The Impact of Competition on Bank Risk Taking Under Negative Policy Rates*

William Hodik† and Grim Sjöberg‡

Stockholm School of Economics

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Abstract

We show that competition has a significant impact on the transmission of negative monetary policy rates via bank risk taking. By comparing stock returns for banks before and after the introduction of negative monetary policy rates, it is evident that high-deposit banks in highly competitive financial markets experienced the sharpest decline in net worth. Their inability to charge negative interest rates on deposits, together with high asset- and liability-side competition, put pressure on profitability, reduce net worth and increase risk taking. Therefore, high-deposit banks operating in highly competitive markets experience higher stock return volatility, higher CDS-spread returns and are also prone to invest in riskier asset classes when policy rates go below zero. A placebo test indicates that our findings indeed are a result of negative policy rates, as we see no effect when rates are non-negative. In addition to helping assess the long-term effects of negative monetary policy rates, our results might help further evaluate the well-studied trade-off between competition and financial stability.

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†Email: 23278@student.hhs.se

‡Email: 23307@student.hhs.se

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1 Introduction

The introduction of negative monetary policy rates is an experiment with unknown long-term consequences. What will be the impact on the real economy and will this differ between countries?

This paper builds on the work of Heider et al. (2017), in which they explain how negative monetary policy rates impacts the real economy by inducing riskier lending behavior among deposit-funded banks. We further detail the transmission of interest rates by examining the role of competition in this context. More specifically, we use concentration indices to measure how competition interacts with deposit funding when negative monetary policy rates are introduced. Our findings suggest that the level of competition among banks acts as a moderating variable and has a significant impact on the extent to which negative interest rates stimulate bank risk taking.

As the European Central Bank (ECB) introduced a negative deposit facility rate of -0.10% on June 5, 2014, banks with more deposit funding increased their risk taking (Heider et al. (2017)). The magnitude of this effect is highly impacted by competition as banks' inability to prevent pass-through of negative interest rates on the asset side together with their inability to pass on negative rates to depositors is the mechanism that induces risk taking among deposit-reliant banks. If these deposit-reliant banks can maintain high lending rates, they essentially avoid the interest margin pressure that the negative interest rates otherwise cause.

The fundamental mechanism explaining our results is consistent with that of Heider et al. (2017). Given that retail depositors would likely withdraw their money if banks introduced negative deposit rates, banks with significant deposit funding have limited ability to reduce their funding cost in a negative monetary policy rate environment. If these banks face competitive pressures that together with negative monetary policy rates leads to a reduction in lending rates, their net margin and net worth is negatively impacted. Increased risk taking as a result of a reduction in net worth is consistent with common economic theory about moral hazard and adverse selection.

We use a difference-in-differences approach to strengthen identification. This helps us control for endogeneity problems, such as the general state of the economy, which is a confounding factor that can impact both monetary policy and bank risk taking. By using low deposit banks as a control group, we separate the effect of negative monetary policy rates from confounding factors. By then holding the deposit ratio constant and using high-deposit banks in markets with low competition as a second control group, we display the role of competition in the context of negative monetary policy rates.

In line with Heider et al. (2017), we look at the impact on risk taking of having a high deposit ratio during times of negative monetary policy rates. To this, we add a second variable, which is the triple interaction of the deposit ratio, the negative monetary policy rate, and the level of competition. The latter is proxied by market concentration indices. The results using the triple interaction variable show that low competition offsets all or part of the effect on risk taking associated with a high deposit ratio when negative policy rates are introduced. The difference-in-differences approach implies that this is a result of pass-through of the negative policy rate as time-invariant differences between the groups are eliminated. This relies on the assumption that without the introduction of a negative monetary policy rate, the treatment and control groups would have parallel trends. In a supplementary regression, we confirm that this assumption holds pre-treatment by adding a placebo treatment. One year before the introduction of negative monetary policy rates, there should be no diversion or convergence in net worth or risk taking between the treatment and control groups. We find that the placebo variables are insignificant, supporting the validity of our difference-in-differences methodology.

Bank and country-month-year fixed effects are applied to further strengthen identification. While the difference-in-differences approach is limited to capturing time-invariant differences between the treatment and control groups, bank fixed effects control for any time-invariant characteristics of individual banks in our sample. This could for example be the organisational structure or firm culture of a specific bank, given that these factors are constant over time. The country-month-year fixed effects capture time-variant characteristics for certain countries. This avoids distortion of our results from peculiar periods in certain countries, such as Greece in June 2015, where some of the risk measures we use spiked due to sovereign default worries. Such controls are essential to study the impact of competition since the concentration indices used to measure competition are constant across time and firms in a given country. By including the country-month-year fixed effects, we only examine how competition impacts the magnitude of the deposit ratio effect when negative interest rate are introduced. In other words, when country-month-year fixed effects are used, competition is only relevant to include as a triple interaction variable with the deposit ratio and a dummy variable for negative policy rates. Because our time-series of observations for a given bank are not independent of each other, robust standard errors are clustered at the bank level.

We first verify that the results of Heider et al. (2017) applies to our dataset by showing that high-deposit banks increase their stock return volatility and CDS-spread returns more than low-deposit banks when negative policy rates are introduced. Our triple interaction variable then shows that high market concentration, i.e. low competition, can offset this effect. In other words, high-deposit banks' response to negative policy rates depends on the level of competition in their domestic market. In our baseline regression, market concentration is measured using the Herfindahl-Hirschman Index based on total assets for credit institutions in a given country. Assuming a deposit ratio equal to the top tercile mean value of each sample, a one standard deviation decrease in the Herfindahl-Hirschman Index is associated with a 24.2% and 18.8% increase in the stock return volatility and CDS-spread return, respectively. Our results are also robust to using the market share of the top five credit institutions in a country as a measure of market concentration.

To verify that we measure risk taking appropriately, we show that the results also hold when risk taking is measured as the quarterly percentage change in RWA density, which is a regulatory accounting measure of the riskiness of the bank's asset composition. The idea is that banks suffering from a reduction in net worth due to negative policy rates will shift their asset composition to riskier assets, which our results support.

The validity of our results is tested by two more robustness checks. Firstly, we extend the event window such that it ends in December 2015, instead of February 2015. The reason our baseline regression ends in February 2015 is that the ECB launched its public sector purchase program (PSPP) in March 2015, which is a potential issue for identification. Secondly, we add Swedish and Danish banks to the sample, whom faced negative policy rates at other points in time than the Eurozone banks. Our results are robust to this inclusion, hence it is unlikely that they were driven by any peculiar characteristics of the Eurozone.

Our findings might help further explain what impact negative monetary policy rates have on the real economy. Increased bank risk taking can be desirable if it translates to economic growth. Heider et al. (2017) show that high-deposit banks lend less, but also that their increase in risk taking overcomes credit rationing and that this leads to higher investment by risky borrowers. The latter could have a positive impact on economic growth. Our contribution could therefore potentially help explain how negative policy rates stimulate economic growth more in some countries than in others. A downside of increased bank risk taking is its potentially negative impact on financial stability. Therefore our contribution might also add an additional piece of support to the commonly studied trade-off between competition and financial stability.

1.1 Related Literature

Hicks (1937) wrote; "If the cost of holding money can be neglected, it will always be profitable to hold money rather than lend it out, if the rate of interest is not greater than zero. Consequently the rate of interest must always be positive". As negative interest rates are unprecedented and the long-term effect of it still is unknown, few papers have examined how such an expansive monetary policy translates to the real economy, and when connecting monetary policies to the real sector most of them focus on an environment where interest rates are and remain positive (Bernanke & Gertler (1995); Kashyap & Stein (2000); Jiménez & Ongena (2012); Ioannidou et al. (2015); Paligorova & Santos (2016); Dell'Ariccia et al. (2017); Di Maggio & Kacperczyk (2017)).

