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Bank's interest rate risk and profitability in a prolonged environment of low interest rates

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Abstract

This paper investigates the size and development of banking book interest rate risk positions of Dutch banks during 2008 to 2015. Due to hedging, interest rate risk is small and the income from maturity transformation is only a small share of the net interest margin and the return on assets. However, interest rate risk positions do vary significantly between banks and over time. My results suggest that banks lower their interest rate risk significantly when the yield curve flattens. Interest rate risk is negatively related to on-balance sheet leverage and has a U-shaped relation with solvability for banks that do not use derivatives. Banks that received government assistance during the financial crisis have higher interest rate risk than banks that did not receive assistance.

Keywords: interest rate risk, banks, banking book, hedging, profitability.

JEL classifications: D81, E43, G21.

[1] The views expressed in this paper are those of the author and do not necessarily reflect official positions of De Nederlandsche Bank. I would like to thank Jakob de Haan for his guidance in completing this paper and the referee and the associate editor as well as participants in a seminar at De Nederlandsche Bank for their helpful comments.

1. Introduction

This paper investigates the interest rate risk position of Dutch banks in their banking books during the period from 2008 until the middle of 2015 using confidential data of the Dutch banking supervisor. The availability of this data presents an exceptional opportunity to analyse individual bank behaviour. The main question this paper addresses is whether Dutch banks are risk averse hedgers of interest rate risk or speculators. This question is answered in three steps: (1) what is the interest rates risk position of Dutch banks and how does it vary over time?; (2) how much of banks' return on assets and net interest margin can be accounted for by income from maturity transformation? and (3) which factors influence banks' interest rate risk position?

This paper adds to the literature in a number of ways. Firstly, the data on interest rate risk in the banking book of Dutch banks is unique since it is collected directly from banks and takes into account both on-balance positions as well as hedging. Secondly, the length of the time-series used (up to a maximum of 30 quarters) brings the advantage that the estimations can be performed by standard fixed effects panel methods as they are less affected by the Nickell bias in dynamic panel data (see Nickell, 1981 and Kievit, 1995). Thirdly and finally, I compare two measures of the profitability of maturity transformation. Most previous studies of interest rate risk – such as Purnanandam (2007) and Esposito et al. (2015) – employ a simple measure for the profitability of 'playing the yield curve', such as the spread between a long-term and a short-term interest rate. This measure does not yield any significant results in my estimations. I therefore repeat the estimations with excess holding yields, measuring the ex-post violation of the pure expectations theory of interest. This measure yields significant results, which suggests that simple term spreads are inappropriate for explaining the behaviour of banks' management of interest rate risk.

During the period studied, interest rates fell to historically low levels and yield curves flattened as the result of monetary policies in response to the world-wide financial crisis in 2008 and the European sovereign debt crisis in 2010. This has heightened the concern for an erosion of banks' profits. Low levels of interest rates and flat yield curves have been cited as reasons for the slow recovery of banks' profitability in Japan in the early 2000s (International Monetary Fund, 2003). Borio and Zhu (2012) have suggested a 'risk taking channel' for the transmission of monetary policy, where low interest rates lead to reduced risk perceptions and increased risk tolerance, a "search for yield". The effects of monetary policy on bank risk taking have received increased attention also in the theoretical literature (e.g. Dell'Ariccia et al., 2014). Rey (2015) suggests that cross-border risk cycles are to a large extent synchronised and depend on monetary policy conditions in the world's main currency areas. Chodorow-Reich (2014) presents an excellent overview of the effects of unconventional monetary policy on different financial sectors. Whether low interest rates have eroded banks' profits and caused them to take more risk has become a major issue for supervisors and policy makers (see for instance Chapter VI of the BIS Annual Report 2015, Chapter 3 of the IMF Global Financial Stability Report, April 2013, and Deutsche Bundesbank, 2015). Since net interest income represents an important source of profits for banks, healthy net interest income is seen as a precondition for banks to build up higher capital buffers as required by the latest Basel framework. Managing interest rate risk is therefore of vital interest to banks and supervisors. It should therefore not come as a surprise that the Basel Committee has recently updated its recommendations on interest rate risk and proposes stricter limits than in its previous guidelines (Basel Committee, 2016).

The main takeaways of the paper are as follows. Net interest income is a very stable and important component of net operating income for Dutch banks. The interest rate risk positions of Dutch banks are, however, rather small primarily because they hedge most of the risk. As a result, income from maturity transformation is limited to about a tenth or less of the net interest margin. Although the interest rate risk levels are relatively modest, banks do seem to take advantage of persistent excess long-term yields by strategically enlarging their positions. My results also suggest that interest rate risk is negatively related to on-balance sheet leverage and has a U-shaped relation with solvability for banks that do not use derivatives. Banks that receive government assistance during the financial crisis have higher interest rate risk than banks that do not receive assistance.

The paper is structured as follows. Section 2 presents the return on assets, net interest margins and interest rate risk positions of Dutch banks during the period from 2008 to the middle of 2015. Section 3 uses this information to decompose net interest income into income from maturity transformation, income from equity and from commercial margins. Section 4.1 details the econometric model and the variables used in dynamic panel estimations of banks' interest rate risk. Section 4.2 presents the results. Section 5 offers conclusions.

2. Return on assets, net interest margins and interest rate risk positions

2.1. Data sources

Unlike other studies on interest rate risk, this paper uses confidential quarterly data on interest rate risk in the banking book collected by De Nederlandsche Bank (DNB, the Dutch central bank) directly from banks for supervisory purposes since 2008.[2] Studies, such as Flannery and

[2] Most supervisors in Europe only collect information on interest rate risk from banks through their annual supervisory reviews or when banks breach the outlier criterion, as defined in the Basel guidelines (e.g. Basel Committee, 2016).

James (1984), Hirtle (1997), Fraser et al (2002), Bharati et al. (2006), Pinheiro and Ferreira (2008), Czaja et al. (2009) and English et al. (2012) employ an approach pioneered by Fama and McBeth (1973) to derive the interest rate risk position indirectly from the sensitivity of banks' share prices to changes in interest rates. This approach severely limits the potential sample of banks for analysis, since (especially in Europe) many banks are not listed. Also, these studies are primarily concerned with the estimation of the sensitivity of (portfolios of) bank stock returns to interest rate movements, not with the interest rate risk positions of banks or their hedging behaviour.

Other studies, such as Sierra and Yeager (2004) and Purnanandam (2007), are based on interest rate risk measures derived from accounting information. Entrop et al. (2008) use a similar approach on data from German banks. As noted by Pagano (2001, p. 304), accounting data is usually not granular enough, there is usually no information on prepayment behaviour and the influence of derivatives cannot be incorporated. Data on interest rate risk from the banks themselves that account for these issues provide a more reliable measure on the actual interest rate risk of banks. A dataset that is similar to the one used here is Esposito et al. (2015), who use supervisory data collected on a semi-annual basis from Italian banks. Their data on duration gaps is divided by on-balance and off-balance sheet gaps, a distinction which is lacking in the data collected in the Netherlands. My data, however, is of higher (quarterly) frequency, which allows for analysing short-term changes in banks' risk position. A drawback of this data, however, is that banks employ different methods to calculate prepayment behaviour and make different assumptions for the duration of non-maturity deposits. The interest rate risk measures used here may therefore have been calculated differently by different banks. The sample consists of 42 banks representing roughly 90% of the balance sheet total of the Dutch banking sector during this period.

