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Market timing, maturity mismatch, and risk management: evidence from the banking industry

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Non-technical summary

Banks are exposed to interest rate risk through their function of transforming short-term deposits into long-term loans. This interest rate risk is visible on the balance sheet as the maturity mismatch or duration gap (i.e., the difference between the average residual time to maturity of the assets and the liabilities). Financial intermediation theory stresses that this risk should be hedged, and banks should instead concentrate on managing credit risk. An easy way to eliminate interest rate risk is to use interest rate swaps for hedging purposes.

In our empirical study, we analyze both German universal banks' on-balance-sheet duration gap and off-balance-sheet interest rate swap use in a simultaneous equation framework using data from 2000-2011. We derive the following results for banks' interest rate risk management:

- German universal banks use on-balance-sheet adjustments of the duration gap and interest rate swaps as substitute strategies for managing their overall interest rate risk exposure.
- The cost of default makes banks take less risk on the balance sheet and hedge more of their risk off the balance sheet.
- Banks engage in selective hedging and take more interest rate risk when the yield curve is steep and term transformation is profitable, but they reduce their interest rate risk when interbank funding uncertainty makes them vulnerable to the closely associated liquidity risk.
- For banks with trading books, the decision to use interest rate swaps and the duration gap are statistically independent. For pure banking book intermediaries, the decision to use interest rate swaps depends on the maturity gap. Only banks that start using swaps for the first time make a simultaneous decision when they determine the magnitude of their duration gap and whether to use interest rate swaps. The extent of interest rate swaps being used always depends on the duration gap.

All in all, our results provide support for the maturity gap being largely determined by customers' liquidity preferences. Banks' willingness to offer borrowers the maturity they demand is supported by legal and institutional settings of the German financial system, especially the high degrees of creditor and proprietary rights as well as the conservative valuation of pledged collateral. The use of interest rate swaps is driven mainly by the attempt to comply with the current interest rate risk regulation in order to avoid regulatory actions.

Nicht-technische Zusammenfassung

Banken sind Zinsrisiken aufgrund ihrer Geschäftstätigkeit, kurzfristige Einlagen in langfristige Kredite zu transformieren, ausgesetzt. Das Zinsänderungsrisiko wird in der Bilanz über die Fristeninkongruenz bzw. den "Duration Gap" (d.h. den Unterschied zwischen der durchschnittlichen Restlaufzeit der Anlagen auf der Aktivseite und der Verbindlichkeiten auf der Passivseite der Bilanz) sichtbar. Die Theorie der Finanzintermediation hat vielfach hervorgehoben, Zinsrisiken zu hedgen und sich stattdessen auf das Management von Kreditrisiken zu fokussieren. Der Einsatz von Zins-Swaps ist eine einfache Möglichkeit, Zinsrisiken zu eliminieren.

In unserer empirischen Studie untersuchen wir mit einem Simultangleichungsmodell den bilanziellen Duration Gap zusammen mit dem außerbilanziellen Einsatz von Zins-Swaps für deutsche Universalbanken in den Jahren 2000 bis 2011. Im Hinblick auf das Zinsrisikomanagement deutscher Banken kommen wir zu den folgenden Aussagen:

- Es findet eine gleichzeitige aktive Steuerung des bilanziellen Duration Gap und des außerbilanziellen Einsatzes von Zins-Swaps statt.

- Mögliche Kosten eines Ausfalls lassen Banken mit einem vergleichsweise geringen Duration Gap operieren und vermehrt Zins-Swaps einsetzen.

- Banken betreiben ein selektives Hedging von Zinsrisiken in Abhängigkeit vom makroökonomischen Umfeld. Bei einer steilen Zinsstrukturkurve, d.h. wenn Fristentransformation besonders profitabel ist, werden höhere Zinsrisiken eingegangen. Letztere werden hingegen reduziert, wenn Unsicherheiten auf den Interbankenmärkten die Banken verstärkt dem (eng mit dem Zinsrisiko verbundenen) Liquiditätsrisiko aussetzten.

- Handelsbuch-Institute treffen die Entscheidung "Duration Gap vs. Verwendung von Zins-Swap" unabhängig voneinander. Bei reinen Bankbuch-Instituten hingegen wird lediglich die Entscheidung über den Einsatz von Zins-Swaps vom Umfang des Duration Gaps getrieben; lediglich Banken, welche erstmalig Zins-Swaps nutzen, treffen beide Entscheidungen gemeinsam. Das Volumen der gehaltenen Zins-Swaps wird dahingegen immer in Abhängigkeit vom bilanziellen Duration Gap festgelegt.

Zusammenfassend zeigen unsere Ergebnisse, dass der Duration Gap primär durch die Liquiditätspräferenzen der Kunden beeinflusst wird. Die Bereitschaft der Banken, ihren Kunden Kredite mit der gewünschten Laufzeit anzubieten, wird durch zentrale Charakteristika des deutschen Rechts- und Bankensystems begünstigt. Hierzu zählen insbesondere Gläubiger- und Eigentumsrechte sowie die konservative Bewertung hinterlegter Sicherheiten. Die Entscheidung zum Einsatz von Zins-Swaps ist hingegen überwiegend durch das Befolgen der geltenden Zinsrisiko-Regulierung getrieben, um hierdurch gleichzeitig auch Maßnahmen der Aufsicht zu vermeiden.

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

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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. A higher likelihood of bank distress makes banks reduce their on-balance sheet interest rate exposure and simultaneously intensify their swap use. Exogeneity tests indicate that both decisions are only endogenous to each other for banks that start using swaps for the first time. For other banks, the maturity gap is endogenous to the decision to use swaps, but the reverse relationship is exogenous. For banks with trading activity, both decisions are exogenous to each other. 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

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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 their IRR, almost no bank will hedge its IRR exposure completely (e.g., Landier, Sraer, and Thesmar, 2013). 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 expected profitability of maturity or term transformation, which we will use interchangeably. A on average 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.[1] 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.

Therefore, the question arises as to what determines banks' IRR management decisions? To answer this question, we investigate German universal banks' IRR management between 2000 to 2011 by simultaneously estimating their maturity mismatch and interest rate swap activities. Our empirical approach relates 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 universal 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

[1] 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.

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 (2007) examined. We find that buffer stocks of liquid assets have indeed a differing impact on the propensity to use interest rate swaps for hedging purposes. In the U.S. they serve as substitutes whereas German universal banks seem to consider them complementary hedging strategies.

We test the endogeneity assumptions underlying the simultaneous equations framework and cannot reject for banks with a trading book that both, the maturity gap and the decision to use interest rate swaps are exogenous to each other. 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 the first time both variables are found to be endogenous to each other. 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 its overall exposure and will likely do so by using interest rate swaps. Only in these circumstances, the maturity gap and the decision to hedge are endogenous to each other. 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 exogenous. 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 suggests 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, Scharfstein, and Stein (1993) endogenize the cost of financial distress by assuming external capital to be more expensive than internally generated funds. In support of their model, Brewer, Jackson, and Moser (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 (2014) show — for the same sample of German universal banks we 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. In contrast to the papers that show that banks use interest rate swaps predominately for hedging purposes, Begenau, Piazzesi, and Schneider (2013) prove that the largest four U.S. banks that serve as swap dealers used their swap positions to increase their exposure to IRR.

Bolton, Chen, and Wang (2011) 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.[2]

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 managers have an information advantage, but sum

[2]The model of Bolton et al. (2011), however, incorporates equity market timing through the issuance of new shares, and not debt market or derivatives market timing.

up to zero otherwise.

