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Real estate markets and bank distress

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Abstract

We investigate the relationship between real estate markets and bank distress among German universal and specialized mortgage banks between 1995 and 2004. Higher house prices increase the value of collateral, which reduces the probability of bank distress (PDs). But higher prices at given rents may also indicate excessive expectations regarding the present value of real estate assets, which can increase PDs. Increasing price-to-rent ratios are positively related to PDs and larger real estate exposures amplify this effect. Rising real estate price levels alone reduce bank PDs, but only for banks with large real estate market exposure. This suggests a positive, but relatively small 'collateral' effect for banks with more expertise in specialized mortgage lending. Likewise, lower price-to-rent ratios are estimated to reduce the riskiness of banks. The multilevel logit model used here further shows that real estate markets are regionally segmented and location-specific effects contribute significantly to predicted bank PDs.

Keywords: Real estate; distress; universal vs. specialized banks; multilevel mixed-effect model

JEL: C25; G21; G3

Non-technical summary

The detrimental effects of overheated real estate markets for financial stability are obvious in light of the recent turmoil in international financial systems. But the relation between real estate markets and bank distress is hardly analyzed for the majority of economies that do not show clear signs of overheating, such as Germany. The scarcity of empirical evidence on the relation between house prices and bank distress relates to two measurement problems. First, comparable series on house prices are often unavailable or mask important regional differences that influence banking risks. Also, in addition to price levels, the ratio of rents generated from real estate assets relative to their price may be a more adequate determinant of bank risk. But corresponding data on both property prices and rents is usually even more difficult to obtain. Second, bank distress is usually not announced to the public. Failures are resolved within banking groups to reduce the risk of negative externalities, which complicates the measurement of bank's risk in most studies.

We address both issues by combining information on bank distress collected by the Deutsche Bundesbank with regional house price information collected by a private data provider, Bulwien AG. We suggest a novel multilevel hazard rate model as to account more explicitly for the regional differences of housing markets and the respective location of banks in different states of the Federal Republic of Germany. Within this framework, we provide empirical evidence on the relation between real estate price developments and bank distress for a large bank-based economy.

Especially the regional aspect of house price developments has important implications for bank distress. Random region-specific effects contribute significantly to the PD of banks. Approximately one third of predicted PDs of banks located in the new federal states of Germany is due to this location effect. In contrast, the location contribution to PDs is relatively low and negative for banks headquartered in the old federal states.

The level of real estate prices is of minor importance for bank distress, both statistically and economically. Price-to-rent ratios that indicate the extent to which cash flows are expected to be generated from property are in turn consistently positively related to bank PDs. Akin to the price-earnings ratio from the finance literature, higher prices per Euro of expected rent generated from real estate assets may therefore indicate deviations from fundamentals, thereby contributing to a larger probability of banks to face distress. Note, however, that in contrast to price-earnings ratios of liquid financial assets, property rents do not adjust very often. This might limit the ability of our proxy to measure changes in the expectation of the value of real estate assets in the future perfectly.

Nichttechnische Zusammenfassung

Die gegenwärtigen Turbulenzen in internationalen Finanzsystemen unterstreichen die negativen Auswirkungen überhitzter Immobilienmärkte für die Finanzstabilität entwickelter Volkswirtschaften. Viele Immobilienmärkte, z. B. in Deutschland, weisen jedoch keine Anzeichen derartiger Blasen auf. Theoretisch sind Immobilienmärkte jedoch auch ohne offensichtliche Überhitzung für den Zustand des Bankwesens relevant, da Kreditinstitute Hypothekenkredite vergeben und Immobilien als Sicherheiten nutzen. Empirisch ist der Zusammenhang zwischen Immobilienmärkten und Bankstabilität jedoch weitgehend unerforscht.

Der Mangel an empirischer Evidenz ist vor allem auf Messprobleme von Hauspreisen und der Wahrscheinlichkeit einer Schieflage bei Banken (PD) zurück zu führen. Vergleichbare Hauspreisindizes sind entweder nicht oder nur auf nationalem Niveau vorhanden. Dies vernachlässigt wichtige regionale Unterschiede von Immobilienmärkten, welche für die Stabilität lokaler Banken relevant sind. Korrespondierende Preis- und Mietzinsdaten sind ebenfalls selten vorhanden, was die Ermittlung entsprechender Quotienten in Analogie zu Kurs-Gewinn-Verhältnissen (KGV) anderer Finanzanlagen verhindert. Diese sind jedoch zur Einschätzung von Bankrisiken eher geeignet. Bankrisiken selbst sind ebenfalls nur selten akkurat zu ermitteln, weil Schieflagen meist innerhalb des Bankensystems gelöst werden, um negative Externalitäten zu vermeiden.

In der vorliegenden Studie nutzen wir die Ausfalldatenbank der Bundesbank und regional erhobene Immobilienmarktdaten des privaten Dienstleisters Bulwien AG, um diese Probleme zu umgehen. Wir nutzen ein neues *multilevel hazard model*, um regionale Unterschiede des Banken- und Immobilienmarktes in der empirischen Schätzung von Bank PDs explizit zu berücksichtigen.

Unsere Ergebnisse bestätigen die Wichtigkeit regionaler Immobilienmarktentwicklungen für Bank PDs auch dann, wenn es keinerlei Anzeichen einer Überhitzung von Immobilienmärkten gibt. Das hier genutzte empirische Modell schätzt den Einfluss regionaler Effekte auf Bank PDs separat. Diese Effekte sind sowohl statistisch als auch ökonomisch signifikant. Etwa ein Drittel der Bank PD von Instituten in den neuen Bundesländern ist auf diesen regionalen Effekt zurückzuführen. Regionale PD Effekte für Banken mit Sitz in den alten Bundesländern sind hingegen negativ und wesentlich kleiner.

Unsere Ergebnisse zeigen auch, dass allein das Niveau von Immobilienpreisen keinen wirtschaftlich signifikanten Einfluss auf Bank PDs hat. Im Gegensatz dazu ist das Verhältnis von Kaufpreisen zu Mietzinsen durchgehend signifikant positiv. Insoweit dieser Quotient in Analogie zu KGVs die Höhe zu erwartender Erträge aus dem Erwerb von Immobilien misst, deutet dieses Ergebnis darauf hin, dass möglicherweise von Fundamentaldaten abweichende Erwartungen höhere PDs nach sich ziehen. Im Gegensatz zu KGVs gehandelter Finanzanlagen ist allerdings zu bemerken, dass Mietzinsen sich nicht häufig ändern sondern oftmals nur dann, wenn es zu einem Mieterwechsel kommt. Möglicherweise schränkt dies die Fähigkeit der Variable ein, die tatsächlichen Anpassung von Erwartungen des zukünftigen Wertes von Immobilien perfekt zu messen.

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Real estate markets and bank distress[1]

1 Introduction

Recent turbulence in international financial systems originating from mortgage markets highlights the close relationship between real estate price developments and the soundness of the financial sector. Real estate market problems are likely to precede financial crises as shown from a theoretical angle in Allen and Gale (2000) and as confirmed by historical crises.[2] Therefore, it is not surprising that policy makers also consider property prices among other indicators in their financial sector assessment programs (IMF, 2003).

Most studies on the relation between house prices and financial system soundness share two characteristics. First, they often focus on economies with overheated housing markets. But the vast majority of economies does not exhibit clear signs of real estate prices deviating excessively far from fundamentals. Allen and Gale (2000) show that financial stability can generally be impaired if (mortgage) credit expansion inflates (real estate) asset prices, leaving leveraged investors crippled when prices decline after having departed too far from fundamental levels. Real estate markets are particularly prone to such deviations since supply is fixed in the short run and the ability of banks to verify the riskiness of borrowers' investments is imperfect. Often it is only possible with hindsight to determine, which deviations from fundamentals constitute a bubble. Therefore, it is surprising that only few studies investigate the relation between bank distress and real estate markets when the latter are not obviously overheated.

