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## Market Timing, Maturity Mismatch, and Risk Management: Evidence from the Banking Industry

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# Market Timing, Maturity Mismatch, and Risk Management: Evidence from the Banking Industry\*

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# Market Timing, Maturity Mismatch, and Risk Management: Evidence from the Banking Industry

## **Abstract**

We investigate financial intermediaries' interest rate risk management as the simultaneous decision of on-balance-sheet exposure and interest rate swap use. Our findings show that both decisions are substitute risk management strategies. Hausman exogeneity tests indicate that both decisions are only endogenous to one another for banks that start using swaps for the first time. For other banks, the maturity gap is exogenous to the decision to use swaps, but the reverse relationship is endogenous. For banks with trading activity, both decisions are exogenous to one another. We interpret these findings as the maturity gap being largely determined by customer liquidity needs, whereas the decision to use swaps relies on compliance with the interest rate risk regulation. Although hedging motives dominate, we find selective hedging behavior in swap use driven by the slope of the yield curve as well as by funding uncertainty.

**Keywords:** Duration gap; Interest rate swaps; Selective hedging

**JEL classification:** G21; G32; G33

# 1 Introduction

Through their function as qualitative asset transformers, financial intermediaries are exposed to non-diversifiable risks, specifically liquidity and interest rate risk. Financial intermediation theory has derived models that explain the management and allocation of these risks. Among the seminal studies explicitly related to interest rate risk (IRR), Diamond (1984) stresses that banks should focus on managing credit risk for which they possess a monitoring advantage, and hedge all IRR. Hellwig (1994) suggests that banks allocate IRR to their depositors by offering contracts that do not necessarily repay deposits at par, thereby focusing on the liquidity risk of deposit withdrawal. Froot and Stein (1998) propose that banks hedge all risks that can be sold to the capital market at fair conditions, especially interest rate and currency risks.

However, although empirical evidence shows that banks manage IRR, almost no bank will hedge its IRR exposure completely. A large fraction of smaller banks, in particular, can be observed that do not use any off-balance-sheet (OBS) IRR derivatives. The most obvious reason for banks to keep IRR on the balance sheet instead of hedging it — for example, by using interest rate swaps — is the profitability of maturity or term transformation, which we will use interchangeably. A steep normally shaped yield curve increases profits when a bank operates with a positive maturity mismatch, i.e. its assets have longer maturities and reprice less frequently than its liabilities.<sup>1</sup> However, these profits are associated with the risk that a rise in the yield curve, especially at the lower maturity rates, may generate losses as in the savings and loan (S&L) crisis. Moreover, the close alignment of interest and liquidity risk through the maturity mismatch can threaten banks' existence when they rely too heavily on short-term wholesale funding, as the 2007-2008 financial crisis showed quite plainly. If banks hedge in response

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<sup>1</sup>Memmel (2011) estimates the income from term transformation generated by German savings and cooperative banks over the business cycle to be around 30 basis points annually, which is a significant share of their overall interest income.

to their managers' views on macroeconomic determinants, such as the yield curve or funding liquidity, these banks would engage in selective hedging as a mild form of speculation (Stulz, 1996).

Therefore, the question arises as to what determines banks' IRR management decisions? To answer this question, we investigate German commercial banks' IRR management between 2000-2011 by simultaneously estimating their maturity mismatch and interest rate swap activities. Our empirical approach combines the simultaneous risk management framework of Purnanandam (2007) with the cross-sectional and time-series regression models of Chernenko and Faulkender (2011) to distinguish the use of interest rate swaps for hedging and speculative purposes in panel data. We find that on-balance-sheet IRR management and the use of interest rate swaps are substitutes for one another in pursuit of the goal of keeping the overall IRR exposure below regulatory thresholds. We also give evidence of hedging theories which predict that the cost of bankruptcy makes firms pursue more conservative risk management. Selective market timing behavior is observed for the maturity mismatch, the decision to use interest rate swaps and the extent of their use with regard to the slope of the yield curve and interbank funding uncertainty. The profitability of a steep yield curve induces commercial banks to simultaneously increase their duration gap and to hold fewer interest rate swaps for hedging purposes, while the opposite holds for increasing funding uncertainty.

One central determinant of the decision to manage risk on the balance sheet or off it is the financial environment in which a bank operates. Allen and Santomero (2001) stress that banks' risk management techniques will differ between market-based and bank-based financial systems as a result of the degree of competition financial intermediaries face from financial markets. In bank-based economies, like Germany, financial intermediaries apply intertemporal smoothing of non-diversifiable risks through the accumulation of liquid reserves. In market-based economies,

households will withdraw their funds when banks build up liquidity reserves. Financial intermediaries need different, cross-sectional risk management strategies to shield themselves and households' portfolios against the aforementioned risks (Allen and Gale, 1997). Increasingly popular cross-sectional risk sharing encompasses derivatives hedging. Our study adds to the literature by investigating if there do exist differences between the market-based German sample and the U.S. commercial bank sample Purnanandam examined.

We test the exogeneity assumptions underlying the simultaneous equations framework using Hausman-type tests. These tests give evidence that, for banks with a trading book, both the maturity gap and the decision to use interest rate swaps are exogenous to one another. For banks without a trading book, the decision to hedge is exogenous to the maturity gap, but the reverse relationship is endogenous. Only in samples of banks that use interest rate swaps for the first time are these variables both endogenous to one another. On the other hand, the maturity gap is always an endogenous driver of the extent of banks' swap holdings. These results seem to reflect the impact IRR regulation has on bank behavior. Banks with too high an IRR exposure after netting out the OBS effects are considered "outlier" banks that can expect supervisory scrutiny and even additional capital charges. Hence, once the on-balance-sheet IRR exposure becomes too large, a bank has to look for ways to decrease the overall exposure and will likely do so using interest rate swaps. Only in these circumstances, the maturity gap and the decision to hedge are endogenous to one another. Before a bank reaches the critical threshold for on-balance-sheet exposure or once it has set up a derivative risk management department, the decision to use interest rate swaps is endogenous. As banks that have a comparatively large duration gap are those that decide to use interest rate swaps, the duration gap is an endogenous driver of the volume of swaps held. This implies that banks manage their overall exposure to comply with the IRR regulation, whereas the maturity gap is determined by the liquidity needs

of bank-dependent borrowers and depositors.

The paper proceeds as follows. Section 2 gives an overview of the literature on IRR management as well as selective hedging and speculation of IRR. Section 3 describes the empirical research strategy and puts emphasis on the instruments used to identify the system of equations in the IRR framework. Data and summary statistics are presented in Section 4, before we proceed with the empirical analysis. Section 5 introduces the hazard rate model which is estimated in order to derive proxies for the cost of default in the risk management analysis. Section 6 presents the results for the simultaneous equations of the IRR management decisions, i.e. the on-balance-sheet exposure measured as the duration gap, the decision to use swaps and the extent of interest rate swap use. Whenever possible, regressions are run both cross-sectional and based on time-series estimators. The paper ends with concluding remarks in Section 7.

## **2 Interest Rate Risk Management, Selective Hedging and Speculation**

In spite of banks' importance as suppliers of external capital and the IRR related to their activities, the literature on banks' IRR management is relatively scarce, whereas the majority of risk management literature focuses on corporate hedging decisions, mainly commodity price hedging. Among the few exemptions, Schrand and Unal (1998) examine thrifts' overall risk management and find — in line with the models of Diamond (1984) and Froot and Stein (1998) — a shift from interest rate risk towards credit risk following thrift conversion. These authors suggest that risk management is a mean of allocating risks from homogeneous risk sources, such as IRR, to core-business risks, where the bank possesses a comparative information advantage.

A central motive of hedging is the reduction of cash flow variability and consequently bankruptcy risk. Froot et al. (1993) endogenize the cost of financial distress by assuming exter-

nal capital to be more expensive than internally generated funds. In support of these models, Brewer et al. (1996) show that hedging IRR reduces the cost of uninsured debt, i.e. rates paid on commercial paper issued by thrifts. Purnanandam (2007) simultaneously investigates the use of derivatives for hedging purposes and on-balance-sheet IRR management of the duration gap for U.S. commercial banks. He finds that banks intensify IRR management in response to increasing default risk. Additionally, the use of interest rate derivatives makes banks less vulnerable to monetary shocks and allows them to change the composition of their portfolios less drastically. Memmel and Schertler (2011) show for the same sample of German commercial banks we also investigate that net interest income is more heavily affected by changes in the yield curve than by changes in the composition of asset and liability portfolios. Banks that use IRR derivatives are less vulnerable to interest rate shocks, and hence derivatives are mainly employed for hedging purposes. However, when the yield curve steepens derivative users increase their maturity mismatch more significantly.

Bolton et al. (2013) present a dynamic risk management model where bankruptcy risk increases the risk of not having sufficient funds for value-adding investment projects, thus increasing the incentives to hedge. However, for financially constrained firms it is optimal not to hedge as margin requirements override cash flow volatility concerns. Moreover, their model shows that *market timing* behavior can be rational in terms of ensuring sufficient funding sources.<sup>2</sup>

*Market timing* of risk management activities has received increasing attention in financial research. Stulz (1996) defines *selective hedging* as managers incorporating market views into the timing of risk management activities, and considers this a mild form of *speculation*. Empirical and survey evidence from non-financial firms suggests that timing derivatives markets is done quite frequently. Such strategies should, however, result in permanent additional profits only if

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<sup>2</sup>The model of Bolton et al. (2013), however, incorporates equity market timing through the issuance of new shares, and not debt market or derivatives market timing.



managers have an information advantage, but sum up to zero if not.

The main drivers of selective IRR risk management when entering into new debt contracts or interest rate derivatives are the level and, especially, the slope of the yield curve. Faulkender (2005) finds that firms alter the IRR exposure of new debt issues from fixed to floating by jointly entering into interest rate swaps when the yield curve is steep. Vickery (2008) confirms these results for small bank-dependent firms that choose between fixed-rate and variable-rate loans. Credit constrained firms, however, are more likely to choose fixed-rate interest *per se*. Recently, Mian and Santos (2012) have found evidence of active maturity management driven by liquidity considerations. Credit-worthy firms tend to renegotiate and extend loan maturity early during periods of good financial conditions. The behavior of bank-dependent borrowers should have a directly observable effect on banks' balance sheets and might trigger changes in their OBS risk management. Besides selective hedging, corporate use of interest rate derivatives also reveals *speculation* on interest movements. Géczy et al. (2007) and Chernenko and Faulkender (2011) find evidence that financially unconstrained firms incorporate market views into their derivatives positions and use interest rate swaps, at least partly, for speculative purposes, too.

### 3 Research Design

#### 3.1 Regressions and Variables

Following Purnanandam (2007), we estimate both the maturity mismatch and the swap use decision simultaneously in a system of equations. In line with most of the risk management literature, we estimate a Cragg (1971) model and separate the decision to hedge from the extent of derivative use (e.g., Purnanandam, 2007; Zhu, 2012). The decision to hedge corresponds to a dummy variable that takes the value of 1 if a given bank reports a non-zero volume of interest rate swaps outstanding. The degree of hedging is modeled as the natural logarithm of the

nominal volume of interest rate swaps outstanding to total assets. To control for the potential sample selection bias arising from taking the logarithm of the nominal swap volume, we include the inverse Mills ratio. The modified duration gap is modeled using information available to the banking supervisors on different brackets of remaining time to maturity for classes of assets and liabilities and the interest rate sensitivities from the standard approach for IRR regulation of the German banking supervisory authority BaFin. See Appendix B, for more details of the modified duration gap.

We exploit both the cross-sectional and the time-series variation in panel data ranging from 2000-2011. Cross-sectional variation in linear models is captured applying both between effects and Fama-MacBeth estimators. The results are then compared with pooled OLS models to evaluate the impact of potential bias. Time-series variation is investigated applying the within transformation of a fixed effects estimator. Just for models of the decision to use swaps, we apply pooled probit regressions only in order not to lose observations on banks that never hedge or, alternatively, hedge during the whole sample period.

The use of cross-sectional as well as time-series estimators for IRR management decisions, such as the on-balance-sheet exposure and the extent of interest rate swap, is related to the empirical approach of Chernenko and Faulkender (2011) who examine non-financial firms' interest rate swap use. One of the key elements of interpreting the coefficients is that these firms are assumed to have a constant exposure to IRR over time. When firms manage towards a target fixed-to-floating IRR exposure, average hedge ratios should be explained by between effects and Fama-MacBeth models. In contrast, deviations from a target hedge ratio over time can be regarded as market views on IRR drivers incorporated into the hedging decision. Such market timing is then captured by fixed effects estimators.

Although the assumption of a constant IRR exposure over time is doubtful for banks, there

is nevertheless evidence that banks focusing on providing financial intermediation services to local market retail customers have a comparably stable on-balance-sheet exposure. In Germany, especially the smaller savings and cooperative banks have stable, homogeneous business models with a focus on granting loans and accepting deposits. Assuming that a bank's on-balance-sheet maturity structure remains stable through replacement of maturing assets and liabilities with new business of the same initial maturity, Memmel (2008) and Entrop et al. (2012) prove that the majority of German banks' interest income and expenses can be explained, and thus the authors give support to the empirical validity of the assumptions underlying the estimators.

<sup>3</sup> The results of Memmel and Schertler (2011) give further support that the on-balance-sheet exposure is comparatively stable among German banks.

These small commercial banks are also more likely not to engage in trading activities, and fee income is a less important source of profitability. Most of them only have a banking book and no trading book. Pure banking book institutions are not only more likely to have a stable on-balance-sheet exposure but are also prohibited from using OBS interest rate instruments for speculation purposes to a substantial extent.<sup>4</sup>

In analyzing only pure banking book institutions, we thus have a similar setting to Chernenko and Faulkender (2011). In order to examine the whole German banking sector, we run regressions for the total sample, which consists of around 90% non-banking book institutions, and on the sub-sample of trading book banks. The latter not only have more exposure to market risk, they may also use interest rate swaps for speculation which goes beyond the market timing of risk management activities. Empirically, trading revenues are often found to be the riskier source

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<sup>3</sup>A very simplified approach using revolving portfolios is even able to capture the general time-series dynamics of German banks' overall interest exposure, after netting on- and off-balance-sheet positions (Mommel, 2011).

<sup>4</sup>The German Banking Act (*KWG*) defines banks as trading book institutions when they have on average (in a single year) either trading activities of more than 5% (6%) in relation to both total assets and off-balance-sheet activities, or of more than €15 (20) million in absolute terms. These volumes are minor compared to the total assets of commercial banks in Germany, even of the small cooperative banks. See Table 2 for details.

of income (e.g., Stiroh, 2004) and establishing a trading book might result in risk shifting from traditional relationship banking to trading (Boot and Ratnovski, 2012).

