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Bank profitability and risk taking in a prolonged environment of low interest rates: a study of interest rate risk in the banking book of Dutch banks*

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Abstract

This paper investigates the size and development of Dutch banks' interest rate risk positions in the banking book during the period from 2008 to 2015. Interest rate risk positions are rather modest and the income from maturity transformation it generates is only a small proportion of the net interest margin and the return on assets. Interest rate risk positions do, however, vary significantly between banks and over time. In fact, banks adjust their interest rate risk in order to benefit from persistent excess long-term yields. 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.

Keywords: interest rate risk, banks, banking book, hedging, profitability.
JEL classifications: D81, E43, G21.

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1. Introduction

This paper investigates the interest rate risk position of Dutch banks during the period from 2008 until the middle of 2015. In those years, interest rates fell to historically low levels as the result of monetary policies in response to the world-wide financial crisis that originated in the United States in 2008 and the European sovereign debt crisis in 2010. Central banks nowadays not only control the shorter ends of the yield curve but, through a variety of unconventional monetary policies such as quantitative easing, also influence the longer segments, which has not only lowered interest rates but has also led to a flattening of the yield curve. Low levels of interest rates and a flattening of the yield curves in many of the main currencies have heightened the concern for an erosion of banks' profits. Low levels of interest rates and flat yield curves have, for instance, 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" and a reliance on central bank policy that insures against adverse market movements (an insurance effect, exemplified by the "Greenspan put"). Whether low interest rates have caused banks to take more risk has become a major issue for supervisors and policy makers (see for instance Chapter VI, Bank for International Settlements, Annual Report 2015, Chapter 3, International Monetary Fund, 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 will therefore be of vital interest to banks and supervisors in the coming years.

Banks perform a vital role in the economy as financial intermediaries that provide deposits in various degrees of liquidity and maturity to savers and loans to borrowers. As a result of this, the maturity and liquidity profile of the assets of a bank will usually differ from the profile of its liabilities, which creates interest rate risk through the so-called maturity mismatch. The stereotypical view is that banks borrow short-term funds (mostly in the form of non-maturity deposits) and extend long-term loans. But this view is incomplete. Banks have a varied set of instruments, consisting mostly – but not exclusively – of derivatives, to manage the ultimate maturity risk position taken. This risk position is monitored and managed by departments responsible for the risk position of the bank as a whole, the asset-liability management (ALM) departments. In this paper, I investigate how Dutch banks have managed their interest rate risk in the banking book – the part of their balance sheet which consists of assets and liabilities which are mostly held to maturity and contains the bulk of its loans and deposits – in the face of declining interest rates and a flattening yield curve. The main question 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 on this subject 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. Studies, such as Flannery and 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) all 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 severely limits the potential sample of banks for analysis, since (especially in Europe) many banks are not listed. Some previous studies are also based on supervisory data. For instance, some studies on American banks, such as Sierra and Yeager (2004) and Purnanandam (2007) derive their measure for the interest rate risk positions on the basis of quarterly Call Reports (Consolidated Reports of Condition and Income) collected by American supervisors. Esposito et al. (2015) use supervisory data collected on a semi-annual basis directly 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 used here. My data, however, is of higher (quarterly) frequency, which allows for analysing short-term changes in banks' risk position. The length of the time-series used (up to a maximum of 30 quarters) also 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). I assess the bias by comparing the results from standard fixed effects estimations and bias corrected estimations using the methods proposed by Bruno (2005).

Another innovation presented here is the use of a new measure to assess the profitability of maturity transformation. Most studies of interest rate risk – Purnanandam (2007) and Esposito et al. (2015) are two examples – employ a simple measure for the profitability of 'playing the yield curve', such as the spread between a long-term interest rate and a short-term interest rate (e.g. the difference between the 10 and one year government bond yield). This measure does not yield any significant results in my estimations. I therefore construct an alternative measure which assesses actual profits from maturity transformation and which measures the ex-post violation of the pure expectations theory of interest. This measure does yield significant results, which suggests that simple term spreads are inappropriate for explaining the behaviour of banks' management of interest rate risk.

The remainder of this 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 the information on interest rate positions described in section 2 to decompose net interest income into income from maturity transformation, income from equity and from commercial margins. Section 4 reviews the relevant theoretical literature on interest rate risk in banking from which I gather relevant variables to include in the dynamic panel estimations, which are presented in section 5. The model relates the interest rate risk position of banks during this period to both macro-economic variables and bank-specific characteristics. I compare the results from my estimations to those of earlier studies. Section 6 offers my conclusions.

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

2.1. Data sources

De Nederlandsche Bank (DNB, the Dutch central bank and prudential supervisor) has collected quarterly data on interest rate risk in the banking book from banks for supervisory purposes, among which the price value of a basis point (PV01), since 2008. 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[1]. Other researchers derive banks' interest rate risk indirectly from studies of share prices or from accounting data on assets and liabilities by remaining maturity (see the studies referred to in the introduction). As noted by Pagano (2001, p. 304), the accounting data is usually not granular enough, there is usually no information on prepayment behaviour and the influence of derivatives cannot be incorporated. Collection of the measures directly from the banks therefore provides for a much more reliable measure on the actual interest rate risk of banks. 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 measures for interest rate risk used here may therefore have been calculated by different methods for different banks. Nevertheless, the duration gap data provided by the banks themselves is the best available at the moment. The sample consists of 42 banks representing roughly 90% of the balance sheet total of the Dutch banking sector during this period. All other data for individual banks were taken from quarterly supervisory reporting (so-called FINREP and COREP reports).

Money market interest rates and constant maturity zero yields were obtained from the Deutsche Bundesbank. The constant maturity zero yields published daily by the Deutsche Bundesbank are constructed from the yields on German government bonds (see Schich, 1997). Yields on German government bonds are widely considered to be the best approximation of risk-free interest rates. The bonds are very liquid which means that prices are available for a wide range of remaining maturities.

[1] This is defined as a position which would lead to a decline in the economic value of equity by 20% following an interest rate shock of 200 basis points, as stated in article 98(5) of directive 2013/36/EU on the prudential supervision of credit institutions. This level of risk is equivalent to a value for the duration of equity of ten.

