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The dependency of the banks' assets and liabilities: evidence from Germany

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Abstract

Developments in risk-transfer instruments and risk management techniques in the last two decades have fundamentally changed how banks manage their assets and liabilities. In this document we show that, for all three sectors of German universal banks (private commercial banks, savings banks, and cooperative banks), asset-liability dependency declined over the period 1994-2007, the decline was strongest for those banks that use more than sector-average amounts of derivatives. Only in the case of private commercial banks, we do find that lower regulatory capital has coincided with higher asset-liability dependencies. Over our sample period, the difference has diminished since poorly-capitalized private commercial banks have reduced their asset-liability dependencies more intensively than their well-capitalized counterparts. Moreover, we find that profitability matters for the asset-liability dependency but not in the same way for all three sectors. Asset-liability dependency is lower for private commercial banks with higher provision income, savings banks with lower ROE volatilities and cooperative banks with higher ROEs.

JEL classification: G 21, G32

Keywords: Asset-liability dependency, maturity, correlation analysis

Non-technical summary

The classic business model of banks consists of granting long-term loans and collecting deposits of short maturity. These term and liquidity transformations can be a substantial part of banks' earnings, but they are accompanied by risk. Especially in times of crisis, banks with considerable term and liquidity mismatches will find it difficult to secure sufficient funding. These banks may be obliged to sell their assets at large discounts.

The degree of term and liquidity transformation can be approximately inferred from banks' balance sheets. If a bank's assets are closely matched with its liabilities, then this bank will practice term and liquidity transformation only to a small degree.

In our paper, we analyse three research topics. Our first topic is the development of the term and liquidity transformation in recent years. We expect that the change in the economic conditions (regulation, competition, financial innovations) have influenced the term and liquidity transformation. The second topic is the role of banking regulation. It can be assumed that regulation has an impact especially on those banks that operate at the regulatory limit. The third topic concerns banks' earnings. As stated above, term and liquidity transformation is profitable, but may be risky. Therefore, we analyse the earnings, the composition of the earnings and their volatility.

Our empirical results for the German banking market can be summarised in three core statements: (i) There is an upward trend with respect to the term and liquidity transformation for all three sectors (private commercial banks, savings banks and cooperative banks). This trend is mainly driven by long-term loans to non-banks and by short-term deposits of non-banks. (ii) Private commercial banks that are close to the regulatory limit concerning capital and liquidity practise less term and liquidity transformation. We do not find this effect for savings and cooperative banks. (iii) Contrary to expectations, banks tend to be riskier (measured by the earnings volatility) the smaller the extent of their term and liquidity transformation.

Nichttechnische Zusammenfassung

Das klassische Geschäft der Banken besteht darin, langfristige Kredite herauszureichen und kurzfristige Mittel anzunehmen. Diese Fristen- und Liquiditätstransformation kann einen erheblichen Teil der Bankerträge ausmachen. Allerdings gehen diese Erträge mit Risiken einher. Besonders in Krisenzeiten wird es Banken schwerfallen, sich zu refinanzieren, wenn sie im großen Umfang Fristen- und Liquiditätstransformation betreiben. Sie sind dann gezwungen, Vermögensgegenstände mit großen Abschlägen zu verkaufen.

Das Ausmaß der Fristen- und Liquiditätstransformation lässt sich approximativ aus der Bilanz einer Bank erschließen. Sind etwa die Aktivpositionen eng an die Passivpositionen gebunden, dann wird diese Bank wohl nur zu einem geringen Teil Fristen- und Liquiditätstransformation betreiben.

In unserem Papier untersuchen wir drei Themenbereiche. Der erste Bereich widmet sich dem zeitlichen Trend der Fristen- und Liquiditätstransformation. Wir erwarten, dass sich die Änderungen der wirtschaftlichen Rahmenbedingungen (Regulierung, Wettbewerb, Finanzinnovation) in der Fristen- und Liquiditätstransformation niedergeschlagen hat. Der zweite Bereich befasst sich mit der Regulierung. Es ist anzunehmen, dass sich die Regulierung besonders bei denjenigen Banken als wirksam erweist, die nahe am regulatorischen Limit operieren. Der dritte Bereich befasst sich mit den Gewinnen. Wie oben erwähnt, ist es ertragreich, aber auch riskant, Fristen- und Liquiditätstransformation zu betreiben. Deshalb untersuchen wir die Gewinne, die Zusammensetzung der Gewinne und deren Volatilität.

Unsere empirischen Ergebnisse für den deutschen Bankenmarkt können in drei Kernaussagen zusammengefasst werden: Erstens gibt es für alle drei Bankensektoren (private Geschäftsbanken, Sparkassen und Kreditgenossenschaften) einen zunehmenden Trend in Bezug auf das Ausmaß der Fristen- und Liquiditätstransformation. Dieser Trend wird vor allem von den langfristigen Kundenkrediten und den kurzfristigen Einlagen von Nichtbanken getrieben. Zweitens betreiben private Geschäftsbanken, die nahe an der regulatorischen Grenze für das Eigenkapital bzw. für die Liquidität sind, eine geringere Fristen- und Liquiditätstransformation. Bei den Sparkassen und Genossenschaften finden wir diesen Effekt nicht. Drittens sind – entgegen den Erwartungen – die Banken risikoreicher (gemessen als Volatilität der Gewinne), je geringer das Ausmaß deren Fristen- und Liquiditätstransformation ist.

Contents

The Dependency of the Banks' Assets and Liabilities: Evidence from Germany[1]

1 Introduction

These on-going term and liquidity transformations conducted in the banking industry are an essential practice as banks earn a substantial part of their profits from carrying out these transformations. However, the profits from these transformations are accompanied by risks. Especially in times of crisis, banks with a considerable degree of term and liquidity transformation may find it difficult to secure new funding and may be forced to sell illiquid or even liquid assets at large discounts. As various examples in the current crisis have demonstrated, large term and liquidity transformation may call the whole existence of the bank into question.

Several decades ago, banks limited their exposure to term and liquidity risks mainly by constraining their asset and liability structure. Two decades of developments in new financial instruments and risk management techniques appear to have given banks leeway in structuring their assets and liabilities without increasing their exposure to term and liquidity risks. For instance, the increasing notional amounts of interest rate swaps and other derivatives would seem to indicate that nowadays banks mitigate maturity mismatches between assets and liabilities more frequently than in the past. Apart from derivative instruments, banks may limit their exposure to term and liquidity risks by using loans sales and securitization or loans with adjustable interest rates.

Our paper determines how asset-liability dependency has developed in recent years. To our mind, the banks' asset-liability dependency is closely (negatively) related to the extent to which banks practise term and liquidity transformation: Banks that are involved in only a little transformation are inclined to fund their assets with liabilities of the same maturity and nature. We develop two measures that condense the information from pairwise correlation coefficients between single asset and liability positions. Our first measure

[1]The opinions expressed in this paper are those of the authors and do not necessarily reflect the opinions of the Deutsche Bundesbank. We thank John V. Duca and the participants of the SGF 2009 meeting, of the Banking Workshop 2009 (Münster) and of the Bundesbank research seminar for their helpful comments. We thank Henriette Reinhold for her help with the data preparation and evaluation.

is a weighted sum of all squared pairwise correlations that provides information on the overall asset-liability dependency. Our second measure is the coefficient of determination of a certain regression. This measure complements our first measure, since it gives insights into the dependency degree of single asset and liability positions. Using data on the three sectors of universal banks in the German banking industry (private commercial banks, savings banks, and cooperative banks), we find that dependency between the assets and liabilities decreased over the period 1994 to 2007; the effect is most pronounced for savings banks and least pronounced for private commercial banks. This decline in asset-liability dependency can be attributed to a lower liability dependency of long-term loans to non-banks and to a lower asset dependency of short-term deposits.

Our analysis also provides evidence relating to whether the regulatorily defined bank capital and the bank profitability shape the asset-liability dependency. As capital absorbs risks and expands a bank's risk-bearing capacity (Bhattacharaya and Thakor (1993), Repullo (2004)), well-capitalized banks may transform maturities more intensively leading to a lower asset-liability dependency. A higher profitability may be accompanied by a lower asset-liability dependency since banks may lose profit opportunities when keeping a strong asset-liability dependency. While these arguments may have been relevant two decades ago, it is questionable whether they are still relevant today. Only in the case of private commercial banks we do find that banks with lower regulatory capital have higher asset-liability dependencies than banks with higher regulatory capital. However, the difference between well-capitalized and poorly-capitalized banks diminishes over time; this is because the asset-liability dependency of poorly-capitalized private commercial banks declines more strongly than that of their well-capitalized counterparts. Bank profitability matters for the asset-liability dependency, but not in the same way for all three sectors. We find that the asset-liability dependency is lower for private commercial banks with higher provision income, savings banks with lower ROE volatilities and cooperative banks with higher ROEs.