In our empirical study, we investigate the impact of on-balance-sheet IRR, captured in the modified duration gap, on the decision to use interest rate swaps and vice versa, and therefore estimate our model as a system of three simultaneous equations. The third equation analyzes the extent of swap use and includes the duration gap as an explanatory variable. Our bank-specific explanatory variables are consistent with those used in the study by Purnanandam (2007). As corporate risk management theory stresses the importance of the cost of bankruptcy for risk taking, hedging and speculation behavior, we include the natural logarithm of the *Probability of default* (PD) derived from a hazard rate model to proxy for this determinant. *Size*, measured as the logarithm of total assets, is included to proxy for economies of scale in setting up a derivatives department. Larger banks are more likely to have a risk management department that is proficient enough to deal with derivatives. At the same time, larger banks are also more likely to have other income sources apart from interest income and might, as a result, not depend to the same extent on income from term transformation. Based on Froot et al. (1993) banks with more investment opportunities should be more likely to decrease IRR, both on balance sheet and off balance sheet. Investment opportunities are proxied in line with the banking literature (e.g., Froot and Stein, 1998) as the (annual) *Total asset growth* rate. As current risk management literature stresses the importance of liquidity management considerations, we include two measures which capture liquidity on the asset and liability side, *Liquid assets*, the sum of cash reserves and securities which can be sold within one year, and the ratio of *Savings deposits* to total assets as a measure of funding strength.

In addition to Purnanandam, we include a *Branch HHI*, a Herfindahl (-Hirschman) index of branch concentration at the county level, as a measure of bank competition. Most of the

savings banks and cooperative banks, and, therefore, the majority of banks in our sample, are limited to running branches in their municipality, which is referred to as the regional principle. We therefore consider the county level the relevant market to measure banking concentration, although merger activity has now created some savings banks and cooperative banks with a territory exceeding a single county and even though private banks were never limited to the regional principle. The model derived by Adam et al. (2007) predicts that competition has a direct impact on the decision to hedge risks in equilibrium. Furthermore, competition may have an effect on the maturity mismatch choice via its nexus with risk taking. When we investigate the total sample, we also include a dummy that takes the value of 1 for banks with a *trading book*, and we include banking group dummies (savings, cooperative and private commercial banks) to control for different business models in the cross-sectional settings. Time-series models of the maturity gap and the extent of interest rate swap use as well as the pooled probit models of the decision to use interest rate swaps also include macroeconomic variables to test for market timing behavior in IRR management. These include the slope of the yield curve (e.g., Faulkender, 2005; Vickery, 2008) and a variable we refer to as *LIBOR spread*, the difference between the 12-month LIBOR and the German government bond yield. The latter is intended to capture the effects of the TED spread used in U.S. banking studies and proxies for interbank funding uncertainty. We also interact both of the aforementioned macroeconomic variables with the 1-year government bond yield to analyze differing effects of banks' risk taking behavior in response to the monetary environment (Borio and Zhu, 2012).<sup>5</sup>

When analyzing banks' internally calculated overall IRR exposure after netting on and off-balance-sheet exposures, Memmel (2011) finds that regulatory screening and time effects only explain a minor share in the variation of IRR exposure. The majority of variation is due to bank-

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<sup>5</sup>For an overview of the variables used in the empirical study, including those in the hazard rate model, see Appendix A.

specific, idiosyncratic effects. With our regression setting, we not only shed light on the drivers of these idiosyncratic effects, but also distinguish between their effects on on-balance-sheet and off-balance-sheet risk management.

### 3.2 Identification Strategy: Exclusion Restrictions

We expect the maturity mismatch and the decisions to use interest rate swaps and the extent of their use to be jointly determined as banks manage their overall IRR exposure. The strict exogeneity assumption of an OLS estimator is then violated and the derived coefficients are biased. A strategy to overcome this violation is an instrumental variable (IV) estimation. Valid IVs are only allowed to influence one of the two risk management decisions, either the on-balance-sheet or the off-balance-sheet decision, but not to have a direct impact on the other decision, which is referred to as the exclusion restriction. Having more than one IV for each endogenous variable, we can statistically test validity via an overidentification test. With strong as well as valid instruments at hand, we test the endogeneity assumed in the simultaneous equation framework, using a Durbin-Wu-Hausman type specification test (Hahn et al., 2011).

We will use the following instruments in the risk management equations. For the duration gap, we propose the use of the share of *Customer loans* in relation to total assets and *Loan commitments* to total assets. For the decision to use interest rate swaps and their extent we include *Past swap experience* as a dummy variable that is 1 when a bank has once used a swap, both interest and/or currency swaps, since 1998. We additionally use *Average board experience*, as the average experience of all board members in relevant executive management positions measured in years, as an instrument for the decision to use interest rate swaps but not for their extent. This allows us to correct for the sample selection bias by adding the inverse Mills ratio into the extent of interest rate swap regressions. Furthermore, we include an exogenous

instrument with regard to the risk management decisions in the estimation of the hazard rate model. Here, we choose *Hidden liabilities*, a dummy variable that takes the value of 1 when a bank avoids writing off assets by making use of an accounting option. Below, we justify the use of these specific IVs.

*Instruments to identify the probability of default:*

Risk management theory postulates that the cost of bankruptcy and the resulting financial constraints are an endogenous determinant of risk management decisions. Although the variables we use in the hazard rate model are not identical to those in the risk management analysis, many of the variables that explain a bank's default are also drivers of its risk management decisions. Hence, these variables do not qualify as IVs.

In order for the PD derived from the hazard rate model to be an exogenous determinant of the IRR management decisions, at least one explanatory variable must not have a direct influence on the magnitude of the duration gap, the decision to use swaps, and the extent of their use. We argue that avoiding write-offs on assets,<sup>6</sup> — creating so called *Hidden liabilities* — satisfies the exclusion restriction. This accounting option in the German GAAP — (the commercial code, *HGB*) — is often used as a form of “window dressing” for accounting statements by postponing realized losses into the future.

Biddle et al. (2012a) observe that accounting conservatism<sup>7</sup> reduces subsequent corporate bankruptcy risk through restricted earnings management and higher cash reserves. Moreover, Biddle et al. (2012b) find that accounting conservatism directly reduces distress likelihood by reducing operating cash flow downside risk, consistent with the theoretical model of Froot et al. (1993). It has an additional indirect effect through higher cash holdings. Distinguishing be-

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<sup>6</sup>Write-offs can be avoided by assigning and reclassifying certain kinds of securities to the banking book, where they are accounted for at historical cost instead of their lower market value.

<sup>7</sup>Accounting conservatism is considered to be a prudent reaction to risk and uncertainty and their adequate disclosure in accounting statements.

tween conditional and unconditional conservatism,<sup>8</sup> it is found that conditional accounting conservatism serves as a complementary strategy, whereas unconditional accounting conservatism serves as a substitute strategy for traditional risk management, such as cash management, operative and derivatives hedging. Avoiding hidden liabilities and thereby realizing losses on securities held in a more timely manner is a form of conservative accounting. After controlling for the indirect effect accounting conservatism has on cash holdings, by controlling for liquid assets in the risk management decisions, there should be no effect of hidden liabilities other than through operating cash flow downside risk which is captured in our measures of the distress likelihood.

*Instruments to identify the maturity gap equation:*

The maturity gap, especially for the small, savings and cooperative banks, is driven by the demand for long maturity liquidity on the asset side and the supply of short-term deposits on the liability side. In contrast, interbank loans are used by the smaller savings and cooperative banks to reduce the on-balance-sheet exposure (Ehrmann and Worms, 2004). Instrument validity is given when the *Customer loans* have no direct effect on interest rate swap use except through the (expected positive) effect on the magnitude on the maturity gap.

We argue further that *Loan commitments* have a direct impact on the maturity mismatch but not on interest rate swap usage. This argument seems counterintuitive as loan commitments are OBS activities and do not have a directly observable impact on the on-balance-sheet IRR. Moreover, if they were fixed-rate loan commitments their IRR could be hedged using futures or forwards.

Although we cannot distinguish fixed-rate from floating-rate loan commitments, we try to create a loan commitment proxy that is likely to only include floating-rate agreements. Our definition excludes long-term commitments for investment expenditures and real estate loans.

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<sup>8</sup>Unconditional conservatism is the effect of accounting principles per se. Conditional conservatism relates to more timely recognition of negative corporate outcomes.



Therefore, our definition contains household and corporate lines of credit that are more likely to be short-term and floating-rate agreements.<sup>9</sup>

The literature offers additional arguments why loan commitments that have not been drawn yet might, nevertheless, have a direct impact on banks' balance sheets. Kashyap et al. (2002) derive a model in which banks possess a natural hedge against liquidity risk via imperfectly correlated draw-down risk for loan commitments and withdrawal risk for deposits. Carrying out both lending and deposit activities offers banks synergies in using the buffer stock of liquid assets.

Berger et al. (2005) find that corporates that draw loans under commitment receive loans with no different maturity if they are high-risk firms. On the other hand, high-risk corporates that do not draw under commitment receive only loans with significantly lower maturity. Loan commitments, especially (revolving) lines of credit, are a means of acquiring soft information on borrowers out of relationship lending<sup>10</sup> and provide monitored liquidity insurance that prevents borrowers' illiquidity seeking (Acharya et al., 2012). Therefore, undrawn loan commitments can already have a direct effect on the existing maturity gap via the information collected from relationship lending and via intensified monitoring upon frequent renewal.

Thus, choosing a loan commitment proxy that is likely to be dominated by variable-rate agreements, liquidity is the prevailing risk in loan commitments. After controlling for asset and funding liquidity, loan commitments should not have any additional influence on either the decision to use swaps or the extent of their use; however they have a direct effect on the maturity mismatch through the close relationship between liquidity and interest rate risk.

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<sup>9</sup>Davydenko and Franks (2008) present summary statistics from major German commercial banks' defaulted corporate borrowers. They find that the majority of loans and credit lines are, indeed, short-term with maturities of less than one year and floating-rate. However, their sample might be biased to firms that were already financially constrained when they received their loans and overdrafts.

<sup>10</sup>See, for example, Berger and Udell (1995); Jiménez et al. (2009); Norden and Weber (2010), and specifically for German banks screening for bankruptcy risk, Davydenko and Franks (2008).

*Instruments to identify the swap use decision and the extent of their use equations:*

The *Past swap experience* dummy serves as a proxy for the existence of a derivatives risk management department or experience in handling interest rate derivatives. Chen (2011) uses a similar instrument; specifically, the past experience of fund managers as an IV for the current use of derivatives by the hedge funds they manage. Purnanandam (2007) uses a cross-sectional hedging experience dummy that takes the value of 1 if the bank holds derivatives for purposes other than IRR management during the same period. Unfortunately, in our sample too few banks use currency swaps to create IVs that pass the weak identification test.<sup>11</sup>

One potential concern with a dummy based on past hedging experience is that previous years' interest rate swap use predetermines contemporaneous use. This would be the case if a bank buys swaps with maturities of more than one year and holds them until maturity. We do not see a problem in using past swap use for the following reasons. First, about 10% of the banks in our sample that used swaps in an earlier year, do not do so the year after. Therefore, swap experience does not perfectly predict current swap use and some banks change frequently between years where they use swaps and years where they do not. Even if banks engage in swaps with maturities of more than one year, it is possible for them to close these positions. Second, Gorton and Rosen (1995) report that a substantial share of interest rate swaps held by banks have maturities of less than one year for reasons of regulatory capital charges on counterparty risk. Moreover, during the past decade, there has been a substantial increase in short-term maturity overnight index swaps (OIS) to hedge interbank rates. Current figures presented by Fleming et al. (2012) support these statements. Although 10-year and 30-year interest rate

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<sup>11</sup>We run robustness checks, not reported for brevity, that contain information on whether the bank uses any kind of derivatives to hedge or speculate on currency or market risk. Unfortunately, data is available only until 2008. The coefficients derived are very similar to those reported when employing the *Past swap experience* and overidentification tests are also insignificant for all samples investigated. However, the weak instrument statistics are significantly lower, and although they are still above the values suggested by Stock and Yogo (2005), the coefficients for the instrumented *Dummy interest rate swap use* cannot be distinguished from zero.

swaps are still frequently traded tenors for hedging the IRR from long-term loans, the vast majority of all interest rate derivatives have maturities of less than one-year.

Our second instrument is based on the finding that characteristics of board members have an impact on hedging decisions, but not on the extent of hedging (e.g., Zhu, 2011, 2012). Therefore, we include the average experience of all board members in bank executive positions measured in years as an explanatory variable for the decision to use swaps. As this variable does not influence the extent of hedging, we can use it additionally to estimate the *Inverse Mills ratio* in a sample selection model and do not simply identify the selection model from the non-linearity of a probit estimator. Average board experience therefore qualifies the exclusion restrictions for both the maturity gap and the extent of swap use decision and only has a direct impact on the decision to use interest rate swaps. Zhu (2011) uses a dummy based on whether the CEO is below the age of 45 as a variable identifying the decision to hedge, but not the extent thereof.<sup>12</sup> We argue that board experience has no other influence on the maturity gap decision apart from the effect through the use of interest rate derivatives, as the maturity gap for most banks is largely determined by borrower and depositor liquidity needs.

In summary, we estimate the following system of equations:

$$\begin{aligned}
 DG &= \alpha_{DG} + \beta_{DG1}SU + \beta_{DG2}CL + \beta_{DG3}LC + \beta_{DG4}X + \epsilon_{DG} \\
 SU &= \alpha_{SU} + \beta_{SU1}DG + \beta_{SU2}PSE + \beta_{SU3}BExp + \beta_{SU4}X + \epsilon_{SU} \\
 SE &= \alpha_{SE} + \beta_{SE1}DG + \beta_{SE2}PSE + \beta_{SE3}IMR + \beta_{SE4}X + \epsilon_{SE},
 \end{aligned} \tag{1}$$

where, for simplicity subscripts indicating bank or time units are left out.  $DG$  stands for the (modified) duration gap,  $SU$  for a dummy of the swap use decision, and  $SE$  represents the extent of interest rate swap use, proxied as the logarithm of the nominal volume of interest rate

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<sup>12</sup>For the smaller German savings banks and cooperative banks, it is not possible to identify the CEO or the CFO of a bank as these banks do not distinguish between different board responsibilities.

swaps in relation to total assets.  $CL$  is customer loans, and  $LC$  loan commitments.  $PSE$  is the dummy of past interest rate swap experience, and  $BExp$  the average board experience, while  $IMR$  is the Inverse Mills ratio controlling for sample selection in the extent of interest rate swap use.  $X$  is a vector of all exogenous explanatory variables that influence all risk management decisions.