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, Minton, and Schrand (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 Regression Design

If banks manage their overall IRR exposure, — the composite on- and off-balance sheet exposure — decisions on the maturity mismatch and on the use of interest rate swaps are jointly determined. We therefore follow Purnanandam (2007) in estimating these decisions simultaneously using 2SLS IV regressions in order to overcome endogeneity and the resulting simultaneity bias of OLS coefficients. In line with most of the risk management literature, we separate the decision to hedge from the extent of derivative use by estimating a Cragg (1971) model. The model follows a two-step procedure, and investigates first which determinants drive the decision to use interest rate derivatives. In the subsequent step it examines the drivers of the extent of derivatives use conditional on a positive decision to use derivatives. The decision to hedge corresponds to a dummy variable that takes the value of 1 if a bank reports a non-zero volume of interest rate swaps outstanding. Although interest rate swaps are only one out of several derivatives a bank can use to offset IRR, they are the most common ones to hedge IRR. As information on interest rate swaps is available at the highest quality, we exclusively focus our IRR hedging analysis on the use of interest rate swaps. The extent of hedging is modeled as the natural logarithm of the nominal volume of interest rate swaps outstanding to total assets. The potential sample selection bias arising from conditioning the sample to banks that decide to use interest rate swaps is controlled for by including 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.

To estimate the simultaneous equation system exclusion restrictions are required.

Valid IVs are allowed to influence only one of the two risk management decisions, either the on-balance-sheet or the off-balance-sheet decision. We use two instruments for each equation and provide overidentification tests to support the validity of the IVs. With strong and valid instruments at hand, we test the endogeneity assumed in the simultaneous equation framework, using endogeneity tests based on the C statistic, which is defined as the difference in overidentification J-tests derived from 2SLS models.[3]

We will use the following instruments in the risk management equations and justify their use extensively in Section 3.2. 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 the extent of their use we include *Past swap experience* as a dummy variable that equals 1 from the point in time a bank has first started to use swaps. To create this variable we use data starting in 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 the extent of their use. 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 if a bank avoids writing off assets. This gives 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 subscripts indicating bank or time units are left out for simplicity. DG stands for the (modified) duration gap, SU is the dummy of the swap use decision, and SE represents the extent of interest rate swap use, proxied by the logarithm of the nominal volume of interest rate 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 $BExp$ is 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 explanatory variables that influence all risk management decisions including the *Probability of default* (PD).

For the duration gap and the extent of swap use equations we exploit both the cross-sectional and the time-series variation. The cross-sectional variation is captured applying both, between effects and Fama-MacBeth estimators. The results are then compared to those from pooled OLS models to evaluate the impact of a potential bias. The time-series variation is investigated applying the within transformation of a fixed effects estimator. When modelling 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 use,

[3] The C statistic can be computed for clustered standard errors, whereas the Hausman test is calculated under homoskedasticity. For probit models we use the endogeneity test of Lee (1992) but linear probability models using the C-statistic confirm our results.

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 understood as market views on IRR drivers being 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 in general, small, locally operating savings and cooperative banks have homogeneous business models with a focus on granting loans and accepting deposits, providing them thereby with comparably stable on-balance-sheet exposures. Evidence is provided by Memmel (2008) and Entrop, Memmel, Ruprecht, and Wilkens (2012) who explain the majority of banks' interest income and expenses using revolving portfolios based on the assumption that on-balance exposure remains stable via replacement of maturing assets and liabilities with new business of equal maturity. The results of Memmel and Schertler (2014) provide further support for the on-balance-sheet exposure being comparatively stable among German banks.

Additionally, small universal banks are also more likely not to engage in trading activities and most of them only have a banking book and no trading book. Pure banking book institutions are prohibited from using OBS instruments for speculation purposes to a substantial extent.[4] In analyzing only pure banking book institutions, we thus have a setting similar to Chernenko and Faulkender (2011) for which the constant on-balance exposure assumption and hence the interpretation of cross-sectional and time-series estimators seems justified. 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 for the sub-sample of trading book banks. The latter not only have more exposure to market risk, but they may also use interest rate swaps for speculation which goes beyond the market timing of risk management activities. For example, Begenau et al. (2013) show that the four largest U.S. banks use interest rate swaps to increase their IRR exposure instead of hedging it. Furthermore, banks might use trading activities to shift risks, which harms traditional relationship banking (Boot and Ratnovski, 2013).

3.2 Exclusion Restrictions

In the following we draw on the literature to justify the use of the instruments we introduced above.

Instruments to identify the probability of default:

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 de-

[4]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 universal banks in Germany, even of the small cooperative banks. See Table 2 for details.

terminant. However, the cost of bankruptcy and the resulting financial constraints are endogenous to risk management decisions (e.g., Froot et al., 1993; Bolton et al., 2011). Although the variables we use in the hazard rate model are not identical to those in the risk management regressions, many of the variables that explain a bank's default are also drivers of its risk management decisions and hence 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,[5] — 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, Ma, and Song (2013a,b) observe that accounting conservatism[6] reduces subsequent corporate bankruptcy risk through restricted earnings management and higher cash reserves, as well as by directly reducing operating cash flow downside risk. 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, there should be no further effect of hidden liabilities on the risk management decisions other than through operating cash flow downside risk, which should be correlated with the PD estimates.

Instruments to identify the maturity gap equation:
The maturity gap, especially for 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 these banks to reduce the on-balance-sheet exposure (Ehrmann and Worms, 2004). Instrument validity is given when the only impact *Customer loans* have on interest rate swap use emanates from the IRR they add to the modified duration 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 create a loan commitment proxy that is likely to be dominated by floating-rate agreements. Our definition excludes long-term commitments for investment expenditures and real estate loans, but includes household and corporate lines of credit that are more likely to be short-term floating-rate agreements.[7]

[5]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.

[6]Accounting conservatism is considered to be a prudent reaction to risk and uncertainty and their adequate disclosure in accounting statements. Unconditional conservatism is the effect of accounting principles per se. Conditional conservatism relates to more timely recognition of negative corporate outcomes.

[7]Davydenko and Franks (2008) present summary statistics from major German commercial banks' defaulted corporate borrowers. 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.

The literature offers additional arguments why undrawn loan commitments might have a direct impact on banks' balance sheets. Kashyap, Rajan, and Stein (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, Espinosa-Vega, Frame, and Miller (2005) find that corporates drawing loans under commitment receive loans with no different maturity if they are high-risk firms. On the other hand, high-risk corporates not drawing under commitment receive only loans with significantly lower maturity. Loan commitments, especially (revolving) lines of credit, are means of acquiring soft information on borrowers out of relationship lending[8] and provide monitored liquidity insurance that prevents borrowers' illiquidity seeking (Acharya, Almeida, Ippolito, and Perez, 2014). Undrawn loan commitments can, therefore, have a direct effect on the existing maturity gap via the information collected in the past from relationship lending, intensified monitoring upon frequent renewal, and the liquidity hedge deposits offer.

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 instrumental variable. More precisely, he uses 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.[9]

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 in Fleming, Jackson, Li, Sarkar, and

[8]See, for example, Berger and Udell (1995); Jiménez, Lopez, and Saurina (2009); Norden and Weber (2010), and specifically for German banks screening for bankruptcy risk, Davydenko and Franks (2008).

[9]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.

Zobel (2012) support these statements. Although 10-year and 30-year interest rate 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.[10] 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.

3.3 Common Control and Market Timing Variables

Our bank-specific explanatory variables are consistent with those used in the study by Purnanandam (2007). *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) by 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.[11] The model derived by Adam, Dasgupta, and Titman (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

[10] 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.

[11] 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.

and private 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 *EURIBOR spread*, the difference between the 12-month EURIBOR and the 12-month 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).[12]

4 Data and Summary Statistics

4.1 Data

We use data from 2000 to 2011 in our simultaneous risk management framework. We chose the start date of the analysis in accordance with 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.

To cope with outliers, we windsorize 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 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 to 2011. Although the absolute number of banks reporting interest rate swap use increases only slightly from 599 to 677, 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 2003 and 2007, but slowed thereafter. A clear relation between a bank's size and the use of interest

[12] For an overview of the variables used in the empirical study, including those in the hazard rate model, see Appendix A.