Heider et al. (2017) further develop the risk-taking scenario under negative monetary policy rates and describe how negative interest rates affects the real economy by inducing riskier behavior among banks with more deposit funding. The argument builds on banks' reluctance to pass on negative rates to their depositors, whom in the case of negative deposit rates would withdraw their money and hoard cash.

As the primary goal of this paper is to examine how the effects of negative monetary policy rates are related to domestic competition between banks, we look at how the effect presented by Heider et al. (2017) differs across financial markets. Several papers describe that banks tend to become riskier when operating in highly competitive markets (Keeley (1990); Jiménez et al. (2013)). Low competition among banks has therefore often been seen as beneficial to financial stability. Boyd & De Nicolo (2005) argue that there are other mechanisms that work in the opposite direction, causing banks to take on more risk in less competitive markets. Martinez-Miera & Repullo (2010) further develop this by suggesting that the relationship between bank competition and financial stability is U-shaped. Even though the trade-off between competition and financial stability is well debated, papers in this area focus exclusively on environments with positive policy rates. We bring the discussion below zero, and aim to empirically examine the role of bank competition for the effect of negative monetary policy rates on bank risk taking. By doing this, we hope to contribute to the research on both negative monetary policy rates and the trade-off between competition and financial stability.

2 Data and Empirical Methodology

In this section, we start by giving a short background on the introduction of negative monetary policy rates before presenting the theory on which we build our hypothesis. Lastly, a description of both the data and methodology will be provided.

2.1 Institutional Background

On June 5, 2014, the European Central Bank (ECB) lowered its deposit facility rate to -0.10% from 0.00%, thereby introducing negative monetary policy rates in the Eurozone for the first time in history. The deposit facility rate was then lowered to -0.20%, -0.30%, and -0.40% in September 2014, December 2015 and March 2016, respectively. The deposit facility rate is relevant because short-term market rates, such as the Euro overnight interbank rate, tend to closely follow the deposit facility rate when markets are stable and banks have enough excess liquidity. Therefore, the deposit facility rate is important for banks' funding cost.

Negative monetary policy rates have not only prevailed in the Eurozone, but also in Japan, Switzerland, Denmark, and Sweden. The latter two are the most relevant for our purposes given the availability of Swedish and Danish data, as well as the peculiar characteristics of the Swiss and Japanese banking markets. Nationalbanken, the Danish central bank, was globally the first central bank to introduce negative monetary policy rates when they lowered the deposit rate to -0.20% on July 5, 2012. The Danish deposit rate was then raised to 0.05% on April 24, 2014 and lowered to -0.05% on September 5, 2014. The Swedish Riksbank introduced negative monetary policy rates by lowering the repo rate to -0.10% on February 18, 2015. Bech et al. (2016) provide a detailed description on how central banks have implemented negative monetary policy rates.

2.2 Hypothesis Development

A bank's net worth (the difference between its assets and liabilities) can be seen as a mediating variable for its risk taking. A lower net worth disincentivizes bank managers to make prudent investment decisions by causing adverse selection (Stein (1998)) and moral hazard problems (Holmstrom & Tirole (1997)). When the net worth is high enough and there is no debt overhang, managers are equally exposed to the downside and the upside scenarios, thereby reducing incentives for excessive risk taking. If the net worth is lower, external lenders are exposed to downside scenarios. Given that these external lenders also have inferior information about the quality of the bank's assets, they will require an external finance premium (Bernanke (2007)). The external finance premium causes adverse selection problems in a reverse causality loop, where it is only worthwhile for banks to pay the external finance premium if they also engage in excessive risk taking, which in itself justifies an even higher external finance premium.

Even though most research prove that banks hold more risky assets under periods with easing monetary policies, the theory behind it can be rather equivocal. In general, monetary policy affects both the asset and the liability side of a bank's balance sheet (Dell'Ariccia et al. (2017) and Dell'Ariccia et al. (2014)). At first, lower policy rates would translate into lower lending rates, hence reducing the bank's net worth, all else equal. On the other hand, a reduction in policy rates would also lead to lower funding costs, thereby increasing net worth, all else equal. This means that the net effect on the bank's net worth should be limited.

However, during times of negative monetary policy rates the situation will be different. As the pass-through of negative interest rates to the liability side of the bank's balance sheet is mitigated by their inability to charge depositors negative rates, deposit funded banks mainly experience pass-through on the asset side via lower lending rates. Consequently, deposit-funded banks experience a negative net effect of negative rates, which reduces net worth.

In addition, asset-side competition in banking markets most certainly affect the rates banks charge their customers. According to common economic theory, higher competition should translate into lower lending rates. Contrary, low competition could allow high-deposit banks to maintain high lending rates when the policy rates become negative. Thus, banks in highly competitive markets should experience more pass-through of negative rates on the asset side compared to those in less competitive markets. However, high asset-side competition is most likely synonymous with high liability-side competition. Prior to the introduction of negative monetary policy rates, deposit funded banks operating in highly competitive markets should have relatively high funding costs compared to those operating in less competitive markets. As a result, when negative policy rates are introduced, deposit-funded banks in highly competitive markets would be able to decrease their funding cost to a greater extent before hitting the zero percent lower bound on deposit rates. As deposit-reliant banks in less competitive markets are closer to the zero lower bound on deposits when rates are positive, they "hit the floor" earlier when rates become negative. Accordingly, deposit funded banks in highly competitive markets could potentially see greater pass-through of negative policy rates to depositors than banks in less competitive markets. On the other hand, when operating in a highly competitive market, banks would in general have a harder time lowering their deposit rates. Some banks operating in low-competition environments could potentially even be able to charge negative deposit rates, particularly to customers who cannot use cash as a substitute for deposits. Banks operating in high-competition environments would on the other hand be unlikely to pass through negative rates to these customers, whom would likely just switch to a competitor with non-negative deposit rates. All in all, the net effect of having high liability-side competition under negative policy rates is unclear and likely varies across banks and markets. Taking into account that high asset-side competition clearly speaks for a disadvantage for high-deposit banks operating in highly competitive markets, we expect the net effect on net worth to be negative for these banks, in relation to high-deposit banks operating in less competitive markets.

To conclude, the effect of competition on banks' net worth and bank risk taking under negative policy rates is also rather ambiguous. Heider et al. (2017) proved that when negative policy rates were introduced, deposit-reliant banks increased their risk taking relative to banks mainly financed through capital markets. We argue that this effect differs between countries due to differences in the competitive dynamics. Even though we see contradictory effects from liability-side competition on banks' net worth under negative policy rates, we believe that differences in pass-through on the asset-side will drive the direction of the net effect. We therefore predict high competition to be associated with a lower net worth and higher risk taking among high-deposit banks when negative monetary policy are introduced. Consequently, our hypothesis can be formulated as follows:

Hypothesis

Due to more pass-through of negative monetary policy rates to customers on the asset side than the liability side, high-deposit banks increase their risk taking relative to low-deposit banks. This effect is stronger in highly competitive markets compared to less competitive markets.

2.3 Methodology & Robustness Assessment

We use a difference-in-differences approach by comparing risk taking among banks with different deposit ratios and different levels of competition in their home markets before and after the introduction of negative monetary policy rates in June 2014. Low-deposit banks serve as a control group to separate the effect of negative policy rates from other factors, such as the general state of the economy, which should impact banks with high and low deposit ratios equally. High-deposit banks in low-competition markets serve as a second control group to display how the effect of negative monetary policy rates on bank risk taking varies across markets. High-deposit banks in highly competitive environments serve as our treatment group. A placebo test verifies that the groups follow parallel trends before treatment, which is necessary for the methodology.