## 4 Data and Summary Statistics

### 4.1 Data

We use data from 2000-2011 in our simultaneous risk management framework. The start date of the analysis is due to the availability of data for the variable *Liquid assets*. For the hazard rate model we employ data starting in 1994 to make use of as many default events as possible, especially restructuring mergers during the wave of consolidation, the German banking sector underwent in the 1990s. To create the instrument *Past swap experience*, we use information dating back to 1998. All data is provided by the prudential banking supervision databases of the Deutsche Bundesbank. The data is taken from the P&L and balance sheet statements, the auditor's report, year end values of the monthly balance sheet statistics, and liquidity reporting. Macroeconomic data is identical to that available on the Bundesbank's website. Board experience is taken from a supervisory database on characteristics of bank managers in executive positions, as the appointment to such a position has to be approved by the German banking supervisory authority BaFin. Default data comes from a database on regulatory interventions.

To cope with outliers, we winsorize our variables at the 99th percentile and at the 1st percentile, except for Size and (the logarithm of) the Probability of default estimated in the hazard rate model. The impact of mergers on the consistency of accounting measures is accounted for by creating a new "artificial" banking entity after every merger taking place. This is the

most frequently applied approach when using Bundesbank data. When we create the *Past swap experience* dummy, the variable takes the value of 1 for the new entity if at least one of the two pre-merger institutions used any kind of swaps before the merger. As our variable is intended to proxy for the existence of a derivatives risk management department, this procedure seems justified as the knowledge of how to hedge risks off the balance sheet is unlikely to be lost during a merger process.

## 4.2 Summary Statistics

Table 1 displays the distribution of banks using interest rate swaps over the sample period from 2000-2011. Although the absolute number of banks reporting interest rate swap use increases only slightly from 640 to 678, their relative share increases heavily from 29.95% in 2000 to 49.16% in 2011. This effect is due to the consolidation of the German banking sector that led to the disappearance of about 700 banks during the sample period. The relative increase in the use of interest rate swaps was quite sharp between 2000 and 2007, but slowed thereafter. A clear relation between a bank's size and the use of interest rate swaps is observable. Whereas in the lowest size quintile, less than 13% of banks hold interest rate swaps, the percentage increases gradually and peaks at the highest quintile at more than 83%.

Interestingly, the current share of interest rate swap users is close the 50%, which is the solution of firms hedging in equilibrium in the Adam et al. (2007) model. These authors also summarize many studies which find the percentage of non-financial firms in several industries and indices to be close to this value. As the banking sector is a regulated industry with supervision of risk management, this result should, however, not be mistaken for the industry equilibrium percentage of hedging firms in the model cited above.

Surprisingly, we find a significantly larger percentage of banks that manage IRR off the

balance sheet in our study compared to Purnanandam (2007), although the theory of intertemporal smoothing would have predicted the opposite (Allen and Santomero, 2001). In our sample, 31.28% of commercial banks report interest rate swaps outstanding in 2003, whereas Purnanandam reports 5.94% users of interest rate derivatives for hedging purposes for his U.S. commercial bank sample in the third quarter of 2003.

[Table 1 about here.]

We present summary statistics of the variables used in the risk management equations in Table 2 separately for interest rate swap users and non-users, and test for differences in means and medians between these two groups. Some noteworthy features appear: swap users have a slightly higher modified duration gap, but the economic magnitude of the difference is not too pronounced. The mean difference is only 0.14 percentage points, but significant at the 1% level. Moreover, swap users are larger in size with regard to total assets and are more likely to have a trading book. They hold less liquid assets and receive less funding from savings deposits, but nevertheless make more loan commitments. Interestingly, the average board experience is significantly lower for banks that use swaps. For most of the variables, the differences between users and non-users are significant at the 1% level. One exception is the difference in the means of the probability of default, which cannot be distinguished statistically.

German commercial banks indeed have comparatively large buffer stocks of liquid assets, as predicted by the theory of intertemporal smoothing in Allen and Gale (1997). The mean of liquid assets in relation to total assets is around 43.5% for swap users and 44.5% for non-users, and the difference of 1 percentage point is economically not very large, although statistically significant. Purnanandam (2007) reports non-users as having, on average, 36% and users 30.5% liquid assets. Here, overall levels are smaller and the difference between users and non-users of interest rate derivatives for hedging purposes is more pronounced. It should, however, be borne

in mind that the definitions of liquid assets do not completely match.

[Table 2 about here.]

## 5 Hazard Rate Model

Following Purnanandam (2007), we proxy for the cost of bankruptcy by estimating the bank-specific probability of default (PD) from a hazard rate model.<sup>13</sup> The hazard rate model is estimated using default events from 1994 to 2011. As defaults appear on various dates during a given year, all covariates are lagged values from the previous year-end. Defaults for 2012 were not available at the start of this study. PDs for 2011 have therefore been predicted from the coefficients derived with covariates until 2010. We include the following default indicator dummies as the dependent variable: forced closures and restructuring mergers as well as capital injections by either sectoral insurance schemes or the federal scheme set up during the recent financial crisis. The model is estimated using a pooled multiperiod logit model (Shumway, 2001) with standard errors clustered at bank level. A similar model is used in the banking supervision department of the Bundesbank to gauge the financial soundness of national banks. The bank-specific covariates are based on the CAMELS taxonomy and therefore include variables capturing Capital adequacy, Asset quality, Management, Earnings, Liquidity, and Sensitivity to market risk.<sup>14</sup>

Specifically, we choose the following variables to estimate the PD: capital adequacy is included using the *Tier 1 capital ratio*, the ratio of tier 1 capital to risk-weighted assets (RWA),

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<sup>13</sup>This approach implicitly assumes identical loss given default (LDG) for banks when the PD is the only relevant variable. Purnanandam (2007), however, finds no qualitatively different results when proxying LGD instead of PD. Moreover, the model of Brunnermeier and Oehmke (2012) implies that a bank’s PD, and not the LGD, is the major driver of a “maturity rat race” leading to excessively short durations for banks’ liabilities.

<sup>14</sup>Liquid asset measures are not included as an explanatory variable, which is the common procedure in the “Bundesbank hazard rate model”. If included, such measures show up insignificant as liquidity appears to be an indicator for the lack of business opportunities and not of active risk management (Porath, 2006).

and *Total bank reserves*, the ratio of total banks reserves that serve as equity, to total assets (TA). The dummy *Reserve reduction* takes the value 1 if the aforementioned reserves have been reduced. Asset quality is proxied using a Herfindahl (-Hirschman) index (HHI) of loan concentration over 23 industry sectors. Earnings are captured by *ROE*, the return on equity, defined as operating income to equity. Additionally, the competitive environment is controlled for by the *Branch HHI* on the county level. Financial intermediation theory provides predictions for the nexus of risk taking and competition. Boyd and De Nicoló (2005) show that the effect of competition on bank risk taking depends on borrowers' reaction on the transmission channel of market power into loan rates. More concentrated banking markets can trigger less risk taking through rising charter values. However, raising loan rates can also increase risk taking when the pool of borrowers is more likely to default. Therefore, predictions on the coefficient of the *Branch HHI* cannot be made. The level of the short-term interbank *3-month LIBOR* rate and *regional GDP growth* at the state level are included to control for changes in the macroeconomic environment. Dummies for savings and cooperative banks capture heterogeneity in business models with private commercial banks being the reference group left out.

The impact of these variables can be seen in Table 3 and is presented displaying marginal effects from the logit model. As expected, Tier 1 capital and bank reserve endowments reduce bankruptcy risk significantly, whereas the dummy indicating reserve reductions is an indicator of significantly higher default likelihood. Specialization in certain business sectors via concentrated loan portfolios does not significantly impact default likelihoods. ROE significantly reduces bankruptcy risk through its effect on capital accumulation. A higher value for the Branch HHI indicates more concentrated and, therefore, less competitive banking markets. Our results thus indicate that competition in the banking market slightly improves banking stability. Business conditions captured in local GDP growth have no significant influence on bank default, but a



lower level for short-term interbank rates increases distress likelihood as predicted by the risk-taking channel of monetary policy (Borio and Zhu, 2012). At first glance, this finding contradicts the effect that would have been attributed to funding conditions and experiences of the U.S. savings and loan (S&L) crisis. However, contemporaneous studies confirm the positive relation of short-term interest rates to banks' risk-taking behavior (Jiménez et al., 2012).

[Table 3 about here.]

We consider *Hidden liabilities* to be exogenous to the risk management decisions examined in Section 6. The coefficient is positive as expected and significant with a  $t$ -statistic of almost 3.3. Having hidden liabilities on the balance sheet increases the likelihood of default during the following year by 35%, a change of high economic magnitude. Instrumenting actual defaults with the dummy for hidden liabilities in the risk management regressions of Section 6 — using defaults as the only variable to be instrumented — we receive weak instrument statistics, which are always above the critical value of 16.38 for the Cragg-Donald  $F$ -test adjusted for clustered standard errors. The only exception is the time-series regression of the extent of interest rate swap use, which is analyzed in a panel sample selection setting of Semykina and Wooldridge (2010). In this setting, the  $F$ -statistic falls to 11.08, which is, however, still above the old rule of thumb that the  $F$ -statistic should exceed 10. As indicated by the  $t$ -statistics, *hidden liabilities* are indeed a strong and therefore relevant instrument. In further regressions, where both the actual default and the decision to use swaps or the maturity gap are considered endogenous and therefore instrumented, we can reject tests of overidentifying restrictions conveniently in all cases at the 10% level. Overidentification is achieved using the two instruments for the decision to use interest rate swaps or the maturity gap. As we are, however, interested in the impact the latent variable *Probability of default* has on risk management decisions rather than the actual default, we will not proceed using actual default in the following risk management regressions.

The hazard rate model has both good predictive and discriminatory powers. Statistical power is evaluated using the pseudo  $R^2$ , which has a value of 0.189. Discriminatory power is judged using the value of the area under the Receiver Operating Characteristics (ROC) Curve, which is 0.859. Both values are comparatively good considering the parsimonious use of explanatory variables compared with other studies.

Unlike in the U.S., the German banking industry did not undergo a major crisis with its underlying causes in the dynamics of interest rates, like the S&L crisis that affected thrifts in the U.S. during the 1980s. Although we find that defaulting banks were more sensitive to a decrease in the level of interbank rates, we did not include specific variables related to interest rate risk taking, and there thus exists no ex ante mechanical relation between the PDs derived and IRR management.

## 6 Simultaneous Interest Rate Risk Management

Although we estimate the regressions for the (modified) maturity gap and the decision to use interest rate swaps and their extent as a system of simultaneous equations, we will present and discuss the results in different tables. For brevity, we do not display the results of first-stage regressions as these regression tables are similar to the second-stage results for the other risk management decision in the simultaneous equation framework. We estimate the simultaneous equations framework as two-stage least squares (2-SLS) regressions with standard errors generally clustered at the bank level.

The results presented in Table 4 show that the coefficients derived from pooled OLS models, controlling with time dummies, are very close to those from Fama-MacBeth regressions, when the swap use dummy is considered exogenous. This holds especially for the total and the non-trading book samples. We therefore argue that pooled models capture cross-sectional variation

without too severe a bias. Fama-MacBeth regressions derive the significance of coefficients solely from the time-series variation of coefficients over distinct periods using Newey-West standard errors with automatic lag selection. This approach, however, would treat instruments created in the first stage as variables and not as estimated instruments and standard errors would be underestimated. We will therefore focus on 2-SLS pooled regressions together with between effects IV regressions when we simultaneously investigate interest rate swap use and on-balance-sheet IRR management. Another advantage is that we can then draw on the complete IV statistics available for 2-SLS regressions. Similarly, Table 5 compares between effects, Fama-MacBeth and pooled OLS estimators for the extent of interest rate swap use regression models when the modified duration gap is taken as exogenous. Again, pooled OLS gives quite similar results to Fama-MacBeth. The best results are now achieved for the two sub-samples of non-trading and trading book banks.

[Table 4 about here.]

[Table 5 about here.]

## 6.1 Maturity Gap

### 6.1.1 Cross-Sectional Variation

Table 6 presents the cross-sectional results of the maturity gap equation within the simultaneous risk management framework. As expected, the coefficients of the swap use dummy are significantly positive, indicating that banks deciding to use interest rate swaps are operating with a higher maturity mismatch. On average, commercial banks that use swaps have a 0.16 percentage point higher modified duration gap. The effect is highest for trading book institutions where the effect amounts to 0.65, or 0.48 percentage points, depending on the estimated model, between

effects or pooled OLS. The positive coefficients give evidence that, although trading book institutions might use interest rate swaps for the purpose of speculation, they predominantly seem to use them for the purpose of hedging. This confirms previous results from Memmel and Schertler (2011) who demonstrate, based on the effect of interest rate swap usage on the variability of net interest income, that interest rate swaps are mainly used for hedging purposes.

The effect of the PD supports the predictions of theoretical risk management models, such as Froot et al. (1993) and Froot and Stein (1998), that the potential distress cost leads commercial banks to take less IRR. Again, this effect is most pronounced for trading book institutions. As trading book institutions receive more of their funding from capital markets and arms-length relationships in interbank markets, whereas the majority of pure banking book institutions receive interbank loans from their associated head institutions (Ehrmann and Worms, 2004), these results can be interpreted as the effect of risk taking on the cost of external finance, as also found by Brewer et al. (1996).

Size leads pure banking book institutions to take more, but trading book institutions to take less IRR on the balance sheet. Business opportunities show the expected negative effect as predicted by Froot et al. (1993) and Froot and Stein (1998) only for pure banking book institutions. For trading book financial intermediaries the opposite holds, although the coefficients are only significant in the pooled OLS setting. Asset and funding liquidity both lead banks to engage in less maturity transformation. This finding is not surprising for liquid assets as a substantial portion of these assets have short-term maturity that reduces the modified duration gap. For savings deposits the finding is, however, surprising as the short-term funding nature of deposits leads to a higher duration gap per se. On the other hand, many small regional banks with strong deposit funding lack business opportunities and hold proportionally large liquidity buffers, often deposited via interbank loans at their head institutions. The results of all coefficients presented

so far are consistent with those found by Purnanandam (2007) in cross-sectional regressions where Fama-MacBeth estimators have been applied. More concentrated and therefore less competitive markets lead to more on-balance-sheet interest rate risk taking — giving support of the theory developed by Boyd and De Nicoló (2005).

