DEUTSCHE
BUNDESBANK
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# Discussion Paper

Deutsche Bundesbank
No 39/2013

## Uncertainty and bank wholesale funding

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ISBN 978–3–86558–963–7 (Printversion)
ISBN 978–3–86558–964–4 (Internetversion)

## Non technical summary

In this paper we relate a bank's choice between retail and wholesale liabilities to real economic uncertainty and the resulting volatility of bank loan volumes. We argue that since the volume of retail deposits is slow and costly to adjust to shocks in the volume of bank assets, banks facing more intense uncertainty and more volatile loan demand tend to employ more wholesale liabilities rather than retail deposits.

We empirically confirm this argument using a unique dataset constructed from the weekly reports of the 122 largest U.S. commercial banks. The high frequency of the data allows us to employ dynamic identification schemes. The results of our analysis show an economically and statistically strongly significant effect of bank-level uncertainty on liabilities structure. Banks which face high uncertainty as measured by the volatility of loan volumes have significantly lower ratios of retail deposits to total liabilities. Such banks also tend to adjust their retail deposit volumes slower to loan volume shocks relative to banks facing lower volatility. Banks facing high uncertainty in loan volumes react to loan shocks by mainly adjusting their wholesale funding while those facing lower volatility are quicker to modify retail deposit volumes.

A major contribution of our analysis is the identification of bank uncertainty as a determinant of bank liability structure. By showing that uncertainty is not only a result but also a determinant of wholesale funding, we shed new light on the discussion on the risk increasing role of wholesale funding. If, as we find, wholesale liabilities increase as a response to "real" uncertainty, regulatory measures targeting a cap on wholesale funding would limit funding uncertainty but will increase the exposure to asset-side shocks.

We add bank uncertainty to the battery of proposed liability structure determinants. The main contribution of uncertainty in this framework is that it is one of the few determinants that affect both the time-series and the cross-sectional variation in wholesale funding use. Our results are consistent with the findings in the literature that banks which have higher costs of switching between retail and wholesale markets will have a higher propensity to hold low-return liquid assets. Finally, we contribute to the macroeconomic literature on investment under uncertainty by showing for banks that uncertainty affects the choice of capital employed in the “production” in a manner consistent with that observed for nonfinancial firms.

## Nicht-technische Zusammenfassung

In der vorliegenden Studie wird die Entscheidung einer Bank zwischen der Finanzierung über Kundeneinlagen und der Finanzierung über die Finanzmärkte zur realwirtschaftlichen Unsicherheit und der daraus resultierenden Volatilität des Kreditvolumens in Beziehung gesetzt. Es wird dargelegt, dass die Banken, die einer höheren Unsicherheit und volatileren Kreditnachfrage ausgesetzt sind, sich tendenziell eher über die Finanzmärkte als über Kundeneinlagen refinanzieren, da eine Anpassung des Umfangs von Kundeneinlagen im Falle von Schocks, die das Volumen der Bankaktiva betreffen, langsam und kostspielig ist.

Grundlage für die empirischen Ergebnisse bildet ein einheitlicher Datensatz, der auf den wöchentlichen Meldungen der 122 größten US-amerikanischen Geschäftsbanken beruht. Das hohe Datenaufkommen ermöglicht die Verwendung dynamischer Identifikationsschemata. Die Ergebnisse der Analyse weisen darauf hin, dass die Unsicherheit der Banken einen ökonomisch und statistisch sehr signifikanten Effekt auf deren Passivastruktur hat. Bei Banken, die gemessen an der Volatilität ihres Kreditvolumens einer hohen Unsicherheit ausgesetzt sind, ist der Anteil der Kundeneinlagen an den gesamten Passiva deutlich niedriger. Diese Banken passen ihr Kundeneinlagenvolumen bei Schocks, die das Kreditvolumen tangieren, auch tendenziell langsamer an als Banken, die mit einer geringeren Volatilität konfrontiert sind. Während Banken, deren Kreditvolumen mit hoher Unsicherheit behaftet ist, auf derartige Schocks vornehmlich mit einer Anpassung ihrer Finanzierung über die Finanzmärkte reagieren, ändern Banken mit geringerer Volatilität rascher ihr Kundeneinlagenvolumen.

Ein wesentlicher Beitrag der Analyse ist die Identifikation der Unsicherheit der Banken als eine Bestimmungsgröße der Passivastruktur der Banken. Indem nachgewiesen wird, dass Unsicherheit nicht nur ein Ergebnis, sondern auch eine Bestimmungsgröße der Finanzierung über die Finanzmärkte ist, liefert diese Studie neue Anhaltspunkte bezüglich der Diskussion über die risikosteigernde Rolle der Refinanzierung von Banken über die Finanzmärkte. Nehmen danach die Verbindlichkeiten aus der Finanzierung über die Finanzmärkte als Reaktion auf die „reale" Unsicherheit zu, würden regulatorische Maßnahmen, durch die eine Obergrenze für diese Art der

Finanzierung festgelegt wird, die Refinanzierungsunsicherheit der Banken zwar begrenzen, jedoch würde das Risiko von Schocks, die die Aktivseite betreffen, erhöht.

Zu den zahlreichen vorgeschlagenen Bestimmungsgrößen für die Passivastruktur kommt somit die Unsicherheit der Banken als weiterer Faktor hinzu. Der wesentliche Beitrag der Unsicherheit in diesem Rahmen ist, dass die Unsicherheit eine der wenigen Bestimmungsgrößen darstellt, die sowohl die Zeitreihen als auch die Querschnittsunterschiede bei der Inanspruchnahme der Finanzierung über die Finanzmärkte tangiert. Die Ergebnisse der Studie stehen mit der Literatur im Einklang, wonach Banken, deren Umschichtungskosten zwischen Kundeneinlagen und Finanzmärkten höher ausfallen, eher dazu neigen, liquide Vermögenswerte mit geringen Renditen zu halten. Schließlich leistet diese Studie einen Beitrag zur makroökonomischen Literatur, die sich mit Investitionen unter Unsicherheit beschäftigt, indem gezeigt wird, dass die Wahl des für den „Betrieb“ der Banken verwendeten Kapitals genauso durch Unsicherheit beeinflusst wird, wie dies bei einem nichtfinanziellen Unternehmen der Fall ist.

# Uncertainty and Bank Wholesale Funding[1]

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**Abstract**

In this paper we relate a bank's choice between retail and wholesale liabilities to real economic uncertainty and the resulting volatility of bank loan volumes. We argue that since the volume of retail deposits is slow and costly to adjust to shocks in the volume of bank assets, banks facing more intense uncertainty and more volatile loan demand tend to employ more wholesale liabilities rather than retail deposits. We empirically confirm this argument using a unique dataset constructed from the weekly reports of the 122 largest U.S. commercial banks. The high frequency of the data allows us to employ dynamic identification schemes. Given the evidence presented in this paper we argue that regulatory measures targeting a cap on wholesale funding would limit funding uncertainty but will increase the exposure to asset-side shocks.

**Keywords:** wholesale funding, retail deposits, bank uncertainty, loan volume volatility

**JEL-Classification:** G21, E44

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# 1 Introduction

An extensive theoretical and empirical literature recognizes wholesale funding as a factor increasing the uncertainty of both individual banks and the banking system as a whole (see Ratnovski and Huang 2011, Ivashina and Scharfstein 2010, Segura and Suarez 2012, Brunnermeier and Oehmke forthcoming). This literature, motivated by the 2007-2009 financial crises, illustrates how the excessive use of uninsured bank wholesale liabilities increases liquidity risks and accelerates the propagation of financial system shocks. In response to the negative externalities of wholesale funding a number of policy measures such as Basel III's net stable funding ratio and the introduction of a tax on non-core bank liabilities (Shin et al 2011) have been proposed. These proposed policy measures aim at stabilizing the banking system by limiting the use of wholesale funding. Given the current state of the banking literature, however, researchers have only a very limited ability to evaluate the effects of such policies, since the driving forces behind a bank's choice between alternative funding sources are severely underexplored. In particular, research on the motives and determinants of banks' use of short-term wholesale funding and their cross-sectional variation is limited.[2]

In this paper we contribute to the analysis of bank liability structure determinants by exploring the role that a bank's uncertainty about the demand for its assets plays in the bank's choice between alternative bank liabilities. To our knowledge existing research has so far ignored this potential determinant of bank funding structure. We close this gap and argue that an environment with high uncertainty about the available sets of potential bank assets (e.g. an environment with a very volatile loan demand) will generate incentives for a bank to fund its assets by wholesale liabilities which typically have short-term maturities and are flexible to adjust[3], rather than by retail deposits which because of retail customers' inertia, switching costs, time needed to expand deposit gathering networks, etc. represent a very inflexible source of funding. Our analysis, therefore, shows how bank uncertainty stemming from "real" economic fluctuations is transmitted into the structure of bank liabilities, which in turn (as shown by earlier studies) affects real outcomes by affecting banks' susceptibility to financial shocks and thus non-financial firms' access to funding.

The intuition of our argument combines the implications of the literature on bank retail deposit liabilities as a quasi-fixed factor in the production of bank loans (Flannery, 1982) and the macroeconomic literature on firm investment behavior under uncertainty (Leahy and Whited 1996, Bloom et al 2007). The typical argument in the macroeconomic uncertainty literature is that firms facing a high degree of uncertainty with respect to the demand for their products will tend to postpone investments in irreversible forms of capital and predominantly invest in more flexible types of capital which can easier be disinvested. We translate this argument to the case of banking by

[2] Some studies (e.g. Gorton 2010) point to the shift to originate-and-distribute business model as a determinant of the use of wholesale funding, these studies however do not explain why some banks adopt this models while others keep to traditional commercial banking.

[3] Throughout the paper we use the term wholesale liabilities to denote uninsured short-term bank liabilities. Both aggregate and bank-level data suggest that uninsured bank debt effectively has a much shorter maturity relative to retail bank liabilities.

adopting Flannery's (1982) approach[4] of modeling the bank as a firm which employs retail and wholesale liabilities in the production of loans and alternative assets. Following this approach the key difference between retail and wholesale liabilities is that retail deposits despite their short de jure maturity are typically costly and slow to adjust in both an upward and a downward direction, while wholesale liabilities can, given their short maturity and low adjustment costs, be immediately and free of costs be adjusted to shocks.

The costs of adjusting bank retail deposits can be viewed in two alternative directions. To start with, any increase in the volume of retail deposits that goes beyond an exogenous shift in deposit supply will generate substantial costs to the bank. Well documented examples of such costs are the costs of increasing deposit rates (as modeled by Hannan and Berger 1991), the compensation for depositors' switching costs (Sharpe 1997), the costs of mergers with retail-deposits rich banks, building new branched, etc.[5] Next, any decrease in the volume of retail deposits is again costly since depositors have to be compensated for their decision to "abandon" the bank[6]. These costs of reducing the volume of retail deposits correspond to the irreversibility of investment in a macroeconomic sense. They become particularly relevant in the case when a bank operating in an uncertain environment "overinvests" in retail deposits (collects more deposits than optimal under the ex post realization of the loan volume). In this case it can lend the idle funds to the interbank market only at a rate lower than the loan interest rate and potentially even lower than the costs of deposits. The unattractiveness of an overinvestment in retail deposits becomes more dramatic in an environment of very low interest rate levels in the economy, since the costs of deposit collection are nominally fixed and independent of interest rates, while return realized on interbank lending is very low[7].