The money market interest rates and constant maturity zero yields used in this paper were obtained from the Deutsche Bundesbank. The constant maturity zero yields are constructed from the yields on German government bonds (see Schich, 1997) and are used as an approximation of risk-free euro interest rates.

2.2. Operating income and net interest margins

Figure 1, based on the quarterly consolidated supervisory data on profits and losses, presents the return on assets for the period from 2008 to 2015 for the 42 banks in my sample. The return on assets is divided into three components: the net interest margin on the banking book, net fees and commissions and the results on financial transactions, including other income. On aggregate, the net interest margin on the banking book was remarkably stable over the whole period, despite continuously falling interest rates. The full period average of the net interest margin amounts to 1.20% and its standard deviation is 0.14%, giving a coefficient of variation of 0.115. Net fees and commissions average at 0.31%, with a coefficient of variation of 0.142, slightly higher than that of net interest income. The statistics on the results on financial transactions are of course heavily influenced by the credit crisis in the fourth quarter of 2008. But even after dropping this ‘outlier’, it averages just 0.17% with a coefficient of variation of 0.843. Making up over three quarters of operating income, net interest margins clearly form the bedrock of banks’ profits in the Netherlands. Figure 2 presents the net interest margin of the banks along with the yield on 10 year German government zerobonds and the difference between 10 and one year zero yields. The volatility of net interest income is much lower than that of either the long-term interest rate or the yield spread. In fact, while net interest income has a coefficient of variation of 0.115, the 10 year zero yield and the yield spread have coefficients of variation of 0.488 and 0.436 respectively.[3]

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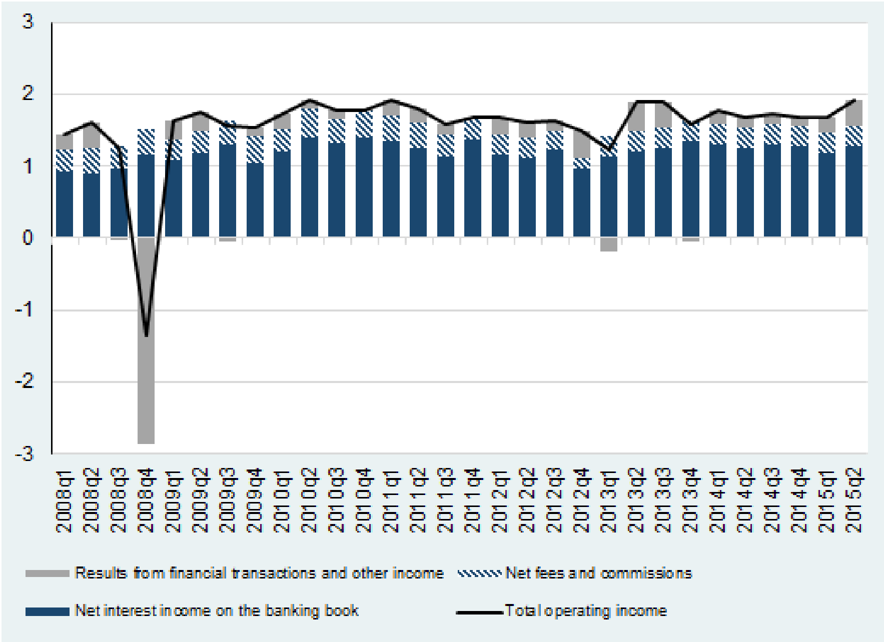
[3] This observation does not depend on the period analysed. Over both longer and shorter time frames, net interest margins are

Figure 1: Decomposition of the return on assets

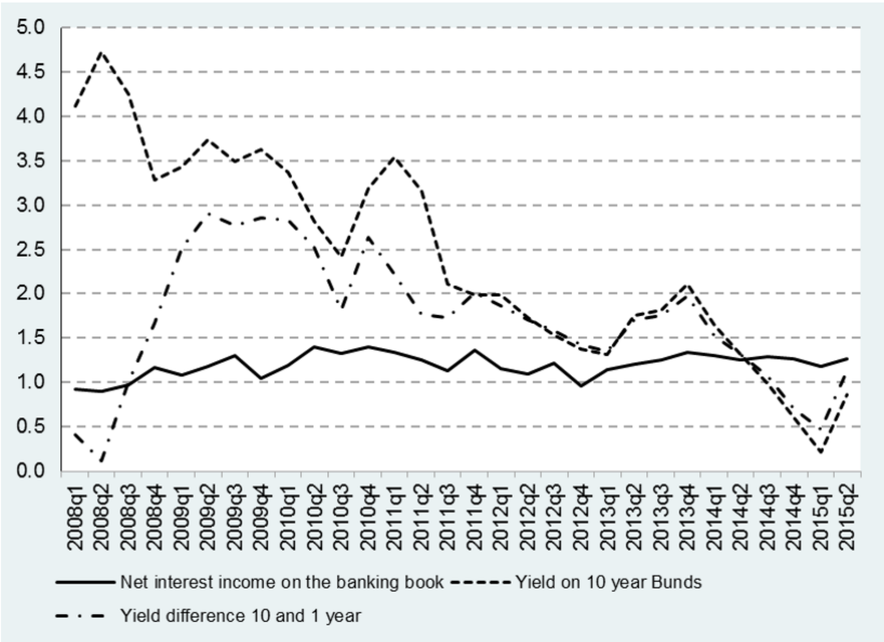


Note: This figure depicts the different parts of banks' (annualised) net operating income per quarter as a percentage of end-of-quarter assets. Source: De Nederlandsche Bank.

Figure 3 is a box-and-whisker plot of net interest income divided by total assets for individual banks per quarter. The figure shows that there is quite a lot of variation in net interest margins among banks. The distribution of the net interest margins seems to be quite stable, though. The unweighted average net interest margin fluctuates little around a full period average of 1.21%. A two-sided T-test for inequality of the (unweighted) average interest rate margins when the period is divided into equal halves is rejected (p-value 0.23). The dispersion of the margins has also not changed significantly over the period either. An F-test for inequality of the variances produces a p-value of 0.955. Therefore, the hypothesis that the location or the dispersion of the distributions changed significantly over time is refuted.