2.2. Operating income and net interest margins

As shown in equation (1), a bank's return on assets (*ROA*), defined by its operating income (*OI*) divided by end-of-period total assets (*TA*), can be divided into three separate components: net interest income on the banking book (*NII*)[2], net fees and commissions (*NCOM*) and the results on financial transactions, including other income (*RFT*).

$$ROA_i = \frac{OI_i}{TA_i} = \frac{NII_i}{TA_i} + \frac{NCOM_i}{TA_i} + \frac{RFT_i}{TA_i} \tag{1}$$

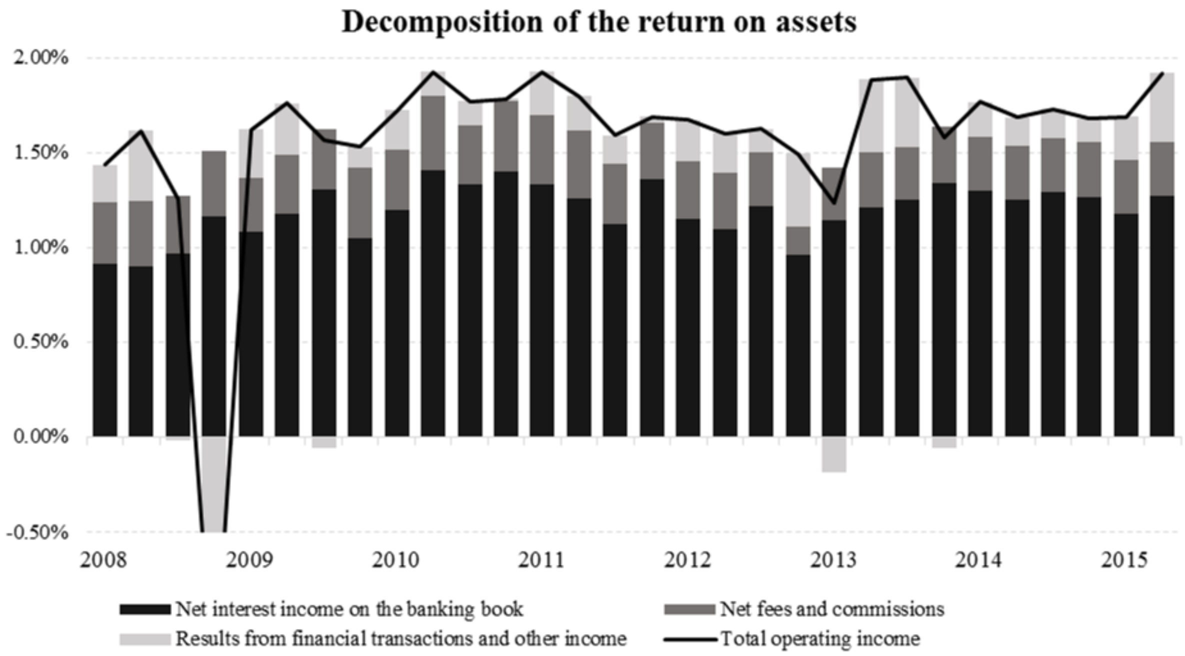
Figure 1, based on the quarterly consolidated supervisory data on profits and losses, summarises the developments of all three components for the period from 2008 to 2015 for the 42 banks in this investigation. The effect of the 'sub-prime' crisis in 2008 is easy to identify. Although the results on financial transactions were negative for the third and fourth quarters of 2008, net operating income was negative only in the fourth quarter of 2008, just after the failure of Lehman Brothers.

On aggregate, net interest margins were remarkably stable over the whole period, despite continuously falling interest rates. The full period average of net interest income amounts to 1.20% and its standard deviation is 0.14%, giving a coefficient of variation of 0.115. Net fees and commissions amount to 0.31% on average, with a standard deviation of 0.04%. Its coefficient of variation is slightly higher than that of net interest income, at 0.142. 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 standard deviation of 0.14%, its coefficient of variation comes to 0.843. It is therefore safe to conclude that net interest margins form the bedrock of banks' profits in the Netherlands.

Figure 2 presents the net interest income 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.

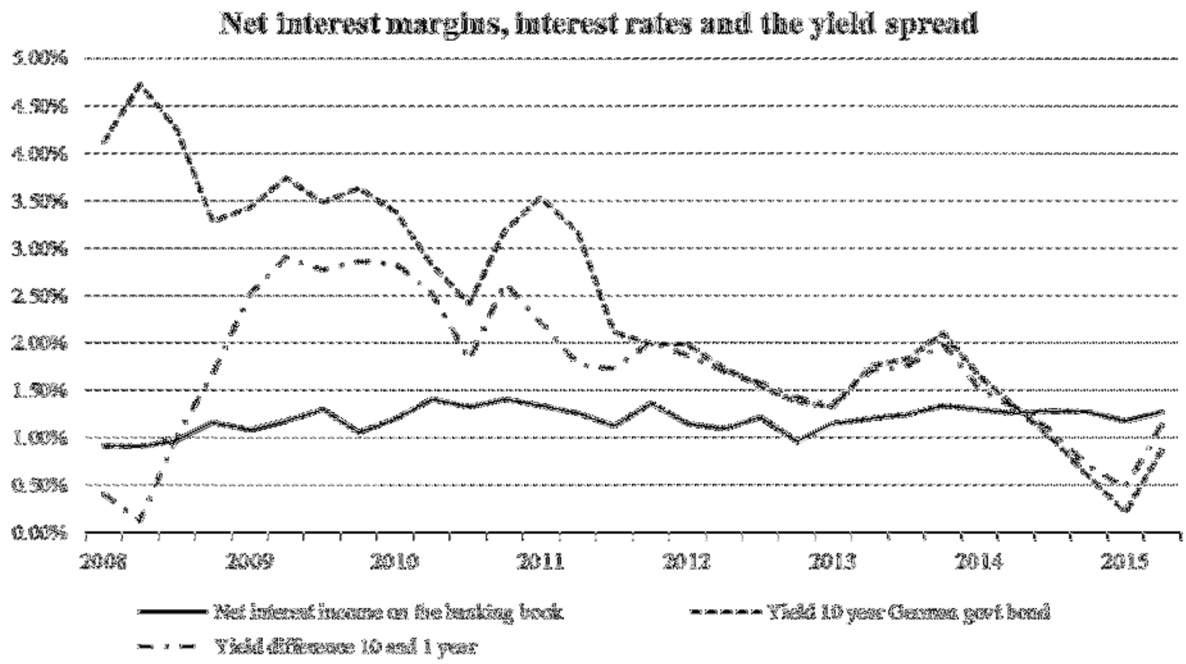
[2] Defined here as interest income minus interest expenses, excluding interest on assets and liabilities held for trading. For aggregate data on the whole banking sector, see table 5.7: Income and expenses of registered credit institutions; Yearly/Quarterly, http://www.dnb.nl/en/statistics/statistics-dnb/financial-institutions/banks/consolidated-banking-statistics-supervisory/index.jsp.