Second, most studies take a macro perspective and focus on mortgage loan supply (dynamics) following monetary shocks (Bernanke et al., 1994; Kiyotaki and Moore, 1997; Aoki et al., 2004).[3] But financial stability implications of real estate developments might apply in particular to more granular micro and regional levels of the banking system. For example, Case et al. (2000) acknowledge the importance of macroeconomic conditions for delinquencies and defaults in general. But they emphasize the crucial importance of banks' abilities to score mortgage customers to explain most of the variability of distress when there is no turbulence in housing markets. Related, Calomiris and Mason (2003) study the Great Depression in the U.S. at the individual bank level and find that distress is triggered partially by fundamentals and partially by panics. In line with Case and Shiller (1996), they emphasize the importance of avoiding the aggregation of fundamentals, which might camouflage critical regional or sectoral shocks.

[1] M.Koetter@rug.nl (M. Koetter) and T.Poghosyan@rug.nl (T. Poghosyan). The opinions expressed in this paper are those of the authors and not necessarily those of the Deutsche Bundesbank. We are grateful to Heinz Herrmann and Thilo Liebig for both hospitality as well as feedback and thank the Bundesbank for the provision of data. We also acknowledge helpful comments from Jaap Bos, Clemens Kool, Iman van Lelyveld, Michael Wedow and participants of the NAKE conference 2007 and the Bundesbank research seminar. This paper is part of a research project sponsored by the foundation 'Geld und Währung'. Michael Koetter gratefully acknowledges support from the Netherland's Organization for Scientific Research NWO.

[2] For example, in the U.S. (late 1980's), Scandinavia (late 1980's), Mexico (early 1980's), Japan (early 1990's), and Southeast Asia (1998) (Hilbers et al., 2001; BIS and IMF, 2002).

[3] This 'financial accelerator' literature focuses on the implications for the propagation of monetary policy. See also Borio et al. (1994) and Higgins and Osler (1999).

We provide empirical evidence on the relation between bank distress and housing prices when real estate markets are not in exceptional circumstances. We measure bank distress at the individual firm level and account explicitly for local heterogeneity across real estate markets to which banks are exposed. Both issues appear to constitute hurdles in the existing literature due to two difficulties. The first relates to the valuation of real estate assets taking into account regional differences. These assets are heterogenous and therefore it remains unclear to what extent price levels reflect deviations from fundamentals (BIS and IMF, 2002). Clayton (1996), McCarthy and Peach (2004) and Ayuso and Restoy (2006) suggest to use instead house price-to-rent ratios. Similar to price-earnings ratios in the finance literature, they reflect expectations on cash flows to be generated from holding real estate assets. This ratio is better suited to indicate deviations from fundamentals if expectations are excessive, however, corresponding price and rent data for comparable assets is usually absent. We use annual information on real estate prices and rents in 125 German cities consistently collected by the data provider Bulwien AG. Price developments are different across Germany's regions due to structural disparity in economic activity and most likely may influence bank distress differently. We construct both price levels and price-to-rent ratios at the German state level, thereby taking into account regional differences.

The second challenge most studies face concerns the measurement of bank distress. Usually, information on bank distress is not publicly available. We have access to the bank distress database assembled by the Deutsche Bundesbank. Therefore, we can directly estimate probabilities of distress (PD) conditional on bank's exposure to the real estate market and other bank traits. Banks with larger exposures may be more experienced in real estate lending and possess therefore superior screening and monitoring skills in this business segment that reduce their PD. In turn, an explicit focus on this line of business might imply low risk diversification and could thus result in systematically higher PDs. We are able to test these competing hypotheses explicitly in this paper.

Methodologically, we aim to advance beyond previous bank hazard studies of thrifts and mortgage banks (Harrison and Ragas, 1995; Guo, 1999; Gan, 2004) by applying a multilevel mixed-effect discrete choice model to identify the impact of regional housing price developments on the riskiness of German banks. Instead of merely including macroeconomic conditions as controls in the hazard estimation (Nuxoll et al., 2003), we specify random region-specific effects. This allows us to dissect the contributing factors to predicted bank-specific PDs into a random regional component exogenous to bankers and a part attributable to bank-specific characteristics.

Our results confirm that real estate markets affect bank distress. In particular price-to-rent ratios significantly increase bank PDs. House price measures are significantly independent of other regional macroeconomic characteristics. The random contribution to bank distress due to location in the new federal states is positive, while it is negative for banks located in the old states. Larger exposures to mortgage lending amplify both positive price-to-rent ratio and negative price level effects. Negative price level coefficients indicate a 'collateral' effect. But substantially larger magnitudes of positive price-to-rent ratio coefficients highlight the relative importance of this indicator to assess bank stability.

The remainder of the paper is structured as follows. We review existing theoretical and empirical literature on the relationship between real estate prices and the soundness of the financial sector in section 2. Section 3 outlines our empirical methodology, a multilevel mixed-effect binary choice model, and describes the data. We discuss estimation and robustness checks in section 4. Section 5 concludes.

2 Real estate prices and bank distress

2.1 Real estate prices

In a frictionless world, real estate can be priced just as any other asset by discounting expected cash flows generated from rental payments. Cash flows are influenced by demand and supply of real estate assets, which in turn depend on macroeconomic fundamentals, such as population growth, real income and wealth, and interest rates. Real estate prices would then reflect economic cycles (Higgins and Osler, 1999). But this relationship is unlikely to hold perfectly for three reasons. First, real estate concerns non-standardized assets that differ considerably regarding quality and that are by definition regionally segmented. Second, the absence of central trading places implies that real estate prices are not generated with perfect information. Consequently, trading usually involves price negotiations that are characterized by a lack of transparency and high transaction costs. As a result, real estate markets are less liquid compared to financial markets. Third, relatively long construction lags of real estate hinder the match of demand and supply for real estate (McCarthy and Peach, 2004). Due to these particularities, real estate prices are prone to deviate from their fundamental values, which implies the potential to cause turmoil in financial systems. Hilbers et al. (2001) survey a number of studies that theorize on the mechanics of such bubbles, which are primarily driven by a combination of constrained real estate supply in the short run, lenders' limited ability to assess project risks, and herding behavior of investors (Allen and Gale, 2000).

Empirical work on the relation between real estate prices and banking stability is plagued by a number of factors that relate to measurement problems of the former. Hilbers et al. (2001) use a probit model to estimate the likelihood of a financial crises as defined in Kaminsky and Reinhart (1999) conditional on country characteristics and the real residential property price index. They report a positive relation between housing prices and crises for only two countries. Partly, this may reflect measurement problems of property prices that hamper international comparisons due to differences across countries in terms of real estate financing schemes, tax laws, or regulation regarding the use of real estate as a collateral. Alternatively, some studies argue that property price levels contain only limited information regarding deviations from the fundamental value. Ayuso and Restoy (2006) present a model of (dis-)equilibria in real estate markets emphasizing the role of real estate price-to-rent ratios. High ratios indicate high, potentially too high, expectations of investors regarding the possible cash flows to generate from the asset, i.e. rents and terminal value. In a competitive market, homeowners will then sell property and rent instead. Higher supply of property will reduce prices while increasing demand for leased space will increase rents, thereby reducing price-to-rent ratios. However, if expectations on either cash flows or terminal values are exuberant, this will entail higher price-to-rent ratios, which therefore serve as better indicators of overheating compared to levels alone (McCarthy and Peach, 2004).[4] Ayuso and Restoy (2006) report overvalued real estate markets in Spain and the UK on the order of 20 and 30 percent, respectively. In contrast to McCarthy and Peach (2004), who conclude on the basis of a price-to-rent model for the U.S. that real estate markets were not overheated, Ayuso and Restoy (2006) report that U.S. property was also overvalued by 10 percent. Note, that we do not investigate in this paper if German real estate markets are in equilibrium or not. Instead, we want to test if house prices influence bank distress even if there are no obvious signs of a real estate bubble. To this end, the previous literature shows that price-to-rent ratios, whether in equilibrium or not, most likely contain more relevant information to predict bank distress than prices per se.

