crisis (2003–2006) and crisis period (2007–2010). Table 4 shows that the average PTI and PTR exposures across the banks before the crisis were around 3.6 and 15.4, respectively. Panel C shows that PTI and PTR risk measures decreased during the crisis as the house prices collapsed, whereas delinquency and charge-off rates increased significantly. Market unemployment rate faced by banks also increased during the crisis. The table further shows that banks included in these regressions had on average 15 percent of their balance sheet invested in residential mortgages and 32 percent in non-residential real estate loans.

Table 5 presents similar summary statistics for our mortgage risk measures and bank control variables before the crisis (at the end of 2005 and 2006) for the sample used in our bank failure regressions. The data indicate that the average PTI exposure across the banks in our sample was around 3.7 in 2005. This ratio was already leveling off in 2006. The table also includes the means of these variables for banks that failed between 2008 and 2011.
and for those that did not fail, and reports the results of a t-test of the mean differences between the two groups (columns (5) and (10)). Notice that failed banks had significantly higher PTI and PTR exposure in 2005 and 2006. Interestingly, the ratio of total traditional home mortgage portfolio to total assets was significantly smaller for failed banks, indicating that this may not be a good measure of mortgage risk. The table shows significantly higher exposures to on- and off-balance sheet CRE exposures for failed banks (the last two variables in the table). Failed banks were also larger on average, and they had less stable sources of funding, smaller cash buffers, more illiquid assets, and larger credit lines.

4 Empirical Results

4.1 Mortgage Performance Measures: RRE Delinquencies and Charge-offs

We start by testing the relationship between exposure to counties with high PTI/PTR during the build-up phase of the crisis and RRE loan delinquencies and net charge-offs during the crisis. The testing specification follows the difference-in-differences design. Therefore, it is comparing crisis outcomes based on pre-crisis exposure to PTI or PTR. Pre-crisis PTI and PTR are calculated by taking the average for a bank over four years: 2003–2006. The crisis period is defined as the following four years: 2007–2010. Time ($\eta_t$) and bank ($\theta_i$) fixed effects are used in the baseline specification. The baseline regression specifications are

\[
\text{Delinquency rate}_{i,t} = \alpha + \beta_1 \text{Pre-crisis PTI}_i \times \text{Crisis period}_t + \gamma X_{i,t} + \eta_t + \theta_i + \varepsilon_{i,t}
\]

\[
\text{Net charge-off rate}_{i,t} = \alpha + \beta_1 \text{Pre-crisis PTI}_i \times \text{Crisis period}_t + \gamma X_{i,t} + \eta_t + \theta_i + \varepsilon_{i,t}.
\]
In these regressions $X_{i,t}$ is a vector of bank characteristics that include proxies for CAMELS measures. In particular, we include the equity ratio for *capital adequacy*; nonperforming loans to total loans for *asset quality*; efficiency ratio (ratio of revenue to operational expense) for *management capability*; return on assets (ROA) for *earnings*; cash ratio, money market assets, and illiquid assets to total assets for *liquidity*; and core deposits ratio for *sensitivity to market risk* (interest rates). We also include other important risk characteristics such as size, unused lines of credit to total assets, and additional real estate controls such as on- and off-balance sheet CRE exposures and home equity loans. As discussed previously, we also run specifications where PTR replaces PTI.

A particular area of concern in these regressions is that our housing market risk measures could be correlated with local economic factors. Aubuchon and Wheelock (2010) show that during the last crisis bank failure rates were generally higher in states experiencing more severe economic distress. Therefore, it is possible that banks that operated in counties with overheated housing markets are more likely to experience stress or failure due to deteriorating local economic conditions that are not necessarily related to the housing market developments. For example, local economic shocks that lead to higher unemployment rates and lower incomes could then increase delinquency and charge-off rates on mortgage loans as well banks’ likelihood of failure. The latter could also be driven by banks’ exposures to the local markets through non-housing related credit such as business loans, auto loans, personal loans, and credit card debt.

Because we do not observe each bank’s exposure to these products at the county level, we develop proxy variables to control for local non-housing related shocks that can affect banks. First, we estimate alternative specifications in which bank fixed effects ($\theta_i$) are replaced with county fixed effects ($\phi_c$), where the latter is defined based on the headquarter of the bank. Therefore, the alternative specifications control for local economic conditions by comparing banks that have similar operating locations but different mortgage risk exposure.
However, we understand the limitations of these fixed effects, especially for banks that collect significant amount of deposits and make loans outside of their home counties. Therefore, we also add a control to all of our regressions that captures a bank’s overall exposure to the economic shocks in all counties it operates. We measure the size of the local economic shock by the change in the unemployment rate between 2006 and 2009 at the county level. We then use the Summary of Deposits data to calculate each banks’ exposure to this local economic shock. In particular, we calculate a weighted average shock for each bank using a bank’s deposits in each county in the pre-crisis years as weights. We call this variable a bank’s “market unemployment rate” and include it in all of the specifications.

Finally before moving on to the difference-in-differences regressions, we test whether the parallel trends hypothesis holds. Figure 5 shows delinquency and charge-off rates on residential mortgages separately for banks with large and small exposures to high PTI or PTR counties. We define highly exposed banks as having those with above median weighted PTI or PTR rates between 2003–2006. As evident in Figure 5, delinquency and charge-off rates follow very similar patterns for highly exposed and less exposed banks in the pre-crisis period. However, once the crisis hits, highly exposed banks begin to observe a larger increase in delinquency and charge-off rates, and the gap between the banks in the control group and exposed group increases as the crisis deepens.

Table 6 reports the results of the delinquency rate regressions. Columns (1)–(2) show the results of regressing RRE delinquency rates (delinquent RRE loans divided by total RRE loans) on PTI exposure. Columns (3)–(4) show the results using PTR. In all specifications, the coefficient on the variable of interest, the interacted term, is positive and significant as expected. Banks with higher exposure to markets with high PTI/PTR in the pre-crisis period

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6A bank has exposure to many more markets than where its branches are located. However, market exposure is likely concentrated in the those regions as both retail and wholesale customers tend to get banking services from a local branch. As a result, the Summary of Deposit data provide a reasonable proxy of market exposure. The limitations of branch-weighted data is why we use actual mortgages to weight PTI.
have higher RRE delinquency rates in the crisis period. In terms of economic significance, the average RRE delinquency rate in 2008 for the banks in the sample is 1.7 percent. The average pre-crisis PTI for those same banks is 3.5. Using the coefficient from column 1, pre-crisis PTI explains about one-third of the delinquency rate \((0.0016 \times 3.5 \div 0.0174 = 0.32)\).

The control variables include exposure to traditional home mortgages (RRE loans divided by total assets). When the coefficient on traditional home mortgages is statistically significant, the sign is negative, demonstrating that mortgage share alone is not a good measure of mortgage risk. This weak relationship between the share of assets in RRE loans and bad loan performance is likely why prior research has down-played the role of mortgages in bank performance during the crisis.

Table 7 reports similar regressions as table 6 but replaces the left hand side variable with RRE net charge-offs (RRE net charge-offs divided by RRE loans). Again, the coefficient on the interacted term is positive and statistically significant. Using average values for 2008, pre-crisis PTI explains 40 percent of RRE net charge-offs \((0.0004 \times 3.5 \div 0.0033 = 0.40)\).

Note that once again the coefficient on traditional home mortgages is often negative. Basic on-balance sheet mortgage measures do not capture risk. In contrast, higher values of PTI and PTR exposure are associated with higher charge-offs during the financial crisis.

### 4.2 Bank Failures

Higher delinquency and charge-offs deplete bank capital and may eventually precipitate a bank’s failure. Hundreds of commercial banks failed during the last financial crisis. Because we have established that PTI and PTR exposure capture mortgage risk, we now examine if these measures are useful in explaining bank failures as well. Summary statistics in table 5 show that failed banks had significantly higher PTI and PTR exposure in 2005 and 2006. Figure 6 plots the median PTI exposure for failed and survived banks between 2000 and 2008. The figure shows that banks that failed during the crisis already had higher PTI exposure.
in 2000, and this gap widened until right before the crisis in 2006. In this section we test whether PTI and PTR exposure are significant predictors of bank failures after controlling for important bank risk characteristics.

