Negative Interest Rates:
Forecasting Banks' Profitability in a New Environment

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Abstract

We analyze the consequences of unconventional monetary policy by several central banks on the profitability of banks. In many countries the low interest rate environment has been slowly replaced by a negative interest rate environment. Many articles show that banks' profitability with respect to interest income (measured by net interest margin) declines in a low interest rate environment. However, we are skeptical of extrapolating these findings to a negative environment: While the returns on loans follow the decreasing reference rate, costs of deposits are (legally) floored at zero. To address this nonlinearity we first employ an ARIMA model on a bank-by-bank basis for many different interest income drivers using a unique supervisory data set on Austrian banks of around 49,000 observations between 1998 and 2016. Second, we show that net interest margin models underestimate the impact of negative rates. Third, we forecast that a hypothetical reference rate close to −2% poses a substantial burden to banks' profitability.

Keywords: bank profitability, low interest rate environment, negative interest rate environment, net interest margin, panel econometrics, ARIMA models.
JEL: classification: G21, C22, C23

1. Introduction

1.1. The low interest rate environment

What is the effect of low interest rates on banks' profitability? While it is reasonable to assume that a flat yield curve puts pressure on banks' net interest income (for banks engaging in maturity transformation), the effect of a low interest rate level (ie. a parallel movement of the yield curve) on net interest margin is less clear. If the asset and liability side of a bank is symmetrically affected by the parallel shift, then there would be no impact. However, recent studies, e.g. Claessens et al. (2016) Genay & Podjasek (2014) and

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Busch & Memmel (2015) show that net interest income from banks is lower the lower the interest rate environment. This suggests that some liability positions are not reacting or reacting more sluggishly than the asset side to changes in the interest rate level.

The contribution of our paper concerning the the low interest rate environment is twofold. First, empirical studies show that there is substantial heterogeneity in the results across jurisdictions (Claessens et al., 2016). Therefore, analyzing the Austrian banking market, we add to these findings. Second, studies so far focused only on large international banks (Claessens et al. 2016 and Borio et al. 2015) where data coverage is best. However, under the hypothesis that large banks typically have greater ability to manage interest rate risks and can increase lending in foreign countries more easily (Claessens et al. 2016), smaller banks will be affected more by a low interest rate environment. We explicitly test this hypothesis in a panel econometric approach in Section 2.

1.2. The negative interest rate environment

Since the famous speech by Mario Draghi (*whatever it takes*) in 2012, the expansionary monetary policy in several European countries has continued and the low interest rate environment is more and more replaced by a negative interest rate environment. Denmark (Jul 2012), the Euro area (June 2014), Switzerland (Dec 2014), Sweden (Feb 2015), Bulgaria (Nov 2015), Japan (Jan 2016) and Hungary (Mar 2016) all introduced negative central bank deposit rates (Scheiber et al. 2016). Similarly, the list of sovereign bonds trading at negative yield is growing. Bean et al. (2015) present a comprehensive background summary on these developments and IMF (2015) provide a comparison of key figures of several banking markets on this topic.

A central question is, if the insights from a low interest rate environment can be extrapolated to a negative environment. While this depends on the legal setting of a country, we conclude that for Austria this is not the case. We argue that negative interest rates are a game-changer and lead to a profound impact on banks' profitability.

To see why a negative interest rate environment might differ from a low interest rate environment, consider the following simplistic banking model: A bank refinances itself at a reference rate (e.g. Euribor) plus an add-on (e.g. a spread depending on its credit quality). Let us call this sum "the total refinancing rate". The interest charged on its asset side is the total refinancing rate plus a surcharge that aims at covering operational costs, (expected) risk costs and cost of equity (ie. unexpected risk costs). The key issue of the current situation is that the refinancing rate of retail deposits is floored at zero, while this floor is not passed on to the asset side. This means, if market rates drop the asset side follows potentially even into negative while the bank still pays for its refinancing.In other words: a negative interest rate environment causes the reference rate to be unrepresentative of the true refinancing rate of a bank. We see that the bank will suffer high losses if interest rates move sufficiently far into the negative and the bank holds deposits.

From a financial stability perspective, this risk is of high relevance as many financial institutions are exposed to it at the same time. We focus on the situation in Austria where the zero floor on deposits rests on a supreme court decision.[2] Banks in other European countries face a similar situation (see e.g. Drescher et al. (2016) on the situation in Germany).

However, even in countries where negative deposit rates are legally possible, banks seem to shy away from such measures, at least form charging the classical small retail depositors. For example, Swiss banks knew that imposing negative interest rates on ordinary retail customers would risk a disastrous bank run (Atkins, 2016). Also Irish banks had a similar thought process, by considering negative deposits on large customers but not small ones. [3]

Economics theory would suggest that if banks charged negative deposit rates rational customers would look for alternatives to save their cash. It might not go under the mattress but into a safe instead. Most customers already pay deposit fees (independent of the deposit size), hence additional costs in terms of negative deposit rates would make safes an even better option. In the worst case scenario negative deposit rates could trigger a (gradual) bank run.

On the asset side zero or negative rates are clearly relevant for sovereign bonds holdings, for interbank claims and – most crucially – also for loans to customers which are typically referenced to the Euribor. According to several court decisions[4] a negative reference rate has to passed on to the interest charged on customer loans.

In other words, banks experience a systemic mispricing of assets, not because the risk has been incorrectly assessed, but because the refinancing rate does not reflect the true conditions the bank faces once rates move into the negative. This asymmetric dilemma is new to banks as negative rates are to history.