Figure 1



Source: De Nederlandsche Bank

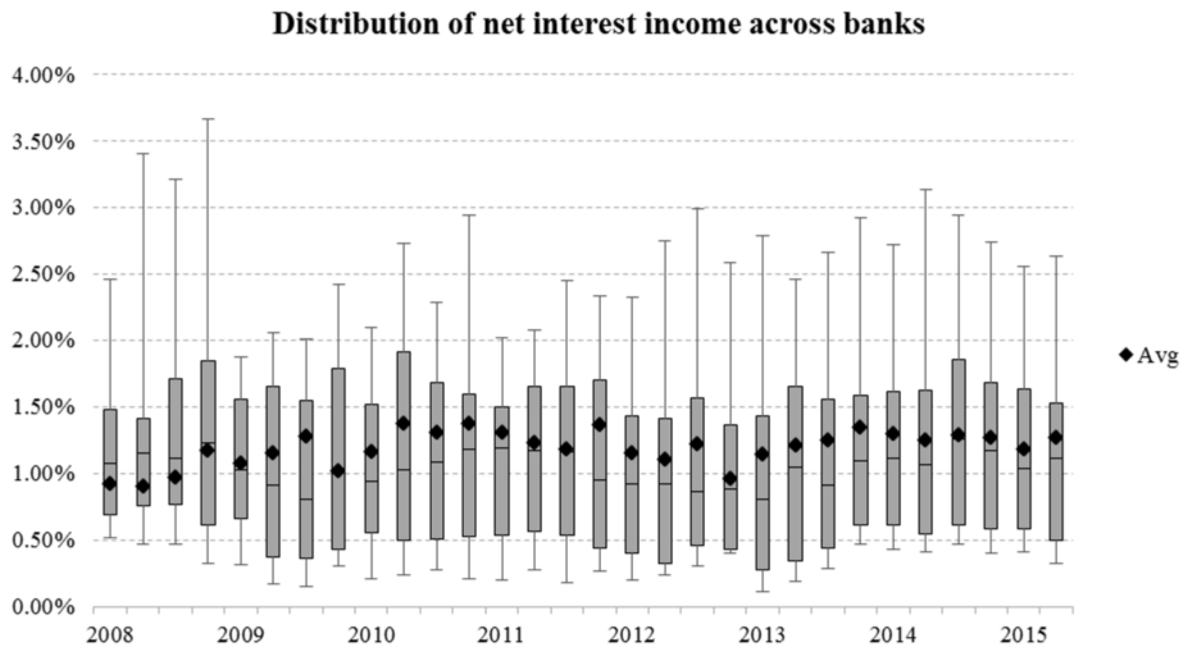
Figure 2



Source: De Nederlandsche Bank, Deutsche Bundesbank

figure 3 is a box-and-whisker plot of net interest income divided by total assets, depicting first, second (medians) and third quartiles as boxes and first and ninth deciles as error bars across banks for each quarter. The average depicted in the figure is the weighted average. The figure shows that there is quite a lot of variation in the net interest margins among banks. Net interest margins vary from as low as a few tenths of a percent to over three percent. The distribution of the net interest margins seems to have been quite stable, though. The unweighted average net interest margin fluctuates little around a full period average of 1.21%. If the period is divided into two equal segments of 15 quarters from the first quarter of 2008 to the third quarter of 2011 and from the fourth quarter of 2011 to the second quarter of 2015, the p-value of a two-sided T-test for inequality of the (unweighted) average interest rate margin in both periods comes to 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. These tests refute the hypothesis that the location or the dispersion of the distributions changed significantly over time.

Figure 3



Source: De Nederlandsche Bank

2.3. Interest rate risk positions

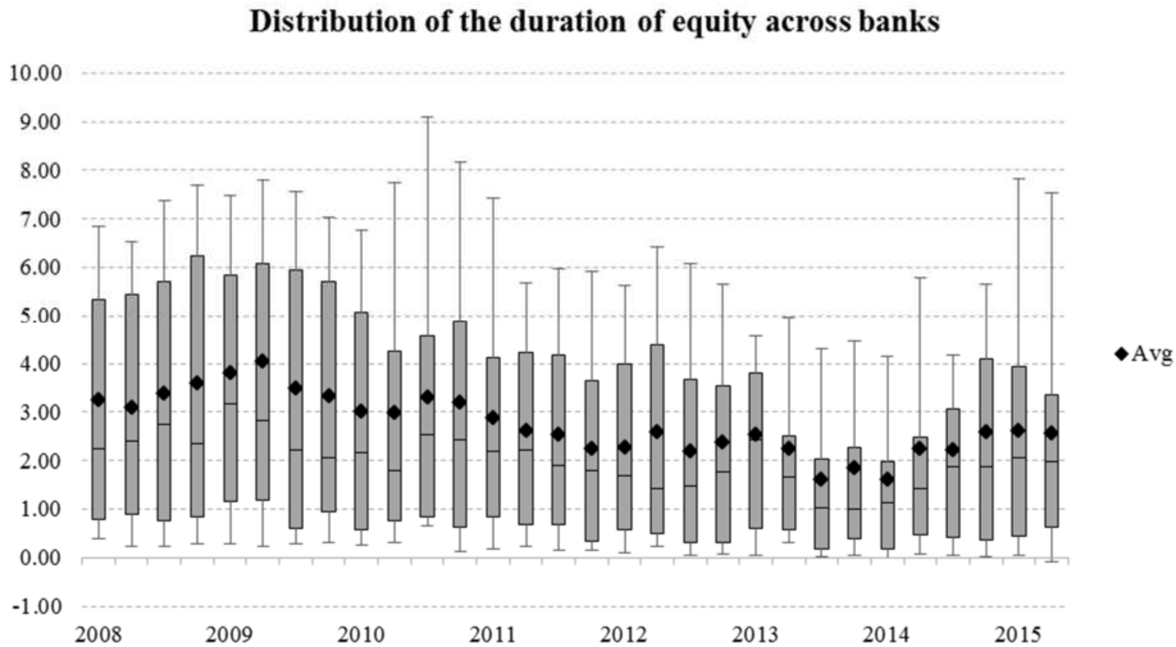
The measure of interest rate risk reported by the banks which I use throughout the rest of my analysis is the basis point value, usually abbreviated as PV01. PV01 is the change in the economic value of equity as a result of a change in the interest rate (*dr*) by one hundredth of a percent (0.01%).

$$PV01 = D_E \cdot E \cdot 0.0001 \qquad (2)$$

Using equation (2) I derive the duration of equity by multiplying the reported PV01 by 10,000 and dividing by the economic value of equity, which is also reported by the banks[3]. Figure 4 presents the distributions per quarter of the resulting duration of equity for the banks in the sample over the period under investigation. The average depicted is again the weighted average.

