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Banks' interest rate risk and search for yield: a theoretical rationale and some empirical evidence

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Non-technical summary

Research Question

Banks with deteriorating earnings are said to be prone to taking risks. One kind of risk that banks can well control is the interest rate risk, which arises from different fixed interest periods on the asset and liability side of a bank's balance sheet. In the present paper, we theoretically and empirically investigate whether banks in a stressed earnings situation behave differently to the other banks concerning their exposure to interest rate risk. This issue is relevant in the context of the low interest rate environment which can lead to a massive reduction in banks' earnings.

Contribution

Normally, the demand for a risky asset increases if its expected return goes up. In our theoretical model, we show that the opposite outcome is possible as well, meaning that the risky asset becomes the more coveted the lower its expected return. In the paper, we interpret the risky asset as the exposure to interest rate risk. In our empirical study for the banks in Germany, we investigate the relationship between a bank's exposure to interest rate risk, the bank's earning situation and the expected returns from bearing interest rate risk for the period 2005-2014.

Results

We find a pronounced co-movement between a banks' exposure to interest rate risk and the corresponding expected return, i.e. a bank will increase the difference between the repricing periods on its assets and liabilities if the expected return from bearing interest rate risk increases. This relationship becomes weaker if a bank's earning situation deteriorates. If the earnings fall below a certain threshold, the relationship even changes its sign: We observe, depending on the sample specification and estimation methodology, in about 0.6 to 8.3 per cent of the events in our sample that a bank increases its exposure to interest rate risk even though the expected returns from bearing this risk are falling.

Nichttechnische Zusammenfassung

Fragestellung

Banken, deren Ertragslage sich verschlechtert, gelten als anfällig dafür, erhöhte Risiken einzugehen. Ein Risiko, das sich aus Sicht der Bank gut steuern lässt, ist das Zinsänderungsrisiko, das sich aus den unterschiedlichen Zinsbindungsfristen auf der Aktiv- und Passivseite der Bankbilanz ergibt. Im vorliegenden Papier wird theoretisch und empirisch untersucht, ob Banken mit schlechter Ertragslage sich anders als die übrigen Banken verhalten, was das Eingehen von Zinsänderungsrisiken anbelangt. Diese Fragestellung ist im Hinblick auf das Niedrigzinsumfeld relevant, das zu einer Verschlechterung der Ertragslage der Banken führen kann.

Beitrag

Normalerweise steigt die Nachfrage nach einem riskanten Anlageobjekt, wenn dessen erwartete Rendite ansteigt. In unserem theoretischen Modell zeigen wir, dass auch das gegenteilige Verhalten vorkommen kann, dass also das riskante Anlageobjekt umso begehrter wird, je geringer seine erwartete Rendite ist. In dem Papier setzen wir das riskante Anlageobjekt mit dem Eingehen von Zinsänderungsrisiken gleich. In einer empirischen Studie für die Banken in Deutschland, untersuchen wir den Zusammenhang zwischen dem Zinsänderungsrisiko einer Bank, ihrer Ertragslage und den erwarteten Erträgen aus dem Zinsänderungsrisiko für den Zeitraum 2005 bis 2014.

Ergebnisse

Wir finden einen stark gleichlaufenden Zusammenhang zwischen dem Eingehen von Zinsänderungsrisiken und den damit verbundenen erwarteten Erträgen, d.h. eine Bank wird die Unterschiede der Zinsbindungsfristen auf ihrer Aktiv- und Passivseite vergrößern, wenn die erwarteten Erträge aus dem Eingehen von Zinsänderungsrisiken ansteigen. Darüber hinaus zeigt sich, dass dieser Zusammenhang schwächer wird, wenn sich die Ertragslage der Bank verschlechtert. Fallen die Erträge unter eine bestimmte Schwelle, dann dreht sich der Zusammenhang sogar um: Wir beobachten, abhängig von der Spezifikation der Stichprobe und dem Schätzmodell, in ungefähr 0,6 bis 8,3 Prozent der Fälle in unserer Stichprobe, dass eine Bank vermehrt Zinsänderungsrisiken eingeht, obwohl die erwarten Erträge aus der Übernahme dieses Risikos fallen.

Bundesbank Discussion Paper No 22/2016

Banks' Interest Rate Risk and Search for Yield: A Theoretical Rationale and Some Empirical Evidence*

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Abstract

We investigate German banks' exposure to interest rate risk. In finance, higher demand for a risky asset is typically associated with higher expected return. However, employing a utility function which implies both risk-averse and risk-seeking behavior depending on the level of profits, we show that this relationship may get weaker and even change its sign at low profit levels. For the period 2005-2014, we find not only the common positive relationship of higher expected returns and rising interest rate exposure but also that this relationship does become weaker with falling operative income, its sign eventually changing.

Keywords: Banks' risk taking, exposure to interest rate risk, low interest rate environment

JEL classification: G11, G21

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1 Introduction

Banks bear interest rate risk. This risk stems from traditional banking business activity, in which banks hand out long-term loans and collect short-term deposits. By making use of hedging instruments, banks can decide how much of this risk they want to retain. Many banks do not hedge their interest rate risk completely in practice. In Germany, for example, interest rate risk is one of the most material risks taken by small and medium-sized banks. The interest rate risk is important from an aggregate perspective too, since, due to its high correlation in the cross section of banks, it may have a significant impact on financial stability.[1]

In finance, one typically observes a positive relationship between the demand for a risky asset and its expected return. Hence, banks' interest rate risk is generally expected to decrease if the expected return from bearing the risk falls. Recently, however, a number of German banks seem to have taken more interest rate risk despite falling expected return. In this paper, we first show the theoretical possibility that a falling expected return may induce the taking of a higher interest rate risk. We then estimate empirically the critical level of bank profitability below which a negative relationship prevails between the taking of interest rate risk and its expected return. Put differently, in the current paper we present a theoretical rationale and some empirical evidence for a search for yield in the form of higher risk-taking due to lower profitability.