To estimate banks' profitability under negative rates we use an ARIMA forecast modeling approach that is adjusted to account for the floor on deposits. This allows us to simulate banks' profitability under hypothetical negative rates (Section 3) and the assumption that banks do not adjust their product pricing substantially.

Analyzing the effects of the low to negative interest rate environment on banks' profitability is a very new and hot topic. Dombret et al. (2017) look at the German banking system. They forecast the so called Core Business Interest Margin which is a mixture of interest margins on outstanding volumes and interest margins on new businesses. Their data set include around 230 German banks. They analyze three scenarios (i) interest rates stay constant for the next four years, (ii) interest rates decrease by another 1% in the first two years and then stay constant in the next two years and (iii) interest rates stay constant in

[2]See court case decision 5 Ob 138/09v of the Supreme Court of Justice (13th October 2009).

[3]http://www.zerohedge.com/news/2016-08-22/irelands-biggest-bank-charging-depositors-negative-interest-rate-madness.

[4] While a total negative interest on customer loans is ruled out, negative reference rates need to be passed on until the total rate reaches zero (Oberlandesgericht Innsbruck, 4 R 58/16k, 14th July 2016, AK vs. Hypo Tirol). See also court case decisions dealing with Swiss-Frank foreign currency loans where the reference rate, CHF Libor, moved into negative already at year end 2014: Landesgericht Feldkirch (5 Cg 18/15z, 28th August 2015, VKI vs. Raiffeisenbank am Bodensee), Handelsgericht Wien (57 Cg 10/15v, 24th September 2015, VKI vs. Uni Credit BA) and Landesgericht Eisenstadt (27 Cg 32/15x, 15th November 2015, VKI vs. HYPO-BANK Burgenland). A case at the Supreme Court of Justice is currently pending.

the first two years and rise by 1% in the last two years. Moreover, they assume that banks should meet the cost of equity target of 8% and their balance sheet is static. Their results indicate that only 20% of the German banks would meet the target of 8%, and around 13% of all banks would earn negative income.

Relying on a sample of 108 large international banks Borio & Gambacorta (2017) show that the profitability of these banks diminishes with a decrease in the short term interest rate. They also doubt the effectiveness of monetary policy to boost lending in a low interest rate environment by further lowering the policy rate.

2. Low interest rate environment: a panel econometric approach

In this section we estimate the effect of changes in the interest rate environment on the net interest margin (NIM) of banks by employing a panel econometric approach. The NIM is the main source of income of Austrian banks accounting to around two thirds of their total earnings.

2.1. The data

Our empirical analysis is based on quarterly supervisory data reported by domestically operating banks at the unconsolidated level according to national Generally Accepted Accounting Principles (GAAP). A considerable advantage compared to other studies is that our dataset features all banks in Austria, small and large, whereas typically large banks are over-sampled due to data availability reasons.

Bank-specific variables are built from data on balance sheet items, the profit and loss statement and data on regulatory capital and capital requirements. The observation span runs from the first quarter of 1998 to the first quarter of 2016, yielding $T = 73$ time periods. We consider all institutions that held a banking license at some point during the sample period, but exclude special purpose banks and affiliates of foreign banks in Austria, thus arriving at a sample of $N = 946$ banks.

As control variables we use a wide set of bank-specific and macroeconomic variables, see Table 1. Macroeconomic data are taken from the macroeconomic dataset of the Austrian National Bank (OeNB). To prevent outliers from distorting the empirical analysis, we apply a two-stage cleaning algorithm to the variables used. First, we eliminate outliers across banks for each time period. An observation is considered an outlier if it is too far from the median (more than four times the distance between the median and the 2.5% or 97.5% quantile). In a second stage, we eliminate outliers across time for each bank. Here, the threshold distance is defined as 12 times the distance between the median and the 10% or 90% quantile.[5] Such parameters ensure that the number of removed observations remains limited and the resulting distributions exhibit a reasonable shape when judged from a qualitative perspective. This procedure eliminates 0.77% of observations that are considered as reporting errors, and leaves us with

[5]This procedure was not invented for this exercise but is an established good practice to remove reporting errors in the regulatory reporting system for many supervisory applications relying on regressions (Gunter et al., 2013).

Table 1: Description of variables

Name	Description	Normalized by total assets	Expected sign on NIM
Dependent variable:			
NIM	Net interest income over total assets	by definition	n.a.
Explanatories of particular interest:			
Euribor	Short-term nominal interest rate (3-month Euribor) p.a.	no	+
Euribor^2	*Euribor* squared (but with the sign kept).	no	±
Term spread	10-year Austrian government bond yield minus short-term interest rate	no	+
Interaction: Euribor x RBD	Interaction effect including regional bank dummy (see below)	no	+
Bank-level control variables:			
RBD	regional bank dummy: 1 if at least one branch per 25 mEUR total assets and at least 60% deposit financed, 0 otherwise.	no	+
Total Assets	log of total assets	no	±
Euro loans to domestic customers	Loans to domestically domiciled nonbanks (i.e. customers) in EUR	yes	+
FX loans to domestic customers	Loans to domestically domiciled nonbanks (i.e. customers) in non-EUR	yes	+
Loans to foreign customers	Loans to foreign domiciled nonbanks (i.e. customers)	yes	+
Interbank loans	Loans to domestic and foreign banks, all currencies	yes	+
Interest-bearing securities	Exchange-traded interest-bearing securities (held as assets) issued by domestic and foreign banks and nonbanks	yes	+
Nonbank deposits	Deposits taken from domestic and foreign nonbanks (i.e. customers)	yes	−
Bank deposits	Deposits taken from domestic and foreign banks, all currencies	yes	−
Securitized debt	Liabilities in the form of securitized debt obligations and transferable certificates	yes	−
Net fee income	Net fee and commission income	yes	−
Staff expenses	Staff expenses	yes	+
Other administrative expenses	Administrative expenses other than staff expenses	yes	+
RWAs to total assets	Average risk-weight (credit risk only)	by definition	±
LLP ratio	Specific loan loss provisions over gross exposure (loans to domestic and foreign nonbanks)	no	±
Macroeconomic control variables:			
GDP growth	Annual growth of quarterly real GDP	no	+
Unemployment growth rate	Harmonized unemployment growth rate	no	−

