Do regional real estate market developments affect bank distress? A multilevel mixed-effect analysis ⋆

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Abstract

A priori, the relationship between real estate market developments and bank distress is unclear. On the one hand, rising house prices can increase the value of collateral and bolster banks' buffers against other risks. On the other hand, increasing house prices might indicate deviations from fundamental values and induce banks to lend excessively to sub-prime borrowers, thereby increasing the likelihood of distress. We test these competing hypotheses using data of all German universal and specialized mortgage banks between 1995 and 2005. We find that increasing price-to-rent ratios are positively related to bank distress probabilities. Larger exposures to real estate lending amplify this effect. This suggests that deviations from fundamentals increase bank risk. Rising real estate price levels alone, in turn, reduce bank distress probabilities, but only for those banks that extensively lend to the real estate market. This suggests a positive but relatively small 'collateral' effect for banks with more expertise in specialized mortgage lending. The multilevel logit model used here further shows that real estate markets are regionally segmented and location-specific effects should be modeled explicitly.

Key words: real estate prices, bank distress, multilevel mixed-effect model
JEL: C25, G21, G3

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1 Introduction

The recent turbulence in the international financial system originating from the US sub-prime mortgage market vividly highlights the intimate relationship between price developments in the real estate market and the soundness of the financial sector. [1] The phenomenon that turmoil in real estate markets frequently precedes financial crises is well known both from a theoretical angle (Allen and Gale, 2000) and observed crises in the past. [2] Given the important role played by real estate markets, it is not surprising that policy makers therefore also consider property prices among other financial soundness indicators in their financial sector assessment programs (ECB, 2000; IMF, 2003).

The relation between house prices and financial system soundness are mostly analyzed from a macro perspective, frequently focusing on mortgage loan supply (dynamics) following monetary shocks (Bernanke et al., 1994; Kiyotaki and Moore, 1997; Aoki et al., 2004). [3] The reported results of pro-cyclical mortgage lending owed to the use of real estate as collateral (financial accelerator) bear implications primarily for the propagation of monetary policy. In addition, Allen and Gale (2000) show that financial stability can be impaired if (mortgage) credit expansion inflates (real estate) asset prices, leaving leveraged investors crippled once prices return suddenly to fundamental levels. The excessive inflation of prices is possible, if not likely, in real estate markets given the fixed supply in the short run and banks imperfect ability to verify the riskiness of borrower's investments.

These studies suggest that financial stability responses to the real estate developments might only be detectable at a more granular micro and regional level. The importance of economic climate for delinquencies and defaults is explicitly mentioned in Case et al. (2000). The authors claim that variation in borrowers' economic characteristics, such as credit scores, explain most of the variability of distress when there is no turbulence on the part of the national and regional housing markets. However, they argue that in the case of a drastic housing price reversal, actual default rates would substantially exceed the ones predicted by the most sophisticated credit-scoring models in the industry.

In fact, 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

[1] The subprime market consists of mortgage loans characterized by relatively large loan-to-value ratio and given out to clients with relatively poor credit rating.
[2] Examples are the US savings and loans crisis in the late 1980's, financial crises in Southeast Asia in 1998, the Scandinavian crisis in the late 1980's, Mexico in the early 1980's, and Japan in the early 1990's (Hilbers et al., 2001; BIS and IMF, 2002).
[3] Examples of empirical studies are Borio et al. (1994), Higgins and Osler (1999), and ECB (2000).

fundamentals, such as property market developments, and partially by panics. They emphasize the importance of avoiding the aggregation of fundamentals, which might camouflage critical regional or sectoral shocks. Related, Case and Shiller (1996) show that regional property price reductions accounted for most of the losses incurred by holders and insurers of mortgage papers.

We seek to contribute empirical evidence on the relation between bank distress and housing prices taking into account exactly these two issues: (i) the measurement of distress at the individual bank level and (ii) an explicit account of local heterogeneity across real estate markets to which the individual 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 nonstandard and described by substantial heterogeneity and hedonic structure (BIS and IMF, 2002). Even if comparable house price indices are available, it remains challenging to what extent these reflect deviations from fundamentals, as suggested by Allen and Gale (2000). Some studies, such as Clayton (1996), McCarthy and Peach (2004) and Ayuso and Restoy (2006), therefore suggest to resort to house price-to-rent ratios in the vein of price-earnings ratios from the finance literature to assess deviations from fundamentals. This complicates empirical work further due to the absence of respective price and rent data for comparable assets. We are able to tackle this issue by using a dataset provided by the private agency Bulwien AG that contains systematic annual information about real estate prices and rents in 125 German cities. Since these represent cities from all states in the Republic, we are able to construct both price level as well as price-to-rent ratios at the German state level, thereby taking into account regional differences. We hypothesize that, first, price developments are different across these regions due to fundamental regional disparity in economic activity and, second, that these different real estate price developments have a differential impact on bank distress.

The second challenge concerns the measurement of bank distress. Usually, information of individual bank distress are not publicly available. But Kick and Koetter (2007) show that although no German bank violated minimum reserve requirements recently, a number of weaker distress events occurred among German universal banks since 1993. Therefore, we use a dataset on historical distress events among banks from the German central bank, Deutsche Bundesbank, to estimate probabilities of distress more directly. We can test more succinctly if the ability to assess the riskiness of real estate borrowers depends on the level of individual bank exposure to the real estate market. This is crucial according to Allen and Gale (2000) because it can fuel excessive real estate price deviations from fundamentals. On the one hand, banks that are more experienced in real estate lending might develop better skills to assess these markets and thus reduce their probability of distress from house price developments due to superior pricing skills. On the other hand, an explicit focus on just this line of business may imply the inability to diversify risk sufficiently across income categories and thus result in systematically higher probabilities compared to universal banks. We are able to test these competing hypotheses explicitly in this paper.

In addition to these two contributions, we aim to advance methodologically 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 housing price developments on the riskiness of German (mortgage) banks. Instead of merely including environmental macroeconomic conditions as covariates in the hazard estimation (Porath, 2006; Nuxoll, 2003), we allow thus for random region-specific effects and can dissect the contribution to predicted bank-specific probabilities of distress into a regional component, presumably exogenous to bankers, and a portion attributable to bank-specific characteristics.