The deviating findings of Ayuso and Restoy (2006) and McCarthy and Peach (2004) with respect to the valuation of real estate markets may be due to the neglect of accounting explicitly for regional differences of property prices. As shown in Calomiris and Mason (2003), this is crucial to explain the financial crisis in the U.S. in the 1930s. More recently, Holly et al. (2007) developed a spatio-temporal model of housing prices for the U.S. and report findings that corroborate the importance to account for regional differences. They demonstrate that after accounting for spatial effects, four U.S. states suffered from overvalued property markets.

Regional differences are relevant for the German economy, too. Figure 3 in the appendix depicts both the level of house prices and the corresponding price-to-rent ratio for each of the 16 states (*'Bundesländer'*) between 1995 and 2004. It shows that, on average, real estate price levels have declined in Germany. Especially in the new states both price levels and price-to-rent ratios have deteriorated substantially, for example by approximately one third in Saxony. To some extent this price deterioration may reflect a substantial increase in supply of real estate in the new states due to favorable depreciation rules and tax breaks provided to investors renovating existing or constructing new property. Another reason is related to weak demand. While population growth in old federal states was 1.7 percent between 1995 and 2005, the population in the new states shrank by 5.5 percent. Note again that we do neither intend to estimate equilibrium real estate prices, nor do we argue that declining real estate prices indicate a return to fundamentals. Instead, the present sample allows us to analyze the relation between bank distress in an environment of constantly deteriorating real estate values. Evidence on the ability of banks to cope with declining prices therefore complements studies investigating bank stability in times of soaring real estate prices. Our sample permits analysis of the relevance of regional real estate markets for bank distress while avoiding well-known measurement problems related to both measures.

[4]Clearly, the determination of equilibria in real estate markets is a subject in it's own right, which is beyond the scope of our paper. In fact, the described characteristics of real estate imply complex feedback dynamics between the supply of mortgage credit and houses as well as respective demand schedules. Here, we focus on the prediction of bank PDs rather than the determination of house prices and consider house prices as given based on the rejection of bivariate causality between house prices and bank credit in Hofmann (2004).

2.2 Exposure and distress

The at times sharp downturn in real estate prices in Germany's states may affect banks both directly through the decline of collateral value and indirectly through deteriorating financial positions of bank clients, for example households. Intuitively, a larger exposure of a bank to the real estate sector renders it more likely to be affected by real estate market fluctuations. The exposure of banks to the real estate sector can take many different forms (Hilbers et al., 2001), such as lending to customers for real estate purchases (often collateralized), or lending to non-bank intermediaries that engage in real estate lending.

Such links are obvious for specialized mortgage banks. Empirical studies therefore often focus on the performance and soundness of specialized intermediaries such as thrifts (Guo, 1999; Gan, 2004), savings and loan associations (Harrison and Ragas, 1995), or building societies and cooperatives (Haynes and Thompson, 1999). However, Davis and Zhu (2005) point out that non-specialized banks are also exposed to fluctuations in the real estate market. Many credit lines extended to the various sectors of the economy (e.g. manufacturing) are based on a real estate collateral, for example commercial property owned by the borrower.[5] Therefore, not only financial institutions specialized in mortgage lending are potentially influenced by negative trends in the real estate market but also universal banks.

Previous studies on German bank distress do not consider specialized mortgage banks (Kick and Koetter, 2007) and failure studies on specialized banks elsewhere do not explicitly investigate the relation with regional real estate prices.[6] But accounting for both specialized and universal banks is particularly relevant in Germany's banking system (Hackethal, 2004). Universal banks are not restricted in their scope of business activities and thus also engage in real estate lending. On average, the share of mortgage loans of all credit extended for five or more years by universal banks was 38 percent compared to 89 percent among specialized banks during 1995 and 2004 (see Table 1).

Table 1: Number of banks, distress events and exposure to housing loan market

	Number of banks			Distress events	Housing loan
	New states	Old states	Total	(number)	share (%)
Universal banks	310	3,186	3,496	1,570	38.3
Commerical	15	250	265	185	16.4
Savings	110	537	647	140	47.7
Credit cooperative	185	2,399	2,584	1,245	36.9
Specialized mortgage banks	4	71	75	47	89.0
Total	314	3,257	3,571	1,617	47.5

Note: New states are former states of the German Democratic Republic that joined the Federal Republic of Germany in 1990.

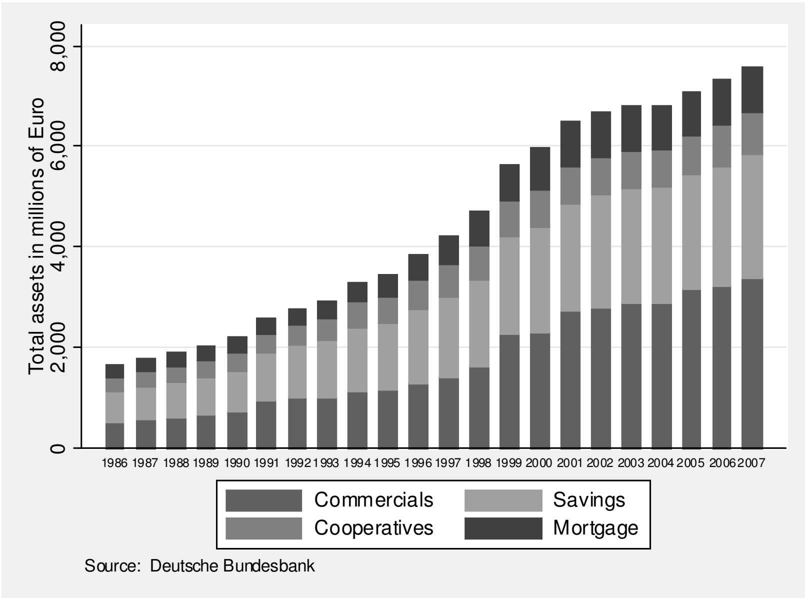
At the same time, Figure 1 underpins the importance of specialized banks in Germany's financial system. While only 75 out of a total of 3,571 banks in our

[5]Real estate markets can also influence the stability of banks via asset backed securities (ABS) in the trading book. This creates a link between property values and distress of financial institutions that are not directly exposed to mortgage lending. While we control in the hazard estimation for securities hold by banks, data to identify separate investments in ABS is not available.

[6]Nuxoll et al. (2003) specifies only regional macroeconomic variables as a catch-all control.

sample are classified by the Bundesbank as specialized mortgage banks, their share of total assets vividly illustrates the importance of these intermediaries. Given the historical deterioration of property prices, we hypothesize that increasing real estate price levels reduce bank PDs since they increase the value of collateral and enhance household wealth. However, Hilbers et al. (2001) emphasizes that the appropriate assessment of the present value of real estate projects is notoriously difficult. Given that previous studies argue that rising price-to-rent ratios are indicative of increasing risks due to departures from fundamental values, we hypothesize in turn that price-to-rent ratios are positively related to bank PDs.