In economics, it is well known that there exist situations where increasing prices lead to an increase in the demand for the respective good. Counter-intuitive though this may seem, this is not merely a theoretical possibility. There is empirical evidence for the existence of such a phenomenon, for instance in labor economics: An increase in hourly wages (which corresponds to an increase in the opportunity cost and thus the price of leisure) may lead to a decrease in the labor supply and, hence, to an increase in the demand for leisure (e.g. Camerer, Babcock, Loewenstein, and Thaler (1997)). More recently, Domanski, Shin, and Sushko (2015) find that the demand curve of German insurance companies for long-term bonds is upward-sloping. In our paper, we also deal with situations where an increase in the price of a good (here: a decline in the expected return of the risky asset) may lead to an increase in the demand for this good. Although the ensuing empirical effects are similar to the foregoing labor market example, a different mechanism is at work in our case: In the labor market example, the income effect dominates the substitution effect. By contrast, in our paper, the effect of a change in expected profits on risk-taking is due to the preference structure: Whereas risk is seen as negative and the decision-makers act in a risk-averse manner in normal times, in times with very low profits, risk becomes something which is desirable and the decision-makers seek risk.

As mentioned above, interest rate risk can easily be hedged and its amount is hence, to a large extent, within the discretion of bank managers. Therefore, the observable level of interest rate risk is a rather accurate reflection of bank managers' underlying incentives. In this paper, we work with a measure for a bank's exposure to interest rate risk which is closely linked to the bank's Basel interest rate coefficient, which is the supervisors' yardstick for the interest rate risk in the banking book. Covering both on- and off-balance sheet items, this coefficient is a rather comprehensive standardized measure of

[1] An extensive discussion of interest rate risk in the German banking sector can be found in Deutsche Bundesbank (2014).

interest rate risk concerning banks' traditional business.

The low interest rate environment is a crucial motivation for our investigation. It is consistently understood as driving down banks' profit margin and, if it persists, as further reducing banks' income in the future.[2] Accordingly, due to low profits, an increasing share of bank managers can be expected to act as if they were risk-prone. In other words, the share of banks which increase their interest rate risk exposure even though the term structure flattens can be expected to rise if the low interest rate environment persists. Since the interest rate risk applies to a large number of banks simultaneously, financial stability risks can ensue, among others, also through this channel in the low interest rate environment. This is a major topical takeaway from our investigation.

We look at German banks' interest rate risk for the period 2005-2014 and find the usual direct positive relationship between expected returns from term transformation and exposure to the corresponding interest rate risk. In addition, we show that this relationship becomes weaker if a bank's operative income goes down. Eventually, if the operative income falls below a certain threshold, the relationship changes its sign, meaning that the bank starts to increase its exposure to interest rate risk even though the expected returns from term transformation decrease. We find that, depending on the sample specification and estimation methodology, about 0.6 to 8.3 per cent of the observations are below this threshold. This indicates that the prevalence of the search for yield in the sense described above has been limited until now. However, this may change if the current low interest rate environment persists.

The paper is structured as follows: In Section 2, we provide a review of the literature concerning banks' risk taking and search for yield, especially in a low interest rate environment. In Section 3, we present an illustrative theoretical model and its empirical implications. Section 4 describes the data and in Section 5 we discuss the empirical results. Section 6 concludes.

2 Literature

Our paper is the first to establish a general link between lower expected return from interest rate risk and increased taking of this risk by banks. We show that there is a threshold level of profitability below which banks search for yield, i.e. below that profitability level banks increase their exposure to interest rate risk although the term structure becomes flatter and thus earning opportunities become smaller.

Research on how interest rates affect banks' risk-taking has gained momentum, not least due to the low interest environment, in recent years. Most recent contributions dealing with the subject are framed as investigations of the risk-taking channel of monetary policy as advanced by, e.g., Borio and Zhu (2012). Theoretical research on how a low interest rate environment affects banks' risk-taking addresses reactions to both lower short-term rates and lower long-term rates as well as a combination of both. Depending on the differing reactions of short-term and long-term rates to the low-interest rate environment, the yield curve may become steeper or flatter, the former (latter) generally

[2] The European Central Bank (2015) expects that, in the current low interest rate environment, the net interest margins of banks are going to remain under pressure. See also Borio, Gambacorty, and Hofmann (2015) and Busch and Memmel (2015) for empirical evidence on decreased bank profitability as a result of low interest rates and a flat yield curve.

leading to a higher (lower) profitability of the lending business due to term transformation. Thus, various possible incentives for risk-taking are conceivable in a low interest environment. Diamond and Rajan (2009) and Acharya and Naqvi (2012), for example, model how lower short-term rates, or open market operations bringing them about, lead to higher liquidity in the form of deposits and thus to a lower probability of punishment in the form of a bank run or a penalty for the manager. Adrian and Shin (2010) explain how an increase in asset valuesfollowing from lower long-term rates leads to a larger risk-bearing capacity of financial institutions, provided that the balance sheet is marked to market and there is a binding value-at-risk constraint. Adrian and Shin (2011) point out that increased profitability of classic lending business resulting from a steeper yield curve leads to a larger risk-bearing capacity. Fishburn and Porter (1976), who provide the classic discussion of the general link between risk and expected return, point to a what can be called "risk-return slack", i.e. a lower level of risk associated with every given level of expected return. Banks may be inclined to increase their risk due to a risk-return slack. In contrast, Rajan (2005) points out how a decreased profitability of classic lending business, as it results from a flatter yield curve, induces what he calls a search for yield, whereby higher risks are taken in order to counteract decreasing profits.[3]

Note that, reversing the arguments presented in the foregoing paragraph, a low interest environment with a steeper or flatter yield curve can also induce lower risk-taking. How a low interest environment effects risk-taking hence depends on which of its opposite effects on risk-taking is dominant. Dell'Ariccia, Laeven, and Marquez (2014) develop, for example, a model in which a steepening yield curve generates two opposing effects. While, on the one hand, it leads to higher risk-taking due to a risk-return slack, it lowers, on the other hand, incentives for risk-taking due to an inverted search for yield through risk-shifting. In their model, the relative strength of these two channels on risk-taking depends on the leverage of the bank.