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	599	29.25	11.83	28.13	43.10	41.95	64.81
2001	1,901	552	29.04	7.92	25.53	38.59	43.43	69.64
2002	1,783	527	29.56	6.55	24.03	35.92	45.52	69.30
2003	1,659	519	31.28	7.63	25.96	37.50	46.52	70.24
2004	1,646	576	34.99	8.03	30.31	38.24	50.36	72.34
2005	1,597	577	36.13	7.82	28.99	38.41	56.02	73.31
2006	1,579	669	42.37	9.00	36.36	45.83	61.82	78.09
2007	1,548	710	45.87	10.26	39.58	51.61	64.10	80.71
2008	1,494	701	46.92	10.86	34.77	51.68	65.11	83.83
2009	1,446	682	47.16	12.34	32.43	46.50	64.93	85.71
2010	1,442	682	47.30	12.54	31.80	45.89	61.57	85.22
2011	1,377	677	49.16	12.00	31.64	49.64	65.82	86.59
Total	19,520	7,471	38.27	9.48	30.42	43.47	55.61	77.38

This table presents the distribution of German universal banks' use of interest rate swaps according to size quintiles between 2000 to 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.

rate swaps is observable. Whereas in the lowest size quintile 12% of banks hold interest rate swaps in 2011, the percentage increases gradually and peaks at the highest quintile at more than 86%.

Interestingly, the current share of interest rate swap users is close 50%, which corresponds to 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 universal 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.

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 indeed a higher modified duration gap. The mean difference is 0.14 and 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 universal 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.

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.[13] The hazard rate model is estimated using default events from 1994 to 2011. 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 indicators into the dependent variable dummy: forced closures, restructuring mergers, and 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 the 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.[14]

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), 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

[13] 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 (2013) 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.

[14] 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).

Table 2: Summary Statistics

	Swap Users		Non-Swap Users		Group Differences		p-values	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Hazard Rate Model								
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
IRR Simultaneous Equations								
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	11.000	13.63	13.000	-2.029	-2.000	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	0.000	3.096	0.000	16.816	0.000	0.000	0.000

This table presents descriptive statistics of German universal banks between 2000 to 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.

and De Nicoló (2005) show that the effect of competition on bank risk taking depends on borrowers' reaction to 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 if 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 EURIBOR* 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 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, Ongena, Peydró, and Saurina, 2014).

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 hidden liabilities* in the risk management regressions of Section 6 — using defaults as the only variable to be instrumented in a linear probability model — we receive weak instrument statistics which are always above the rule of thumb threshold of 10. Except for the extent of swap use time-series equation the Kleibergen-Paap F-statistic is also above the critical threshold of 16.38 Stock and Yogo (2005) calculated for the Cragg-Donald F-statistic received under the assumption of i.i.d. standard errors for a 10% maximal size distortion of the 2SLS estimator. Although no critical values for the Kleibergen-Paap statistic with clustered standard errors exist, the F-statistics are in general of conveniant magnitude to conclude that hidden liabilities are an instrument strong enough to estimate a PD that is exogenous to the risk management decisions. In further regressions where both, the actual default and the decision to use swaps or the maturity gap are considered endogenous and are therefore instrumented, we cannot reject tests of overidentifying restrictions with the null of valid instruments 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. Furthermore, we provide in the column on the right to the Kleibergen-Paap statistics also the Angrist-Pischke statistic when the effect of the other two instruments is partialled out. Again, these statistics

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 EURIBOR	-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	
Kleibergen-Paap (Angrist-Pischke) F-stat. Duration Gap Pooled	86.80	47.79
Kleibergen-Paap (Angrist-Pischke) F-stat. Duration Gap FE	29.04	14.58
Kleibergen-Paap (Angrist-Pischke) F-stat. Swap Use Pooled	26.78	38.41
Kleibergen-Paap (Angrist-Pischke) F-stat. Swap Extent Pooled	34.22	16.28
Kleibergen-Paap (Angrist-Pischke) F-stat. Swap Extent Time Series	11.08	7.47
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 */**/***. Kleibergen-Paap and Angrist-Pischke 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. Angrist-Pischke statistics are the F-statistics when the impact of the other two instruments has been partialled out. Kleibergen-Paap 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 (Angrist, 2001). 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.

confirm the strength of hidden liabilities as an instrument to identify the PD, except for the time-series equation of the extent of swap use. As we are 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 thus there exists no ex ante mechanical relation between the PDs derived and IRR management.

6 Simultaneous Interest Rate Risk Management

We present and discuss the results of the three equations in the simultaneous model — estimated using two-stage least squares (2SLS) — in different tables. Standard errors are either clustered at bank level or bootstrapped. Results for cross-sectional models are presented as between effects as well as pooled IV models. In Table 4 and 5 we provide support that pooled models for the modified duration gap and the extent of interest rate swap use derive coefficients quite similar to Fama-MacBeth models when all explanatory variables are considered exogenous. In contrast to the Fama-MacBeth method, pooled 2SLS offers a rich variety of test statistics for the IVs and corrects standard errors for the fact that the endogenous variables have been instrumented in the first stage.

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, universal 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. The economic magnitude of these coefficients is quite substantial. In the pooled OLS setting switching from a non-swap user to a user increases the modified duration gap on average by 0.2 standard deviations (sd), for pure banking book institutions by 0.19 sd, and for trading book banks by even 0.47 sd. 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, and confirm previous results from Memmel and Schertler (2014).

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

	Between effects			Fama-MacBeth			Pooled OLS		
	Total sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book
Dummy interest rate swap use	0.143***	0.104***	0.417***	0.115***	0.0981***	0.373***	0.114***	0.096***	0.247***
	(0.0268)	(0.0271)	(0.1177)	(0.0120)	(0.0138)	(0.00931)	(0.0193)	(0.0199)	(0.0685)
Probability of default (ln)	-0.048***	-0.051***	-0.069***	-0.0127**	-0.0127**	-0.0592***	-0.013**	-0.013**	-0.043**
	(0.0058)	(0.0061)	(0.0200)	(0.00512)	(0.00531)	(0.0109)	(0.0056)	(0.0059)	(0.0173)
Size	0.064***	0.080***	-0.114***	0.0376***	0.0425***	-0.201***	0.040***	0.045***	-0.060*
	(0.0118)	(0.0129)	(0.0337)	(0.00226)	(0.00447)	(0.00795)	(0.0134)	(0.0136)	(0.0354)
Total asset growth	-0.685	-1.295***	1.708	-1.166***	-1.453***	0.923***	-0.988***	-1.317***	0.846**
	(0.4674)	(0.4098)	(1.1546)	(0.241)	(0.277)	(0.259)	(0.1834)	(0.1929)	(0.3915)
Savings deposits	-1.168***	-0.987***	-3.323***	-0.635***	-0.426***	-1.868***	-0.740***	-0.548***	-2.643***
	(0.2175)	(0.2095)	(0.7623)	(0.0723)	(0.0658)	(0.189)	(0.1852)	(0.1799)	(0.6825)
Liquid assets	-0.690***	-0.701***	-0.244	-0.783**	-0.868**	-0.150	-0.473***	-0.481***	-0.154
	(0.1290)	(0.1414)	(0.3543)	(0.260)	(0.296)	(0.116)	(0.0924)	(0.0978)	(0.2396)
Branch HHI	0.005***	0.004**	0.004	0.00748***	0.00641***	0.0159***	0.006***	0.005**	0.012*
	(0.0016)	(0.0018)	(0.0063)	(0.00126)	(0.00145)	(0.00287)	(0.0020)	(0.0020)	(0.0065)
Loan commitments	23.563***	23.173***	17.622**	13.79***	13.57***	16.91***	14.360***	14.116***	8.483*
	(2.4511)	(2.7454)	(7.5005)	(0.853)	(0.867)	(0.483)	(1.8212)	(1.7968)	(4.6977)
Customer loans	0.634***	0.487***	1.907***	0.899***	0.682***	2.761***	1.025***	0.838***	2.369***
	(0.1294)	(0.1114)	(0.4095)	(0.132)	(0.137)	(0.182)	(0.1283)	(0.1262)	(0.3423)
Dummy trading book	-0.159***			-0.0815***			-0.093*		
	(0.0463)			(0.0205)			(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^2	0.423	0.347	0.725	0.385	0.327	0.606	0.398	0.350	0.636