Figure 1: Decomposition of total assets across different banking groups in Germany



Our second hypothesis relates to the inherent regional nature of both real estate and banking markets. Most banks engage in local lending relations and therefore we assign banks to regions based on the location of their headquarters.[7] We thus evaluate the impact of housing price developments at the local level on the PDs of individual banks. We separate the impact of developments in the housing market from the aggregate, random impact of other state-specific factors and test for it's significance to predict PDs.

Third, we hypothesize that intermediaries concentrating in mortgage lending develop expertise and possess superior skills to assess the real estate values and risks. We test below if the effect of house prices on bank distress differs significantly between banks with and without large exposures to real estate lending.

[7]While realistic for the vast majority of commercial, cooperative, and savings banks, which operate locally, this assumption may not hold for large commercial banks. We test below if results remain qualitatively unchanged when excluding the latter.

3 Methodology

3.1 Empirical model

To estimate the probability of bank distress (PD), most studies employ a logistic regression model.[8] The log odd's ratio form of a standard logistic model is:

$$\log\left[\frac{PD_{ijt}}{1-PD_{ijt}}\right] = \alpha + \beta X_{ijt} + \eta D \tag{1}$$

where $PD_{ijt} = Prob(Y_{ijt} = 1|X_{ijt}, D)$ is the probability that the bank i located in state j will encounter a distress event at time t conditional on the set of explanatory variables, X_{ijt} is a vector of bank-specific explanatory variables,[9] D represents a vector of time and banking group dummy variables, and α, β and η are parameters to estimate. The intercept parameter α in equation (1) controls for the logarithm of the probability ratio if all explanatory variables X_{ijt} are simultaneously equal to zero.[10] An important assumption in this model is that the intercept parameter is constant for all banks. This reflects the so-called independence of irrelevant alternatives (IIA) property of the simple logit model. It entails that odd ratios remain constant regardless of the number of possible events analyzed.

Here, we estimate the relationship between housing prices at the German state level and the riskiness of individual banks. This implies a multilevel hierarchy clustering: banks are nested within states, for which we have aggregate information on housing prices. Consequently, the standard IIA across subjects is likely to be violated within the clusters. Ignoring this inter-cluster dependence diminishes the variance of estimated parameters and overstates their significance (Hox, 2002). In addition, the interdependence gives raise to the so-called spatial autocorrelation problem. This problem is more severe than time series autocorrelation since not only the standard errors of the parameters are biased in the presence of spatial autocorrelation, but parameter estimates are also inconsistent.

To account appropriately for state-specific effects, we employ a multilevel mixed-effect binary choice model.[11] The existence of spatial clusters provides additional information on economic processes operating at different hierarchical levels. The multilevel method extends the conventional econometric techniques to handle such a dependence and exploits the information about economic relationships at different levels. In our setup, we measure how large the state-level variation across bank distress events is in comparison to the bank-level variation. Thereby, we can assess which part of the state-level variation can be explained by the variation of housing prices across German states and how it relates to the exposure of banks to the

[8] Kick and Koetter (2007) test various limited dependent variable models to estimate PDs.

[9] We use financial accounts data to construct CAMEL measures (C-capital adequacy, A-asset quality, M-managerial quality, E-earnings, and L-liquidity), which we discuss below.

[10] Since CAMEL indicators are different from zero, we take the difference of X_{ijt} from sample means before estimating the model(s). Slope coefficients β remain unaffected, but the intercept α represents the baseline hazard indicating the PD for a bank with an average CAMEL profile.

[11] These models are frequently used when the micro data is clustered, for example students nested in schools, employees in firms, or cities in states (see Hox, 2002 for a textbook exposition and Guo and Zhao, 2000 for a survey of applications in the various fields of social science).

mortgage business. To relax the restrictive assumptions present in equation (1), we extend the model by assuming the intercept to be state-specific:

$$\log\left[\frac{PD_{ijt}}{1-PD_{ijt}}\right] = \alpha_j + \beta X_{ijt} + \eta D \quad (2a)$$

$$\alpha_j = \alpha + u_j \quad (2b)$$

This is a random effect logistic model in which the intercept parameter for the individual bank is $\alpha + u_j$, where $u_j \sim N(0, \sigma_u^2)$. The random intercept u_j represents the combined effect of all omitted state-specific time-constant covariates that cause the banks located in that particular state to be more or less prone to distress than predicted by the mean probability of distress for the whole sample (α). The random effect model is an example of a broader class of generalized linear mixed effect models.[12] The variation of the intercept at the state-level can be modeled as a function of a vector of state-specific covariates Z_j, in which case the model is extended to:

$$\log\left[\frac{PD_{ijt}}{1-PD_{ijt}}\right] = \alpha_j + \beta X_{ijt} + \eta D \quad (3a)$$

$$\alpha_j = \alpha + \lambda Z_j + u_j \quad (3b)$$

In this specification, the impact of state-specific factors Z_j is measured by the parameter λ and can be interpreted as systematic effects influencing the baseline bank hazard at the state-level. In our setup, the state-specific factor is the housing price measure for individual German states.

It is important to notice the difference between the specification where housing price variables are specified as additional explanatory variables on the right hand side of the simple logit specification and the random effect formulation (3a-3b). The later introduces more flexibility by assuming state-specific random heterogeneity, i.e. state-specific factors apart from housing price changes that might be important in predicting distress probabilities. The reduced form of the structural general multilevel mixed-effect logistic model (3a-3b) is given by:

$$\begin{aligned}\log\left[\frac{PD_{ijt}}{1-PD_{ijt}}\right] &= \alpha + \beta X_{ijt-1} + \eta D + \lambda_1 HP_{jt-1} + \lambda_2 HPR_{jt-1} + \\ &+ \lambda_3 HP_{jt-1} SH_{ijt-1} + \lambda_4 HPR_{jt-1} SH_{ijt-1} + u_j\end{aligned} \quad (4)$$

where SH is the percentage share of real estate loans in the bank's total long-term loans, HP and HPR are the logarithms of housing prices and price-to-rent ratios (the state-specific factors), respectively.[13] Specification (4) allows us to test the competing hypotheses outlined in section 2. First, the coefficients λ_1 and λ_2 measure the relative impact of housing price levels and price-to-rent ratios, respectively, on bank PDs. Second, the random state effect u_j and its variance σ_u^2 allow us to compare this model to the traditional, simple logit specifications and, hence, to evaluate the importance of accounting for state-specific influences on bank risk. Third, interaction terms with bank's exposure to the housing market SH allow us to test whether the impact of the two housing price indicators changes with the degree of bank involvement into the real estate market. The coefficients λ_3 and λ_4 show the impact of housing prices and price-to-rent ratios on the likelihood of bank distress due to a percentage point increase of its exposure to the real estate loans market.

[12] These are called mixed effects models since they contain both fixed (β) and random (α_j) effects.
[13] We describe all data in the next subsection.

3.2 Data

We combine three different databases to evaluate the impact of housing price fluctuations on the riskiness of German banks: financial accounts, a distress database, and a commercially provided set on real estate prices for 125 German cities.

Financial accounts We use Bundesbank data on banks balance sheets, income statements, the credit register (*'Kreditnehmerstatistik'*), and audit reports for the 1994-2005 period. To specify financial covariates X_{ijt} to predict bank distress we follow the convention in the bank hazard literature and select proxies for banks' capitalization, asset quality, management skills, earnings, and liquidity (CAMEL) to predict bank PDs. Since the potential number of proxies is very large and lacks specific theoretical priors, we use a selection technique suggested by Hosmer and Lemshow (2000). We generate a list of around 150 potential CAMEL covariate candidates. Based on individual explanatory power, we select around 50 covariates that are tested with stepwise logistic regressions within each CAMEL category. Stepwise regression and economic significance result in the final vector of CAMEL covariates. Table 2 provides descriptive statistics.