Source: OeNB. Notes: Theoretical considerations and/or evidence in the existing literature suggest that the impact of a variable on NIM is either positive (+), negative (−) or mixed (±).

around 48,000 observations. To our knowledge our data set is the most comprehensive on regulatory reporting data among central banks. It combines stock and flow data, as well as price and quantity data. It combines balance sheet and P&L items with regulatory classification standards on bank's capital and risk weighted assets.

2.2. The model

To assess the average effect of the interest rate level on banks' interest income we follow the standard literature (Saunders & Schumacher, 2000; Maudos & de Guevara, 2004; Gunter et al., 2013) and employ a fixed effects panel regression:

$$y_{i,t} = \alpha_i + X_{i,t}\beta + Z_t\gamma + e_{i,t}, \quad i = 1, \cdots, N, \quad t = 1, \cdots, T, \tag{1}$$

where $y_{i,t}$ denotes the dependent variable net interest margin (NIM). NIM is the standard dependent variable to analyze the factors that drive interest income. $X_{i,t}$ represent the K individual specific explanatory variables (e.g. total assets), Z_t the M global explanatory variables (e.g. Euribor) and $e_{i,t}$ the idiosyncratic error term. The α_is in Eq. (1) are the fixed effects. We choose the specification after running a set of statistical tests (see Appendix B) and building on the previous work of Gunter et al. (2013).

2.3. The results

Figure 1: Estimated effect of a change of 100bps to the NIM (y-axis) depending on the interest rate environment (x-axis). 95% confidence levels using robust errors.

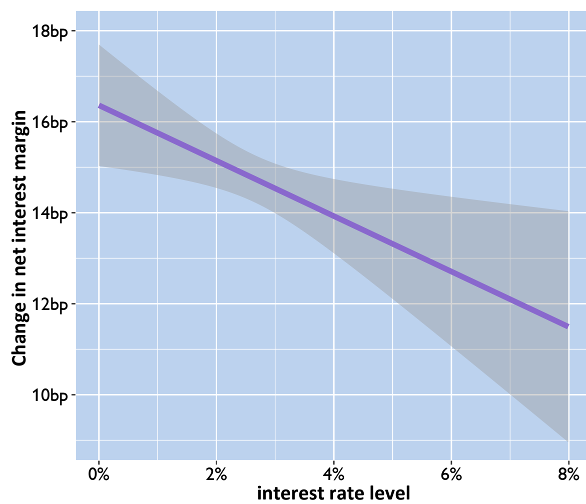


Table 2 displays the coefficient estimates of the panel model. For brevity, we will focus here on the regressors of interest. Our results suggest that a drop of 1% point in the Euribor is on average associated with a drop of the NIM of around 16bps. The non-linear term is not significant but negative: the higher the Euribor rate the less effect from a change in interest rate levels on NIM. The non-linearity effect is also in line with the findings of Borio et al. (2015) and Claessens et al. (2016) and also depicted in Figure 1.

Furthermore, the model output suggests that a 1% point decrease in the difference of long to short rates, i.e. a flattening of the yield curve, causes NIM to drop by 11bps. While regional banks have on average a higher NIM (by 10bps), they are more affected by changes in market rates, although only slightly, ie. by +1.7bps compared to other banks. That smaller banks are affected more is in line with the findings of Genay & Podjasek (2014). See Appendix C for a discussion on the regression coefficients that are in no direct connection with the interest rate level.

Table 2: Panel estimation result: coefficients and robust standard errors.

	Coefficients	(Standard Errors)
Euribor	0.164***	(0.014)
Euribor^2	-0.003	(0.002)
Term spread	0.115***	(0.005)
Interaction: Euribor x RBD	0.017***	(0.006)
RBD	0.098***	(0.017)
Total Assets	-0.400***	(0.040)
Euro loans to domestic customers	4.270***	(0.239)
FX loans to domestic customers	3.312***	(0.309)
Loans to foreign customers	3.770***	(0.411)
Interbank loans	2.719***	(0.247)
Interest-bearing securities	3.398***	(0.228)
Nonbank deposits	-1.571***	(0.276)
Bank deposits	-1.875***	(0.300)
Securitized debt	-1.892***	(0.406)
Net fee income	-0.036**	(0.017)
Staff expenses	-0.083	(0.078)
Other administrative expenses	0.162***	(0.021)
RWAs to total assets	0.215***	(0.076)
LLP ratio	-2.558***	(0.433)
GDP growth	0.020***	(0.002)
Unemployment growth rate	0.001***	(0.000)
R^2 within	0.550	
R^2 between	0.440	
R^2 overall	0.468	
Number of observations	47980	
Number of groups	902	
Obs per group: minimum	2	
average	53.2	
maximum	73	

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

This table presents the fixed effects estimation output with STATA's xtreg.The dependent variable, NIM, is in percentage points. Standard Errors are adjusted in order to correct for heteroskedasticity.