Dependent variable: *modified 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 standard errors clustered at the 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 sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book
Modified duration gap	0.032	0.110*	-0.211*	0.065	0.184**	-0.165*	0.026	0.143**	-0.185**
	(0.0528)	(0.0654)	(0.1080)	(0.1038)	(0.0809)	(0.0775)	(0.0517)	(0.0644)	(0.0856)
Probability of default (ln)	0.087***	0.035*	0.084*	0.153***	0.098***	0.146***	0.136***	0.080***	0.122***
	(0.0140)	(0.0193)	(0.0434)	(0.0063)	(0.0153)	(0.0218)	(0.0170)	(0.0205)	(0.0332)
Size	0.447***	0.213***	0.497***	0.471***	0.261**	0.465***	0.414***	0.162***	0.467***
	(0.0421)	(0.0770)	(0.0767)	(0.0515)	(0.1109)	(0.0211)	(0.0384)	(0.0585)	(0.0475)
Total asset growth	2.772***	2.812**	1.665	1.101	1.192	0.605	0.630	0.891*	0.378
	(1.0056)	(1.2497)	(2.1721)	(0.6968)	(0.6707)	(0.4330)	(0.4053)	(0.4706)	(0.8338)
Savings deposits	-1.686***	-1.685***	-0.564	-0.920**	-0.621**	-0.857	-1.075**	-0.716	-1.019
	(0.5222)	(0.6434)	(1.6073)	(0.4062)	(0.2673)	(0.7458)	(0.4838)	(0.5357)	(1.0815)
Liquid assets	-0.859***	-0.660*	-1.033	-1.030*	-0.903	-1.116*	-0.629***	-0.383*	-1.033**
	(0.2580)	(0.3431)	(0.6454)	(0.5119)	(0.5083)	(0.5278)	(0.2020)	(0.2058)	(0.4750)
Branch HHI	-0.002	0.001	0.020	0.001	0.006**	-0.003	-0.001	0.005	-0.006
	(0.0054)	(0.0055)	(0.0147)	(0.0018)	(0.0022)	(0.0065)	(0.0054)	(0.0053)	(0.0150)
Past swap experience	2.154***	1.524***	0.268	2.232***	1.699***	0.986***	1.677***	1.009***	0.942**
	(0.2515)	(0.3884)	(1.1297)	(0.3474)	(0.4458)	(0.2817)	(0.2076)	(0.2252)	(0.4758)
Dummy trading book	0.648***			0.525***			0.483***		
	(0.1159)			(0.0506)			(0.1052)		
Inverse Mills ratio	0.946***	0.446*	-1.044	1.022***	0.627*	-0.468**	0.578***	0.083	-0.596*
	(0.1754)	(0.2685)	(0.7208)	(0.2656)	(0.3422)	(0.2027)	(0.1563)	(0.1716)	(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^2	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 standard errors clustered at the 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 */**/***.

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 banks to take less IRR. Again, this effect is most pronounced for trading book institutions. A one sd change in the PD decreases the modified duration gap by 0.04 sd for non-trading book banks, and by 0.13 sd 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), the coefficients found might reflect the effect of risk taking on the cost of external finance, as documented 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. Both, asset and funding liquidity induce banks to engage in less maturity transformation. This finding is not surprising for liquid assets as a substantial portion of these assets have a 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.

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.[15] Past swap experience and the average board experience have high explanatory power for the interest rate swap use dummy. The F-statistics are always larger than 10 and also exceed the Stock and Yogo (2005) threshold of 19.93 for the Cragg-Donald statistics for a 10% maximal size distortion calculated under homoscedastic standard errors. Overidentification tests under the joint null that the model is correctly specified and that instruments are exogenous cannot be rejected at a 10% level. Interestingly, the endogeneity test statistics show that the null of interest rate swap use being exogenous to the magnitude of the maturity gap cannot be rejected at levels always above a p-value of 25% for all three samples. Hence, the results derived are quite similar to pooled OLS models

[15] Using fitted values from a first-stage probit model as instruments — as described in Wooldridge (2010) — does not change the results qualitatively. This holds for all other regression models, both cross-sectional and time-series. However, this approach would not allow a test for overidentification.

that take the decision to employ interest rate swaps as exogenous.

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 insignificant, 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 structural parameter of 0.15, corresponding to a 0.24 sd increase of the duration gap when a bank switches from being a non-user to a user, and significant at the 1% level. As the majority of banks, around two-thirds, do not change their swap use status once during the sample period, and either never use swaps or do 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 signs 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 induces non-trading book institutions to take on less risk, the opposite holds for trading book banks.

The macroeconomic variables confirm the 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 (2014). 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. (2014) find that short-term instead of long-term rates matter for banks' risk taking. 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 EURIBOR over the 1-year government rate (Panel C and D). However, when interbank uncertainty arises contemporaneously with a steep yield curve, banks decrease

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***	0.119**	0.646***	0.154***	0.131***	0.484***
	(0.0491)	(0.0534)	(0.2166)	(0.0481)	(0.0501)	(0.1574)
Probability of default (ln)	-0.049***	-0.051***	-0.088***	-0.014**	-0.013**	-0.054***
	(0.0061)	(0.0057)	(0.0199)	(0.0056)	(0.0059)	(0.0183)
Size	0.061***	0.077***	-0.245***	0.033**	0.038**	-0.221***
	(0.0133)	(0.0150)	(0.0286)	(0.0158)	(0.0162)	(0.0279)
Total asset growth	-0.678	-1.286***	1.724	-0.974***	-1.305***	1.064**
	(0.4301)	(0.4134)	(1.0803)	(0.1835)	(0.1932)	(0.4134)
Savings deposits	-1.163***	-0.982***	-2.826***	-0.731***	-0.540***	-1.944***
	(0.2408)	(0.2087)	(0.7623)	(0.1846)	(0.1790)	(0.6956)
Liquid assets	-0.687***	-0.699***	-0.326	-0.469***	-0.479***	-0.100
	(0.1359)	(0.1496)	(0.4197)	(0.0923)	(0.0977)	(0.2475)
Branch HHI	0.005**	0.004**	0.005	0.006***	0.005**	0.014**
	(0.0020)	(0.0021)	(0.0071)	(0.0020)	(0.0020)	(0.0065)
Loan commitments	23.516***	23.117***	26.046***	14.252***	14.007***	15.998***
	(2.7681)	(2.4296)	(7.6293)	(1.8286)	(1.8048)	(5.0454)
Customer loans	0.637***	0.490***	2.107***	1.028***	0.839***	2.713***
	(0.1170)	(0.1425)	(0.3539)	(0.1283)	(0.1262)	(0.3428)
Dummy trading book	-0.160***			-0.097**		
	(0.0561)			(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
Kleibergen-Paap 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 standard errors clustered at the bank level, respectively. Standard errors are corrected for potentially small sample size. Significance at the 10%/5%/1% level is marked by */**/***. Kleibergen-Paap F-stat. is the weak instruments statistic. Overidentification stat. is the test statistic of the Hansen-J test on instrument validity. Endogeneity stat. is the χ^2-statistic of the C-test 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).

their maturity mismatch less drastically as there are still profits to earn from maturity transformation (Panel D).