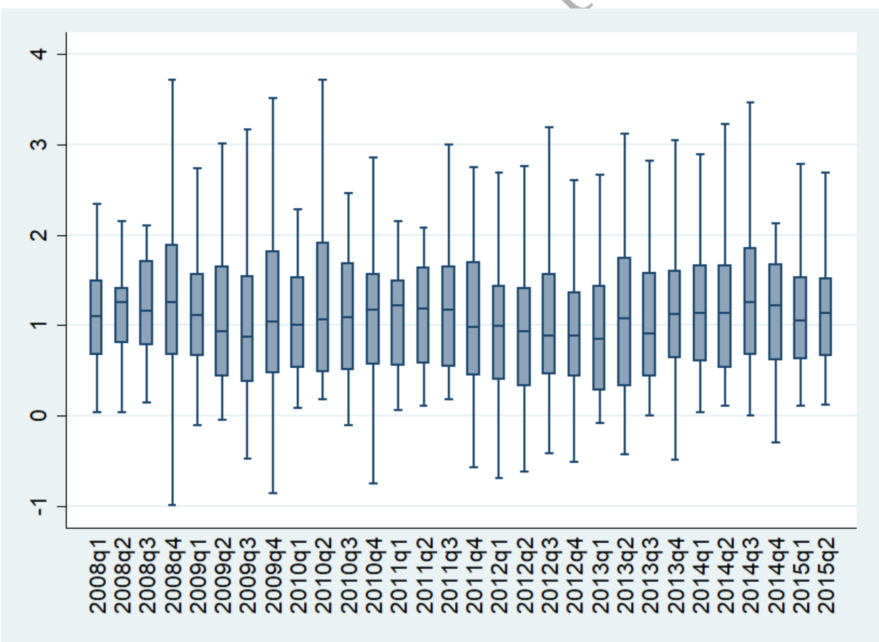
less volatile than either long-term interest rates or yield spreads.

Figure 2: Net interest margin, interest rate and the yield spread



Note: This figure depicts banks' net interest margin (annualised net interest income in the banking book as a percentage of assets) along with the yield on 10 year German government bonds and the spread between 10 year and 1 year yields. Source: De Nederlandsche Bank, Deutsche Bundesbank.

Figure 3: Distribution of the net interest margin across banks



Note: This figure depicts the distributions of the net interest margin (annualised net interest income in the banking book as a percentage of assets) across banks for each quarter. The top, middle and bottom of the boxes represent 75th, median (50th) and 25th percentiles respectively. The error bars represent upper and lower adjacent values. Source: De Nederlandsche Bank.

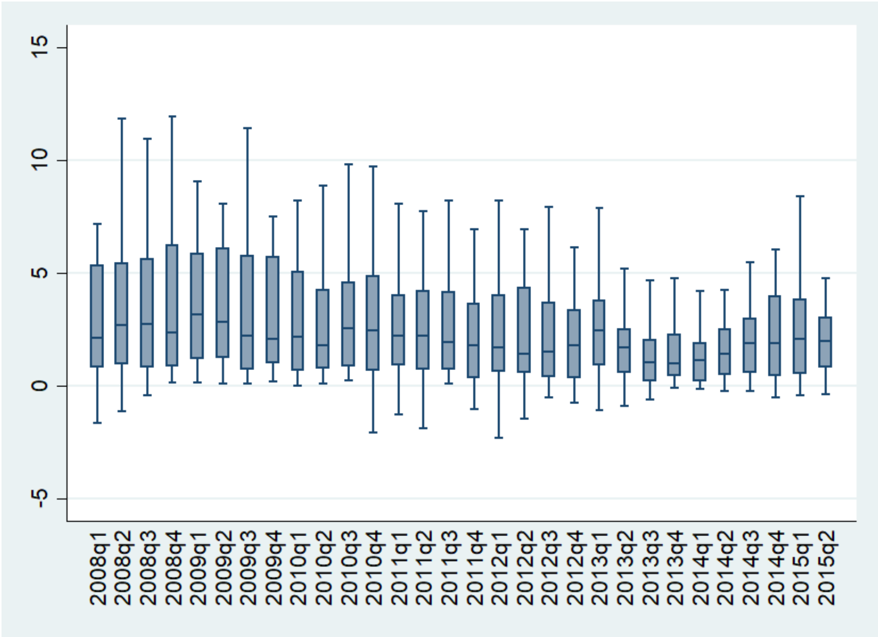
2.3. Interest rate risk positions

Throughout the rest of my analysis, I use the duration of equity (D_E) as the measure of interest rate risk since it is independent of a bank's size. It is derived from banks' basis point value as submitted to the Dutch central bank in their quarterly supervisory report on interest rate risk.[4] Figure 4 presents the distributions for each of the quarters of the resulting duration of equity for the banks in the sample over the period under investigation. The durations of equity, although positive, seem relatively small. Durations of equity after hedging of around two amount to an average difference between the durations of assets and liabilities of just two to three months. Banks seem to be active in maturity transformation, borrowing short and lending long, but only in a very limited way. Applying the method developed by American supervisors (Sierra and Yeager, 2004) to data from banks' annual reports, suggest duration gaps between assets and liabilities before hedging of around two years. This suggests that banks manage their ultimate interest rate risk very actively. The variation in the durations of equity suggests that there is quite some heterogeneity among banks. There is also substantial variation over time which suggests that banks do not maintain a constant interest risk position, but adjust their interest rate risk to changes in the economic environment. Dividing the period into two equal segments of 15 quarters each, allows me to test for the inequality of the average duration of equity for the two periods. The test indicates banks' average duration declines from 3.22 in the first period to 2.25 in the second period (p-value of 0.000).

In order to assess whether interest rate risk taking differs between banks that use derivatives and those that don't, I calculate the average durations of equity for each quarter for both groups. I assess the use of derivatives by looking at whether a bank reports having traded

[4] Banks report their interest rate risk measures by currency. I only analyse the measures for the euro denominated assets and liabilities, which represent between 89% and 98% of the total.

Figure 4. Distribution of the duration of equity across banks



Note: This figure depicts the distributions of the duration of equity (measured in years) across banks for each quarter. The top, middle and bottom of the boxes represent 75th, median (50th) and 25th percentiles respectively. The error bars represent upper and lower adjacent values. Source: De Nederlandsche Bank.

derivatives or having hedged any kind of asset or liability in the banking book in its FINREP report. This criterion (adopted from Purnanandam, 2007) indicates that a bank has the ability to use derivatives, although it does not necessarily use them to hedge interest rates. I assume that such a bank would be able to use derivatives for interest rate hedging if it wanted to do so. The results for banks not using derivatives deviate significantly from those of banks using derivatives, but it turns out that the results are heavily influenced by the inclusion of one particular bank. Dropping this bank causes the difference between the developments in the duration of equity to disappear.

Before investigating the interest rate risk taking behaviour using dynamic panel models, I first investigate the economic significance of the variation in the duration of equity both over time and between banks. I do so by quantifying the importance of the income from maturity transformation relative to the net interest margin of the banks.

3. Decomposition of net interest income

I decompose net interest income into income from maturity transformation, income from equity and commercial margins in order to assess the contribution of interest rate risk to net interest income using a method developed by Memmel (2008, 2011). Each bank's balance sheet is modelled as two portfolios of zero bonds – one for assets and one for liabilities – that mimic the shifting composition of a bank's banking book over time. Using zero bonds greatly simplifies the calculations. Also, the yield curve data is expressed as zero yields, so using zero bonds obviates the need to calculate coupon yields. The portfolios are constructed so that the interest rate risk characteristics are consistent with the duration of equity as derived from the *PV01* measures reported.