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 inequality of banks' average duration cannot be rejected. My estimations show that average duration has declined from 3.22 in the first period to 2.25 in the second period (p-value of the T-test for the difference of 0.000).

Figure 4



Source: De Nederlandsche Bank

The size of the durations of equity as reported by the banks after the effects of hedging, although positive, seem relatively small, amounting to an average difference between the durations of assets and liabilities of just two to three months[4]. This suggests that banks were active in maturity transformation, borrowing short and lending long, but only to a fairly limited degree. The variation in the durations of equity suggests that there is quite some heterogeneity among banks. There is also substantial variation

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

[4] A T-test on the average duration gap for two periods of 15 quarters shows they declined from 0.26 to 0.18 (p-value of the T-test of 0.000) measured in years.

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. Banks also do not appear to treat their interest rate risk position as a binary one, alternating between a position which completely eliminates interest rate risk and one which maximises it just below the level where a bank would be identified as an outlier under supervisory regulations.

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 reported to have hedged any kind of asset or liability in either the banking or the trading 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 the derivative non-users deviate significantly from those of the derivative users, 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 this 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, commercial margins and income from equity in order to assess the contribution of interest rate risk to net interest income using a method developed by Memmel (2008, 2011). The analysis is based on data from the same 42 banks reporting on interest rate risk using data from consolidated supervisory reporting as before.

In order to decompose net interest income, a bank's balance sheets 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 has a number of computational advantages. To begin with, the duration of a zero bond equals its remaining maturity, which simplifies the calculation of the duration for an individual bond and for the portfolios as a whole. Furthermore, the yield of a zero bond equals the coupon of a fixed rate bond valued at par with an equal duration/maturity of the zero bond. 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 gaps as derived from the PV01 measures reported in the quarterly interest rate risk reports. Net interest income (*NII*) is defined as before. 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:

$$NII_i = (r_i^a + m_i^a)BA_i - (r_i^l + m_i^l)BL_i \tag{3}$$

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. All interest rates and margins can be regarded as averages across the individual assets and liabilities. r_i^a and r_i^l are only dependent on the maturity structure of the assets and liabilities of bank i, respectively, so that their difference represents the pure 'profits' from maturity transformation. A bank's banking book is represented by the following identity:

$$BA_i = BL_i + E_i \tag{4}$$

where *E* represents the economic value equity of bank i's banking book. After rearranging equation (3) using equation (4), I arrive at the following expression for net interest income:

$$NII_i = \left[\left(r_i^a - r_i^l\right) \cdot BA_i\right] + \left[\left(m_i^a - m_i^l\right) \cdot BA_i + m_i^l \cdot E_i\right] + \left[r_i^l \cdot E_i\right] \tag{5}$$

This equation states that the total net interest margin equals the sum of interest income from maturity transformation (the first term in square brackets) plus net (commercial) margins (the second term in square brackets) and interest income on the part of the assets financed by equity (the final term in square brackets). *E* does not correspond to the actual accounting measure of equity but is derived as the residual between the economic values of the interest bearing assets and liabilities in the banking book. I calculate the first and third 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. In order to do this, I start with the well-known formula for the duration of equity (see the appendix for its derivation):

$$D_E = \frac{BA}{E} \cdot \left[D_{BA} - \left(\frac{BL}{BA}\right) \cdot D_{BL}\right] \tag{6}$$

The duration gap, the term in brackets, unfortunately only indicates the difference between the durations of the assets and liabilities, not the exact durations. Without information on the durations of the assets and liabilities 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 equation (6) for D_{BA}:

$$D_{BA} = \left(\frac{E}{BA} \cdot D_E\right) + \left(\frac{BL}{BA} \cdot D_{BL}\right) \quad (7)$$

By fixing the duration of the liabilities (D_{BL}) 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 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 fairly 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 from equation (5). There are many strategies to construct a portfolio of bonds with a certain portfolio duration, denoted here as D_P. The simplest way to construct a portfolio with a certain duration, is to assume a uniformly constructed portfolio over remaining maturities m so that the portfolio duration is just over half that of the original maturity of an individual zero bond. To see this, note that the average duration $\overline{D_P}$ (in years) of a portfolio constructed from uniform investments in zero bonds with remaining maturities m ranging from 1 to M months (where 1/M is the discrete uniform probability density function and the amount invested in each bond) equals:

$$\overline{D_P} = \frac{1}{12} \cdot \frac{(M+1)}{2} \quad (8)$$

A bond portfolio with $\overline{D_P}$ = 1 year, for instance, can then be constructed from equal monthly investments over a 23 month period in zero bonds with an original maturity of 23 months. The interest income of such a portfolio would then be simulated as the average zero yield for a maturity of 23

[5] Using the accounting-based method developed by American supervisors, see Sierra and Yeager (2004), I estimate the duration of the 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 comes to 1.74 for the end of 2014. The range from 1.00 to 2.50 spans this number appropriately.

months over the preceding 23 months. A bank's interest income at risk free rates is thus simulated as a trailing average of past interest rates.