Our results suggest that developments in the real estate market, especially the discrepancy between housing price levels and their fundamentals, have a significant impact on the probabilities of bank distress. The variation of housing prices across states helps in predicting part of the variation of the regional distress, but the remaining random variability is still significantly positive. We attribute this random variability to other regional macroeconomic factors not captured by our model. Hence, house price developments have a significant influence on banking stability independent of other regional macroeconomic characteristics. Generally, the random contribution to bank distress due to location in Eastern states is positive while it is negative for banks located in Western states. Regarding the impact of bank exposure to the real estate market, we find that those banks which are more extensively involved in mortgage lending are more vulnerable to deviations of housing prices from their fundamentals. With respect to the price levels, we find that the risk of distress of largely exposed banks declines if real estate prices increase. Hence, price level hikes seem to have a positive effect, for example by increasing collateral value. However, increasing price-to-rent ratios have an even larger negative impact on bank risk and therefore seem the more important indicator to consider from a stability point of view.

Three issues are important to bear in mind regarding the results of this study. First, considering the German economy has the advantage that its banking market is the most fragmented one of all OECD economies. This implies that regional developments have important implications for the banks operating in those regions. Second, evidence on the importance of deviations from fundamentals in a market characterized by declining real estate prices suggests that real estate markets are of importance for banking distress even without bubbles. Potentially, the latter may be of even greater relevance for economies that have witnessed large swings in housing markets, for example the U.S., the UK, or Spain. Finally, it is important to notice that our analysis does not aim to identify the determinants of regional house price developments. Instead, we abstract from the possible feedback effects and take the regional house price developments as given in our empirical investigation. [4]

The remainder of the paper is structured as follows. The next section provides an overview of existing theoretical and empirical literature on the relationship between real estate prices and the soundness of the financial sector. The third section outlines our empirical methodology, a multilevel mixed-effect binary choice model, and describes the data. The results section discusses the estimation outcomes and provides a robustness check. Section five concludes.

2 Real estate prices and bank distress

2.1 Real estate prices

Numerous studies analyze the determinants of real estate prices. In a frictionless world, real estate can be priced just as any other asset, generating cash flows in the form of rental payments. Discounted cash flows are influenced by demand for and supply of real estate, which in turn depend on macroeconomic fundamentals, such as population growth, real income and wealth, and interest rates. In this respect, real estate prices would reflect economic cycles (Higgins and Osler, 1999; IMF, 2000).

However, real estate prices are unlikely to reflect only fundamentals for three reasons. First, real estates are non-standardized assets which differ considerably regarding quality and which are by definition regionally segmented. Second, the absence of central trading places implies that real estate prices are not generated with perfect information. Instead, trading usually involves price negotiations which are characterized by a lack of transparency and substantial transaction costs. Consequently, real estate markets are less liquid compared to financial markets, for instance. Third, relatively long construction lags of real estate hinder the match of demand and supply for real estate (Herring and Wachter, 1999; 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

[4] This is in line with evidence reported by Hofmann (2004) and Davis and Zhu (2004), which rejects the hypothesis of bivariate causality between housing price developments and banking credit.

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, limited lenders' ability to assess project risk, and herding behavior of investors (Carey, 1990; Allen and Gale, 2000).

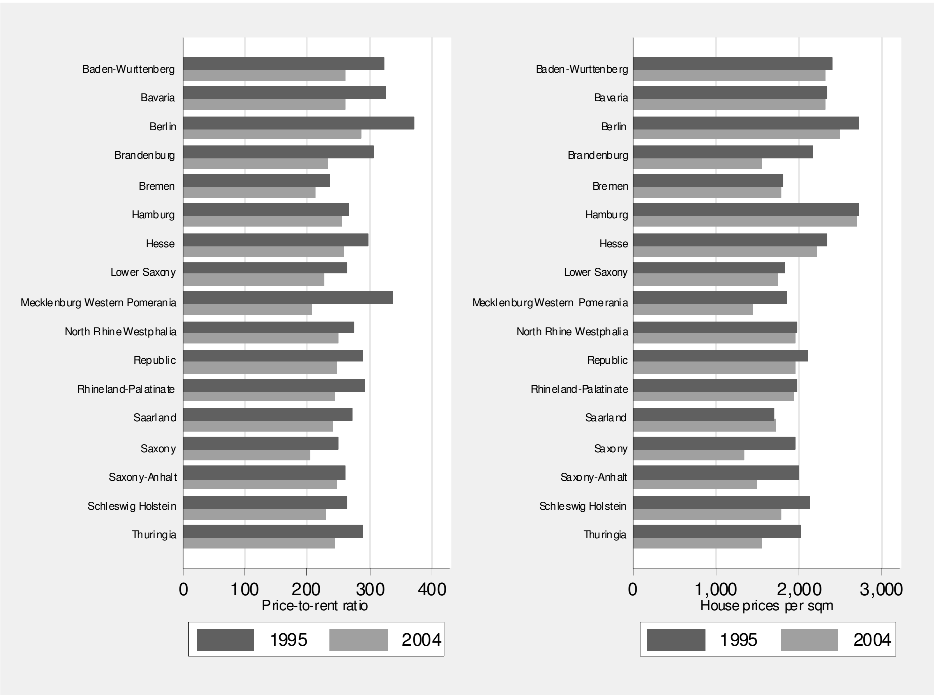
Empirical work on the relation between real estate prices and banking stability is plagued by a number of factors that relate to measurement problems of the former. For instance, Hilbers et al. (2001) use a probit model to estimate the likelihood of a financial crises, defined as in Kaminsky and Reinhart (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 merely reflect measurement problems of property prices that hamper international comparisons due to differences across countries in terms of real estate financing schemes, regulatory structures, tax brackets, or regulation regarding the use of real estate as a collateral.

Alternatively, some studies argue that property price levels contain only limited information regarding the deviation from fundamentals. Ayuso and Restoy (2006) present a model of (dis-)equilibria in real estate markets emphasizing the role of real estate price-to-rent ratios. They 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) also report that U.S. property was overvalued by 10 percent.