It should also be noted that there are possible second-order effects of a low interest environment on risk taking as well. Adrian and Shin (2011) model, for example, how low short-term rates first lead to increased lending, which in turn leads to higher asset valuations and thus to a larger risk-bearing capacity. Bernanke and Gertler (1989, 1990) show how changes in interest rates reduces the riskiness of borrowers and, if existing borrowers become less risky, a bank might be induced to accept riskier new borrowers. Finally, there are possible effects of low interest rates on the risk-taking of an individual bank which result from the interaction with other banks and the central bank. Most notably, Farhi and Tirole (2012) identify incentives for banks to correlate their risk exposures in order to be bailed-out in the event of failure. Such second-order effects are not investigated in our paper.

Some of the above mentioned mechanisms may affect incentives for both credit risk and interest rate risk exposure. The model of Dell'Ariccia et al. (2014), for example, centers on the decision about the monitoring level of a loan portfolio, which is assumed to be inversely related to the corresponding credit risk, and a steeper yield curve which

[3]Borio et al. (2015) report evidence for particularly decreased bank profitability as a result of particularly low interest rates and a particularly flat yield curve. Furthermore, a decreased profitability of classic lending business may also be due to a smaller margin contribution from deposits as a result of lower short-term rates as the findings of Ruprecht, Kick, Entrop, and Wilkens (2013) and Busch and Memmel (2015) suggest.

induces an increased maturity mismatch and hence interest rate risk. Data from lending surveys and credit registers are analyzed by De Nicolo, Dell'Ariccia, Laeven, and Valencia (2010), Paligorova and Santos (2013) and Buch, Eickmeier, and Prieto (2014) for the US, by Maddaloni and Peydró (2011) for the US and the euro area, by Jimenez, Ongena, and Peydró (2014) for Spain and by Ioannidou, Ongena, and Peydró (2015) for Bolivia. The common outcome of these studies is that lower short-term rates, which are generally associated with a steeper yield curve, lead to increased credit risk-taking by banks.

Search for yield is a crucial aspect of our study. In the existing body of literature, two potential explanations for search for yield have been proposed. The first explanation refers to some sort of risk-shifting as introduced by Jensen and Meckling (1976), elaborated on notably by Stiglitz and Weiss (1981) and Kane (1989) and observed in a recent case study by Landier, Sraer, and Thesmar (2011). Explanations of this type maintain the assumption of perfect rationality and rely on an institutional setup or some appropriate contractual arrangement such as limited liability or bonus incentive schemes. The second explanation relies instead on an assumption of bounded rationality. Explanations of this type feature a behavioural assumption that might be very simple, for example the inability of market participants to account for all available information as suggested by Rajan (2005), or they are more sophisticated, say, along the lines of the prospect theory developed by Kahneman and Tversky (1979).

It should be noted that parts of the existing literature seem to imply a diverse understanding of what constitutes a search for yield. In particular, some studies diagnose a search for yield when lower short-term rates lead to increased risk-taking. For example, when lower short-term rates are accompanied by a steeper yield curve, what might be called search for yield may occur in the form of increased taking of interest rate risk due to increased earning opportunities from term transformation. In contrast, we in this paper understand search for yield as a link between *lower* earning opportunities from taking a certain risk and *increased* taking of that risk. Construed in this way, a shift of risk preferences turns out to be one explanation for search for yield. Our concept as such is a narrow notion of search for yield which is in line with the reasoning of Rajan (2005) who defines search for yield as a reaction to lower earning opportunities that consists in an increase in risk-taking as a means to bolster profitability.

There already exists empirical research on the link between interest rates and the taking of interest rate risk. Hanson and Stein (2015) find that a steepening of the yield curve due to a decrease in short-term interest rates induces US banks to increase their holdings of long-term bonds and thereby to increase their interest rate risk.[4] Memmel (2011), Memmel and Schertler (2013) and Ruprecht et al. (2013) study data from interest rate risk and annual account reporting from Germany with the overall result that a flatter yield curve, implying a lower expected return from interest rate risk, leads to a decreased taking of this risk by banks. Our paper refines the findings of these studies by establishing a general *potential* link between lower expected return from interest rate risk and increased taking of this risk. Namely, we start out by showing the existence of the

[4] Hanson and Stein (2015) actually go even further and show that this increased demand for long-term bonds leads to an increase in price and by this to a reduction of long-term interest rates also, though to a smaller extend than the initial decrease in short-term interest rates. Chodorow-Reich (2014) reports evidence for increased risk taking of money market funds seeking to cover administrative costs in a low-interest rate environment.

theoretical possibility that below a threshold level of profitability banks search for yield by increasing their interest rate risk despite, say, a flatter yield curve. Subsequently, we estimate empirically the level of the threshold and the share of banks falling short of it.

3 Modeling

3.1 Theoretical Model

In our illustrative theoretical model, we include the search for yield in a bank's taking of interest rate risk by assuming a utility function which is convex below a target rate of return and concave above this rate. Fishburn and Kochenberger (1979) find that a utility function of this form best captures the risk attitude of managers. Laughhunn, Payne, and Crum (1980) present additional evidence for risk-seeking behavior of managers in case of below target returns.

Note that, by assuming a utility function which is symmetric to the reference point, we do not accommodate the assumption of loss aversion common in behavioral economics. This assumption, advanced by Benartzi and Thaler (1995) in the field of behavioural finance, postulates that more disutility results from a loss of a given size than utility from a gain of the same size. In contrast, we focus on an expected utility framework with a symmetric combination of risk seeking below the target rate of return and risk aversion above it. Such a utility function captures the essence of the search for yield behavior we are investigating in the most stripped-down way and without loss of generality of our conclusions. However, it is straightforward to extend our theoretical model to feature loss aversion.

With the empirical specification derived from the following theoretical model, it is possible for the first time to identify the critical value of the expected return below which search for yield dominates the link between expected return from interest rate risk and taking of this risk by banks. Our empirical findings are the first to document this richer picture of banks' interest rate risk-taking.