The remainder of the paper is organized as follows: Section 2 illuminates the background for our empirical analysis of the (on-balance sheet) asset-liability dependency. Section 3 introduces the dependency measures and test procedures, and Section 4 describes the data. Section 5 presents our findings, and Section 6 contains the conclusion.

2 Background

The traditional intermediary function of banks is to collect money of short maturity from a large number of depositors and invest it in illiquid, long-term loans. These transformation activities expose banks to interest rate, liquidity and credit risks. While credit risk is only related to the asset-side of the banks' balance sheets, the interest rate and liquidity risk is associated with the liability side, which reflects the funding decision of banks, and with the asset side, which reflects the investment decision of banks. In the past, when risk-transfer instruments were not available, banks could limit their exposure to interest rate and liquidity risks by applying the golden balance-sheet rule. According to this rule, long-term assets were to be financed by long-term liabilities and equity, while short-term liabilities were to be used to finance short-term assets only. In later years, duration methods allowed banks to match their assets and liabilities more precisely. When yield-sensitive assets and liabilities have the same repricing periods (Staikouras (2006)), a duration matching of assets and liabilities immunizes the banks' net wealth against interest rate movements because present-value gains or losses of the assets through interest rate changes are offset by present-value gains or losses of the liabilities.

Decades of financial innovations have changed how banks manage their assets and liabilities as, nowadays, risk-mitigation techniques enable banks to transfer interest risks along with other kinds of risks to third parties. At an early stage, interest rate swaps were introduced, allowing banks to exchange interest payments, such as a stream of fixed interest payments against a stream of interest payments that varies with the market interest rate. When employing appropriately designed interest rate swaps, banks can fund long-term loans with short-term liabilities without being exposed to the risks stemming from interest rate movements. While banks may employ interest rate swaps for hedging reasons, they can also employ them for speculative reasons. Empirical evidence focused on US banks indicates, however, that hedging considerations seem to drive banks' use of these swaps: banks that use derivatives have higher growth rates in business lending and they hold lower levels of capital than banks that do not use derivatives (e.g. Brewer et al. (2000), Brewer et al. (2001)).

Interest rate swaps are also commonly used in Germany, but the intensity of their use differs across the three sectors of the German (universal) banking system, which is not

surprising when one considers the substantial differences between these three pillars.[2] The notional amounts of total interest rate swaps of private commercial banks were 53 % of total assets in 1993, the respective number in 2007 was 1,283 % of total assets. The bulk of interest rate swaps in the sector of private commercial banks is conducted with the big banks: in the case of big banks, interest rate swaps accounted for 96 % (2,016 %) of total assets in 1993 (2007) (Deutsche Bundesbank (2000), Deutsche Bundesbank (2008)). For savings and cooperative banks, the volume of interest rate swaps to assets was relatively low in 1993 (1.1 % for savings banks and 0.3 % for cooperative banks, respectively). It increased substantially during our sample period: for savings banks, interest rate swaps were 22.5 % in 2007, the compound annual growth rate of interest rate swaps was (at 29.3 % p.a.) between 1993 and 2000 much more pronounced than between 2000 and 2007, when it was just 18.8 % p.a.(Deutsche Bundesbank (2000), Deutsche Bundesbank (2008)).

More recently, several new risk mitigation tools, such as loan sales, asset securitization and adjustable loans, have been introduced that allow banks to increase their liquidity and to reduce their exposure to interest rate risks (Ambrose et al. (2005)). A loan sale allows the bank to reduce the duration of its assets, while a loan with adjustable rates allows the bank to have a mismatch in the maturities of assets and liabilities without being exposed to interest rate movements (Strahan (2008)). In particular, cash transactions leading to cash inflows allow banks to restructure their balance sheet (Gorton and Pennacchi (1995)). These new financial instruments have also gained in popularity with German banks in recent years: Bannier and Hänsel (2007) use a sample of European banks for the period 1997 to 2004, which includes about 60 German banks of larger size. Between 1997 and 1999, their securitization activity was negligible, while between 2000 and 2004 approximately 12 German banks were involved in asset securitization per year. Not only are German private commercial banks active in asset securitization of performing loans, but also cooperative banks: using VR Circle, a securitization platform created in 2005, cooperative banks securitized loans with a volume of 1.1 billion euro (Financial Times

[2]For instance, whereas the private commercial banks and the cooperative banks are privately owned, most savings banks belong to the state or the local communities. In contrast, savings and cooperative banks share similar aims in business activities: for banks of both sectors, profit maximization is not their primary goal; the general welfare and the welfare of their members, respectively, are also of great importance. For more information about the German banking system see "Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Lage (2008)".

Deutschland, November 11, 2008). With regard to adjustable loans, the amount of bonds with variable rates to total bond holdings increased substantially during our sample period. In 1996, almost 11 % of the German banks' bonds holdings had variable interest rates, while in 2007 more than 45 % of the bond holdings had variable interest rates (Deutsche Bundesbank (2000), Deutsche Bundesbank (2005), Deutsche Bundesbank (2008)).

Use of a mix of these old and new risk-mitigation instruments might have allowed banks to reduce their asset-liability dependencies in recent years. However, during the last two decades, other features of the financial landscape in which banks operate have changed fundamentally, and these changes may also have motivated or even pressured banks to reduce their asset-liability dependency. One huge change that has shaped the financial landscape was the adoption of the information and communication technologies within the banking business. The supply of online banking services may have reduced, at least temporarily, banks' ability to set prices, especially of those banks who have relied on more traditional business models and adopted new services at a later date, such as savings and cooperative banks. However, the long-term implications of these technological innovations on competition is unclear (Guzman (2001)) and recent evidence based on the H-statistic (Rosse and Panzar (1987)), which summarizes input price elasticities, does not indicate a change in the degree of competition among German banks (see Hempell (2002) for the period 1993-1998 and Schaeck and Cihak (2007) for the period 1999-2004).

While these technological innovations may not have changed the degree of competition, they have certainly had an impact on how banks do their business. Computer technologies allowed banks to develop computationally intensive techniques to measure and manage the various kinds of risks they face. Moreover, it has made it possible for banks to offer customers a wide range of online services, such as paying bills or making investments online (Pikkarainen et al. (2004)), yielding a lowering in transportation costs (Vives (2001)). As a result of lower costs, traditional banks might face increased competition from non-traditional banks and non-bank firms, thus influencing the prices of banking products on both side of the balance sheet. This, in turn, may have changed the composition of banks' funding sources: in the US, traditional deposit funding has declined in recent years and banks have had to supplement traditional sources with potentially less stable and more expensive funding sources (Harvey and Spong (2001)).

Finally, the regulatory landscape in which banks operate changed almost continu-

ously during the sample period. Examples of this are the minimum requirements for the conduct of trading business (Mindestanforderungen an das Betreiben von Handelsgeschäften, MaH) in 1995, the minimum requirements for the organisation of internal revision (Mindestanforderungen an die Ausgestaltung der internen Revision, MaIR) in 2000, the minimum requirements for the credit business (Mindestanforderungen an das Kreditgeschäft, MaK) in 2002, and finally, the minimum requirements for risk management (Mindestanforderungen an das Risikomanagement, MaRisk) in 2005 that replaced the MaH, MaIR and MaK. The MaRisk gives concrete form to the supervisory review process specified in Pillar II of the Basel Accord.

Apart from these requirements, which formulate how banks have to behave when conducting their business, the prudential regulations specifying minimum requirements for banks' capital and liquidity changed, as well. During our sample period, the prudential capital regulation was made concrete in Principle I (Grundsatz I) and underwent only just a few minor changes. The banks' regulatory capital ratio according to Principle I was the quotient of their regulatory capital and their risk weighted assets (capital adequacy ratio according to Basel I). The regulator required this ratio to be at least equal to 8%. In 2007, Principle I was replaced by the Solvency Regulation (Solvabilitätsverordnung) which transposes the Pillar I and III of the Basel Accord into German law.