Two important limitations of these studies may drive these deviating findings. The first concerns the measures of bank distress, which we discuss in the next subsection. Second, the importance of accounting explicitly for regional differences of property prices is neglected, which is of crucial relevance in explaining the financial crisis in the U.S. in the 1930's (Calomiris and Mason, 2003). More recently, Holly et al. (2007) have 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 in the German economy, too. Figure 1 depicts both the level of house prices and the corresponding price-to-rent ratio for each of the 16 states (*'Bundesländer'*) in 1995 and 2004. On average, real estate price levels have declined in Germany. Especially in Eastern states both price levels and price-to-rent ratios have deteriorated substantially, for example approximately one third in Saxony. Note that we do not argue that this decrease in real estate prices indicate the period after the burst of a bubble or 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. [5]

Figure 1. Real estate price and rent ratios in Germany 1995-2004



The fact that real estate price developments exhibit considerable variation across states and price-to-rent ratios illustrate that levels alone contain only limited information. Especially the latter measure highlights the importance to account more explicitly for the regional dispersion of real estate market developments. Thus, our sample permits analysis of the relevance of regional effects while avoiding well-known measurement problems of real estate prices inherent to international comparisons (Hilbers et al., 2001). [6] We turn next to

[5] Note that we do neither claim that there has been a bubble that burst in the mid 1990s nor that the observed price developments represent a return to fundamentals. Here, we focus merely on testing whether there is a relation between (regional) real estate market developments and bank distress.

[6] The Bank for International Settlements maintains a small dataset on annual residential and commercial property prices in 20 industrialized countries. But this data suffers from limitations since only real estate prices from the largest cities per country are considered (Davis and Zhu, 2005).

the structure of German banking to formulate our hypotheses on the relationship between the stability of particular banking groups and housing prices.

2.2 Bank 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 the value of real estate property used as a collateral, and indirectly through financial positions of bank clients, for example real estate companies and 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 nonbank intermediaries that engage in real estate lending.

Such links are obvious for specialized mortgage financial institutions. 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; Worthington, 2002). 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 collateral, for example commercial property owed by the borrower. Additionally, real estate market developments can have a systematic impact on the stability of banks due to the increasing importance of banks investing in asset backed securities. The prices for these financial instruments are closely related to the developments in the real estate market. This creates a link between real estate market fluctuations and financial distress of institutions holding them, as was vividly documented by the recent sub-prime crisis in the U.S. mortgage market. Thus, not only financial institutions specialized in mortgage lending are potentially influenced by negative trends in the real estate market but also universal banks.

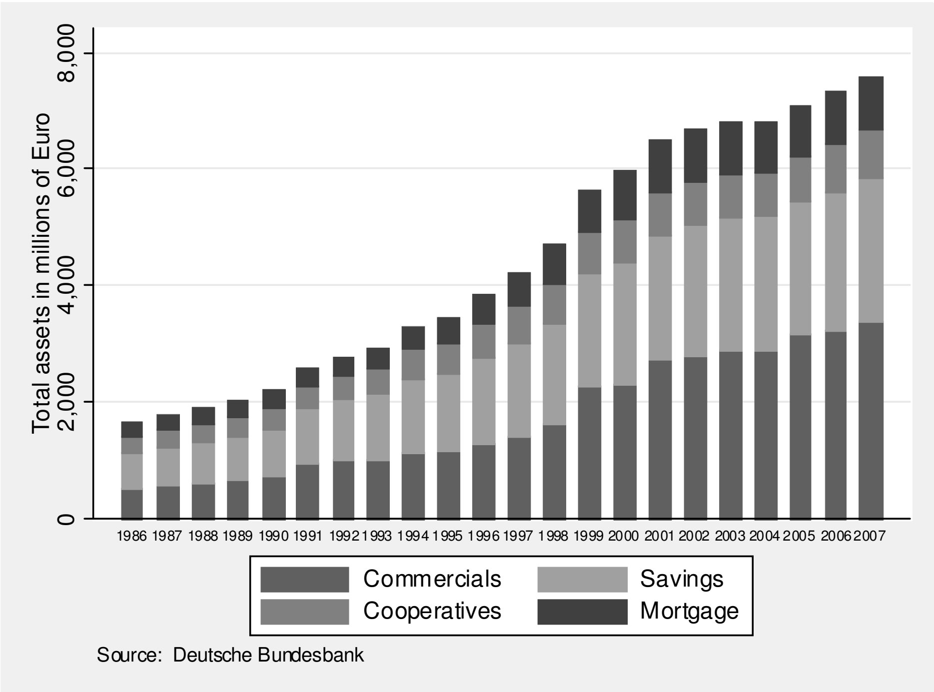
Table 1
Number of banks, distress events and exposure to housing loan market

	Number of banks			Distress events	Distress events	Housing loan
	East	West	Total	(number)	(per bank)	share (%)
Universal banks	310	3186	3496	1570	0.45	38.3
Commerical	15	250	265	185	0.70	16.4
Savings	110	537	647	140	0.22	47.7
Credit cooperative	185	2399	2584	1245	0.48	36.9
Specialized mortgage banks	4	71	75	47	0.63	89.0
Total	314	3257	3571	1617	0.45	47.5

To our knowledge neither do studies on German bank distress consider specialized mortgage banks (Porath, 2006; Kick and Koetter, 2007) nor do bank failure studies on specialized banks elsewhere explicitly investigate the relation with real estate price developments.[7] The former shortcoming is particularly relevant in Germany's banking system, which promotes universal banks (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 of universal banks was 38 percent compared to 89 percent among specialized banks during 1995 and 2004 (see Table 1).

At the same time, figure 2 underpins the importance of specialized banks in Germany's financial system. While only 75 out of a total of 3,571 banks covered in our sample are classified by the Bundesbank as specialized mortgage banks, their share of total assets vividly illustrates the importance of these intermediaries. These banks are also characterized by a relatively high mean distress frequency (see Table 1).