Our main specification for the probability of a bank failing is:

\[ Y_i = \alpha + \beta_1 PTI_i + \beta_2 PTI_i \times RRE + \beta_3 RRE + \gamma X_i + \varepsilon_i, \]  

(2)

where \( Y_i \) is a dummy variable that is equal to 1 if bank \( i \) fails between 2008 and 2011, RRE is traditional home mortgages as used above, and \( X_i \) is a vector of controls for bank characteristics as before. The coefficient of interest is \( \beta_2 \). While PTI exposure captures risk, it is the interaction between that risk and the total balance sheet exposure that is of interest. PTI captures the riskiness of the mortgage loan portfolio, but that risk is only an important consideration for the potential failure of the bank to the extent that RRE loans are a large part of the bank’s balance sheet. For the delinquency and net charge-off regressions, because the left hand side variable is specific to RRE loans, a similar scaling was not needed. Given that higher PTI exposure indicates higher risk, the expected sign on the interacted term is positive. We also run an alternative version of equation (2) where PTR replaces PTI. Note that this specification is a cross-sectional regression. We run separate regressions during the years leading up to the financial crisis.

We estimate this binary dependent variable model using a logistic regression.\(^7\) Results are shown in table 8, which reports the average marginal effects. Columns (1)–(3) use the main specification for three different years: 2005, 2006, and 2007. This benchmark includes variables used in the previously discussed literature. Across all three years, the coefficients on the interaction term (\( \beta_2 \)) are significant, with a p-value ranging from 0.003 in 2005 to 0.029 in 2007. This result suggests that banks with large residential mortgage exposures

\(^{7}\)The main conclusions of the results are similar if a probit regression is used.
concentrated in over-appreciated housing markets were more likely to fail during the crisis. Columns (4)–(6) confirm that PTR exposure also captures this risk. The interacted term is positive and significant. These results establish, for the first time, to the best of our knowledge, that residential mortgage exposures played a significant role in large scale bank failures during the crisis. Meanwhile, as in some of the existing studies, the coefficient of traditional home mortgages turns out to be negative and significant. Although this is a somewhat puzzling result in the existing studies, our approach to account for the riskiness of the mortgage portfolio provides a resolution: banks with a large mortgage business were generally solvent as long as they were well diversified or did not concentrate most of their business in counties with high PTI or PTR.

All specifications also include proxies for CAMELS measures (vector $X_i$). The results for these additional controls are consistent with the findings in the literature, such as Cole and White (2012), Berger and Bouwman (2013), and Antoniades (2020), and indicate that banks that relied on stable sources of funding, such as equity capital and core deposits, were less likely to fail during the crisis. Furthermore, smaller cash buffers, more illiquid assets, and more nonperforming loans increased the probability of failure. As shown in prior research, CRE exposure is an important predictor of bank failure. The coefficients on both CRE loans and CRE lines of credit are positive and statistically significant. Finally, we control for local economic conditions in all specifications by adding the market unemployment rate measure. This variable has a positive coefficient as expected, but it becomes significant only in 2007.

### 4.3 Economic Significance

The average marginal effects reported in table 8 do not reveal the economic significance, and the coefficients are not comparable across variables as each variable has a different distribution. To test the economic significance of these results, we do the following exercise: For each variable that enters the logit regression with a positive and significant coefficient,
we set the value of each observation to the 25th quartile of this variable. Because we keep all other variables at their original values, this exercise allows us to isolate the relationship of each variable and bank failure. One exception to this keep-fixed rule is when we change the PTI exposure to the lowest quartile, we also recalculate the interaction of PTI exposure with traditional home mortgages. \(^8\) Therefore, the reported effect of PTI exposure is the sum of the direct effect of PTI exposure and the indirect effect that comes from the interaction of PTI exposure with traditional home mortgages. In this experiment, we keep the traditional home mortgages at their original values, so that the test result measures the effect of exposing banks to riskier housing markets while keeping their overall mortgage business size constant. We then use the baseline regression results with household mortgage risk controls, presented in table 8, to calculate the predicted probability of failure for each bank.

For variables that enter the logit regression with a negative and significant coefficient, such as traditional home mortgages, equity capital, and core deposits, we raise the values to the 75th quartile of the distribution and repeat the exercise. For traditional home mortgages, this time we keep PTI exposure stable but recalculate the interaction term after raising the values of traditional home mortgages to its 75th quartile in a given year. Therefore, the reported values show the sum of the direct and indirect effect of this variable through its interaction with PTI exposure. Table 9 shows the results of this exercise. Results for PTI exposure are in panel A. PTR exposure is shown in panel B. Reported values are the differences between the average probability of failure under this exercise for each variable and the predicted probability of failure from baseline specification, reported in the last row.

The test shows that reducing PTI exposure for each bank to the 25th quartile of its distribution in the sample lowers the average probability of failure across banks by 2.04 percentage points in 2005, 2.23 percentage points in 2006, and 1.92 percentage points in 2007. This effect is economically significant because it corresponds to an approximate 28 percent

\(^{8}\)This method is described for PTI, but the same will be done using PTR.
(2.04/7.33) reduction in the failure rate. Similarly, reducing PTR exposure lowers the failure rate approximately 31 percent (2.26/7.33). Meanwhile, increasing the traditional home mortgages to the 75th quartile of its distribution leaves the average probability of bank failure in 2005 almost unchanged because the indirect effect coming from the interaction term cancels out the direct effect. However, this exercise lowers the average probability of failure across banks by 0.73 percentage points in 2006 using the main specification.

To summarize all of these results, the economic significance of PTI and PTR adjusted for exposure is larger than that of equity capital and traditional home mortgages, is close to the effect of core deposits, but it is smaller than measures of CRE exposures. In fact, CRE exposures have the largest economic significance among all variables, and this result is consistent with the literature. However, unlike the results presented here, previous studies dismiss any statistically or economically significant effect of residential mortgage exposures on bank failures during the crisis.

5 Robustness Tests

5.1 Alternative Samples

In this section we subject our main bank failure results to a battery of robustness tests. First, we show that results reported in table 8 are robust to changes in the sample. In table 10 we redo the analysis with a variety of samples: include acquired banks among the failed banks in column (1), exclude large banks (over $10 billion) from the sample in column (2), and change the time windows for bank failures to between 2008 and 2013 in column (3). The general results still hold. We present the results for 2006, but we obtain similar results for 2005 and 2007. In particular, the coefficient of the interaction term between PTI/PTR exposure and traditional home mortgages remains positive and significant. Its p-value increases when we include acquired banks indicating that the effect mainly comes from failed banks not from
those acquired during the crisis. The p-value also increases when we exclude the large banks, but the coefficient is still significant at the 95 percent level, indicating that our results are not driven by the large banks.

5.2 Other Possible Measures of Mortgage Risk

5.2.1 Considering Regional Dynamics of PTI

One main concern about using PTI/PTR ratios as regional mortgage risk measures is whether it would penalize areas that tend to have high house prices relative to incomes or rents.\(^9\) A sustainable level of PTI ratio is determined by several factors such as demographic and supply dynamics, changes in real interest rates, shifts in term or inflation premia, and changes in credit availability (BOE, 2016). As these underlying factors could differ across regions, so can the sustainable level of the PTI. In fact, there are significant variations across different geographies in the long-run averages of PTI ratio and its deviation from this average in a given year. For example, figure 7 plots the dynamics of PTI ratio for four different states between 1990 and 2015. First, the figure shows that the level of PTI ratio is remarkably higher in California and Florida throughout the period compared with West Virginia and Kansas. Second, there are some regional trends that differ from the national average. For example, in West Virginia, PTI ratio continues to decline after the crisis in the first half of 2010s, whereas in the three other states it starts to increase again in 2011 or 2012. Nevertheless, the substantial increase in the ratio at the onset of the crisis and the collapse afterwards is common to almost all 50 states.