Again, the instruments swap use experience and average board experience are strong instruments, even in a time-series setting where variables have been demeaned in order to eliminate the time-invariant unobserved heterogeneity. Kleibergen-Paap statistics from the first-stage instrumentation process are again above the rule-of-thumb threshold, i.e., the F-statistic should exceed a value of 10, as well as above the critical threshold posted by Stock and Yogo (2005) for the size distortion derived from the Cragg-Donald statistic, which is 19.93 given a single endogenous variable being instrumented with two variables. Hansen-J tests of overidentification cannot reject the null of valid, exogenous instruments at a 10% level for all regressions and samples being run. The endogeneity tests of interest rate swap use cannot be rejected at a 10% level for the total, the non-trading book and the trading book sample, — as for the cross-sectional regression models — but exogeneity is rejected for the sample of starters. However, this finding depends on the macroeconomic covariates included and does not hold for Panel B where the yield curve slope and its intercation with the 1-year interest rate are included.

6.2 Interest Rate Swap Use Decision

In this section we analyze the determinants of 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 trading book institutions. In the baseline model the presented structural coefficients translate into an increase in the propensity to use interest rate swaps by 46%, 60%, 25%, and 28% given a 1 sd increase for the overall sample, pure banking book institutions, trading book banks, and starters, respectively. Therefore, the underlying on-balance IRR is a driver of high economic magnitude for the decision to use interest rate swaps.

The sign of the coefficient of the PD provides evidence for the predictions of risk management theory (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. The coefficient of 0.095 in the baseline model of Panel A corresponds to a 23% higher propensity to employ interest rate swaps given a one sd increase in the log of the PD. However, these banks might use interest rate swaps, at least partly, also for speculation purposes. 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 are the coefficients related to bank liquidity measures, for which Purnanandam

Table 7: Maturity Gap - Simultaneous Time-Series Models

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
			Panel A				*Panel B*	
Dummy interest rate swap use	0.001	-0.014	0.199	0.156***	0.050	0.034	0.247	0.094*
	(0.0466)	(0.0481)	(0.1617)	(0.0493)	(0.0467)	(0.0483)	(0.1634)	(0.0487)
Probability of default (ln)	-0.015***	-0.013**	-0.017	-0.055***	-0.051***	-0.054***	-0.032**	-0.050***
	(0.0056)	(0.0060)	(0.0152)	(0.0076)	(0.0049)	(0.0052)	(0.0143)	(0.0080)
Size	-0.464***	-0.513***	-0.215*	-0.180*	-0.303***	-0.348***	-0.105	-0.482***
	(0.0758)	(0.0847)	(0.1245)	(0.0952)	(0.0631)	(0.0713)	(0.1003)	(0.1066)
Total asset growth	-0.227**	-0.377***	0.659***	-0.613***	-0.527***	-0.662***	0.454*	-0.582***
	(0.0994)	(0.1069)	(0.2473)	(0.1549)	(0.0940)	(0.1016)	(0.2358)	(0.1632)
Savings deposits	-0.416***	-0.374***	-0.903**	-1.029***	-0.734***	-0.671***	-1.169***	-0.978***
	(0.1317)	(0.1377)	(0.3775)	(0.2010)	(0.1292)	(0.1350)	(0.3609)	(0.1943)
Liquid assets	-0.407***	-0.387***	-0.337***	-0.382***	-0.499***	-0.517***	-0.327**	-0.367***
	(0.0543)	(0.0597)	(0.1278)	(0.0740)	(0.0555)	(0.0613)	(0.1285)	(0.0749)
Branch HHI	0.004	0.001	0.021***	0.005	-0.005**	-0.009***	0.015**	-0.001
	(0.0030)	(0.0031)	(0.0070)	(0.0045)	(0.0026)	(0.0027)	(0.0060)	(0.0038)
Loan commitments	4.758***	5.117***	3.091*	5.850***	5.805***	6.409***	3.279*	6.275***
	(1.0073)	(1.1317)	(1.8366)	(1.7551)	(0.9971)	(1.1324)	(1.8198)	(1.6707)
Customer loans	1.793***	1.700***	2.744***	1.438***	1.461***	1.319***	2.700***	1.551***
	(0.1395)	(0.1443)	(0.3955)	(0.2456)	(0.1396)	(0.1426)	(0.4098)	(0.2387)
Dummy trading book	-0.006			0.022	0.042			0.070
	(0.0532)			(0.0669)	(0.0531)			(0.0636)
Yield curve slope					0.079***	0.078***	0.087***	0.071***
					(0.0061)	(0.0065)	(0.0177)	(0.0096)
Yield curve slope x 1-year interest rate					-0.038***	-0.038***	-0.045***	-0.041***
					(0.0048)	(0.0051)	(0.0130)	(0.0080)
Adj. GR^2	0.248	0.264	0.231	0.213	0.157	0.157	0.210	0.164
Kleibergen-Paap 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

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Table 7 continued: Maturity Gap - Simultaneous Time-Series Models

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
			Panel C				*Panel D*	
Dummy interest rate swap use	0.102**	0.093*	0.265	0.159***	0.100**	0.089*	0.257	0.160***
	(0.0475)	(0.0493)	(0.1670)	(0.0501)	(0.0474)	(0.0492)	(0.1682)	(0.0497)
Probability of default (ln)	-0.069***	-0.072***	-0.042***	-0.070***	-0.071***	-0.073***	-0.049***	-0.072***
	(0.0046)	(0.0049)	(0.0133)	(0.0073)	(0.0045)	(0.0048)	(0.0131)	(0.0071)
Size	-0.146**	-0.156**	-0.084	-0.300***	-0.158**	-0.183**	-0.060	-0.311***
	(0.0644)	(0.0739)	(0.1029)	(0.1076)	(0.0637)	(0.0730)	(0.1013)	(0.1060)
Total asset growth	-0.637***	-0.761***	0.390	-0.638***	-0.557***	-0.673***	0.394*	-0.565***
	(0.0926)	(0.0999)	(0.2384)	(0.1567)	(0.0935)	(0.1013)	(0.2381)	(0.1595)
Savings deposits	-0.917***	-0.849***	-1.341***	-1.114***	-0.805***	-0.728***	-1.349***	-1.019***
	(0.1319)	(0.1381)	(0.3568)	(0.2009)	(0.1334)	(0.1389)	(0.3693)	(0.2056)
Liquid assets	-0.526***	-0.534***	-0.342***	-0.410***	-0.579***	-0.596***	-0.370***	-0.448***
	(0.0527)	(0.0578)	(0.1285)	(0.0706)	(0.0547)	(0.0603)	(0.1294)	(0.0729)
Branch HHI	-0.008***	-0.011***	0.012*	-0.004	-0.010***	-0.013***	0.010*	-0.005
	(0.0025)	(0.0027)	(0.0059)	(0.0038)	(0.0025)	(0.0027)	(0.0060)	(0.0038)
Loan commitments	6.383***	7.090***	3.546*	6.633***	5.992***	6.595***	3.585**	6.189***
	(1.0201)	(1.1613)	(1.8101)	(1.7259)	(1.0294)	(1.1732)	(1.8172)	(1.7378)
Customer loans	1.276***	1.104***	2.674***	1.311***	1.290***	1.127***	2.685***	1.321***
	(0.1439)	(0.1456)	(0.4239)	(0.2527)	(0.1441)	(0.1457)	(0.4297)	(0.2538)
Dummy trading book	0.024			0.049	0.022			0.048
	(0.0543)			(0.0687)	(0.0555)			(0.0696)
Yield curve slope					0.049***	0.049***	0.051***	0.041***
					(0.0046)	(0.0049)	(0.0142)	(0.0068)
EURIBOR spread	-0.085***	-0.090***	-0.040	-0.102***	-0.038***	-0.049***	0.060*	-0.063***
	(0.0113)	(0.0119)	(0.0333)	(0.0175)	(0.0119)	(0.0127)	(0.0312)	(0.0186)
Yield curve slope x EURIBOR spread	0.048***	0.041***	0.096***	0.041***				
	(0.0075)	(0.0081)	(0.0229)	(0.0115)				
Adj. GR^2	0.145	0.145	0.204	0.154	0.150	0.151	0.199	0.156
Kleibergen-Paap 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	2.132	1.894	1.079	6.126
p-val	0.110	0.122	0.261	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 */**/***. Kleibergen-Paap F-stat. is the weak instruments statistic. Overidentification stat. is the test statistic of the Hansen-J test on instrument validity. Endogeneity stat. is the χ^2-statistic of the C-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).