In the following stylized model, we assume that the bank management's utility function is

$$u(\pi) = \arctan(\pi) \tag{1}$$

where the first derivative is

$$u'(\pi) = \frac{1}{1+\pi^2}$$

i.e. the marginal utility is always positive. For $\pi > 0$, the function is concave, meaning risk aversion, for $\pi < 0$, it is convex which means risk seeking.[5]

The income π of a bank is assumed to be composed of an on-balance sheet part a and a part due to derivatives (interest rate swaps) d where the bank can determine its exposure w:

$$\pi = a + w \cdot d \tag{2}$$

with

[5]Note that the second derivative of the function reads $u''(\pi) = -2\pi/(1+\pi^2)^2$. Pratt (1964) mentions this utility function, albeit only the positive part where it is concave.

$$d = \begin{cases} \mu + \sigma & p = 0.5 \\ \mu - \sigma & 1 - p = 0.5 \end{cases} \tag{3}$$

where p stands for the probability that the first outcome in (3) materializes. We assume $\sigma > \mu > 0$ so that there are no arbitrage opportunities. Note that, for banks without derivative usage, d and w can be interpreted as describing what may be called the *pure* interest rate risk of on-balance sheet business. Combining (1), (2) and (3), we can express the expected utility of the bank management as

$$E(u) = 0.5 \cdot \arctan\left(a + w \cdot (\mu + \sigma)\right) + 0.5 \cdot \arctan\left(a + w \cdot (\mu - \sigma)\right). \tag{4}$$

Differentiating (4) with respect to w, one obtains

$$\frac{dE(u)}{dw} = 0.5 \cdot \frac{(\mu + \sigma)}{1 + \left(a + w \cdot (\mu + \sigma)\right)^2} + 0.5 \cdot \frac{(\mu - \sigma)}{1 + \left(a + w \cdot (\mu - \sigma)\right)^2}. \tag{5}$$

Setting (5) to zero and solving for w,[6] one obtains the optimal exposure w_{opt} as

$$w_{opt} = -\frac{a}{\mu} + \sqrt{\frac{a^2}{\mu^2} + \frac{1 + a^2}{\sigma^2 - \mu^2}}. \tag{6}$$

The expected income $E(\pi)$ when using the optimal weights is always positive (combining (2) and (6)), irrespective of the on-balance sheet income part a, which can be seen from Equation (7):

$$\begin{aligned} E\left(\pi_{opt}\right) &= a + w_{opt} \cdot \mu \\ &= \sqrt{a^2 + \mu^2 \cdot \frac{1 + a^2}{\sigma^2 - \mu^2}} > 0. \end{aligned} \tag{7}$$

The rationale behind this result is as follows. Suppose the expected income were negative. In this case, the probability mass would be mainly in the convex part of the utility function. Accordingly, the decision-maker would be mainly risk-seeking, not risk-averse, meaning that he/she derives a higher expected utility from higher risk. Therefore, a portfolio with negative expected return could not be the optimal one because the decision-maker could in this case always achieve a higher expected utility by increasing the off-balance sheet exposure w (which leads to higher risk and higher expected return). For a sufficiently large derivative exposure w, however, the expected return of the entire bank π would turn positive (even if the on-balance sheet expected return a is negative) because, by assumption, the expected return of the derivative is positive. In this case, the usual trade-off between risk and expected return would apply.

In order to compute the change in the optimal risk exposure in response to changes in the expected return of the risky asset, we calculate the derivative of the optimal amount

[6] See the appendix.

of the investment in the risky asset with respect to its expected return and obtain

$$\frac{\partial w_{opt}}{\partial \mu} = \frac{a}{\mu^2} \cdot \left(1 - \sqrt{\frac{\frac{a^2}{\mu^2}}{\frac{a^2}{\mu^2} + \frac{1+a^2}{\sigma^2-\mu^2}}}\right) + \frac{\mu(1+a^2)}{(\sigma^2-\mu^2)^2} \cdot \frac{1}{\sqrt{\frac{a^2}{\mu^2} + \frac{1+a^2}{\sigma^2-\mu^2}}}. \tag{8}$$

The first summand in (8) has the same sign as a, because the term in the brackets is always positive. The second summand is likewise always positive. With this in mind, we rewrite (8) as

$$\frac{\partial w_{opt}}{\partial \mu} = x_1(a) + x_2(a) \cdot a \tag{9}$$

where $x_1(\cdot)$ and $x_2(\cdot)$ are functions with strictly positive values.

3.2 Empirical specification

(9) can lead to the following empirical implementation

$$\Delta w_{opt} = (\beta_1 + \beta_2 \cdot a)\, \Delta\mu \tag{10}$$

or – more concretely with indices for time t and bank i –

$$\Delta w_{opt,t,i} = \alpha + \beta_1 \Delta\mu_t + \beta_2 \cdot (a_{t,i}\Delta\mu_t) + \gamma' z_{t,i} + \varepsilon_{t,i} \tag{11}$$

where $z_{t,i}$ is a vector including bank-specific and time-variant control variables, $\Delta\mu_t$ is the change in steepness of the yield curve (or the change in the earning opportunities from term transformation), $a_{t,i}$ is the deviation of bank i's operative income from its historic mean and $\Delta w_{opt,t,i}$ is the interest rate risk. Of special interest is the term

$$\beta_1 + \beta_2 \cdot a_{t,i} \tag{12}$$

which gives the effect of changes in the earnings opportunities from term transformation (which can be positive or negative). The expression $-\hat{\beta}_1/\hat{\beta}_2$ is an estimate for the critical value a^* where the sign of the effect changes, i.e. for $a_{t,i} > -\hat{\beta}_1/\hat{\beta}_2$, an increase in the earning opportunities from term transformation leads to an increase in the interest rate risk exposure (see Figure 1).