To address this concern that some areas have consistently higher PTIs, we re-estimate our regressions for delinquency rates, charge-offs, and bank failures using the changes in PTI exposure instead of the levels of this variable. In particular, we focus on two measures

\(^9\)In this section we present results for PTI. We obtain similar results using PTR, and those are available upon request.
of change: deviation of current PTI exposure from a medium-run average of 8 years and average log-change in PTI exposure in the past five years. We present the results for bank failure regressions with these alternative measures in the first two columns of table 11. Our results remain robust to using these change variables: the coefficients on the interaction between the new mortgage risk measure and traditional home mortgages are positive and significant. In general, deviations from medium to long-run average yield lower p-values compared with the average changes over a set number of years. In particular, the coefficient on the interacted term using average change is less significant in 2007 as house prices start to decrease (not shown).

5.2.2 Alternative House Price Indexes and House Price Growth

We separately use house price data from CoreLogic and Zillow to construct our mortgage risk measures. Zillow and CoreLogic have smaller coverage of county level house prices compared with the Moody’s data. Nevertheless, we obtain similar results using these alternative data sources. PTI results with Zillow in 2006 are presented in column (3) of table 11.

Price growth could also be used to proxy for mortgage risk. However, this measure does not control for market conditions, in particular, the driver of price increases. For example, price increases due to economic growth are more sustainable than price increases driven by overly optimistic expectations.

6 Mortgage Risk and Macroprudential Policies

In this section we test to see how banks managed their mortgage risk. As mortgage risk was building in the system, were banks individually accounting for their exposure to this risk and increasing their capital? Figure 8 plots the relationship between PTI exposure and total

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10The results for delinquency rates and charge-offs are available upon request.
regulatory capital ratio in the run up to the crisis. The four charts show the plot separately for each year between 2003 and 2006. The red line is the estimated regression line. The lines are slightly downward sloping, suggesting that the banks that operated in high PTI counties tend to have, if anything, smaller capital buffers.

We further test this relationship formally by running a panel regression of total regulatory capital ratio on our mortgage risk measures in the pre-crisis period (2003–2006). Table 12 presents the results. In the first column, we include only the variables of interest, without additional controls. The coefficients of PTI and, importantly, its interaction with traditional home mortgages over total assets turn out to be insignificant. Meanwhile, the coefficient on traditional home mortgages is negative and statistically significant, suggesting that unconditionally banks with large mortgage loans on their balance sheet had lower capital ratios. This sign changes in the second column when we add additional controls, similar to those included in our previous regressions. However, after adding controls, PTI remains insignificant and the interaction term becomes negative and significant at the 10 percent level, suggesting that banks with large exposures to high PTI counties had in fact somewhat smaller capital buffers. In the last two columns we repeat the exercise using the PTR and obtain similar results. While exposure to overvalued housing markets presents a greater likelihood of house price correction, we find no evidence that banks reacted to this vulnerability by bolstering loss-absorption capacity.

This lack of capital build can partially be attributed to the notion that markets did not anticipate an imminent house price correction in the 2000s. It may also reflect moral hazard—banks expected to be bailed out by the government in case of a downturn and therefore did not voluntarily provision for such a scenario. However, it may simply reflect incentives created by regulatory capital requirements in which differences in the quality of RRE portfolios across banks can be obscured.\textsuperscript{11} The risk-weight for most residential

\textsuperscript{11}Basel II, which allows large and internationally active banks to implement internal risk models to calcu-
mortgages is 50 percent. Our results suggest that there is scope for risk-weights that vary with the vulnerability of a bank’s mortgage portfolio. Proper bank risk management can have important economic implications other than charge-offs and bank failure. For example, Glancy (2017) shows that banks exposed to distressed housing markets during the crisis cut mortgage and small business lending relative to other banks in the same county, and this lending contraction had real effects.

One way to make RRE risk weights more risk sensitive would be to explicitly relate them to forward looking measures of risk such as PTI. In fact, the European Union’s 2013 Capital Requirements Regulation (CRR) law allows national authorities to set risk weights up to 150 percent for real estate exposures due to financial stability concerns. More specifically, the article allows setting higher risk weights for different loans, where geographic area is one factor. Higher risk weights based on forward looking measures such as PTI would also address overheating in specific housing markets that may develop into systemic risk concerns (ESRB, 2014, p. 59). Indeed, several countries have begun using PTI in determining macroprudential policies. For example, the Financial Stability Committee of the United Kingdom includes PTI among the core real estate indicators used in adjusting housing policy instruments such as LTV and DTI limits. The European Systemic Risk Board (ESRB) also lists PTI among a list of promising indicators that can be monitored by national authorities to adjust macroprudential policies directed at the real estate sector.

Using macroprudential policy instruments that target banks by relating risk weights to PTI or PTR exposure may pose its own set of issues, but it does have some advantages over policy instruments that set limits on loan characteristics such as LTV and borrower DTI. First, higher risk weights have a clear effect on bank resilience and can target specific regional real estate markets. Second, LTV and DTI limits are subject to frontloading of loan late required regulatory capital under the advanced approach, was not fully implemented in the U.S. before the crisis. The effective date was April 1, 2008.
applications in anticipation of the enactment of or changes in the limit. Third, individual limits are easier to manipulate by banks for example by overvaluing the property in the case of LTV limits or by increasing the maturity of loan in the case of debt-service-to-income caps (ESRB, 2014).

PTI and PTR can also be used to measure mortgage risk in regulatory and company-run stress tests. Due to the Dodd–Frank Act and the Economic Growth, Regulatory Relief, and Consumer Protection Act, banks in the United States are required to conduct stress tests. These tests push banks to hold capital to withstand a major simulated macroeconomic downturn. As described in FRB (2018b), the Federal Reserve model for loan losses on RRE do account for local area house prices and economic variables. Even more, current stress test scenario design by the Federal Reserve incorporates the countercyclical approach that we promote in this paper, as it suggests that “declines in aggregate U.S. residential real estate prices and commercial real estate prices should be assumed to be concentrated in regions that have experienced rapid price gains over the past two years” (FRB, 2018a). While our results support this approach, they also point to using PTI or PTR not just the house price growth in determining overheating markets for CCAR scenarios.

Along these lines, a recent change by the Federal Reserve on the scenario design framework establishes a quantitative guide for house prices, which is informed by the ratio of the nominal house price index to nominal per capita disposable income (FRB, 2019). Such a quantitative guide is expected to enhance the counter-cyclicality of the stress test because without the guide, scenarios had the risk of becoming less severe when house price growth is fast and outpaces income growth. The scenario guide change dismissed alternative metrics based on house real house prices relative to trend or the PTR ratio, which exhibits a trend.

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12 Large banks with more than $250 billion in assets are subject to the Federal Reserve-run tests and the company-run tests. Banks above $100 billion in assets but below $250 billion are subject to periodic regulator-run stress tests, and the Federal Reserve can designate an institution to conduct a company-run stress test.
Bank internal risk measures and company-run stress tests can similarly account for local area effects specific to their geographic markets. By using measures like PTI, risk managers can account for local area miss-pricing as well as economic conditions. Notice that county level PTI and PTR exposures are easy for a bank to calculate and can capture varying risks for specific mortgage portfolios. In addition, while our measure was limited to mortgages originated in the last three years, the bank can calculate a more precise measure of risk using the exact composition of its portfolio. Our policy recommendation, of using PTI/PTR exposure to better calibrate capital buffers is similar in spirit to the stress test for mortgage assets proposed by Smith and Weiher (2012) and demonstrated by Smith et al. (2016). If banks appropriately measure mortgage risk, they can take steps to hedge that risk. In the cross-section, that could push banks with more vulnerable mortgage portfolios to build stronger capital buffers.