Contrary to retail deposits, wholesale liabilities can typically be adjusted almost free of costs. This claim is consistent with the empirical observations (Shin 2011) that in credit boom times some banks are able to extremely fast inflate their balance sheet by heavier use of wholesale liabilities. However, one important exception exists: wholesale funding can become prohibitively costly to adjust in a situation when either the bank or the banking system as a whole is in distress. It is this particular situation of explosive wholesale adjustment costs that the recent literature (Huang and Ratnovski 2011, Segura and Suarez 2012) has been focused on when modeling the negative externalities arising from short-term wholesale funding. We argue here that this exclusive focus on the prohibitive costs of wholesale funding in the rare events of substantial wholesale

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[4] Flannery (1982) employs the concept of deposits quasi-fixed factor of production in order to explain why banks in certain periods of time offer retail deposit rates higher than the rates on more flexible funding sorces such as uninsured large certificate of deposits.

[5] Flannery (1982) summarizes these different types of costs by the introduction of a combination of fixed and variable adjustment costs.

[6] Flannery and James (1984) provide indirect empirical evidence based on interest rate sensitivity that independent of their de jure maturities retail bank liabilities typically have a maturity of significantly more than one year.

[7] Some anecdotal evidence claims that wholesale funding is preferred by banks since it is cheap. Although this claim has not been thoroughly empirically exploited so far, back on the envelope comparison of retail and wholesale funding interest rates show that retail rates are typically much lower than wholesale rates. The claim of "cheap" wholesale funding can, therefore, only be defended relative to the costs of accumulation and servicing of retail deposits.

market distress omits the potentially important advantages of wholesale funding in normal times as well as the risks of "overinvesting" in inflexible retail funding which for the sake of completeness of the analysis should also be taken into consideration. We, nevertheless, also explore how the relation between bank level uncertainty and funding sources is modified in periods with substantial wholesale market distress.

Our focus is on the uncertainty related to the challenges of predicting the volume of liabilities a bank has to issue in order to fund its assets. In particular, we focus on a "real" economic dimension of uncertainty where a bank has only a very noisy prediction about the volume of loans it is going to supply[8]. Accordingly, following the uncertainty literature (Leahy and Whited 1996, Bloom et al 2007) we measure bank uncertainty by alternative measures of bank loan volume volatility. Our focus on loans is motivated by several considerations. First, loan origination is a key banking activity, which distinguishes banks from other financial intermediaries. Second, given their typically long maturity as well as their huge liquidation costs, loans are a key determinant of a bank's funding needs.

The uncertainty about the future volumes of loans can arise from various sources. Besides business cycle effects and aggregate shocks, which affect all banks and therefore create mainly a time-series variation of uncertainty, a cross-sectional variation of uncertainty[9] can be generated by idiosyncratic loan demand shocks which hit only individual banks. Individual bank's uncertainty can emerge from banking market deregulation which allows market entry of new players and a redistribution of loan market shares. Uncertainty can, as well, emerge from global trends not necessarily limited to the financial industry, such as the globalization and market deregulation of specific industries, which affect firms' investment behavior and therefore the demand for loans of the banks typically serving these industries. These sources of uncertainty correspond closely to the sources of uncertainty faced by non-financial firms discussed by Bloom et al (2007).

Our empirical strategy is based on exploring how various measures of bank specific uncertainty about loan volumes affect bank funding choices. The analysis employs weekly data on key bank balance sheet positions for the largest US commercial banks in the period 1997-2009. We examine the impact of bank-level uncertainty both (i) on liabilities structure in a static panel model and (ii) on the dynamics of retail and wholesale liabilities by estimating a panel vector error correction model of the reaction of retail deposits to changes in loan volumes and uncertainty. The static analysis serves as a starting point establishing key stylized facts about the determinants of bank liability structure. It raises a few issues about identification which are then solved in the

[8] Data availability limitations make the precise disentangling of loan demand and loan supply effects challenging. That is why we perform the analysis on the volatility of loan volumes which reflects the demand and supply equilibrium outcomes which the bank can only imperfectly predict.

[9] A key difference between aggregate and idiosyncratic uncertainty is that the former is usually a common knowledge for all market participants and can therefore affect the pricing of wholesale funding while the latter is typically observable only by the insiders of the bank who have detailed knowledge of the bank portfolio and its dynamics. Since we are concerned with the uncertainty about the volumes rather than the repayment probability of bank assets, the price of wholesale funding should not necessarily depend on this kind of uncertainty.

dynamic framework, where identification is based on the high frequency of the data which allows us to precisely track the timing of changes in loans and liabilities.

The results of our analysis show an economically and statistically strongly significant effect of bank-level uncertainty on liabilities structure. Banks which face high uncertainty as measured by the volatility of loan volumes have significantly lower ratios of retail deposits to total liabilities. Such banks also tend to adjust their retail deposit volumes slower to loan volume shocks relative to banks facing lower volatility. The former banks react to loan shocks by mainly adjusting their wholesale volumes while the later are quicker to modify retail deposit volumes.

A major contribution of our analysis is the identification of bank uncertainty as a determinant of bank liability structure. By showing that uncertainty is not only a result but also a determinant of wholesale funding, we shed new light on the discussion on the risk increasing role of wholesale funding. If, as we find below, wholesale liabilities increase as a response to "real" uncertainty, regulatory measures targeting a cap on wholesale funding would limit funding uncertainty but will increase the exposure to asset-side shocks. The joint effect on financial system stability will thus be ambiguous.

Our study also contributes to several other strands of the literature. To start with, we contribute to the literature focused on the identification of bank liability structure determinants. This literature has so far suggested alternative reasons for the broad use of wholesale funding including bank market power (Berlin and Mester 1998; Craig and Dinger, 2010) and market entry barriers (Park and Pennacchi 2008; Dinger and von Hagen 2009); taxes (Pennacchi et al 2010); a shift to a new originate-and-distribute business model (Gorton and Metrick 2011); as well as the fact that in periods of lending booms the growth rate of deposits is insufficient to cover loan demand needs (Shin et al 2011). We add bank uncertainty to the battery of proposed liability structure determinants. The main contribution of uncertainty in this framework is that it is one of the few determinants that affect both the time-series and the cross-sectional variation in wholesale funding use.

Next we contribute to the literature focused on the effect of bank financial flexibility by illustrating the different dynamics of retail and wholesale liabilities. For example, our results are consistent with the finding of Billet and Garfinkel 2004[10] that banks which have higher costs of switching between retail and wholesale markets will have a higher propensity to hold low-return liquid assets. And last but not least, we contribute to the macroeconomic literature on investment under uncertainty by showing for banks as a particular type of firms that uncertainty affects the choice of capital employed in the "production"[11] in a manner consistent with that observed for nonfinancial firms.

The rest of the paper is organized as follows. Section 2 presents the data sources and the sample. Section 3 discusses measurement issues and the identification and establishes the key summary statistics concerning wholesale funding. Section 4 presents the empirical methods employed and their results. Section 5 explores how the relation

[10] These authors introduce a rough measure of the costs of adjusting insured deposits derived from the elasticity of deposit volumes to changes in the rate on bank bonds which is used as a proxy for the costs of uninsured liabilities.

[11] Similarly, the labor literature argues that firm-level uncertainty results in a rise in firms' demand for flexible labor, e.g. firm-level uncertainty is a significant determinant of temporary employment contracts (Laird and Williams 1996).

between bank specific uncertainty measures and funding modes is modified during times of wholesale market disruptions. Section 6 concludes.

## 2 Data

The analysis is based on data from the "Weekly Report of Selected Assets and Liabilities of Domestically Chartered Commercial Banks and U.S. Branches and Agencies of Foreign Banks". These "Weekly Reports", which present data on key balance sheet positions[12], are required by the Federal Reserve System from the largest regulated institutions. Numerous changes in the reporting requirements restricted our sample period to the weeks between the beginning of January 1997 and end of July 2009. Extending the sample beyond this period would have raised some comparability concerns.

**Table 1: Number of sample banks and their average total assets**

| year | number of banks in the sample | average bank total assets in USD bill |
|---|---|---|
| **1997** | 118 | 23 |
| **1998** | 96 | 30 |
| **1999** | 88 | 34 |
| **2000** | 81 | 50 |
| **2001** | 47 | 71 |
| **2002** | 42 | 81 |
| **2003** | 37 | 98 |
| **2004** | 36 | 117 |
| **2005** | 31 | 145 |
| **2006** | 29 | 169 |
| **2007** | 33 | 187 |
| **2008** | 34 | 196 |
| **2009** | 31 | 222 |

Source: Own calculations

In this period a total of 122 U.S banks submitted weekly reports, although mergers and bank failures lead to an unbalanced panel of bank observation. The summary of the number of banks covered by the sample and their average size illustrates the substantial consolidation of the banking industry which took place during this period. As presented

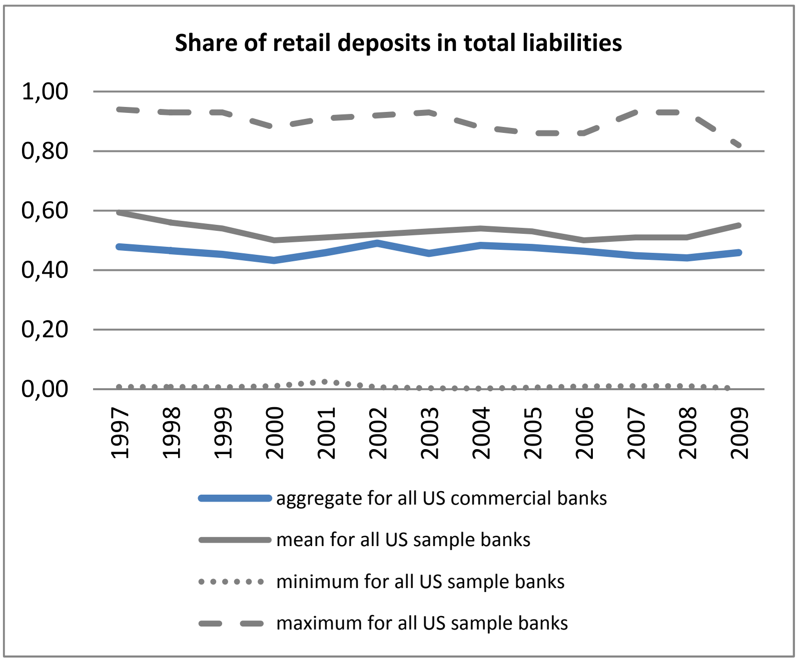
[12] The weekly reports include a substantially smaller set of variables relative to the quarterly call reports. In particular they do not include a distribution of loans and deposits across different maturities. We nevertheless base the analysis on the weekly reports' information since the high frequency of the data allow a solution to the major identification challenges.

in Table 1, the number of sample banks significantly declines during the examined period but the volume of individual banks' total assets increased tremendously.

A comparison with the aggregate size of the US commercial banking sector as presented in the "Flow of Funds" issues of the Federal Reserve System shows that the total banking assets covered in our sample reflect throughout the sample years an almost constant portion of 43-47% of the banking sector. In order to control for the obviously large number of mergers which can substantially affect the volatility measures used in the analysis we add information on the timing of bank mergers from the Supervisory Master File of Mergers and Acquisitions. The periods when the respective bank was involved in a merger are excluded from the computation of the uncertainty measures.

The length of the time span of the data enables us to track the dynamics of individual bank's liabilities during a period for which it has often been claimed that a substantial shift in the funding modes have taken place (Gorton and Metrick 2011). Figure 1 illustrates that the notorious shift towards wholesale funding reflects the situation of a few individual institutions rather than a general time series trend affecting the banking industry as a whole.