By assuming that the interest earned on assets and paid on liabilities consist of a risk free interest rate and a margin (e.g. for credit risk and costs), we can write *NII* as:

$$NII_i = (r_i^a + m_i^a)BA_i - (r_i^l + m_i^l)BL_i \tag{1}$$

where *BA* and *BL* are the economic values of the assets and liabilities in the banking book, r_i^a is the risk free interest rate earned on assets, m_i^a is the interest margin applied for assets by bank *i*, r_i^l is the risk free interest paid on liabilities and m_i^l is the interest margin paid by bank *i*. The interest rates and margins are averages across assets and liabilities of different remaining maturities. Since r_i^a and r_i^l are dependent only on the maturity structure of the assets and liabilities, their difference represents the pure 'profits' from maturity transformation. Using the identity:

$$BA_i = BL_i + E_i \tag{2}$$

where E represents the economic value of equity of bank i's banking book and after rearranging, I arrive at the following expression for net interest income:

$$NII_i = \left[\left(r_i^a - r_i^l\right) \cdot BA_i\right] + \left[r_i^l \cdot E_i\right] + \left[\left(m_i^a - m_i^l\right) \cdot BA_i + m_i^l \cdot E_i\right] \quad (3)$$

This equation shows that total net interest income equals the sum of interest income from maturity transformation (the first term in square brackets) plus interest income on the part of the assets financed by equity (the second term in square brackets) and net (commercial) margins (the final term in square brackets). I calculate the first and second terms directly and derive net (commercial) margins as a residual.

The income from maturity transformation can now be determined by choosing the appropriate interest rates from the yield curves that are consistent with the durations of equity calculated in the previous section. The duration of equity only indicates the difference between the durations of the assets and liabilities. Without information on the durations of the assets (D_{BA}) and liabilities (D_{BL}) separately, but only about the gap between them, the precise points on the yield curve for each are undetermined. I therefore repeat the calculations for three different values for the duration of the liabilities, ranging between 1.00 and 2.50[5] and derive the duration of assets, by solving the equation for the duration of equity for D_{BA}:

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[5] Using the accounting-based method developed by American supervisors (Sierra and Yeager, 2004), I estimate the duration of liabilities for ABN AMRO, one of the largest banks in the sample, from the table on page 208 of its 2014 Annual Report: Maturity based on contractual undiscounted cash flows. My estimate came to 1.74 at the end of 2014. The range from 1.00 to 2.50 spans this number appropriately.

$$D_{BA} = \left(\frac{E}{BA} \cdot D_E\right) + \left(\frac{BL}{BA} \cdot D_{BL}\right) \tag{4}$$

By fixing the duration of the liabilities at values between 1.00 and 2.50, I assess plausible ranges of outcomes for income from maturity transformation. The economic value of equity (*E*) is reported together with PV01 in the banks' interest rate risk reports, but the economic values of banking book assets (*BA*) and liabilities (*BL*) are not. I therefore take the book value of banking book assets as a proxy for *BA* and calculate *BL* as the difference between *BA* and *E*. Since interest rates have declined steadily over the period under investigation, the book value of assets underestimates its economic value. This will introduce a small but unknown downward bias in the duration of assets.

The final unknown is the distribution of the assets and liabilities by duration which is needed to calculate the average interest rates for equation (3). The simplest way to do this is to assume a portfolio distributed uniformally over remaining maturities *m* so that the portfolio duration is just over half that of the original maturity of an individual zero bond. A bank's income from maturity transformation is thus simulated as a simple trailing average of past interest rates.

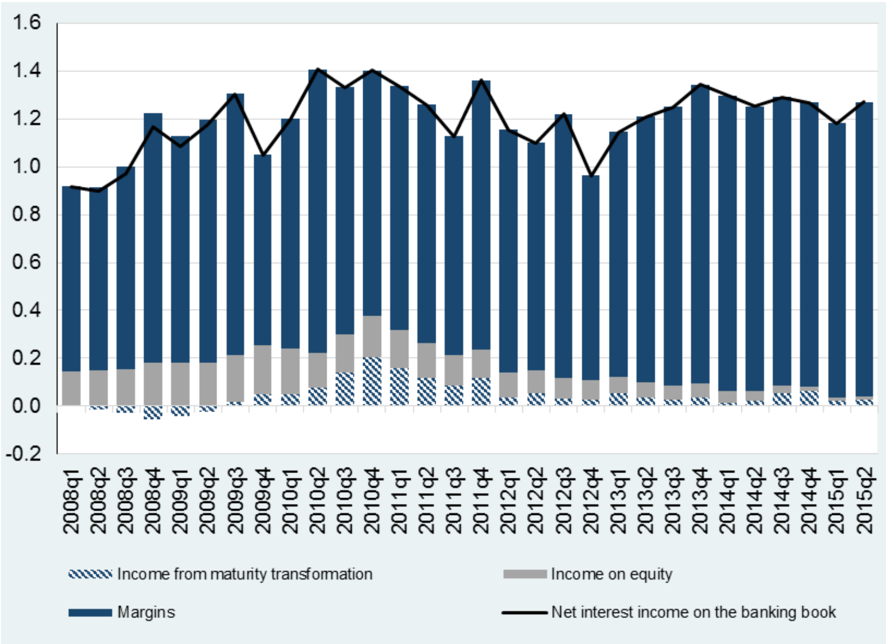
Table 1 presents the decomposition of the net interest margin, investigated in the previous section, for three possible values of D_{BL}, calculated as a weighted average for all 42 banks. Figure 5 shows the corresponding quarterly time series graphically for D_{BL}=1.75. It is quite clear from these decompositions that the income from maturity transformation constitutes a relatively small and volatile part of the net interest margin. Its contribution to the net interest margin is largest in 2010, when the yield curve was steep, and accounts for just under a third of the interest margin for D_{BL}=1.00. For the other two possible values of D_{BL}, income from maturity transformation peaks at 12 basis points in 2010, accounting for some 9 percent of the net interest margin. In the crisis year 2008, it is even negative for two values of D_{BL}, but it seems to contribute positively to the improvement of banks' profitability in the three subsequent years. In the final three years, the income from maturity transformation declines to nil, as the yield curve flattens. As the distribution of the duration of equity shown in figure 4 suggests, there is quite some heterogeneity among the banks. Especially in 2010 and 2011, for D_{BL}=1.75, there are banks that lose some 40 to 50 basis points on maturity transformation, whereas others profit for up to 50 basis points. In other years, the range in income from maturity transformation is much smaller. Income from equity declines steadily throughout the

Table 1: Decomposition of the net interest margin using three possible values for D_{BL} (percentages)

	2008	2009	2010	2011	2012	2013	2014
D_{BL} = 1.00							
Maturity transformation	-0.055	0.202	0.392	0.131	0.050	0.099	0.016
Equity	0.173	0.158	0.084	0.069	0.048	0.011	0.004
Commercial margins	0.869	0.793	0.862	1.070	1.013	1.124	1.255
Net interest margin	0.987	1.153	1.338	1.269	1.111	1.234	1.276
D_{BL} = 1.75							
Maturity transformation	-0.025	0.001	0.120	0.120	0.038	0.039	0.038
Equity	0.157	0.190	0.166	0.137	0.091	0.062	0.036
Commercial margins	0.854	0.962	1.052	1.012	0.982	1.134	1.201
Net interest margin	0.987	1.153	1.338	1.269	1.111	1.234	1.276
D_{BL} = 2.50							
Maturity transformation	0.018	0.023	0.014	0.014	-0.019	-0.018	-0.018
Equity	0.158	0.190	0.192	0.194	0.158	0.117	0.085
Commercial margins	0.811	0.940	1.131	1.061	0.972	1.135	1.210
Net interest margin	0.987	1.153	1.338	1.269	1.111	1.234	1.276

Source: own calculations based on data from De Nederlandsche Bank

Figure 5: Decomposition of the net interest margin (D_{BL} = 1.75)



Note: This figure depicts the decomposition of the net interest margin for all banks in the sample into three parts. The first part consists of income from maturity transformation, which is approximated as the difference between the interest income from two synthetic portfolios with different durations. The second part consists of income earned on the assets financed with equity. The remainder is regarded as income earned from net commercial margins. The data is measured in percentage of assets. Source: De Nederlandsche Bank.

period. It only depends on the level of interest rates, which for all relevant maturities, declines consistently.