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., 2011). 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, significant at the 1% level in all samples and regression setups. Average board experience, on the other hand, reduces the likelihood of using 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. Our results suggest that experience does not seem to be an indicator for risk aversion.

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). 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).[16] Interbank funding uncertainty increases banks' likelihood of using interest rate swaps (Panel C and D). Interestingly, both the overall and aggregate sectoral — calculated separately for savings, cooperative, and private banks — interest rate swap use quotas are highly correlated with the EURIBOR spread. 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. Again, when uncertainty is accompanied by a steep yield curve making term transformation profitable, the effect of the EURIBOR spread becomes smaller (Panel D).

Customer loans and loan commitments are relevant instruments with Kleibergen-Paap F-statistics always above 10 and, again, also always above the size distortion threshold

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

of 19.93 reported by Stock and Yogo (2005) in the case of homoscedastic standard errors. Instrument validity is supported using overidentification tests that are insignificant at a 10% level for all samples being estimated. The exogeneity tests of Smith and Blundell (1986) only cannot be rejected at a 10% level for the sample of trading book institutions. This indicates that the maturity gap seems to be an exogenous driver of their decision to hold swaps, but exogeneity is rejected for all other samples, including the sub-samples of non-trading book banks and starters. However, for the starter sample the test statisic depends on the macroeconomic covariates included and decreases when the EURIBOR spread is included. For Panels C and D exogeneity can only be rejected at 9% and 7.3% level which is not too far from the 10% threshold usually employed.

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 for between effects and a pooled specification. For trading book banks, only three variables are found to be significant. These 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 the trading book bank samples than for the 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 for the trading book sub-sample should therefore be interpreted with caution.

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.

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., 2011). Savings deposits as an indicator of stable funding sources significantly reduce the extent of interest rate swap use. The same holds for the buffer of liquid assets, however, only when a between estimator is used. Again, competition has no influence on the extent of interest rate swap use in a regulated industry. Controlling for sample selection bias is only necessary for the pure banking book sample and the total sample, but not for the trading book sample.[17]

Again, for the pooled models, Kleibergen-Paap statistics for weak instruments are always clearly above 10 and also above the threshold of 19.93 calculated for the Cragg-Donald statistic for a maximum size distortion of 10%. Hence, customer loans and loan

[17]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.

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

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
			Panel A				*Panel B*	
Modified duration gap	0.615***	0.852***	0.241**	0.420***	0.624***	0.909***	0.217**	0.384***
	(0.0867)	(0.1305)	(0.1029)	(0.0874)	(0.0875)	(0.1420)	(0.0984)	(0.0929)
Probability of default (ln)	0.041***	0.032***	0.095***	0.027***	0.046***	0.043***	0.091***	0.024***
	(0.0074)	(0.0075)	(0.0228)	(0.0081)	(0.0076)	(0.0077)	(0.0221)	(0.0080)
Size	0.450***	0.445***	0.254***	0.177***	0.446***	0.434***	0.251***	0.181***
	(0.0169)	(0.0189)	(0.0516)	(0.0186)	(0.0195)	(0.0201)	(0.0514)	(0.0205)
Total asset growth	0.111	0.609	0.394	0.054	0.350	0.921**	0.252	0.421
	(0.3040)	(0.3994)	(0.8718)	(0.3856)	(0.3089)	(0.4482)	(0.8504)	(0.3409)
Savings deposits	-0.140	-0.089	0.209	0.202	-0.002	0.095	0.280	0.255
	(0.2283)	(0.2136)	(0.6239)	(0.2636)	(0.2245)	(0.2375)	(0.6162)	(0.2352)
Liquid assets	0.340***	0.531***	-0.193	0.174	0.346***	0.596***	-0.286	0.116
	(0.1145)	(0.1477)	(0.2865)	(0.1109)	(0.1244)	(0.1554)	(0.3122)	(0.1241)
Branch HHI	0.001	0.003	-0.005	-0.001	0.001	0.003	-0.005	-0.001
	(0.0021)	(0.0023)	(0.0066)	(0.0030)	(0.0020)	(0.0024)	(0.0078)	(0.0028)
Past swap experience	1.700***	1.688***	1.919***	1.070***	1.697***	1.679***	1.924***	1.091***
	(0.0299)	(0.0341)	(0.1129)	(0.0437)	(0.0340)	(0.0377)	(0.1218)	(0.0385)
Avg. board experience	-0.010***	-0.009***	-0.027**	-0.012***	-0.010***	-0.009***	-0.025**	-0.011***
	(0.0025)	(0.0027)	(0.0116)	(0.0032)	(0.0027)	(0.0028)	(0.0104)	(0.0031)
Dummy trading book	0.285***				0.282***			
	(0.0506)				(0.0499)			
Yield curve slope					-0.072***	-0.115***	0.113*	-0.012
					(0.0204)	(0.0217)	(0.0613)	(0.0238)
Yield curve slope x 1-year interest rate					-0.051***	-0.028**	-0.131***	-0.114***
					(0.0121)	(0.0137)	(0.0358)	(0.0148)
Time dummies	YES	YES	YES	YES	NO	NO	NO	NO
Adj. CR^2	0.443	0.401	0.339	0.166	0.443	0.400	0.340	0.162
Kleibergen-Paap F-stat.	47.377	33.235	55.653	33.295	42.116	27.695	55.329	32.607
Overidentification stat.	2.342	1.780	0.0807	2.471	1.435	0.723	0.118	1.664
p-val.	0.126	0.182	0.776	0.116	0.231	0.395	0.731	0.197
Endogeneity stat.	19.46	30.30	1.515	8.489	19.47	31.21	2.271	6.760
p-val.	0.000	0.000	0.218	0.004	0.000	0.000	0.132	0.009