**Figure 1: Share of retail liabilities in total liabilities for the aggregate of US banks and for the sample banks, 1997-2009**




Source: Flow of Funds for the aggregate numbers and own calculation for the sample mean, maximum and minimum. Retail liabilities are defined as the sum of all bank deposits (line 2215 "*total transaction accounts*" and line 2385 "*total non-transaction accounts*").

The share of retail deposits in total liabilities aggregated across all US banks varies between 43 and 49% in the time period (without an unambiguous time trend); whereas the variation across banks is huge in each of the sample years: while some banks have less than 1% of their total liabilities as retail funding others have a share of retail deposits in total liabilities of more than 90%. Note that this variation is present even though we only cover the largest banking institutions, so diversity of liability structure is present in an otherwise homogenous sample of very large US banking institutions. The exploration of this huge cross-sectional variation is at the very core of the analysis pursued in this paper.

The time period also encompasses a few periods of financial system distress such as the LTCM failure, September 11 as well as the financial system turmoil of 2007-2009 that mark substantial shocks in aggregate uncertainty and allows us to address the differences in the bank's reaction to loan market shocks in time of well-functioning versus distressed markets for wholesale funding.

The balance sheet and income statement information from the weekly report is enriched by a few variables, such as the number of branches and number of local bank markets operated by the bank, from the Summary of Deposits concerning the bank retail market positions and used as controls. And last but not least, we control for the variable costs of retail and wholesale liabilities by the interest rates incurred by the banks in both markets. To this end we provide both aggregate measures, such as average commercial paper rates reported by the Federal Reserve Bank of St. Louis (FRED) and the bank level retail interest rate data reported by BankRate Monitor.

After presenting the sources of the data we next turn to the key measurement issues of the empirical analysis.

## 2.1 Uncertainty

A key measurement issue in testing the effect of uncertainty on bank liability structure is the choice of appropriate uncertainty measures. Our goal of explaining the reaction of bank-level funding structure to uncertainty about the volume of loans requires measures which are not exclusively driven by aggregate factors but can as well affect the volatility of the environment faced by individual banks. These should be measures that are allowed to differ across banks for a given time period.

To this end we borrow from the macroeconomic literature which has examined how heterogeneous firm and/or industry level conditions generate firm-level variations in uncertainty (Leahy and White 1996, Bloom at al 2007). This firm level uncertainty is studied as being complementary to aggregate uncertainty, e.g. the shocks generated by

September 11 (as in Bloom 2009), financial system disruptions, oil price shocks (as in Jo 2012), whose effect on different firms is also allowed to vary. This literature employs firm-specific uncertainty proxies such as stock market volatility (Leahy and White 1996) or output volatility (Bloom et al 2007) [13,14]. Leaning on this approach we measure bank uncertainty by the volatility of bank loan volumes as a measure of uncertainty.

Measuring uncertainty by loan volume volatility bears a direct analogy to the use of firm output volatility as an uncertainty measure and allows the comparability of our results to those of studies focused on non-financial firms. It also suffers similar identification challenges since we only observe equilibrium loan volumes and have a limited ability to disentangle demand from supply effects. However, in the case of banking we benefit from the high frequency of available data that allow us to employ dynamic identification schemes which are not applicable to industries for which only low frequency data are available.

Our focus on loans potentially ignores the dynamics of alternative assets that the bank may hold in its portfolio. We justify this focus by the following considerations: (i) bank loans are the most important illiquid bank assets. (ii) They represent an asset category for which utilizing the advantages of the weekly data we can reasonably identify changes exogenous with respect to liability structure[15]. This type of identification is hard to be achieved if we use alternative bank assets such as securities whose volumes can almost immediately be adjusted to liability shocks. And last but not least, (iii) the fact that bank loans are particularly illiquid makes them a major determinant of bank

[13] Extant banking literature does not provide analogical measures for uncertainty. The bank specific uncertainty measures employed by the existing banking literature have so far been focused on the uncertainty of investors about the value of the banking projects (Morgan 2002) or market microstructure properties of bank equity (Flannery et al 2004). Only few studies explore bank uncertainty about its own portfolio performance (Pritsker, 2010 and Valencia 2010), but these reflect uncertainty of investments which have already been funded rather than ex ante uncertainty about the volume of funding needs.

[14] The use of volatility as a proxy for uncertainty can be justified by the following example (see Bloom et al 2007 and Bloom 2012): Consider the following process which follows a Brownian motion: $dX_t=\mu dt+\sigma_{t-1}dw_t$, where $dw_t \sim N(0,1)$. Uncertainty should ideally be measured by $dX_{t+1}=\sigma_t$ but since $\sigma_t$ is not observable it can be approximated by the volatility over period (t-s, t) which is equal to the variance ($dX_{t-s}, dX_{t-s+1} \ldots dX_t$). The fact that E[variance of $dX_{t+1}$]$=\sigma_t$ illustrates the link between volatility and uncertainty.

[15] Some models of investment under uncertainty use a broader measure of volatility suggested by Leahy and Whited (1996) that approximates uncertainty by the standard variation of the daily stock return of the firm. Given the effect of liability structure on liquidity risk and therefore on bank performance this broad uncertainty measure is not suitable for the goal of our analysis. In particular, the inability of a bank to roll over wholesale debt can generate a pressure for the bank to liquidate assets and thus affect general performance. Moreover, measuring uncertainty by asset return volatility is not feasible either since these could as well be affected by potential liquidation pressures with origins in the liability structure.

funding needs, since alternative bank assets are both easier to liquidate and suitable as collateral in bank refinancing operations, e.g. repo transactions.

More specifically, we use three measures for the volatility of loan volumes. We start with the standard deviation of the loan volume (LOANS SD) as a classical measure of volatility[16]. The disadvantage of the standard deviation is its symmetric reflection of positive and negative loan volume shocks. Further, we account for the potential asymmetry, e.g. the possibility that large negative shocks generate a stronger reluctance of the bank to produce with inflexible "inputs"[17], by introducing the negative skewness (NEGATIVE SKEWNESS) of the loan volume as an additional measure of uncertainty. Unlike the standard deviation, negative skewness isolates the impact of the large, infrequent and abrupt loan volume drops[18]. The standard deviation and the negative skewness are generated for each individual bank by constructing rolling windows including the loan volume observations of the past 52 weeks. And last but not least, we measure bank level uncertainty by the conditional volatility of the bank's loan volumes predicted by a GARCH (1,1) model (LOANS GARCH).

In addition to these three bank-level uncertainty measures in Section 5 we also explore the effect of prominent shocks to aggregate uncertainty which potentially lead to disruptions in the wholesale market and can therefore generate substantial adjustment costs (or even unavailability) of wholesale funding. In particular, we focus on the dynamics of bank liabilities in the weeks following the failure of LTCM in the summer of 1998, the weeks after September 11, 2001 and the weeks after the failure of Lehman Brothers in September 2008. The inclusion of these aggregate uncertainty proxies in the analysis not only allows us to relate our results to those of studies on the negative externalities of wholesale funding but also to explore how banks rebalance their liabilities in periods when adjusting wholesale market volumes is costly.

## 2.2 Liability Structure

The choice of appropriate measures of the liability structure is also challenging, especially given the large variety of wholesale liabilities. Since we can only track the

[16] Bloom et al (2007) similarly use the volatility of sale changes as a measure for uncertainty.
[17] This will be the case when a bank is cautious about "overinvesting" in retail deposits which exceed the amount of loan demand.
[18] Tornell et al (2008), for example, employ loan volume skewness as a volatility measure in an aggregate level analysis of financial system risk.

dynamics of very few subtypes of bank wholesale liabilities with weekly frequency, we choose to apply a broad distinction between retail (insured) and wholesale (uninsured) liabilities. The first category includes classical deposit products such as checking accounts, money market deposit accounts, and certificates of deposits with a nominal value of less than USD 100,000 (computed as the sum of line 2215 "*total transaction accounts*" and line 2385 "*total non-transaction accounts*"). The latter category includes all other liabilities of the bank (defined as the difference between bank liabilities - excluding equity- and retail deposits) such as federal funds purchased, subordinated debt, commercial paper borrowing of the bank as well as funds sold under agreement to repurchase (repo borrowing).

## 2.3 Identification Challenges

The use of loan volume dynamics as uncertainty measure faces three major identification challenges. The first one is related to the fact that both the loan volumes and their volatility can be affected by the liability structure. This will be the case if a bank that heavily relies on wholesale funding finds itself in a situation when it has to liquidate loans since it is unable to rollover short-term wholesale debt. In this case identification requires a focus on those movements in loan volume for which we can convincingly claim to be unrelated to liquidity issues. This identification challenge will be solved in both the static and the dynamic model through the advantages of the high frequency of the data which allows us to precisely track the timing of loan, deposit and wholesale funding volume changes.

The second challenge reflects the spurious relation between securitization, loan volume volatility and funding structure. Using on-balance-sheet loan volume variation as a measure of uncertainty bears the risk that banks operating according to an originate-and-distribute model systematically have higher loan-volume volatility if loans appear on the balance sheet immediately after origination and disappear from the balance sheet once they are transferred to a special purpose vehicle for securitization. For those banks we will observe both a high volatility of the loan volume and a low reliance on retail liabilities for reasons that have nothing to do with uncertainty. We deal with this issue by using a broader measure of bank loan volume. This measure includes the joint volume of on-the-balance-sheet loans plus sold and/or securitized loans serviced by the bank[19]. The advantage of this measure is that it will not reflect the ups and downs of the loan volume solely generated by the securitization process. As a robustness check we

[19] Unfortunately we have no information on the volumes of loans which are issued and sold by the bank if these loans are not serviced by the bank.

rerun the estimations using only on-balance-sheet loans. The results which for the sake of parsimonious exposition are not reported here are qualitatively the same.

The third challenge is related to the fact that the observed positive correlation between wholesale funding and uncertainty can emerge from a self-selection of immanently more risky banks into both riskier funding as well as riskier (more volatile) assets. This selection concern are on the one hand mitigated, by the fact that our focus is on the volatility of loan volumes rather than on loan returns' volatility (which is a more direct measure of the banks' riskiness). On the other hand, we solve the selection issue by explicitly focusing on the dynamics of bank liabilities in reaction to individual loan volume shocks.

# 3 Empirical Model

## 3.1 Uncertainty and liability structure: a static analysis

We start the empirical analysis by estimating the relations between uncertainty and the share of retail deposits in banks' liabilities in a static framework using the following econometric model:

$$deposit\_share_{i,t} = \alpha_0 + \alpha_1 * uncertain_{i,t} + \alpha_2 * X_{i,t} + \varepsilon_{i,t} \qquad (1)$$

where $deposit\_share_{i,t}$ denotes the share of retail deposits to total liabilities[20] of bank $i$ in week $t$, $uncertain_{i,t}$ is a measure of the uncertainty faced by the bank in the corresponding period (we estimate the model using each of the uncertainty measures discussed in Section 3).

Since a bank's liability structure potentially depends on a number of bank characteristics, we extend the static model to a multivariate framework which includes the vector of control variables $X_{i,t}$ consisting of:

(i) the size of the bank as measured by the natural logarithm (BANK SIZE) of its total assets (and its squared term – BANK SIZE SQUARED- in order to control for non-linearities). We include bank size in the regressions as a proxy for banks' costs of retail and wholesale funding which could be affected by too-big-to-fail concerns, economies of scale, etc.