Before looking at changes in risk taking, we look at the underlying mechanism that drives this change, which is the reduction in net worth. High-deposit banks in highly competitive markets should experience worse stock returns than low-deposit banks and high-deposit banks in markets with low competition, when negative policy rates are introduced. Equation 2.1 presents the regression.

$$y_{jt} = \beta_1 Top\ tercile_j \times After(06/2014)_t + \beta_2 HHI_i \times Top\ tercile_j \times After(06/2014)_t$$
$$+\gamma_{it} + \eta_j + \epsilon_{jt} \tag{2.1}$$

Where:

$$\begin{aligned}
y_{jt} &= Monthly\ stock\ return_{jt} \\
Top\ tercile_j &= \text{Dummy variable for the top tercile banks by 2013 deposit ratios} \\
After(06/2014)_t &= \text{Dummy variable for the period from June 2014 onwards} \\
HHI_i &= \text{Herfindahl-Hirschman Index 2013 for banks in country } i \\
\gamma_{it} &= \text{Country-month-year fixed effects} \\
\eta_j &= \text{Bank fixed effects} \\
\epsilon_{jt} &= \text{Standard errors clustered at the bank level}
\end{aligned}$$

In Equation 2.1 we expect the β_1-coefficient to be negative, meaning a relative reduction in net worth for high-deposit banks after the introduction of negative monetary policy rates. The β_2-coefficient is expected to work in the other direction, showing that a reduction in net worth is less prevalent for high-deposit banks in low-competition markets.

As the reduction in net worth is the mechanism that causes banks to become more risky, we extend the regression to look at our risk-taking measures. Two different measures of risk are used in the baseline regression. The first measure is the logged unlevered monthly standard deviation of daily stock returns for each bank in our sample. The standard deviation is unlevered by multiplying it with the bank's equity-to-assets ratio. Without this adjustment, the standard deviation would be higher for banks with high leverage as not only asset risk would be captured. The bank's asset risk is an important measure of its default risk according to the Merton (1974) model. Stock returns, deposit ratios and equity-to-asset ratios for this regression are from Bloomberg. The second measure is the logged monthly CDS-spread return for each bank. CDS spreads and deposit ratios for this regression are from Thomson Reuters Datastream. As the CDS spread is a function of a bank's credit default risk, higher risk taking should translate to a higher CDS spread.

Before running our baseline regressions we verify that the results of Heider et al. (2017) hold for our sample of banks. To replicate their results, we formulate the regression in the following way:

$$y_{jt} = \beta_1 Deposit\ ratio_j \times After(06/2014)_t + \gamma_t + \eta_j + \epsilon_{jt} \tag{2.2}$$

Where:

$$\begin{aligned}
y_{jt} &= \ln(\sigma(Stock\ return_{jt})^{1m})\ or\ \ln(CDS\ return_{jt})^{1m} \\
Deposit\ ratio_j &= \text{Total deposits} \div \text{total assets in 2013 for bank } j \\
After(06/2014)_t &= \text{Dummy variable for the period from June 2014 onwards} \\
\gamma_t &= \text{Month-year fixed effects} \\
\eta_j &= \text{Bank fixed effects} \\
\epsilon_{jt} &= \text{Standard errors clustered at the bank level}
\end{aligned}$$

In Equation 2.2 we hypothesize the β_1-coefficient to be positive, implying that high-deposit ratios are associated with higher risk taking under negative monetary policy rates. We then amend the regression equation to test the impact of competition. Competition is assumed to be closely linked to market concentration, for which we use the Herfindahl-Hirschman Index (HHI) from 2013 based on total bank assets. To verify our results, we also change the market concentration measure to the 2013 market share of the top five credit institutions by total assets in a country. The data on both of these measures are collected from the ECB's Statistical Data Warehouse. Figure 4 on page 27 shows the Herfindahl-Hirschman Index and the top five banks' market share for all the countries in the Eurozone including Sweden and Denmark. Lastly, the final regression equation can be formulated as follows:

$$y_{jt} = \beta_1 Deposit\ ratio_j \times After(06/2014)_t + \beta_2 HHI_i \times Deposit\ ratio_j \times After(06/2014)_t$$
$$+\gamma_{it} + \eta_j + \epsilon_{jt} \tag{2.3}$$

Where:

$$\begin{aligned}
y_{jt} &= \ln(\sigma(Stock\ return_{jt})^{1m})\ or\ \ln(CDS\ return_{jt})^{1m} \\
Deposit\ ratio_j &= \text{Total deposits} \div \text{total assets 2013 in for bank } j \\
After(06/2014)_t &= \text{Dummy variable for the period from June 2014 onwards} \\
HHI_i &= \text{Herfindahl-Hirschman Index 2013 for banks in country } i \\
\gamma_{it} &= \text{Country-month-year fixed effects} \\
\eta_j &= \text{Bank fixed effects} \\
\epsilon_{jt} &= \text{Standard errors clustered at the bank level}
\end{aligned}$$

In Equation 2.3 we expect to see that a high deposit ratio is associated with higher risk taking, while high market concentration has an opposite relationship with risk taking, meaning that the β_2-coefficient will be negative. Furthermore, by multiplying the Herfindahl-Hirschman Index with the components of the first explanatory variable, we test how competition impacts the magnitude of the effect showed by Heider et al. (2017). Any other effects related to market concentration will be captured by the country-month-year fixed effects. Time-varying effects specific to a country are also captured, such as Greece in June 2015, where some of the risk measures we use spiked due to sovereign default worries. The bank fixed effects capture time-invariant effects that are specific to a bank, such as the organisational structure if it is constant over time. This is different from the effects captured by the difference-in-differences approach, which only control for time-invariant differences between the treatment and control groups.

In a supplementary regression we verify that high- and low-deposit banks, as well as banks in markets with high and low competition, follow parallel pre-treatment trends. This is done by adding placebo variables that are identical to our original variables with exception for the treatment date, which is set one year earlier to June 2013. There should be no significant correlation between the placebo variables and banks' net worth or risk taking given that we only expect such a relationship when negative monetary policy rates are introduced.

The time window used in our baseline regressions runs from January 2013 to February 2015, ending just before the launch of the ECB's public sector purchase program (PSPP) in March 2015. The PSPP could potentially strengthen the effect we are trying to observe by further reducing market interest rates. It could however also impact bank risk taking in other ways as well, making identification difficult. We choose to take the safer route to identification in our baseline regressions, while also running additional supporting regressions with a time window from January 2013 to December 2015.

When selecting the sample of banks, we try to make it as wide as possible and use Bloomberg and Thomson Reuters Datastream to screen for Eurozone banks that have the relevant data available. However, Bloomberg and Thomson Reuters Datastream fail to classify the industry for some banks, hence our sample cannot be assumed to be fully exhaustive despite efforts to manually add missing banks. Banks of smaller size or with unusual business models are most likely to be missing from our sample. We then further reduce our sample by eliminating banks with highly illiquid stocks or CDS contracts, as extremely low liquidity makes it inappropriate to use standard deviation of stock returns and CDS-spread returns as measures of risk taking. For our baseline regressions we end up with 58 and 39 banks for the standard deviation of stock returns and CDS-spread return samples, respectively.