The coefficients for Customer loans and Loan commitments are positive and significant at the 1% level in all regressions. Banks with a higher share of customer loan volume indeed have a higher duration gap as already documented by Ehrmann and Worms (2004). The positive coefficient for the ratio of loan commitments confirms the results of Berger et al. (2005) that banks use loan commitments to gather information on borrower quality and finally to offer loans with longer maturity. The significance levels serve as upfront indicators of instrument relevance in the swap use regressions presented in Section 6.2.

The first-stage instrumentation process of *Interest rate swap use* — which has been carried out for simplicity as a linear probability model — proves instrument relevance as the test statistics for weak instruments are always conveniently above the critical value of 19.93.<sup>15</sup> The magnitude of the weak identification tests is largely driven by the variable Past swap experience. Overidentification tests strengthen our arguments as to the exogeneity of the instruments included. Interestingly, the Durbin-Wu-Hausman test statistics indicate that the choice of using interest rate swaps is exogenous to the magnitude of the maturity gap. Hence, instrumenting the dummy variable of interest rate swap use is not necessary.

[Table 6 about here.]

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<sup>15</sup>Using fitted values from a first-stage probit model as instruments — as described in Wooldridge (2010) — does not change the results qualitatively. This also holds for the fixed effects time-series models. However, this approach would not allow a test for overidentification.

### 6.1.2 Time-Series Variation

In this Section, we investigate the time-series behavior of the modified duration gap and present the results in Table 7. The use of panel data allows us to include macroeconomic variables which we can use to prove market timing behavior in on-balance-sheet IRR exposure. Our standard model (Panel A) includes time dummies to control for the potential impact of several macroeconomic indicators. Compared to the cross-sectional model, the time-series model has significantly lower explanatory power based on the coefficient of determination  $R^2$ . The variables included are therefore better able to distinguish cross-sectional differences between banks than to explain the adjustment of the duration gap over time.

In the baseline model, we find the coefficients for the *Interest rate swap use* to be not significant except for the sub-group of banks that changed their status of swap use at least once, which we refer to as “starters”. Most of these banks started hedging during the sample period and therefore changed from non-users to users at least once. For this sub-sample we find a coefficient of 0.15 percentage points, significant at the 1% level and comparable in magnitude to the cross-sectional models. As the majority of banks, around two-thirds, not change their swap use status once during the sample period, and either never uses swaps or does so in all years, too little intertemporal variation exists for the fixed effects estimator to deliver significant results in the other three samples.

For the other explanatory variables, we find the same coefficient sign in the time-series models as in the cross-sectional models. The only exemption is *Size*, which now has significantly negative coefficients. Hence, as banks become larger, they decrease their on-balance-sheet exposure resulting from term transformation. One explanation is that bigger banks start engaging in other business lines that generate fee and trading income. The significance of loan commitments decreases in the trading book sample, but is still significant at the 10% level. The effect

of competition shows ambiguous results. Whereas decreasing competition leads non-trading book institutions to take on less risk, the opposite holds for trading book banks. However, mixed empirical findings for the relation between competition and risk taking have already been documented by Boyd and De Nicoló (2005).

The macroeconomic variables confirm results from previous analysis. Banks increase their duration gap when the yield curve becomes steeper and maturity transformation becomes more profitable. Similar results were found by Purnanandam (2007) and Memmel and Schertler (2011). As the level of the short-term 1-year government yield is highly collinear to the slope of the yield curve, we do not include it as an extra variable but create an interaction term with the slope instead. These interaction terms are significantly negative and confirm theories related to the risk-taking channel of monetary policy (Borio and Zhu, 2012). Jiménez et al. (2012) find that short-term rates matter for banks' risk taking, whereas the long-term 10-year rate has no significant impact. During times of high short-term rates, when short-term lending funded with deposits that pay less than market rates is also profitable, banks engage in less maturity transformation (Panel B). Interestingly, banks decrease their duration gap in times of uncertainty in interbank markets, measured by a higher spread of the 1-year LIBOR over the 1-year government rate (Panel C and D). However, when interbank uncertainty arises contemporaneously with a steep yield curve, banks decrease their maturity mismatch less drastically, as there are still profits to earn from maturity transformation (Panel D).

[Table 7 about here.]

## 6.2 Interest Rate Swap Use Decision

In this section we analyze the determinants for the use of interest rate swaps by applying pooled probit models into which we include macroeconomic variables. The results are presented in

Table 8. Again, the baseline model in Panel A includes time dummies, whereas the other model specifications use the same sets of macroeconomic variables as in the time-series setting of the duration gap analysis.

Maturity gap has the expected positive coefficients, always significant at the 1% level. Pure banking book institutions show a three to four times higher sensitivity to on-balance-sheet IRR than banking book institutions. Once the smaller non-trading book banks decide to use interest rate swaps, they can hedge the IRR from maturity transformation and can accept short-term deposits and make long-term loans, as long as they keep their overall exposure below the “outlier” thresholds of the IRR regulation schemes.

The sign of the coefficient of the PD provides evidence on the predictions of static hedging models (Froot et al., 1993; Froot and Stein, 1998). The higher the default risk and the associated cost of bankruptcy, the higher the propensity to use interest rate swaps. Again, the sensitivity of trading book financial intermediaries, which are more likely to depend on their credit rating in interbank and capital markets, is higher in magnitude. However, these banks might use interest rate swaps, at least partly, for speculation purposes too. Also for banks, we find the empirically well-documented effect that larger entities are more likely to use OBS derivatives. This is most likely due to economies of scale in establishing risk management departments that are proficient enough to use interest rate swaps.

So far, all our results are consistent with those of Purnanandam (2007). The major difference is the coefficients related to bank liquidity measures, for which Purnanandam finds significantly negative relationships. We find that savings deposits have no impact on the interest rate swap use decision. The buffer stock of liquid assets is found to be insignificant for trading book institutions, but significantly negative for pure banking book intermediaries. This indicates that these banks consider liquid assets to be a complementary hedging tool, whereas risk management



theory stresses the substitutionary relation (e.g., Bolton et al., 2013). One potential explanation for this finding lies in the role that liquidity buffers have in the theory of intertemporal smoothing of non-diversifiable liquidity and interest rate risk (Allen and Gale, 1997).

Competition is not found to have an effect on banks' likelihood to use swaps, although theory would have suggested so (Adam et al., 2007). Zhu (2011) finds significant effects from hedging on competition and vice versa. However, she investigates unregulated industries' commodity price hedging. In the regulated banking industry, competition has no effect on the decision to use swaps after controlling for all the other determinants that affect interest rate risk taking.

Past swap experience has the expected positive sign and coefficients are far above 1 and have a significance level of 1% in all samples and regression setups. Average board experience, on the other hand, reduces the likelihood of the use of interest rate swaps and is always conveniently significant at 5%. The negative effects are most pronounced for trading book institutions. These results contradict those found in the literature hitherto. Zhu (2012) finds that younger and therefore less experienced CEOs are less likely to use OBS hedging.

The macroeconomic variables serve as indicators of market timing in hedging decisions. Pure banking book institutions are less likely to use swaps when the yield curve is steep (Panel B). These findings are consistent with Memmel and Schertler (2011). As non-trading book banks can use interest rate swaps only for hedging purposes, they hedge less of their floating-rate debt exposure in times when corporates also hedge less (Faulkender, 2005; Vickery, 2008). For trading book banks, we find insignificant or significantly positive relationships. Here, it has to be taken into account that these banks can use interest rate swaps for speculation on the yield curve and positive coefficients can indicate increasing off-balance-sheet IRR exposure. The interaction term with the 1-year yield is significantly negative for all samples (Panel B).<sup>16</sup>

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<sup>16</sup>It should be noted that the elasticities of interacted variables in probit models should be interpreted with caution as the correction proposed by Ai and Norton (2003) has not been applied. However, we derive similar

Interbank funding uncertainty increases banks' likelihood of using interest rate swaps (Panel C and D). Interestingly, both the overall and aggregate sectoral quotas of banks that use interest rate swaps are highly correlated with the LIBOR spread. Sectoral quotas have been calculated by separating savings, cooperative and private commercial banks. Hence, funding uncertainty seems to be a major driver of the swap use decision on an industry level. This is further evidence for the dynamic risk management theories that incorporate liquidity issues into hedging decisions. Furthermore, our finding is supported by the increasing use of overnight index swaps in the banking industry. Banks seem especially interested in hedging against a potential increase in short-term wholesale funding exposure and not so much the IRR that results from transforming savings deposits into long-term loans. Again, when uncertainty is accompanied by a steep yield curve making term transformation profitable, the effect of the LIBOR spread becomes smaller (Panel D).

Customer loans and loan commitments are relevant instruments that conveniently pass the weak instrument tests and always have Cragg-Donald  $F$ -statistics above the threshold of 19.93. Their validity is supported using overidentification tests that are insignificant for all samples being estimated. The exogeneity tests of Smith and Blundell (1986) indicate that, for pure banking book institutions, the maturity gap is an endogenous driver of their decision to hold swaps, but exogeneity cannot be rejected for trading book banks as well as starters.

[Table 8 about here.]

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coefficients in magnitude for the interacted and all other variables from linear probability models (LPM).

## 6.3 Extent of Interest Rate Swap Use

### 6.3.1 Cross-Sectional Variation

Table 9 shows the cross-sectional results of the extent of interest rate swaps used for between effects and a pooled specification. For trading book banks, only three variables are found to be significant. The significant determinants are the PD, which increases the extent of interest rate swap use, Size, which also has a significantly positive impact, and the Past swap experience. Although only three variables are significant, the  $R$ -squares are higher for trading book bank samples than for pure banking book institution samples. As the cross-sectional estimators should explain constant extent of swap use, whereas we cannot distinguish whether interest rate swaps are used for speculation or hedging purposes, the assumptions underlying the estimators may be violated. The results should therefore be interpreted with caution. In particular, concluding that the positive coefficient found for the Probability of default indicates a reduction of IRR through interest rate swaps is not straightforward. The opposite could be true, namely that trading book banks with a higher likelihood of default increase their risk by speculating on interest rate movements, as predicted by dynamic risk management models for financially constrained firms (e.g., Bolton et al., 2013).

For the sample of pure banking book institutions, we find results in line with those Purnanandam (2007) obtained when he investigated interest derivatives for hedging purposes. Banks with higher duration gaps hold significantly more interest rate swaps, and banks with a higher cost of distress also increase their swap use to hedge IRR, consistent with the implications for the risk management behavior of unconstrained firms in corporate finance theory. As for trading book banks, Size also shows significantly positive coefficients and asset growth is found to be insignificant.

Liquidity endowments, in general, reduce the volume of swaps held. This is consistent

with the predictions of modern dynamic risk management theory, where cash is considered a substitute for hedging activities (e.g., Bolton et al., 2013). Savings deposits as an indicator of stable funding sources significantly reduce the extent of interest rate swaps. The same holds for the buffer of liquid assets, however only when a between estimator is used. Competition has no influence on the extent of interest rate swaps.

Controlling for sample selection bias is only necessary for the pure banking book sample as well as the total sample, but not for the trading book sample. The reduction of sample size conditional on using swaps is most substantial for non-trading book institutions, while the observations in the trading book sample drop only slightly. Observations decrease by more than two-thirds in the pure banking book sample from 17,166 to 5,725, whereas the reduction is only around 20% for the banking book institutions, from 2,170 to 1,701.

Again, the instruments pass the weak instrument tests and are clearly above the threshold of 19.93 calculated by Stock and Yogo (2005). Instrument validity is confirmed by the Hansen- $J$  test of overidentification. The Durbin-Wu-Hausman exogeneity tests indicate that the modified duration gap is indeed an exogenous determinant of the nominal volume of banks' interest rate swaps. This result holds for all sub-samples of the pooled OLS models.

[Table 9 about here.]

### **6.3.2 Time-Series Variation**

In a time-series setting — results are presented in Table 10 — the duration gap has a positive and even larger impact on the extent of interest rate swaps used than in the cross-sectional settings. To address problems of unobserved heterogeneity and endogeneity as well as sample selection, we estimate these models following Semykina and Wooldridge (2010). The impact is largest for commercial banks that start using interest rate swaps during the sample period. In contrast to

the cross-sectional regressions, we do not find a significant influence of the probability of default in any of the regressions run on the swap extent. The same is true of liquid asset endowments and mostly also of savings deposits. These results are in contrast to our cross-sectional findings and also to the time-series models of Purnanandam (2007), who finds a significantly negative impact for both variables.

Size has a significantly positive impact on the extent of interest rate swap use and is larger than in the cross-sectional regressions. Total asset growth is largely found to be insignificant, except for trading book institutions, where significantly negative coefficients can be observed. However, again this finding is hard to interpret as we do not know whether swaps are held for speculative or for hedging purposes.

The exogeneity tests cannot reject the endogeneity of the duration gap, as in the cross-sectional regressions. The critical threshold of 16.38, as stated by Stock and Yogo (2005), for the Cragg-Donald  $F$ -tests is not passed in all regression models. However, even the smallest values observed for the  $F$ -tests are close to 15 and we therefore consider our instruments to be relevant. Hansen- $J$  tests again support the exclusion restrictions and are conveniently insignificant at least at a 25% level.

[Table 10 about here.]

## **6.4 Summary of Results from the Simultaneous Equations**

### **6.4.1 Simultaneous Risk Management**

For banks in the non-trading book sample we find that more restrictive on-balance-sheet IRR management, resulting in lower maturity gaps, and an intensified use of interest rate swaps are substitute strategies. The coefficients derived for the probability of default largely provide an empirical support for the behavior of unconstrained firms in theoretical corporate finance risk

management models. However, the proxy for profitable growth opportunities — the growth rate of total assets — is most often insignificant. In robustness checks this also holds for the growth rate of customer loans, and total loans, and if we choose real instead of nominal growth rates by deflating monetary volumes. The market timing behavior we find for the slope of the yield curve is in line with the results Memmel (2011) receives for the overall, combined on-balance-sheet and off-balance-sheet IRR exposures.

#### 6.4.2 Exogeneity Tests

Table 11 summarizes the results from the exogeneity tests of the potentially endogenous explanatory variables within the simultaneous regression framework. As the results for cross-sectional and time-series regressions do not differ, no differentiation is made. We also display only the results for the total sample and the sample of banks starting to use interest rate swaps for the first time. The only exemption is that the result for trading book institutions in the interest rate swap use probit regressions as it differs from the results for exogeneity tests for the total and non-trading book sample.