(ii) the three-month T-Bill rate (T-BILL RATE) as a measure for the general interest rate level in the economy. Assuming that the overhead costs of accumulating and servicing deposits are insensitive to the interest rate level, the T-Bill rate is also

[20] An alternative formulation of the empirical model that uses the share of wholesale to total liabilities naturally produces very similar results.

used to approximate the difference between the costs of wholesale and retail deposits. If the T-Bill rate is low, retail deposits become relatively more expensive since they contain a component which is interest-rate-insensitive. The information on the relative costs of retail and wholesale funding is also enriched by:

(iii) the spread between 3-month AA financial commercial paper (reported by the Federal Reserve Bank of St. Louis' information system FRED) and the 3-month T-Bill rate (BOND SPREAD). This spread reflects only the average costs of market funding for all firms at a given point of time. The de facto cost of a bank's wholesale funding can substantially differ from this rate, but the differences are potentially endogenous with respect to liability structure so that for the sake of identification we use this average measure of wholesale funding spread[21].

(iv) the spread of the three-month T-Bill rate over the average deposit rate offered by the bank (RETAIL SPREAD) as a proxy for the variable costs of retail deposits. The average deposit rate is a bank specific variable computed across all local markets where the bank reports operation in a given week, it represents a bank specific cost of insured retail liabilities reflecting numerous factors previously reported in the literature to affect liability structure such as the deposits market power of the bank (Hannan and Prager 2006, Dinger and von Hagen 2009, Craig and Dinger 2011).

(v) the ratio of total deposits to the number of branches operated by the bank (DEPOSITS PER BRANCH), which is informative for the degree of retail deposit market access of the bank.

(vi) the share of loans to total assets (LOANS TO TOTAL ASSETS) as an indicator on the business model of the bank. It gives information whether a bank perceives an originate-and-distribute model or a classical deposit – loan origination model.

The summary statistics of the variables employed in the model estimation are illustrated in Table 2.

Since most of the control variables stem from sources other than the weekly report we are not able to perfectly match all weekly report observations with the corresponding controls (e.g. the retail rate variables were not available for the full sample[22]), so that for each uncertainty measure we first estimate the model without control variables for the full available sample of weekly observations and then re-estimate the model with all control variables but using only the subsample of observations for which the complete

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[21] A similar measure of the costs of uninsured bank liabilities has been proposed by Billet and Garfinkel 2004.

[22] We have also re-estimated the model excluding only the retail market variables, the results which are available from the authors upon request are qualitatively the same as the ones presented below.

information on the control variables is available. The results of the estimations of the static model are presented in Table 3.

**Table 2: Summary statistics**

| | Number of observations | mean | median | standard deviation |
|---|---|---|---|---|
| $\Delta_{(t)-(t-1)}$DEPOSITS (in mill USD) | 32858 | 62.64 | 2.05 | 2434.96 |
| $\Delta_{(t)-(t-1)}$LOANS (in mill USD) | 32858 | 57.47 | 16.00 | 1472.80 |
| LOANS SD | 33103 | 0.03 | 0.01 | 0.10 |
| NEGATIVE SKEWNESS | 33103 | -0.22 | 0.05 | 2.23 |
| LOANS GARCH | 33104 | 0.05 | 0.00 | 0.54 |
| DEPOSITS (in mill USD) | 33104 | 43800 | 18400 | 82300 |
| LOANS (in mill USD) | 33104 | 45800 | 19500 | 80000 |
| BANKS SIZE (log of total assets) | 33104 | 17.37 | 17.31 | 1.19 |
| T-BILL RATE (in %) | 33104 | 3.79 | 4.56 | 1.71 |
| RETAIL SPREAD | 4913 | 2.50 | 2.58 | 1.21 |
| BOND SPREAD | 33012 | 0.47 | 0.42 | 0.35 |
| DEPOSITS PER BRANCH (in mill USD) | 4688 | 141.53 | 70.29 | 205.16 |
| LOANS TO TOTAL ASSETS | 33104 | 0.63 | 0.66 | 0.17 |

Source: Authors' computations

These results indicate a robust statistically significant negative relation between bank uncertainty as measured by the loans standard deviation, the conditional GARCH volatility and the negative skewness and the share of retail deposits. The economic significance of the effect, however, differs substantially across the different uncertainty measures. So for example, raising the LOAN SD variable by one standard deviation (which is equal in our sample to 0.10) corresponds to reducing the share of deposits to total liabilities by 1.2% in the model which does not include additional control variables and to a drop of more than 5% if we control for interest rates, deposit market structure and loans' shares. Similarly, a one standard deviation rise of LOANS GARCH (equal to 0.54) relates to a 0.1-0.3% decline in the share of deposits depending on whether we include additional control variables or not. A one standard deviation increase in

**Table 3: Bank uncertainty and liability structure: static panel estimations**

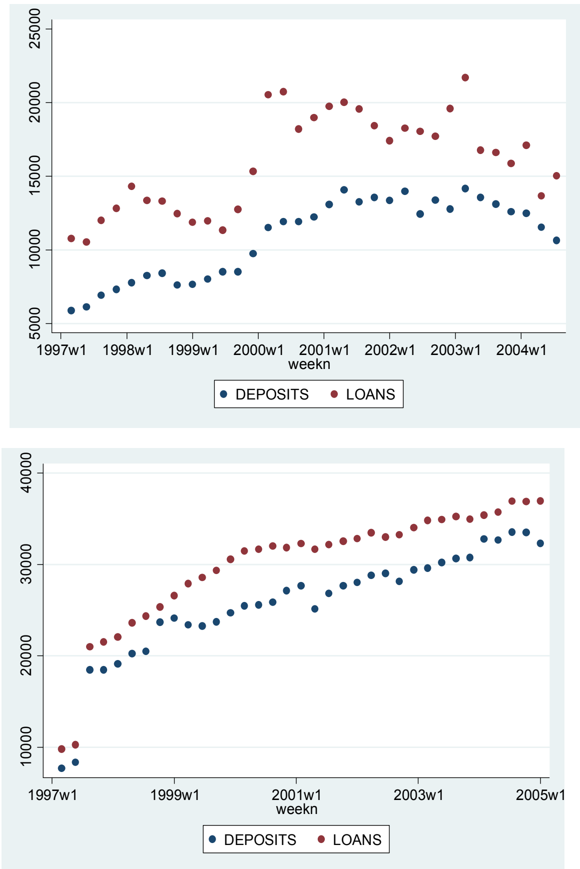
| VARIABLES | (1) Deposits/ Total liabilities | (2) Deposits/ Total liabilities | (3) Deposits/ Total liabilities | (4) Deposits/ Total liabilities | (5) Deposits/ Total liabilities | (6) Deposits/ Total liabilities |
|---|---|---|---|---|---|---|
| LOANS SD | -0.122** | -0.511*** | | | | |
| | (0.052) | (0.105) | | | | |
| NEGATIVE SKEWNESS | | | -0.001** | -0.001 | | |
| | | | (0.000) | (0.001) | | |
| LOANS GARCH | | | | | -0.002** | -0.005** |
| | | | | | (0.001) | (0.002) |
| BANK SIZE | -0.465*** | -1.542*** | -0.469*** | -1.468*** | -0.472*** | -1.497*** |
| | (0.016) | (0.073) | (0.016) | (0.073) | (0.016) | (0.074) |
| BANK SIZE SQUARED | 0.013*** | 0.042*** | 0.013*** | 0.040*** | 0.013*** | 0.041*** |
| | (0.000) | (0.002) | (0.000) | (0.002) | (0.000) | (0.002) |
| T-BILL RATE | | -0.010*** | | -0.012*** | | -0.011*** |
| | | (0.002) | | (0.002) | | (0.002) |
| RETAIL SPREAD | | 0.005** | | 0.007*** | | 0.007*** |
| | | (0.002) | | (0.002) | | (0.002) |
| BOND SPREAD | | -0.003 | | -0.002 | | -0.002 |
| | | (0.005) | | (0.005) | | (0.005) |
| DEPOSITS PER BRANCH | | -0.002*** | | -0.003*** | | -0.002*** |
| | | (0.001) | | (0.001) | | (0.001) |
| LOANS TO TOTAL ASSETS | | 0.120*** | | 0.155*** | | 0.154*** |
| | | (0.021) | | (0.019) | | (0.019) |
| CONSTANT | 4.811*** | 14.685*** | 4.847*** | 13.980*** | 4.868*** | 14.235*** |
| | (0.141) | (0.639) | (0.141) | (0.634) | (0.142) | (0.641) |
| Observations | 33,103 | 4,688 | 33,103 | 4,688 | 33,104 | 4,688 |
| R-squared | 0.027 | 0.179 | 0.027 | 0.175 | 0.027 | 0.175 |
| Number of banks | 122 | 77 | 122 | 77 | 122 | 77 |

Note: Fixed effect panel estimations of deposits to total liabilities ratios on (i) loans' standerd deviation, (ii) loans' skewness or (iii) loans' conditional volatility predicted using a GARCH (1,1) model. *,**,*** indicate statistical significance at 10% , 5% and 1%, respectively.

NEGATIVE SKEWNESS (equal in our sample to 2.23), however, corresponds to a drop in the share of deposits in total liabilities of only about 0.2%.

All control variables enter the regressions with the expected signs. So as previously documented (e.g. Park and Pennacchi 2008) we show that larger banks fund a smaller share of their assets by retail deposits. However, the positive sign of the squared size terms indicates that this effect is exhausted at a certain size level. Also the positive significant coefficient of the retail spread variable indicates that banks which generate high margins from retail deposit market operation as measured by the difference between the T-Bill rate and the average retail deposits rate of the bank in the respective week tend to use larger shares of retail deposits. The spread of the commercial paper to T-Bill rate enter the regressions with a negative insignificant coefficient. An underdeveloped branch network as signaled by large average deposit volumes per branch corresponds to lower shares of retail deposits in total liabilities. And last but not least, banks with a large share of loans in their assets tend to have larger shares of retail deposits in their liabilities. This result is consistent with the view that some banks follow traditional deposit-loan business model while others pursue a originate-and-distribute strategy.

**Figure 2: Loans and deposits of two of the sample banks (in million USD)**




Note: Deposit and loan volumes of two banks present in our sample. Graph is based on publicly available information about deposit and loan volumes with quarterly frequency.

In sum, the results presented in Table 3 confirm our hypothesis that banks facing higher degrees of uncertainty fund smaller shares of their assets by retail deposits. A graphical illustration of this econometrically documented negative link between loan volume volatility and the share of deposits in bank's total liabilities is given in Figure 2, which plots loan and deposit volumes of two of the sample banks.

The left panel reflects a bank with very volatile loan volumes. One can easily see that deposits hardly react to loan volume fluctuations and that the bank funds a substantial share of its liabilities by non-deposit liabilities. The bank reflected in the right panel, on the contrary, has a stable loan volume trend. For this bank the largest portion of loans are funded by retail deposits.

## 3.2 Identification

After controlling for the loan volume volatility induced by securitization we are left with the following identification challenges discussed in Section 3: (i) uncertainty could be caused by the use of wholesale funding if the inability to rollover short-term wholesale debt generates liquidation pressures and thus loan volume volatility; (ii) the observed positive correlation between wholesale funding and uncertainty can emerge from a self-selection of immanently more risky banks into both riskier funding as well as riskier (more volatile) assets. These issues challenge the inference of causality between uncertainty and the use of wholesale funding using the simple static model. We, therefore, interpret the results presented in Table 2 solely as evidence of a robust positive correlation between uncertainty and the relative volume of wholesale liabilities.