Table 1: Summary Statistics by Sample

		Mean	Std. Dev.	Min	Max
Standard deviation of stock returns					
Deposit ratio - Entire sample (%)		44.36	17.06	9.77	85.69
Deposit ratio - Top tercile (%)		62.63	9.86	51.89	85.69
Deposit ratio - Bottom tercile (%)		25.88	6.04	9.77	34.19
Number of banks in sample	58				
Number of countries in sample	13				
Herfindahl-Hirschman Index		0.12	0.08	0.03	0.31
CDS-spread return					
Deposit ratio - Entire sample (%)		43.43	13.81	9.62	62.34
Deposit ratio - Top tercile (%)		60.97	1.20	59.19	62.34
Deposit ratio - Bottom tercile (%)		22.74	7.74	9.62	30.86
Number of banks in sample	39				
Number of countries in sample	10				
Herfindahl-Hirschman Index		0.09	0.07	0.03	0.21
RWA density					
Deposit ratio - Entire sample (%)		46.72	11.17	21.01	61.17
Deposit ratio - Top tercile (%)		58.52	1.72	56.50	61.17
Deposit ratio - Bottom tercile (%)		32.63	6.23	21.01	40.08
Number of banks in sample	30				
Number of countries in sample	10				
Herfindahl-Hirschman Index		0.12	0.09	0.03	0.31

Notes: The table shows descriptive statistics for the deposit ratio distributions as well as the Herfindahl-Hirschman Index for our Eurozone samples.

Another robustness check we use is to add Swedish and Danish banks to the sample of banks. The sample size increases to 75 and 44 banks for the standard deviation of stock returns and CDS-spread return regressions, respectively (see Table 6 on page 28 for summary statistics). The dummy variable $After(06/2014)_t$ in Equation 2.3 is amended to $After_{jt}$, matching the relevant time period of negative monetary policy rates for each country's banks, which is from February 2015 onwards for Swedish banks and from January 2013 to April 2014 as well as from September 2014 onwards for Danish banks.

A potential problem is that the risk measures we use might not reflect banks' risk-taking behavior. A reduction in net worth could in itself imply higher stock return volatility and higher CDS spreads, without a change in the risk-taking behavior of banks. To address this, we show that our results hold when measuring risk taking with a regulatory accounting-based measure instead of a market-based measure. For this supporting regression, we define the dependent variable as the quarterly percentage change of risk-weighted assets over total assets (%-change in RWA density). The idea is that if a bank takes on more risk by shifting its asset base to riskier assets, this should be reflected by an increase in the RWA density. Each bank has discretion over whether they should calculate the risk-weighted assets using a standardized method or using internal models to estimate the risk of its assets. However, this inconsistency across banks should not be a problem as any bank specific time-invariant effects are captured by the bank fixed effects. The regulation covering RWA calculation has also evolved over time, but any such time-variant effects are consistent within countries and will therefore be captured by the country-month-year fixed effects. What is more problematic with the risk-weighted assets is inconsistencies for specific banks across time periods. Banks may have changed their method of calculation during our time window. Basel III has transformed the regulatory landscape and put risk-weighted assets high on the agenda for banks, incentivizing them to opt for the calculation that is most beneficial for them. For many banks, the calculation method that minimizes risk-weighted assets is the internal model-based approach. At the same time, the internal model-based approach requires significant investment and comes with a time consuming regulatory approval process. For these reasons, it is highly likely that several banks in our sample have changed their calculation method during our time window, even though Basel III was introduced earlier. This potential problem is the reason we only use RWA density as a supporting regression.

Table 2: RWA Density: Descriptive Statistics

	Mean	St. Dev.	Min	Max
December 2012 (%)	49.68	17.86	16.50	98.88
December 2014 (%)	49.20	15.89	18.44	83.89
Number of banks in sample	30			

Notes: The table shows descriptive statistics for the RWA density distribution of our sample in December 2012 and December 2014.

3 Empirical Findings

In this section, we start by detailing the underlying mechanism that induces risk taking by showing how competition impacts net worth when negative policy rates are introduced. We then present our empirical findings and robustness checks verifying our results, displaying the role of competition for bank risk taking in the context of negative monetary policy rates.

3.1 Underlying Mechanism

Table 3: Net Worth

	Stock Return$_j$	
Top Tercile × After(06/2014)	-0.116***	-0.182***
	(-5.14)	(-4.52)
HHI × Top Tercile × After(06/2014)	3.156***	
	(3.73)	
Top5 × Top Tercile × After(06/2014)		0.00491***
		(3.73)
Bank FE	Y	Y
Country-month-year FE	Y	Y
Observations	884	884

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample consists of 58 public banks in the Eurozone. Monthly stock returns for bank j from January 2013 to February 2015 are used as the dependent variable. The Herfindahl-Hirschman Index (HHI) and the market share of the top five banks (Top5) are market concentration measures from 2013 that vary at the country level. They are based on total assets and serve as a proxy for competition. Top Tercile is a dummy for the banks in the top tercile of the 2013 deposit ratio distribution (the mid tercile is dropped). After(06/2014) is a dummy variable for the time period from June 2014 onwards. Robust standard errors are clustered at the bank level. A few observations are dropped in both regressions as we only have one Slovakian bank in our sample. As a result, it is not possible to estimate country-month-year fixed effects for Slovakia. See Figure 3 on page 26 for the full distribution of banks by country.

Table 3 shows the underlying mechanism that explains changes in risk taking. The difference-in-differences approach shows that high-deposit banks experience a relative reduction in net worth compared to low-deposit banks when negative policy rates are introduced. In other words, negative monetary policy rates penalize banks with high reliance on deposit funding, which is reflected by the stock return (see Figure 1 on page 24 for an illustration of how the stock price for the top versus bottom tercile of banks in the deposit-ratio distribution diverge after negative policy rates are introduced). Moreover, the triple interaction variable with the Herfindahl-Hirschman Index, as well as the market share of the top five credit institutions both show an offsetting effect. This indicates that the negative effect on net worth of having a high deposit ratio is less severe in countries with a less competitive banking sector. Given that fixed effects are used, the regression confirms our belief that the diversion between high-deposit banks in highly competitive and less competitive markets in Figure 2 on page 25 are not due to time invariant bank effects or time variant country-specific effects.

3.2 Main Results

Table 4: Baseline Regression

	$\ln(\sigma(Stock\ return_j)^{1m})$		$\ln(CDS\ return_j)^{1m}$	
Deposit ratio × After(06/2014)	0.512***	0.787**	0.132*	0.177***
	(3.57)	(2.40)	(1.96)	(3.15)
HHI × Deposit ratio × After(06/2014)		-4.835***		-4.394***
		(-2.74)		(-6.02)
Bank FE	Y	Y	Y	Y
Month-year FE	Y	N	Y	N
Country-month-year FE	N	Y	N	Y
Observations	1508	1482	1014	988

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample for the first two columns consists of 58 public banks in the Eurozone. The dependent variable is the logged unlevered monthly standard deviation of daily stock returns for bank j and time t, ranging from January 2013 to February 2015. The sample in the last two columns consist of 39 banks in the Eurozone. The dependent variable is the logged monthly CDS spread return for bank j and time t, ranging from January 2013 to February 2015. HHI is the Herfindahl-Hirschman Index from 2013 based on total bank assets, which varies at the country level. The deposit ratio is a bank's total deposits over total assets in 2013. After(06/2014) is a dummy variable for the time period from June 2014 onwards. Robust standard errors are clustered at the bank level. A few observations are dropped in the second and fourth columns as we only have one bank for a few countries in our sample, making it impossible to estimate country-month-year fixed effects. In the first two columns, we only have one bank in Slovakia. In the last two columns, we only have one bank in Ireland. See Figure 3 on page 26 for the full distribution of banks by country.

Table 4 describes our main empirical findings. Overall, a bank's deposit ratio is positively correlated with both of the variables used to measure risk. I.e. a higher deposit ratio is associated with a higher standard deviation of stock returns and higher CDS-spread returns after negative policy rates are introduced. The negative coefficient of the triple interaction variable imply that this effect is more pronounced for highly competitive markets, under the assumption that low market concentration is equivalent to high competition. Assuming a deposit ratio equal to the top tercile mean value of each sample, a one standard deviation decrease in the Herfindahl-Hirschman Index is associated with a 24.2% and 18.8% increase in the stock return volatility and CDS-spread return, respectively. Deposit-financed banks in highly concentrated markets did not experience the same decrease in net worth following the introduction of negative policy rates (see Figure 2 on page 25). As a result, these banks have less incentives to increase their risk taking. This is likely a result of more market pricing power for banks in highly concentrated markets.