Figure 2. Decomposition of total assets across different banking groups in Germany



We hypothesize, first, that increasing real estate price levels and earning ratios

[7] Nuxoll (2003) is one of the few bank distress studies that incorporates regional macroeconomic variables into the model. However, regional housing prices are not considered among those macroeconomic variables.

affect bank distress among both universal and specialized banks positively. Herring and Wachter (1999) and Hilbers et al. (2001) argue that banks tend to underestimate the risks associated with exposures to the real estate sector for a number of reasons. The first relates to so-called *disaster myopia*. The low frequency of negative shocks in real estate markets implies that prices may grow for decades in excess of fundamentals before a drastic negative shock occurs. Another reason is *inadequate data and weak analysis*, which renders the appropriate assessment of the present value of real estate projects notoriously difficult. Imprecise information can then cause banks to incur losses when trying to sell the collateral in the market. Excessive increase in price levels may thus induce banks to engage too intensively in real estate lending from a risk perspective. In turn, rising price-to-rent ratios are indicative of increasing risks that real estate prices deviate too far from fundamentals.

Our second hypothesis relates to the inherent regional aspects of real estate markets on the one hand and the fact that the vast majority of German banks engages in local lending relations on the other. We assign banks to regions based on the location of their headquarters.[8] The existence of a very large number of banks and their geographical dispersion allows us to evaluate the impact of housing price developments at the local level on the PDs of individual banks. In addition, we separate the impact of housing market developments from aggregate impact of other state-specific factors influencing bank PDs, which are not captured by our model, and test for the significance of the later factors.

Our third and final hypothesis relates to the impact of individual bank exposure to the real estate market on its vulnerability to housing price developments. If it is true that banks easily underestimate the risks associated with real estate lending activities, we suspect that those intermediaries concentrating their expertise in only this line of business should possess superior skills to assess the former. Hence, we test below whether the effect of house prices on bank distress differs significantly between banks with and without large exposures to real estate lending.

3 Methodology

To account appropriately for state-specific effects, we employ a multilevel mixed-effect binary choice model to estimate the relationship between housing prices at the German state level and the riskiness of individual banks. Multi-

[8] 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.

level mixed-effect 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; Snijders and Bosker, 1999, and Rabe-Hesketh and Skrondal, 2005). In our setup, the multilevel hierarchy clustering takes place at the German state level: banks are nested within states, for which we have aggregate information on housing prices. The time variation within our panel is assumed to have a fixed-effect origin and is controlled by time dummies.

An important implication is that the standard assumption of independence 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 also the parameter estimates are inconsistent. [9]

At the same time, the existence of spatial clusters provides additional information on economic processes operating at different hierarchical levels. The multilevel methods extend the conventional econometric techniques to handle such a dependence and exploit the information about economic relationships at different levels. In our setup, we are interested to know how large the state-level variation across bank distress events is in comparison to the bank-level variation. Ultimately, we would like to see 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 mortgage business.

3.1 Simple logistic regression

To illustrate our approach, consider a standard logistic model employed in the bank distress literature:

$$P(Y_{ijt} = 1|X_{ijt}) = \frac{exp(\alpha + \beta X_{ijt})}{1 + exp(\alpha + \beta X_{ijt})} \tag{1}$$

where P is the probability that the bank i located in state j will encounter a distress event at time t, X_{ijt} is a vector of explanatory variables (CAMEL covariates, [10] state-specific variables, time dummies) and α and β are param-

[9] In some sense, spatial autocorrelation problem is similar to the problem of endogeneity due to self-selection.

[10] CAMEL abbreviation stands for bank ratings used by the regulators to identify potentially falling banks based on five conventional bank-specific character-

eters to be estimated. We can rewrite specification (1) in the log odd's ratio form:

$$\log\left[\frac{P(Y_{ijt}=1|X_{ijt})}{1-P(Y_{ijt}=1|X_{ijt})}\right]=\alpha+\beta X_{ijt} \tag{2}$$

In specification (2) the intercept parameter α controls for the logarithm of the probability ratio for the case when all the explanatory variables X_{ijt} are simultaneously equal to zero. [11] An important assumption in this model is that the intercept parameter is constant for all banks, which implies the so-called independence of irrelevant alternatives (IIA) property of the simple logit model stating that the odd ratios remain constant regardless of the number of possible events analyzed. Another assumption is that observations for the same bank are independent across time, which is too restrictive.

3.2 Multilevel mixed-effect logistic regression

One way of relaxing these assumptions is to extend the model by assuming the intercept to be state-specific:

$$\begin{aligned}\log\left[\frac{P(Y_{ijt}=1|X_{ijt})}{1-P(Y_{ijt}=1|X_{ijt})}\right]&=\alpha_j+\beta X_{ijt}\\ \alpha_j&=\alpha+u_j\end{aligned} \tag{3}$$

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

istics (C-capital adequacy, A-asset quality, M-managerial quality, E-earnings, and L-liquidity).

[11] Since in practice it is very unlikely that CAMEL indicators for any particular bank will have zero values, it is reasonable to take the difference of the individual variables X_{ijt} from their total sample means before doing the estimations. In this case, the slope coefficient vector β will remain unaffected, but the intercept parameter α will be possible to interpret as a baseline hazard. More specifically, the intercept would indicate the probability of distress for a bank characterized by average CAMEL profile.

class of generalized linear mixed effect models. [12]

In general, the variation of the intercept at the state-level can be modelled as a function of a vector of state-specific covariates Z_j, in which case the model is extended to:

$$\log\left[\frac{P(Y_{ijt}=1|X_{ijt})}{1-P(Y_{ijt}=1|X_{ijt})}\right] = \alpha_j + \beta X_{ijt} \qquad (4)$$
$$\alpha_j = \alpha + \lambda Z_j + u_j$$

In this specification, the impact of state-specific factors Z_j can be interpreted as systematic shocks 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 (4). 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.

3.3 Data and model specification

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 The first is the Bundesbank internal database, which contain information about balance sheets, income statements, credit register (*'Kreditnehmerstatistik'*), and audit reports for all German banks in the 1994-2005 period. To specify financial covariates X_{ijt} to predict bank distress we follow the convention of the bank hazard literature and thus select proxies for banks' capitalization, asset quality, management skills, earnings, and liquidity (CAMEL) that allow the prediction of bank probabilities of distress. 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). [13] We generate a list of around 150 potential CAMEL covariate candidates. Based

[12] These are called mixed effects models, because they contain both fixed (β) and random (α_j) effects.