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

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
			Panel C				*Panel D*	
Modified duration gap	0.593***	0.900***	0.216***	0.326***	0.613***	0.937***	0.210**	0.341***
	(0.1108)	(0.1409)	(0.0823)	(0.1111)	(0.1137)	(0.1603)	(0.0895)	(0.1094)
Probability of default (ln)	0.042***	0.043***	0.080***	0.010	0.041***	0.044***	0.075***	0.009
	(0.0070)	(0.0090)	(0.0208)	(0.0090)	(0.0073)	(0.0079)	(0.0193)	(0.0076)
Size	0.446***	0.431***	0.252***	0.181***	0.447***	0.431***	0.250***	0.182***
	(0.0175)	(0.0176)	(0.0421)	(0.0179)	(0.0171)	(0.0205)	(0.0488)	(0.0196)
Total asset growth	0.282	0.848**	0.266	0.156	0.151	0.732**	0.106	0.023
	(0.3191)	(0.3895)	(0.8963)	(0.3820)	(0.3182)	(0.3453)	(0.9581)	(0.3449)
Savings deposits	0.035	0.207	0.126	0.152	-0.096	0.077	-0.043	-0.035
	(0.2242)	(0.2503)	(0.6025)	(0.2387)	(0.2097)	(0.2215)	(0.6077)	(0.2829)
Liquid assets	0.223	0.493***	-0.292	-0.068	0.307**	0.611***	-0.294	0.012
	(0.1386)	(0.1488)	(0.2518)	(0.1222)	(0.1420)	(0.1928)	(0.2540)	(0.1117)
Branch HHI	0.000	0.002	-0.007	-0.002	0.001	0.003	-0.008	-0.002
	(0.0020)	(0.0023)	(0.0063)	(0.0027)	(0.0023)	(0.0022)	(0.0070)	(0.0028)
Past swap experience	1.693***	1.670***	1.920***	1.084***	1.694***	1.670***	1.923***	1.090***
	(0.0304)	(0.0346)	(0.1232)	(0.0394)	(0.0305)	(0.0314)	(0.1115)	(0.0396)
Avg. board experience	-0.010***	-0.009***	-0.027**	-0.011***	-0.010***	-0.009***	-0.026**	-0.011***
	(0.0029)	(0.0027)	(0.0114)	(0.0032)	(0.0024)	(0.0030)	(0.0112)	(0.0033)
Yield curve slope					-0.112***	-0.143***	0.001	-0.098***
					(0.0201)	(0.0204)	(0.0500)	(0.0228)
EURIBOR spread	0.250***	0.266***	0.238*	0.343***	0.185***	0.161***	0.380***	0.331***
	(0.0411)	(0.0471)	(0.1388)	(0.0612)	(0.0296)	(0.0310)	(0.0946)	(0.0430)
Yield curve slope x EURIBOR spread	-0.078***	-0.116***	0.106	-0.032				
	(0.0253)	(0.0276)	(0.0766)	(0.0321)				
Time dummies	NO	NO	NO	NO	NO	NO	NO	NO
Adj. CR^2	0.441	0.399	0.339	0.157	0.442	0.399	0.339	0.159
Kleibergen-Paap F-stat.	36.749	22.640	55.387	28.516	35.917	22.033	54.664	28.067
Overidentification stat.	0.970	0.403	0.121	1.110	1.159	0.531	0.112	1.300
p-val.	0.325	0.526	0.728	0.292	0.282	0.466	0.738	0.254
Endogeneity stat.	14.16	24.38	2.247	2.881	14.92	25.81	2.542	3.212
p-val.	0.000	0.000	0.134	0.090	0.000	0.000	0.111	0.073
Banking group dummies	YES	YES	YES	YES	YES	YES	YES	YES
Observations	19,336	17,166	2,170	7,980	19,336	17,166	2,170	7,980

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*. Kleibergen-Paap F-stat. is the weak instruments statistic. The overidentification test displays the test statistic of Lee (1992). The endogeneity test the χ^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. CR^2 is the generalised R^2 Taylor (1997) proposes for censored and limited dependent data.

commitments are also relevant instruments for the reduced sample of banks that decided to use interest rate swaps. Instrument validity is supported by overidentification tests which all fail to reject the null with p-values conveniantely above 50%. The endogeneity tests reject the null of exogeneity of the modified duration gap for all three samples clearly. Thus, the modified duration gap is indeed an endogenous determinant of the nominal volume of interest rate swaps held by German universal banks.

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 swap use than in the cross-sectional settings. To address problems of unobserved heterogeneity, endogeneity, and sample selection, we estimate these models following Semykina and Wooldridge (2010). In the baseline model, a one sd increase in the duration gap leads to a rise in the extent of interest rate swap use by 1.22, 0.86, 1.10, and 1.01 sd for the overall, the non-trading book, the trading book and the starter sample, respectively. None of these coefficients can statistically be distinguished from 1. This might be an indicator that German banks try indeed to keep their hedge ratios constant over time in relation to their on-balance IRR. 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 extent of swap use. However, it should be kept in mind, that the strength of hidden liabilities in the hazard rate model did not fully match the requirements of being a strong instrument. Also, liquid asset endowments as well as savings deposits are found to be insignificant. These results stand 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.

Kleibergen-Paap weak instrument statistics are even in the smallest cases close to 15, and hence customer loans and loan commitments are strong instruments for the maturity gap in the time-series sample selection setting. Hansen-J tests support the exclusion restrictions as the null of instrument validity cannot be rejected conveniently at a 25% level. The endogeneity tests reject the null of the maturity gap being exogenous for all samples, as in the cross-sectional regressions.

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 mostly 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

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***	0.429**	0.274	0.819***	1.044***	0.160
	(0.1673)	(0.2176)	(0.2437)	(0.1951)	(0.2552)	(0.1608)
Probability of default (ln)	0.066***	0.043**	0.060	0.123***	0.109***	0.074**
	(0.0178)	(0.0188)	(0.0504)	(0.0188)	(0.0212)	(0.0349)
Size	0.633***	0.458***	0.685***	0.821***	0.775***	0.602***
	(0.0899)	(0.0972)	(0.1015)	(0.0992)	(0.1265)	(0.0744)
Total asset growth	1.481	2.448**	-0.570	-0.075	0.904	-0.874
	(1.0879)	(1.0751)	(2.2389)	(0.5186)	(0.6386)	(0.8354)
Savings deposits	-1.534**	-1.982***	-0.170	-0.706	-1.252**	-0.656
	(0.6022)	(0.5605)	(1.9363)	(0.6101)	(0.5857)	(1.2594)
Liquid assets	-0.654**	-0.797**	-0.508	-0.203	0.003	-0.655
	(0.2831)	(0.3862)	(0.7662)	(0.2346)	(0.2714)	(0.4109)
Branch HHI	0.007	0.006	0.021	0.009*	0.015**	-0.004
	(0.0049)	(0.0048)	(0.0185)	(0.0055)	(0.0057)	(0.0156)
Past swap experience	3.532***	2.939***	1.136*	4.236***	4.153***	1.440***
	(0.4198)	(0.4208)	(0.6264)	(0.4682)	(0.5395)	(0.3190)
Dummy trading book	0.698***			0.628***		
	(0.1160)			(0.1127)		
Inverse Mills ratio	2.074***	1.544***		2.661***	2.631***	
	(0.3281)	(0.3193)		(0.3737)	(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
Kleibergen-Paap 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 standard errors clustered at the 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). Kleibergen-Paap F-stat. is the weak instruments statistic. Overidentification stat. is the test statistic of the Hansen-J test on instrument validity. Endogeneity stat. is the χ^2-statistic of the C-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
			Panel A				*Panel B*	
Modified duration gap	1.554***	1.304***	1.035***	1.499***	1.477***	1.283***	0.979***	1.441***
	(0.3632)	(0.3597)	(0.3609)	(0.4060)	(0.3761)	(0.3658)	(0.3617)	(0.4117)
Probability of default (ln)	0.024	-0.009	-0.066	-0.005	0.053	0.015	-0.059	0.019
	(0.0303)	(0.0282)	(0.0584)	(0.0379)	(0.0345)	(0.0307)	(0.0524)	(0.0389)
Size	1.558***	1.366***	0.933**	1.878***	1.784***	1.785***	1.049**	2.293***
	(0.4153)	(0.4118)	(0.4378)	(0.5360)	(0.3980)	(0.4094)	(0.4085)	(0.5192)
Total asset growth	-0.425	0.209	-1.667***	-0.515	0.072	0.621	-2.004***	-0.149
	(0.4729)	(0.5070)	(0.6208)	(0.6655)	(0.4867)	(0.5033)	(0.5430)	(0.6601)
Savings deposits	-0.062	0.121	1.006	1.097	1.173	0.953	1.264	2.039**
	(0.6801)	(0.7146)	(1.2158)	(0.9627)	(0.7603)	(0.7658)	(1.2240)	(1.0379)
Liquid assets	0.105	-0.064	0.052	-0.085	-0.033	-0.157	-0.043	-0.207
	(0.2464)	(0.2465)	(0.3625)	(0.2776)	(0.2358)	(0.2391)	(0.3350)	(0.2638)
Branch HHI	-0.029*	-0.008	-0.097***	-0.030	-0.011	0.005	-0.077***	-0.007
	(0.0155)	(0.0151)	(0.0328)	(0.0204)	(0.0122)	(0.0125)	(0.0250)	(0.0163)
Past swap experience	2.796***	0.670***	1.005***	0.588***	2.498***	0.717***	1.054***	0.464***
	(0.4153)	(0.2551)	(0.3480)	(0.1269)	(0.3938)	(0.0765)	(0.3553)	(0.1260)
Dummy trading book	0.023			0.003	-0.076			-0.072
	(0.2545)			(0.3967)	(0.2523)			(0.4056)
Inverse Mills ratio	1.648***	-0.024		-0.098	1.390***			-0.345***
	(0.3313)	(0.1938)		(0.1409)	(0.3162)			(0.1320)
Yield curve slope					0.068*	0.072*	0.073	0.090*
					(0.0372)	(0.0385)	(0.0532)	(0.0458)
Yield curve slope x 1-year interest rate					-0.137***	-0.075**	-0.086**	-0.050
					(0.0230)	(0.0297)	(0.0427)	(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
Kleibergen-Paap 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	9.044	7.888	11.939
p-val.	0.000	0.001	0.003	0.000	0.000	0.003	0.005	0.001