4. Panel model estimation of risk taking behaviour

4.1. The empirical model and estimation method

This section presents the empirical model to gauge the influences of time-varying bank specific and macroeconomic variables (mainly interest rate variables) on banks' interest rate risk positions as presented in section 2.3. It is assumed that a bank is able to adjust the maturity structures of its assets and liabilities and/or that it is able to employ some form of macro-hedging (through the use of financial derivatives such as swaps or futures) to affect the interest rate risk position it wishes to take. Banks use these instruments to achieve a certain interest rate risk position that is regarded as optimal given a certain level and shape of the yield curve. Since the duration of equity available from the banks' reporting already takes into account the effects of hedging, I analyse the on-balance-sheet and off-balance-sheet (hedging) decisions on the interest rate risk position together.

I assume that a bank's target duration of equity depends on bank-specific factors and (macro-economic) interest rate variables. In order to account for the fact that banks might not adjust their duration of equity to its target within one quarter (e.g. due to adjustment costs), I assume that banks' duration of equity follows a partial adjustment mechanism. The relationship can be summarised by the following equation:

$$y_{i,t} = (1-\theta)y_{i,t-1} + \theta\alpha_i + \theta\beta\boldsymbol{x}_{i,t} + \theta\gamma\boldsymbol{z}_t + \varepsilon_{i,t} \qquad (5)$$

where the dependent variable y is the duration of equity of bank i at time t, α is a time-invariant bank fixed effect, $\boldsymbol{x}$ is a vector of bank specific time-variant variables and $\boldsymbol{z}$ is a vector of interest rate variables with corresponding coefficient vectors β and γ. Both vectors of explanatory variables are clarified further below. The coefficient θ represents the speed of adjustment and $\varepsilon_{i,t}$ is an idiosyncratic error term.

Equation (5) is a so-called dynamic or autoregressive fixed-effects panel model. Since the model contains a lagged dependent variable, there is a bias through the dependence between y_{t-1} and the bank fixed effects α_i, so that the estimation technique needs to be chosen with care. The panel data set contains data for 41 banks (one of the 42 banks is dropped since it has only two observations) and an average time period of nearly 24 quarters. The length of the time series per individual bank varies between 5 and 30 quarters but there are no gaps. The Ahrens and Pincus gamma-index comes to 0.77 making the panel fairly unbalanced. Although the bias is often found to be small for panels with T approaching 30, the fact that the panel is unbalanced should also be taken into account in choosing the estimation technique. Flannery and Hankins (2013) note that the choice of an efficient estimator is especially important for quarterly data (which I use here), since it contains smaller innovations than annual data, increasing the difficulty of estimating coefficients accurately. Flannery and Hankins investigate various estimation methods and find that, under data limitations comparable to here, the bias-corrected least-squares dummy variable (LSDVC) estimator proposed by Bruno (2005) performs better than the standard fixed effects model as well as commonly used GMM methods and differencing strategies. The superiority of LSDVC over other methods is confirmed by the findings of Dang et al. (2015). I therefore estimate the model using both standard fixed effects and LSDVC methods and compare the outcomes. In order to investigate possible differences in behaviour between derivative users and non-users, I estimate the model both for the whole sample and for the groups of derivative users and non-users separately.[6]

The definitions of the variables and the expected signs of the coefficients are summarised in Table 2. To begin with, I expect only the size of the yield spread but not the level of interest rates to influence risk taking. The coefficient on the level of interest rates is therefore expected to be statistically insignificant. These expectations are based on models of interest rate risk management such as Grove (1974), which was extended in Prisman and Tian (1993),

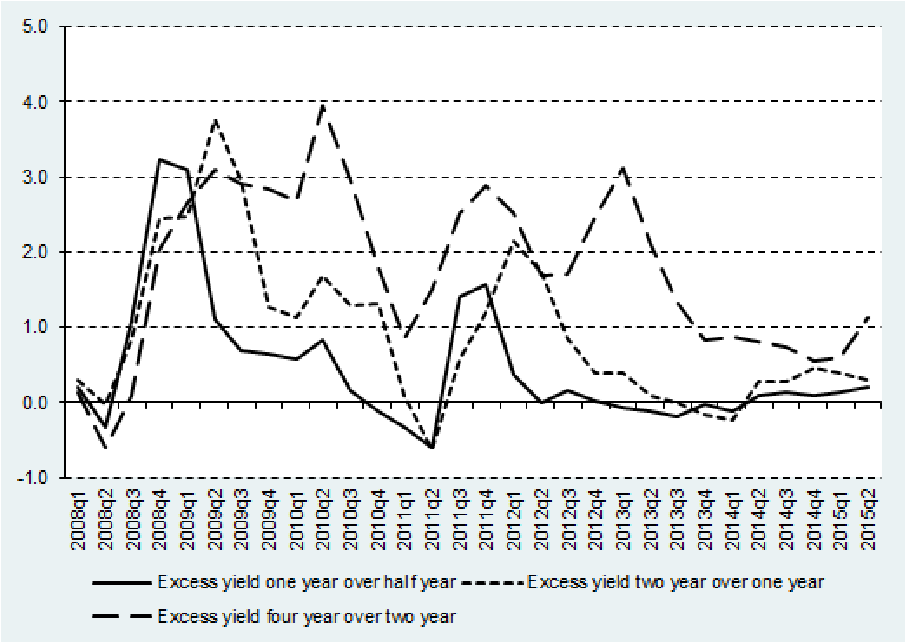
[6] Purnanandam (2007) estimates the probability that a bank uses derivatives using a logistic model and includes the predicted probability in a two-stage estimation of the interest rate risk. In the relatively small sample of banks under investigation here, derivative use does not vary enough over time to enable using a similar approach. Over the period studied, banks in the sample were either derivative user over the whole period or not.

Niehans and Hewson (1976) and Koppenhaver (1985).