[13] See Kick and Koetter (2007) for a recent application of this approach to the German banks.

on the individual explanatory power a set of around 50 covariates is then selected. A stepwise logistic regression is used to further reduce covariates within each CAMEL category. The stepwise regression results paired with economic significance yield the final vector of the CAMEL covariates, for which table 2 depicts descriptive statistics and t-tests on the significance of differences between distressed and non-distressed banks.

Table 2
Mean values for CAMEL covariates

		Distress			
CAMEL covariate		**No**	**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.		24524	1554	26078	

Note: All variables are in percentage terms. Universal banks: 3,496. Specialized banks: 75. Observations: 26,078.*,**,*** indicate significantly different t-test at the 1%, 5%, and 10% level.

The resulting sample is an unbalanced panel comprising 3496 universal and 75 specialized German banks for the 1995-2004 period, which contains 26,078 observations. 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. Following a common approach employed in the previous literature, the management quality variable is approximated by the level of bank-specific cost efficiency obtained using stochastic frontier analysis (SFA). 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. This approach remains agnostic as to which 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

Table 3
Number of distress events across German states

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total	Per bank
Baden-Wurttemberg	19	34	20	31	38	21	20	20	10	8	221	0.33
Bavaria	19	47	38	41	42	32	27	25	29	22	322	0.39
Berlin	4	5	6	3	2	1	3	1	1	1	27	1.23
Bremen	2	2	2	2	1	0	2	1	1	0	13	0.81
Hamburg	6	5	4	5	1	0	2	2	1	0	26	0.65
Hesse	12	11	17	23	21	15	13	15	10	6	143	0.38
Lower Saxony	10	10	15	9	12	9	12	8	11	6	102	0.28
North Rhine Westph.	14	14	19	26	23	29	54	58	48	32	317	0.57
Rhineland-Palatinate	8	4	6	11	3	11	10	14	14	8	89	0.41
Saarland	1	0	4	2	2	2	5	3	2	2	23	0.46
Schleswig-Holstein	2	4	11	7	4	3	12	14	11	6	74	0.61
M. W. Pomerania	2	1	3	6	2	1	3	4	3	4	29	0.67
Brandenburg	1	4	8	4	3	1	1	1	0	2	25	0.54
Saxony	5	2	5	9	8	2	0	3	1	0	35	0.56
Thuringia	6	5	11	11	6	9	10	6	6	2	72	1.24
Saxony-Anhalt	5	8	12	16	12	9	11	8	11	7	99	1.21
Total	116	156	181	206	180	145	185	183	159	106	1617	0.45

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 probabilities of distress. In contrast to most failure studies, we are able to draw on data assembled by the Bundesbank recording distressed events among German universal and specialized banks in the 1995-2004 period. 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. Since we are in particular interested in accounting for the regional disparity of both bank riskiness and spatial differences in real estate markets, we allocate banks to regions as outlined above and depict the number of distressed events in table 3 below.

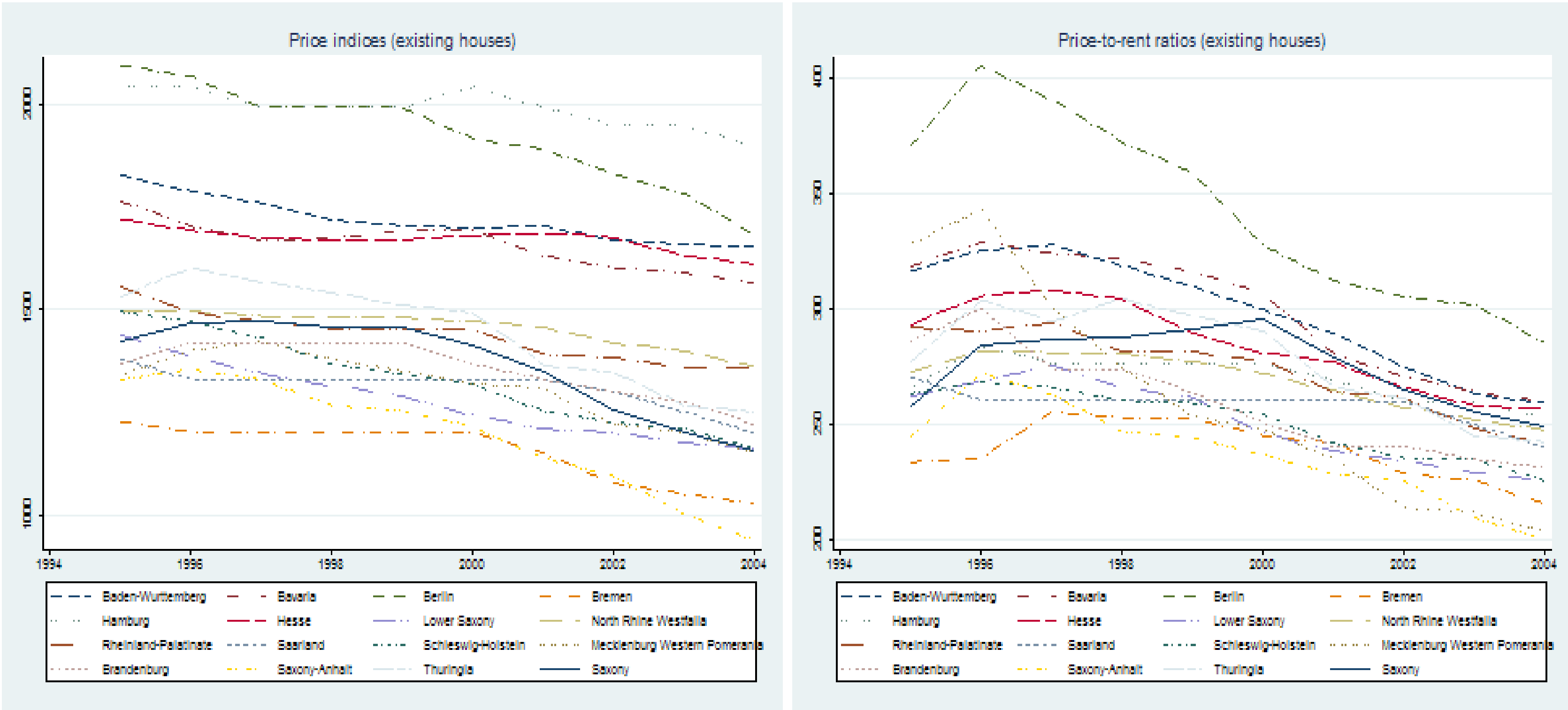
Table 3 highlights that the regional dispersion is an important aspect that must not be discarded neither regarding real estate price developments nor regarding distressed events. We suspect that a considerable part of bank PDs is attributable to region-specific effects, which the bank can hardly influence 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 Eastern states.