[Table 11 about here.]

The decision to use interest rate swaps is only endogenous to the maturity gap for the sub-sample of banks that start hedging during the sample period. These results are robust if we replace the dummy of current swap use by the volume of swaps scaled by total assets. For all other banks, including the total sample which is dominated by banks that either use interest rate swaps in all years or in not a single year, the decision is exogenous. The duration gap is an endogenous determinant of the decision to use interest rate swaps even for starters. It is only for trading book institutions that exogeneity cannot be rejected. With regard to the extent of interest rate swaps held conditional on a positive decision to use interest rate swaps at all, the

maturity gap is always endogenous.

We interpret the results as follows. The decision to use interest rate swaps and the extent of their use seem mainly driven by the contemporaneous IRR regulation in Germany, whereas the maturity gap seems to be largely determined by borrower and lender liquidity preferences. Banks that face the decision to newly start employing interest rate swaps are likely to have a maturity gap close to the threshold of being considered an “outlier” bank by the regulator. “Outliers” lose more than 20% of their regulatory equity in a simulated 130 basis point parallel upward shift of the yield curve.<sup>17</sup> Starters face the decision of paying the one-time initial cost of establishing a derivatives hedging department, becoming an “outlier” bank that exceeds the regulatory threshold<sup>18</sup> or, alternatively, rejecting the loan maturity borrowers demand. In contrast, banks whose exposure is far away from the threshold or those whose exposure is above the threshold but which have already initiated an OBS risk management desk in order to comply with the IRR regulation can offer any loan maturity borrowers demand and accept all volumes of short-term deposits. Hence, only for starters the decision to use interest rate swaps is endogenous to the maturity gap.

The IRR regulation in Germany can also explain the more pronounced use of interest rate derivatives in Germany compared to the U.S., although the intertemporal smoothing theory of Allen and Gale (1997) predicts a higher propensity of derivative use for the U.S., German commercial banks seem to use interest rate swaps predominantly for compliance with the IRR regulation and not to manage liquidity risk.<sup>19</sup>

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<sup>17</sup>The IRR regulation was revised in the fourth quarter of 2011. The relevant interest rate shock has been increased to 200 basis points and banks are no longer referred to as “outliers” but as institutions with “elevated interest rate risk”. For more details of the IRR regulation, see Deutsche Bundesbank (2012). Excluding observations from the end of 2011, when the new regulatory framework became effective, does not change our results.

<sup>18</sup>The effects of being classified as an “outlier” by the regulator on the overall IRR exposure have been documented by Memmel (2011). Banks decrease overall IRR exposure drastically afterwards.

<sup>19</sup>We are not aware of a similar “outlier” threshold with regard to a potential equity loss in the Economic Value Model applied by the Federal Reserve to investigate U.S. commercial banks’ IRR, although also a 200 basis point

We additionally interpret the finding that the interest swap use dummy is exogenous for most samples to the fact that German commercial banks' maturity mismatch is largely determined by customers' liquidity needs. Research on borrowers' preferences reveals that loan size is most sensitive to the maturity being offered, whereas interest rate sensitivity is less pronounced. These findings are interpreted as the existence of binding borrower liquidity constraints (e.g., Karlan and Zinman, 2008; Attanasio et al., 2008). Germany's legal and institutional environment provide banks with incentives to supply borrowers with long-term liquidity if demanded. In the German bank-dominated financial system only few large corporates have access to equity and debt capital markets, whereas the majority of Germany's small and medium-sized enterprises, known as the "Mittelstand", depend completely on banks with which they most often have longstanding relationships. Additionally households have most of their savings as deposits with banks (e.g., Allen and Santomero, 2001).

Major determinants of the loan maturity being granted by a bank are the degrees of information asymmetry and moral hazard that are inherent to the borrower relationship. Ways to mitigate the maturity-reducing impact of the aforementioned factors are pledging collateral and relationship lending. The German "Hausbank" principle is one of the strongest forms of relationship lending. Additionally, most often commercial property or real estate is pledged as collateral and valued quite conservatively. Therefore, German banks are likely to offer the same long-term loans as banks in the U.K., although Germany offers less favorable creditor rights (Davydenko and Franks, 2008; Qian and Strahan, 2007). The property rights prevailing in Germany are among the most friendly what additionally facilitates granting long-term loans (Bae and Goyal, 2009). To sum up, the German legal and institutional environment helps to reduce moral hazard, and therefore banks seem to be able and willing to offer their lenders

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shift in the yield curve is also simulated. The threshold seems more likely to be one comparing banks relative IRR (Haupt and Embersit, 1991) than an absolute one.



the maturities they demand. Given this setting, it appears plausible that the decision to use swaps is exogenous to the maturity gap except for those banks that face the decision to set up a derivatives department for the first time. Banks at the “outlier” threshold which decide to manage IRR solely on the balance sheet are likely to use their interbank lending and borrowing to adjust their maturity gap endogenously (Ehrmann and Worms, 2004).

Our findings thus confirm that banks use interest rate swaps predominantly for hedging purposes in compliance with IRR regulation. Pure banking book institutions seem at first to choose the magnitude of their maturity gap based on liquidity demand. Afterwards, they decide on the extent of swaps that is necessary in order not to exceed the “outlier” threshold. With regard to the set-up of our simultaneous equation framework, we summarize that the decision to use swaps and the maturity gap do not necessarily have to be estimated simultaneously, except for banks that start using derivatives for the first time.

## 7 Conclusion

Modeling German commercial banks’ IRR management as the simultaneous choice of on-balance-sheet maturity gap management and OBS interest rate swap use, we find that both decisions serve as substitutes for one another. The effect of bankruptcy risk on risk management decisions is consistent with the predictions of corporate finance models for financially unconstrained firms. Being faced with a higher default likelihood makes banks pursue more conservative on-balance-sheet portfolio management with less maturity mismatch, and increases their propensity to hedge on-balance-sheet risk with interest rate swaps.

Our empirical findings are largely in line with those of Purnanandam (2007) who investigates IRR management for U.S. commercial banks. One major exemption is the effect that liquid assets have on the use of interest rate derivatives. U.S. banks manage buffer stocks of liquid assets

as substitutes to OBS hedging in line with the theoretical impact predicted by dynamic risk management theories. German commercial banks, on the other hand, consider liquidity buffers complementary risk management strategies to the decision to hold interest rate swaps. Once banks decide to employ interest rate swaps, the extent of their use serves as a substitute for liquid assets. The differences in managing liquidity and interest rate risk on the balance sheet or off the balance sheet have been stressed by Allen and Santomero (2001) based on the theoretical model of Allen and Gale (1997). U.S. banks are more likely to manage risks using derivative hedging, whereas German banks can rely more heavily on on-balance-sheet risk management due to intertemporal smoothing.

The reason why we nevertheless observe more commercial banks in Germany using OBS risk management instruments than in the U.S. is the outcome of the IRR regulation in Germany. Exogeneity tests on the endogenous regressors in the simultaneous equations suggest that swap use is exogenous to the magnitude of the duration gap. Hence, banks seem first to decide on their duration gap, which is driven by the liquidity preferences of their customers. Afterwards, they make their decisions on using interest rate swaps. This holds for all banks, except for banks that start using interest rate swaps for the first time. Only these banks simultaneously decide on their maturity mismatch and the use of interest rate swaps.

We find market timing behavior in IRR management in samples of banks that are by law prohibited from engaging in substantial OBS speculation. Our results show that banks are willing to take more IRR when a steep yield curve makes maturity transformation profitable. Funding uncertainty in the interbank markets urges banks to reduce on-balance-sheet risk by means of derivatives hedging. High levels of short-term nominal interest rates induce banks to further reduce IRR exposure. This finding is consistent with the risk-taking channel of monetary policy. Including macroeconomic variables does not change the relationship between

on-balance exposure and interest swap use decisions, and therefore the speculative element in market timing appears minor compared to the dominant effect that on-balance and off-balance IRR management serve as substitutes.

Our research has strong implications for banking supervisory authorities as the design of IRR regulation has a major impact on banks' decision to hedge on-balance-sheet risk with OBS derivatives. As OBS derivatives only allow for trading the interest rate but not (fully) the liquidity risk, there is room for future research to investigate how a combined interest rate and liquidity risk regulation, as proposed by Basel III, with the Liquidity Coverage Ratio and the Net Stable Funding Ratio, will affect banks' portfolio structures. For banks in market-based and bank-based financial systems which both adopt Basel III, it will be interesting to observe whether the theoretical predictions from Allen and Gale's model on the relation between liquid assets and OBS risk management still hold after liquidity risk becomes more heavily regulated.

## Appendix A Variable Description

Table 12 gives an overview of the variables used in the hazard rate model and the interest rate risk management analysis and how these variables were calculated.

[Table 12 about here.]

## Appendix B Modified Duration Gap

Time-to-maturity is defined either as the remaining time-to-maturity or as the time remaining until the next repricing. The modified duration gap is calculated by first assigning the modified durations of the standard BaFin approach to the maturity brackets, and then summing up the volume-weighted assets' and liabilities' time-to-maturity brackets. The modified duration gap can then be calculated from the modified asset and liability duration by

$$D_{gap} = D_{mod}^A - D_{mod}^L \frac{\text{total interest-earning liabilities}}{\text{total interest-paying assets}},$$

where total interest-bearing assets (liabilities) is the sum of business volume reported in the time-to-maturity brackets. Information on assets' remaining time to maturity is available for loans to banks and non-banks. For liabilities' remaining time to maturity in addition to loans from banks and non-banks, savings accounts and bonds issued are also available. For each of these categories, four maturity brackets have been collected ranging from three months or less, more than three months up to one year, more than a year up to five years, and finally, more than five years. The interest rate sensitivities assigned to these brackets are 0.16%, 0.71%, 3.07%, and 5.08%, respectively. In order to eliminate unrealistic outliers, we drop all banks that report negative volumes in any of the time-to-maturity brackets. Additionally, we require that three out of the four brackets reported for loans to and from non-banks have non-zero volume.

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## Tables

Table 1: Distribution of Swap Users over Time

Year	Total No. of banks	No. of Swap Users	in %	Size Quintiles				
				1st	2nd	3rd	4th	5th
2000	2,048	640	29.25	10.82	27.97	41.13	45.57	66.54
2001	1,902	601	29.07	7.74	26.20	39.35	45.75	70.61
2002	1,784	572	29.60	6.54	25.32	37.60	47.04	71.28
2003	1,659	546	31.28	7.69	25.63	39.15	47.26	72.08
2004	1,646	595	34.99	8.21	29.08	39.08	50.46	73.01
2005	1,597	593	36.13	8.26	28.21	38.42	55.35	75.00
2006	1,579	682	42.37	8.79	35.90	45.60	59.56	77.78
2007	1,548	715	45.87	10.59	38.10	49.72	62.86	78.59
2008	1,494	702	46.92	10.44	33.62	50.71	62.96	80.24
2009	1,446	684	47.16	11.59	32.19	46.43	64.24	83.04
2010	1,442	685	47.30	12.14	30.29	46.42	60.26	82.18
2011	1,377	678	49.16	12.79	31.10	49.55	62.20	83.15
Total	19,522	7,693	38.28	10.02	29.31	42.63	53.39	75.69

This table presents descriptive statistics on 19,522 bank-year observations of German commercial banks between 2000-2011. Size quintiles are based on total assets in 2011, where the 1st quintile encompasses the smallest and the 5th the largest banks. Swap users are defined according to a positive nominal volume of interest rate swaps at the end of a given calendar year. This table encompasses all commercial banks and is not limited to the data requirements of the samples used for the regression analysis.

Table 2: Summary Statistics

	Swap Users		Non-Swap Users		Group Differences		<i>p</i> -values	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
<i>Hazard Rate Model</i>								
Capital ratio	5.107	4.982	5.765	5.424	-0.658	-0.442	0.000	0.000
Total reserves	1.741	1.661	1.796	1.611	-0.055	0.050	0.000	0.000
HHI credit portfolios	15.562	12.608	15.600	13.319	-0.038	-0.712	0.415	0.000
ROE	11.936	12.122	11.009	11.742	0.927	0.380	0.000	0.000
Dummy hidden liabilities	16.018	0.000	12.167	0.000	3.851	0.000	0.000	0.000
<i>IRR Simultaneous Equations</i>								
Modified duration gap	3.300	3.402	3.16	3.228	0.14	0.174	0.000	0.000
Probability of default	3.162	0.699	3.256	0.802	-0.094	-0.103	0.514	0.000
Total assets	6,112.57	900,648	1,257.88	221,936	4,854.69	678,712	0.000	0.000
Total asset growth	1.116	0.753	1.198	1.022	-0.082	-0.269	0.103	0.000
Savings deposits	13.065	12.070	15.449	14.564	-2.384	-2.494	0.000	0.000
Liquid assets	43.476	41.443	44.452	42.751	-0.976	-1.307	0.000	0.000
Loan commitments	0.687	0.477	0.614	0.450	0.073	0.027	0.000	0.000
Customer loans	57.403	59.21	58.422	59.811	-1.018	-0.601	0.000	0.000
Avg. board experience	11.601	11	13.63	13	-2.029	-2	0.000	0.000
Branch HHI	19.383	18.378	19.065	18.275	0.318	0.104	0.000	0.000
Dummy trading book	19.912	0	3.096	0	16.816	0	0.000	0.000

This table presents descriptive statistics on 19,336 bank-year observations of German commercial banks between 2000-2011. Total assets are in €millions. Avg. board experience is in years. All other variables are in percentage points. The *p*-value on mean differences is a two-sided *t*-test computed under the assumption of independence. The *p*-values of median differences are based on the Wilcoxon rank-sum test. The branch HHI can take values between 0 and 10,000.