3. From low to negative rates

3.1. Why negative rates are a game-changer

Can the results from the previous section be extrapolated to negative market rates? As argued in the introduction, we are skeptical of this: The floor on deposit rates constitutes a non-linearity that the panel-approach of Section 2 does not pick-up. In non-technical terms, these floors are invisible to the model as negative rates have not been observed in history.[6] In consequence, we outline below an approach which is suited to address the non-linearity.

3.2. The econometric approach

To simulate hypothetical negative rates for each bank we estimate a set of separate econometric models: one for each bank and P&L item. This is necessary to account for the floor on deposits. As a drawback of this large number of models, each one uses a smaller dataset. As a merit, the approach allows for bank-specific sensitivities to changes in the interest rate level. Bank-by-bank results that pay heed to the individual portfolio sensitivity of banks means that the results can also enter top-down stress tests. Additionally and most importantly, we can restrict the forecast for those P&L items with a legal floor to zero and thereby simulate the effect of interest rates never visited in history.

Using the regulatory reporting system containing detailed P&L statements of each bank for each quarter, we forecast these individual P&L items by a seasonal $ARIMA(p_{i,j}, d_{i,j}, q_{i,j}, P_{i,j}, D_{i,j}, Q_{i,j})_m$ time series model:

$$\Phi(B^m)\,\phi(B)\,(1-B^m)^{D_{i,j}}\,(1-B)^{d_{i,j}}(y_{t,i,j}-\mu_{i,j}) = \Theta(B^m)\,\theta(B)\,\epsilon_{t,i,j}, \tag{2}$$

where $\{\epsilon_{t,i,j}\}$ is a white noise process with mean zero and variance $\sigma^2_{i,j}$, B is the back-shift operator, m the length of seasonality (ie. four quarters in one year), $\phi(z)$, $\Phi(z)$, $\Theta(z)$ and $\theta(z)$ are polynomials of order $p_{i,j}$, $P_{i,j}$, $Q_{i,j}$ and $q_{i,j}$ respectively and $y_{t,i,j}$ is the P&L item i of bank j at time t with mean $\mu_{i,j}$.

For P&L items that are sensitive to interest rates (see Table 3 for an overview[7]) we add the exposure specific to that item[8] times the Euribor rate as an exogenous regressor, so the model becomes

$$(1-B^m)^{D_{i,j}}\,(1-B)^{d_{i,j}}(y_{t,i,j}-\mu_{i,j}) = \gamma'_{i,j}\,(Euribor_t\,Exp_{t,i,j}) + \gamma''_{i,j}\,(Euribor_{t-1}\,Exp_{t,i,j}) + \eta_{t,i,j} \tag{3}$$

[6] The recent rates are a period too short and too close to zero to gain a reliable statistical estimate.

[7] The P&L structure we use is finer than depicted in Table 3. E.g. for interest from customer loans there is a further division into income from domestic and non-domestic customers and into EUR-amounts and foreign currency amounts.

[8] The regulatory reporting system provides for each interest bearing P&L item the asset or liability value associated with generating this income or expense. This is a great feature of our database.

$$\Phi(B^m)\,\phi(B)\,\eta_{t,i,j} = \Theta(B^m)\,\theta(B)\,\epsilon_{t,i,j}. \tag{4}$$

$\gamma'_{i,j}$ and $\gamma''_{i,j}$ are coefficients measuring the sensitivity of the incomes or expenses to the interest rate level. Economically, these coefficients measure how fast reference rates are passed on to the banks' creditors and debtors. Again a subset of these positions is floored to zero, the interest expenses concerning deposits. To include this legal situation in the model, we replace $y_{t,i,j}$ by $\max(0, y_{t,i,j})$ if i is the cost of deposits (Table 3). This restriction is important when we use the ARIMA models for forecasting under varying scenarios (see below).

In words, the approach outlined above models interest sensitive P&L items of each bank as a function of the interest rate level times the exposure to that item. For instance, the interest income from mortgage loans depends on the size of the mortgage portfolio times the current reference rate (captured by $\gamma'_{i,j}$ above where i would correspond to the P&L item "income from mortgage loans"). As many loan contracts stipulate a slower reaction of rates charged to changes in the reference rate, we also add the lagged reference rate times the (current) exposure to that item (captured by $\gamma''_{i,j}$ above). We know that many more factors influence revenues and expenses that differ from P&L item to item and from bank to bank. In consequence, we need to model the error term in a flexible function of its own past values (the AR-component, $\phi(B)$) and recent shocks (the MA-component, $\theta(B)$).

To estimate the effect of negative rates on banks' profits, we proceed as follows: First, we estimate for each bank and for each P&L item an ARIMA model as described above. The order of the polynomials is chosen by following Hyndman & Khandakar (2008). Second, we use the model for forecasting eight quarters into the future, whereby we hold the exposure constant ("constant balance sheet assumption") but vary the reference rates. Although the constant balance sheet assumption is convenient, it might not be completely unrealistic and can be (theoretically and empirically) supported by the so-called adjustment cost theory (Elyasiani et al., 1995; Kopecky & Van Hoose, 2004a,b, 2012). These papers assume theoretically and test empirically that there are quadratic costs associated with changing the volumes of loans and deposits. As a consequence banks cannot change their complete portfolio overnight to adjust to a new interest scenario. For the reference rate we use three scenarios. *Scenario(-1)* assumes a drop of reference rates to -1%, *Scenario(-2)* explores the extremes and assumes a reference rate of -2%. *Scenario(+1)* for comparison purpose calculates banks' profitability under a reference rate of +1%.[9] Third, we re-construct the main positions (esp. net interest income and earnings before risk costs and taxes) by aggregating over the individual positions and present the results for each banking sector. The sectors that we use and key summary statistics are displayed in Table 4.