3.3 Robustness Checks

To verify the validity of our difference-in-differences approach, we perform a placebo test. Table 11 on page 33 shows the result of including variables with placebo treatment one year before the introduction of negative policy rates. As expected, these variables are insignificant, implying that there is no clear relationship between a bank's deposit ratio, its domestic market competition and its net worth or risk taking when monetary policy rates are non-negative.

To ensure the robustness of our results, we also extend the time window to December 2015 in Table 7 on page 29. The results are largely unchanged, but the risk of problems with endogeneity is higher for this regression. As mentioned in subsection 2.3, the European Central Banks launched it's public sector purchase program (PSPP) in March 2015, which might not impact all countries or high- and low-deposit banks equally.

In Table 8 on page 30 we show that our results hold when Swedish and Danish banks are included, verifying that our results are not biased towards factors exclusive to the Eurozone. Given that Sweden introduced negative monetary policy rates in February 2015, it might be more relevant to use the extended time window ending in December 2015. Table 9 on page 31 shows that the results are largely unchanged.

Lastly, we show that the results still hold when we use the percentage change in RWA density as our dependent variable. This implies that high-deposit banks shift their asset composition to riskier assets when negative policy rates are introduced. Furthermore, the results also show that this effect is more pronounced in highly competitive markets than in less competitive markets. However, it is worth emphasizing that identification is difficult for this risk measure, as discussed in subsection 2.3. Table 5 shows the regression for the baseline time window ending in February 2015, while Table 10 on page 32 shows it for the time window extended to December 2015.

Table 5: RWA Density

	$\% - change\ in\ RWA\ Density_j^{3m}$	
Deposit ratio × After(06/2014)	0.123**	0.623**
	(2.09)	(2.56)
HHI × Deposit ratio × After(06/2014)		-13.84**
		(-2.70)
Bank FE	Y	Y
Month-year FE	Y	N
Country-month-year FE	N	Y
Observations	234	212

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table uses the quarterly percentage change in the ratio of risk-weighted assets over total assets (RWA density) as an alternative measure of bank risk taking, varying by bank j over time t, which ranges from March 2013 to December 2014. The time window for this regression is slightly shorter than usual as quarterly data is used and we want to avoid distortion from the ECB's public sector purchase program launch in March 2015. The sample consists of 30 public banks in the Eurozone. HHI is the Herfindahl-Hirschman Index from 2013 based on total bank assets, which varies at the country level. The deposit ratio is a bank's total deposits over its total assets in 2013. After(06/2014) is a dummy variable for the time period starting in June 2014. Robust standard errors are clustered at the bank level. A few observations are dropped when including country-month-year fixed effects as we only have one bank for a few countries in our sample, preventing estimation of country-month-year fixed effects.

Finally, Table 12 on page 34 and Table 13 on page 35 provide a summary of our main results by comparing all three risk measures and both of our concentration indices for both time windows. These tables show that the results hold also when competition is measured as the market share of the top five banks by total assets in a given country. This was expected as the correlation with the Herfindahl-Hirschman Index is 0.91.

4 Conclusion and Further Remarks

4.1 Conclusion

The long-term effect of negative monetary policy rates is still unknown. We describe the implications competition has on bank risk taking when monetary policy rates go below zero. More specifically, we conclude that deposit-reliant banks in highly competitive markets experience the sharpest decline in net worth. This effect is due to the absence of pass-through on the liability side caused by banks' reluctance to charge negative interest rates to their depositors, together with high competition on both the liability and asset side, all reducing profitability and net worth. As the net worth of a bank is highly linked to risk-taking incentives, high-deposit banks in highly competitive markets not only experience both higher stock return volatility and higher CDS-spread returns after the introduction of negative monetary policy rates, but are also shown to switch to more risky asset compositions. After reassuring that the trends of high-deposit banks in highly- versus less competitive markets are parallel when non-negative interest rates are prevalent, we identify that the introduction of negative monetary policy rates is what causes this effect.

Moreover, the debate regarding monetary policies' effect on the real economy has re-entered the spotlight after the financial crisis. Heider et al. (2017) showed that when high-deposit banks increased their lending to risky firms under negative monetary policy rates, these risky borrowers also started to invest significantly more. This speaks for a positive effect on the real economy from bank risk taking. On the other hand, high bank risk taking could be a problem for financial stability. Our findings might add valuable insights on the widely discussed trade-off between competition and financial stability - a discussion in which negative monetary policy rates are rarely mentioned. More broadly, we hope that our findings can contribute to the discussion on the long run consequences of keeping interest rates below zero and shed light on how this effect might vary across countries.

4.2 Improvements and Further Research

One of the main areas where we see room for improvement is the details on how negative monetary policy rates are passed through on the asset side. While we have shown on a broad level how competition affects the pass-through of negative monetary policy rates on the asset side in relation to the liabilities side, we have not been able to describe this in detail. A researcher with access to regulatory data could look at the development of lending rates and compare this to the competition measures across countries.

How competition is measured could also be improved to gain a deeper understanding of our results. In particular, it would be helpful to separate asset-side competition from deposit-side competition to see where most of the effects on net worth come from. This could be done by using a Herfindahl-Hirschman Index calculated based on specific asset classes and deposits, instead of total assets which we use. An even better measure, if estimated correctly, would be the Lerner Index as it ultimately is market pricing power that matters rather than market concentration.

Finally, the fact that our sample of liquid banks is not exhaustive offers room for further improvement. With better data screening tools, a more complete set of banks could be used. This would address a potential sample selection problem as our screening method, using mainly industry classifications in Bloomberg and Thomson Reuters Datastream, is likely to be slightly biased towards larger banks and banks with more traditional business models.