Table 3: Hazard Rate Model

Capital ratio	-0.0382**	
	(0.016)	
Total reserves	-1.6612***	
	(0.138)	
Dummy reserve reduction	0.6270***	
	(0.115)	
HHI credit portfolios	-0.0062	
	(0.005)	
ROE	-0.0451***	
	(0.004)	
Branch HHI	0.0002**	
	(0.000)	
3-month LIBOR	-0.1416***	
	(0.045)	
Regional GDP growth	0.0016	
	(0.012)	
Dummy hidden liabilities	0.3521***	
	(0.108)	
Dummy savings banks	-0.6421***	
	(0.151)	
Dummy private banks	-0.8537***	
	(0.210)	
Constant	-2.2435***	
	(0.280)	
Observations	40,661	
Area under ROC curve	0.859	
Pseudo $R^2$	0.186	
Cragg-Donald $F$ -stat. Duration Gap Pooled	86.80	
Cragg-Donald $F$ -stat. Duration Gap FE	29.04	
Cragg-Donald $F$ -stat. Swap Use Pooled	26.78	
Cragg-Donald $F$ -stat. Swap Extent Pooled	34.22	
Cragg-Donald $F$ -stat. Swap Extent Time Series	11.08	
Overidentification stat. [ $p$ -val.] Duration Gap Pooled	0.057	[0.811]
Overidentification stat. [ $p$ -val.] Duration Gap FE	0.073	[0.788]
Overidentification stat. [ $p$ -val.] Swap Use Pooled	2.058	[0.151]
Overidentification stat. [ $p$ -val.] Swap Extent Pooled	0.875	[0.350]
Overidentification stat. [ $p$ -val.] Swap Extent Time Series	0.716	[0.397]

Dependent variable: distress event, including forced closures, restructuring mergers, and capital injections. The model is estimated as a logit regression over the time period from 1994-2011. Coefficients are displayed as marginal effects. All covariates are lagged from the previous year end. Standard errors are clustered at bank level and displayed in parentheses. Significance at the 10%/5%/1% level is marked by \*/\*\*/\*\*\*. Cragg-Donald  $F$ -statistics for weak identification and overidentification statistics are from the regressions run in Section 6 when distress events are included instead of the probability of default and instrumented using hidden liabilities. Overidentification is achieved using two instruments each for either the duration gap or interest rate swap use. Cragg-Donald statistics, on the other hand, are the first stage  $F$ -statistics when only the distress events are instrumented and are always carried out as linear probability models using OLS (Angrist, 2001). The critical Stock and Yogo (2005) value for each of these regressions accounting for clustered standard errors is 16.38. The regression for deriving the overidentification statistic with the hedging decision as the dependent variable is a two-step IV-Probit regressions (Newey, 1987) and the overidentification statistic is from Lee (1992). In all other regressions the overidentification test is a Hansen- $J$  test. The overidentification and Cragg-Donald  $F$ -statistics in the time-series swap extent regressions are based on the setting proposed by Semykina and Wooldridge (2010).

Table 4: Maturity Gap - Cross-Sectional Models (Exogenous)

	Between effects				Fama-MacBeth				Pooled OLS			
	Total sam- ple	Non- trading book	Trading book	Total sam- ple	Non- trading book	Trading book	Total sam- ple	Non- trading book	Trading book	Total sam- ple	Non- trading book	Trading book
Dummy interest rate swap use	0.143*** (0.0268)	0.104*** (0.0271)	0.417*** (0.1177)	0.115*** (0.0120)	0.0981*** (0.0138)	0.373*** (0.00931)	0.114*** (0.0193)	0.096*** (0.0199)	0.247*** (0.0685)			
Probability of default (ln)	-0.048*** (0.0058)	-0.051*** (0.0061)	-0.069*** (0.0200)	-0.0127** (0.00512)	-0.0127** (0.00531)	-0.0592*** (0.0109)	-0.013** (0.0056)	-0.013** (0.0059)	-0.043** (0.0173)			
Size	0.064*** (0.0118)	0.080*** (0.0129)	-0.114*** (0.0337)	0.0376*** (0.00226)	0.0425*** (0.00447)	-0.201*** (0.00795)	0.040*** (0.0134)	0.045*** (0.0136)	-0.060* (0.0354)			
Total asset growth	-0.685 (0.4674)	-1.295*** (0.4098)	1.708 (1.1546)	-1.166*** (0.241)	-1.455*** (0.277)	0.923*** (0.259)	-0.988*** (0.1834)	-1.317*** (0.1929)	0.846** (0.3915)			
Savings deposits	-1.168*** (0.2175)	-0.987*** (0.2095)	-3.323*** (0.7623)	-0.635*** (0.0723)	-0.426*** (0.0658)	-1.868*** (0.189)	-0.740*** (0.1852)	-0.548*** (0.1799)	-2.643*** (0.6825)			
Liquid assets	-0.690*** (0.1290)	-0.701*** (0.1414)	-0.244 (0.3543)	-0.783** (0.260)	-0.868** (0.296)	-0.150 (0.116)	-0.473*** (0.0924)	-0.481*** (0.0978)	-0.154 (0.2396)			
Branch HHI	0.005** (0.0016)	0.004** (0.0018)	0.004 (0.0063)	0.00748*** (0.00126)	0.00641*** (0.00145)	0.0159*** (0.00287)	0.006*** (0.0020)	0.005** (0.0020)	0.012* (0.0065)			
Loan commitments	23.563*** (2.4511)	23.173*** (2.7454)	17.622** (7.5005)	13.79*** (0.853)	13.57*** (0.867)	16.91*** (4.83)	14.360*** (1.8212)	14.116*** (1.7968)	8.483* (4.6977)			
Customer loans	0.634*** (0.1294)	0.487*** (0.1114)	1.907*** (0.4095)	0.899*** (0.132)	0.682*** (0.137)	2.761*** (0.182)	1.025*** (0.1283)	0.838*** (0.1262)	2.369*** (0.3423)			
Dummy trading book	-0.159*** (0.0463)			-0.0815*** (0.0205)			-0.093* (0.0487)					
Time dummies	NO	NO	NO	NO	NO	NO	YES	YES	YES			
Banking group dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES			
Observations	19,520	17,322	2,198	19,520	17,322	2,198	19,520	17,322	2,198			
Number of banks	2,907	2,624	283	2,907	2,624	283	2,907	2,624	283			
R <sup>2</sup>	0.423	0.347	0.725	0.385	0.327	0.606	0.398	0.350	0.636			

Dependent variable: *modifies duration gap*. Standard errors in parentheses. Between effects regressions use bootstrapped standard errors with 100 repetitions, Fama-MacBeth regressions use Newey-West HAC standard errors with automatic lag selection, and pooled OLS regressions use clustered standard errors at bank level, respectively. Automatic lag length is selected as the integer portion of  $12(T/100)^{(2/9)}$ , where  $T$  is the number of periods and equals 12. Significance at the 10%/5%/1% level is marked by \*/\*\*/\*\*\*\*.

Table 5: Extent of Interest Rate Swap Use - Cross-Sectional Models (Exogenous)

	Between effects			Fama-MacBeth			Pooled OLS		
	Total sam- ple	Non- trading book	Trading book	Total sam- ple	Non- trading book	Trading book	Total sam- ple	Non- trading book	Trading book
Modified duration gap	0.032 (0.0528)	0.110* (0.0654)	-0.211* (0.1080)	0.065 (0.1038)	0.184** (0.0809)	-0.165* (0.0775)	0.026 (0.0517)	0.143** (0.0644)	-0.185** (0.0856)
Probability of default (ln)	0.087*** (0.0140)	0.085* (0.0193)	0.084* (0.0434)	0.153*** (0.0063)	0.098*** (0.0153)	0.146*** (0.0218)	0.136*** (0.0170)	0.080*** (0.0205)	0.122*** (0.0332)
Size	0.447*** (0.0421)	0.213*** (0.0770)	0.497*** (0.0767)	0.471*** (0.0515)	0.261** (0.1109)	0.465*** (0.0211)	0.414*** (0.0384)	0.162*** (0.0585)	0.467*** (0.0475)
Total asset growth	2.772*** (1.0056)	2.812** (1.2497)	1.665 (2.1721)	1.101 (0.6968)	1.192 (0.6707)	0.605 (0.4330)	0.630 (0.4053)	0.891* (0.4706)	0.378 (0.8338)
Savings deposits	-1.686*** (0.5222)	-1.685*** (0.6434)	-0.564 (1.6073)	-0.920** (0.4062)	-0.621** (0.2673)	-0.857 (0.7458)	-1.075** (0.4838)	-0.716 (0.5357)	-1.019 (1.0815)
Liquid assets	-0.859*** (0.2580)	-0.660* (0.3431)	-1.033 (0.6454)	-1.030* (0.5119)	-0.903 (0.5083)	-1.116* (0.5278)	-0.629*** (0.2020)	-0.383* (0.2058)	-1.033** (0.4750)
Branch HHI	-0.002 (0.0054)	0.001 (0.0055)	0.020 (0.0147)	0.001 (0.0018)	0.006** (0.0022)	-0.003 (0.0065)	-0.001 (0.0054)	0.005 (0.0053)	-0.006 (0.0150)
Past swap experience	2.154*** (0.2515)	1.524*** (0.3884)	0.268 (1.1297)	2.232*** (0.3474)	1.699*** (0.4458)	0.986*** (0.2817)	1.677*** (0.2076)	1.009*** (0.2252)	0.942*** (0.4758)
Dummy trading book	0.648*** (0.1159)			0.525*** (0.0506)			0.483*** (0.1052)		
Inverse Mills ratio	0.946*** (0.1754)	0.446* (0.2685)	-1.044 (0.7208)	1.022*** (0.2656)	0.627* (0.3422)	-0.468** (0.2027)	0.578*** (0.1563)	0.083 (0.1716)	-0.596* (0.3185)
Time dummies	NO	NO	NO	NO	NO	NO	YES	YES	YES
Banking group dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	7,399	5,725	1,674	7,399	5,725	1,674	7,399	5,725	1,674
Number of banks	1,509	1,257	252	1,509	1,257	252	1,509	1,257	252
R <sup>2</sup>	0.272	0.079	0.487	0.268	0.090	0.452	0.269	0.115	0.428

Dependent variable: *extent of interest rate swap use*. Standard errors in parentheses. Between effects regressions use bootstrapped standard errors with 100 repetitions, Fama-MacBeth regressions use Newey-West HAC standard errors with automatic lag selection, and pooled OLS regressions use clustered standard errors at bank level, respectively. Automatic lag length is selected as the integer portion of  $12(T/100)^{(2/9)}$ , where  $T$  is the number of periods and equals 12. Significance at the 10%/5%/1% level is marked by \*/\*\*/\*\*\*\*.

Table 6: Maturity Gap - Simultaneous Cross-Sectional Models

	Between effects			Pooled OLS		
	Total sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book
Dummy interest rate swap use	0.157*** (0.0491)	0.119** (0.0534)	0.646*** (0.2166)	0.154*** (0.0481)	0.131*** (0.0501)	0.484*** (0.1574)
Probability of default (ln)	-0.049*** (0.0061)	-0.051*** (0.0057)	-0.088*** (0.0199)	-0.014** (0.0056)	-0.013** (0.0059)	-0.054*** (0.0183)
Size	0.061*** (0.0133)	0.077*** (0.0150)	-0.245*** (0.0286)	0.033** (0.0158)	0.038*** (0.0162)	-0.221*** (0.0279)
Total asset growth	-0.678 (0.4301)	-1.286*** (0.4134)	1.724 (1.0803)	-0.974*** (0.1835)	-1.305*** (0.1932)	1.064** (0.4134)
Savings deposits	-1.163*** (0.2408)	-0.982*** (0.2087)	-2.826*** (0.7623)	-0.731*** (0.1846)	-0.540*** (0.1790)	-1.944*** (0.6956)
Liquid assets	-0.687*** (0.1359)	-0.699*** (0.1496)	-0.326 (0.4197)	-0.469*** (0.0923)	-0.479*** (0.0977)	-0.100 (0.2475)
Branch HHI	0.005** (0.0020)	0.004** (0.0021)	0.005 (0.0071)	0.006*** (0.0020)	0.005** (0.0020)	0.014** (0.0065)
Loan commitments	23.516*** (2.7681)	23.117*** (2.4296)	26.046*** (7.6293)	14.252*** (1.8286)	14.007*** (1.8048)	15.998*** (5.0454)
Customer loans	0.637*** (0.1170)	0.490*** (0.1425)	2.107*** (0.3539)	1.028*** (0.1283)	0.839*** (0.1262)	2.713*** (0.3428)
Dummy trading book	-0.160*** (0.0561)			-0.097** (0.0489)		
Time dummies	NO	NO	NO	YES	YES	YES
Banking group dummies	YES	YES	YES	YES	YES	YES
Observations	19,520	17,322	2,198	19,520	17,322	2,198
Number of banks	2,907	2,624	283	2,907	2,624	283
Adj. $GR^2$	0.417	0.342	0.672	0.395	0.348	0.584
Cragg-Donald $F$ -stat.				651.8	574.3	166.9
Overidentification stat.				0.291	0.308	2.452
p-val				0.590	0.579	0.117
Endogeneity stat.				0.975	0.551	1.096
p-val				0.323	0.458	0.295

Dependent variable: *modified duration gap*. All regressions are 2SLS regressions with *dummy interest rate swap use* being instrumented with the *average board experience* and a *past swap use dummy* in a linear probability model (see, Angrist, 2001). Standard errors in parentheses. Between effects regressions use bootstrapped standard errors with 100 repetitions, and pooled OLS regressions use clustered standard errors at bank level, respectively. Standard errors are corrected for potentially small sample size. Significance at the 10%/5%/1% level is marked by \*\*\*/\*\*/\*, Cragg-Donald  $F$ -stat. is the  $F$ -statistic for weak instruments. The critical value of the Cragg-Donald  $F$ -statistic taking heteroskedasticity as well as clustered standard errors into account is 19.93. Overidentification stat is the test statistic of the Hansen- $J$  test on instrument validity. Endogeneity stat. is the  $\chi^2$ -statistic of the Durbin-Wu-Hausman test on the endogeneity of the *dummy interest rate swap use*. Adj.  $GR^2$  is the adjusted generalised  $R^2$  of Pesaran and Smith (1994).