Real estate Real estate prices and rents are obtained from the Bulwien AG. The data contain annual information on housing prices and rents for 125 German cities for the 1995-2004 period. We use city-level information on existing house prices and rents to generate aggregate state-level indices. [14] ANOVA estimations 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 (see Appendix). The evolution of the state-level price and rent indices is present in Figure 3.

In most of the states we observe declining house prices, which is also confirmed by our ANOVA analysis. However, the speed of the decline varies across states and shows different dynamics over time. A similar picture emerges from the descriptive statistics for price-to-rent ratios, which is our measure of discrepancy between housing prices and the underlying fundamentals.

[14] The dataset also contains information on new house prices and rents, which we utilize to check the robustness of our estimation results.

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



4 Results

4.1 Specification

The structural form of our general multilevel mixed-effect logistic model is given by:

$$\log\left[\frac{P}{1-P}\right] = \alpha_j + \beta X_{ijt-1} + \delta TIME + \eta BGR \quad (5)$$
$$\alpha_j = \alpha + \lambda_1 HP_{jt-1} + \lambda_2 HPR_{jt-1} +$$
$$+ \lambda_3 HP_{jt-1}SH + \lambda_4 HPR_{jt-1}SH + u_j$$

where P is the probability of distress at the individual bank level, X is the vector of CAMEL covariates, $TIME$ and BGR are time and banking group dummies, 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, respectively. The reduced form equation is:

$$\log\left[\frac{P}{1-P}\right] = \alpha + \beta X_{ijt-1} + \delta TIME + \eta BGR + \quad (6)$$
$$+ \lambda_1 HP_{jt-1} + \lambda_2 HPR_{jt-1} +$$
$$+ \lambda_3 HP_{jt-1}SH + \lambda_4 HPR_{jt-1}SH + u_j$$

Specification (6) allows 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 their deviation from fundamentals, respectively, on bank PD. Second, specification of the random state effect u_j and its variance σ_u^2 allows a comparison to traditionally used simple logit specifications and hence the relevance to account for state-specific influences on bank risk. Third, interaction terms with the measure of bank 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 their deviations from fundamentals on the riskiness of banks (logarithm of odds ratio) as a result of an increase in their exposure to the real estate loans market by a percentage point.

Having obtained the final set of CAMEL covariates, 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 log-likelihood ratio tests and Akaike information criterion.

Table 4
Multilevel mixed-effect logit model specifications

	Model0	Model1	Model2	Model3	Model4
State effect u_j	x	x	x	x	x
HP		x		x	x
HPR			x	x	x
HP*SH					x
HPR*SH					x
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
Model4	–	–	–	–	–

Note: All estimations on 22,429 observations including all CAMEL covariates as well as time and banking group specific effects. x 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 4 displays model specifications and specification 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 modelling 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 the housing prices alone in Model 1 does not improve the model fit as indicated by the likelihood ratio test. In contrast, the specification of price-to-rent ratios in Model 2 is supported on grounds of both the likelihood ratio test and the information criterion (AIC). While the 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 likelihood ratio 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 (6) 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 likelihood ratio 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 Estimation results

The multilevel mixed-effect logit estimation results for the reference specification Model 4 are displayed in Table 5. 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 our indicator of deviations from the fundamentals, the housing price-to-rent ratio. 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. Related to our third hypothesis on exposure, this impact is significantly more pronounced for banks largely involved into real estate lending (positive and significant λ_4). This finding provides empirical support for the 'disaster myopia' hypothesis advanced in Herring and Wachter (1999), according to which banks tend to underestimate real estate market risks. Deviations from the fundamentals in the housing market may induce bank clients to believe that favorable market conditions will continue in the future. This could foster speculative transactions. As a consequence of reversal tendencies in the housing market, the customers might become insolvent and unable to repay their loans extended for financial real estate purchases. This, in turn, can jeopardize the soundness of the individual banks. Larger bank exposures to real estate lending then imply that banks become more vulnerable to sudden price reversals.

Table 5
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	-0.04668*	-0.04634*	-0.05407**	-0.06396**	-0.04885*
Equity ratio (c_2)	β_2	-0.2464***	-0.2489***	-0.2765***	-0.2951***	-0.2463***
Risky loans (a_1)	β_3	0.02139***	0.02135***	0.02172***	0.02175***	0.02171***
OBS activities (a_2)	β_4	0.00853***	0.0086***	0.00814***	0.00912***	0.00882***
Customer loans (a_3)	β_5	0.01802***	0.01791***	0.01794***	0.01713***	0.01808***
Cost efficiency (m_1)	β_6	-0.01881***	-0.01858***	-0.01853***	-0.02109***	-0.01858***
Return on assets (e_1)	β_7	-0.05002***	-0.05013***	-0.04964***	-0.05161***	-0.04991***
Liquidity (l_1)	β_8	0.02095***	0.02066***	0.02041***	0.02633***	0.02092***
Commercial (BGR_1)	η_1	0.2831*	0.2857*	0.2857*	-0.2026	0.2868*
Savings (BGR_2)	η_2	-1.168***	-1.169***	-1.198***	-1.301***	-1.178***
Specialized (BGR_3)	η_3	0.1561	0.1536		-0.3084	0.1855
Housing prices	λ_1	0.1103	0.1142	0.1422	-0.01687	0.00274
Housing price-to-rent ratio	λ_2	0.2615**	0.2574**	0.243**	0.329**	0.3055*
Housing prices*SH	λ_3	-0.00424***	-0.00416***	-0.0052***	-0.00275	-0.00411***
Housing price-to-rent ratio*SH	λ_4	0.00343***	0.00336***	0.0042***	0.0022	0.00358***
GDP					0.00571	
Intercept	α	-14.92***	-14.89***	-15.21***	-13.75***	-13.4***
Random state-level variance	σ_u^2	0.5377***	0.5357***	0.5408***	0.4902***	0.5729***
Observations		22,419	22,393	22,253	19,058	22,419
Log-likelihood		-4,366	-4,355	-4,287	-3,777	-4,369

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

Consider next the impact of the housing price levels on bank PDs. We find no significant impact of housing prices per se on the PD of banks that are not heavily involved in real estate lending (insignificant λ_1); however, the impact is significantly negative for banks extending large parts 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. Intuitively, this finding provides empirical support for the '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, is significant at the one percent level.[15] The significant variation of the state-specific random part in the overall intercept, denoted by σ_u^2, supports the hypothesis that location matters for bank distress even after accounting explicitly for real estate price developments.