5 Appendix

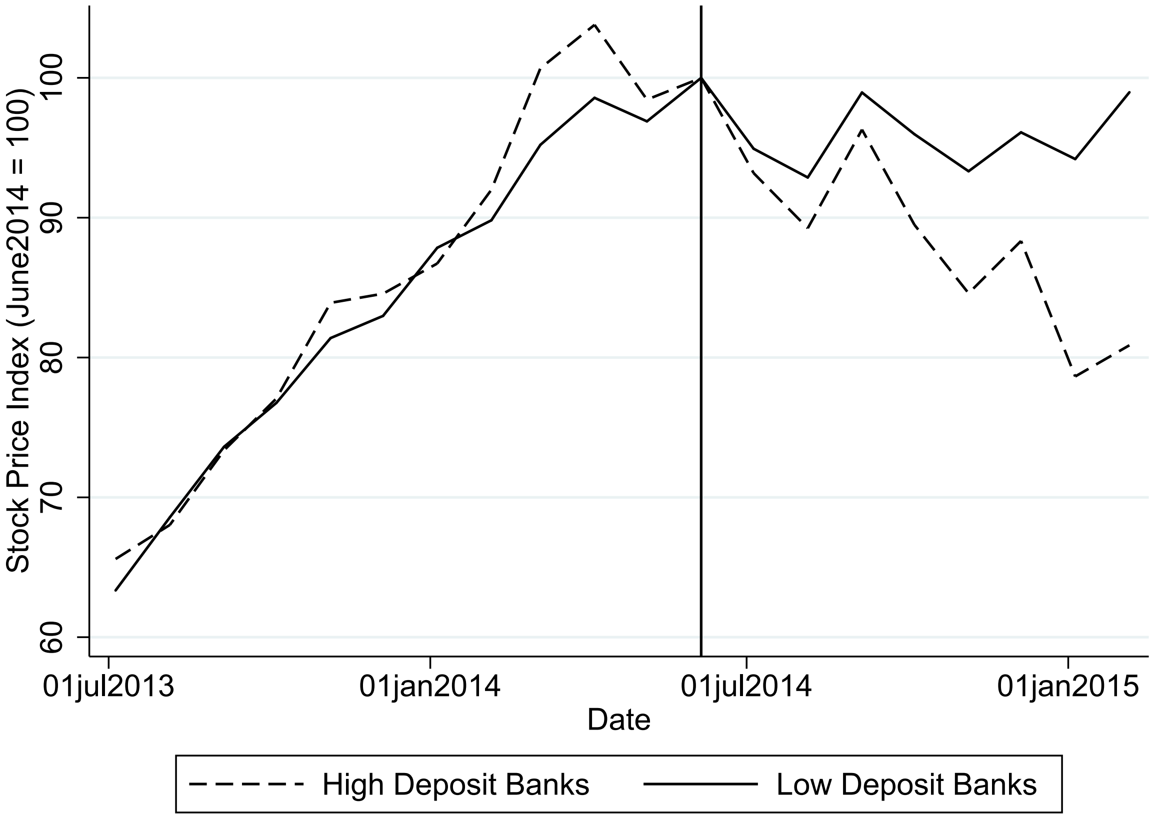

Figure 1: Stock Price Index of Listed Eurozone Banks

Figure 1 is a replication of the work presented by Heider et al. (2017) using our sample of banks. It shows the evolution of the monthly stock price for the banks in our sample between July 2013 and January 2015. The price is indexed to 100 on June 5, 2014, when the European Central Bank introduced the negative deposit facility rate of -0.10% (se vertical line), and is calculated taking the average monthly stock return of our top versus bottom tercile banks sorted on deposit ratios. As Heider et al. (2017) proved, these lines diverge after the introduction of negative rates. Stock price data is taken from Bloomberg.

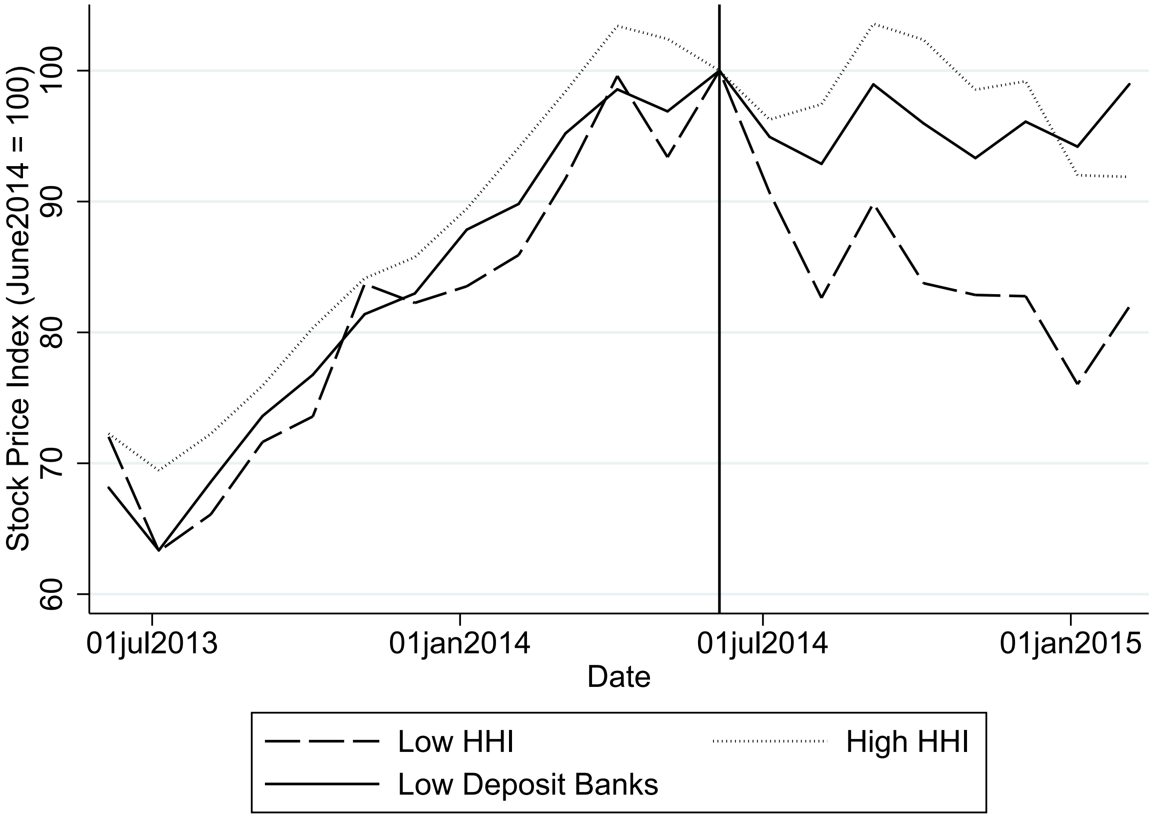

Figure 2: Stock Price Index of Listed High-Deposit Eurozone Banks

Figure 2 shows the evolution of a monthly stock price for the high-deposit banks, split into banks that operate in a highly competitive market (low HHI) versus banks that operate in a less competitive market (high HHI), between June 2013 and February 2015. The dotted line shows the top two quintiles of the HHI distribution within the top tercile deposit ratio distribution. The dashed line shows the bottom two quintiles of the HHI distribution within the top tercile deposit ratio distribution. Stock price data is taken from Bloomberg.