Table 7: Maturity Gap - Simultaneous Time-Series Models

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
		<i>Panel A</i>				<i>Panel B</i>		
Dummy interest rate swap use	0.001 (0.0466)	-0.014 (0.0481)	0.199 (0.1617)	0.156*** (0.0493)	0.050 (0.0467)	0.034 (0.0483)	0.247 (0.1634)	0.094* (0.0487)
Probability of default (1h)	-0.015*** (0.0056)	-0.013** (0.0060)	-0.017 (0.0152)	-0.055*** (0.0076)	-0.051*** (0.0049)	-0.054*** (0.0052)	-0.032** (0.0143)	-0.050*** (0.0080)
Size	-0.464*** (0.0758)	-0.513*** (0.0847)	-0.215** (0.1245)	-0.180** (0.0952)	-0.303*** (0.0631)	-0.348*** (0.0713)	-0.105 (0.1003)	-0.482*** (0.1066)
Total asset growth	-0.227** (0.0994)	-0.377*** (0.1069)	0.659*** (0.2473)	-0.613*** (0.1549)	-0.527*** (0.0940)	-0.662*** (0.1016)	0.454* (0.2358)	-0.582*** (0.1632)
Savings deposits	-0.416*** (0.1317)	-0.374*** (0.1377)	-0.903*** (0.3775)	-1.029*** (0.2010)	-0.734*** (0.1292)	-0.671*** (0.1350)	-1.169*** (0.3609)	-0.978*** (0.1943)
Liquid assets	-0.407*** (0.0543)	-0.387*** (0.0597)	-0.337*** (0.1278)	-0.389*** (0.0740)	-0.499*** (0.0555)	-0.517*** (0.0613)	-0.327*** (0.1285)	-0.367*** (0.0749)
Branch HHI	0.004 (0.0030)	0.001 (0.0031)	0.021*** (0.0070)	0.005 (0.0045)	-0.005** (0.0026)	-0.009*** (0.0027)	0.015** (0.0060)	-0.001 (0.0038)
Loan commitments	4.758*** (1.0073)	5.117*** (1.1317)	3.091* (1.8366)	5.805*** (1.7551)	5.805*** (0.9971)	6.409*** (1.1324)	3.279* (1.8198)	6.275*** (1.6707)
Customer loans	1.793*** (0.1395)	1.700*** (0.1443)	2.744*** (0.3955)	1.438*** (0.2456)	1.461*** (0.1396)	1.319*** (0.1426)	2.700*** (0.4098)	1.551*** (0.2387)
Dummy trading book	-0.006 (0.0532)			0.022 (0.0669)	0.042 (0.0531)			0.070 (0.0636)
Yield curve slope								
Yield curve slope x 1-year interest rate								
Adj. $GR^2$	0.248	0.264	0.231	0.213	0.157	0.157	0.210	0.164
Cragg-Donald $F$ -stat.	342.5	309.0	34.71	251.8	357.6	321.9	37.37	260.6
Overidentification stat.	0.021	0.098	0.696	0.715	1.500	2.076	0.735	0.441
$p$ -val	0.886	0.755	0.404	0.398	0.221	0.150	0.391	0.507
Endogeneity stat.	0.204	0.385	0.693	6.349	0.347	0.163	1.090	1.928
$p$ -val	0.652	0.535	0.405	0.012	0.556	0.687	0.297	0.165
		<i>Panel C</i>				<i>Panel D</i>		
Dummy interest rate swap use	0.102** (0.0475)	0.093* (0.0493)	0.265 (0.1670)	0.159*** (0.0501)	0.100** (0.0474)	0.089* (0.0492)	0.257 (0.1682)	0.160*** (0.0497)
Probability of default (1h)	-0.069*** (0.0046)	-0.072*** (0.0049)	-0.042*** (0.0133)	-0.070*** (0.0073)	-0.071*** (0.0045)	-0.073*** (0.0048)	-0.049*** (0.0131)	-0.072*** (0.0071)
Size	-0.146** (0.0644)	-0.156** (0.0739)	-0.084 (0.1029)	-0.300*** (0.1076)	-0.158** (0.0637)	-0.183** (0.0730)	-0.060 (0.1013)	-0.311*** (0.1060)
Total asset growth	-0.637*** (0.0926)	-0.761*** (0.0999)	0.390 (1.3384)	-0.638*** (0.1567)	-0.557*** (0.0935)	-0.673*** (0.1013)	0.394* (0.2381)	-0.565*** (0.1595)
Savings deposits	-0.917*** (0.1319)	-0.849*** (0.1381)	-1.114*** (0.3568)	-1.114*** (0.2009)	-0.805*** (0.1334)	-0.728*** (0.1389)	-1.349*** (0.3693)	-1.019*** (0.2056)
Liquid assets	-0.526** (0.0527)	-0.534*** (0.0578)	-0.342*** (0.1285)	-0.410*** (0.0706)	-0.579*** (0.0547)	-0.506*** (0.0603)	-0.370*** (0.1294)	-0.448*** (0.0729)
Branch HHI	-0.008*** (0.0025)	-0.011*** (0.0027)	0.012* (0.0059)	-0.004 (0.0038)	-0.010*** (0.0027)	-0.013*** (0.0027)	0.010* (0.0060)	-0.005 (0.0038)
Loan commitments	6.383*** (1.0201)	7.090*** (1.1613)	3.546* (1.8101)	6.633*** (1.7259)	5.992*** (1.0294)	6.595*** (1.1732)	3.585*** (1.8172)	6.189*** (1.7378)
Customer loans	1.276*** (0.1439)	1.104*** (0.1456)	2.674*** (0.4239)	1.311*** (0.2527)	1.290*** (0.1441)	1.127*** (0.1457)	2.685*** (0.4297)	1.321*** (0.2538)
Dummy trading book	0.024 (0.0543)			0.049 (0.0687)	0.022 (0.0555)			0.048 (0.0696)
Yield curve slope								
LIBOR spread	-0.085*** (0.0113)	-0.090*** (0.0119)	-0.040 (0.0333)	-0.102*** (0.0175)	0.049*** (0.0046)	0.049*** (0.0049)	0.051*** (0.0142)	0.041*** (0.0068)
Yield curve slope x LIBOR spread	0.048*** (0.0075)	0.041*** (0.0081)	0.096*** (0.0229)	0.041*** (0.0115)	-0.038*** (0.0119)	-0.049*** (0.0127)	0.060* (0.0312)	-0.063*** (0.0186)
Adj. $GR^2$	0.145	0.145	0.204	0.154	0.150	0.151	0.199	0.156
Cragg-Donald $F$ -stat.	351.6	316.1	38.79	251.2	355.1	320.0	37.96	256.8
Overidentification stat.	1.773	2.279	1.023	0.888	1.879	2.430	0.879	0.937
$p$ -val	0.183	0.131	0.312	0.346	0.170	0.119	0.348	0.333
Endogeneity stat.	2.551	2.391	1.261	6.341	2.321	1.894	1.079	6.126
$p$ -val	0.110	0.122	0.121	0.012	0.144	0.169	0.299	0.013
Observations	18,916	16,772	2,144	7,969	18,916	16,772	2,144	7,969
Number of banks	2,429	2,175	254	862	2,429	2,175	254	862

Dependent variable: *modified duration gap*. All regressions are 2SLS-FE regressions with *dummy interest rate swap use* being instrumented with the *average board experience* and a *past swap use* dummy in a linear probability model (see, Angrist, 2001). Clustered standard errors in parentheses are corrected for potentially small sample size. Significance at the 10%/5%/1% level is marked by \*/\*\*/\*\*\*\*. Cragg-Donald  $F$ -stat. is the  $F$ -statistic for weak instruments. The critical value of the Cragg-Donald  $F$ -statistic taking heteroskedasticity as well as clustered standard errors into account is 19.93. Overidentification stat. is the test statistic of the Hansen- $J$  test on instrument validity. Endogeneity stat. is the  $\chi^2$ -statistic of the Durbin-Wu-Hausman test on the endogeneity of the *dummy interest rate swap use*. Adj.  $GR^2$  is the adjusted generalised (within)  $R^2$  of Pesaran and Smith (1994).

Table 8: Interest Rate Swap Use Decision - Simultaneous Pooled Models

	Total sample	Non-trading book	Trading book	Starter	Total sample	Non-trading book	Trading book	Starter
		<i>Panel A</i>				<i>Panel B</i>		
Modified duration gap	0.615*** (0.0867)	0.852*** (0.1305)	0.241** (0.1029)	0.420*** (0.0874)	0.624*** (0.0875)	0.908*** (0.1420)	0.217** (0.0984)	0.384*** (0.0929)
Probability of default (1h)	0.041*** (0.0074)	0.032*** (0.0075)	0.095*** (0.0228)	0.027*** (0.0081)	0.046*** (0.0077)	0.043*** (0.0077)	0.091*** (0.0221)	0.024*** (0.0080)
Size	0.450*** (0.0169)	0.445*** (0.0189)	0.254*** (0.0516)	0.177*** (0.0186)	0.446*** (0.0195)	0.434*** (0.0201)	0.251*** (0.0514)	0.181*** (0.0205)
Total asset growth	0.111 (0.3040)	0.609 (0.3994)	0.394 (0.8718)	0.054 (0.3856)	0.350 (0.3809)	0.921** (0.4482)	0.252 (0.8504)	0.421 (0.3409)
Savings deposits	-0.140 (0.2283)	-0.089 (0.2136)	0.209 (0.6239)	0.202 (0.2636)	-0.002 (0.2245)	0.095 (0.2375)	0.280 (0.6162)	0.255 (0.2352)
Liquid assets	0.340*** (0.1145)	0.531*** (0.1477)	-0.193 (0.2865)	0.174 (0.1109)	0.346*** (0.1244)	0.596*** (0.1554)	-0.286 (0.3122)	0.116 (0.1241)
Branch HHI	0.001 (0.0021)	0.003 (0.0023)	-0.005 (0.0066)	-0.001 (0.0030)	0.001 (0.0020)	0.003 (0.0024)	-0.005 (0.0078)	-0.001 (0.0028)
Past swap experience	1.700*** (0.0299)	1.688*** (0.0341)	1.919*** (0.1129)	1.070*** (0.0437)	1.697*** (0.0340)	1.679*** (0.0377)	1.924*** (0.1218)	1.091*** (0.0385)
Avg. board experience	-0.010*** (0.0025)	-0.009*** (0.0027)	-0.027*** (0.0116)	-0.019*** (0.0032)	-0.010*** (0.0027)	-0.009*** (0.0028)	-0.025*** (0.0104)	-0.011*** (0.0031)
Dummy trading book	0.285*** (0.0506)				0.282*** (0.0499)			
Yield curve slope		YES	YES	YES	NO	NO	NO	NO
Yield curve slope x 1-year interest rate		0.443 (47.377)	0.339 (55.653)	0.166 (33.295)	0.443 (42.116)	0.400 (27.695)	0.340 (55.329)	0.162 (32.607)
		2.342 (0.126)	1.780 (0.0807)	2.471 (0.116)	1.435 (0.231)	0.723 (0.395)	1.118 (0.731)	1.664 (0.197)
		19.46 (0.000)	30.30 (0.000)	8.489 (0.004)	19.47 (0.000)	31.21 (0.000)	2.271 (0.132)	6.760 (0.009)
		0.000 (0.1108)	0.000 (0.1409)	0.000 (0.0431)	0.000 (0.1108)	0.000 (0.1409)	0.000 (0.1108)	0.000 (0.1108)
		0.000 (0.0070)	0.000 (0.0090)	0.000 (0.0176)	0.000 (0.0070)	0.000 (0.0090)	0.000 (0.0070)	0.000 (0.0070)
		0.446*** (0.0175)	0.431*** (0.0176)	0.252*** (0.0421)	0.181*** (0.0179)	0.431*** (0.0205)	0.250*** (0.0488)	0.182*** (0.0196)
		0.282 (0.3191)	0.848** (0.3895)	0.266 (0.8963)	0.156 (0.3820)	0.732** (0.3453)	0.106 (0.9581)	0.023 (0.3449)
		0.035 (0.2242)	0.207 (0.2503)	0.126 (0.6025)	0.152 (0.2387)	0.077 (0.2215)	-0.043 (0.6077)	-0.035 (0.2829)
		0.223 (0.1386)	0.493*** (0.1488)	-0.292 (0.2518)	-0.068 (0.1222)	0.611*** (0.1928)	-0.294 (0.2540)	0.012 (0.1117)
		0.000 (0.0020)	0.002 (0.0023)	-0.007 (0.0063)	-0.002 (0.0027)	0.003 (0.0022)	-0.008 (0.0070)	-0.002 (0.0028)
		1.693*** (0.0304)	1.670*** (0.0346)	1.920*** (0.1232)	1.084*** (0.0394)	1.670*** (0.0314)	1.923*** (0.1115)	1.090*** (0.0396)
		-0.010*** (0.0029)	-0.009*** (0.0027)	-0.027*** (0.0114)	-0.011*** (0.0032)	-0.009*** (0.0024)	-0.026** (0.0112)	-0.011*** (0.0033)
		0.250*** (0.0411)	0.266*** (0.0471)	0.238* (0.1388)	0.343*** (0.0612)	-0.143*** (0.0204)	0.001 (0.0500)	-0.098*** (0.0228)
		-0.078*** (0.0253)	-0.116*** (0.0276)	0.106 (0.0766)	-0.032 (0.0321)	0.161*** (0.0310)	0.380*** (0.0946)	0.331*** (0.0430)
		NO	NO	NO	NO	NO	NO	NO
		0.441 (36.749)	0.399 (22.640)	0.339 (55.387)	0.442 (35.917)	0.399 (22.033)	0.339 (54.664)	0.159 (28.067)
		0.970 (0.325)	0.403 (0.526)	0.121 (0.728)	1.159 (0.292)	0.531 (0.466)	0.112 (0.738)	1.300 (0.254)
		14.16 (0.000)	24.38 (0.000)	2.47 (0.134)	14.92 (0.000)	25.81 (0.000)	2.542 (0.111)	3.212 (0.073)
		YES	YES	YES	YES	YES	YES	YES
		19.336 (17.166)	17.166 (2.170)	7.980 (19.336)	19.336 (17.166)	17.166 (2.170)	7.980 (19.336)	7.980 (19.336)

Dependent variable: *dummy interest rate swap use*. Coefficients display marginal effects. All regressions are two-step IV-Probit regressions (Newey, 1987) with *modified duration gap* being instrumented with *customer loans* and *loan commitments*. Cragg-Donald *F*-stat. is the *F*-statistic for weak instruments derived from a linear probability model. The critical value of the Cragg-Donald *F*-statistic taking heteroskedasticity as well as clustered standard errors into account is 19.93. The overidentification test displays the test statistic of Lee (1992). The endogeneity test is the  $\chi^2$  Wald statistic of Smith and Blundell (1986). Standard errors in parentheses are bootstrapped with 100 repetitions. Significance at the 10%/5%/1% level is marked by \*/\*\*/\*\*\*\*. Adj.  $R^2$  is the generalised  $R^2$  Taylor (1997) proposes for censored and limited dependent data.