3.3. Results

By following the approach outlined in the previous section we estimate 14,739 ARIMA models. While it is difficult to summarize such a high number of models, Appendix D gives a try. The ARIMA models

[9] In all three scenarios the reference rate does not vary over the eight quarters forecast horizon. Our scenarios could also be seen as being part of a stress test (see Schuermann, 2014, for a more complex stress testing model).

Table 3: **Summary of the P&L structure used in the ARIMA approach.**

P&L item	Separate ARIMA model	Interest sensitive	Floored at zero
1. Interest income			
Interest income from interbank loans	yes	yes	
Interest income from non-bank cust. loans	yes	yes	
Interest income from bonds	yes	yes	
Interest income from other	yes	yes	
2. Interest expenses			
Interest expenses from interbank loans	yes	yes	
Interest expenses from non-bank cust. deposits	yes	yes	yes
Interest expenses from bonds issued	yes	yes	
Interest expenses from other	yes	yes	
3. Net interest income (1+2)			
4. Income from equity positions	yes	yes	
5. Fee and commission income	yes		
6. Fee and commission expenses	yes		
7. Net income from other financial transactions	yes		
8. Other income	yes		
9. Administrative expenses	yes		
10. Other expenses	yes		
11. Earnings before risk costs and taxes (3+4+5+6+7+8+9+10)			

Table 4: Summary statistics of sectors: means across banks and last eight quarters.

Sector	Total assets (mEUR)	Deposit share (% of TA)	Loans to cust. (% of TA)	Net interest income (% of total earnings)	Net interest margin (% of TA)
Car finance banks	708.75	63.79	78.37	59.04	2.32
Branches	494.48	50.37	31.60	30.12	0.88
Building societies and housing finance banks	3300.88	33.86	41.45	96.42	0.72
Large banks	33009.89	34.63	34.43	32.88	0.72
Medium universal banks	5802.67	52.19	70.62	66.96	1.65
Private stock banks	697.91	70.81	27.22	17.84	0.78
Raiffeisen banks	258.18	79.30	58.92	64.57	1.80
Sparkassen	1349.13	72.18	67.82	60.84	1.69
Specialized institutions	2487.84	26.37	52.88	42.77	1.07
Volksbanks	705.71	79.07	68.33	60.98	1.86

chosen most frequently are of order (0,0,0,0,0,0) and (1,0,0,0,0,0), thus typically with no seasonal components, no MA term and one or no autocorrelation term. However, the orders chosen differ from bank to bank and from P&L item to P&L item. The Euribor sensitivities ($\gamma'_{i,j} + \gamma''_{i,j}$ in eq. (3)) are reasonable. We find a low sensitivity for income from bonds and a high one for income from interbank loans with a sensitivity for loans to customers (domestic, non- domestic, in EUR and in foreign currency) moderately high.

In what follows, we will focus our attention to the results of our scenario analysis. Table 5 depicts the net interest margin (NIM) for banks under the scenarios considered. Looking at the last two columns of the table, Δ(-1) and Δ(-2), we see that negative reference rates would have a profound impact on banks profitability. Under a reference rate of -1% this impact ranges from (a median of) -43.4bps in the Volksbanken sector to -5.8bps for large banks. Under the extreme assumption of a a reference rate of −2% the impact is generally scaled by a factor larger than two, ranging from −90.6bps to −11.6bps. Looking at the last row, "all banks", we see that in case of a reference rate of −2% median NIM is 98.6 basis points or −66.7 less than current levels. While this is a substantial decline, NIM still remains fairly positive under this extreme reference rate and the assumption (that the model automatically takes) that there is little adaptation from the side of banks.

Let us compare the model outcome with that of Section 2 which estimated a 16.4bps rise in NIM when reference rates increase 100bps (at current levels). The model employed here comes to a very similar estimate (19.2bps for 119bps increase[10], see Table 5 last row). However, the panel model of Section 2 did not take the non-linear floor on deposits into consideration — which is irrelevant in normal times. To be more precise it only explains the NIM, not its main components such as different sources of interest income and expenses (see Table 3). These components are only approximated by the share of certain assets and liabilities (volumes) on the balance sheet. Therefore the panel model's estimate was a symmetrical one: it also predicted a 16.4bps *drop* in NIM when reference rates *decrease* 100bps. This is where the

[10]The last Euribor rate entering the model is -0.19% for 2016Q1.

models disagree. The ARIMA approach employed in this section disentangles the NIM, taking the floor on deposits into account and casts a more meager picture on the profitability of banks under negative rates. It predicts a decline of -29.8bps in NIM if reference rates dive to -1% and of -66.7bps if they dive to -2% — substantially more than predicted without taking the floor on deposits into account.

Table 5: Net interest margin of sectors in bps across scenarios, where ”realized” is the average of the last four quarters, ”Scen.” are the three scenarios and ”Δ” are differences between scenario- and realized values. Medians for each sector. Sectors are ordered by last column.