Table 2: Mean values for CAMEL covariates

CAMEL covariate		Distress No	Distress Yes	Total	Difference
Reserves	c_1	2.22	2.36	2.23	0.14**
Equity ratio	c_2	5.48	5.00	5.45	-0.48***
Risky loans	a_1	20.77	29.64	21.30	8.87***
OBS activities	a_2	9.92	11.22	9.99	1.30***
Customer loans	a_3	58.90	58.93	58.91	-0.02
Cost efficiency	m_1	93.71	90.72	93.53	-2.99***
Return on assets	e_1	14.17	-3.55	13.12	-17.72***
Liquidity	l_1	6.70	8.10	6.78	1.40***
Number of obs.		24,524	1,554	26,078	

Note: All variables are in percentage terms. The sample contains 3,496 universal and 75 specialized banks. ** and *** indicate significance at the 5 and 10 percent levels, respectively.

The resulting sample is an unbalanced panel containing 26,078 observations on 3,496 universal and 75 specialized German banks for the 1995-2004 period.[14] Both capitalization measures should reduce the likelihood of bank distress. The next three variables capture bank asset quality, including off-balance sheet activities. The larger the value of these indicators, the lower is the asset quality of a bank. We expect a positive coefficient for these covariates. The management quality variable is approximated by the level of bank-specific cost efficiency obtained using stochastic frontier analysis (SFA) (see also Wheelock and Wilson, 2000; Koetter et al., 2007). Given the heterogeneous sample of banks (commercial, savings, cooperative and specialized) with different types of technological frontiers, we measure the cost efficiency using the latent class frontier approach.[15] This approach remains agnostic as to which

[14]Due to missing observations regarding CAMEL covariates and using one year lags in the hazard estimation, the number of observations decreased to 22,419 observations.

[15]See Bos et al. (2008) for the importance to account for heterogeneity and Koetter and Poghosyan (2008) for further details on the latent class frontier model.

banks are allocated to which technology regime. Rather than choosing a priori an ultimately arbitrary allocation, we condition group membership probabilities on the bank's mortgage loan share and an indicator variable capturing classification according to the Bundesbank. The appendix provides technical details of the latent class stochastic efficiency frontier model used to obtain the bank-specific efficiency scores. We expect a negative coefficient in front of this variable, since banks with better managerial skills and expertise are expected to be less prone to distress. The last two variables measure earnings and liquidity of banks. Stronger earnings should decrease distress probabilities. The impact of liquidity is ambiguous. More liquidity might mean that banks have more free resources at their disposal to alleviate distress. Alternatively, it may imply an inefficient allocation of resources to low-yield assets that contributes to the distress.

Distressed events CAMEL covariates are specified in the hazard rate model to estimate bank-specific PDs. In contrast to most failure studies, we use data assembled by the Bundesbank recording distressed events among German universal and specialized banks between 1995 and 2004 (see Table 1). Distressed events are defined pursuant to the credit act and guidelines issued by the Federal Financial Supervisory Authority (*BaFin*). The data comprise obligatory notifications from banks in line with the credit act, compulsory notifications about losses amounting to 25 percent of the liable capital, a decline of operational profits by more than 25 percent, or more direct measures forwarded by the *BaFin*, for example official warnings to the bank CEO, orders to restructure operations, restrictions to lending and deposit taking, dismissal of the bank CEO as well as bank takeovers and enforced closures. The regional dispersion of bank distress is high and represents an important aspect that must not be discarded neither regarding real estate price developments nor regarding distressed events.[16] We suspect that a considerable part of bank PDs is attributable to region-specific effects, which the bank can hardly influence in the short run. Specifically, the development of housing prices discussed next and the well-known persistence of structural deficiencies lead us to expect that individual bank PDs are positively influenced by a bank's location in one of the new states.

Real estate Real estate prices and rents are obtained from the data provider Bulwien AG. The dataset contains annual information on housing prices and rents for 125 German cities for the 1995-2004 period.[17] We use city-level information on existing house prices and rents to generate aggregate state-level indices.[18] ANOVA estimations shown in the appendix corroborate the idea of aggregation since we find that state-level housing price variation is relatively large in comparison to the city-level variation within the states.[19] The evolution of the state-level price and rent indices is shown in Figure 3 in the appendix. House price levels decline continuously, but both levels and dynamics differ across states. A similar picture emerges from the descriptive statistics for price-to-rent ratios. Note, however, that some states, such

[16] Distress frequencies per state and year in addition to Table 1 are available upon request.

[17] Note that rents do not change frequently, mostly when tenants change. Therefore, rental prices may not fully reflect faster and more frequent expectation changes of future real estate prices. To some extent this concern is mitigated by the fact that rental prices per city are averages, thus covering a sample also including vacated, and hence rent-adjusted, premises in a given year.

[18] We also use data on new house prices and rents for robustness checks. The latter usually exclude energy cost, which differ at times across regions, too.

[19] City-specific effects in equation (4) are infeasible since banks also operate outside the cities where they are headquartered. Furthermore, this would neglect most banks in the industry.

as Bremen, Baden-Wurttemberg, or Hesse, exhibit price-to-rent ratios that increased prior to 2000. Hence, this measure seems to contain additional information.

4 Results

4.1 Specification

Our empirical estimation strategy is to start from the simplest multilevel mixed-effect logistic specification, which we label Model 0, and to augment it incrementally to more general models and test their validity using likelihood ratio (LR) tests and the Akaike information criterion (AIC).

Table 3: Multilevel mixed-effect logit model specifications

	Model0	**Model1**	**Model2**	**Model3**	**Model4**
State effect (u_j)	×	×	×	×	×
HP		×		×	×
HPR			×	×	×
HP*SH					×
HPR*SH					×
Log-likelihood	-4,382	-4,381	-4,374	-4,373	-4,366
AIC	8,806	8,807	8,791	8,792	8,782
LR test (p-value)					
Simple logit	0.0000	–	–	–	–
Model0	–	0.3571	0.0000	0.0000	0.0000
Model1	–	–	N/A	0.0000	0.0000
Model2	–	–	–	0.3380	0.0000
Model3	–	–	–	–	0.0000

Note: 22,419 observations. Time- and group-specific effects included. × indicates the variables included in each of the specifications. LR test is not applicable for Models 1 and 2. Lower Akaike Information Criterion (AIC) indicate preference for Model 2.

Table 3 displays model specifications and according test results for the set of models under consideration. First of all, the comparison of the simplest multilevel mixed-effect logistic specification Model 0 to an ordinary logistic model employed in previous studies provides unambiguous support for the multilevel specification. This finding corroborates our prior that, even after controlling for the impact of bank-specific CAMEL covariates, there still remains a substantial state-level random variation of bank distress. This variation might be related to various state-specific characteristics, which would be neglected if we were to follow the conventional stream of the literature by modeling bank distress using a simple logistic specification. Our objective now is to explore the extent to which the state-specific heterogeneity can be described by regional developments in the real estate market.

Second, including house price levels alone in Model 1 does not improve the model fit as indicated by the LR test. In contrast, the specification of price-to-rent ratios in Model 2 is supported on grounds of both the LR test and the information criterion (AIC). While Models 1 and 2 are not nested, thus prohibiting the former test, the lower AIC for Model 2 supports the importance of price-to-rent ratios. This suggests that especially this proxy for deviations from the fundamentals is of importance for bank distress. This is corroborated by a comparison of the specification with both ratios and levels (Model 3) to a specification including only the former (Model 2). The relative power of the former model does not improve significantly relative to Model 2 and the LR test confirms the lack of the significant improvement. This finding implies that the level of real estate price indices alone contributes only little to explain the state-specific random variation in PDs, as opposed to the price-to-rent ratios.