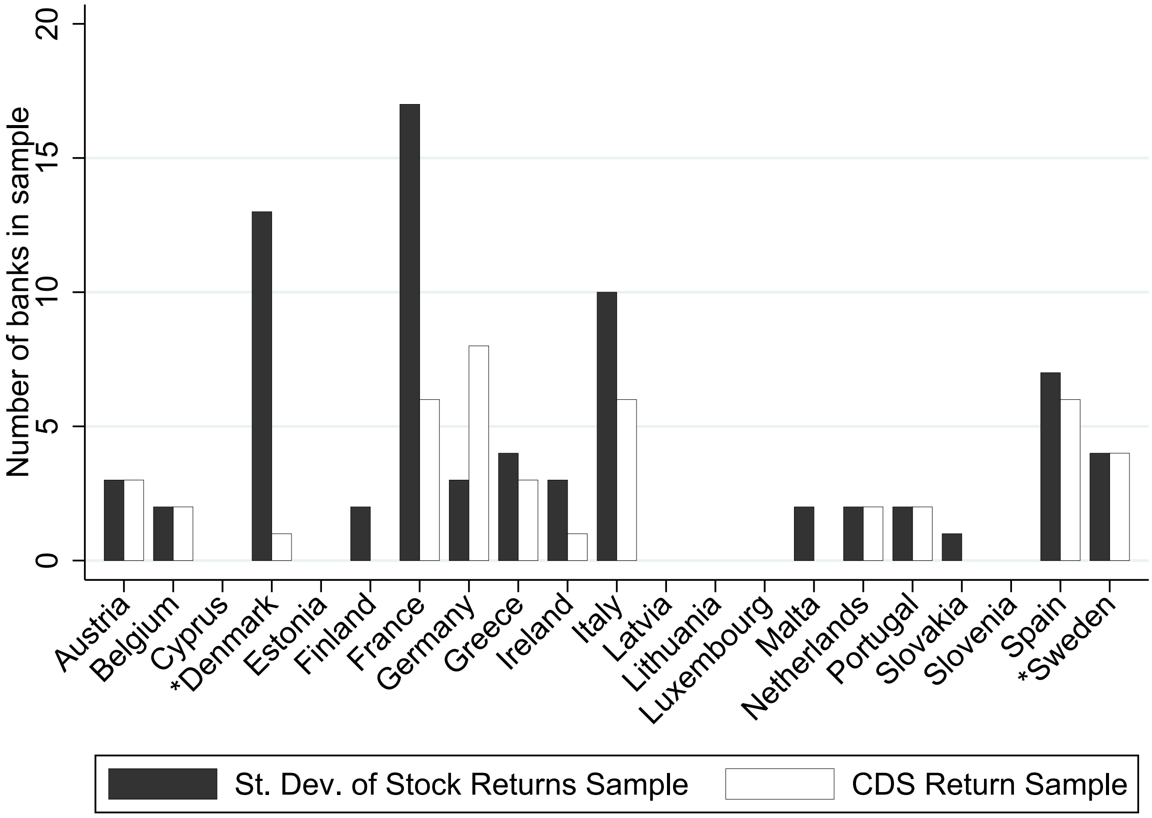

Figure 3: Number of banks by country in samples

Figure 3 shows the number of banks by country in each of our baseline samples. Sweden and Denmark are only included in supporting regressions (thereby denoted with *).

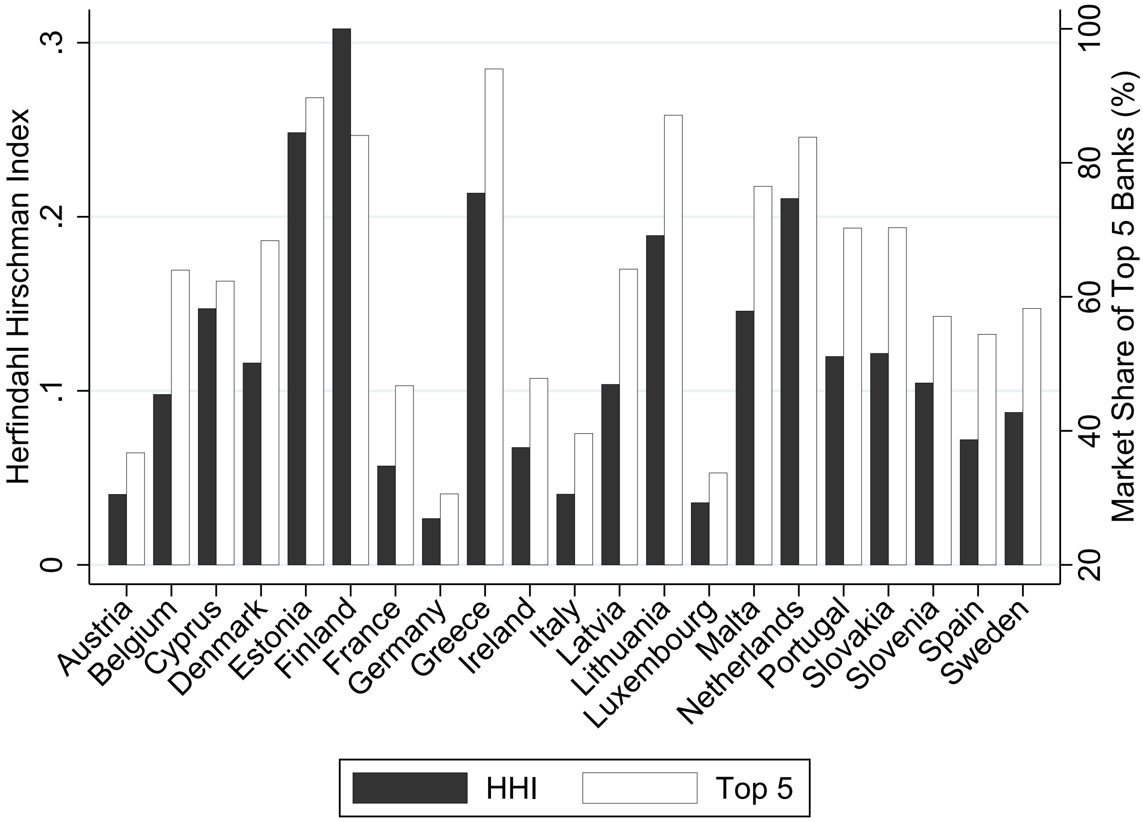

Figure 4: HHI and Top 5 market share

Figure 4 shows the Herfindahl-Hirschman Index and the top five credit institutions' market share in each country. The two measures have a correlation of 0.91. The data is taken from the European Central Bank's Statistical Data Warehouse.

Table 6: Summary Statistics by Sample Including Sweden and Denmark

		Mean	Std. Dev.	Min	Max
Standard deviation of stock returns					
Deposit ratio - Entire sample (%)		47.04	18.24	9.77	85.69
Deposit ratio - Top tercile (%)		67.59	9.28	56.66	85.69
Deposit ratio - Bottom tercile (%)		26.79	5.86	9.77	34.19
Number of banks in sample	75				
Number of countries in sample	15				
Herfindahl-Hirschman Index		0.11	0.08	0.03	0.31
CDS-spread return					
Deposit ratio - Entire sample (%)		41.95	13.68	9.62	62.34
Deposit ratio - Top tercile (%)		57.30	4.30	50.07	62.34
Deposit ratio - Bottom tercile (%)		27.21	6.96	9.62	33.06
Number of banks in sample	44				
Number of countries in sample	12				
Herfindahl-Hirschman Index		0.10	0.06	0.03	0.21

Notes: The table shows descriptive statistics for the deposit ratio distributions as well as the Herfindahl-Hirschman Index for our sample including the Eurozone, Denmark and Sweden.

Table 7: Baseline Regression - Extended Time Window

	$\ln(\sigma(Stock\ return_j)^{1m})$		$\ln(CDS\ return_j)^{1m}$	
Deposit ratio × After(06/2014)	0.559***	0.634**	0.0865*	0.122**
	(3.61)	(2.01)	(1.84)	(2.56)
HHI × Deposit ratio × After(06/2014)		-6.095***		-2.531***
		(-3.36)		(-4.06)
Bank FE	Y	Y	Y	Y
Month-year FE	Y	N	Y	N
Country-month-year FE	N	Y	N	Y
Observations	2084	2048	1404	1368

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample for the first two columns consists of 58 public banks in the Eurozone. The dependent variable for this regression is the logged unlevered monthly standard deviation of daily stock returns for bank j and time t, ranging from January 2013 to December 2015 (i.e. this regression uses an extended time window which includes the ECB's public sector purchase program launched in March 2015). The sample for the third and fourth columns consists of 39 banks in the Eurozone. The dependent variable for this regression is the logged monthly CDS-spread return for bank j and time t, ranging from January 2013 to December 2015. HHI is the Herfindahl-Hirschman Index from 2013 based on total assets, which varies at the country level. The deposit ratio is a bank's total deposits over its total assets in 2013. After(06/2014) is a dummy variable for the time period from June 2014 onwards. Robust standard errors are clustered at the bank level. The reason a few observations are dropped in the second and fourth columns is that we only have one bank for a few countries in our sample, which means that it is not possible to estimate country-month-year fixed effects for these countries. In the first two columns, we only have one bank in Slovakia. In the last two columns, we only have one bank in Ireland. See Figure 3 on page 26 for the full distribution of banks by country.