continued on next page

Table 10 continued: 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
			Panel C				*Panel D*	
Modified duration gap	1.679***	1.327***	1.054***	1.730***	1.718***	1.344***	1.053***	1.714***
	(0.4115)	(0.3976)	(0.3625)	(0.4784)	(0.4231)	(0.4057)	(0.3595)	(0.4799)
Probability of default (ln)	0.056	0.026	-0.074	0.058	0.047	0.016	-0.073	0.045
	(0.0397)	(0.0385)	(0.0518)	(0.0477)	(0.0405)	(0.0390)	(0.0523)	(0.0477)
Size	1.427***	1.272***	0.950**	1.855***	1.594***	1.445***	0.944**	1.978***
	(0.3620)	(0.3614)	(0.4035)	(0.5153)	(0.3804)	(0.3697)	(0.3984)	(0.5141)
Total asset growth	-0.089	0.198	-1.976***	-0.443	-0.475	-0.021	-1.952***	-0.583
	(0.5325)	(0.5357)	(0.5577)	(0.7263)	(0.5175)	(0.5233)	(0.5695)	(0.7270)
Savings deposits	1.115	0.748	0.860	2.120*	0.535	0.456	0.899	1.886
	(0.8312)	(0.8094)	(1.2710)	(1.1654)	(0.7909)	(0.7916)	(1.2800)	(1.1552)
Liquid assets	-0.113	-0.212	0.044	-0.069	0.020	-0.146	0.047	-0.063
	(0.2427)	(0.2565)	(0.3419)	(0.3007)	(0.2665)	(0.2729)	(0.3468)	(0.3060)
Branch HHI	-0.022*	0.005	-0.083***	-0.006	-0.015	0.007	-0.083***	-0.005
	(0.0121)	(0.0126)	(0.0235)	(0.0174)	(0.0125)	(0.0131)	(0.0233)	(0.0173)
Past swap experience	2.572***	0.431*	1.022***	0.478***	2.670***	0.461*	1.022***	0.474***
	(0.4224)	(0.2383)	(0.3518)	(0.1289)	(0.4486)	(0.2436)	(0.3524)	(0.1295)
Dummy trading book	-0.008			0.017	-0.014			0.003
	(0.2553)			(0.4145)	(0.2587)			(0.4146)
Inverse Mills ratio	1.511***	-0.181		-0.199	1.579***	-0.164		-0.221
	(0.3458)	(0.1780)		(0.1401)	(0.3669)	(0.1841)		(0.1438)
Yield curve slope					-0.078**	0.000	-0.002	0.038
					(0.0379)	(0.0313)	(0.0442)	(0.0366)
EURIBOR spread	0.549***	0.359***	0.368***	0.369***	0.611***	0.455***	0.352***	0.484***
	(0.0786)	(0.0674)	(0.0966)	(0.0831)	(0.0643)	(0.0582)	(0.0939)	(0.0725)
Yield curve slope x EURIBOR spread	0.044	0.098**	-0.015	0.128**				
	(0.0427)	(0.0424)	(0.0688)	(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
Kleibergen-Paap 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 sample averages 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 */**/***. Kleibergen-Paap F-stat. is the weak instruments statistic. Overidentification stat. is the test statistic of the Hansen-J test on instrument validity. Endogeneity stat. is the χ^2-statistic of the C-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	
Sample	Total	Starters	Total	Trading	Starters	Total	Starters
Explanatory Variable							
Maturity gap			endog.	exog.	endog.	endog.	endog.
Dummy interest rate swap use	exog.	endog.					

This table summarizes the results of the endogeneity tests of the variables determined in the simultaneous equations framework.

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 the cross-sectional and the 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, and for trading book banks for the swap use decisions.

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. For all other banks, including the total sample which is dominated by banks that either use interest rate swaps in all years or do not use them in any 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.[18] 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[19] 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

[18]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.

[19]Banks decrease overall IRR exposure drastically after having been classified as an "outlier" (Memmel, 2011).

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 universal banks seem to use interest rate swaps predominantly for compliance with the IRR regulation and not to manage liquidity risk.[20]

We additionally account the finding that the interest swap use dummy is exogenous for most samples to the fact that German 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, Koujianou Goldberg, and Kyriazidou, 2008). Germany's legal and institutional environment provides 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 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 indicate 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,

[20] 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 a 200 basis point shift in the yield curve is also simulated. The threshold seems more likely to be one comparing banks relative IRR (Houpt and Embersit, 1991) than an absolute one.

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 universal 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 universal 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 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 holds 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.

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

$$D_{gap} = D^A_{mod} - D^L_{mod} \frac{\textit{total interest-earning liabilities}}{\textit{total interest-paying assets}},$$

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, are also available for savings accounts and bonds issued. 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 modified duration 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.

Table 12: Variable Description

Hazard rate model	
Tier 1 capital ratio	Tier 1 capital to total assets
Total bank reserves	Total reserves that qualify as equity to total assets
Dummy reserve reduction	Dummy taking the value 1 if any reserve included in *Total bank reserves* has been reduced
Sector HHI	Herfindahl index of credit portfolio concentration over 14 industry sectors
Dummy hidden liabilities	Dummy taking the value 1 if the bank avoided writing off assets
ROE	Return on equity calculated as operating income to equity
Branch HHI	Herfindahl index of bank branches per county averaged over all counties in which a bank runs branches
Dummy savings banks	Dummy taking the value 1 if the bank is a savings bank
Dummy cooperative banks	Dummy taking the value 1 if the bank is a cooperative bank
EURIBOR	3 month EURIBOR (Euro interbank offered rate)
Regional GDP growth	Real GDP growth at the state level
IRR management model	
Dependent variables:	
Modified duration gap	Calculated according to Appendix B
Dummy interest rate swap use	Dummy taking the value 1 if the bank has non-zero volume of interest rate swaps
Extent of interest rate swap use	ln of the nominal volume of interest rate swaps
Explanatory variables:	
Probability of default (ln)	ln of the probability of default derived from the hazard rate model
Size	ln of total assets
Savings deposits	Savings deposits to total assets
Liquid assets	Cash and securities to total assets
Total asset growth	Annual growth rate of total assets
Dummy trading book	Dummy that takes the value 1 if a bank is qualified as a trading book bank according to the German Banking Act (KWG)
Inverse Mills ratio	Inverse Mills ratio is calculated according to Wooldridge (2010) in cross-sectional and according to Semykina and Wooldridge (2010) in time-series models
Customer loans	Sum of all non-bank loans to total assets
Loan commitments	Loan commitments, excluding those for investment expenditure and real estate, to total assets
Past swap experience	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.
Avg. board experience	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.
Yield curve slope	The spread between the 10-year and the 1-year yield of German government bonds
1-year interest rate	The 1-year yield on German government bonds
EURIBOR spread	The spread between the 12-month EURIBOR and the 12-month German government yield

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