7 Conclusion

During and following the crisis, hundreds of banks failed. The financial crisis was marked by a large decline in residential housing prices which led to many defaults, foreclosures, and bankruptcies. However, research has generally found commercial real estate to be the primary driver of bank failures, while dismissing any significant contribution from residential real estate exposures. We provide evidence that this result in the literature may be attributable to the fact that residential real estate exposure is generally measured by mortgage loans or mortgage-backed securities held on balance sheet, measures which do not account for real financial risk from the underlying asset, namely the deviation of assets prices from fundamentals.

In this paper, we propose to measure mortgage risk by using forward looking measures
of housing overvaluation, such as the price-to-income (PTI) and price-to-rent (PTR) ratios. PTI and PTR are good indicators of risk across markets and through time because they link the asset value to fundamentals. We show that direct exposure to counties where house prices have grown faster than household income or rent is significant in predicting bank failure, mortgage delinquencies, and mortgage charge-offs. Because PTI or PTR exposure can be calculated for nearly every bank that holds residential mortgages, it can be used to identify growing vulnerabilities in the financial system and to assess the possible effects of a housing price correction in specific markets. In addition, we find that banks that experienced large increases in PTI exposure before the crisis did not increase their capital buffers relatively more to counteract this extra risk. Therefore, our results suggest that it could be appropriate to consider regulation that would provide stronger incentives to build capital against vulnerable mortgage portfolios.
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Figures and Tables

Figure 1: House Price-to-Income 2006

![Map showing House Price-to-Income 2006 with color coding for different price ranges.]

Figure 2: Change in the Price-to-Income between 2006 and 2010

![Map showing change in House Price-to-Income between 2006 and 2010 with color coding for different change ranges.]

Electronic copy available at: https://ssrn.com/abstract=3656619
Figure 3: House Price-to-Income in 2006 vs Change in Unemployment Rate between 2006–2009 (US County Level)

Figure 4: House Price-to-Income in 2006 vs Change in Median Household Incomes between 2006–2009 (US County Level)
Figure 5: Parallel Trends Test: Bank Outcomes and Exposure to Mortgage Risk

Figure 6: Banks’ Exposure to the Mortgage Risk and Failures
Figure 7: Price-to-Income 1990–2015, Selected States

Figure 8: Regulatory Capital Ratio and Banks’ Exposure to Mortgage Risk
### Table 1: Variable Definitions

| Variable                        | Definition                                                                                                                                 |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| **Price-to-income (PTI) exposure** | A median house price to median household income ratio is calculated annually for each county. The weights for each bank are based on the dollar amounts of loans that are originated or purchased by that bank and kept (not sold within the year). Weights use such loans over the past three years. See equation 1. |
| **Price-to-rent (PTR) exposure** | Same calculation as PTI except use rent instead of income: median annual rent for a 3-bedroom house. See equation 1 and replace income with rent. |
| **Pre-crisis PTI or PTR**       | Average PTI or PTR during the period 2003–2006                                                                                           |
| **RRE Delinquency rate**        | $\frac{RRE \text{ nonaccruing loans} + RRE \text{ past due loans}}{RRE \text{ loans}}$                                                   |
| **RRE net charge-off rate**     | $\frac{RRE \text{ loans charged-off} - RRE \text{ recoveries}}{RRE \text{ loans}}$                                                        |
| **Traditional home mortgages**  | $\frac{\text{first lien } + \text{ junior lien}}{\text{total assets}}$                                                                    |
| **Home equity loans**           | $\frac{\text{home equity lines of credit}}{\text{total assets}}$                                                                       |
| **Non-household RE loans**      | $\frac{\text{total real estate loans–first lien – junior lien–home equity lines of credit}}{\text{total assets}}$ |
| **CRE lines of credit**         | commitments to fund commercial real estate, secured and unsecured $\frac{\text{total assets}}{\text{total assets}}$ |
| **Nonperforming loans**         | $\frac{\text{total nonaccruing loans} + \text{loans past due for 90 days or more}}{\text{total loans}}$                               |
| **Equity capital**              | $\frac{\text{total equity}}{\text{total assets}}$                                                                                      |
| **Core deposits**               | $\frac{\text{transaction deposits } + \text{ savings } + \text{ small time deposits}}{\text{total assets}}$                             |
| **Cash**                        | $\frac{\text{cash } + \text{ balances at depository institutions}}{\text{total assets}}$                                                   |
| **Money market**                | $\frac{\text{federal funds sold } + \text{ securities purchased under agreements to resell}}{\text{total assets}}$                         |
| **Illiquid assets**             | $\frac{\text{total assets } - \text{ cash } - \text{ money market } - \text{ total securities } - \text{ trading assets}}{\text{total assets}}$ |
| **Size**                        | $\ln(\text{total assets})$                                                                                                               |
| **Return on assets**            | $\frac{\text{net income}}{\text{average annual assets}}$                                                                                 |
| **Efficiency**                  | $\frac{\text{interest income } - \text{ interest expense } + \text{ noninterest income}}{\text{noninterest expense}}$                      |
| **Credit lines**                | $\frac{\text{unused commitments}}{\text{total assets}}$                                                                                   |
| **Market unemployment rate**    | Change in county unemployment rate between 2006–09 weighted by deposit share of bank                                                      |
Table 2: Correlation between PTI and PTR

|                  | A. Correlations 2003-2010 | B. Correlations 2003-2006 | C. Correlations 2007-2010 |
|------------------|---------------------------|---------------------------|---------------------------|
|                  | PTI | PTR | PTI | PTR | PTI | PTR |
| PTR              | 0.86| PTI | 0.86| PTR | 0.87| PTI | 0.87|
| L.PTR            | 0.80| L.PTI| 0.81| L.PTR| 0.81| L.PTI| 0.85|
| L2.PTR           | 0.72| L2.PTI| 0.72| L2.PTR| 0.75| L2.PTI| 0.81|
| L3.PTR           | 0.62| L3.PTI| 0.62| L3.PTR| 0.69| L3.PTI| 0.79|
| L4.PTR           | 0.56| L4.PTI| 0.55| L4.PTR| 0.63| L4.PTI| 0.74|

Table 3: Correlation between PTI/PTR and Control Variables

This table summarizes the variable correlations during various time periods: Sample period (2003–2010), Pre-crisis (2003–2006), and Crisis (2007-2010).

|                  | A. 2003-2010 | B. 2003-2006 | C. 2007-2010 |
|------------------|--------------|--------------|--------------|
|                  | PTI | PTR | PTI | PTR | PTI | PTR |
| Traditional home mortgages | -0.13 | -0.08 | -0.15 | -0.07 | -0.11 | -0.08 |
| Home equity loans | 0.22 | 0.27 | 0.22 | 0.30 | 0.22 | 0.27 |
| Non-household RE loans | 0.21 | 0.22 | 0.22 | 0.23 | 0.23 | 0.25 |
| CRE lines of credit | 0.26 | 0.29 | 0.24 | 0.23 | 0.23 | 0.31 |
| Equity capital | 0.00 | 0.00 | -0.01 | 0.00 | 0.01 | 0.01 |
| Core deposits | -0.15 | -0.12 | -0.14 | -0.13 | -0.21 | -0.15 |
| Cash | -0.01 | -0.11 | 0.03 | -0.03 | -0.02 | -0.12 |
| Money market | 0.06 | 0.04 | 0.07 | 0.03 | 0.00 | 0.00 |
| Illiquid assets | 0.07 | 0.10 | 0.06 | 0.11 | 0.12 | 0.14 |
| Size | 0.30 | 0.24 | 0.33 | 0.28 | 0.32 | 0.25 |
| Return on assets | 0.03 | 0.10 | 0.06 | 0.06 | -0.07 | 0.02 |
| Efficiency | 0.08 | 0.13 | 0.08 | 0.10 | 0.03 | 0.09 |
| Non-performing loans | -0.03 | -0.11 | -0.09 | -0.09 | 0.07 | -0.03 |
| Credit lines | 0.29 | 0.33 | 0.29 | 0.30 | 0.24 | 0.31 |
| Market unemployment rate | -0.14 | -0.34 | -0.10 | -0.23 | -0.13 | -0.36 |