*Static identification: the exclusion of liquidity shock events*

A straightforward way to address the first identification issue is to focus explicitly on the uncertainty and liability structure relation for a subset of observation for which we can explicitly guarantee that loan volume volatility is not driven by wholesale funding. As argued in the literature on the destabilizing role of short-term wholesale funding, loan volumes and their volatility can be affected by wholesale funding use if banks are not able to roll over wholesale debt. A positive correlation between a bank's use of wholesale liabilities and the observed loan volatility can, therefore, arise from both the preference of banks facing uncertain asset demand to fund through flexible wholesale liabilities but also through the fact that the use of wholesale liabilities causes loan volatility, e.g. through liquidation of illiquid loans in the case of a liquidity shock arising from wholesale debt. In this sense, the issue is to disentangle loan shocks from liquidity shocks. We achieve that goal by focusing on the component of loan volume dynamics that is not related to liquidity motives. For this purpose we relate the volume

**Table 4: Bank uncertainty and liability structure: static panel estimations excluding liquidity shock observations**

| VARIABLES | (1)<br>Deposits/<br>Total<br>liabilities | (2)<br>Deposits/<br>Total<br>liabilities | (3)<br>Deposits/<br>Total<br>liabilities | (4)<br>Deposits/<br>Total<br>liabilities | (5)<br>Deposits/<br>Total<br>liabilities | (6)<br>Deposits/<br>Total<br>liabilities |
|---|---|---|---|---|---|---|
| LOANS SD | -0.104** | -0.576*** | | | | |
| | (0.046) | (0.145) | | | | |
| NEGATIVE SKEWNESS | | | -0.001** | -0.001 | | |
| | | | (0.000) | (0.001) | | |
| LOANS GARCH | | | | | -0.002** | -0.004** |
| | | | | | (0.001) | (0.002) |
| BANK SIZE | -0.349*** | -1.541*** | -0.351*** | -1.466*** | -0.355*** | -1.517*** |
| | (0.024) | (0.103) | (0.024) | (0.103) | (0.024) | (0.105) |
| BANK SIZE SQUARED | 0.010*** | 0.042*** | 0.010*** | 0.040*** | 0.010*** | 0.041*** |
| | (0.001) | (0.003) | (0.001) | (0.003) | (0.001) | (0.003) |
| T-BILL RATE | | -0.012*** | | -0.013*** | | -0.013*** |
| | | (0.002) | | (0.002) | | (0.002) |
| RETAIL SPREAD | | 0.006** | | 0.008*** | | 0.008*** |
| | | (0.003) | | (0.003) | | (0.003) |
| BOND SPREAD | | -0.008 | | -0.008 | | -0.008 |
| | | (0.007) | | (0.007) | | (0.007) |
| DEPOSITS PER BRANCH | | -0.000*** | | -0.000*** | | -0.000*** |
| | | (0.000) | | (0.000) | | (0.000) |
| LOANS TO TOTAL ASSETS | | 0.093*** | | 0.131*** | | 0.130*** |
| | | (0.029) | | (0.028) | | (0.028) |
| CONSTANT | 3.776*** | 14.779*** | 3.793*** | 14.055*** | 3.827*** | 14.499*** |
| | (0.216) | (0.895) | (0.217) | (0.896) | (0.218) | (0.914) |
| Observations | 16,039 | 2,298 | 16,039 | 2,298 | 16,039 | 2,298 |
| R-squared | 0.013 | 0.194 | 0.013 | 0.189 | 0.013 | 0.189 |
| Number of bankno | 122 | 76 | 122 | 76 | 122 | 76 |

Note: Fixed effect panel estimations of deposits to total liabilities ratios on (i) loans' standard deviation, (ii) loans' skewness or (iii) loans' conditional volatility predicted using a GARCH (1,1) model. *,**,*** indicate statistical significance at 10% , 5% and 1%, respectively.

of loans on the bank weekly call report to the dynamics of the volume of liquid assets held by the bank. Observed loan volume can be affected by the liability structure by either a liquidity shortage or by a situation of abundant liquidity. In the case of a liquidity shortage the bank possibly liquidate loans because it is unable to fund them. In this case, the drop in the observed loan volume should be accompanied by a decrease in the volume of liquid assets since banks reduce these before undertaking costly liquidation of illiquid loans. In the opposite case, when banks increase loan volumes because of abundant liquidity, the rise in observed loan volumes is accompanied by a rise in liquid assets. We can, therefore, generate a liquidity insensitive measure of bank uncertainty by computing the $uncertain_{i,t}$ variable using only the observations where loan volume and liquid assets change in opposite directions[23]. Note that the ability to disentangle asset- from liability-side effects in this empirical framework is a direct benefit from the very high frequency of the data. The use of this identification scheme based on the high frequency of the observations is simple and intuitive and avoids the pitfalls of alternative identification schemes: e.g. the challenges of the search of suitable instruments and the computational burden of a structural estimation.

The results of the estimations using this identification strategy are presented in Table 4. These results confirm the relationship documented in the unrestricted set of static regressions reported in Table 3.

They indicate that the results presented in the unrestricted case were not driven by the spurious effects of wholesale funding driving uncertainty.

Next, we present an alternative approach to address the identification challenges based on a dynamic model where identification is given by tracking the high frequency dynamics of loans and retail deposit volume changes.

## 3.3 Uncertainty and the adjustment of retail deposits to loan shocks

In this subsection we address the shortcoming of the static analysis by presenting a dynamic econometric model. The idea of the dynamic model is to estimate the speed of adjustment of retail deposit volumes to loan volume changes and how this speed of adjustment is affected by uncertainty. The underlying hypothesis of the dynamic analysis is that banks facing more stable loan volume dynamics will adjust to loan shocks by covering a larger portion of the shock by retail deposits, since they can better predict the volume of required funding. Banks operating in an uncertain environment, on the contrary, will be hesitant and slow to adjust inflexible retail deposit volumes to a loan volume shock.

We start by exploring the time series characteristics of the volumes of loans and retail deposits in the context of the high frequency panel data. For both the loan and the

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[23] In the baseline specification we compute $uncertain_{i,t}$ using observations where loans and liquid assets change in opposite directions during the preceding week. As a robustness check we also rerun the regressions using uncertainty measures computed by using observations where loans and total assets move in opposite directions in a four weeks interval.

deposit series a battery of econometric tests confirm a unit root of the time series. The use of a standard vector-autoregression model is, therefore, implausible. As a next step we perform a panel cointegration test using the tests suggested by Westerlund (2007) that are general enough to allow for substantial heterogeneity, both in the long-run cointegrating relationship and in the short-run dynamics. All tests overwhelming reject the null of no cointegration between the deposit and loan volumes.

Having shown the existence of cointegration we next proceed to estimating a panel vector error correction model (VECM) explaining retail deposit volume dynamics as a function of loan volume dynamics. Under the assumption of the model both the long-term cointegration relation between loan and retail deposit volumes and short-term speed of adjustment toward the long term effect are allowed to depend on uncertainty. Formally the model is given by the following equation:

$$\begin{aligned}\Delta_{(t+1)-(t)}Deposits_i &= \alpha_0 + \alpha_1 * \Delta_{(t)-(t-1)}Deposits_i + \alpha_2 * \Delta_{(t)-(t-1)}Loans_i + \alpha_3 * Deposits_{i,t-1} \\ &+ \alpha_4 * Loans_{i,t-1} + \alpha_5 * uncertain_{i,t} + \alpha_6 * uncertain_{i,t} * \Delta_{(t)-(t-1)}Loans_i + \alpha_7 * X_{i,t-1} + \varepsilon_{i,t}\end{aligned} \tag{2}$$

where $\Delta_{(t+1)-(t)}Deposits_i$ and $\Delta_{(t)-(t-1)}Loans_i$ denote the changes in deposit and loan volumes in respective periods. $Deposits_{i,t-1}$ and $Loans_{i,t-1}$ denote the volumes of retail deposits and of loans. The subscript *i* refers to the bank and *t* to the period of the observation. $uncertain_{i,t}$ is respectively one of the measures of uncertainty faced by the bank (LOANS SD, NEGATIVE SKEWNESS and LOANS GARCH) and $X_{i,t}$ reflects the vector of control variables such as the bank size, the average spread in the wholesale and retail liabilities market and the proxy for retail deposit market access. In order to reduce endogeneity concerns all control variables are taken with one period lag. To control for the interaction between the uncertainty measures and the change in the loan volume we also include the cross-products of the uncertainty measure and the magnitude of the loan volume change. Since both the negative skewness and the $\Delta_{t-(t-1)}$ LOANS variables can take negative values a meaningful interpretation of their cross-product requires us to control for the direction of the loan volume change. To this end, we introduce a dummy variable (POSITIVE $\Delta_{(t)-(t-1)}$LOANS) for positive loan volume changes which is also included in the construction of the cross-product terms of uncertainty and loan volume change.

In our baseline specification we use one week as the frequency interval. That is we estimate the speed of adjustment of deposits in week *t+1* to a loan volume shock in week *t*. As a robustness check we also allow for longer intervals for the adjustment to take place and rerun the model for the adjustment of deposits in the four weeks following the loan volume change.

Given the dynamic nature of the model its estimation employs the GMM technique suggested by Arellano and Bond (1991), which ensures efficiency and consistency of the estimates. A main advantage of the model is that it is fairly general to fit banks with different degrees of specialization in deposit collection or loan provision. In particular heterogeneity across banks both in terms of the determination of the long-term relation between loans and deposit and in term of the speed of adjustment towards the long-term relation is allowed.

## 3.4 Identification

The dynamic empirical model avoids the identification challenge related to the self-selection of banks with more volatile loans into more volatile sources of funding. This is the case since we not only illustrate static correlations but show that ex ante uncertainty affects deposit volume changes in reaction to individual loan volume shocks.

However, we are still concerned with the issue of endogeneity and potential reverse causality of loan volatility with respect to liability structure. To this end we base the identification on the assumption that given the high frequency of the observations both loan volume changes and loan volatility are exogenous with respect to deposit volume changes. This claim would represent a serious challenge if we would estimate the model on low frequency data, where we cannot control for the possibility that loan volumes are responding to deposit volume changes. However, in the high frequency framework adopted here we motivate this assumption by the fact that loan volume expansions require sufficient amount of time for both the establishment of new customer relationship and for the formal credit quality assessment and loan approval which even given automated loan processing require a few weeks[24]. The only possibility of a quick loan volume expansion reflects a situation when a substantial portion of customers pull down their approved credit lines, but this event will be driven by reasons other than a positive deposit volume shock and are therefore also exogenous. Looking at negative shifts, on the other hand, we argue that given the longer average maturity of bank loans, a drop in the loan volumes is unlikely to follow almost immediately after a drop in deposit volumes. Furthermore, we similarly exclude the possibility that loan volume dynamics is driven by expectations about deposit volume changes which realize in the

[24] Mester (1997) reports evidence that even after the introduction of automated credit score procedures loan approval times where well above 3 days. This time should be added to the time required to attract potential loan applicants.