The most general specification of equation (4) interacts both housing price indicators with the banks' share of mortgage loans in long term lending (Model 4). This specification outperforms all previous models in terms of fit as indicated by both the LR test statistics and the AIC. Hence, housing prices in levels appear to add to the information on bank distress of those intermediaries, which are involved more actively in real estate lending. Therefore, we use Model 4 as a reference specification in our further discussion.

4.2 Estimations

The multilevel mixed-effect logit estimation results for the reference specification Model 4 are displayed in the first column of Table 4. The CAMEL covariates are significant and exhibit the expected signs. In line with the previous evidence, greater capitalization, higher managerial quality and earnings decrease individual bank PDs. Inferior asset quality and accumulation of low-yield liquidity, in turn, increase the hazard of bank distress.

Consider first the relation between distress and price-to-rent ratios. The coefficient λ_2 is significant and positive, suggesting that larger acquisition costs of real estate per square meter relative to the rent extractable from these assets increase the riskiness of banks. To some extent, this result is in line with the 'disaster myopia' hypothesis advanced in Herring and Wachter (1999). Disaster myopia entails in general that risks might be systematically underestimated if sudden corrections occur only infrequently. Intuitively, the likelihood of sudden correction is increasing with higher deviation from fundamentals. The latter is the result of the willingness of investors to pay more per square meter of real estate, since these investors expect higher returns from either rents or asset values in the future. While price levels in general are low in Germany, these expectations might still indicate at any given point in time overly optimistic expectations that banks are willing to finance.

Related to our third hypothesis on exposure, this impact is significantly more pronounced for banks largely involved into real estate lending. The positive additional effect on PDs of banks with relatively larger exposures (λ_4) then suggests that especially the risk of these intermediaries increases if expectations of returns from real estate investments are too high. Put differently, large existing mortgage loan exposures interacted with rising, perhaps unfounded, expectations increase bank PDs, potentially reflecting a systematic underestimation of real estate market risks. Since price-to-rent ratios have consistently declined since 1997 in (almost) all states, the estimated positive coefficients for λ_2 and λ_4 indicate that declining expectations regarding the future value of real estate assets reduced the riskiness of German banks.

Table 4: Multilevel mixed-effect logit estimation results

Variable	Coeff.	Existing houses (Model 4)	Excluding large banks	Excluding specialized banks	Including real GDP growth	New houses
Reserves (c_1)	β_1	-0.0467*	-0.0463*	-0.0541**	-0.0640**	-0.0489*
Equity ratio (c_2)	β_2	-0.2464***	-0.2489***	-0.2765***	-0.2951***	-0.2463***
Risky loans (a_1)	β_3	0.0214***	0.0214***	0.0217***	0.0218***	0.0217***
OBS activities (a_2)	β_4	0.0085***	0.0086***	0.0081***	0.0091***	0.0088***
Customer loans (a_3)	β_5	0.0180***	0.0179***	0.0179***	0.0171***	0.0181***
Cost efficiency (m_1)	β_6	-0.0188***	-0.0186***	-0.0185***	-0.0211***	-0.0186***
Return on assets (e_1)	β_7	-0.0500***	-0.0501***	-0.0496***	-0.0516***	-0.0499***
Liquidity (l_1)	β_8	0.0210***	0.0207***	0.0204***	0.0263***	0.0209***
Commercial (BGR_1)	η_1	0.2831*	0.2857*	0.2857*	-0.2026	0.2868*
Savings (BGR_2)	η_2	-1.1680***	-1.1690***	-1.1980***	-1.3010***	-1.1780***
Specialized (BGR_3)	η_3	0.1561	0.1536		-0.3084	0.1855
Housing prices (HP)	λ_1	0.1103	0.1142	0.1422	-0.0169	0.0027
Price-to-rent ratio (HPR)	λ_2	0.2615**	0.2574**	0.2430**	0.3290**	0.3055*
Housing prices interacted (HPR*SH)	λ_3	-0.0042***	-0.0042***	-0.0052***	-0.0028	-0.0041***
Price-to-rent ratio interacted (HPR*SH)	λ_4	0.0034***	0.0034***	0.0042***	0.0022	0.0036***
GDP					0.0057	
Intercept	α	-14.92***	-14.89***	-15.21***	-13.75***	-13.40***
Random state-level variance	σ_u^2	0.54***	0.54***	0.54***	0.49***	0.57***
Observations		22,419	22,393	22,253	19,058	22,419
Log-likelihood		-4,366	-4,355	-4,287	-3,777	-4,369

Note: All estimations including time-specific fixed effects (not reported). *, ** and *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Consider next the impact of house price levels on bank PDs. We find no significant impact of housing prices per se on the PD of banks that are not involved in real estate lending (insignificant λ_1). However, the impact is significantly negative for banks extending some part of their loans to this market (negative and significant λ_3). The negative impact of housing prices increases for this set of banks and can be explained by an increase in the values of the real estate collateral these banks hold. Therefore, even if the customers are unable to repay their debt, the bank will be able to compensate the losses by liquidating the collateral at a higher price. This is in line with a 'collateral channel' of housing price transmission to balance sheet positions of banks and their clients, which is also documented to propagate credit cycles through the financial accelerator mechanism (Kiyotaki and Moore, 1997).

Finally, note that our hypothesis of the relevance of accounting more explicitly for the regional nature of real estate markets is supported throughout. Estimates of the intercept α, which can be interpreted as a baseline hazard rate, are significant at the one percent level.[20] The significant variation of the state-specific random part in the overall intercept, denoted by σ_u^2, supports the hypothesis that bank distress is affected by its location even after netting out the impact of regional real estate price developments.

4.3 Robustness

We investigate the implications of some important assumptions we made with respect to the validity of our previous conclusions. First, in evaluating the impact of state-specific housing price variables on the distress of banks operating in those states, we implicitly assume that banks are active in the states where their headquarter is located. While realistic for the majority of German banks, this assumption is too restrictive for large banks, which conduct their operations all over the Republic and also abroad. Therefore, we re-estimate our model after excluding large commercial, savings, and cooperative banks from the sample. As shown in Table 4, the qualitative results of the preferred specification regarding the impact of real estate price proxies remain unchanged.

Next, by pooling universal and specialized German banks in our estimations, we assume that banks belonging to different banking groups respond in a similar way to housing market fluctuations. Accounting for possible group differences only by means of dummy variables might be too restrictive, especially when considering specialized mortgage banks. Their primary business is real estate lending and they might therefore be more experienced in hedging against housing market risks. Therefore, we exclude specialized banks from the sample as another robustness check.[21] The qualitative results regarding the impact of housing prices remain unchanged, which implies that it is not only specialized banks that are affected by the developments in the housing market, but also the rest of the banking system.

[20] The significance of the baseline hazard implies that a bank with an average CAMEL profile is significantly exposed to distress with a certain probability.

[21] Ideally, we would estimate PDs only for specialized banks, which was infeasible due to the small group size. Also, we showed in Table 1 that 71 out of 75 specialized banks are located in the old federal states, which implies that geographical coverage of specialized banks is not encompassing.

Clearly, housing prices do not exhaust the list of potentially relevant state-specific factors influencing bank stability. One important variable that might be relevant for predicting bank PD at the state-level is the degree of economic activity as measured by regional real GDP growth (Nuxoll et al., 2003). Economic growth can affect bank stability either directly (aggregate income, demand for new loans), or indirectly (impact on housing prices). Similar to Nuxoll et al. (2003), real per capita GDP growth does not have significant explanatory power. However, its inclusion eliminates the significance of the interaction effects with bank exposure proxies. Nevertheless, the impact of price-to-rent ratios is still positive and significant, supporting the importance of this variable as an indicator of real estate market risks for banks.