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Table 4: Summary Statistics for Delinquency and Charge-off Regressions

This table summarizes the variables used in delinquency and charge-off regressions. Panel A reports the mean and standard deviation of the dependent variable and control variables for the entire sample. Panel B shows these statistics for the pre-crisis period (2003-2006) and Panel C shows them during the crisis period (2007-2010). Variable definitions are provided in table 1.

| Variable                  | A. 2003-2010 | B. 2003-2006 | C. 2007-2010 |
|---------------------------|--------------|--------------|--------------|
| PTI exposure              | 3.391        | 3.558        | 3.228        |
| PTR exposure              | 14.564       | 15.394       | 13.748       |
| RRE delinquencies         | 0.014        | 0.008        | 0.020        |
| RRE net charge-offs       | 0.003        | 0.001        | 0.005        |
| Traditional home mortgages| 0.154        | 0.152        | 0.156        |
| Home equity loans         | 0.026        | 0.026        | 0.026        |
| Non-household RE loans    | 0.323        | 0.312        | 0.333        |
| CRE lines of credit       | 0.036        | 0.045        | 0.027        |
| Equity capital            | 0.098        | 0.098        | 0.099        |
| Core deposits             | 0.666        | 0.675        | 0.658        |
| Cash                      | 0.047        | 0.040        | 0.053        |
| Money market              | 0.024        | 0.028        | 0.019        |
| Illiquid assets           | 0.777        | 0.762        | 0.791        |
| Size                      | 12.623       | 12.510       | 12.733       |
| Return on assets          | 0.009        | 0.013        | 0.005        |
| Efficiency                | 1.547        | 1.623        | 1.471        |
| Credit lines              | 0.126        | 0.140        | 0.112        |
| Market unemployment rate  | 6.087        | 5.199        | 6.960        |
| Observations              | 22,398       | 11,103       | 11,295       |
Table 5: Summary Statistics for Bank Failure Regressions

This table compares the characteristics of failed banks between 2008 and 2011 and bank survivors. The “difference” column shows the results of a t test between the two groups. Variable definitions are provided in table 1. *** p<0.01, ** p<0.05, * p<0.1

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
|     | 2005 |     |     |     | 2006 |     |     |     |      |
|     | All banks | Banks by failure | All banks | Banks by failure |     |     |     |      |
| Mean | St. dev. | Mean | Mean | Difference | Mean | St. dev. | Mean | Mean | Difference |
| Fail dummy (2008–11) | 0.07 | 0.26 | 0 | 1 | 0.07 | 0.26 | 0 | 1 | 0.06*** |
| PTI exposure | 3.67 | 1.54 | 3.59 | 4.61 | 1.09*** | 3.64 | 1.48 | 3.56 | 4.62 | 1.06*** |
| PTR exposure | 15.94 | 4.55 | 15.74 | 18.51 | 2.77*** | 16.17 | 4.67 | 15.93 | 19.13 | 3.20*** |
| Traditional home mortgages | 0.15 | 0.09 | 0.16 | 0.12 | -0.04*** | 0.15 | 0.09 | 0.16 | 0.11 | -0.04*** |
| Home equity loans | 0.03 | 0.03 | 0.02 | 0.03 | -0.01*** | 0.02 | 0.03 | 0.02 | 0.03 | 0.01*** |
| Non-household RE loans | 0.32 | 0.15 | 0.31 | 0.47 | 0.16*** | 0.33 | 0.15 | 0.32 | 0.49 | 0.17*** |
| CRE lines of credit | 0.05 | 0.04 | 0.04 | 0.09 | 0.05*** | 0.05 | 0.04 | 0.04 | 0.09 | 0.05*** |
| Equity capital | 0.10 | 0.03 | 0.10 | 0.10 | 0.00 | 0.10 | 0.03 | 0.10 | 0.10 | 0.00 |
| Core deposits | 0.67 | 0.11 | 0.68 | 0.60 | -0.08*** | 0.65 | 0.11 | 0.66 | 0.58 | -0.08*** |
| Cash | 0.04 | 0.03 | 0.04 | 0.03 | -0.01*** | 0.04 | 0.03 | 0.04 | 0.03 | -0.01*** |
| Money market | 0.03 | 0.04 | 0.03 | 0.03 | 0.00 | 0.03 | 0.04 | 0.03 | 0.03 | 0.00 |
| Illiquid assets | 0.77 | 0.13 | 0.77 | 0.84 | 0.07*** | 0.78 | 0.12 | 0.77 | 0.84 | 0.07*** |
| Size | 12.51 | 1.11 | 12.49 | 12.75 | 0.26*** | 12.60 | 1.12 | 12.57 | 12.93 | 0.36*** |
| Return on assets | 0.01 | 0.01 | 0.01 | 0.01 | 0.00*** | 0.01 | 0.01 | 0.01 | 0.01 | 0.00*** |
| Efficiency | 1.64 | 0.35 | 1.63 | 1.73 | 0.10*** | 1.63 | 0.35 | 1.62 | 1.75 | 0.13*** |
| Non-performing loans | 0.01 | 0.01 | 0.01 | 0.01 | 0.00*** | 0.01 | 0.01 | 0.01 | 0.01 | 0.00*** |
| Credit lines | 0.14 | 0.09 | 0.14 | 0.20 | 0.06*** | 0.14 | 0.08 | 0.14 | 0.18 | 0.04*** |
| Market unemployment rate | 5.11 | 1.24 | 5.12 | 4.97 | -0.16* | 4.62 | 1.14 | 4.63 | 4.47 | -0.17* |
| Observations | 2,455 | 2,275 | 180 | | 2,488 | 2,304 | 184 | |
Table 6: Regression of RRE Delinquency Rate

This table shows the results of regressing RRE delinquency rates on bank characteristics including Pre-crisis PTI exposure and Pre-crisis PTR exposure. Price-to-income (PTI) exposure is a county price-to-income ratio weighted at the bank level using three years of data on the dollar amounts of loans that are originated or purchased by that bank and kept (not sold within the year). Price-to-rent (PTR) exposure is a county price-to-rent ratio weighted at the bank level using the same weights as PTI. Pre-crisis PTI is defined as the average PTI during the period 2003-2006. Pre-crisis PTR is defined similarly. Variable definitions are provided in table 1.

| VARIABLES                        | (1) PTI | (2) PTI | (3) PTR | (4) PTR |
|----------------------------------|---------|---------|---------|---------|
| Pre-crisis PTI * Crisis period   | 0.0016*** | 0.0015*** | 0.0005*** | 0.0004*** |
|                                  | (0.0003) | (0.0004) | (0.0001) | (0.0001) |
| Pre-crisis PTR * Crisis period   | 0.0008 | -0.0068*** | 0.012 | -0.0072** |
|                                  | (0.0066) | (0.0029) | (0.0066) | (0.0029) |
| Traditional home mortgages       | -0.0244 | -0.0514*** | -0.0239 | -0.0534*** |
|                                  | (0.0195) | (0.0085) | (0.0195) | (0.0085) |
| Home equity loans                | -0.0008 | 0.0091*** | -0.0013 | 0.0093*** |
|                                  | (0.0048) | (0.0034) | (0.0048) | (0.0034) |
| CRE lines of credit              | 0.0350*** | -0.0292*** | -0.0349*** | -0.0287*** |
|                                  | (0.0090) | (0.0072) | (0.0090) | (0.0072) |
| Equity capital                   | 0.0057 | 0.0137 | 0.0067 | 0.0140 |
|                                  | (0.0115) | (0.0087) | (0.0115) | (0.0087) |
| Core deposits                    | 0.0088*** | -0.0050** | 0.0081** | -0.0053** |
|                                  | (0.0343) | (0.0023) | (0.0343) | (0.0023) |
| Cash                             | -0.0012 | 0.0028 | -0.0015 | 0.0039 |
|                                  | (0.0073) | (0.0059) | (0.0074) | (0.0058) |
| Money market                     | -0.0053 | 0.0099* | -0.0061 | 0.0099* |
|                                  | (0.0057) | (0.0051) | (0.0058) | (0.0051) |
| Illiquid assets                  | -0.0000 | 0.0089*** | 0.0009 | 0.0088*** |
|                                  | (0.0046) | (0.0026) | (0.0046) | (0.0026) |
| Size                             | 0.0020** | 0.0005** | 0.0021** | 0.0006** |
|                                  | (0.0010) | (0.0002) | (0.0010) | (0.0002) |
| Return on assets                 | -0.6244*** | -0.7239*** | -0.6317*** | -0.7261*** |
|                                  | (0.0364) | (0.0306) | (0.0364) | (0.0305) |
| Efficiency                       | -0.0003 | 0.0040*** | -0.0002 | 0.0040*** |
|                                  | (0.0014) | (0.0008) | (0.0014) | (0.0008) |
| Credit lines                     | -0.0326*** | -0.0203*** | -0.0340*** | -0.0205*** |
|                                  | (0.0056) | (0.0045) | (0.0057) | (0.0044) |
| Market unemployment rate         | 0.0019*** | 0.0009*** | 0.0019*** | 0.0009*** |
|                                  | (0.0002) | (0.0002) | (0.0002) | (0.0002) |
| Constant                         | -0.0196 | -0.0023 | -0.0219 | -0.0040 |
|                                  | (0.0136) | (0.0042) | (0.0136) | (0.0042) |
| Observations                     | 21,732 | 21,794 | 21,729 | 21,791 |
| R-squared                        | 0.57 | 0.30 | 0.57 | 0.30 |
| Bank fixed effects               | X | X | X | X |
| Time fixed effects               | X | X | X | X |
| County fixed effects             | X | X | X | X |
| Cluster                          | Bank | County | Bank | County |

Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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Table 7: Regression of RRE Net Charge-off (NCO) Rate

This table shows the results of regressing RRE net charge-off rates on bank characteristics including Pre-crisis PTI exposure and Pre-crisis PTR exposure. *Price-to-income (PTI) exposure* is a county price-to-income ratio weighted at the bank level using three years of data on the dollar amounts of loans that are originated or purchased by that bank and kept (not sold within the year). *Price-to-rent (PTR) exposure* is a county price-to-rent ratio weighted at the bank level using the same weights as PTI. Pre-crisis PTI is defined as the average PTI during the period 2003-2006. Pre-crisis PTR is defined similarly. Variable definitions are provided in table 1.

| VARIABLES                          | (1)       |       | (2)       |       | (3)       |       | (4)       |       |
|------------------------------------|-----------|-------|-----------|-------|-----------|-------|-----------|-------|
|                                    | NCO rate  |       | NCO rate  |       | NCO rate  |       | NCO rate  |       |
| Pre-crisis PTI * Crisis period     | 0.0004*** | 0.0003* |           |       | 0.0001*** | 0.0001*** |           |       |
|                                    | (0.0001)  |       | (0.0001)  |       | (0.0000)  |       | (0.0000)  |       |
| Pre-crisis PTR * Crisis period     |           |       |           |       | 0.0000    | -0.0054*** |           |       |
|                                    |           |       |           |       | (0.00020) |       | (0.00020) |       |
|                                    |           |       |           |       | -0.0137*** | -0.0005  |           |       |
|                                    |           |       |           |       | (0.0062)  |       | (0.0062)  |       |
|                                    |           |       |           |       | -0.0018   | 0.0006   |           |       |
|                                    |           |       |           |       | (0.0014)  |       | (0.0014)  |       |
| Traditional home mortgages         | -0.0001   | -0.0054*** | 0.0000    | -0.0054*** |           |       |           |       |
|                                    | (0.0020)  |       | (0.0009)  |       | (0.0020)  |       | (0.0009)  |       |
|                                    |           |       |           |       | -0.0137*** | -0.0005  |           |       |
|                                    |           |       |           |       | (0.0062)  |       | (0.0062)  |       |
|                                    |           |       |           |       | -0.0018   | 0.0006   |           |       |
|                                    |           |       |           |       | (0.0014)  |       | (0.0014)  |       |
| Home equity loans                  | -0.0064*** | -0.0050*** | -0.0064*** | -0.0045*** |           |       |           |       |
|                                    | (0.0028)  |       | (0.0017)  |       | (0.0028)  |       | (0.0017)  |       |
| Equity capital                     | 0.0031    | -0.0016 | 0.0034    | -0.0015 |           |       |           |       |
|                                    | (0.0037)  |       | (0.0021)  |       | (0.0037)  |       | (0.0021)  |       |
| Core deposits                      | 0.0060*** | 0.0003  | 0.0058*** | 0.0002  |           |       |           |       |
|                                    | (0.0011)  |       | (0.0007)  |       | (0.0011)  |       | (0.0007)  |       |
| Cash                               | 0.0018    | 0.0003  | 0.0017    | 0.0006  |           |       |           |       |
|                                    | (0.0023)  |       | (0.0018)  |       | (0.0023)  |       | (0.0018)  |       |
| Money market                       | -0.0017   | 0.0035*** | -0.0019   | 0.0035*** |           |       |           |       |
|                                    | (0.0018)  |       | (0.0012)  |       | (0.0018)  |       | (0.0012)  |       |
| Illiquid assets                    | -0.0039*** | 0.0044*** | -0.0036*** | 0.0044*** |           |       |           |       |
|                                    | (0.0014)  |       | (0.0007)  |       | (0.0014)  |       | (0.0007)  |       |
| Size                               | -0.0002   | 0.0005*** | -0.0002   | 0.0005*** |           |       |           |       |
|                                    | (0.0003)  |       | (0.0001)  |       | (0.0003)  |       | (0.0001)  |       |
| Return on assets                   | -0.3046*** | -0.3035*** | -0.3064*** | -0.3043*** |           |       |           |       |
|                                    | (0.0130)  |       | (0.0101)  |       | (0.0130)  |       | (0.0101)  |       |
| Efficiency                         | 0.0021*** | 0.0029*** | 0.0021*** | 0.0029*** |           |       |           |       |
|                                    | (0.0005)  |       | (0.0003)  |       | (0.0005)  |       | (0.0003)  |       |
| Credit lines                       | -0.0080*** | -0.0061*** | -0.0083*** | -0.0062*** |           |       |           |       |
|                                    | (0.0019)  |       | (0.0012)  |       | (0.0019)  |       | (0.0011)  |       |
| Market unemployment rate           | 0.0007*** | 0.0004*** | 0.0007*** | 0.0004*** |           |       |           |       |
|                                    | (0.0001)  |       | (0.0001)  |       | (0.0001)  |       | (0.0001)  |       |
| Constant                           | 0.0007    | -0.0095*** | 0.0001    | -0.0099*** |           |       |           |       |
|                                    | (0.0043)  |       | (0.0012)  |       | (0.0043)  |       | (0.0012)  |       |
| Observations                       | 21,732    | 21,794 | 21,729    | 21,791 |           |       |           |       |
| R-squared                          | 0.58      | 0.40   | 0.58      | 0.40   |           |       |           |       |
| Bank fixed effects                 | X         | X      | X         | X      |           |       |           |       |
| Time fixed effects                 | X         | X      | X         | X      |           |       |           |       |
| County fixed effects               | X         | X      | X         | X      |           |       |           |       |
| Cluster                            | Bank      | County | Bank      | County |           |       |           |       |

Robust standard errors are in parentheses, *** p<0.01, ** p<0.05, * p<0.1

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Table 8: Logit Regression of Bank Failure, New Mortgage Risk Measure

This table shows the results of using a logit regression of bank failure on bank characteristics. The reported values are the average marginal effects. *Price-to-income (PTI) exposure* is a county price-to-income ratio weighted at the bank level using three years of data on the dollar amounts of loans that are originated or purchased by that bank and kept (not sold within the year). *Price-to-rent (PTR) exposure* is a county price-to-rent ratio weighted at the bank level using the same weights as price-to-income. Other variable definitions are provided in table 1.