**Table 5: VECM estimation of deposit volume changes**

| VARIABLES | (1) $\Delta_{(t+1)-(t)}$ DEPOSITS | (2) $\Delta_{(t+1)-(t)}$ DEPOSITS | (3) $\Delta_{(t+1)-(t)}$ DEPOSITS | (4) $\Delta_{(t+1)-(t)}$ DEPOSITS | (5) $\Delta_{(t+1)-(t)}$ DEPOSITS | (6) $\Delta_{(t+1)-(t)}$ DEPOSITS |
|---|---|---|---|---|---|---|
| $\Delta_{(t)-(t-1)}$DEPOSITS | -0.067*** | -0.051*** | -0.062*** | -0.226*** | -0.224*** | -0.224*** |
| | (0.016) | (0.017) | (0.017) | (0.042) | (0.042) | (0.042) |
| $\Delta_{(t)-(t-1)}$LOANS | 0.079*** | 0.030 | 0.066*** | -0.089 | -0.021 | -0.041 |
| | (0.025) | (0.028) | (0.025) | (0.096) | (0.045) | (0.046) |
| LOANS SD | 167.470 | | | 2,044.197 | | |
| | (110.496) | | | (1,288.154) | | |
| LOANS SD*$\Delta_{(t)-(t-1)}$ LOANS | -0.075*** | | | -2.062*** | | |
| | (-0.012) | | | (0.821) | | |
| POSITIVE $\Delta_{(t)-(t-1)}$ LOANS | | -25.346 | | | 0.227 | |
| | | (25.798) | | | (29.147) | |
| NEGATIVE SKEWNESS | | -12.605*** | | | -6.561** | |
| | | (4.363) | | | (3.509) | |
| NEGATIVE SKEWNESS* POSITIVE $\Delta_{(t)-(t-1)}$ LOANS* $\Delta_{(t)-(t-1)}$ LOANS | | -0.018** | | | -0.020** | |
| | | (0.009) | | | (0.011) | |
| LOANS GARCH | | | -6.638** | | | -354.812* |
| | | | (2.758) | | | (-198.526) |
| LOANS GARCH * $\Delta_{(t)-(t-1)}$LOANS | | | -0.024*** | | | -0.040* |
| | | | (0.008) | | | (-0.022) |
| DEPOSITS | -0.001 | -0.001 | -0.001 | 0.010* | 0.009* | 0.007 |
| | (0.002) | (0.002) | (0.002) | (0.005) | (0.005) | (0.005) |
| LOANS | 0.002 | 0.003 | 0.002 | 0.005 | 0.004 | 0.002 |
| | (0.002) | (0.002) | (0.002) | (0.008) | (0.008) | (0.007) |
| BANKS SIZE | -206.137 | -123.540 | -212.381 | 3,021.265 | 2,584.438 | 1,260.902 |
| | (542.297) | (560.781) | (542.106) | (2,628.326) | (2,551.990) | (2,283.632) |
| BANK SIZE SQUARED | 6.074 | 3.566 | 6.278 | -95.261 | -81.734 | -40.326 |
| | (16.742) | (17.309) | (16.738) | (81.329) | (78.992) | (70.673) |
| T-BILL RATE | | | | 9.167 | 3.939 | 9.530 |
| | | | | (19.300) | (19.687) | (19.270) |
| RETAIL SPREAD | | | | -17.886 | -12.558 | -15.273 |
| | | | | (19.261) | (20.144) | (19.805) |
| BOND SPREAD | | | | 32.487 | 30.814 | 37.129 |
| | | | | (65.003) | (65.969) | (63.552) |
| DEPOSITS PER BRANCH | | | | 0.064 | 0.049 | 0.042 |
| | | | | (0.055) | (0.054) | (0.052) |
| LOANS TO TOTAL ASSETS | | | | -9.717 | -62.998 | -4.708 |
| | | | | (206.220) | (211.184) | (193.515) |
| CONSTANT | 1,734.943 | 1,074.481 | 1,787.181 | -24,060.854 | -20,446.185 | -9,903.353 |
| | (4,389.679) | (4,538.636) | (4,387.100) | (21,177.561) | (20,538.991) | (18,380.733) |
| Observations | 32,367 | 32,367 | 32,368 | 4,625 | 4,625 | 4,625 |
| R-squared | 0.011 | 0.009 | 0.011 | 0.078 | 0.076 | 0.092 |
| Number of banks | 122 | 122 | 122 | 77 | 77 | 77 |

Note: Vector error correction panel estimations of retail deposit volumes reaction to a change in loan volumes controlling for uncertainty by (i) loans' standerd deviation, (ii) loans' negative skewness or (iii) loans' conditional volatility predicted using a GARCH (1,1) model. *,**,*** indicate statistical significance at 10% , 5% and 1%, respectively.

following weeks, since the de facto withdrawal of significant amounts of retail deposits is typically hard to predict.

Table 5 presents the results of our baseline dynamic specification. We find that all three forms of uncertainty significantly affect the speed of adjustment of retail deposits to loan volume changes. For two of the uncertainty measures (the NEGATIVE SKEWNESS and LOANS GARCH) we find that both the coefficient of the uncertainty measure itself and that of the cross-product between the uncertainty measure and the magnitude of the loan change are negative and statistically significant. These coefficients indicate that those banks facing stronger uncertainty have slower deposit growth rates, but also that for such high-uncertainty banks the adjustment of deposit volumes to large loan volume shocks is particularly incomplete. To illustrate the magnitude of the economic effect of uncertainty suggested by these results consider a loan volume change between week *t-1* and *t* which has the average magnitude measured in our sample to be roughly equal to 57 million USD. Now consider two ceteris paribus equal banks – bank A and bank B- which differ only in their NEGATIVE SKEWNESS: bank A's NEGATIVE SKEWNESS is one standard deviation (equal in our sample to 2.23) higher than that of bank B. The ceteris paribus reaction of bank A's deposit volume to the loan volume change will be approximately 30 (*=-12.605*2.23-0.018*2.23*57*) million USD lower than that of bank B. This relative slowdown of the reaction to loan volume changes will be of even higher magnitude in the case of larger than the mean loan volume shocks. A similar thought experiment using two banks which differ only by one standard deviation of the LOANS GARCH will imply that the more volatile bank will adjust its deposit volumes by roughly 4.4 (*=-6.638*0.54-0.024*0.54*57*) million USD less than the less volatile bank. With regard to the LOAN SD as an uncertainty measure the coefficient of the variable itself is statistically insignificant but that of the cross-product is negative and statistically strongly significant. A one standard deviation increase of this uncertainty measure (this is equal to 0.1 in our sample) relates to a change of deposits which is roughly 0.5 (*=0.075*0.1*57*) million USD smaller in magnitude.

All bank specific control variables, but the volume of deposits in the preceding period, enter the regression with statistically insignificant coefficients. We have kept their presentation here for the sake of completeness although omitting them does not substantially change the results. The positive coefficient of the volume of deposits in the preceding period signals that banks relying more heavily on deposits are also the ones that are more likely to adjust deposit volumes faster to loan volume shocks.

**Table 6: VECM estimation of deposit volume changes – adjustment during a four weeks period**

| VARIABLES | (1) $\Delta_{(t+4)-(t)}$ DEPOSITS | (2) $\Delta_{(t+4)-(t)}$ DEPOSITS | (3) $\Delta_{(t+4)-(t)}$ DEPOSITS | (4) $\Delta_{(t+4)-(t)}$ DEPOSITS | (5) $\Delta_{(t+4)-(t)}$ DEPOSITS | (6) $\Delta_{(t+4)-(t)}$ DEPOSITS |
|---|---|---|---|---|---|---|
| $\Delta_{(t)-(t-1)}$DEPOSITS | 0.127*** | 0.117*** | 0.131*** | 0.062* | 0.064** | 0.063** |
| | (0.017) | (0.017) | (0.017) | (0.032) | (0.032) | (0.032) |
| $\Delta_{(t)-(t-1)}$LOANS | -0.131*** | 0.003 | -0.176*** | -0.184** | -0.102** | -0.135*** |
| | (0.030) | (0.032) | (0.030) | (0.093) | (0.043) | (0.047) |
| LOANS SD | -123.822 | | | 3,964.815 | | |
| | (231.464) | | | (2,400.863) | | |
| LOANS SD*$\Delta_{(t)-(t-1)}$LOANS | -0.294 | | | 1.592 | | |
| | (0.184) | | | (1.750) | | |
| POSITIVE $\Delta_{(t)-(t-1)}$ LOANS | | -88.056*** | | | -45.377 | |
| | | (31.137) | | | (42.343) | |
| NEGATIVE SKWENESS | | -76.020*** | | | -48.294*** | |
| | | (19.674) | | | (16.649) | |
| NEGATIVE SKWENESS* POSITIVE $\Delta_{(t)-(t-1)}$LOANS* $\Delta_{(t)-(t-1)}$ LOANS | | 0.076*** | | | 0.010 | |
| | | (0.011) | | | (0.034) | |
| LOANS GARCH | | | -360.494* | | | -219.885 |
| | | | (203.328) | | | (218.302) |
| LOANS GARCH *$\Delta_{(t)-(t-1)}$ LOANS | | | 0.027 | | | -0.018** |
| | | | (0.027) | | | (0.008) |
| DEPOSITS | 0.035*** | 0.037*** | 0.037*** | 0.016** | 0.016** | 0.016** |
| | (0.008) | (0.008) | (0.008) | (0.007) | (0.007) | (0.007) |
| LOANS | -0.021** | -0.021** | -0.021** | -0.027*** | -0.027*** | -0.026*** |
| | (0.009) | (0.010) | (0.009) | (0.010) | (0.010) | (0.009) |
| BANKS SIZE | 3,863.323 | 4,863.906 | 4,350.458 | -8,820.370*** | -9,200.092*** | -8,868.716*** |
| | (2,903.445) | (2,971.353) | (2,928.476) | (3,098.756) | (3,064.152) | (3,091.410) |
| BANK SIZE SQUARED | -114.625 | -145.258 | -129.688 | 272.844*** | 284.462*** | 273.765*** |
| | (89.478) | (91.554) | (90.251) | (95.123) | (94.121) | (95.030) |
| T-BILL RATE | | | | 49.210 | 42.498 | 46.765 |
| | | | | (48.267) | (48.138) | (48.395) |
| RETAIL SPREAD | | | | -25.519 | -25.811 | -25.750 |
| | | | | (49.698) | (49.750) | (49.873) |
| BOND SPREAD | | | | -15.834 | -31.680 | -26.740 |
| | | | | (170.967) | (171.530) | (171.140) |
| DEPOSITS PER BRANCH | | | | 0.347** | 0.309* | 0.348** |
| | | | | (0.172) | (0.170) | (0.174) |
| LOANS TO TOTAL ASSETS | | | | 1,364.118*** | 1,226.253*** | 1,179.862*** |
| | | | | (343.326) | (356.643) | (351.990) |
| CONSTANT | -32,335.432 | -40,448.122* | -36,274.346 | 70,282.765*** | 73,613.399*** | 71,031.087*** |
| | (23,540.703) | (24,094.709) | (23,742.704) | (25,142.114) | (24,819.537) | (25,026.232) |
| Observations | 31,991 | 31,991 | 31,992 | 4,584 | 4,584 | 4,584 |
| R-squared | 0.042 | 0.054 | 0.044 | 0.032 | 0.033 | 0.031 |
| Number of banks | 122 | 122 | 122 | 77 | 77 | 77 |

Note: Vector error correction panel estimations of retail deposit volumes reaction to a change in loan volumes controlling for uncertainty by (i) loans' standerd deviation, (ii) loans' negative skewness or (iii) loans' conditional volatility predicted using a GARCH (1,1) model. *,**,*** indicate statistical significance at 10% , 5% and 1%, respectively.

In sum, all results concerning the speed of adjustment are consistent with our hypothesis that banks operating in volatile environments employ relatively low volumes of retail deposits which are perceived as inflexible production factor.