So far, we have used data on prices and rents of existing property, which constitute the majority of the housing market in Germany. To cross-check the robustness of our results regarding the type of the housing market considered, we re-estimate the model with data on housing prices and rents of newly constructed property. The estimation results yield an unchanged outcome, implying that the results do not depend on the housing market under consideration.

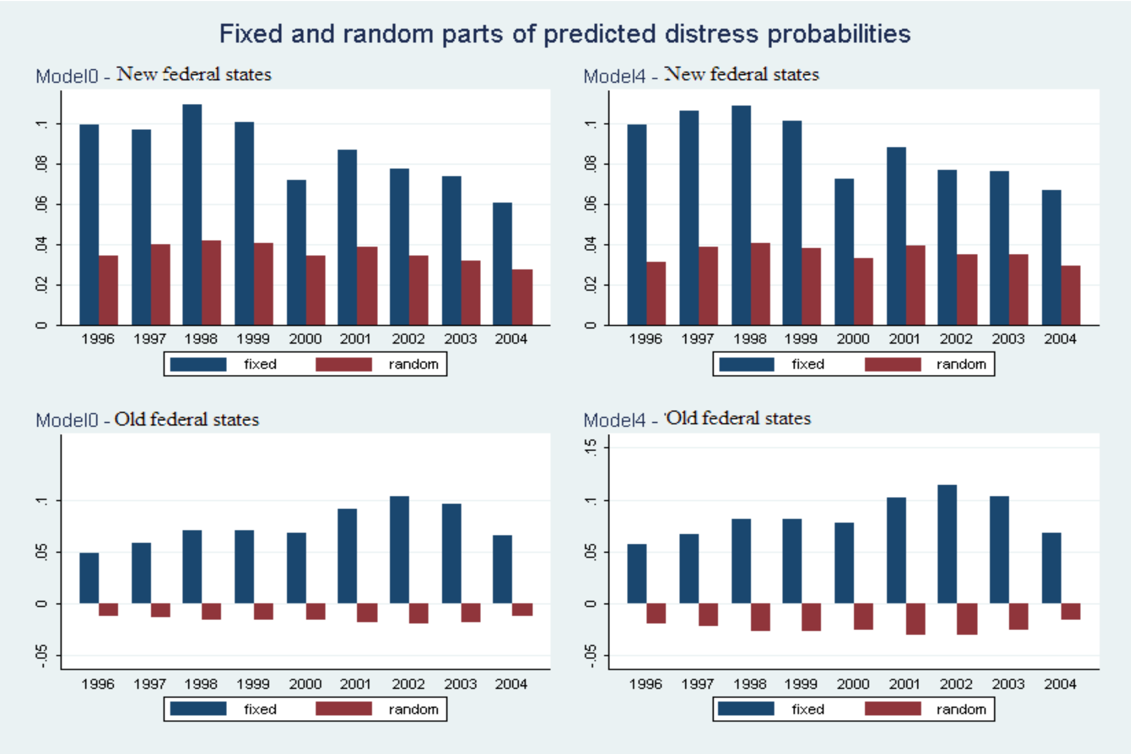
4.4 PD predictions

While the estimation results show that (random) state-specific effects are important, policy makers may be more interested in the implications of banks' location on their PDs. Therefore, we evaluate next the relative importance of both bank-specific CAMEL covariates and state-specific real estate indices to predict bank PDs.

We compare probabilities of distress predicted with the multilevel mixed-effect specification without housing price effects (Model 0) to predicted PDs from our reference specification with housing price effects (Model 4). The PDs are decomposed into two parts: the bank-specific effect and the state-specific random effect (u_j). The first part measures the impact of standard bank-level covariates used in the literature and is expected to constitute the largest part of the total PD. The second part is due to the random variation across the German states as a result of the state-specific heterogeneity, which, in the case of Model 4, is not captured by the variation in housing prices. In Figure 2 we present the dynamics of fixed and random parts of predicted PDs over time for Models 0 and 4. The total PDs are grouped according to the geographical location of the banks (old versus new states).

Several findings emerge from this picture. First, as expected, the fixed effect part of the total PD constitutes the largest part of the total PD in both specifications. Next, the impact of random effects in both model specifications is comparable, which confirms our previous claim that there are other important state-specific variables not present in the model which explain a sizable potion of the state-specific heterogeneity in terms of bank PDs. More importantly, the impact of state-specific heterogeneity is uniformly positive in the new federal states and negative in old ones. Moreover, its impact is more than two times larger in the former regions. This finding is valid also for other specifications (not presented to conserve space) and implies that banks located in the new states are more prone to distress due to the state-specific factors not captured by housing price(-to-rent) fluctuations. Thus, the location of a bank is an important factor affecting bank PDs even after controlling for other conventional covariates.

Figure 2: Predicted distress from Models 0 (without housing prices) and 4 (with housing prices)



One caveat with interpreting this finding is related to the fact that some of the credit extended by banks to the new states originates from banks located in old states. As shown previously in Table 1, only four out of 71 specialized mortgage banks are located in new states, which means that it is likely that a significant part of housing credit extended to these regions is recorded in the books of the banks located outside the state. However, another important source for real estate financing in the new states may be regional saving and cooperative banks, which are also very active in real estate lending. Separate regressions for these banking groups yield qualitatively identical results between housing prices and banking risk. To some extent, this supports the robustness of our previous conclusion.[22]

5 Conclusion

This paper builds on the theoretical work relating individual bank stability to the developments in regional real estate markets. We provide empirical evidence on this relationship using German data on real estate prices per federal state and bank data concerning financial accounts and distress events of both universal and specialized banks between 1995 and 2004. Since Germany's real estate markets are characterized by constantly declining prices during this period, we provide evidence that complements other studies focusing on financial systems where housing prices

[22]However, we caution that we are ultimately unable to trace the particular region to which bank loans are extended with certainty.

exhibit exuberant hikes. Methodologically, we seek to contribute to the literature by combining information at different aggregation levels, state (real estate) versus bank level (financial and distress), and use multilevel mixed-effect logistic regression methods to predict bank distress. Our main results are as follows.

In line with the prediction by Calomiris and Mason (2003), our empirical results support the view that developments of real estate prices at the disaggregated (state) level add significant discriminatory power to predict individual bank distress.

Real estate price levels per se have only a limited impact on bank distress. Instead, price-to-rent ratios are both statistically and economically significant. Since housing prices have declined constantly in Germany without any signs of a bubble, this result suggests the general existence of a relation between bank distress and real estate markets. To the extent that price-to-rent ratios reflect potentially exaggerated expectations of investors regarding the present value of future cash flows, we find that especially such indicators of deviations from fundamental values are related to higher bank PDs. Potentially, the relation between price-to-rent ratios and bank distress might be even stronger in countries that have experienced booms and busts in housing prices.

The exposure of a bank to the real estate market has implications for its sensitivity to housing price developments. After controlling for banking group membership (universal versus specialized), increasing property prices decrease bank PDs, which indicates risk reductions through the increase of collateral value. However, this effect is only significant for banks with relatively large exposure to mortgage lending. In contrast, increasing price-to-rent ratios render all banks more vulnerable to distress, albeit more specialized banks are affected significantly stronger.

Housing prices do not exhaust the list of economic factors at the state level that influence bank distress. The random state-specific variation of bank distress remains significant and explains a relatively large part of the predicted bank PD. The impact of state-specific factors on PDs is uniformly positive for banks headquartered in the new federal states. Hence, an economically significant part of bank PDs appears to depend on factors outside the direct realm of managerial influence, namely location.