With the help of the delta method, it is possible to derive the asymptotic distribution of the estimation for the critical value $\hat{a}^* = -\hat{\beta}_1/\hat{\beta}_2$:

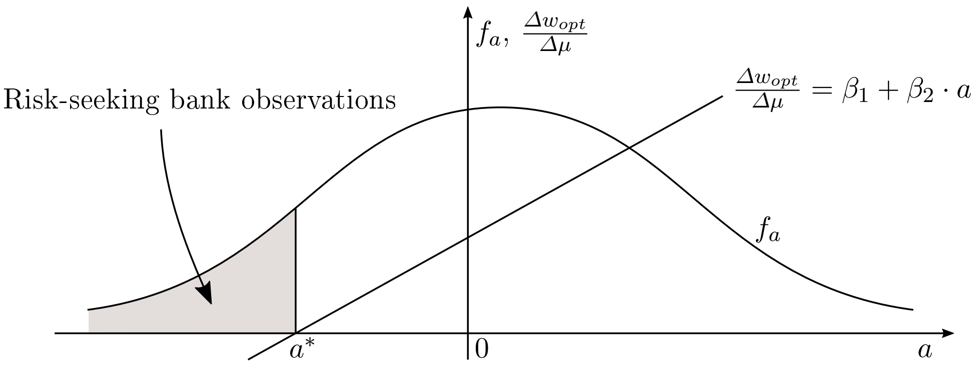
$$\sqrt{T \cdot N}\,(\hat{a}^* - a^*) \to N(0, V) \tag{13}$$

with

$$V = T \cdot N \cdot \left(\frac{var\left(\hat{\beta}_1\right)}{\beta_2^2} - 2 \cdot \frac{cov\left(\hat{\beta}_1, \hat{\beta}_2\right) \cdot \beta_1}{\beta_2^3} + \frac{var\left(\hat{\beta}_2\right) \cdot \beta_1^2}{\beta_2^4}\right) \tag{14}$$

where $T$and N are the numbers of observations in the time and the cross-sectional dimensions, respectively.

Figure 1: Critical Income



4 Data

As the dependent variable, named Δw and corresponding to Δw_{opt} in the previous section, we use the year-to-year change in a bank's exposure to interest rate risk in our regressions. This exposure has to be reported to the supervisor by each bank in Germany, and banks compute it using their internal risk models. For regulatory purposes, this exposure is defined as the change in the present value of a bank's banking book due to an overnight shift of the term structure. The banks perform the calculation twice, once for a parallel upward shift of 200 basis points and once for a downward shift of the same magnitude, assuming the (more) adverse of the two outcomes for regulatory purposes. For reasons of standardization, the present value change is normalized with the banks' regulatory capital (this measure is then called the Basel interest rate coefficient). In this study, we carry out the standardization by using the banks' total assets. This standardization is more convenient for our purposes because the Basel interest rate coefficient includes both the risk exposure and the risk-bearing capacity, whereas with our standardization, only the risk exposure is expressed.[7] Another deviation from the regulatory figure is that, in our analysis, we consider only the upward shift in the term structure. We do so because the conventional business model of banking consists in positive term transformation, which means that maturities are longer on the asset side than they are on the liability side. In fact, for 95% of the banks, the upward scenario is the (more) adverse one in our data set. Our empirical analysis covers the period from 2005 to 2014. For the years from 2005 to 2010, reports of banks' exposure to interest rate risk are available only at unsystematic reporting dates, which we treat as follows: Exposures to interest rate risk with reporting dates from January to June are counted as the year-end value of the previous year. Accordingly, values with reporting dates from July to December are counted as year-end values of the current year. From 2011 on, we use the fourth quarter value as the year-end value. Focusing on the direction of the change in banks' exposure to interest rate risk and in order to avoid noise due to extreme values (in spite of the outlier correction mentioned below) in the data, we introduce an alternative dependent variable,

[7] For the interpretation of the numerical values reported below it is helpful to note that in our sample, the average Basel interest rate coefficient is about 11 times as large as the average interest rate coefficient standardized with total assets.

which is a dummy variable that takes on the value of one if a bank's exposure to interest rate risk standardized with the bank's total assets has increased in a given year and zero if it has declined or stayed the same. This variable is named $I_{\{\Delta w>0\}}$.

The main explanatory variables in our regressions are dmu (corresponding to $\Delta\mu_t$ in Equation (11)), the year-to-year change in the earning opportunities from interest rate risk, and ert, the deviation of a bank's standardized operating income from its mean operating income over time. More precisely, dmu measures possible earnings from term transformation following an investment strategy that consists in revolvingly investing in 10-year par-yield bonds and of revolvingly issuing par-yield bonds with one year of maturity.[8] ert is defined as the deviation from the mean over time in order to account for differences in bank-specific business models.[9] Furthermore, for the sake of consistency with the theoretical results of the previous subsection, ert is multiplied by the variable dmu, yielding the variable $ertdmu$, which corresponds to the term $a_{t,i}\Delta\mu_t$ in Equation (11).[10]

In our regressions, we use several control variables. To measure a bank's credit risk, we look at the write-downs in its credit portfolio and the average riskiness of its assets. The former variable, labeled $writedowns$, is defined as the ratio of a bank's gross write-downs (in a given year) relative to its customer loans. The latter variable, labeled rwa_ta, is the quotient of a bank's risk-weighted assets and total assets. The bank's risk bearing capacity is measured by its regulatory capital ratio, its Tier 1 ratio captured by the variable $Tier1$. According to theory, an increase in this capital ratio should lead to higher risk-taking because of the then larger loss-absorbing capacity. To account for time trends and regulatory changes, the yearly cross-sectional median of the respective variable is subtracted from the variables $writedowns$, rwa_ta, and $Tier1$. Regulatory pressure is captured by the variable reg, which is a dummy variable equaling one if the Basel interest rate coefficient (the measure for a bank's interest rate risk used by supervisory authorities) exceeds 20 per cent, which used to be the regulatory criterion for banks with elevated interest rate risk exposure.

Table 1 gives the summary statistics of the dependent variable Δw, i.e. the change in banks' exposure to interest rate risk standardized with its total assets, the main explanatory variables, dmu and $ertdmu$, as well as the control variables $Tier1$, rwa_ta and $writedowns$. Summary statistics of the variable ert are provided only to enable a better understanding of the variable $ertdmu$. For reasons of confidentiality, we do not report summary statistics concerning the dummy variable reg.

We apply an outlier correction to all variables where we cut off the values beyond the first and the 99th percentile as default. The only exception is the continuous variable dmu for which we abstain from any outlier correction because of limited variation and the dummy variable reg. Applying an alternative more extensive outlier correction, we treat the variable $ertdmu$ differently than in the default specification and exclude its values below the fifth percentile and above the 95th percentile from the sample. Our reason for reporting results from both of these alternative treatments in our baseline estimations is

[8] See Memmel (2008) for details on and Memmel (2011) for an application of this investment strategy.