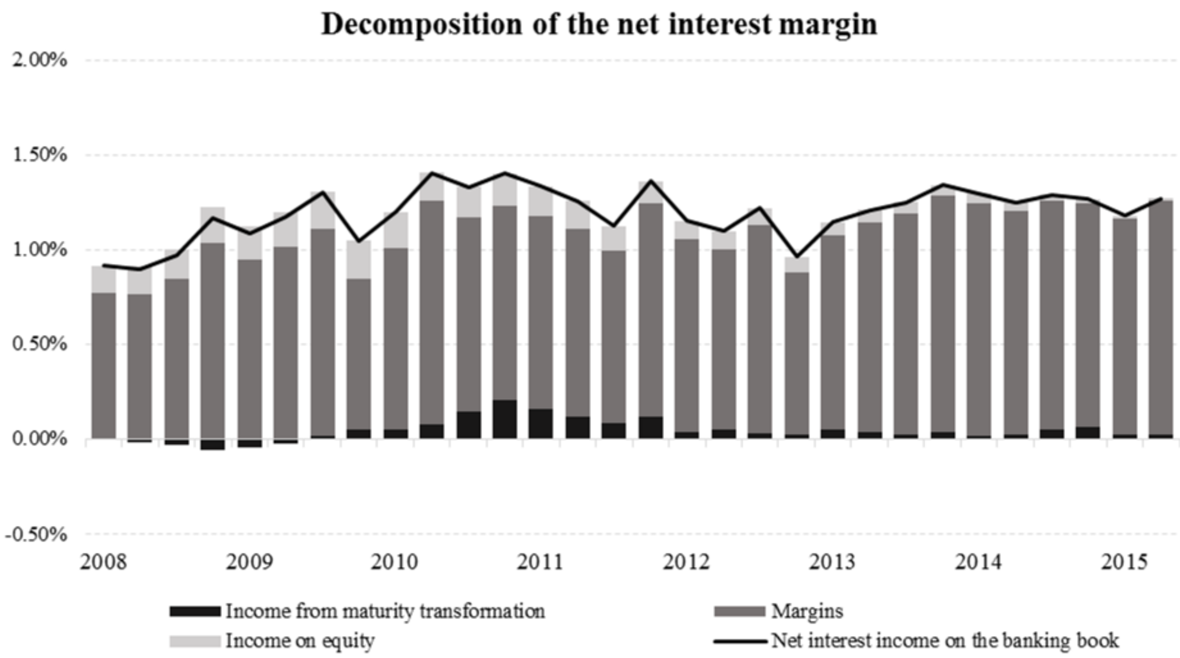
Table 1: Decomposition of the net interest margin using three possible values for D_{BL} (basis points)

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

Table 1 presents the decomposition of the net interest margin (net interest income normalised using total assets), 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 greatest 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 peakes 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 a consequence of the flattening of the yield curve. 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 period. It only depends on the level of interest rates, which for all relevant maturities, declines consistently. The net interest margin falls in 2012 but recovers thereafter, apparently from an increase in commercial margins.

Figure 5



Source: own calculations based on data from De Nederlandsche Bank

In summary, this section and the previous one provided answers to the first two questions posed in the introduction. Banks do engage in maturity transformation, but only to a fairly limited degree. The average durations of equity, after hedging, correspond to differences in the duration of assets and liabilities of around two to three months. There is quite some variation in interest rate risk positions, both between banks and over time. Because interest rate risk positions are relatively small, net interest income is not greatly affected by changes in the level of interest rates or the steepness and shape of the yield curve.

4. Theories on the management of interest rate risk

Allen and Santomero (1997) point to the fact that the 1970s and 1980s saw the emergence of new types of financial instruments, such as asset backed securities, swaps and financial futures, which were predominantly used by financial institutions for risk management purposes. This raises the question of why financial intermediaries engage in risk management as investors in banks' shares and borrowers have access to a plethora of instruments to transform risks in order to align them to their own preferences. As Pagano (2001) points out, it should be a direct consequence of the CAPM-model and Modigliani and Miller's proposition I that: "we should *not* expect the value of a firm to be increased through the use of hedging activities. Corporate hedging is irrelevant because individual investors (depending on their preferences) can costlessly replicate any hedging decision made by the firm" (p. 281). In reality, facts point to exactly the opposite. As Gorton and Rosen (1995) have documented, the use of interest rate swaps – one of the most common instruments to hedge interest rate risk – by US banks grew by a factor of nearly 16 as measured by notional value in the 1980s and 1990s to a multiple of total assets. Statistics from the Dutch central bank on the use of interest rate swaps by Dutch banks collected since 1998 give a similar picture[6]. Allen and Santomero (1997) present four explanations why financial intermediaries engage in risk management: (1) managerial self-interest (also known as the agency problem), (2) the non-linearity of taxes, (3) the cost of financial distress (e.g. bankruptcy costs) and (4) the existence of capital market imperfections. For banks, the cost of financial distress is probably the most important. The potential losses to depositors and the existence of substantial externalities in the form of (systemic) banking crises, have led to the institutionalisation of risk management at banks through prudential supervision. In the Basel framework and its European version, credit risk, market risk and operational risk are all subject to strict capital requirements. There are a few types of risk that are not as strictly regulated through supervisory measures, interest rate risk in the banking book being one of them. For this type of risk, banks retain a large degree of freedom as to whether or not they hedge this risk.

Assuming the explanations for financial intermediaries to engage in risk management are sufficient, the next question presents itself: to what extent are risks hedged and why? Do financial intermediaries hedge completely – turning them into brokers, in the terminology of Niehans (1978) – or is there room left to benefit from profitable opportunities? Although the work of Diamond (1984) is primarily regarded as an important example of the theories explaining financial intermediation through the efficiency of delegated monitoring of debt contracts under moral hazard, his model also provides suggestions as to which risks a bank should hedge. He argues that because systematic risks, such as interest rate risk, are publicly observable, there is no incentive for the bank to monitor them. Since the

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[6] Table 5.10: Over-the-counter derivatives contracts at Dutch banks; Half-yearly, http://www.dnb.nl/en/statistics/statistics-dnb/financial-institutions/banks/consolidated-banking-statistics-supervisory/index.jsp.

monitoring of systematic risks does not provide the intermediary any benefits, it should be hedged completely either in the futures markets or by transferring the risk to creditors and/or debtors. Froot and Stein (1998) address this question in a model of a shareholder value-maximizing bank that deals with residual idiosyncratic (not transferable) risk. They endogenise the concern with risk management by assuming that a bank faces costs in raising new equity capital when it encounters losses, but that excess capital causes a deadweight loss because of taxes. Under these assumptions, a risk averse bank management will choose to fully hedge all (transferable) risks. Since the existence of a multitude of interest rate derivatives implies that interest rate risk is fully transferable, the conclusion would be that banks should hedge interest rate risk completely. Bauer and Ryser (2004) extend the framework of Froot and Stein and conclude that the full hedging strategy for transferable risks is not always optimal for maximising shareholder value when a bank is prone to bank runs and shares confer limited liability. In this environment, a bank may gamble for resurrection ('bet the house') even if this leads to a worse outcome for the liquidation value if the bank does fail in the end. This is caused by the fact that shareholder value disappears but cannot turn negative when the value of assets decline below the value of liabilities. Shareholders in this situation have nothing left to lose, so to speak. This suggests banks could become risk seeking instead of risk averse at low levels of solvability. The hedging decision in the framework of Bauer and Ryser is, however, still a question of 'all or nothing'.