With respect to the liquidity regulation, a new regulatory framework (Principle II) was introduced in 2000 requiring banks to calculate and report a liquidity ratio. The regulator requires this ratio, which results from dividing assets available within the next month by payment obligations callable within the next month, to be at least equal to 1. The liquidity regulation is built on the proposition that solvent and profitable banks face no obstacles in ensuring medium- and long-term refunding (Deutsche Bundesbank (1999)). However, they may be faced with the risk of liquidity shortages in the short run (Federal Banking Supervisory Office (FBSO) (1998)). It focuses, therefore, on the withdrawal risk of liabilities and the refunding risks in the short run (Schöning (2004), Spörk and Auge-Dickhut (1999)). Before 2000, the liquidity regulation (Principle II and III (old)) focused on the middle and long-term liquidity needs of banks and put emphasis on refunding risks resulting from banks' term transformation (Hartmann-Wendels and Wendels (1999), Spörk and Auge-Dickhut (1999)). In doing so, it built on the golden banking rule, specifying that long-term (medium-term) assets were financed by long-term (medium-term) liabilities, as well as on the deposit base theory, assuming that callable

deposits were not withdrawn at once, but were available to the banks for a longer period, and on the shiftability theory, specifying that particular asset types did not need to be funded by liabilities with the same maturity (Schöning (2004)).

The purpose of our paper is not to disentangle the factors that have motivated, pressured or allowed banks to change their asset-liability dependency. Rather, our paper gives preliminary insights into how the dependency of banks' assets and liability has changed over time. By comparing the asset-liability dependency in the three sectors of German universal banks, our analysis gives an initial insight into the question of whether the whole German universal banking system underwent similar changes with respect to the asset-liability dependency, which would indicate a convergence among banks belonging to different sectors, or whether banks belonging to different sectors differ fundamentally with respect to their asset-liability dependency, which would indicate that business models in the sectors differs just as much today as in the past.

We have chosen three questions to guide us in our empirical analysis, the first of these being: Has (on-balance sheet) asset-liability dependency declined in recent years in a similar way for all three German universal banking sectors? Since the funding structure between the three banking sectors differs fundamentally, we also test whether single asset and/or liability accounts drive the overall change in the asset-liability dependency. Since banks within each sector might be relatively heterogenous, we also check whether the decline in asset-liability dependency over time is more pronounced for banks using risk-mitigation techniques more intensively.

The second question we pose is: Do banks whose capital or liquidity ratio is closer to the regulatory threshold have significantly higher asset-liability dependencies than banks whose ratios are farther away from the threshold? The recent literature puts forward a theory on how capital and term and liquidity transformation are related. According to the risk-absorption hypothesis, capital absorbs risks and expands a bank's risk-bearing capacity (Bhattacharaya and Thakor (1993), Repullo (2004)). This hypothesis suggests that well-capitalized banks transform maturities more intensively, reflected in a lower asset-liability dependency. Thus, asset-liability dependency is expected to be negatively correlated with bank capital because capital absorbs risks. A similar reasoning applies to banks whose liquidity is closer to the regulatory threshold: these banks may be more exposed to liquidity risk than banks which are a long way from the regulatory threshold.

The former may limit their overall risk exposure by creating less term transformation risk. This would imply that banks whose liquidity is closer to the threshold have a higher asset-liability dependency than those banks whose liquidity is far away from the regulatory threshold. While these arguments might have been relevant two decades ago, it is questionable whether they are still relevant today.

Our third question is: Has the relationship between profitability and asset-liability dependency changed fundamentally over time? Several decades ago, banks may have lost profit opportunities by keeping a strong asset-liability dependency. Alternatively, banks with few profitable investment opportunities were not obliged to use their financial means intensively for term transformation. Irrespective of this argument and, therefore, of the causality between profitability and asset-liability dependency, a higher profitability can be expected to have been accompanied by a lower asset-liability dependency. Such a high dependency provides an old-style natural hedge against liquidity risk and market risk, possibly suggesting that the return volatility and the asset-liability dependency are negatively correlated. In addition, the changes in the financial landscape have offered banks new sources of income especially in the form of fees levied for money market transactions (Lapavitsas and Santos (2008)). DeYoung and Rice (2004) argue that non-interest income does not replace, but rather coexists with interest income. This additionally generated income may have given banks more leeway in determining their asset-liability structure.

3 Dependency measures

The literature has put forward several dependency measures, such as Pearson's correlation coefficient, regression analysis and canonical correlations as applied in a recent study by DeYoung and Yom (2008) and formerly by Simonson et al. (1983). The starting point of all these measures is (more or less) the (matrix of) pairwise correlation coefficients.

Canonical correlations are not so widespread in use and are sometimes difficult to interpret. This is why we do not use canonical correlations but condense the information from the pairwise correlation coefficients in different measures. We use two measures; each measure is calculated for each point in time and for each banking group. Our first measure, ϕ, is a weighted sum of all squared pairwise correlations that provides information on the overall asset-liability dependency. Our second measure, τ, is the coefficient

of determination of a regression analysis that provides an insight into how single asset (liability) positions depend on the liability (asset) structure.

Let w^A and w^L describe the structure of a bank's assets and liabilities, respectively. w_i^A is the share of the (asset) position i with respect to total assets, and w_j^L is the share of (liability) position j with respect to total liabilities plus equity. The Pearson correlation coefficient between w_i^A and w_j^L is denoted by ρ_{ij}. We define ϕ as the weighted sum of all pairwise correlations:

$$\phi := \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} \mathrm{E}(w_i^A)\mathrm{E}(w_j^L)\rho_{ij}^2}{\sum_{i=1}^{n}\sum_{j=1}^{m} \mathrm{E}(w_i^A)\mathrm{E}(w_j^L)} \tag{1}$$

The measure ϕ has a number of desirable features: (i) In terms of construction, is it confined to the interval between 0 and 1. (ii) It summarizes the single pairwise correlation coefficients ρ_{ij} into one figure. The pairwise correlations are weighted according to their average weight in the balance sheet. The denominator equals one, if all the assets and all the liabilities are included in the positions under consideration. (iii) Although the level of the measure is hard to interpret, it can serve as the basis for comparisons in the time dimension and in the cross section. A higher level of this measure suggests a higher dependency of assets and liabilities.

For the empirical implementation, we replace the variables from above with their empirical counterparts, i.e.

$$\hat{\phi} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} \bar{w}_i^A \bar{w}_j^L \hat{\rho}_{ij}^2}{\sum_{i=1}^{n}\sum_{j=1}^{m} \bar{w}_i^A \bar{w}_j^L} \tag{2}$$

where $\hat{\rho}_{ij}$ is the empirical correlation coefficient of the balance sheet shares w_i^A and w_j^L, which is calculated from the cross section of the K banks. $\bar{w}_i^A$ and $\bar{w}_j^L$ are the averages of the K banks' asset and liability positions, i.e.[3]

$$\bar{w}_i^A = \frac{1}{K}\sum_{k=1}^{K} w_{i,k}^A. \tag{3}$$

To test whether the asset-liability dependency has declined over time, we carry out a non-parametric test of the null hypothesis according to which the dependency measure $\hat{\phi}$ rises at least as often as it drops compared to the previous year. Under the null hypothesis, the number of negative year-to-year changes, i.e. $X = \#\left(\hat{\phi}_t < \hat{\phi}_{t-1}\right)$ is binomially distributed:

$$X \sim B(n-1, p = 0.5) \tag{4}$$

[3]In the empirical analysis, we use the median instead of the mean because the median has proven to be less susceptible to outliers.

where n is the number of years for which the dependency measure $\hat{\phi}$ is available. In our study, we have data for the period 1994 to 2007, which yield $n - 1 = 13$ year-to-year changes. A similar procedure can be applied to test whether the cross sectional order of the measure in different subsamples remains the same over the years. Suppose there are three subsamples, then the number of years Y for which the order of the dependency measure is in a given order, say $Y = \#\left(\phi_{t,1} < \phi_{t,2} < \phi_{t,3}\right)$, is binomially distributed (under the hypothesis that the dependency measure is equal across the subsamples):

$$Y \sim B(n, p = 1/6) \ ^{4} \tag{5}$$

Our second measure gives insights into the degree of dependency between a single asset position i and the structure of the liabilities and vice versa. To determine the degree of dependency for each single asset position we run the following regression:

$$w_{i,k}^{A} = \alpha_i + \beta_{1,i} w_{1,k}^{L} + \ldots + \beta_{J,i} w_{J,k}^{L} + \varepsilon_{i,k}^{A} \quad i = 1, \ldots, I \tag{6}$$

We use the coefficients of determination R_i^2 of these regressions as the dependency measures τ_i^A. This dependency measure can be seen as the maximum squared correlation between the weight of asset i and any linear combination of the liability weights. Note the similarity to canonical correlations which are the maximum correlation of assets and liabilities when one varies both the asset and the liability structure:

$$\tau_i^A = \max_{\beta_i} corr^2\left(w_i^A, \beta_i' w^L\right) \tag{7}$$

For each liability position, the measure τ_j^L is estimated correspondingly using asset shares as RHS variables.