Sector	realized	Scen.(+1)	Scen.(-1)	Scen.(-2)	Δ(+1)	Δ(-1)	Δ(-2)
Volksbanks	176.9	194.3	133.5	86.3	17.4	-43.4	-90.6
Car finance banks	244.9	247.1	212.3	173.9	2.3	-32.6	-71.0
Raiffeisen banks	170.8	189.6	141.0	104.8	18.8	-29.8	-66.0
Sparkassen	161.8	184.8	137.4	99.2	23.0	-24.4	-62.5
Medium universal banks	153.5	151.8	122.2	95.4	-1.7	-31.4	-58.2
Specialized institutions	110.1	103.7	76.5	53.5	-6.4	-33.6	-56.6
Branches	64.5	65.2	26.1	10.7	0.8	-38.4	-53.7
Private stock banks	59.6	110.3	43.4	27.5	50.8	-16.1	-32.0
Building societies and housing finance banks	58.8	54.7	44.5	38.8	-4.1	-14.4	-20.0
Large banks	79.2	113.1	73.4	67.6	33.9	-5.8	-11.6
All banks	165.3	184.5	135.5	98.6	19.2	-29.8	-66.7

Concerning banking sectors, there are two clusters in the results: large banks, building societies and housing finance banks and private stock banks are hit less hard, while in all other banking sectors' NIM decreases more substantially. Large banks hold a lower deposit share, are more strongly financed through interbank-liabilities and bonds issued and are better hedged against interest rate movements. Also, the share of equity positions on the asset side is considerably larger. Building societies and housing finance banks' main asset class (”Bauspardarlehen”) benefits from a contractual interest rate floor of 3% rendering this sector hardly sensitive to negative rates.[11] Private stock banks have a stronger focus on private wealth management with lower deposit finance and are therefore less exposed to the asymmetric dilemma. For all the other sectors these arguments are not valid and are thus impacted much stronger.[12]

Smaller banks focusing on the regional retail banking business, such as Volksbank credit cooperatives, savings banks and Raiffeisen credit cooperatives, are hit hardest. Somewhat surprisingly, the car finance sector also appears among those sectors that are strongly impacted by negative rates. Looking at the data we see that this sector's asset side reacts more sensitively than the other sectors on average to changes in the reference rate implying a strong contractual link between the reference rate and the interest charged. If we compare the ranking of sectors in the last two columns, we see some differences, but the two

[11] However, the floor together with low or negative reference rates is likely to trigger a reduction in volume as the product becomes less competitive. Due to the constant balance sheet assumption employed here, this effect is not captured.

[12] The specialized institutions sector is a zoo of very different animals, including bad banks, credit card companies and factoring banks, which is why we do not discuss this catch basin in detail.

Table 6: Return on Assets before risk costs and taxes of sectors in bps across scenarios, where "realized" is the average of the last four quarters, "Scen." are the three scenarios and "Δ" are differences between scenario- and realized values. Medians for each sector. Sectors are ordered by last column.

Sector	realized	Scen.(+1)	Scen.(-1)	Scen.(-2)	Δ(+1)	Δ(-1)	Δ(-2)
Volksbanks	31.6	23.0	-40.1	-88.3	-8.6	-71.8	-119.9
Branches	54.4	48.5	-6.5	-27.0	-5.9	-61.0	-81.5
Raiffeisen banks	69.5	86.3	36.1	-2.5	16.8	-33.4	-71.9
Sparkassen	78.0	102.0	52.4	13.5	24.1	-25.5	-64.5
Medium universal banks	75.3	90.7	42.6	16.3	15.4	-32.7	-59.0
Private stock banks	15.1	64.1	12.7	-34.2	49.0	-2.4	-49.4
Specialized institutions	106.6	137.3	83.9	69.5	30.7	-22.7	-37.1
Automotive banks	69.6	136.5	76.3	34.1	66.9	6.7	-35.5
Building societies and housing finance banks	15.6	9.7	9.4	5.2	-5.9	-6.2	-10.3
Large banks	72.6	115.4	91.0	62.6	42.8	18.4	-10.0
All banks	65.6	86.6	36.8	-0.6	21.1	-28.8	-66.2

clusters (the bottom three sectors and the rest) are still very distinct. In consequence, the effects driving the results for any single bank is a combination of (i) how sensitive the asset side reacts to changes in the reference rate and (ii) how much of the liability side is floored at zero. Both factors can be influenced in a number of ways, e.g. whether the asset side structure has a higher shares of equities or other assets like real estate, whether interest rate hedges like swaps or interest rate floors (e.g. as in for building societies) are in place etc. Given the distance of current reference rates (-0.19% for Q1 2016) to the extreme -2% simulated above, banks will have time to adapt as conditions change. Of course it is difficult to simulate such adaptive behavior on the side of banks. This is why the "constant balance sheet assumption" is applied (see Section 3.2) which ignores the adaptation behavior of banks. In consequence the results presented here can be understood as a particularly severe case, an extreme reference rate and without adaptive behavior.