Most theoretical studies that focus specifically on interest rate risk frame the problem as the choice of the size of the gap, usually defined as the difference between short-term assets and short-term liabilities (the gap between long-term assets and long-term liabilities being the mirror image). Some authors state the problem in terms of the decision to what extent interest rate risk is hedged, which is the dual formulation of the same problem. These studies can also be classified by the objective function postulated: stabilisation of the economic value of equity (the difference between the fair values of assets and liabilities) or stabilisation of net interest income (known in the industry as the 'earnings-at-risk' approach). In one of the first articles in this field, Grove (1974) employs a classic von Neumann-Morgenstern utility of final wealth optimisation framework to analyse the amount of risk, in terms of the difference between the duration of assets and liabilities, 'investors' would be willing to take. (The term 'investors' should be understood here as any financial organisation, be it a bank, an insurance company or any other financial intermediary.) By framing the model as an optimisation of final wealth, Grove's model can be seen as taking the economic value of equity approach. Grove's model indicates that investors' willingness to take on interest rate risk depends positively on the expected change in interest rates and negatively on its volatility. Put differently, Grove's model suggests that it is only rational to hedge when interest rates are not expected to change. Grove's model also indicates that, under decreasing absolute risk aversion, the size of the investors' duration bet increases with initial wealth. In banking terms: the larger a banks' capital, the larger its interest rate risk position in terms of the difference between the duration of assets and liabilities.

Prisman and Tian (1993) extend Grove's model, which only allows for parallel shifts in the yield curve, by adding other changes to the shape of the yield curve such as steepness and curvature. They conclude that it is optimal to immunize for a risk averse investor even when interest rates are expected to change, namely when they are expected to change by the same amount.

Niehans and Hewson (1976) contribute a simple but elegant two period model to the literature that has gone mostly unnoticed due to the fact that it was tucked away in an appendix to their investigation of the Eurodollar market. Since the Eurodollar market was (and still is) a niche activity of European banks, they assume matching assets and liabilities divided between short-term (maturity of one period) and long-term (maturity of two periods). They abstract from initial capital as a source of funding and assume profits and losses are absorbed by the bank's regular capital. The bank optimises earnings by hedging the only uncertain variable in the model, the short-term interest rate against which it can both borrow (lend) the shortfall (surplus) of funds in the second period. The model has the intuitive solution under risk neutrality that the maturity gap is irrelevant when forward rates are unbiased predictors of future rates. In other words, when the pure expectations theory of the term structure holds, no systematic profits can be made from maturity transformation. Under risk aversion, banks engage in positive maturity transformation (borrow short and lend long) when long rates are persistently above the compounded short rates and negative maturity transformation when they are below the compounded short rates. The volatility of the interest rate has a negative influence on maturity transformation, in line with Grove's model. In other words, maturity transformation depends on the existence of a significant and relatively certain (positive or negative) risk premium in the long interest rate in order to overcome risk aversion.

Santomero (1983) frames the interest rate risk position taken by banks as a standard Markowitz (1952) portfolio selection model. He concludes that a bank's choice of optimal portfolio is not likely to correspond to a completely immunised strategy. In such portfolio models, investment positions taken are functions of the returns and (co)variances of the assets. A corner solution where interest rate risk equals precisely zero is then not very likely. Since he does not model interest rates changes, it cannot provide any guidance on the reaction of banks in response to movements of the yield curve, which renders his model not very useful for the analysis at hand. Koppenhaver (1985) raises a similar critique of portfolio models. The author derives optimal forward positions for hedging both the price and quantity (funding) risks in the money markets to balance an uncertain surplus or deficit in deposits under different assumptions about the degree of risk aversion of the bank's management. The bank optimises a utility function dependent only on net interest income, which puts it firmly in the earnings-at-risk camp. The optimal positions are shown to depend on expected interest rate changes and the correlations with changes in deposit rates and money market rates as well as the change in deposit volume. In simulations (due to a lack of banking data), a comparison of the optimal positions with portfolio-choice (minimum variance of profits) and fully-hedged strategies, indicates that a risk-averse bank management would not even hedge as much as necessary to minimise the variance of profits in order to benefit from opportunities to raise them. Morgan and Smith (1987) and Morgan et al. (1988), extend Koppenhaver's model even further by incorporating a loan provision process through commitments (lines of credit) in which both the take-up and the interest rate is uncertain. Their most important conclusion is that the position of minimum risk is no longer attained by maintaining a zero maturity gap.

In all, the theories discussed here suggest that the interest rate risk position taken by banks does not depend on the level of interest rates but depends positively on the size of the interest rate premium in the long interest rate and negatively on the variability of this premium if such a premium exists.

5. Panel model estimation of risk taking behaviour

5.1. 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 to test the theories summarised in section 4. It is assumed that a financial institution is able to adjust the maturity structures of its assets and liabilities without any limitations 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. Spremann et al. (2009) refer to these as commercial balance sheet management and financial balance sheet management, respectively. It should be pointed out that within this framework, the choice to hedge is not a binary decision (yes versus no) but a continuous one. Banks might hedge their interest rate risk completely (which corresponds to a duration of equity equal to zero), not at all or somewhere in between. I also assume that 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. Banks' interest rate positions are measured by the duration of equity, assuming that this is the primary decision variable in a bank's asset and liability management with regards to interest rate risk in the banking book. 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 simultaneously.

I assume that a bank's target duration of equity depends on bank-specific factors and (macro-economic) interest rate variables. The relationship can be summarised by the following equation:

$$y_{i,t}^{*} = \alpha_i + \beta \boldsymbol{x}_{i,t} + \gamma \boldsymbol{z}_t \qquad (9)$$

where the dependent variable y^* is the target 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. 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 a bank makes adjustments according to the following formula:

$$\left(y_{i,t} - y_{i,t-1}\right) = \theta\left(y^*_{i,t} - y_{i,t-1}\right) + \varepsilon_{i,t} \tag{10}$$

where $\varepsilon_{i,t}$ is an idiosyncratic error term. Substituting equation (10) into (9) produces:

$$y_{i,t} = (1-\theta)y_{i,t-1} + \theta\alpha_i + \theta\beta\boldsymbol{x}_{i,t} + \theta\gamma\boldsymbol{z}_t + \varepsilon_{i,t} \tag{11}$$

Equation (11) 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 was dropped since it had 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. I therefore estimate the model using both standard fixed effects and LSDVC methods and compare their outcomes.

Purnanandam (2007) estimates the probability that derivatives are used 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. Out of the 41 banks, 32 were continuous users of derivatives and 9 were not. 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.