This measure has several advantages: (i) As our first measure, it is confined to the interval between 0 and 1. (ii) It summarizes the single pairwise correlations ρ_{ij} into one figure for each asset and liability position, respectively. (iii) As the coefficient of determination is widely used, this measure is relatively easy to communicate and interpret.

Testing whether this measure of the asset-liability dependency has declined over time is not straightforward as the distribution of the empirical equivalent $\hat{\tau}_A^i$ is not easy to determine, even when the residuals are normally distributed. However, in the appendix, we describe a test which allows us to test the hypothesis of equal measures τ_i^A at different points of time t and t', i.e. $H_0 : \tau_{i,t}^A = \tau_{i,t'}^A$.

[4] The probabilty is 1/6, because there are six permutations of three elements.

4 Data

We use year-end data from the Bundesbank's monthly balance sheet statistics for the years 1994 to 2007. These statistics include the balance sheet information of all banks in Germany, broken down into different asset and liability positions according to the type of the financial asset or liability (e.g. equity or debt), the type of the counterparty (e.g. bank or non-bank) and the maturity of the financial asset or liability (e.g. initial maturities up to one year (*short-term*) and of more than one year (*long-term*)). Our analysis starts in 1994 because otherwise the asset and liability structure would not be defined in a consistent manner over time.

We subdivide the banks' assets and liabilities into eight and seven accounts, respectively. The asset positions are *cash*, *short-term interbank loans*, *long-term interbank loans*, *short-term loans to non-banks*, *long-term loans to non-banks*, *bonds*, *other securities* and *other assets*. Accordingly, the banks liabilities are broken down into *saving accounts*, *short-term interbank liabilities*, *long-term interbank liabilities*, *short-term liabilities from non-banks*, *long-term liabilities from non-banks*, *own funds* and *other liabilities*. To avoid perfect multicollinearity among the asset and liability positions, we skip the positions *other assets* and *other liabilities*.

Insert Table 1 about here

Table 1 depicts the structure of the banks' assets and liabilities summarized across all three banking sectors in our sample, from which we removed all bank-year observations, when the asset or liability position was negative or greater than total assets. For each asset and liability position, we present the value of the 25th, 50th and 75th percentile. Long-term loans to non-banks and bonds are the most relevant asset positions, while savings accounts and short-term deposits are the most relevant liability positions of German banks.

Insert Table 2 about here

Table 2 presents the mean shares of the asset and liability positions broken down into the three banking sectors.[5] A test of equal means across the three banking sectors suggests some pronounced differences among these three banking sectors: On average, (i) private

[5]Private commercial banks include subsidiaries of foreign banks.

commercial banks have much higher volumes of short-term interbank assets and liabilities than savings and cooperative banks. (ii) Private commercial banks have lower volumes of long-term loans to non-banks than savings and cooperative banks. (iii) In the case of private commercial banks, savings accounts are not a prominent source of funding, whereas they are for savings and cooperative banks.

5 Findings

5.1 Trend in the asset-liability dependencies

To gain insights into the trend in the asset-liability dependency, we calculated the measure $\hat{\phi}$ for each year and for each banking sector separately. The results presented in Figure 1 show that the dependency measure $\hat{\phi}$ for assets and liabilities decreases in the last 14 years for all three banking sectors. Since there are single years in which the dependency measure $\hat{\phi}$ rises compared to the previous year, we tested whether the dependency measure rises at least as often as it drops (compared to the previous year). For each banking sector we count 11 negative year-to-year changes in the dependency measure (out of the 13 year-to-year changes of $\hat{\phi}$). Therefore, we can reject the null hypothesis for each sector at the 5%-level.[6] In addition, linear regressions of $\hat{\phi}_t$ on a linear time trend always yield significantly negative coefficients for all three banking sectors. This last test should be interpreted with caution given the low number of observations ($n = 14$).

Insert Figure 1 about here

Figure 1 also reveals that the order in the asset-liability dependency of the three sectors remains the same over the fourteen years of our study. The dependency between assets and liabilities is by far stronger among the savings banks than among the banks of the two other pillars. The lower asset-liability dependency of private commercial banks is not so surprising since savings banks seem to be less reluctant to use new financial instruments than private commercial banks. More surprising is the order of the asset-liability dependency between savings and cooperative banks: savings banks, which are on average larger than cooperative banks, have a much higher dependency than cooperative banks.

[6] If $X \sim B(13, 0.5)$, then $\Pr(X \geq 11) = 1.1\%$.

We use our second measure $\hat{\tau}_i^A$ and $\hat{\tau}_j^L$, which was calculated for each year and each banking sector separately, to determine the trend in single asset and liability positions. Using this second measure in addition to our first measure is useful in two respects. First, it allows insights on whether a particular asset and/or liability position is responsible for the decline in the asset-liability dependency. Second, it may provide insights into why the asset-liability dependency decreased more strongly for savings banks than for private commercial and cooperative banks.

Figure 2 depicts exemplarily the measure $\hat{\tau}$ for the three most important balance-sheet positions: the long-term loans to non-banks, the short-term deposits and the savings accounts. The liability dependency of long-term loans to non-banks declines for savings and cooperative banks but not for private commercial banks. The decline seems to be more pronounced for savings banks than for cooperative banks. The asset dependency for short-term deposits declines for all three banking sectors. The decline is most pronounced for savings banks, and least pronounced for private commercial banks. Finally, the asset dependency of savings accounts declines somewhat for cooperative banks, it stays unchanged for private commercial banks and it increases for savings banks. With respect to the level of $\hat{\tau}$, we observe the highest values for the balance positions long-term loans to non-banks. This is not surprising as loans to non-banks constitute the banks' core business (at least for traditional universal banks).

Insert Figure 2 about here

To check whether the dependency $\hat{\tau}$ of single balance-sheet positions has changed significantly over time, we concentrate on the three positions mentioned above and compare the dependency measure in 1994 with that for 2000 and the dependency measure in 2000 with that for 2007 for each banking sector. In Table 3, we show the changes in the dependency measure $\hat{\tau}$. For instance, for the private commercial banks, the dependency $\hat{\tau}_i^A$ of the long-term loans to non-banks on the liability structure is 0.550 in 1994, 0.611 in 2000 and 0.456 in 2007 (see Figure 2). As displayed in the second row of Table 3, the changes are 0.061 from 1994 to 2000 and -0.155 from 2000 to 2007, respectively. We check whether this difference in the dependency measure is significant according to the test described in the appendix. For example, for the private commercial banks, the change from 2000 to 2007 for the liability dependency of the long-term loans to non-banks is significant at the 1% level.

Insert Table 3 about here

Table 3 shows some similarities between the three banking sectors. First, for all three banking sectors alike, neither the asset nor the liability side of the balance sheet alone can be held responsible for the declining asset-liability dependencies. Second, all three banking sectors have experienced declining dependencies of long-term loans to non-banks and short-term deposits, while the dependency of the savings accounts did not change significantly during the period of our study. Thus, the decline in the asset-liability dependency depicted in Figure 1 seems to be driven by the decline in the dependency of long-term loans to non-banks and short-term deposits. Third, for all three banking sectors, the change in the asset dependency of short-term deposits is more pronounced in the first half (1994-2000) than in the second half of our sample (2000-2007), which might reflect a change in households' behavior: at the end of the 1990s share holdings became more popular for German households.

Table 3 also shows pronounced differences between private commercial and cooperative banks, on the one hand, and savings banks, on the other hand. Thus, it gives insights into why savings banks underwent more severe changes in the asset-liability dependency than the other two banking sectors. In contrast to private commercial and cooperative banks, savings banks also experienced a decline in the asset dependency of short-term deposits in the sample period 2000 to 2007. Moreover, they experienced a stronger decline in the liability dependency of long-term loans to non-banks than private commercial and cooperative banks in both sample periods. This would suggest more severe changes in the behavior of savings banks' borrowers and depositors than in the other two banking sectors.

If changes in the availability of new financial instruments are responsible for declining asset-liability dependency, then the decline should be more pronounced for banks which use these instruments intensively. Since we do not have data on all new financial instruments that the banks can potentially use, we rely on two broad measures: the notional amount of derivatives relative to total assets, and the bank's size, i.e. its total assets. Bank size, a bank characteristic that has received much attention in the literature (e.g., Berger and Bouwman (2008), Kishan and Opiela (2000)), may be positively correlated not only with the use of new financial instruments but also with the use of advanced risk management techniques that allow the banks to estimate and manage their different risk exposures

more precisely. Because of their advanced risk management techniques, larger banks may be characterized by a lower asset-liability dependency than smaller banks.