[9] The main reason to focus on operating income as a measure of profitability is that it is difficult to manipulate for banks.

[10] As one of our robustness checks we additionally include ert by itself as an independent variable. However, the results hardly change and the regression coefficient on ert turns out to be insignificant.

Table 1: Summary Statistics

Variable	Nobs	Mean	Stand. dev.	5th percentile	Median	95th percentile
Δw	6713	0.1109	0.4414	-0.6407	0.1052	0.8487
$I_{\{\Delta w>0\}}$	6713	0.6204	0.4853	0.0000	1.0000	1.0000
dmu	6713	-0.0538	0.6835	-1.2480	-0.0010	1.9430
ert	6713	-0.0254	0.4644	-0.3794	-0.0291	0.3449
$ertdmu$	6713	-0.0006	0.1629	-0.2702	0.0001	0.2073
$Tier1$	6713	0.0050	0.0496	-0.0394	-0.0045	0.0763
rwa_ta	6713	-0.0019	0.1165	-0.1992	0.0006	0.1810
$writedowns$	6713	0.0316	0.3364	-0.4096	-0.0060	0.5648

Summary statistics for the two dependent variables, the year-to-year change in a bank's exposure to interest rate risk Δw (present value losses due to a 200 bp parallel shift of the term structure, in per cent of total assets) and the dummy variable $I_{\{\Delta w>0\}}$ which takes the value one in case $\Delta w > 0$, and the main explanatory variables, *dmu*, *ertdmu*, $Tier1$, *rwa_ta*, *writedowns*. For completeness, we give the corresponding statistics of the variable *ert* as well. The summary statistics in the table refer to the sample after applying the default outlier correction as described in the main text.

that the variable *ertdmu* has particularly extreme values in the tails. For instance, the ratio of the 99th percentile to the 90th percentile is 5.3 for *ertdmu*, whereas it is 2.2 for the dependent variable Δw and 1.8 for normally distributed variables.[11]

During the ten years under consideration (2005-2014), many mergers took place among the banks in the sample. In our subsection about robustness checks, we try out the following alternative treatment: Two merging banks cease to exist after the year of the merger and a new bank is created in the year after the merger. For our baseline results, however, we proceed as follows: The dominant institution among the two merging banks continues to exist, whereas the subordinate bank ceases operation.

5 Empirical Results

5.1 Baseline Models

We estimate four baseline specifications of Equation (11), namely with the continuous (I) or the binary (II) dependent variable and each with the default (a) or the more extensive (b) outlier correction. The results (see Table 2) show that banks – as expected – increase their interest rate risk exposure when the return from this risk goes up; i.e. in all four specifications the regression coefficient on the variable *dmu* is positive and highly significant. Focusing on this regression coefficient, the estimates with the continuous dependent variable (specifications Ia and Ib) show that banks increase their exposure to interest rate risk (standardized with total assets) by around 0.09 percentage points on average if the earning opportunities from interest rate risk increase by one standard deviation, meaning that the Basel interest rate coefficient increases by about 0.7 points

[11]These numbers for *ertdmu* and Δw refer to the sample without any outlier correction applied. The default outlier correction produces similar numbers, namely 5.0 and 1.8, respectively. This suggests that the default outlier correction does not take sufficient care of the fat tail of the distribution of *ertdmu*.

(see Footnote 7). Regressing on the binary dependent variable instead (specifications IIa and IIb), the probability of the average bank increasing its exposure to interest rate risk in the face of a rise in earning opportunities is estimated to increase by around 5 percentage points.[12] This finding is in line with those of Memmel (2011) and Memmel and Schertler (2013). Note that the positive sign of the regression coefficient on the variable *dmu* suggests that banks actively manage their interest rate risk. The reasoning for this interpretation is as follows. Everything else equal, a flatter yield curve tends to shift loan demand toward longer maturities or interest rate fixation periods. Hence, if banks were passive regarding the level of the interest rate risk, a negative relationship between expected return and interest rate risk would prevail. Accordingly, the positive relationship which we obtain in our regressions is evidence for banks' active management of their interest rate risk.

The regression coefficient on the variable *ertdmu* is significantly positive in all specifications, though on different levels. This means that the interest rate risk exposure of a bank with a lower deviation of its operative income from its historic mean shows a weaker response to changes in earning opportunities from interest rate risk (*dmu*) than a bank with a higher deviation. If the deviation of a bank's operative income from its historic mean is very low, i.e. sufficiently negative, the relationship between exposure and earning opportunities can even change its sign from positive – as it is usually the case – to negative. Table 3 gives the level of this critical deviation of operative income a^* below which such a reversal of the relationship is to be expected (see Equation (12)). It is striking that the empirical significance and the economic relevance vary with the outlier correction applied. With the default outlier correction, the regression coefficient on *ertdmu* is significant at the 5% level in the specification with the continuous dependent variable and the critical deviation of operative income is below the threshold for around 0.6% of the observations in the sample (specification Ia). Similarly, the specification with the binary dependent variable produces a critical deviation below which 0.5% of the observations can be found, though on an inferior level of significance of 10%. With the more extensive outlier correction, the regression coefficient on *ertdmu* turns out to be significant at the 1% level for both the specification with the continuous and the specification with the binary dependent variable, and more than 5% of the observations in the sample display a deviation of operative income that falls below the critical threshold (specifications Ib and IIb). This shows that the way in which we treat outliers has a significant impact on the percentage of observations (and banks) that are below the critical value. Put differently, with the default outlier correction, an operating income that is close to 1.7 (specification Ia) or 2.0 (specification IIa) standard deviations below the historic mean takes a bank below the critical level, and with the more extensive outlier correction, the factor is less than 0.7 (specification Ib) or 0.6 (specification IIb) standard deviation.