The spread between long and short rates is an indicator of future changes in the long-term rate (see Campbell and Shiller, 1991) and acts as an indicator of the profitability of playing the yield curve (borrow short and lend long). In addition to the measures usually employed in the literature for the steepness of the yield curve (such as the difference between the 10 and 1 year yields), I also estimate the model using a measure which indicates the ex-post violation of the pure expectations theory. Drawing on Campbell and Shiller (1991), I define the realised excess yield on a zero bond of maturity n (the long bond) as the difference between the forward rate for maturity m (the short bond, where m=½n), m years ago and the current spot rate for maturity m. Figure 6 presents the time-series for the excess yield for n = 1, 2 and 4 years for the time period under investigation.

I also expect the duration of equity to be negatively related to the volatility of interest rates and excess holding yields, as predicted by the models of Grove (1974), Prisman and Tian (1993), Niehans and Hewson (1976) and Koppenhaver (1985). The volatilities are calculated as the annualised daily standard deviations for each of the quarters. In line with the same models, the size of a bank is expected to have a positive influence on the interest rate risk position, since absolute risk aversion decreases as a bank becomes larger. Also, under decreasing absolute risk aversion, risk taking is increasing in net worth. So the larger total assets, the higher risk taking will be. It is also relevant whether the size of a bank leads it to believe that it is 'too-big-to-fail', causing moral hazard and increased risk taking as discussed by Mishkin (2006). On the other hand, relative bankruptcy costs also increase with the size of the bank which would dampen risk taking. I therefore include a number of instruments which are meant to pick up the influence of bankruptcy costs. Expected bankruptcy costs can be seen

Figure 6: Excess yield of long-term over short-term zero bonds



Note: The figure depicts the additional yield earned from investing in a long-term bond as compared to a rolled-over investment in bonds with half the term to maturity. Source: own calculations on yields from the Bundesbank.

as the product of the probability of bankruptcy and the size of the losses. I include the solvability ratio and on-balance sheet leverage as a proxy for the first and the losses on impaired loans as a proxy for the second. I expect positive coefficients for the solvability ratio and negative coefficients for the other variables. Some studies have found a U-shaped relationship between solvability and risk (e.g. Haq and Heaney, 2012). To test this, I include the square of the solvability ratio in the model specifications. I also include the deposit ratio, i.e. the proportion of the banking book financed with deposits, although the effect on risk taking is ambiguous. Purnanandam (2007) suggests a higher deposit ratio might make banks less risk averse – implying a positive expected coefficient – due to the existence of deposit insurance and the moral hazard this introduces. A higher deposit ratio, however, implies a higher proportion of financing with uncertain maturity, which might make banks more risk averse. If the source of financing is purely a question of commercial balance sheet management, the deposit ratio should be insignificant. Return on equity, a measure of a

Table 2: Variable definitions

Variable	**Abbreviations**	**Definition**	**Expected sign**
Bank specific variables			
Duration of equity	DUREV	Duration of the economic value of equity	dependent variable
Size of the bank	TOTAS TOTEQ	Natural logarithm of total assets in the banking book and total own funds, in millions of euro	+
Solvability ratio	SOLV	Solvability ratio as a percentage of own funds	+
On-balance-sheet leverage	LEVER	Ratio of total assets to own funds	-
Losses on impaired loans	LOSS	Losses on impaired loans as a per mille of banking book assets	-
Deposit ratio	DEP	Ratio of deposits to banking book assets	?
Return on equity	ROE	Profits before taxes as a percentage of the book value of equity	+
Government assistance	ASSIS	Dummy indicating the bank received financial support or was temporarily state owned	+
Level of competition	COMPLN COMPDP	Market share of the individual bank in loan and deposit markets in percentage per quarter	+
Macro-economic variables			
Interest rate	INTRxY	Money market rates and zero bond yields, end-of-quarter annualised percentages	0
Volatility of the interest rate	VOLINxY	Annualised daily volatility of the interest rate per quarter	-
Yield curve steepness or spread	SLOPExY_zY	Difference between a long-term and a shorter term interest rate, end-of-quarter annualised percentages	+
Excess holding yield	EXYLDxY	Excess holding yield of a n year zero bond over a ½n year zero bond, end-of-quarter annualised percentages	+
Volatility of the excess holding yields	VOLEYxY	Annualised daily volatility of the excess holding yield per quarter	-

bank's profitability, is expected to have a positive influence on risk taking as profitability is likely to reduce risk aversion and increase (over)confidence. Likewise, the coefficient on a dummy for government assistance, indicating whether the bank was receiving temporary assistance during the financial crisis (either through capital support or other measures such as guarantees) is expected to be positive. (Banks that are publicly owned before the crisis and which do not receive emergency assistance are assigned a dummy equal to zero.) By removing or lowering the chance of bankruptcy, government assistance should reduce a bank's risk aversion. Market share –measured by the share of deposits and by the share of the loan market – is also expected to have a positive influence on risk-taking as it is an indication of market power. More market power leads to lower correlation between loan or deposit demand and interest rates, which enhances the stability of the balance sheet structure. Market share is also a relative proxy for the 'too-big-to-fail' aspect as opposed to an absolute measure such as total assets.

4.2. Results

Table 3 presents descriptive statistics for the interest rate variables and the bank-specific variables for the whole sample of banks, as well as for the subsamples of derivative users and non-users. Since total assets and total equity as well as market share of deposits and market share of loans are very highly correlated, with correlation coefficients of 0.95 and 0.98 respectively, the estimations were performed with either of both pairs separately. I only present the results for the estimations including total assets and the market share of deposits. The other versions of the model produced qualitatively similar results. In order to ensure reliability of the results, I first test the dependent variable for stationarity using the Fisher-type unit-root test based on augmented Dickey-Fuller tests, known as the inverse chi-square test. The hypothesis that all panels were non-stationary is rejected with a p-value of 0.0008. The model presented in section 4.1 is first estimated with measures for the slope of the yield curve and volatility of the interest rate variables for the full sample of banks and for derivative users and non-users separately. Due to the limited number of banks, the estimations for the sub-sample of derivative non-users have to be interpreted with caution, although dropping the bank that was identified as an outlier in section 2.3 only changed the outcomes quantitavely but not qualitatively. The results, presented in the appendix as tables A-1 (standard fixed effects) and A-2 (bias corrected LSDVC estimate), show that the coefficients on the slope of the yield curve and the volatility of interest rates are not significant. I repeat the estimations with the excess holding yiels measure and its volatility, which produce more encouraging results, presented in tables 4 (standard fixed effects) and 5 (bias corrected LSDVC estimate).[7] The excess holding yield on the one-year zero bonds produces the best results (the other outcomes are not presented). Remarkably, derivative users appear to steer their interest rate risk so as to benefit from maturity transformation, while non-derivative users do not. We may therefore conclude that derivative users are active asset transformers, while derivative non-users seemed to be more passive in this respect. Both derivative users and non-users do not react to the level of interest rates, as hypothesised. Surprisingly, the volatility of interest rates is not significant in any of the estimations which includes the excess holding yields but enters with a positive coefficient (contrary to expectations) in the models with the slope measures. In all estimations, the estimate for θ lies between 0.28 and 0.42 and for derivative non-users it is marginally lower than for derivative users. This is in line with the speed of adjustment found in other dynamic panel estimations in corporate finance as reviewed in Dang et al. (2015).