We divided the sample of each sector into terciles according to the characteristic under focus. Being in a higher tercile means to have a higher value in the characteristic under focus. Table 4 gives the medians of the three terciles for each bank characteristic and each sector. These numbers show the existing heterogeneity among the three sectors as well as among the banks within a sector. The median cooperative bank is much smaller than the median savings or private commercial bank. The median savings and cooperative bank employs fewer derivatives than the median private commercial bank. The variation in the notional amounts of derivatives and the assets under management is much more pronounced for private commercial than for savings and cooperative banks. Further information on data definitions and sources is given in the appendix.

Insert Table 4 about here

In Table 5, we report the start values of the dependency measure and the changes in the measure between 1994-2000 and 2000-2007 for derivatives and bank size. With regard to private commercial banks' derivatives, for instance, the dependency measure $\hat{\phi}$ is 0.078 for the first tercile (banks with the lowest derivative volume) and 0.103 and 0.151 for the second and third tercile, respectively. For banks in the third tercile, the asset-liability dependency declined more than that for banks in the first and second tercile in the period 1994-2000. For instance, between 1994-2000, the asset-liability dependency declined by -0.12 for the third tercile of private commercial banks, whereas it declined only by about -0.04 and -0.02 for the first and second tercile. These changes imply that private commercial banks with high notional amounts of derivatives have reduced their asset-liability dependency more intensively than other private commercial banks. The results match with the evidence presented by DeYoung and Yom (2008) for US commercial banks, who also find that the asset-liability linkages are weaker for US banks using swaps intensively. For German savings and cooperative banks, the derivative volume also influences the degree of asset-liability dependency. Savings and cooperative banks with high asset-liability dependencies in 1994 use derivatives more intensively. Between 1994 and 2000, the change in asset-liability dependency is more pronounced for the third tercile than for the first and second terciles of savings and cooperative banks, while in the period 2000-2007, the change in asset-liability dependency is no longer more pronounced for the third tercile.

Insert Table 5 about here

Large private commercial banks initially exhibited a higher asset-liability dependency than their smaller counterparts. In addition, the change in the dependency measure between 1994-2000 was (at -0.08) somewhat more pronounced for large private commercial banks than for smaller ones, while the changes between 2000-2007 were quite similar for large and smaller banks. Thus, larger private commercial banks, which tend to have a higher affinity for using new financial instruments, reduced their asset-liability dependency much more than their smaller counterparts. Although these results are similar but they do also differ from the evidence for US commercial banks (DeYoung and Yom (2008)): The asset-liability dependency is stronger at large German and US commercial banks than at smaller ones and size-based differences have diminished over time both in Germany and the US. However, while small US commercial banks have increased their asset-liability dependency, both large and small German private commercial banks experienced declining dependency. At the beginning of our sample period, large savings banks had, unlike private commercial banks, a lower asset-liability dependency than smaller savings banks, having declined more strongly for large than for small savings banks between 1994 and 2000, while the opposite was true between 2000 and 2007. For cooperative banks, size does not matter in a systematic way for the asset-liability dependency: large and small cooperative banks had similar asset-liability dependencies in 1994 and they experienced similar declines in their dependencies over time.

5.2 Prudential regulations

In the text below, we describe whether the asset-liability dependency is related to prudential capital and liquidity regulations. We group the banks in each banking sector into terciles according to their capital or liquidity adequacy. Table 4, which gives descriptive statistics for capital and liquidity ratios, indicates that even banks in the first tercile (which are closest to the regulatory threshold) have considerably high capital and liquidity ratios as compared to the regulatory threshold of 8% and 1, respectively. We calculated the dependency measure $\hat{\phi}$ for each tercile group of each banking sector and for each year. In Table 6, we condense the results as follows. For each tercile group of each banking sector we report (i) the average dependency measure between 1994 and 2007, (ii) the change in the dependency measure between 1994 and 2007 and (iii) the number of years in which the

dependency measure has a cross-sectional increasing or decreasing order. The dependency measure $\hat{\phi}$ is characterized by an increasing order when $\hat{\phi}_{1st} \leq \hat{\phi}_{2nd} \leq \hat{\phi}_{3rd}$, which implies a negative correlation between the bank characteristic under focus and the asset-liability dependency. It has a decreasing order when $\hat{\phi}_{1st} \geq \hat{\phi}_{2nd} \geq \hat{\phi}_{3rd}$, which implies a positive correlation between the bank characteristic under focus and the asset-liability dependency. Since the order of the tercile groups probably changes over time, we carry out this analysis for two subsamples, the first from 1994-2000 and the second from 2001-2007.

As far as to the prudential capital regulation is concerned, private commercial banks have a time-series means of the dependency measure of 0.154 for the first tercile (banks whose capital ratio is closest to the regulatory threshold) and 0.086 and 0.031 for the second and third tercile, respectively. These time-series means suggest that the capital ratio and the asset-liability dependency are negatively correlated. The cross-sectional order gives deeper insights: we identify a decreasing order for each year between 1994 and 2005 but not in 2006 and 2007. Thus, private commercial banks with a low regulatory capital ratio had, on average, a higher asset-liability dependency than banks with high capital ratios. This effect can reflect a risk-absorbing effect of capital (see the discussion above). The change in the dependency measure between 1994-2007 was most pronounced for the first tercile (-0.18) and least pronounced for the third tercile (-0.016). This indicates that private commercial banks in the second and third tercile had a relatively constant and low asset-liability dependency over time while the private commercial banks belonging to the first tercile systematically reduced their asset-liability dependency. These results show another similarity between US and German commercial banks: DeYoung and Yom (2008) also find that US commercial banks with strong regulatory safety have weaker asset-liability dependencies. While these findings are consistent with the view that regulators allow well-managed banks more leeway in risk-taking (DeYoung et al. (2001)), the question of how the decline in the asset-liability dependency of poorly-capitalized banks (banks in the first tercile) over the sample period are related to the recent stress in the banking industry remains unsolved.

For private commercial banks, the results for the liquidity ratio look similar to the results which we yield for the capital ratio. However, unlike the capital ratio, the classification of banks into terciles is built on the prudential liquidity regulation which only has been in force since 2000. While we do not observe any remarkable change in the asset-liability dependency around the year 2000, we find a decreasing cross-sectional or-

der in the asset-liability dependency between 1994-2002, though not after 2002. More specifically, private commercial banks in the first tercile reduced their asset-liability dependency steadily over the sample period, while banks in the second tercile reduced their asset-liability dependency only slightly. Hence, a high liquidity ratio coincides with a low asset-liability dependency at the beginning of our sample period but this correlation is less pronounced nowadays.

Insert Table 6 about here

For savings and cooperative banks, the closeness to the threshold specified in the prudential capital and liquidity regulation has no systematical relevance for the asset-liability dependency. This might be because savings and cooperative banks enjoy a comprehensive insurance scheme: Not only are the deposits insured, but the guarantee covers the whole institute. Due to this comprehensive guarantee, the capital and liquidity ratio of a single savings bank and cooperative bank may not have such an effect on the asset-liability structure.

5.3 Bank profitability

To test whether the old industry wisdom concerning the relationship between bank profitability and the asset-liability dependency still holds, we use the bank's return on equity (ROE), the share of income that stems from provisions, and the volatility of the ROE. We calculate the ROE volatility as the time-series standard deviation of the ROE for those banks for which we have data during the whole 14-year study period:

$$\hat{\sigma}_k = \sqrt{\frac{1}{13}\sum_{t=1}^{14}\left(ROE_{t,k} - \overline{ROE}_k\right)^2} \tag{8}$$

Table 7 condenses our findings for banks' profitability based on the dependency measure $\hat{\phi}$ which we calculate for each tercile group of each banking sector and for each year. As in Table 6, we report the average dependency measure between 1994 and 2007, the change in the dependency measure between 1994 and 2007, and the number of years in which the dependency measure has a cross-sectional increasing or decreasing order.

In the case of private commercial and savings banks, the findings do not indicate the highest dependency for the banks with low ROE and the lowest dependency for the

banks with high ROE. For the cooperative banks, however, the time-series means of the dependency measure is 0.083 for the first tercile (banks with low ROE) and 0.070 and 0.067 for the second and third tercile, respectively, suggesting a cross-sectional decreasing order in the dependency measure. Between 1994 and 2000 (2001 and 2007), we find six (three) cases of a decreasing order, i.e. the ROE and the asset-liability are negatively correlated in nine out of 14 years. This is significant at the 1%-level.[7] The change in the dependency measure is by and large similar across the tercile groups of cooperative banks suggesting a rather similar, i.e., strictly speaking parallel, decrease in the dependency measure over time.