With the default outlier correction, we find that a deviation of the operating income relative to total assets from its historic mean by -0.80 percentage points (specification Ia) or -0.98 percentage points (specification IIa) is the threshold. With the more extensive outlier correction, the threshold is estimated to be at -0.34 percentage points (specification Ib) or at -0.29 percentage points (specification IIb). Since the mean operating income

[12] This marginal effect is calculated as the difference between the predicted values of the dependent variable with all explanatory variables set to their mean value and with all explanatory variables set to their mean value except for *dmu* which is set to its mean value plus one standard deviation.

Table 2: Main Results

Dependent variable	Δw (I)		$I_{\{\Delta w>0\}}$(II)	
Outlier treatment	default (a)	ext. (b)	default (a)	ext. (b)
dmu	0.0889***	0.0931***	0.3179***	0.3201***
	(0.0092)	(0.0100)	(0.0445)	(0.0485)
ertdmu	0.1105**	0.2733***	0.3255*	1.0882***
	(0.0456)	(0.0671)	(0.1755)	(0.2631)
reg	-0.2744***	-0.2787***	-0.5014***	-0.5021***
	(0.0164)	(0.0168)	(0.0553)	(0.0560)
$Tier1$	1.0103**	0.8027*	-0.2371	-0.2476
	(0.4135)	(0.4709)	(0.5857)	(0.6163)
rwa_ta	0.4047**	0.4321**	-0.5469**	-0.4396*
	(0.1738)	(0.1829)	(0.2411)	(0.2473)
writedowns	-0.0119	-0.0190	-0.1354*	-0.1875**
	(0.0254)	(0.0268)	(0.0770)	(0.0808)
constant	0.1908***	0.1994***	0.6705***	0.6944***
	(0.0051)	(0.0054)	(0.0316)	(0.0325)
Nobs	6713	6469	6713	6469
Banks	1738	1727		
$R^2(within)$	7.43%	7.84%		

Robust standard errors in brackets. In the first specification, bank-fixed effects are included. The second specification is a logit-specification. ***, **, and * denote significance at the 1%, 5%, and 10% level, respectively. "default" means that the extreme 1% of the observations (at both ends of the distribution) of the variable *ertdmu* are treated as outliers, "ext." means that 5% of the observation (at both ends of the distribution) are treated as outliers.

relative to total assets amounts to 0.92 per cent, these results imply that mean critical level of operative income is positive. The only exception is the result produced with the default outlier correction and the binary dependent variable (specification IIa), which, however, has the lowest level of significance.

Concerning the control variables, we find that regulatory pressure, measured by the dummy variable *reg*, has a highly significant impact on the change in the interest rate risk: If a bank is qualified as an outlier, the bank reduces its exposure by 0.3 percentage points (specifications Ia and Ib) (on average) over the next year. According to the specifications with the continuous dependent variable, capital adequacy, measured by the variable $Tier1$, has a significant positive impacti.e. banks with more capital at hand take a higher interest rate risk. The riskiness, measured by the variable *rwa_ta*, is estimated to be significant in all four specifications. But the sign of the estimated coefficient varies. With the continuous dependent variable, it is positive (specifications Ia and Ib) and, with the binary dependent variable, it is negative (specification IIa and IIb). As both the dependent variable and this explanatory variable are normalized with total assets, the positive sign can be regarded as an artefact. If total assets decrease, both variables increase mechanically. Noting that a banks' risk-weighted assets mainly reflect credit risk and not interest rate risk, the negative coefficient for *rwa_ta* (as produced by specification IIa and IIb) suggests that banks have an internal risk budget that they distribute between credit and interest rate

Table 3: Critical operative income

Dependent variable	Δw (I)		$I_{\{\Delta w>0\}}$(II)	
Outlier treatment	default (a)	ext. (b)	default (a)	ext. (b)
critical operative income $\hat{a}^*$	-0.8040** (0.3339)	-0.3405*** (0.0883)	-0.9767* (0.5247)	-0.2942*** (0.0799)
Share of observations below $\hat{a}^*$	0.6%	5.6%	0.5%	8.3%

Robust standard errors in brackets, determined according to Equation (14). ***, ** and * denote significance at the 1%, 5%, and 10% level, respectively. "default" means that the extreme 1% of the observations (at both ends of the distribution) of the variable *ertdmu* are treated as outliers, "ext." means that 5% of the observation (at both ends of the distribution) are treated as outliers.

risk.[13] The estimation results on the other variable that measures credit risk, *writedowns*, tend to support this assumption. Its effect is significant only in the specifications with the binary dependent variable (specification IIa and IIb), the estimated sign being negative.

5.2 Robustness Checks

We run several robustness checks. If not otherwise stated, the results are compared to the ones produced with the baseline specification Ia.

First, we include *ert* as an additional independent variable in the regression. We do because the results for the interaction term *ertdmu* might change, if besides *dmu* the second interacted variable *ert* is seperately included in the regression too. The regression coefficient on *ert* turns out to be highly insignificant. The regression coefficient on *ertdmu* hardly changes and its level of significance remains if *ert* is seperately included in the regression. This suggests that our baseline results for *ertdmu* do not only pick up some spurious regression and justifies the exclusion of *ert* from our baseline models.

Second, we alternatively use the one-year lagged value of the variable *ert* for the calculation of the independent variable *ertdmu*. We do so in order to address a potential endogeneity problem arising from simultaneity, i.e. a two-way determination of the change in a bank's exposure to interest rate risk and its operating income. We find that the regression results hardly differ from the results produced by our baseline model.

Third, we normalize the present value change in a bank's banking book due to an overnight upward shift in the term structure by 200 basis points using the bank's regulatory capital instead of its total assets. As pointed out earlier, this measure is closely related to the Basel interest rate coefficient. We find that the significance of the variable *ertdmu* vanishes under the default outlier correction and becomes a bit weaker given under the more extensive one. The reduction in the significance of the coefficient does not come as a surprise. As noted above, in our baseline models we apply the normalization with total assets in order to disentangle changes in risk exposure and in risk-bearing capacity. The variable included to capture the latter, namely $Tier1$, becomes insignificant, if the alternative normalization is applied.