| VARIABLES                                    | (1) PTI Specification | (2) PTI Specification | (3) PTR Specification | (4) PTR Specification |
|----------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                                              | 2005 | 2006 | 2007 | 2005 | 2006 | 2007 |
| PTI Exposure                                 | 0.001 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 |
|                                              | (0.004) | (0.004) | (0.004) | (0.002) | (0.002) | (0.002) |
| PTI Exp * Traditional home mortgages         | 0.082*** | 0.084*** | 0.069*** | 0.020 | 0.035*** | 0.025** |
|                                              | (0.028) | (0.028) | (0.026) | (0.013) | (0.012) | (0.010) |
| PTR Exposure                                 |       |       |       | -0.399 | -0.783*** | -0.536*** |
|                                              |       |       |       | (0.263) | (0.260) | (0.218) |
| PTR Exp * Traditional home mortgages         | 0.235*** | 0.181*** | 0.199*** | 0.240*** | 0.178*** | 0.194*** |
|                                              | (0.068) | (0.064) | (0.064) | (0.068) | (0.065) | (0.064) |
| Traditional home mortgages                  | -0.395*** | -0.498*** | -0.359** | -0.399 | -0.738*** | -0.536*** |
|                                              | (0.159) | (0.167) | (0.144) | (0.263) | (0.260) | (0.218) |
| Home equity loans                            | 0.241 | 0.599*** | 0.406** | 0.195 | 0.530** | 0.361* |
|                                              | (0.198) | (0.207) | (0.199) | (0.206) | (0.215) | (0.201) |
| Non-household RE loans                       | 0.565*** | 0.909*** | 0.645*** | 0.573*** | 0.930*** | 0.659*** |
|                                              | (0.143) | (0.151) | (0.175) | (0.142) | (0.151) | (0.175) |
| CRE lines of credit                          | -0.372 | -0.588** | -0.922*** | -0.382 | -0.581** | -0.940*** |
|                                              | (0.243) | (0.253) | (0.309) | (0.248) | (0.257) | (0.310) |
| Equity capital                               | -0.246*** | -0.225*** | -0.184*** | -0.258*** | -0.236*** | -0.197*** |
|                                              | (0.042) | (0.044) | (0.052) | (0.042) | (0.043) | (0.051) |
| Cash                                         | -0.735*** | -0.477* | -0.489* | -0.679** | -0.438* | -0.446* |
|                                              | (0.295) | (0.254) | (0.258) | (0.286) | (0.250) | (0.251) |
| Money market                                 | 0.244*** | 0.232* | 0.155 | 0.268** | 0.249* | 0.182 |
|                                              | (0.114) | (0.120) | (0.183) | (0.113) | (0.120) | (0.175) |
| Illiquid assets                               | 0.072 | 0.156** | 0.180** | 0.123** | 0.158** | 0.179** |
|                                              | (0.073) | (0.077) | (0.074) | (0.075) | (0.077) | (0.073) |
| Size                                         | -0.004 | 0.005 | 0.007 | -0.003 | 0.007 | 0.008* |
|                                              | (0.006) | (0.006) | (0.005) | (0.006) | (0.005) | (0.005) |
| Return on assets                              | 0.240 | 0.243 | -2.443*** | 0.279 | 0.208 | -2.343*** |
|                                              | (0.887) | (0.747) | (0.708) | (0.901) | (0.770) | (0.702) |
| Efficiency                                   | -0.026 | -0.019 | 0.027* | -0.030 | -0.022 | 0.023 |
|                                              | (0.018) | (0.017) | (0.016) | (0.019) | (0.017) | (0.016) |
| Non-performing loans                         | 0.834*** | 1.634*** | 1.387*** | 0.769** | 1.629*** | 1.388*** |
|                                              | (0.382) | (0.335) | (0.225) | (0.387) | (0.349) | (0.226) |
| Credit lines                                 | 0.020 | -0.283*** | -0.242** | 0.016 | -0.294*** | -0.252** |
|                                              | (0.083) | (0.109) | (0.117) | (0.084) | (0.109) | (0.118) |
| Market unemployment rate                     | 0.005 | 0.004 | 0.010*** | 0.005 | 0.005 | 0.011*** |
|                                              | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Observations                                 | 2.455 | 2.488 | 2.536 | 2.455 | 2.488 | 2.536 |
| Pseudo R-squared                             | 0.25 | 0.29 | 0.34 | 0.25 | 0.29 | 0.34 |

Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Table 9: Economic Significance of Logit Regression Results

To test the economic significance of the main results, we do the following exercise. For each variable that enter the logit regression with a positive coefficient, we set the value of each observation to the 25th quartile of this variable. We keep all other variables at their original values. We then use the regression results with real estate controls, presented in columns (1)-(6) of 8, to calculate the predicted probability of failure for each bank. Reported values are the differences between the average probability of failure under this exercise for each variable and the predicted probability of failure from the baseline model, reported in the last row. The reported effect of PTI(PTR) is the sum of the direct effect of PTI(PTR) and the indirect effect that comes from the interaction of PTI(PTR) with the traditional home mortgages. For variables that enter the logit regression with a negative coefficient, such as equity capital and core deposits, we raise the values to the 75th quartile of the distribution and repeat the exercise. The reported values for traditional home mortgages show sum of the direct effect of this variable and indirect effect through its interaction with PTI(PTR). The other variable definitions are provided in table 1.

| Variable                        | 2005 | 2006 | 2007 |
|---------------------------------|------|------|------|
| Economic Impact                 |      |      |      |
| Price-to-income (PTI)           | 2.04 | 2.23 | 1.92 |
| Non-household RE loans          | 3.82 | 3.36 | 3.50 |
| CRE lines of credit             | 3.11 | 4.23 | 2.75 |
| Money market                    | 0.68 | 0.62 | 0.28 |
| Illiquid assets                 | 0.84 | 1.71 | 1.98 |
| Non-performing loans            | 0.39 | 1.05 | 2.00 |
| Traditional home mortgages      | 0.38 | 0.58 | 1.08 |
| Equity capital and core deposits| 2.50 | 2.33 | 1.78 |
| Cash                            | 0.90 | 0.53 | 0.60 |
| Number of banks                 | 2,455| 2,488| 2,536|
| Failed                          | 180  | 184  | 177  |
| Bank failure rate in data       | 7.33 | 7.40 | 6.98 |
| Bank failure rate from the model| 7.33 | 7.40 | 6.98 |

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This table shows the results of using a logit regression of bank failure with alternative samples compared with our baseline model in table 8. The reported values are the average marginal effects. We change one dimension of the baseline sample at a time. In the first column we include banks that were acquired between 2008 and 2011 in the list of failed banks. In the second column we exclude large banks (over $10 billion in total assets). In the third column we change the time windows for bank failures to between 2008 and 2013. The variable definitions are provided in table 1.