The share of provision income has some relevance for the asset-liability dependency in all three banking sectors but in varying ways. For private commercial banks, the provision income negatively correlates with the asset-liability dependency: the higher the share of provision income, the lower the asset-liability dependency. For savings and cooperative banks, the provision income is positively correlated with the asset-liability dependency between 2001-2007: the higher the share of provision income, the higher the asset-liability dependency. These adverse findings probably come from the different business models or more concretely from the different sources of the provision income in the three banking sectors. For private commercial banks, provision income is likely to come from investment bank activities unrelated to interest-bearing lending and funding decisions with the result that a higher provision income might allow private commercial banks to bear more term transformation risk. By contrast, provision income in the sectors of savings and cooperative banks is more likely to be generated by account management charges which may coincide with high amounts of short-term deposits that these banks cannot or do not use in term transformation. This would then lead to a higher asset-liability dependency.

Insert Table 7 about here

The banks with the lowest ROE volatility tend to be those with little dependency, and vice versa. This result holds for all three sectors although it is not significant for all three

[7] There are six permutations of the order of the three items. Therefore, under the null hypothesis of random order, the number X of a certain order is binomially distributed: $X \sim B\,(n = 14, p = 1/6)$. If $X \sim B\,(14, 1/6)$, then $\Pr(X \geq 8) = 0.07\%$ and $\Pr(X \geq 9) = 0.01\%$.

banking sectors. For private commercial banks, we find that in 4 out of 7 cases there is an increasing order between 1994 and 2000 but none afterwards. Thus, in our first subsample, banks with low ROE volatility are those with low asset-liability-dependency and vice versa. In the case of savings banks, we find an increasing order in the dependency measure in all 14 of the 14 years. For cooperative banks, we find some cases of a decreasing order in the first subsample but we identify an increasing order in all 7 of the 7 cases in the second subsample.

5.4 Sensitivity checks

In each part of our analysis we carry out a number of sensitivity checks. First, as alternative dependency measures, we use correlation coefficients between the sum of long-term assets and the sum of long-term liabilities and canonical correlations. Irrespective of the dependency measure used, we find that the dependency between assets and liabilities decreased in the course of time and that the asset-liability dependency varies systematically with the use of derivatives, regulatory capital and liquidity and bank profitability.

Second, we take into account that, during our sample period, a large number of banks merged or were acquired.[8] For instance, the number of savings banks shrank from 532 in 1994 to 446 in 2007 while the corresponding number of cooperative banks were 1,946 in 1994 and 1,229 in 2007. To account for these changes in the number of banks we constructed a restricted sample of those banks that stayed in the original sample from 1994 to 2007. The results based on this modified sample are qualitatively the same. Hence, we conclude that the results are not driven by the merger and acquisition wave among the savings and cooperative banks.

Third, we investigate whether our division of banks into terciles is a driving factor behind our findings. The results presented in Tables 5, 6 and 7 (except for derivatives, the liquidity ratio and the ROE volatility) are based on a time-varying classification of banks. This implies that a bank with a particular characteristic can be included in the first tercile in one year and in the second or third tercile in another year. To check whether this classification drives our findings, we alternatively classify banks according to their characteristics in the starting year of our sample and re-calculate our measure of

[8] See for more details Kötter (2005).

the asset-liability dependency. It transpires, however, that the time-constant and time-varying classification produce broadly similar results. We also examine whether classifying banks according to the ROE volatility between 1994-2000 and 2001-2007 changes our main findings. It transpires that the findings are insensitive to this alteration, too.

Finally, we also experiment with banks' credit lines and loan commitments to other banks and non-banks, a further characteristic that may shape the asset-liability dependency. Kashyap et al. (2002) show theoretically and Gatev et al. (2009) find empirically that synergies between credit lines and deposit-taking allow banks to reduce their liquid asset holdings. Both credit lines and deposit-taking require banks to hold large amounts of liquid assets but when loan commitment take-downs and deposit withdrawals are imperfectly correlated banks can reduce their liquid asset holdings. Such a synergy effect might also impact on the asset-liability dependency. However, we do not find any evidence that the degree of the asset-liability dependency varies according to the banks' loan commitments. Since the data on loan commitments are of relatively low quality (the information is not available for all the banks and all the years), we do not conclude from these findings that loan commitments have no relevance and, therefore, do not report these results.

6 Conclusion

We started our analysis by postulating that recent developments in risk transfer instruments, changes in business models due to new technologies, and changes in prudential regulations may have reduced the dependency of banks' assets and liabilities. Our findings describe how the asset-liability dependency for German universal banks behaved over the period 1994 to 2007 without claiming to provide in-depth insights into what have caused these changes in the degree of dependency. Our findings show that the overall dependency between assets and liabilities has decreased in the last 14 years for all three sectors of universal banks (private commercial banks, savings banks, cooperative banks). This overall decline is related to selected asset and liability positions only: It can be attributed to a lower dependency of long-term loans to non-banks and to a lower dependency of short-term deposits, while other positions, such as savings account, did not contribute as much to the overall decline. Our findings also indicate that the decline is most pronounced for those groups of banks within each banking sector that intensively use derivatives instruments.

Our analysis also provides insights into whether the asset-liability dependency systematically varies with the regulatorily defined bank capital and with bank profitability. For private commercial institutions but not for savings and cooperative banks we find that banks with lower regulatory capital have higher asset-liability dependencies than banks with higher regulatory capital. The difference between well-capitalized and poorly-capitalized banks diminishes since the asset-liability dependency of private commercial banks with lower regulatory capital declines more strongly than that of their counterparts with high regulatory capital. We find that profitability has a bearing on the asset-liability dependency but not in the same way for the three sectors. Asset-liability dependency is lower for private commercial banks with higher provision income, for savings banks with lower ROE volatilities and for cooperative banks with higher ROEs.

In this study we mainly applied descriptive statistics, complemented by statistical tests where appropriate and possible. The descriptive analyses have the advantage that the results do not rely on strong econometrical assumptions, for instance concerning the distribution of error terms. Nevertheless such descriptive analyses do not allow us to make any statements about causality. Thus, future research may aim at disentangling whether and how recent developments in risk-transfer instruments and risk management techniques, the adoption of information and communication technology by the banking business and changes in regulations have shaped the structure of the banking industry. Disentangling these effects is necessary to gain insights into the causes of the recent financial instability.

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Appendix

Assume the following regression model ($k = 1, ..., K$ denotes the cross sectional items (here: banks), $t = 1, ..., T$ is the time dimension, and $x_{t,k} = (x_{1,t,k}, \ldots, x_{p,t,k})'$ is a vector of explanatory variables):

$$y_{t,k} = \alpha_t + x'_{t,k}\beta_t + \varepsilon_{t,k} \tag{9}$$

with $\text{var}(y_{t,k}) = \sigma^2_{y,t}$ and $\text{var}(\varepsilon_{t,k}) = \sigma^2_{\varepsilon,t}$, i.e. the parameters α and β as well as the variances may change in the course of time; in the cross section, however, these parameters are constant. The residuals ε are assumed to be uncorrelated in the cross section but may be correlated in the time dimension, i.e. $corr(\varepsilon_{t,k}, \varepsilon_{t,k'}) = 0 \ \forall k, k' \ k' \neq k$, but $corr(\varepsilon_{t,k}, \varepsilon_{t',k}) = \rho_{k,t,t'}$.