The explanatory variables are based on the theories summarised in section 4 and other literature on bank risk taking. 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. 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 and therefore n-m=m), m years ago and the current spot rate for maturity m. In mathematical notation:

$$f_{m,t-m} = \left[\frac{\left(1 + r_{n,t-m}\right)^{n}}{\left(1 + r_{m,t-m}\right)^{m}}\right]^{\frac{1}{n-m}} = \frac{\left(1 + r_{n,t-m}\right)^{\frac{n}{m}}}{\left(1 + r_{m,t-m}\right)} = \frac{\left(1 + r_{n,t-m}\right)^{2}}{\left(1 + r_{m,t-m}\right)}$$

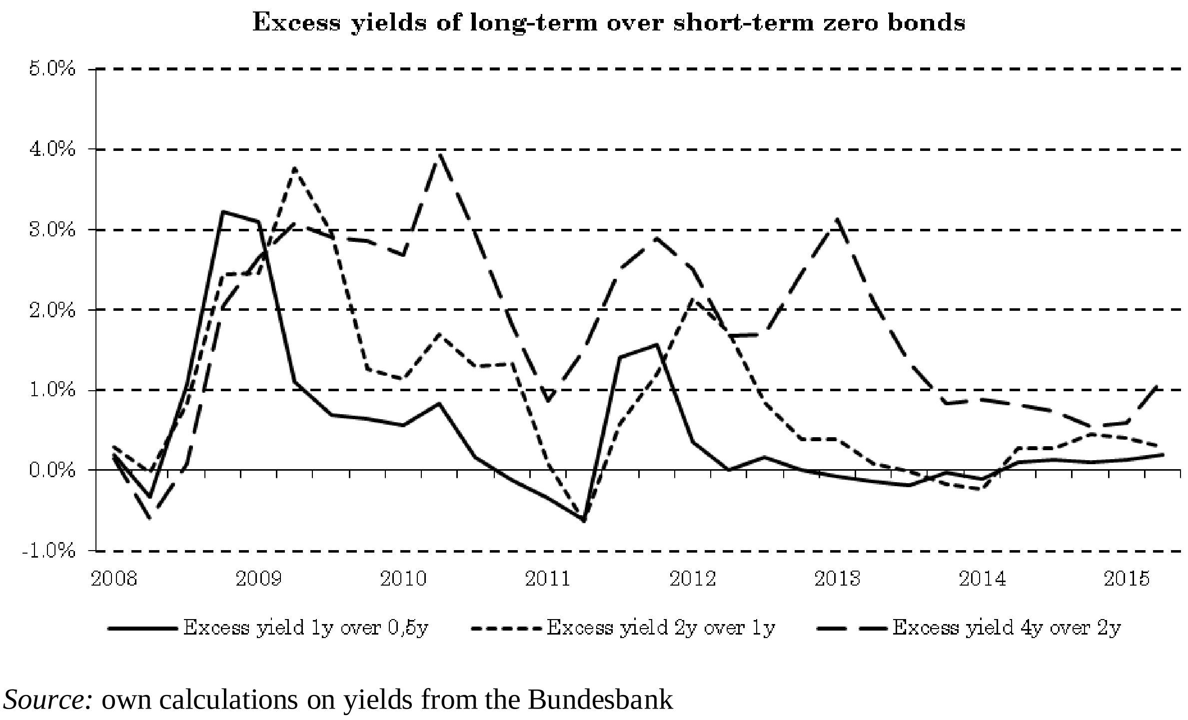
(12)

$$R_{n,t} = \frac{\left(1 + f_{m,t-m}\right)}{\left(1 + r_{m,t}\right)} \approx f_{m,t-m} - r_{m,t}$$

where subscripts indicate the maturity and the point in time, respectively. f stands for the forward rate, r for the spot rate and R for the excess yield. If short spot rates are consistently lower than historical forward rates, long-term investments confer a premium or excess yield over short-term investments. Another interpretation of this excess yield is the additional return from investing in a bond of maturity n over two successive investments (rolling-over) in bonds of maturity m. Figure 6 presents the time-series for the excess yields 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 yields, since this is predicted by most models discussed in section 4. The volatilities are calculated as the annualised daily standard deviations for each of the quarters.

The size of a bank is expected to have a positive influence on the interest rate risk position. In line with the models discussed in section 4, I expect absolute risk aversion to decrease as a bank becomes larger. Also, under decreasing absolute risk aversion, risk taking is increasing in net worth. So the bigger total assets, the higher risk taking. Another reason often cited for a positive influence of size on risk-taking is the fact that large banks have more diversified risks (e.g. Niehans, 1978, p. 181-192). Relevant also is, of course, the question whether the size of a bank leads it to believe it is 'too-big-to-fail', leading to 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 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 hedging 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.

Figure 6



Source: own calculations on yields from the Bundesbank

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 percentage 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 power of the individual bank in loan and deposit markets measured by market share 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 interest rate and a shorter term interest rate, end-of-quarter annualised percentages	+
Realised excess yield	EXYLDxY	Excess holding yield of a n year zero bond over a ½n year zero bond (see equation 12) end-of-quarter annualised percentages	+
Volatility of the realised excess yield	VOLEYxY	Annualised daily volatility of the realised excess yield per quarter (see equation 12)	-

Return on equity, a measure of a 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 the government-assistance dummy, indicating whether the bank was receiving temporary assistance during the credit crisis (banks permanently government owned were assigned a dummy equal to zero), is expected to be positive. 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 should lead to lower correlation between loan or deposit demand and interest rates, which enhances the stability of the balance sheet structure. They might also proxy for the 'too-big-to-fail' aspect if market power also confers political power. The definitions of the variables and the expected signs of the coefficients are summarised in table 2.

5.2. 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 each 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 5.1 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. The results, presented in appendix 2 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 yield measure and its volatility, which produce more encouraging results, presented in tables 4 (standard fixed effects) and 5 (bias corrected LSDVC estimate). The excess 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. With respect to excess yields, 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 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. 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 derivatives non-users sub-sample since none of the banks in this group received assistance) indicates that government help 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-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. Somewhat surprisingly, the size of a bank measured by total assets is not significant in any of the models.

The coefficients on the solvability ratio and its square does 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.

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)				
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)				
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
Derivative non-users (no. obs. = 183)				
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

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)	
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)	
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. 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.

5.3. Comparison with earlier research

In this section, I compare my estimation results with those of other studies that have investigated interest rate risk and hedging behaviour of banks[7].

The earliest 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) focusses mainly on the influence of the size of a bank on interest rate risk taking. Their results suggest that smaller banks have larger interest rate risk positions since they are less able to hedge their positions. I do not find this result, which 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.