| VARIABLES                           | (1) Include Acquired Banks | (2) Exclude Large Banks | (3) Failures 2008-13 |
|-------------------------------------|----------------------------|-------------------------|---------------------|
|                                     | 2006                       | 2006                    | 2006                |
| PTI Exposure                        | 0.002                      | 0.003                   | 0.002               |
|                                     | (0.004)                    | (0.004)                 | (0.005)             |
| PTI Exp * Traditional home mortgages| 0.068***                   | 0.072**                 | 0.101***            |
|                                     | (0.026)                    | (0.030)                 | (0.031)             |
| PTR Exposure                        | 0.000                      | 0.000                   | -0.000              |
|                                     | (0.001)                    | (0.002)                 | (0.002)             |
| PTR Exp * Traditional home mortgages| 0.028**                   | 0.030**                 | 0.039***            |
|                                     | (0.011)                    | (0.012)                 | (0.012)             |
| Traditional home mortgages         | -0.416***                  | -0.465***               | -0.650***           |
|                                     | (0.150)                    | (0.172)                 | (0.182)             |
| Home equity loans                  | 0.435**                    | 0.608***                | 0.703***            |
|                                     | (0.181)                    | (0.209)                 | (0.233)             |
| Non-household RE loans             | 0.144***                   | 0.196***                | 0.214***            |
|                                     | (0.055)                    | (0.066)                 | (0.072)             |
| CRE lines of credit                | 0.799***                   | 0.943***                | 1.007***            |
|                                     | (0.128)                    | (0.152)                 | (0.174)             |
| Equity capital                     | -0.517***                  | -0.532**                | -0.621**            |
|                                     | (0.190)                    | (0.254)                 | (0.260)             |
| Core deposits                       | -0.184***                  | -0.203***               | -0.263***           |
|                                     | (0.039)                    | (0.044)                 | (0.050)             |
| Cash                               | -0.393*                    | -0.497**                | -0.817**            |
|                                     | (0.218)                    | (0.268)                 | (0.319)             |
| Money market                       | 0.204**                    | 0.200                   | 0.388***            |
|                                     | (0.096)                    | (0.125)                 | (0.129)             |
| Illiquid assets                    | 0.109*                     | 0.151*                  | 0.222**             |
|                                     | (0.064)                    | (0.079)                 | (0.087)             |
| Size                               | 0.002                      | 0.003                   | 0.002               |
|                                     | (0.005)                    | (0.006)                 | (0.006)             |
| Return on assets                   | 0.806                      | 0.248                   | -0.369              |
|                                     | (0.624)                    | (0.748)                 | (0.923)             |
| Efficiency                         | -0.023                     | -0.023                  | -0.009              |
|                                     | (0.014)                    | (0.017)                 | (0.020)             |
| Non-performing loans               | 1.417***                   | 1.613***                | 1.828***            |
|                                     | (0.300)                    | (0.327)                 | (0.399)             |
| Credit lines                       | -0.237**                   | -0.319***               | -0.395***           |
|                                     | (0.093)                    | (0.109)                 | (0.125)             |
| Market unemployment rate           | 0.005                      | 0.004                   | 0.006               |
|                                     | (0.003)                    | (0.004)                 | (0.005)             |
| Observations                       | 3.049                      | 2.440                   | 2.328               |
| Pseudo R-squared                   | 0.25                       | 0.29                    | 0.29                |

Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1
### Table 11: Robustness: Alternative Mortgage Measures

This table shows the results of using a logit regression of bank failure on alternative measures of mortgage risk. The reported values are the average marginal effects. Deviation from 8-year average = PTI_t – average(PTI_{t-7:t}). Average change in the past five years = average(ΔPTI_t, ΔPTI_{t-1}, ΔPTI_{t-2}, ΔPTI_{t-3}, ΔPTI_{t-4}). The other variable definitions are provided in table 1.

| VARIABLES                      | (1) Deviation from 8-year Avg. 2006 | (2) Avg. Chg. In Past 5 years 2006 | (3) PTI based on Zillow HPI 2006 |
|--------------------------------|-------------------------------------|------------------------------------|----------------------------------|
| Mortgage risk                  | 0.008 (0.012)                       | 0.049 (0.228)                     | 0.000 (0.004)                    |
| Mortgage risk * Traditional home mortgages | 0.212*** (0.080) (1.547)       | 3.329** (0.228) (0.098)**        |                                  |
| Traditional home mortgages    | 0.011 (0.125)                       | -0.303** (0.125)                  | -0.587** (0.175)                 |
| Home equity loans              | 0.608*** (0.211) (0.216)            | 0.602*** (0.216)                  | 0.782*** (0.229)                 |
| Non-household RE loans         | 0.189*** (0.064) (0.065)            | 0.198*** (0.065)                  | 0.209*** (0.075)                 |
| CRE lines of credit            | 0.883*** (0.152) (0.153)            | 0.882*** (0.153)                  | 1.068*** (0.172)                 |
| Equity capital                 | -0.575** (0.249) (0.248)            | -0.544** (0.248)                  | -0.612** (0.293)                 |
| Core deposits                  | -0.232*** (0.045) (0.045)           | -0.243*** (0.045)                 | -0.255*** (0.052)                |
| Cash                           | -0.481* (0.259) (0.254)             | -0.433* (0.254)                   | -0.599** (0.302)                 |
| Money market                   | 0.240** (0.122) (0.122)             | 0.251** (0.122)                   | 0.269* (0.142)                   |
| Illiquid assets                | 0.145* (0.076) (0.077)              | 0.143* (0.077)                    | 0.141 (0.089)                    |
| Size                           | 0.006 (0.006)                       | 0.008 (0.005)                     | 0.005 (0.006)                    |
| Return on assets               | 0.240 (0.749)                       | 0.192 (0.760)                     | 1.134 (0.888)                    |
| Efficiency                     | -0.021 (0.017)                      | 0.017 (0.017)                     | -0.034* (0.020)                  |
| Non-performing loans           | 1.665*** (0.337) (0.344)            | 1.645*** (0.344)                  | 1.489*** (0.397)                 |
| Credit lines                   | -0.276** (0.111) (0.111)            | 0.273** (0.111)                   | 0.368*** (0.122)                 |
| Market unemployment rate       | 0.005 (0.004)                       | 0.004 (0.004)                     | 0.006 (0.005)                    |
| Observations                   | 2,488                               | 2,488                             | 2,089                            |
| Pseudo R-squared               | 0.29                                 | 0.28                              | 0.30                             |

Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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Table 12: Regression of Capital Ratio

This table shows the results of regressing total capital ratio on bank characteristics including Pre-crisis PTI exposure and Pre-crisis PTR exposure. *Price-to-income (PTI) exposure* is a county price-to-income ratio weighted at the bank level using three years of data on the dollar amounts of loans that are originated or purchased by that bank and kept (not sold within the year). *Price-to-rent (PTR) exposure* is a county price-to-rent ratio weighted at the bank level using the same weights as PTI. Pre-crisis PTI is defined as the average PTI during the period 2003-2006. Pre-crisis PTR is defined similarly. Variable definitions are provided in table 1.

| VARIABLES | PTI (1) | PTI (2) | PTR (3) | PTR (4) |
|-----------|---------|---------|---------|---------|
| High PTI  | 0.0012  | 0.0028  | 0.0018  | 0.0037***|
|           | (0.0020)| (0.0019)| (0.0017)| (0.0015)|
| High PTI * Traditional home mortgages | -0.0115 | -0.0162* | -0.0168* | -0.0189**|
|           | (0.0098)| (0.0091)| (0.0090)| (0.0081)|
| High PTR  |         |         |         |         |
| High PTR * Traditional home mortgages |         |         | -0.0231* | 0.0385***|
| Traditional home mortgages | -0.0265** | 0.0376*** | (0.0118) | (0.0141) |
| Home equity loans | -0.0558* | -0.0566* | (0.0290) | (0.0290) |
| Non-household RE loans | -0.0023 | -0.0028 | (0.0073) | (0.0073) |
| CRE lines of credit | -0.0420*** | -0.0426*** | (0.0061) | (0.0061) |
| Core deposits | -0.0303*** | -0.0307*** | (0.0071) | (0.0070) |
| Cash       | 0.0703*** | 0.0695*** | (0.0196) | (0.0196) |
| Money market | -0.0376** | -0.0379** | (0.0162) | (0.0162) |
| Illiquid assets | -0.1339*** | -0.1337*** | (0.0118) | (0.0118) |
| Size       | -0.0255*** | -0.0256*** | (0.0030) | (0.0030) |
| Return on assets | 0.4014*** | 0.4009*** | (0.0979) | (0.0981) |
| Efficiency | -0.0006 | -0.0007 | (0.0028) | (0.0028) |
| Credit lines | 0.0107 | 0.0103 | (0.0134) | (0.0134) |
| Market unemployment rate | -0.0008* | -0.0008* | (0.0004) | (0.0004) |
| Observations | 10,889 | 10,888 | 10,889 | 10,888 |
| R-squared  | 0.9387 | 0.9478 | 0.9387 | 0.9478 |
| Fixed Effects? | X X | X X | Bank Bank | Bank Bank |

Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1