The regression's coefficient of determination R^2_t is not changed if the dependent variable y_t is divided by a scalar. We choose $\sigma_{y,t}$ as the scalar and run the following regression for each point in time t:

$$\tilde{y}_{t,k} = \tilde{\alpha}_t + x'_{t,k}\tilde{\beta}_t + \tilde{\varepsilon}_{t,k} \tag{10}$$

with $\tilde{y}_{t,k} = y_{t,k}/\sigma_{y,t}$, $\tilde{\beta}_t = \beta_t/\sigma_{y,t}$ and $\tilde{\varepsilon}_{t,k} = \varepsilon_{t,k}/\sigma_{y,t}$. Due to this transformation, the coefficient of determination $R^2_t := 1 - \sigma^2_{\varepsilon,t}/\sigma^2_{y,t}$ simplifies to

$$R^2_t = 1 - \text{var}(\tilde{\varepsilon}_{t,k}). \tag{11}$$

Therefore, testing the null hypothesis $H_0 : R^2_t = R^2_{t'}$ is equivalent to testing the hypothesis $\text{var}(\tilde{\varepsilon}_{t,k}) = \text{var}(\tilde{\varepsilon}_{t',k})$. The latter hypothesis can be tested by running the following regression (See Entrop et al. (2008))

$$\tilde{\varepsilon}_{t,k} = \gamma\left(\tilde{\varepsilon}_{t,k} - \tilde{\varepsilon}_{t',k}\right) + \eta_k \tag{12}$$

and testing whether γ is equal to 0.5. To verify this statement, observe that the regression coefficient γ equals

$$\gamma = \frac{\text{cov}\left(\tilde{\varepsilon}_{t,k}, \tilde{\varepsilon}_{t,k} - \tilde{\varepsilon}_{t',k}\right)}{\text{var}\left(\tilde{\varepsilon}_{t,k} - \tilde{\varepsilon}_{t',k}\right)} \tag{13}$$

$$= \frac{\text{var}\left(\tilde{\varepsilon}_{t,k}\right) - \text{cov}\left(\tilde{\varepsilon}_{t,k}, \tilde{\varepsilon}_{t',k}\right)}{\text{var}\left(\tilde{\varepsilon}_{t,k}\right) + \text{var}\left(\tilde{\varepsilon}_{t',k}\right) - 2\text{cov}\left(\tilde{\varepsilon}_{t,k}, \tilde{\varepsilon}_{t',k}\right)} \tag{14}$$

This regression coefficient is equal to 0.5, if $\text{var}(\tilde{\varepsilon}_{t,k}) = \text{var}(\tilde{\varepsilon}_{t',k})$, irrespective of the correlation between $\tilde{\varepsilon}_{t,k}$ and $\tilde{\varepsilon}_{t',k}$. For the purpose of implementing the test, we replace $\sigma_{y,t}$ and $\tilde{\varepsilon}_{t,k}$ with its empirical counterparts and estimate (12) with a robust covariance matrix (see White (1980)).

Data description and sources

Variable	Description and source
Derivatives	Ratio of notional amounts of derivatives relative to total assets
	(time-constant tercile classification (1996-2007), CREDIT REGISTER)
Size	Total assets
	(time-varying tercile classification, BAKIS)
Capital ratio	Capital ratio according to Principle I
	(time-varying tercile classification, BAKIS)
Liquidity ratio	Liquidity ratio according to Principle II
	(time-constant tercile classification (2000-2007), BAKIS)
ROE	Return on equity
	(time-varying tercile classification, BAKIS)
Provision income	Ratio of provision income to total income
	(time-varying tercile classification, BAKIS)
ROE volatility	Standard deviation of ROE
	(time-constant tercile classification, BAKIS)

BAKIS is the Bundesbank's banking data storage system. For more information about the BAKIS data set see Memmel and Stein (2008). For more information about the German credit register see Schmieder (2006).

Tables and figures

Balance sheet position	Percentiles			Number of observations
	25th	50th	75th	
Cash	1.5%	2.1%	2.6%	32833
Interbank (st)	4.4%	7.7%	12.6%	32833
Interbank (lt)	0.1%	1.1%	4.1%	32833
Loans (st)	5.8%	8.1%	11.1%	32833
Loans (lt)	42.8%	51.8%	58.2%	32833
Bonds	11.1%	16.9%	23.7%	32833
Stocks	0.6%	1.3%	4.2%	32833
Sum of assets incl.	95.6%	96.9%	97.7%	32833
Interbank (st)	0.0%	0.2%	2.1%	32833
Interbank (lt)	7.4%	11.8%	16.9%	32833
Deposits (st)	22.3%	28.0%	34.6%	32833
Deposits (lt)	4.0%	6.6%	9.7%	32833
Savings accounts	25.9%	33.6%	39.9%	32833
Equity	5.1%	6.3%	8.7%	32833
Sum of liabilities incl.	90.5%	94.4%	96.7%	32833

Table 1: Structure of the banks' assets and liabilities. Descriptive statistics of balance-sheet positions over total assets, time span: 1994-2007. Includes private commercial banks, savings banks and cooperative banks. (st) = short-term; (lt) = long-term.

Balance sheet	Mean share			Test
position	Priv. banks	Sav. banks	Coop. banks	statistics
Cash	2.0%	2.2%	2.2%	0.0
Interbank (st)	31.0%	6.1%	9.2%	12.6***
Interbank (lt)	2.9%	1.7%	3.6%	0.5
Loans (st)	17.3%	7.4%	9.0%	3.1
Loans (lt)	25.3%	52.3%	51.1%	13.9***
Bonds	11.7%	20.1%	18.4%	2.0
Stocks	1.9%	6.5%	2.5%	2.1
Interbank (st)	25.0%	3.0%	0.8%	13.3***
Interbank (lt)	12.7%	17.4%	11.9%	2.2
Deposits (st)	27.6%	23.9%	30.8%	3.6
Deposits (lt)	5.8%	6.8%	7.8%	0.3
Savings accounts	4.6%	34.0%	35.1%	44.3***
Equity	12.1%	7.6%	7.0%	0.9

Table 2: Mean share of asset and liability positions, broken down into banking sectors; time span: 1994-2007. (st) = short-term; (lt) = long-term. Test of equal mean shares in a row: */**/*** denote significance at the 10%, 5% and 1% level.