Table 9: Extent of Interest Rate Swap Use - Simultaneous Cross-Sectional Models

	Between effects			Pooled OLS		
	Total sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book
Modified duration gap	0.612*** (0.1673)	0.429** (0.2176)	0.274 (0.2437)	0.819*** (0.1951)	1.044*** (0.2552)	0.160 (0.1608)
Probability of default (ln)	0.066*** (0.0178)	0.043** (0.0188)	0.060 (0.0504)	0.123*** (0.0188)	0.109*** (0.0212)	0.074** (0.0349)
Size	0.633*** (0.0899)	0.458*** (0.0972)	0.685*** (0.1015)	0.821*** (0.0992)	0.775*** (0.1265)	0.602*** (0.0744)
Total asset growth	1.481 (1.0879)	2.448** (1.0751)	-0.570 (2.2389)	-0.075 (0.5186)	0.904 (0.6386)	-0.874 (0.8354)
Savings deposits	-1.534** (0.6022)	-1.982*** (0.5605)	-0.170 (1.9363)	-0.706 (0.6101)	-1.252*** (0.5857)	-0.656 (1.2594)
Liquid assets	-0.654** (0.2831)	-0.797** (0.3862)	-0.508 (0.7662)	-0.203 (0.2346)	0.003 (0.2714)	-0.655 (0.4109)
Branch HHI	0.007 (0.0049)	0.006 (0.0048)	0.021 (0.0185)	0.009* (0.0055)	0.015** (0.0057)	-0.004 (0.0156)
Past swap experience	3.532*** (0.4198)	2.939*** (0.4208)	1.136* (0.6264)	4.236*** (0.4682)	4.153*** (0.5395)	1.440*** (0.3190)
Dummy trading book	0.698*** (0.1160)			0.628*** (0.1127)		
Inverse Mills ratio	2.074*** (0.3281)	1.544*** (0.3193)		2.661*** (0.3737)	2.631*** (0.4307)	
Time dummies	NO	NO	NO	YES	YES	YES
Banking group dummies	YES	YES	YES	YES	YES	YES
Observations	7,399	5,725	1,701	7,399	5,725	1,701
Number of banks	1,509	1,257	255	1,509	1,257	255
Adj. $GR^2$	0.318	0.0997	0.499	0.312	0.133	0.446
Cragg-Donald $F$ -stat.				37.60	21.56	53.65
Overidentification stat.				0.338	0.150	0.350
$p$ -val.				0.561	0.699	0.554
Endogeneity stat.				15.67	10.97	5.305
$p$ -val.				0.000	0.000	0.021

Dependent variable: *extent of interest rate swap use*. All regressions are 2SLS regressions with *modified duration gap* being instrumented with the *customer loans and loan commitments*. Standard errors in parentheses. Between effects regressions use bootstrapped standard errors with 100 repetitions, and pooled OLS regressions use clustered standard errors at bank level, respectively. Standard errors are corrected for potentially small sample size. Significance at the 10%/5%/1% level is marked by \*\*/\*/. Sample selection correction is achieved according to Wooldridge (2010). Cragg-Donald  $F$ -stat. is the  $F$ -statistic for weak instruments. The critical value of the Cragg-Donald  $F$ -statistic taking heteroskedasticity as well as clustered standard errors into account is 19.93. Overidentification stat. is the test statistic of the Hansen- $J$  test on instrument validity. Endogeneity stat. is the  $\chi^2$ -statistic of the Durbin-Wu-Hausman test on the endogeneity of *modified duration gap*. Adj.  $GR^2$  is the adjusted generalised  $R^2$  of Pesaran and Smith (1994).

Table 10: Extent of Interest Rate Swap Use - Simultaneous Time-Series Models

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
	<i>Panel A</i>				<i>Panel B</i>			
Modified duration gap	1.554*** (0.3632)	1.304*** (0.3597)	1.035*** (0.3609)	1.499*** (0.4060)	1.477*** (0.3761)	1.283*** (0.3658)	0.979*** (0.3617)	1.441*** (0.4117)
Probability of default (ln)	0.024 (0.0303)	-0.009 (0.0282)	-0.066 (0.0584)	-0.005 (0.0379)	0.053 (0.0345)	0.015 (0.0307)	-0.059 (0.0524)	0.019 (0.0389)
Size	1.558*** (0.4153)	1.366*** (0.4118)	0.933** (0.4378)	1.878*** (0.5360)	1.784*** (0.3980)	1.785*** (0.4094)	1.049*** (0.4085)	2.293*** (0.5192)
Total asset growth	-0.425 (0.4729)	0.209 (0.5070)	-1.667*** (0.6208)	-0.515 (0.6655)	0.072 (0.4867)	0.621 (0.5033)	-2.004*** (0.5430)	-0.149 (0.6601)
Savings deposits	-0.062 (0.6801)	0.121 (0.7146)	1.006 (1.2158)	1.097 (0.9627)	1.173 (0.7603)	0.953 (0.7658)	1.264 (1.2240)	2.039** (1.0379)
Liquid assets	0.105 (0.2464)	-0.064 (0.2465)	0.052 (0.3625)	-0.085 (0.2776)	-0.033 (0.2358)	-0.157 (0.3350)	-0.043 (0.3350)	-0.207 (0.2638)
Branch HHI	-0.029* (0.0155)	-0.008 (0.0151)	-0.097*** (0.0328)	-0.030 (0.0204)	-0.011 (0.0125)	0.005 (0.0125)	-0.077*** (0.0125)	-0.007 (0.0163)
Past swap experience	2.796*** (0.4153)	0.670*** (0.2551)	1.005*** (0.3480)	0.588*** (0.1269)	2.498*** (0.3938)	0.717*** (0.0765)	1.054*** (0.3553)	0.464*** (0.1260)
Dummy trading book	0.023 (0.2545)			0.003 (0.3967)	-0.076 (0.2523)			-0.072 (0.4056)
Inverse Mills ratio	1.648*** (0.3313)	-0.024 (0.1938)		-0.098 (0.1409)	1.390*** (0.3162)			-0.345*** (0.1320)
Yield curve slope					0.068*	0.072*	0.073	0.090*
Yield curve slope x 1-year interest rate					(0.0372)	(0.0385)	(0.0532)	(0.0458)
					-0.137*** (0.0230)	-0.075** (0.0297)	-0.086** (0.0427)	-0.050 (0.0392)
Time dummies	YES	YES	YES	YES	NO	NO	NO	NO
Adj. $GR^2$	0.301	0.129	0.461	0.151	0.293	0.120	0.455	0.145
Cragg-Donald $F$ -stat.	25.917	25.843	19.659	20.072	23.862	25.960	16.512	18.820
Overidentification stat.	0.213	0.022	1.095	1.147	0.022	0.046	1.283	0.345
$p$ -val.	0.645	0.882	0.295	0.284	0.881	0.830	0.257	0.557
Endogeneity stat.	23.225	10.293	8.838	12.891	18.588	7.888	7.888	11.939
$p$ -val.	0.000	0.001	0.003	0.000	0.000	0.003	0.005	0.001
	<i>Panel C</i>				<i>Panel D</i>			
Modified duration gap	1.679*** (0.4115)	1.327*** (0.3976)	1.054*** (0.3625)	1.730*** (0.4784)	1.718*** (0.4231)	1.344*** (0.4057)	1.053*** (0.3595)	1.714*** (0.4799)
Probability of default (ln)	0.056 (0.0397)	0.026 (0.0385)	-0.074 (0.0518)	0.058 (0.0477)	0.047 (0.0405)	0.016 (0.0390)	-0.073 (0.0523)	0.045 (0.0477)
Size	1.427*** (0.3620)	1.272*** (0.3614)	0.950*** (0.4035)	1.855*** (0.5153)	1.594*** (0.3804)	1.445*** (0.3697)	0.944*** (0.3984)	1.978*** (0.5141)
Total asset growth	-0.089 (0.5325)	0.198 (0.5357)	-1.976*** (0.5777)	-0.443 (0.7263)	-0.475 (0.5175)	-0.021 (0.5233)	-1.952*** (0.5695)	-0.583 (0.7270)
Savings deposits	1.115 (0.8312)	0.748 (0.8094)	0.860 (1.2710)	2.120* (1.1654)	0.535 (0.7909)	0.456 (0.7916)	0.899 (1.2800)	1.886 (1.1552)
Liquid assets	-0.113 (0.2427)	-0.212 (0.2565)	0.044 (0.3419)	-0.069 (0.3007)	0.020 (0.2665)	-0.146 (0.2729)	0.047 (0.3468)	-0.063 (0.3060)
Branch HHI	-0.022* (0.0121)	0.005 (0.0126)	-0.083*** (0.0235)	-0.006 (0.0174)	-0.015 (0.0125)	0.007 (0.0131)	-0.083*** (0.0233)	-0.005 (0.0173)
Past swap experience	2.572*** (0.4224)	0.431* (0.2383)	1.022*** (0.3518)	0.478*** (0.1289)	2.670*** (0.4486)	0.461* (0.2436)	1.022*** (0.3524)	0.474*** (0.1295)
Dummy trading book	-0.008 (0.2553)			0.017 (0.4145)	-0.014 (0.2587)			0.003 (0.4146)
Inverse Mills ratio	1.511*** (0.3458)	-0.181 (0.1780)		-0.199 (0.1401)	1.579*** (0.3669)	-0.164 (0.1841)		-0.221 (0.1438)
Yield curve slope					-0.078**	0.000	-0.002	0.038
LIBOR spread	0.549*** (0.0786)	0.359*** (0.0674)	0.368*** (0.0966)	0.369*** (0.0831)	0.611*** (0.0643)	0.455*** (0.0582)	0.352*** (0.0939)	0.484*** (0.0725)
Yield curve slope x LIBOR spread	0.044 (0.0427)	0.098** (0.0424)	-0.015 (0.0688)	0.128** (0.0570)				
Time dummies	NO	NO	NO	NO	NO	NO	NO	NO
Adj. $GR^2$	0.295	0.124	0.456	0.152	0.294	0.123	0.456	0.150
Cragg-Donald $F$ -stat.	21.097	22.209	14.980	14.869	20.374	21.539	14.816	14.768
Overidentification stat.	0.272	0.706	1.024	0.029	0.222	0.667	1.008	0.037
$p$ -val.	0.602	0.401	0.312	0.865	0.638	0.414	0.315	0.847
Endogeneity stat.	20.395	8.011	8.570	14.122	20.626	8.031	8.555	13.682
$p$ -val.	0.000	0.005	0.003	0.000	0.000	0.005	0.003	0.000
Observations	7,399	5,725	1,701	3,880	7,399	5,725	1,701	3,880
Banking group dummies	YES	YES	YES	YES	YES	YES	YES	YES

Dependent variable: *extent of interest rate swap use*. All regressions are 2SLS regressions according to the sample selection correction of Semykina and Wooldridge (2010) with *modified duration gap* being instrumented with the *customer loans* and *loan commitments*. For brevity the coefficients of the explanatory variables are not displayed. Tests of sample selection have also been conducted according to Semykina and Wooldridge (2010) but results are not displayed. Standard errors in parentheses are clustered at bank level and are corrected for potentially small sample size. Significance at the 10%/5%/1% level is marked by \*/\*\*/\*\*\*. Cragg-Donald  $F$ -stat. is the  $F$ -statistic for weak instruments. The critical value of the Cragg-Donald  $F$ -statistic taking heteroskedasticity as well as clustered standard errors into account is 16.38. Overidentification stat. is the test statistic of the Hansen- $J$  test on instrument validity. Endogeneity stat. is the  $\chi^2$ -statistic of the Durbin-Wu-Hausman test on the endogeneity of Modified duration gap. Adj.  $GR^2$  is the adjusted generalised (within)  $R^2$  of Pesaran and Smith (1994).

Table 11: Summary Hausman Tests

Dependent variable	Modified duration gap		Dummy interest rate swap use			Extent of interest rate swap use	
	Total	Starters	Total	Trading	Starters	Total	Starters
Sample							
<i>Explanatory Variable</i>							
Maturity gap			endog.	exog.	endog.	endog.	endog.
Dummy interest rate swap use	exog.	endog.					

This table summarizes the results of the Hausman-type tests of the exogenous variables in the simultaneous equations framework.

Table 12: Variable Description

Hazard rate model	
<i>Tier 1 capital ratio</i>	Tier 1 capital to total assets
<i>Total bank reserves</i>	Total reserves that qualify as equity to total assets
<i>Dummy reserve reduction</i>	Dummy taking the value 1 if <i>Total bank reserves</i> have been reduced
<i>Sector HHI</i>	Herfindahl index of credit portfolio concentration over 14 industry sectors
<i>Dummy hidden liabilities</i>	Dummy taking the value 1 if the bank avoided writing off assets
<i>ROE</i>	Return on equity calculated as operating income to equity
<i>Branch HHI</i>	Herfindahl index of bank branches per county averaged over all counties a bank runs branches
<i>Dummy savings banks</i>	Dummy taking the value 1 if bank is a savings bank
<i>Dummy cooperative banks</i>	Dummy taking the value 1 if bank is a cooperative bank
<i>LIBOR</i>	12 month LIBOR
<i>Regional GDP growth</i>	Real GDP growth at the state level
IRR management model	
Dependent variables:	
<i>Modified duration gap</i>	Calculated according to Appendix B
<i>Dummy interest rate swap use</i>	Dummy taking the value 1 if the bank used either interest rate or currency swaps once since 1998
<i>Extent of interest rate swap use</i>	ln of the nominal volume of interest rate swaps
Explanatory variables:	
<i>Probability of default (ln)</i>	ln of the probability of default derived from the hazard rate model
<i>Size</i>	ln of total assets
<i>Savings deposits</i>	Savings deposits to total assets
<i>Liquid assets</i>	Liquid assets to total assets
<i>Total asset growth</i>	Growth rate of total assets
<i>Dummy trading book</i>	Dummy that takes the value 1 if a bank is qualified according to the German Banking Act
<i>Inverse Mills ratio</i>	Inverse Mills ratio is calculated according to Wooldridge (2010) in cross-sectional and according to Semykina and Wooldridge (2010) in time-series models
<i>Customer loans</i>	Customer loans to total assets
<i>Loan commitments</i>	Loan commitments, excluding those for investment expenditure and real estate, to total assets
<i>Past swap experience</i>	Dummy that takes the value of 1 when a bank used either interest or currency swaps once in previous years since 1998. This variable is adjusted for mergers and assigns a 1 if one of two merging banks had swap experience.
<i>Avg. board experience</i>	Average experience measured in years of all board members. Experience encompasses all positions in banking where candidates need to be approved by the German Federal Financial Supervisory Authority BaFin.
<i>Yield curve slope</i>	The spread between the 10 year and the 1 year yield of German government bonds
<i>1-year interest rate</i>	The 1-year yield on German government bonds
<i>LIBOR spread</i>	The spread between the 12-month LIBOR and the 12-month German government yield