The results presented in Table 5 are focused on the speed of adjustment of deposit volumes that takes place in the week following the week of the loan volume change. We next present in Table 6 the results of a model where the adjustment during the four weeks following the loan volume change is used as a dependent variable. These results are qualitatively the same as those reported in Table 5. The only substantial difference between the results concerning deposit volume changes within one week and within four weeks reflects the statistical significance of the control variables. So, for example, for the four-weeks window deposit volume changes significantly correlate with bank size, deposits per branch and the loans-to-total assets ratio. More specifically large banks, banks having a relatively small number of branches and banks with low share of loans in total assets have a weaker reaction of deposit volumes to loan volume shocks. The regressions presented in Table 5 and Table 6 generally do not control for the direction of the loan volume changes. They are, therefore, unable to address the potential asymmetry in the reaction to positive relative to negative loan volume shocks. This asymmetry could arise because of the different costs of adjusting retail deposits in a downward and upward direction as well as by the different persistency of positive relative to negative loan volume shocks. In a next set of regression we address this asymmetry by re-estimating our baseline dynamic model separately for the case of positive and for the case of negative loan volume changes.

Table 7 reports the results reflecting only positive loan volume changes, while Table 8 reflects those of the regressions including only negative loan volume changes. These results suggest that deposit volumes react stronger to positive loan volume changes than to negative ones. While the coefficients of the $\Delta_{(t)-(t-1)}$LOANS variable in Table 7 are of a significantly higher magnitude relative to Table 5, those in Table 8 are of a significantly lower magnitude. These results signal that banks are either very reluctant or unable to reduce the level of retail deposits. The sources of this downward inflexibility of retail deposit volumes have still not been thoroughly explored. Potential explanations are related to customers' inertia, high switching costs of changing a deposit account (Sharpe 1997), etc. The documentation of this downward rigidity of retail deposit volumes presents strong empirical support for the claim that retail deposit are an inflexible funding source.

**Table 7: VECM estimation of deposit volume changes: only positive loan volume changes**

| VARIABLES | (1)<br>$\Delta_{(t+1)-(t)}$DEPOSITS | (2)<br>$\Delta_{(t+1)-(t)}$DEPOSITS | (3)<br>$\Delta_{(t+1)-(t)}$DEPOSITS |
|---|---|---|---|
| $\Delta_{(t)-(t-1)}$DEPOSITS | 0.011 | 0.014 | 0.025 |
| | (0.024) | (0.024) | (0.025) |
| $\Delta_{(t)-(t-1)}$LOANS | 0.096** | -0.072 | 0.039 |
| | (0.048) | (0.047) | (0.041) |
| LOANS SD | -618.374** | | |
| | (246.658) | | |
| LOANS SD*$\Delta_{(t)-(t-1)}$LOANS | -1.400* | | |
| | (0.715) | | |
| NEGATIVE SKEWNESS | | -83.443* | |
| | | (19.426) | |
| NEGATIVE SKEWNESS*$\Delta_{(t)-(t-1)}$ LOANS | | -0.030** | |
| | | (0.013) | |
| LOANS GARCH | | | -237.078 |
| | | | (163.906) |
| LOANS GARCH *$\Delta_{(t)-(t-1)}$ LOANS | | | -0.037** |
| | | | (0.016) |
| DEPOSITS | 0.002 | 0.000 | 0.002 |
| | (0.002) | (0.002) | (0.002) |
| LOANS | 0.001 | 0.003 | 0.001 |
| | (0.003) | (0.003) | (0.003) |
| BANKS SIZE | 703.148 | 559.145 | 789.178 |
| | (1,016.308) | (1,014.979) | (1,014.428) |
| BANK SIZE SQUARED | -21.914 | -17.596 | -24.744 |
| | (31.197) | (31.147) | (31.150) |
| CONSTANT | -5,655.779 | | -6,295.513 |
| | (8,277.622) | | (8,259.067) |
| Observations | 18,365 | 18,365 | 18,365 |
| R-squared | 0.006 | 0.008 | 0.007 |
| Number of banks | 122 | 122 | 122 |

Note: Vector error correction panel estimations of retail deposit volumes reaction to a change in loan volumes controlling for uncertainty by (i) loans' standerd deviation, (ii) loans' negative skewness or (iii) loans' conditional volatility predicted using a GARCH (1,1) model. *,**,*** indicate statistical significance at 10% , 5% and 1%, respectively.

The effect of uncertainty on the adjustment of retail deposit volumes is also shown to be asymmetric at least when it is measured by the standard deviation of loan volumes (LOAN SD) and the conditional volatility as measured by the LOANS GARCH. While the volatility of loan volumes decreases the speed of adjustment to positive shocks (statistically significant for both LOAN SD and LOANS GARCH), it increases the speed of adjustment to negative shock (statistically significant only in the case of LOANS GARCH).

**Table 8: VECM estimation of deposit volume changes: only negative loan volume changes**

| VARIABLES | (1)<br>$\Delta_{(t+1)-(t)}$DEPOSITS | (2)<br>$\Delta_{(t+1)-(t)}$DEPOSITS | (3)<br>$\Delta_{(t+1)-(t)}$DEPOSITS |
|---|---|---|---|
| $\Delta_{(t)-(t-1)}$DEPOSITS | -0.014 | -0.011 | 0.005 |
| | (0.027) | (0.027) | (0.027) |
| $\Delta_{(t)-(t-1)}$LOANS | 0.053 | 0.060 | -0.028 |
| | (0.046) | (0.042) | (0.045) |
| LOANS SD | 246.198 | | |
| | (153.735) | | |
| LOANS SD*$\Delta_{(t)-(t-1)}$LOANS | 0.158 | | |
| | (0.153) | | |
| NEGATIVE SKEWNESS | | -75.283*** | |
| | | (17.753) | |
| NEGATIVE SKEWNESS*$\Delta_{(t)-(t-1)}$ LOANS | | -0.023 | |
| | | (0.030) | |
| LOANS GARCH | | | 559.479*** |
| | | | (159.027) |
| LOANS GARCH *$\Delta_{(t)-(t-1)}$ LOANS | | | 0.119*** |
| | | | (0.031) |
| DEPOSITS | -0.004* | -0.004 | -0.004 |
| | (0.003) | (0.003) | (0.003) |
| LOANS | 0.004 | 0.004 | 0.004 |
| | (0.003) | (0.003) | (0.003) |
| BANKS SIZE | -622.707 | -634.076 | -367.828 |
| | (733.712) | (739.058) | (732.843) |
| BANK SIZE SQUARED | 19.830 | 20.184 | 11.767 |
| | (22.791) | (22.951) | (22.768) |
| CONSTANT | 4,877.209 | 4,974.902 | 2,867.118 |
| | (5,897.453) | (5,941.349) | (5,889.074) |
| Observations | 13,992 | 13,992 | 13,993 |
| R-squared | 0.004 | 0.004 | 0.015 |
| Number of banks | 122 | 122 | 122 |

Note: Vector error correction panel estimations of retail deposit volumes reaction to a change in loan volumes controlling for uncertainty by (i) loans' standerd deviation, (ii) loans' negative skewness or (iii) loans' conditional volatility predicted using a GARCH (1,1) model. *,**,*** indicate statistical significance at 10% , 5% and 1%, respectively.

This asymmetry implies that banks with very volatile loan volumes slowly increase deposits if their loans grow but quickly drop deposits if their loans start declining. It presents in a more disaggregate framework support for the negative correlation between uncertainty and retail deposits use documented in Section 4.1. The asymmetry of the effect of uncertainty is not confirmed when the negative skewness is employed as an uncertainty measure. In this case uncertainty reduces the speed of deposit volume's adjustment to both positive and negative loan changes.

# 4 Uncertainty and wholesale funding in times of distressed wholesale funding markets

The underlying hypothesis of the analysis presented in Section 4 is derived from the assumption that short-term wholesale funding is cheaper to adjust relative to retail deposit funding. However, as illustrated by earlier studies (Huang and Ratnovski 2010 etc) this assumption only holds if markets for wholesale funding function smoothly and provide solvent banks with the desired liquidity. Our sample period, however, also encompasses periods of substantial disruptions in the functioning of the market for wholesale bank funding, when banks access to wholesale funding was potentially either prohibitively expensive or even impossible. The most notorious of these periods has been the time immediately after the failure of Lehman Brothers in September 2008, but substantial disruptions can also be suspected in the weeks following the LTCM failure in August 1998 as well as in the weeks after September 11, 2001.

In this section we explore how the banks' behavior described in the previous sections is modified in periods with substantial shocks to the wholesale funding market when access to wholesale funding might be limited. To this end our research is closely related to the analysis presented by Ivashina and Scharfstein (2010) who relate the inability of banks to roll over wholesale funding in the months after the Lehman failure to a substantial drop of lending of those banks which heavily rely on wholesale funding. We complement Ivashina and Scharfstein's (2010) analysis by exploring the effect of wholesale market disruptions on the composition of bank liabilities while controlling for loan volume dynamics. Our analysis is structured around testing the hypothesis that in periods with substantial wholesale market disruptions the negative relation between bank specific uncertainty and the use of retail deposits will break apart. This is the case since in such periods the costs of adjusting wholesale liabilities which are low in normal times become prohibitively high.

We proceed in three steps. First, we re-estimate the dynamic model from Section 4 for subsamples of observations prior to and post August 2007. August 1, 2007 is chosen as a cut-off since it marks the period of time when wholesale markets started to show first signs of distress in the 2007-2009 financial crisis[25]. The results of the estimations are presented in Table 9.

[25] In early August 2007 problems with the subprime market became evident after BNP Paribas announced that it was ceasing activity in three hedge funds that specialized in US mortgage debt.

**Table 9: Relation between loans, deposits and uncertainty: VECM estimates for pre-crisis and crisis sub-periods**

| VARIABLES | Prior to 2007 | | | 2007-2009 | | |
|---|---|---|---|---|---|---|
| | $\Delta_{(t+1)-(t)}$ DEPOSITS | $\Delta_{(t+1)-(t)}$ DEPOSITS | $\Delta_{(t+1)-(t)}$ DEPOSITS | $\Delta_{(t+1)-(t)}$ DEPOSITS | $\Delta_{(t+1)-(t)}$ DEPOSITS | $\Delta_{(t+1)-(t)}$ DEPOSITS |
| $\Delta_{(t)-(t-1)}$DEPOSITS | -0.116*** | -0.094*** | -0.106*** | 0.042 | 0.039 | 0.045 |
| | (0.019) | (0.019) | (0.019) | (0.040) | (0.040) | (0.040) |
| $\Delta_{(t)-(t-1)}$LOANS | 0.109*** | 0.047 | 0.098*** | 0.053 | -0.001 | -0.023 |
| | (0.028) | (0.031) | (0.028) | (0.061) | (0.064) | (0.055) |
| LOANS SD | 156.333** | | | 1,265.515 | | |
| | (75.896) | | | (1,505.387) | | |
| LOANS SD*$\Delta_{(t)-(t-1)}$LOANS | -0.075** | | | -1.017 | | |
| | (0.032) | | | (1.165) | | |
| POSITIVE $\Delta_{(t)-(t-1)}$LOANS | | -42.136* | | | 38.310 | |
| | | (24.060) | | | (117.127) | |
| NEGATIVE SKEWNESS | | -12.050*** | | | -11.181 | |
| | | (4.422) | | | (14.359) | |
| NEGATIVE SKEWNESS* POSITIVE $\Delta_{(t)-(t-1)}$LOANS* $\Delta_{(t)-(t-1)}$ LOANS | | -0.018* | | | -0.019 | |
| | | (0.011) | | | (0.023) | |
| LOANS GARCH | | | -91.655 | | | 269.096 |
| | | | (85.700) | | | (166.764) |
| LOANS GARCH *$\Delta_{(t)-(t-1)}$LOANS | | | 0.027 | | | 0.066* |
| | | | (0.020) | | | (0.035) |
| DEPOSITS | 0.001 | 0.001 | 0.001 | -0.004 | -0.004 | -0.005 |
| | (0.002) | (0.002) | (0.002) | (0.004) | (0.004) | (0.004) |
| LOANS | 0.001 | 0.001 | 0.001 | 0.009 | 0.007 | 0.007 |
| | (0.002) | (0.002) | (0.002) | (0.006) | (0.005) | (0.005) |
| BANKS SIZE | -166.646 | -51.684 | -201.747 | 4,334.246 | 1,825.482 | 2,619.689 |
| | (536.325) | (558.584) | (535.627) | (5,173.048) | (4,089.754) | (4,102.437) |
| BANK SIZE SQUARED | 4.813 | 1.365 | 5.897 | -127.042 | -55.901 | -78.002 |
| | (16.736) | (17.423) | (16.717) | (149.854) | (119.361) | (119.761) |
| CONSTANT | 1,424.067 | 495.417 | 1,711.773 | -37,037.920 | -14,863.909 | -21,968.139 |
| | (4,297.416) | (4,476.184) | (4,290.710) | (44,727.596) | (35,067.599) | (35,161.110) |
| Observations | 28,444 | 28,444 | 28,445 | 3,923 | 3,923 | 3,923 |
| R-squared | 0.023 | 0.018 | 0.023 | 0.006 | 0.006 | 0.010 |
| Number of banks | 118 | 118 | 118 | 34 | 34 | 34 |