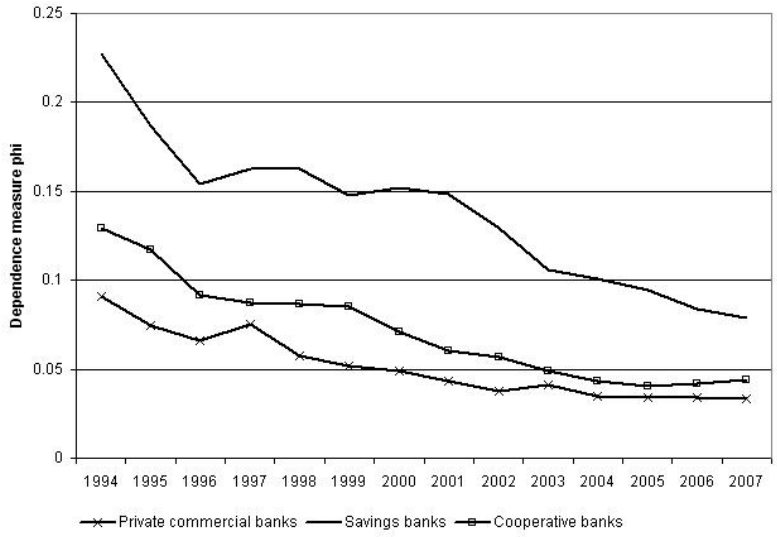

Figure 1: Dependency measure $\hat{\phi}$

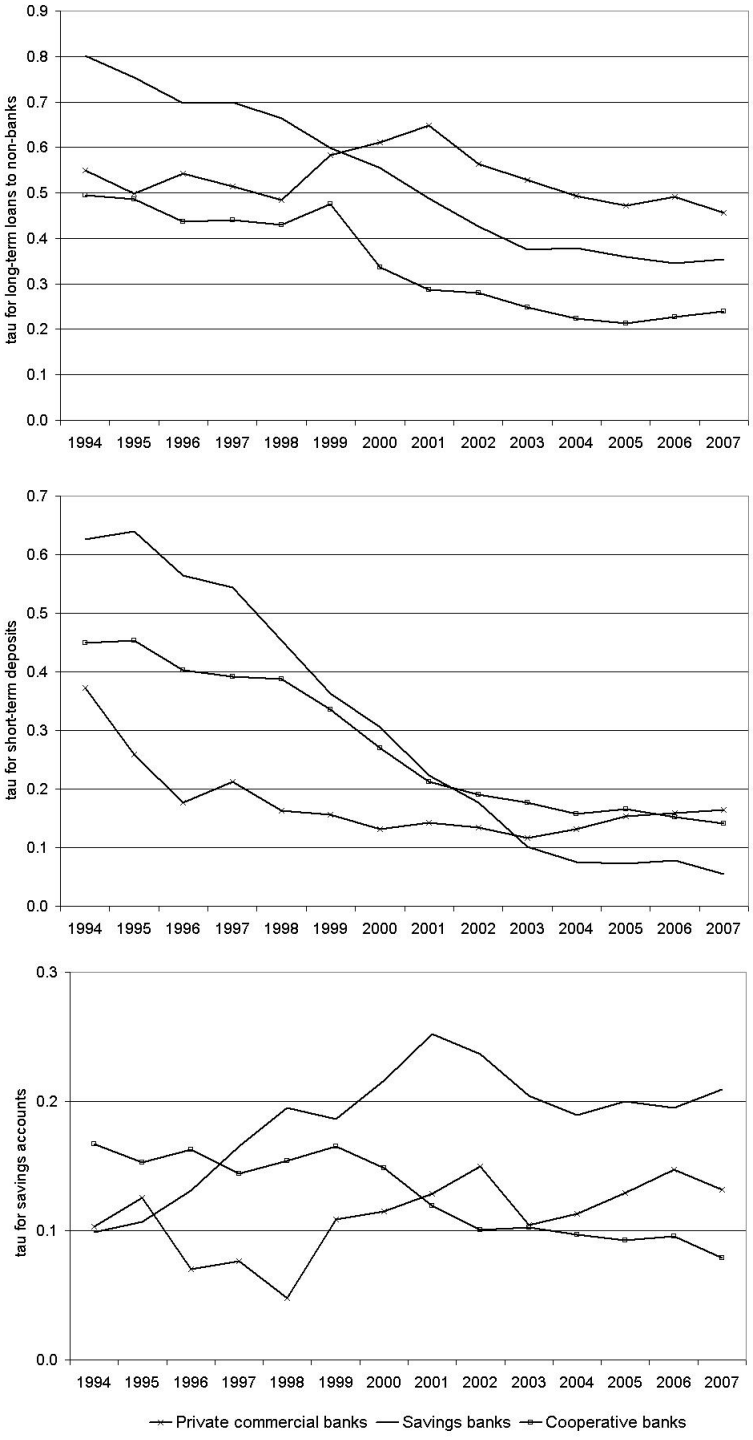

Figure 2: Dependency measure $\hat{\tau}$ for selected asset and liability positions.

Balance sheet position	Sector	Change in $\hat{\tau}$	
		1994-2000	2000-2007
Loans (lt) to non-banks	Private commercial banks	0.061	-0.155***
	Savings banks	-0.247***	-0.200***
	Cooperative banks	-0.158***	-0.096
Deposits (st)	Private commercial banks	-0.241*	0.033
	Savings banks	-0.320***	-0.251***
	Cooperative banks	-0.178*	-0.130
Savings accounts	Private commercial banks	0.012	0.017
	Savings banks	0.117	-0.007
	Cooperative banks	-0.018	-0.070

Table 3: Change in the dependency measure $\hat{\tau}$ for selected balance-sheet positions broken down into banking sectors. (st) = short-term; (lt) = long-term. */**/*** denote significance at the 10%, 5% and 1% level.

	Private com. banks			Savings banks			Cooperative banks		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Variable		Tercile			Tercile			Tercile	
Derivatives	0.0%	3.5%	59.6%	0.0%	0.8%	4.8%	0.0%	0.4%	3.8%
Size	54	361	2,474	379	975	2,402	40	113	352
Capital ratio	10.3%	19.3%	66.2%	9.76%	11.0%	13.1%	9.71%	11.2%	13.7%
Liquidity ratio	1.3	2.1	5.9	2.0	2.6	3.5	1.7	2.1	2.9
ROE	-1.0%	2.7%	9.5%	3.1%	4.8%	6.5%	3.3%	5.2%	6.9%
Provision income	0.0%	14.1%	51.7%	15.1%	18.9%	21.8%	12.5%	17.6%	22.6%
Volatility	2.2%	5.4%	12.7%	1.3%	2.3%	3.8%	1.2%	2.2%	4.1%

Table 4: Median of the terciles (the first tercile includes the 33% lowest values) of different variables (time series means).

Criterion	Sector		Tercile		
			1st	2nd	3rd
Derivatives	Priv. c. banks	Start	0.078	0.103	0.151
		1st change	-0.042	-0.020	-0.115
		2nd change	0.026	-0.050	-0.008
	Savings banks	start	0.144	0.225	0.250
		1st change	-0.020	-0.046	-0.087
		2nd change	-0.072	-0.075	-0.077
	Coop. banks	Start	0.118	0.122	0.150
		1st change	-0.043	-0.044	-0.075
		2nd change	-0.034	-0.035	-0.017
Size	Priv. c. banks	Start	0.039	0.117	0.172
		1st change	0.016	-0.048	-0.079
		2nd change	-0.030	0.017	-0.035
	Savings banks	Start	0.237	0.236	0.188
		1st change	-0.054	-0.050	-0.084
		2nd change	-0.085	-0.096	-0.049
	Coop. banks	Start	0.125	0.139	0.130
		1st change	-0.049	-0.054	-0.062
		2nd change	-0.029	-0.022	-0.036

Table 5: Start values and changes in the dependency measure $\hat{\phi}$ for derivatives and bank size. *Start* gives the value of the measure in 1994. *1st change* and *2nd change* is the change in the dependency measure between 1994-2000 and 2000-2007, respectively.

Criterion	Sector		Tercile			# years for which $\hat{\phi}$ is	
			1st	2nd	3rd	decreasing	increasing
	Priv. c. banks	mean	0.154	0.086	0.031	7*** / 5***	0 / 0
		change	-0.180	-0.028	-0.016		
Capital	Savings banks	mean	0.120	0.089	0.129	0 / 2	1 / 1
ratio		change	-0.162	-0.127	-0.175		
	Coop. banks	mean	0.068	0.070	0.072	1 / 0	0 / 5***
		change	-0.106	-0.082	-0.071		
	Priv. c. banks	mean	0.128	0.078	0.074	7*** / 2	0 / 0
		change	-0.204	-0.070	0.081		
Liquidity	Savings banks	mean	0.087	0.070	0.158	0 / 0	1 / 0
ratio		change	-0.080	-0.099	-0.134		
	Coop. banks	mean	0.089	0.101	0.063	1 / 2	0 / 0
		change	-0.047	-0.104	-0.072		

Table 6: Time series means of and changes in the dependency measure $\hat{\phi}$ for prudential regulations. The last but one column gives the number of years for which the dependency measure $\hat{\phi}$ is on the decrease, i.e. the order is $\hat{\phi}_{1st} \leq \hat{\phi}_{2nd} \leq \hat{\phi}_{3rd}$ for the period 1994-2000/2001-2007. The last column gives the number of years for which the dependency measure $\hat{\phi}$ is on the increase, i.e. $\hat{\phi}_{1st} \geq \hat{\phi}_{2nd} \geq \hat{\phi}_{3rd}$ for the period 1994-2000/2001-2007. */**/*** denote significance at the 10%, 5% and 1% level.

Criterion	Sector		Tercile			# years for which $\hat{\phi}$ is	
			1st	2nd	3rd	decreasing	increasing
	Priv. c. banks	mean	0.054	0.078	0.080	0 / 0	3* / 1
		change	-0.053	-0.081	-0.066		
ROE	Savings banks	mean	0.157	0.105	0.152	0 / 0	0 /1
		change	-0.177	-0.066	-0.077		
	Coop. banks	mean	0.083	0.070	0.067	6*** / 3*	0 / 0
		change	-0.099	-0.077	-0.077		
	Priv. c. banks	mean	0.098	0.071	0.045	6*** / 5***	0 / 0
		change	-0.092	-0.088	-0.043		
Provision	Savings banks	mean	0.126	0.142	0.153	0 / 0	1 /6***
income		change	-0.152	-0.166	-0.098		
	Coop. banks	mean	0.064	0.074	0.092	0 / 0	3* / 4**
		change	-0.075	-0.101	-0.082		
	Priv. c. banks	mean	0.076	0.086	0.116	0 / 0	4** / 0
		change	-0.042	-0.067	-0.101		
Volatility	Savings banks	mean	0.095	0.144	0.180	0 / 0	7*** / 7***
		change	-0.099	-0.093	-0.139		
	Coop. banks	mean	0.063	0.071	0.075	3* / 0	1 / 7***
		change	-0.083	-0.081	-0.069		

Table 7: Time series means of and changes in the dependency measure $\hat{\phi}$ for bank profitability. The last but one column gives the number of years for which the dependency measure $\hat{\phi}$ is on the decrease, i.e. the order is $\hat{\phi}_{1st} \leq \hat{\phi}_{2nd} \leq \hat{\phi}_{3rd}$ for the period 1994-2000/2001-2007. The last column gives the number of years for which the dependency measure $\hat{\phi}$ is on the decrease, i.e. $\hat{\phi}_{1st} \geq \hat{\phi}_{2nd} \geq \hat{\phi}_{3rd}$ for the period 1994-2000/2001-2007. */**/*** denote significance at the 10%, 5% and 1% level.

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