Fourth, we apply a different merger treatment as described in Section 4: No longer does the dominating bank prevail, but a new bank appears and the two merging banks

[13]The canonical reference for this finding is the paper by Schrand and Unal (1998).

disappear from the sample after a merger. Due to this different treatment of the mergers, we lose some observations. However, the qualitative results remain, although the significance of the variable *ertdmu* becomes slightly weaker.

Fifth, we control for bank size. To this end, we include the logarithm of a bank's total assets normalized by the cross-sectional median for each year as an additional control variable. The regression coefficient on this variable turns out to be negative and highly significant. More importantly, the regression coefficients on the main variables of interest hardly change and their levels of significance remain unaltered.

Sixth, we investigate whether banks applying interest rate derivatives behave differently. We define a dummy variable which takes the value one in each year if a bank reports a positive figure for the nominal derivative volume. This is the case in 48.7% of the observations. We interact this dummy variable with *dmu* as well as with *ertdmu*. We find a positive relationship between expected return and risk for both values of the dummy variable. As noted above, this highly significant relationship suggests that banks' interest rate risk is actively managed in both subsamples. Anecdotal evidence suggests that it is common for smaller banks which do not apply interest rate derivatives to actively manage their interest rate risk by means of bidirectional loans of different maturities with their respective central institutions.[14,15] However, it is only for banks not using interest rate derivatives that we find the variable *ertdmu* to be significant. One possible explanation for the variable *ertdmu* to be significant only for these banks is that banks using interest rate derivatives are likely to use other instruments such as credit default swaps to manage their risk.[16] According to this interpretation, interest rate risk is a viable means of controlling a bank's risk position, although other and possibly more convenient means to that end exist and it might be the case that only banks with an elaborate risk management (here proxied by the use of interest rate derivatives) have access to them.[17]

Seventh, we break up the sample period 2005-2014 into two subperiods, ranging from 2005-2008 and from 2009 on with the low interest rate environment, by interacting the variables of main interest, *dmu* and *ertdmu*, with an appropreately defined dummy variable. We find that the regression coefficients on both variables are significant only for the first subperiod and insignificant for the second. The lack of significance in the second subperiod is likely due to relatively little variation of the variable *dmu*.

Eighth, the empirical specification in Equation (11) is a linearization of the relationship derived in Equation (9). This relationship is non-linear, which suggests including the term $a_{t,i}^2 \Delta\mu_t$ in the empirical specification (11). The corresponding coefficient is positive and significant at the 5% level, suggesting a convex relationship. Note that no real critical operating income can be calculated with the resulting coefficients. Moreover, the

[14] Ehrmann and Worms (2004) have a related study on bank networks in Germany.

[15] Readers who are unfamiliar with the German banking system are referred to the recent overview provided in chapter 2.1 of Koetter (2013). The three pillars of the German banking system are commercial banks, savings banks, and cooperative banks. Savings banks and cooperative banks have dedicated central institutions. Unlike most savings banks and cooperative banks, their central institutions are active on the capital markets. One of their functions can be described as providing mediated access for savings banks and cooperative banks to these markets.

[16] Gündüz, Ongena, Tümer-Alkan, and Yu (2015) find that banks apply CDS as an effective tool to control bank risk.

[17] See also Ruprecht et al. (2013), who find that banks with trading book differ from banks without trading book with respect to their behavior towards interest rate risk.

estimated coefficients other than for the quadratic term are all very similar to the ones that we obtain with the default sample specification.

Nineth, we further restrict the sample to observations with an interest rate risk exposure that occupies a substantial part of the risk-bearing capacity. The underlying hypothesis is that banks for which this is not the case do not take interest rate risk as a part of their business model and are, in effect, not subject to the mechanism we investigate. However, we find that restricting the sample to banks with a net present value change in the banking book due to an overnight upward shift in the term structure by 200 basis points normalized with regulatory capital of 5% or 10% does not lead to materially different results. Interestingly, these restrictions reduce the number of observations only by about 4% or 10%, respectively. This shows that our sample is dominated by banks with an interest rate risk exposure that occupies a substantial part of the risk-bearing capacity. This, in turn, explains why restricting the sample in the way described does not lead to materially different results.

Tenth, for the sake of completeness, we dispense with any outlier correction in our sample. Compared to the default outlier correction, the regression coefficients in the estimation with the continuous dependent variable hardly change. The significance of the coefficient of the variable *ertdmu* even improves from the 5% to the 1% level.

6 Conclusion

In our theoretical model, we allow for the possibility that, in some situations, the bank management may change its risk preference from risk aversion to risk seeking. This behaviour can lead the bank management to increase the bank's risk exposure even if the expected return from the risk is falling. In our empirical study on the interest rate risk exposure of banks in Germany, we observe the usual positive direct relationship between expected return and exposure. Furthermore, we find evidence that in extreme situations, such as the ones with very low profit levels, the relationship is reversed. The reverse relationship is relevant for about 0.6% to 8.3% of the observations, depending on the sample specification and the estimation technique used.

This study is a first attempt to empirically document the search for yield by banks in a narrow sense. We characterize the extreme situations mentioned above as situations in which a banks' operative income falls below a certain threshold. If the low interest rate environment becomes entrenched and banks' earning opportunities are squeezed further, such extreme situations may become more likely.

Appendix

Setting (5) to zero, we get

$$\begin{aligned}(\mu-\sigma)\cdot(1+a^2)+(\mu-\sigma)\cdot 2aw(\mu+\sigma)+(\mu-\sigma)\cdot w^2(\mu+\sigma)^2 \\ +(\mu+\sigma)\cdot(1+a^2)+(\mu-\sigma)\cdot 2aw(\mu+\sigma)+(\mu+\sigma)\cdot w^2(\mu-\sigma)^2 &= 0. \qquad (15)\end{aligned}$$

Rearranging gives

$$w^2 + 2 \cdot \frac{a}{\mu} \cdot w - \frac{1 + a^2}{\sigma^2 - \mu^2} = 0. \tag{16}$$

(16) has two solutions; due to our assumption $\mu > 0$, the solution in (6) is the maximum (which we look for) and the other is the minimum. If we tolerated the case $\mu \geq \sigma$, investing in derivates would always lead to a non-negative result and to a strictly positive result with at least probability of 0.5, making arbitrage possible.

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