Of the other variables only on-balance sheet leverage and the dummy for government assistance turn out to be significant in the estimations for the full sample and for the derivative-users. The dummy for government assistance (which had to be dropped in the

[7] A specification with time fixed effects showed none of the quarter dummies to be significant. Also, F-tests for joint significance could not reject them as different from zero. I therefore only present specifications without time fixed effects.

derivatives non-users sub-sample since none of the banks in this group received assistance) indicates that government support leads to higher levels of interest rate risk-taking. Since data on interest rate risk do not extend further back to before the crisis, it is impossible to conclude whether this might stem from reversed causality or whether this is a real cause and effect. On-

Table 3: Descriptive statistics

Variable (no. obs. = 926)	**Mean**	**Std. dev.**	**Minimum**	**Maximum**
INTR3M	0.9815	1.2109	-0.0140	5.2770
SLOPE3M_10Y	1.2628	2.3505	0.0366	12.7105
VOLIN3M	1.3585	0.8816	-1.0270	2.9300
EXYLD1Y	0.4584	0.8818	-0.6120	3.2318
VOLEY1Y	1.5835	1.7803	0.1696	7.6740
Full sample (no. obs. = 926, no. banks = 41)				
DUREV	2.6987	2.8440	-8.6199	21.4743
TOTAS	8.4536	2.3216	2.3061	13.6536
TOTEQ	5.9301	1.9618	1.5623	10.8331
SOLV	21.5446	14.1042	6.0100	111.1900
LEVER	18.1699	15.8693	1.0843	175.6038
LOSS	1.0345	5.9163	-12.8624	145.5615
DEP	0.6444	0.2783	0.0000	1.0417
ROE	0.9425	8.9081	-99.2432	98.6253
ASSIS	0.1156	0.3199	0.0000	1.0000
COMPLN	2.9810	9.1220	0.0000	55.2226
COMPDP	2.9584	8.1439	0.0005	44.1445
Derivative users (no. obs. = 743, no. of banks = 32)				
DUREV	2.6299	2.7513	-8.6199	21.4743
TOTAS	9.0565	1.9866	5.7230	13.6536
TOTEQ	6.4497	1.7347	3.2607	10.8331
SOLV	20.1547	14.3638	6.0100	111.1900
LEVER	18.3856	13.5648	2.5159	78.6474
LOSS	1.2694	6.5597	-12.8624	145.5615
DEP	0.6421	0.2533	0.0000	1.0246
ROE	0.2393	8.6674	-99.2432	29.1453
ASSIS	0.1440	0.3513	0.0000	1.0000
COMPLN	3.6841	10.0609	0.0000	55.2226
COMPDP	3.6669	8.9517	0.0153	44.1445

Table 3 (continued)

Derivative non-users (no. obs. = 183, no. of banks = 9)				
DUREV	2.9783	3.1858	-0.3250	17.4817
TOTAS	6.0056	1.9479	2.3061	9.1031
TOTEQ	3.8202	1.3096	1.5623	6.5380
SOLV	27.1881	11.4007	11.5900	73.7900
LEVER	17.2944	22.9956	1.0843	175.6038
LOSS	0.0808	1.1533	-12.8318	6.6262
DEP	0.6537	0.3632	0.0000	1.0417
ROE	3.7976	9.3180	-11.875	98.6253
ASSIS	0.0000	-	0.0000	0.0000
COMPLN	0.1266	0.1859	0.0000	0.7361
COMPDP	0.0820	0.1181	0.0005	0.4459

Source: De Nederlandsche Bank, Deutsche Bundesbank

balance sheet leverage is significant in most of the estimations except in some of the estimations for the sub-samples, and is of the correct sign. We may therefore conclude that interest rate risk positions are decreasing in on-balance sheet leverage. Unlike earlier research on interest rate risk of banks, such as Mitchell (1989) and Ahmed et al. (1997) as well as some more recent research by Entrop et al. (2008) and Esposito et al. (2015), I do not find that smaller banks have larger interest rate risk positions since they are less able to hedge their positions. This suggests that all the banks in my sample have attained a sufficient level of sophistication needed to manage interest rate risk, either through the use of derivatives or through commercial balance sheet management. The coefficients on the solvability ratio and its square do not turn out to be statistically significant in the LSDVC estimations. In the standard fixed effects estimation, the coefficients are in fact significant, albeit marginally (p-values of 0.043 and 0.096 respectively) for the derivative non-users. Since the standard fixed effects estimates often have lower standard errors than those of other estimation methods, one may conclude that for banks that do not use derivatives, there is at least tantalising evidence that interest rate risk remains low for normal levels of solvability, but increases with very high levels of solvability (above 45%). The marginal differences between the standard fixed effects results and those from the bias-corrected estimations indicate that the standard fixed effects estimations suffer little if at all from Nickell bias.

5. Conclusions

Referring to the three questions posed in the introduction, one can conclude the following. Net interest income is a very stable and important component of net operating income for Dutch banks. During and after the crisis, net interest income functioned as the bedrock of banks' profitability. The interest rate risk positions of Dutch banks are rather small primarily because they hedge most of the risk. Income from pure maturity transformation as a result is limited to about a tenth or less of the net interest margin. Although the interest rate risk levels are relatively modest, banks do seem to take advantage of persistent excess long-term yields by strategically enlarging their positions. Interest rate risk positions are negatively related to on-balance sheet leverage and exhibit a U-shaped relation with solvability. Interest rate risk positions do not vary systematically with the size of a bank, in contrast to results found in other studies. Lastly, banks that received government support during the crisis take on more interest rate risk. Taken together, concerns for increased interest rate risk taking by banks due to low levels of interest rates across maturities – as alluded to by international organisations such as the BIS (2015) and the IMF (2013) – seem to be unfounded for Dutch banks.

Table 4: Results from the dynamic panel estimation for the duration of equity on excess yields and bank specific variables, standard fixed-effects LSDV-estimator

Variable	Full sample		Derivative users		Derivative non-users	
DUREV(t-1)	0.6083	***	0.5802	***	0.6226	***
	(0.0265)		(0.0302)		(0.0630)	
INTR3M	0.0660		0.1317		0.0037	
	(0.0716)		(0.0818)		(0.1842)	
EXYLD1Y	0.1770	*	0.3256	***	-0.1354	
	(0.0917)		(0.1049)		(0.2100)	
VOLEY1Y	-0.0323		-0.0882		0.0826	
	(0.0603)		(0.0679)		(0.1391)	
TOTAS	0.1820		0.4549		0.0282	
	(0.2624)		(0.3590)		(0.5688)	
SOLV	-0.0270		0.0108		-0.1736	**
	(0.0235)		(0.0328)		(0.0850)	
SOLV-squared	0.0001		-0.0001		0.0019	*
	(0.0002)		(0.0002)		(0.0012)	
LEVER	-0.0212	***	-0.0399	**	-0.0136	*
	(0.0064)		(0.0184)		(0.0078)	
LOSS	0.0088		0.0065		-0.0405	
	(0.0104)		(0.0108)		(0.1220)	
DEP	1.0118		0.6009		1.7219	
	(0.6367)		(0.7852)		(1.1952)	
ROE	0.0081		0.0061		0.0083	
	(0.0073)		(0.0086)		(0.0149)	
ASSIS	0.9175	**	0.8773	**	-	
	(0.4065)		(0.4075)		(-)	
COMPDP	-0.0062		-0.0118		1.8949	
	(0.0593)		(0.0596)		(2.7708)	
Bank fixed effects	Yes		Yes		Yes	
Number of obs.	926		743		183	

Note: Standard errors shown in parentheses. All models were estimated using standard least squares dummy variables (LSDV) without bias correction. Variables are defined in table 2. Data covers the period 2008Q1-2015Q2. *** Indicates significance at 1% level, ** at 5% level and * at 10% level.