4.3 Robustness check

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 5, the qualitative results of the preferred specification (Model 4) regarding the impact of housing prices 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 differences only by means of according banking group dummies might be too restrictive,

[15] In a nutshell, the significance of the baseline hazard implies that a representative German bank characterized by average CAMEL profile is significantly exposed to distress with a certain probability.

especially when considering specialized mortgage banks. Their primary business is real estate lending; thus, they might be more experienced in hedging against housing market risks. Ideally, we would fit the bank PD model solely for banks belonging to this banking group. However, this is infeasible due to very low number of distress events in this banking group paired with the generally small group size. Also, we showed in Table 1 that 71 out of 75 specialized banks are situated in the Western states, which implies that geographical coverage of specialized banks is not encompassing. For these reasons, we exclude specialized banks from the sample as another robustness check. 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.

Furthermore, as we mentioned earlier, 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 the real GDP growth rate (Nuxoll, 2003). Economic growth can affect bank stability either directly (aggregate income, demand for new loans), or indirectly (impact on housing prices). The estimation results suggest that real per capita GDP growth does not have significant explanatory power. [16] However, its inclusion eliminates the significance of the bank exposure to the housing market on its riskiness. The impact of deviations from the fundamentals is still positive and significant, supporting the robustness of this result.

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 vulnerability of our results regarding the type of the housing market considered, we re-estimate the model by using 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. This is likely to be explained by the similar trends observed for housing prices in both markets.

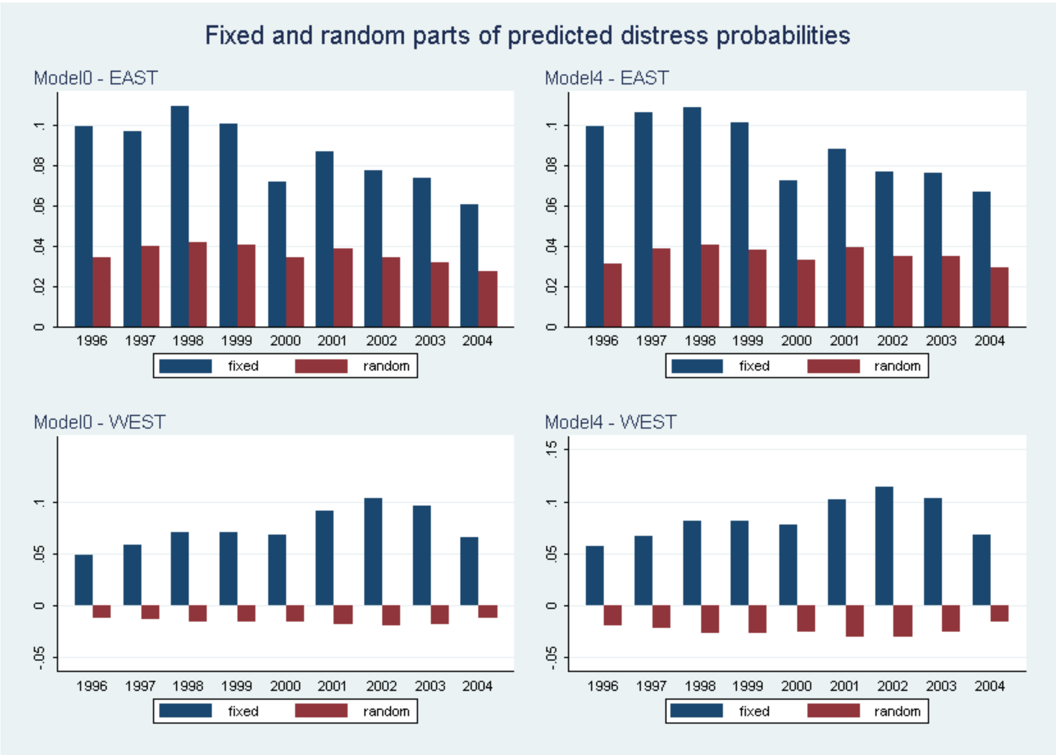
4.4 Predicted probabilities of distress (PD)

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

[16] This finding is in line with Nuxoll (2003), who finds that regional macroeconomic variables are not significant in explaining financial distress in the U.S. banks.

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 mainly 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 4 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 (West vs. East Germany).

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



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. Furthermore, and most importantly, the impact of state-specific heterogeneity is uniformly positive in the East and negative in the West. Moreover, its impact is more than two times larger in the East. This finding is valid also for other specifications (not presented to conserve space) and implies that banks located in the

East 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.

One caveat with interpreting this finding is related to the fact that some of the credit extended by banks to the Eastern states comes from the West. For instance, as shown in Table 1, only four out of 71 specialized mortgage banks are located in the East, which means that it is likely that a significant part of housing credit extended to the Eastern states is recorded in the books of the Western banks. However, another important source for real estate financing in the East 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. However, we caution that we are ultimately unable to trace the particular region to which bank loans are extended with certainty and thus some caution is appropriate when drawing inference on these results.

5 Conclusion

This paper builds on the theoretical work relating individual bank stability to the developments in the real estate market. We provide empirical evidence on this relationship using German data on real estate prices 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 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.