Purnanandam (2007) uses a two-stage simultaneous equations model to investigate hedging behaviour among American banks. He estimates the probability of default and the use of derivatives in the first stage and enters the predicted likelihoods as explanatory variables in a second stage fixed effects model for the size of the on-balance-sheet one-year maturity gap. The gap calculated by Purnanandam does not take into account the effect of hedging through derivatives and therefore does not represent the actual interest rate risk position taken. Of the interest rate variables level, term spread and volatility, only the level is significant in the gap estimation. In the results for the use of derivatives though, the term spread is significant and negative. In other words, the gap is hedged less extensively as the term spread increases. Among the non-users of derivatives, the level of the interest rate has a negative effect on the gap, suggesting that these banks employ commercial balance sheet management instead of derivatives to manage their gap. The estimations also indicate that size has a positive effect on the gap and the probability of default a negative effect. Purnanandam's results are somewhat comparable to mine, in the sense that banks in both studies take the shape of the yield curve into account when managing interest rate risk. The level of interest rates, however, does not seem to influence Dutch banks' behaviour.

My estimations are very similar to those of Esposito et al.(2015), who use semi-annual data on duration gaps as calculated by 67 banks according to a standardised framework developed by the Bank of Italy based on the Basel rules (see Basel Committee on Banking Supervision, 2004). The Bank of Italy collected the data on interest rate risk positions divided by on-balance and off-balance positions,

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[7] I leave out the numerous studies that have derived measures of banks' interest rate risk from the interest rate sensitivity of banks' stock prices such as mentioned in the introduction. 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 themselves or their hedging behaviour.

which allows the authors to study the commercial and financial balance sheet management separately. Their data show that banks use derivatives both to decrease and increase their duration gaps, which indicates that banks make deliberate choices regarding their interest rate risk positions. The banks' behaviour not only varies by type of bank, but also over time. They estimate a model where the on-balance-sheet gap estimate is used in a 2SLS model to explain the off-balance-sheet gap. They hypothesise that the off-balance-sheet gap should have a negative coefficient, if derivatives are used for hedging and positive if used for enhancing the interest rate risk[8]. Concentrating on their results for the off-balance-sheet gap (the hedging decision), banks hedge more for larger on-balance-sheet gaps. Larger banks hedge more than smaller banks, contrary to my findings. Banks with a larger funding gap are also more risk averse. The coefficients for the slope of the yield curve, non-performing assets and the Tier 1 ratio are insignificant. The authors do not include a measure of interest rate volatility.

6. Conclusions

This investigation addresses three questions: (1) what is the interest rates risk position of Dutch banks and how does it vary over time, (2) how much of operating income and net interest income can be accounted for by income from maturity transformation and (3) which factors influence banks' interest rate risk position?

My results suggest that 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. Income from pure 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. 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 the banks, in contrast to results found in other studies. Lastly, banks that receive government assistance 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.

[8] They do not consider the possibility that the on-balance-sheet positions could result in an interest rate gap which lies below the bank's optimum, given the position and shape of the yield curve, in which case derivatives could be used to increase this position.

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Appendix 1: Derivation of equation (2) – the duration of equity.

To derive the duration of equity, I start with the basic formula for the present value of an asset or liability (P) with known future cash-flows (C_t) at moments 1 to T. It is calculated by summing the future cash-flows discounted using the relevant interest rate (r):

$$P = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} \tag{A.1}$$

To derive the sensitivity of the present value to changes in the interest rate, take the first derivative of P with respect to r. This gives:

$$\frac{dP}{dr} = \sum_{t=1}^{T} \frac{-t \cdot C_t}{(1+r)^{t+1}} = \frac{-1}{(1+r)} \cdot \sum_{t=1}^{T} \frac{t \cdot C_t}{(1+r)^t} \tag{A.2}$$

When we bring dr to the other side of the equation and divide both sides by P, we get the elasticity of the present value with respect to r:

$$\frac{dP}{P} = \frac{-1}{(1+r)} \cdot \left(\frac{\sum_{t=1}^{T} \frac{t \cdot C_t}{(1+r)^t}}{P} \right) dr = \frac{-1}{(1+r)} \cdot D_M dr \tag{A.3}$$

The term in parentheses is called *Macaulay's duration* (D_M). Macaulay's duration divided by the term (1+r) is called the modified duration. Macaulay's duration equals the weighed term to maturity where the weights are the individual cash-flows as a proportion of the total present value. It has the well-known interpretation of indicating the average 'life' of the asset or liability. Equation (A.3) thus states that the change in the present value of an interest bearing asset or liability is approximately negatively proportional to the change in the interest rate with a proportionality constant equal to the modified duration. Another interpretation is that – in terms of interest rate risk – an investment in an asset paying a fixed coupon valued at par with duration D_M is equivalent to the investment in a zero-bond with the same yield to maturity and residual maturity equal to D_M. Another useful property is that duration is (by approximation) additive: the duration of a portfolio of assets (or liabilities) is equal to the weighed duration of its constituent instruments, where the weights are the proportions of the instruments' values in the total value of the portfolio. Taken together the two previous properties of duration suggest that the interest bearing assets and liabilities of a bank can be simulated by a (portfolio of) zero-bonds.

Equations (A.2) and (A.3) are only valid for relatively small changes in the interest rate as the duration represents only the slope of the present value function at a particular value of *r*. This function is actually a convex function which – for larger changes in *r* – necessitates taking into account the second derivative of *P* with respect to *r*. This concept – which is known as *convexity* – is not further explored here to avoid unnecessary complexity.

When a bank's banking book consists solely of interest rate sensitive assets and interest rate sensitive liabilities, its economic value of equity (*E*) represents the difference between the present values of those assets (B*A*) and liabilities (B*L*):

$$E = BA - BL \tag{A.4}$$

The derivative of the economic value of equity with respect to interest rate changes then equals:

$$\frac{dE}{dr} = \frac{dBA}{dr} - \frac{dBL}{dr} \tag{A.5}$$

Inserting the equivalents of equation (A.3) for equity, assets and liabilities and solving for the duration of equity (D_E) gives:

$$\begin{aligned} D_E = \frac{(1+r)}{E} \cdot \left(\frac{BA \cdot D_{BA}}{1+r} - \frac{BL \cdot D_{BL}}{1+r}\right) &= \frac{BA}{E} \cdot D_{BA} - \frac{BL}{E} \cdot D_{BL} \\ &= \frac{BA}{E} \cdot \left[D_{BA} - \left(\frac{BL}{BA}\right) \cdot D_{BL}\right] \end{aligned} \tag{A.6}$$

The term between square brackets is called the *duration gap*.

Appendix 2: 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)	
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)	
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. 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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