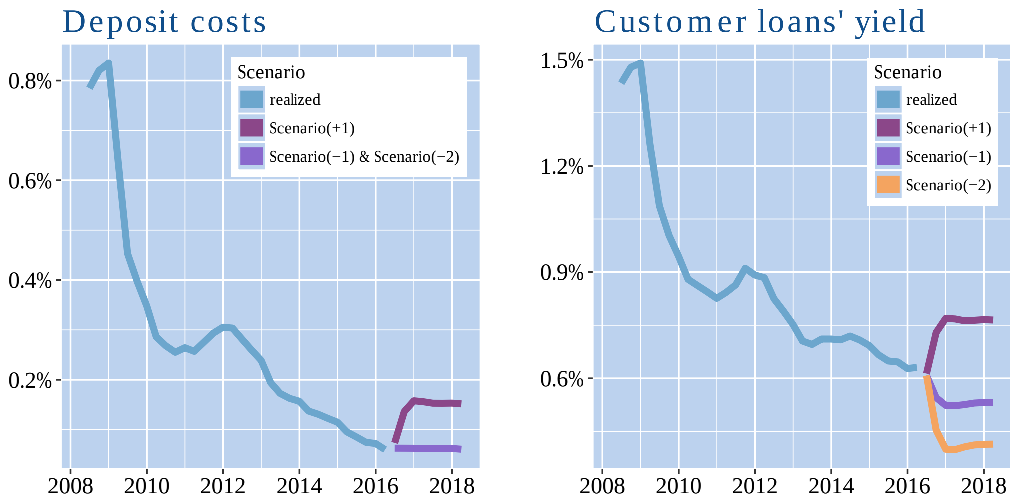
The asymmetric dilemma responsible for squeezing NIM is also depicted in Figure 2 which shows that while deposits costs have reached a level close to zero (long term deposits keep the costs above zero) and do not fall if the reference rate drops further into the negative, the yield on customer loans follows the reference rate and would decrease further. Although the yield on customer loans would remain positive it would not be sufficient to cover costs for the majority of banks.

This is also shown in Table 6 which depicts the Return on Assets (before risk costs and taxes)[13] in bps for all sectors and across scenarios.[14] The major differences to the NIM in Table 5 is that income from equity exposure, net fee and commission income, administrative expenses and other income and expenses are considered. In total (last row of Table 6) the impact in all three considered scenarios is very similar to the

[13] Position 11 in Table 3 divided by total assets.

[14] Risk costs in the P&L statements are not available on a quarterly basis.

Figure 2: Deposits costs (left hand panel) and customer loans' yields (right hand panel) in percent of respective volumes over time. Median across all banks.



NIM with only few basis points deviation. Individual sectors are hit harder, e.g. branches, or less hard, e.g. car finance sector. However, as the P&L items that are added compared to the looking at NIM are prone to one-off effects that make forecasting difficult, we focus on the NIM result.

4. Summary and conclusions

In this paper we analyze the effects of low and negative rates on the profitability of Austrian banks. We found that banks' NIM is linked to the interest rate environment. The link is strong when reference rates are close to zero (at around 16 basis points per 100 basis points) but — due to nonlinearities — subdued in normal times. Smaller, regional banks are affected more, but this does not trigger a considerable economic impact.

While the above is expected in an environment of low and zero rates, we are skeptical of extrapolating these findings to negative rates. To better investigate negative rates we employ an ARIMA simulations approach that takes into account the asymmetric dilemma that deposit rates are legally floored at zero while loan rates directly track reference rates by breaking the NIM in its components. Using such an approach, we find that negative rates can create a substantial risk burden to the profitability of banks and that smaller deposit-financed banks, in particular, are hit hardest. This finding is important as these banks often do not participate in empirical studies due to a shortage of data. Simulations of reference rates that venture close to of -2% show that under such extreme conditions erode the profits of a large part of the banking system is eroded.

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Appendix A. Summary statistics

Table A.7: Descriptive statistics

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	StD	Data C.
NIM	-3.04	1.64	2.08	2.11	2.59	13.84	0.79	80%
Euribor	-0.19	0.72	2.15	2.29	3.59	5.03	1.60	100%
Euribor^2	-0.03	0.52	4.62	7.83	12.89	25.30	7.77	100%
Term spread	-0.41	0.77	1.41	1.33	1.99	2.99	0.83	100%
Interaction: Euribor x RBD	-0.19	0.00	0.00	0.47	0.00	5.03	1.20	99%
RBD	0.00	0.00	0.00	0.18	0.00	1.00	0.39	99%
Total Assets	5.64	10.77	11.56	11.74	12.41	18.87	1.48	80%
Euro loans to domestic customers	0.00	0.39	0.49	0.48	0.59	1.00	0.17	80%
FX loans to domestic nonbanks	0.00	0.01	0.04	0.07	0.09	0.65	0.08	79%
Loans to foreign customers	0.00	0.00	0.01	0.03	0.02	1.00	0.09	78%
Interbank loans	0.00	0.14	0.20	0.23	0.29	1.00	0.14	80%
Interest-bearing securities	0.00	0.02	0.07	0.09	0.14	1.00	0.09	79%
Nonbank deposits	0.00	0.70	0.79	0.74	0.85	1.00	0.19	80%
Bank deposits	0.00	0.03	0.07	0.11	0.15	1.00	0.13	78%
Securitized debt	0.00	0.00	0.00	0.02	0.00	1.00	0.08	79%
Net fee income	-9.61	0.50	0.65	0.88	0.80	85.03	2.69	80%
Staff expenses	0.00	1.00	1.00	0.94	1.00	1.00	0.17	80%
Other administrative expenses	0.00	0.55	0.70	0.70	0.87	1.00	0.21	80%
RWAs to total assets	0.00	0.48	0.57	0.57	0.67	7.34	0.18	80%
LLP ratio	0.00	0.03	0.04	0.05	0.06	0.71	0.03	79%
GDP growth	-4.71	0.70	1.84	1.68	3.08	4.10	1.78	100%
Unemployment growth rate	-24.18	-8.13	3.10	1.84	7.74	39.34	12.49	100%

Source: OeNB. Data C. defines the percentage of available data (sample period 1998Q1 to 2016Q1 with 946 banks). The other columns to sample statistics. Euribor, long-term interest rates (part of the term spread), NIM and net fee income are annualized rates. Staff expenses and other operating expenses are expressed as yearly costs divided by total assets. Euro loans to domestic nonbanks, FX loans to domestic nonbanks, interbank loans, interest bearing securities, bank deposits, nonbank deposits, securitized debt, RWA, the leverage ratio and the LLP ratio are defined as annual rates. GDP growth and unemployment growth rate are defined as the year-on-year growth rate of real GDP and of the unemployment rate respectively. See also Table 1.