Table 5: Results from the dynamic panel estimation for the duration of equity on excess yields and bank specific variables, LSDVC bias corrected estimator

Variable	Full sample		Derivative users		Derivative non-users	
DUREV(t-1)	0.6829	***	0.6542	***	0.7115	***
	(0.0277)		(0.0329)		(0.0654)	
INTR3M	0.0694		0.1286		0.0369	
	(0.0770)		(0.0917)		(0.2542)	
EXYLD1Y	0.1846	*	0.3329	**	-0.1284	
	(0.0964)		(0.1057)		(0.3484)	
VOLEY1Y	-0.0339		-0.0840		0.0610	
	(0.0634)		(0.0728)		(0.2117)	
TOTAS	0.1293		0.2546		-0.0015	
	(0.3100)		(0.3805)		(0.9412)	
SOLV	-0.0265		0.0072		-0.1708	
	(0.0242)		(0.0369)		(0.1342)	
SOLV-squared	0.0001		-0.0001		0.0019	
	(0.0002)		(0.0003)		(0.0018)	
LEVER	-0.0196	**	-0.0360		-0.0125	
	(0.0068)		(0.0220)		(0.0138)	
LOSS	0.0087		0.0064		-0.0429	
	(0.0108)		(0.0133)		(0.1840)	
DEP	1.0418		0.5473		1.7623	
	(0.7161)		(0.8052)		(2.2935)	
ROE	0.0081		0.0067		0.0086	
	(0.0088)		(0.0090)		(0.0221)	
ASSIS	0.8911	**	0.8552	**	-	
	(0.4502)		(0.4314)		(-)	
COMPDP	-0.0021		-0.0052		2.6091	
	(0.0660)		(0.0690)		(4.8351)	
Bank fixed effects	Yes		Yes		Yes	
Number of obs.	926		743		183	

Note: Standard errors shown in parentheses. All models were estimated using bias corrected least squares dummy variables (LSDVC) with full bias correction initialised by Anderson and Hsiao estimator. Standard errors were calculated by bootstrap using 100 repetitions. Variables are defined in table 2. Data covers the period 2008Q1-2015Q2. *** Indicates significance at 1% level, ** at 5% level and * at 10% level.

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Appendix: Results from the dynamic panel estimations using the slope of the yield curve

Table A-1: Results from the dynamic panel estimation for the duration of equity on the slope of the yield curve instead of excess yields, standard fixed-effects LSDV-estimator

Variable	Full sample		Derivative users		Derivative non-users	
DUREV(t-1)	0.6090	***	0.5858	***	0.6179	***
	(0.0268)		(0.0305)		(0.0635)	
INTR3M	0.0493		0.0723		0.1364	
	(0.0611)		(0.0737)		(0.1607)	
SLOPE10Y_3M	0.0184		0.0278		0.1304	
	(0.0775)		(0.0909)		(0.1888)	
VOLIN3M	0.0427	*	0.0631	**	-0.0290	
	(0.0247)		(0.0274)		(0.0624)	
TOTAS	0.1809		0.4035		0.0942	
	(0.2685)		(0.3653)		(0.5836)	
SOLV	-0.0281		0.0020		-0.1680	**
	(0.0241)		(0.0349)		(0.0849)	
SOLV-squared	0.0001		-0.0001		0.0019	
	(0.0002)		(0.0003)		(0.0012)	
LEVER	-0.0213	***	-0.0395	**	-0.0118	
	(0.0064)		(0.0188)		(0.0079)	
LOSS	0.0094		0.0073		-0.0625	
	(0.0104)		(0.0108)		(0.1242)	
DEP	1.0695	*	0.8025		1.7811	
	(0.6498)		(0.8145)		(1.1942)	
ROE	0.0077		0.0052		0.0067	
	(0.0074)		(0.0087)		(0.0149)	
ASSIS	0.9095	**	0.8571	**	-	
	(0.4097)		(0.4139)		(-)	
COMPDP	-0.0011		0.0002		2.3292	
	(0.0594)		(0.0601)		(2.7458)	
Bank fixed effects	Yes		Yes		Yes	
Number of obs.	926		743		183	

Note: Standard errors shown in parentheses. All models were estimated using standard least squares dummy variables (LSDV) without bias correction. Variables are defined in table 2. Data covers the period 2008Q1-2015Q2. *** Indicates significance at 1% level, ** at 5% level and * at 10% level.

Table A-2: Results from the dynamic panel estimation for the duration of equity on the slope of the yield curve instead of excess yields, LSDVC bias corrected estimator

Variable	Full sample		Derivative users		Derivative non-users	
DUREV(t-1)	0.6851	***	0.6604	***	0.7182	***
	(0.0283)		(0.0331)		(0.0654)	
INTR3M	0.0711		0.0832		0.1946	
	(0.0651)		(0.0835)		(0.2552)	
SLOPE10Y_3M	0.0490		0.0467		0.1665	
	(0.0848)		(0.1046)		(0.2941)	
VOLIN3M	0.0466	*	0.0687	**	-0.0338	
	(0.0267)		(0.0304)		(0.0886)	
TOTAS	0.1347		0.1999		0.0873	
	(0.3299)		(0.3934)		(0.9190)	
SOLV	-0.0275		-0.0015		-0.1652	
	(0.0259)		(0.0398)		(0.1270)	
SOLV-squared	0.0001		0.0000		0.0019	
	(0.0002)		(0.0003)		(0.0017)	
LEVER	-0.0197	***	-0.0351		-0.0106	
	(0.0069)		(0.0233)		(0.0132)	
LOSS	0.0093		0.0071		-0.0641	
	(0.0109)		(0.0135)		(0.1800)	
DEP	1.1243		0.7628		1.9095	
	(0.7305)		(0.8631)		(2.1893)	
ROE	0.0076		0.0056		0.0070	
	(0.0090)		(0.0090)		(0.0214)	
ASSIS	0.8868	*	0.8350	*	-	
	(0.4742)		(0.4468)		(-)	
COMPDP	0.0024		0.0075		3.4141	
	(0.0655)		(0.0704)		(4.3838)	
Bank fixed effects	Yes		Yes		Yes	
Number of obs.	926		743		183	

Note: Standard errors shown in parentheses. All models were estimated using bias corrected least squares dummy variables (LSDVC) with full bias correction initialised by Anderson and Hsiao estimator. Standard errors were calculated by bootstrap using 100 repetitions. Variables are defined in table 2. Data covers the period 2008Q1-2015Q2. *** Indicates significance at 1% level, ** at 5% level and * at 10% level.