Note: Vector error correction panel estimations of retail deposit volumes reaction to a change in loan volumes controlling for uncertainty by (i) loans' standerd deviation, (ii) loans' negative skewness or (iii) loans' conditional volatility predicted using a GARCH (1,1) model. *,**,*** indicate statistical significance at 10% , 5% and 1%, respectively.

They illustrate that the negative effect of uncertainty on the speed of adjustment of deposits to loan volume shocks disappears in the post 2007 sample. Only the interaction term between the LOANS GARCH and the loan volume change enter the post-2007 regressions with a statistically significant coefficient, which is, however, of a positive sign, which indicates that more uncertain banks face a higher increase in retail deposit funding. In other words, not only does the negative relation between uncertainty and the use of retail deposits break apart after 2007 but for some uncertainty measures we even observe a positive link after 2007.

**Table 10: Retail deposits in times with high aggregate uncertainty: VECM Estimations**

| VARIABLES | (1)<br>$\Delta_{(t+1)-(t)}$ DEPOSITS | (2)<br>$\Delta_{(t+1)-(t)}$ DEPOSITS | (3)<br>$\Delta_{(t+1)-(t)}$ DEPOSITS |
|---|---|---|---|
| $\Delta_{(t)-(t-1)}$DEPOSITS | -0.058*** | -0.042** | -0.053*** |
| | (0.017) | (0.017) | (0.017) |
| $\Delta_{(t)-(t-1)}$LOANS | 0.070*** | 0.025 | 0.056** |
| | (0.025) | (0.028) | (0.025) |
| LOANS SD | 164.660 | | |
| | (111.156) | | |
| LOANS SD*$\Delta_{(t)-(t-1)}$LOANS | -0.066** | | |
| | (0.029) | | |
| POSITIVE $\Delta_{(t)-(t-1)}$LOANS | | -29.612 | |
| | | (26.002) | |
| NEGATIVE SKWENESS | | -13.611*** | |
| | | (4.445) | |
| NEGATIVE SKWENESS* POSITIVE $\Delta_{(t)-(t-4)}$LOANS* $\Delta_{(t)-(t-4)}$LOANS | | -0.016* | |
| | | (0.010) | |
| LOANS GARCH | | | -9.377 |
| | | | (74.041) |
| LOANS GARCH *$\Delta_{(t)-(t-1)}$ LOANS | | | 0.025 |
| | | | (0.018) |
| DEPOSITS | -0.001 | -0.001 | -0.001 |
| | (0.002) | (0.002) | (0.002) |
| LOANS | 0.002 | 0.002 | 0.002 |
| | (0.002) | (0.002) | (0.002) |
| BANKS SIZE | -156.060 | -66.649 | -159.838 |
| | (552.196) | (571.868) | (552.335) |
| BANK SIZE SQUARED | 4.476 | 1.751 | 4.599 |
| | (17.050) | (17.654) | (17.057) |
| LTCM | 15.396 | 6.681 | 14.415 |
| | (55.762) | (57.700) | (56.037) |
| SEPTEMBER 11 | -7.146 | -9.120 | 12.730 |
| | (132.631) | (137.258) | (133.387) |
| LEHMAN | 1,164.467*** | 1,203.177*** | 1,170.607*** |
| | (176.571) | (182.488) | (177.450) |
| CONSTANT | 1,342.589 | 631.044 | 1,376.001 |
| | (4,469.019) | (4,627.517) | (4,469.081) |
| Observations | 32,367 | 32,367 | 32,368 |
| R-squared | 0.011 | 0.009 | 0.011 |
| Number of banks | 122 | 122 | 122 |

Note: Vector error correction panel estimations of retail deposit volumes reaction to a change in loan volumes controlling for uncertainty by (i) loans' standerd deviation, (ii) loans' negative skewness or (iii) loans' conditional volatility predicted using a GARCH (1,1) model. *,**,*** indicate statistical significance at 10% , 5% and 1%, respectively.

Second, we re-estimate the model including the full sample of observations but controlling for wholesale market disruptions by including dummy variables taking a value of 1 if the observation is within a 8-weeks period after the events listed above (LTCM failure, September 11 or Lehman Brothers failure) and 0, otherwise. The results of this model's estimations are presented in Table 10.

**Table 11: Wholesale market disruptions: VECM estimates of retail funding adjustments in the weeks after Lehman's failure**

| | (1) | (2) | (3) |
|---|---|---|---|
| VARIABLES | $\Delta_{(t+1)-(t)}$ DEPOSITS | $\Delta_{(t+1)-(t)}$ DEPOSITS | $\Delta_{(t+1)-(t)}$ DEPOSITS |
| $\Delta_{(t)-(t-1)}$DEPOSITS | -0.060*** | -0.040** | -0.056*** |
| | (0.017) | (0.017) | (0.017) |
| $\Delta_{(t)-(t-1)}$LOANS | 0.069*** | 0.062** | 0.072*** |
| | (0.023) | (0.025) | (0.023) |
| LEHMAN | 1,082.079*** | 1,219.299*** | 844.993*** |
| | (169.735) | (188.842) | (150.235) |
| LOANS SD | 127.971* | | |
| | (72.983) | | |
| LOANS SD*$\Delta_{(t)-(t-1)}$LOANS*LEHMAN | 9.186* | | |
| | (4.817) | | |
| POSITIVE $\Delta_{(t)-(t-1)}$LOANS | | -55.375** | |
| | | (27.383) | |
| NEGATIVE SKEWNESS | | -17.305*** | |
| | | (4.280) | |
| NEGATIVE SKEWNESS* POSITIVE $\Delta_{(t)-(t-4)}$LOANS*$\Delta_{(t)-(t-4)}$LOANS*LEHMAN | | 0.095* | |
| | | (0.051) | |
| LOANS GARCH | | | -26.108 |
| | | | (72.884) |
| LOANS GARCH *$\Delta_{(t)-(t-1)}$ LOANS*LEHMAN | | | 0.066** |
| | | | (0.034) |
| DEPOSITS | -0.001 | -0.001 | -0.001 |
| | (0.002) | (0.002) | (0.002) |
| LOANS | 0.002 | 0.002 | 0.002 |
| | (0.002) | (0.002) | (0.002) |
| BANKS SIZE | -148.936 | -65.029 | -160.446 |
| | (552.069) | (571.927) | (551.184) |
| BANK SIZE SQUARED | 4.252 | 1.704 | 4.621 |
| | (17.044) | (17.653) | (17.021) |
| CONSTANT | 1,287.594 | 631.349 | 1,380.124 |
| | (4,468.636) | (4,628.454) | (4,459.773) |
| Observations | 32,367 | 32,367 | 32,368 |
| R-squared | 0.011 | 0.008 | 0.010 |
| Number of bankno | 122 | 122 | 122 |

Note: Vector error correction panel estimations of retail deposit volumes reaction to a change in loan volumes controlling for uncertainty by (i) loans' standerd deviation, (ii) loans' negative skewness or (iii) loans' conditional volatility predicted using a GARCH (1,1) model. *,**,*** indicate statistical significance at 10% , 5% and 1%, respectively.

They show that among the three periods with supposedly distressed wholesale markets only the period immediately after the failure of Lehman Brothers had a statistically significant effect on adjusting retail deposits. In this case the effect works in the expected direction: when wholesale markets are stressed banks choose to adjust retail deposit volumes upwards.

The increase of deposit volumes following a period of financial distress can in principle reflect a deposit supply effect stemming from the fact that investors substitute other financial assets for insured deposits as a reaction of the unexpected failure of a major bank. To address this issue in a third set of regressions we explicitly focus on the period after Lehman and explore how banks adjust their retail deposits in this period depending on the volatility of loan volumes measured at the bank level.

This model's results are illustrated in Table 11. They again confirm the implications of the results of the previous two exercises by showing that not only the Lehman dummy had a significant positive effect on deposit volume changes but also more volatile banks tend to increase their retail deposits faster in this particular time period.

These results show that it is unlikely that the shift to more retail funding is exclusively driven by deposits supply side effects since even though in adverse times depositors increase their supply of deposits, there is no reason why they should systematically prefer riskier to less risky banks.

# 5 Conclusion

In this paper we explore the role of a bank's uncertainty about the volumes of loans it is going to supply as a determinant of the bank's choice of liability structure. Our analysis traces the relation between uncertainty and liability structure both within a static and a dynamic econometric model. We identify the empirical relations taking advantage of unique high frequency dataset, which allows us to determine the existence of causality going from uncertainty to liability structure. The results of both the static and the dynamic empirical approach show a robust positive link between a bank's use of wholesale liabilities and the uncertainty the bank faces on the asset side of its balance sheet. As suggested by the literature on the negative externalities of wholesale funding, however, this relation completely breaks down during the period of wholesale market distress in the onset of the 2007-2009 financial crisis.

One of the major implications of our results is that a bank's substantial dependence on wholesale liabilities can be a reaction to the uncertainty of the bank's "real" economic environment. This result sheds new light in the discussion of the effects of proposed regulatory measures targeting a limit on banks' use of wholesale liabilities, as a regulatory tool of limiting banks' exposure to financial system liquidity shocks. If banks use wholesale funding in order to reduce their exposure to loan market volatility, then a regulation imposing restrictions on the use of wholesale funding will potentially make banks more susceptible to real economic volatility. In particular, at least two adverse effects can emerge from the restricted use of wholesale funding given the current inflexibility of retail deposits. First, banks can limit their loan supply in reaction to the loan volume volatility. This will be the case if banks following a real option "wait-and-see" policy decide not to adjust their retail deposit volumes to short-term loan shocks. Second, restricting wholesale liability volumes can lead to an overinvestment in deposit gathering capacity, which both lowers bank profitability and generates the incentives of the banks to invest the excess deposit volumes in very risky projects. Both scenarios contain serious macroprudential risks which should be endogenized in the formulation of optimal liability structure regulation.

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