Appendix B. Econometric considerations for choosing the panel model approach

The Breusch-Pagan Lagrangian multiplier test for random effects supports the use of a panel estimator as it rejects the null of poolability at the 1% level, thereby underlining the importance of taking the presence of any type of bank-specific effect into account. Moreover, the Wooldridge test for autocorrelation in panel data rejects the null of no first order autocorrelation in the idiosyncratic error terms at the 1% level (see Wooldridge, 2002; Drukker, 2003). A modified Wald test for groupwise heteroskedasticity likewise rejects the null of homoskedasticity of the idiosyncratic error variances at the 1% level. In the presence of autocorrelation and heteroskedasticity within panels, we have to make a more general assumption about the distribution of the error term and thus employ robust estimators of the variance-covariance matrix. For deciding between fixed or random effects we use the Hausman test.

Appendix C. Interpretation of regression coefficients

Here we discuss those results of the regression presented in Table 2 in more detail that do not have a direct connection to the interest rate level. In general, the results are inline with expectations. Banks engaging in riskier lending as indicated by the RWA density tend to have a higher NIM, as do smaller banks and banks with higher non-staff administrative costs. When risks materialize, banks book loan loss provisions and face non-performing loans which in consequence lowers the NIM. Several regressors describe the composition of the asset or liability side and some explanation is required here: To understand why the fraction of interbank loans on the asset side has a positive contribution to the NIM while these positions are generally considered to yield lower interest than other assets sides, note that this is the case here too. interbank loans show a positive contribution to the NIM but their contribution is less than the one from loans to customers. The reason why the coefficient is positive (and not negative) is that interbank loans contribute (little but non-zero) to the net interest income while other asset side positions yield even less or no interest (e.g. exposure to sovereigns, buildings, intangible assets). The same holds for the liability side where deposits — while being less expensive[15] than e.g. securitized debt — still reduce the NIM of a bank compared to liability positions not included in the regression as e.g. equity. Staff expenses show a negative sign, which we think is caused by banks engaging in fee-, commission- and wealth management activities or trading that tend to have high staff expenses but a low NIM. The only surprising sign is the one on the unemployment growth rate implying a higher NIM when unemployment grows. However, while the coefficient is statistically significant, it is not so economically. Finally, GDP growth has the expected positive effect on the NIM.

To check the robustness of our results in Table 2 we add the lagged net interest margin as an additional coefficient.

$$y_{i,t} = \alpha_i + \phi y_{i,t-1} + X_{i,t}\beta + Z_t\gamma + e_{i,t}, \quad i = 1, \cdots, N, \quad t = 1, \cdots, T, \tag{C.1}$$

To avoid the famous Nickell bias (Nickell, 1981) we use the system GMM estimator for our fixed effects single equation dynamic panel model (Blundell & Bond, 1998).

Overall the results are in line with Table 2. The lagged dependent variable NIM(-1) reduces the size of the other coefficients as described in Achen (2001). Most importantly the coefficient of the Euribor is reduced to 10.5bp, further supporting our new approach for forecasting banks' profitability in a negative interest rates in Section 3.

Appendix D. Summary of ARIMA-output

Figure D.3 shows the summary of the ARIMA models for the most important P&L items. For each P&L item (in rows) the graph shows a distribution of Euribor sensitivities ($\gamma'_{i,j} + \gamma''_{i,j}$ in eq. (3)) across banks in the left panel, the frequency of the respective orders (p, d, q, P, D, Q) in the middle panel and

[15]Note that this comparison takes only the interest expenses into account and not other costs like e.g. branch networks.

Table C.8: Panel estimation result: coefficients and robust standard errors.

		Coefficients	(Standard Errors)
NIM(-1)		0.384***	(0.042)
Euribor		0.105***	(0.020)
$Euribor^2$		-0.000	(0.002)
Term spread		0.090***	(0.008)
Interaction: Euribor x RBD		-0.017**	(0.007)
RBD		0.171***	(0.031)
Total Assets		-0.132***	(0.047)
Euro loans to domestic customers		3.306***	(0.286)
FX loans to domestic customers		3.029***	(0.374)
Loans to foreign customers		1.971***	(0.652)
Interbank loans		1.689***	(0.235)
Interest-bearing securities		2.440***	(0.311)
Nonbank deposits		-0.467*	(0.258)
Bank deposits		-1.299***	(0.272)
Securitized debt		-2.091***	(0.469)
Net fee income		0.012	(0.018)
Staff expenses		-0.018	(0.058)
Other administrative expenses		0.025	(0.025)
RWAs to total assets		0.346***	(0.107)
LLP ratio		-3.369***	(0.593)
GDP growth		0.013***	(0.002)
Unemployment growth rate		0.000**	(0.000)
Hansen J Statistic		878.881	
Hansen p value		0.126	
Number of observations		46904	
Number of groups		902	
Obs per group:	minimum	2	
	average	52	
	maximum	72	

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

This table presents the system GMM estimation of the dynamic panel estimation model. Most importantly the Hansen J test does not reject the null hypothesis that the frequency of order combinations in the left panel. See also Section 3.3 for a short description of the results.

Figure D.3: Summary of ARIMA output for key P&L items.