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

Second, housing price levels per se have only a limited impact on bank distress. Instead, price-to-rent ratios, indicating deviations from the fundamentals, 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. Potentially, the positive relationship between price-to-rent ratios and bank distress might be even stronger in countries that have experienced booms and busts in housing prices, for instance the U.S., the UK, or Spain.

Third, the exposure of a bank to the real estate market has implications for its vulnerability to housing price developments. After controlling for banking group membership (universal versus specialized), declining nominal housing price levels increase bank PDs only for those banks that are intensively exposed to this line of business, potentially due to the effects of deteriorating collateral value. In contrast, positive deviations from housing price fundamentals implied by increasing price-to-rent ratios render all banks more vulnerable to distress, albeit specialized banks are affected significantly stronger.

Finally, 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. Notably, the impact of state-specific factors on the bank PD is uniformly positive for the Eastern states, which are characterized by worse economic conditions. Hence, an economically significant part of bank PDs appears to depend on factors outside the direct realm of managerial influence, namely location.

Appendix

Estimation of cost efficiency using latent class approach

We use stochastic frontier analysis (SFA) to estimate cost functions and associated inefficiency (CE) (Berger and Mester, 2003). In line with the intermediation approach (Sealey and Lindley, 1977), banks k demand inputs x at prices w. We also account for the role of equity z as an alternative to finance outputs (Hughes and Mester, 1993). In contrast to virtually all empirical banking 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. In addition, deviations from optimal cost can be due to either random noise or suboptimal use of inputs. One possibility is to estimate group-specific frontiers separately (Mester, 1993). But this approach requires to allocate banks a priori to groups, which is ultimately arbitrary. Instead, we estimate latent production technologies of banks simultaneously. To this end, we follow Greene (2005) and specify a latent class frontier model as:

$$TOC_{kt} = \alpha + \beta_j' x_{kt} + \epsilon_{kt|j}, \tag{7}$$

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:

$$P_{kt|j} = f(TOC_{kt}|\beta_j', x_{kt}, \sigma_j, \lambda_j). \tag{8}$$

Greene (2005) demonstrates that a convenient parameterizations to estimate bank-specific probabilities of group belonging is the multinomial logit model. We denote the latter as:

$$\Pi(k, j) = \frac{exp(\pi_j' z_k)}{\sum_{m=1}^{J} exp(\pi_m' z_k)} \quad , \quad \text{for } \pi_J = 0, \tag{9}$$

where $j = J$ is the last group serving as the reference group, and z_k are bank-specific determinants of group membership. The conditional likelihood averaged over classes for bank k can then be written as:

$$\begin{aligned} P_k &= \sum_{j=1}^{J} \frac{exp(\pi_j z\prime)}{\sum\limits_{m=1}^{J} exp(\pi_m z\prime)} \prod_{t=1}^{T} P_{kt|j} \\ &= \sum_{j=1}^{J} \Pi(k,j) \prod_{t=1}^{T} P_{kt|j} \\ &= \sum_{j=1}^{J} \Pi(k,j) P_{k|j}. \end{aligned} \tag{10}$$

Parameters for equations (7) and (8) 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. We condition group membership on both a specialization dummy based on the taxonomy of the Bundesbank and the share of mortgage loans. Descriptive statistics for the specified cost function variables are provided in table 6.

Table 6
Descriptive statistics of variables used in latent class model

Variable		**Mean**	**SD**	**Min**	**Max**
Customer loans	Y_1	466.7	4,923.4	0.001	219,000
Interbank loans	Y_2	1,000.3	8,120.5	0.025	457,000
Securities	Y_3	446.6	4,502.6	0.003	297,000
Off balance	Y_4	247.0	3,322.7	0.000	141,000
Price of fixed assets	W_1	22.7	481.5	0.219	73,847
Price of labor	W_2	52.3	151.8	0.377	20,693
Funding cost	W_3	3.6	2.9	0.273	507
Equity	Z	67.4	546.6	0.175	21,600
Cost	TOC	104.0	846.5	0.144	40,500

Notes: 33,903 observations for period 1993-2005.

Thereby, we obtain for each bank an estimate of it's respective peer group membership as well as related efficiency measures without imposing any a priori grouping. The simultaneous estimation of latent parameters in our model curbs the comparison problem inherent in studies that relate efficiency measures derived from different frontiers to each other (Coelli, 1998).

ANOVA analysis of housing prices

In this appendix we present the decomposition of housing price changes in Germany into two different levels: city and state. The objective is to evaluate the importance of housing price variation across different hierarchical levels by means of the explained variation. 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.[17] City level variation of housing prices exists only within 13 out of 16 German states. The remaining three (city-) states (Berlin, Hamburg and Saarland) are represented by a single price index only. The structural form of the multilevel model is given by:

$$\begin{aligned} \Delta \log HP_{ijt} &= \gamma_{0ij} + \varepsilon_{ijt} \\ \gamma_{0ij} &= \gamma_{00j} + \upsilon_{0ij} \\ \gamma_{00j} &= \gamma_{000} + \zeta_{0j} \end{aligned} \tag{11}$$

where HP_{ijt} is the housing 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. Specification (11) assumes that average changes in price indices vary across cities and states, as it is indicated by the indices attached to the intercept γ. The reduced form of equations (11) takes the following form:[18]

$$\Delta \log HP_{ijt} = \gamma_{000} + \zeta_{0j} + \upsilon_{0ij} + \varepsilon_{ijt} \tag{12}$$

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

[17] The Bundesbank uses this data to estimate a housing price index for whole Germany.

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

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

where E is the expectation operator. The parameter ρ_i is referred to as the intraclass correlation on the city level. Intuitively, this coefficient shows the expected level of correlation of log price differences between two randomly selected cities belonging to the same state. The larger the intraclass correlation, 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 (12) using mixed effect linear regression methods are summarized in Table 7. First of all, we find that German housing prices on average had a declining pattern, as highlighted by the significant negative intercept coefficient. Next, 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% on the state level, which can be interpreted as the expected correlation between two randomly chosen price indices within the same state. The city-level intraclass correlation is zero, which implies that the city-level variation over the state averages does not contribute to the total variation.

Table 7
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		

The ANOVA estimations show that the city-level variation within states is negligible compared to the state-level variation. Thus, aggregation of housing price indices to the state-level would not result in a substantial loss of information.

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