In sum, price-to-rent ratios rather than housing price levels alone seem to contain important information, especially if obvious signs of overheating are absent from real estate markets. Even after controlling for other state-specific effects, this proxy appears to provide useful information on potential hazards to bank stability. Note, however, that the relatively low frequency of rent changes may constitute a potential limitation of this proxy to fully capture changing expectations of future cash flows.

Appendix

A latent class cost frontier

We use stochastic frontier analysis (SFA) to estimate cost functions and associated inefficiency (CE). Banks k demand inputs x at prices w, and we also account for equity z. In contrast to most studies, we assume that the transformation function of the banking firm can differ across J latent classes, $T(y,x,z|j)$. Banks choose a production plan that minimizes total operating cost (TOC). Optimal costs depend on the technology employed by the bank and deviations from optimal cost are either due to random noise or inefficiency. Instead, of estimating (arbitrary) group-specific frontiers separately, we estimate latent production technologies of banks simultaneously. We follow Greene (2005) and specify a latent class frontier model as:

$$TOC_{kt} = \alpha + \beta_j' x_{kt} + \epsilon_{kt|j}, \tag{5}$$

where x_{kt} is a short-hand for the cost function arguments consisting of outputs y, input prices w, control variables z, and the respective interaction terms of the translog functional form. Coefficients β can vary across an a priori specified number of groups $j = 1, .., J$ and ϵ is an error term composed of random noise v_{kt} and inefficiency u_{kt} conditional on group j. Note that it is unknown into which group individual banks k belong. Instead, we add an equation that represents the likelihood of a bank to be classified into a certain group j conditional on it's production technology x_{kt} as well as group specific elasticities β_j and efficiency parameters to estimate, i.e. σ_j and λ_j:

$$P_{kt|j} = f(TOC_{kt}|\beta_j', x_{kt}, \sigma_j, \lambda_j). \tag{6}$$

As in Greene (2005), we estimate bank-specific probabilities of group membership using a multinomial logit model:

$$\Pi(k,j) = \frac{exp(\pi_j' z_k)}{\sum_{m=1}^{J} exp(\pi_m' z_k)}\ , \quad \text{for } \pi_J = 0, \tag{7}$$

where $j = J$ is the reference group and z_k are bank-specific determinants of group membership. The conditional likelihood averaged over classes is:

$$\begin{aligned} P_k &= \sum_{j=1}^{J} \Pi(k,j) \prod_{t=1}^{T} P_{kt|j} \\ &= \sum_{j=1}^{J} \Pi(k,j) P_{k|j}. \end{aligned} \tag{8}$$

Parameters for equations (5) and (6) are obtained by estimating the joint likelihood incorporating production and probability parameters (Greene, 2005). This allows us to avoid the usual assumption of one identical frontier across banks and permits a comparison of relative efficiency scores. We condition group membership on both a specialization dummy based on the taxonomy of the Bundesbank and the share of mortgage loans.[23]

[23] Descriptive statistics and parameter estimates are available upon request. For a more detailed discussion of approaches to control for heterogeneity see Bos et al. (2008). More details on the latent class frontier model are discussed in Koetter and Poghosyan (2008).

ANOVA analysis of housing prices

We decompose housing price changes in Germany into two different levels, city and state, to evaluate the importance of housing price variation across different hierarchical levels by means of the explained variation.[24] If the variation across cities within states is smaller than the variation across states, it is reasonable to aggregate the city level information to the state level and base estimations on state-specific housing price indices. We employ data on housing prices collected for 125 German cities by the Bulwien AG provided by the Bundesbank.[25] The structural form of the multilevel model is given by:

$$\Delta \log HP_{ijt} = \gamma_{0ij} + \varepsilon_{ijt} \tag{9a}$$

$$\gamma_{0ij} = \gamma_{00j} + \upsilon_{0ij} \tag{9b}$$

$$\gamma_{00j} = \gamma_{000} + \zeta_{0j} \tag{9c}$$

where HP_{ijt} is the price index for city i, in state j at time t, $\upsilon_{0ij} \sim N(0, \sigma_\upsilon)$ and $\zeta_{0j} \sim N(0, \sigma_\zeta)$ are city- and state-level random error terms, and $\varepsilon_{ijt} \sim N(0, \sigma_e)$ is the i.i.d. residual. Equations (9a)-(9c) assume that average changes in price indices vary across cities and states, as indicated by the subscripts of intercepts γ. The reduced form is:[26]

$$\Delta \log HP_{ijt} = \gamma_{000} + \zeta_{0j} + \upsilon_{0ij} + \varepsilon_{ijt} \tag{10}$$

An intuitive measure that summarizes the importance of shocks affecting housing price changes at different hierarchical levels is the intraclass correlation given by:

$$\begin{aligned} Corr(\Delta \log HP_{ijt}, \Delta \log HP_{i'jt}) &= \frac{Cov(\Delta \log HP_{ijt}, \Delta \log HP_{i'jt})}{\sqrt{Var(\Delta \log HP_{ijt})}\sqrt{Var(\Delta \log HP_{i'jt})}} \\ &= \frac{\sigma_\zeta}{\sqrt{\sigma_\zeta + \sigma_\upsilon + \sigma_\varepsilon}\sqrt{\sigma_\zeta + \sigma_\upsilon + \sigma_\varepsilon}} \\ &= \frac{\sigma_\zeta}{\sigma_\zeta + \sigma_\upsilon + \sigma_\varepsilon} = \rho_{city} \end{aligned} \tag{11}$$

The parameter ρ_i denotes the intraclass correlation at the city level. This coefficient shows the expected level of correlation of log price differences between two randomly selected cities belonging to the same state. The larger ρ_i, the more clustered the observations are within states and therefore more care needs to be taken to model this intraclass dependence explicitly. Similarly, intraclass correlation on the state level can be expressed as: $\rho_{state} = \frac{\sigma_\upsilon}{\sigma_\zeta + \sigma_\upsilon + \sigma_\varepsilon}$. Estimation results for specification (10) using mixed effect linear regression methods are summarized in Table 5.

The significant negative intercept coefficient means that on average German housing prices declined. The variation of deviations across the total average varies at different levels. Most of the variability originates from the state level (σ_ζ), while the city-level variation within states is negligible and insignificant (σ_υ). This is also confirmed by the intraclass correlation coefficient, which is about 2% at the state level. This can be interpreted as the expected correlation between two randomly chosen price indices within the same state. The city-level intraclass correlation is zero. This

[24] See Jones and Bullen, 1994 for a similar application using urban house prices in the UK.

[25] We exclude Berlin, Hamburg and Saarland, since there is only a single price index.

[26] The residuals ζ_{0j}, υ_{0ij} and ε_{ijt} nested at different levels are assumed to be uncorrelated.

Table 5: ANOVA regression results for different housing price indices

	γ_{000}	σ_ζ	σ_υ	σ_ε	Intraclass correlation	
					state	city
Housing prices	-1.8376	0.6020	0.0012	3.8308	2.41%	0.00%
(st. err.)	0.2168	0.2025	0.1159	0.0823		

Note: Estimations are performed using information on prices of houses per square meter for 122 German cities located in 13 German states for the 1995-2004 period. Berlin, Hamburg and Saarland are excluded from estimations, since the dataset does not contain house price information on more than one city in each of these states. Total number of observations is 1,230.

implies that the city-level variation averaged over states does not contribute to the total variation. Thus, aggregation of housing price indices to the state-level would not result in a substantial loss of information.

Figure 3: Housing prices and price-to-rent ratios (Euros per sqm)

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