Table 8: Baseline Regression Including Sweden and Denmark

	$\ln(\sigma(Stock\ return_j)^{1m})$		$\ln(CDS\ return_j)^{1m}$	
Deposit ratio × $After_{jt}$	0.211***	0.764**	0.113***	0.178***
	(2.94)	(2.42)	(3.08)	(3.16)
HHI × Deposit ratio × $After_{jt}$		-5.566**		-4.405***
		(-2.27)		(-6.04)
Bank FE	Y	Y	Y	Y
Month-year FE	Y	N	Y	N
Country-month-year FE	N	Y	N	Y
Observations	1950	1924	1144	1092

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample for the first two columns consists of 75 public banks in the Eurozone, Denmark and Sweden. The dependent variable for this regression is the logged unlevered monthly standard deviation of daily stock returns for bank j and time t, ranging from January 2013 to February 2015. The sample for the last two columns consists of 45 banks in the Eurozone, Denmark and Sweden. The dependent variable for this regression is the logged monthly CDS-spread return for bank j and time t, ranging from January 2013 to February 2015. HHI is the Herfindahl-Hirschman Index from 2013 based on total assets, which varies at the country level. The deposit ratio is a bank's total deposits over its total assets in 2013. $After_{jt}$ is a dummy variable matching the relevant time period of negative monetary policy rates for each country's banks, which is from February 2015 onwards for Swedish banks and from January 2013 to April 2014 as well as from September 2014 onwards for Danish banks. Robust standard errors are clustered at the bank level. The reason a few observations are dropped in the second and fourth columns is that we only have one bank for a few countries in our sample, which means that it is not possible to estimate country-month-year fixed effects for these countries. In the first two columns, we only have one bank in Slovakia. In the last two columns, we only have one bank in Denmark and Ireland. See Figure 3 on page 26 for the full distribution of banks by country.

Table 9: Baseline Regression Incl. Sweden and Denmark - Extended Time Window

	$\ln(\sigma(Stock\ return_j)^{1m})$		$\ln(CDS\ return_j)^{1m}$	
Deposit ratio × $After_{jt}$	0.243***	0.626**	0.0905***	0.121**
	(3.15)	(2.07)	(3.03)	(2.55)
HHI × Deposit ratio × $After_{jt}$		-6.368***		-2.516***
		(-3.05)		(-4.03)
Bank FE	Y	Y	Y	Y
Month-year FE	Y	N	Y	N
Country-month-year FE	N	Y	N	Y
Observations	2696	2660	1584	1512

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample for the first two columns consists of 75 public banks in the Eurozone, Denmark and Sweden. The dependent variable for this regression is the logged unlevered monthly standard deviation of daily stock returns for bank j and time t, ranging from January 2013 to December 2015 (i.e. this regression uses an extended time window which includes the ECB's public sector purchase program launched in March 2015). The sample for the third and fourth columns consists of 45 banks in the Eurozone, Denmark and Sweden. The dependent variable for this regression is the logged monthly CDS spread return for bank j and time t, ranging from January 2013 to December 2015. HHI is the Herfindahl-Hirschman Index from 2013 based on total assets, which varies at the country level. The deposit ratio is a bank's total deposits over its total assets in 2013. $After_{jt}$ is a dummy variable matching the relevant time period of negative monetary policy rates for each country's banks, which is from February 2015 onwards for Swedish banks and from January 2013 to April 2014 as well as from September 2014 onwards for Danish banks. Robust standard errors are clustered at the bank level. The reason a few observations are dropped in the second and fourth columns is that we only have one bank for a few countries in our sample, which means that it is not possible to estimate country-month-year fixed effects for these countries. In the first two columns, we only have one bank in Slovakia. In the last two columns, we only have one bank in Denmark and Ireland. See Figure 3 on page 26 for the full distribution of banks by country.

Table 10: RWA Density - Extended Time Window

	$\% - change\ in\ RWA\ Density_j^{3m}$	
Deposit ratio × After(06/2014)	0.0909*	0.374**
	(1.86)	(2.77)
HHI × Deposit ratio × After(06/2014)		-8.228***
		(-3.19)
Bank FE	Y	Y
Month-year FE	Y	N
Country-month-year FE	N	Y
Observations	345	313

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table uses the quarterly percentage change in the ratio of risk-weighted assets over total assets (RWA density) as an alternative measure of bank risk taking, varying by bank j over time t, ranging from March 2013 to December 2015. Risk-weighted assets are used to determine banks' capital requirements as it represents a measure of the total riskiness of a bank's assets. The sample consists of 30 public banks in the Eurozone. HHI is the Herfindahl-Hirschman Index from 2013 based on total assets, which varies at the country level. The deposit ratio is a bank's total deposits over its total assets in 2013. After(06/2014) is a dummy variable for the time period from June 2014 onwards. Robust standard errors are clustered at the bank level. A few observations are dropped when we include country-month-year fixed effects as we only have one bank for a few countries in our sample. It is not possible to estimate country-month-year fixed effects for these countries.

Table 11: Placebo Treatment Test

	$Stock\ Return_j$		$\ln(\sigma(Stock\ return_j)^{1m})$	
Top Tercile × After(06/2014)	-0.116***	-0.137***		
	(-5.14)	(-5.40)		
HHI × Top Tercile × After(06/2014)	3.156***	3.834***		
	(3.73)	(4.02)		
Top Tercile × After(06/2013)		0.0917		
		(1.19)		
HHI × Top Tercile × After(06/2013)		-2.884		
		(-0.99)		
Deposit ratio × After(06/2014)			0.787**	0.700**
			(2.40)	(2.51)
HHI × Deposit ratio × After(06/2014)			-4.835***	-5.351**
			(-2.74)	(-2.39)
Deposit ratio × After(06/2013)				0.293
				(0.62)
HHI × Deposit ratio × After(06/2013)				1.754
				(0.52)
Bank FE	Y	Y	Y	Y
Country-month-year FE	Y	Y	Y	Y
Observations	884	884	1482	1482

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: The sample for all regressions in this table consists of 58 public banks in the Eurozone. The dependent variable for the first two columns is the monthly stock returns for bank j from January 2013 to February 2015. The dependent variable for the last two columns is the logged unlevered monthly standard deviation of daily stock returns for bank j from January 2013 to February 2015. The Herfindahl-Hirschman Index (HHI) is from 2013 and is based on total bank assets. It varies at the country level and serves as a proxy for competition. Top Tercile is a dummy for the top tercile of the 2013 deposit ratio distribution of banks in our sample (the mid tercile is dropped in the first two columns). After(06/2014) is a dummy variable for the time period starting with the introduction of negative monetary policy rates in June 2014. After(06/2013) is a dummy variable used as a placebo treatment one year before the introduction of negative monetary policy rates. Robust standard errors are clustered at the bank level. A few observations are dropped in the regressions as we only have one Slovakian bank in our sample. As a result, it is not possible to estimate country-month-year fixed effects for Slovakia. See Figure 3 on page 26 for the full distribution of banks by country.

Table 12: Comparison of Risk Measures

	$\ln(\sigma(Stock\ Return_j)^{1m})$			$\ln(CDS\ return_j)^{1m}$			$\%-change\ RWA\ Density_j^{3m}$		
Deposit ratio × After(06/2014)	0.512***	0.787**	1.156**	0.132*	0.177***	0.373***	0.123**	0.623**	1.083**
	(3.57)	(2.40)	(2.26)	(1.96)	(3.15)	(4.11)	(2.09)	(2.56)	(2.13)
HHI × Deposit ratio × After(06/2014)		-4.835***			-4.394***			-13.84**	
		(-2.74)			(-6.02)			(-2.70)	
Top5 × Deposit ratio × After(06/2014)			-0.0147*			-0.00974***			-0.0264**
			(-1.80)			(-5.39)			(-2.19)
Bank FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Month-year FE	Y	N	N	Y	N	N	Y	N	N
Country-month-year FE	N	Y	Y	N	Y	Y	N	Y	Y
Observations	1508	1482	1482	1014	988	988	234	212	212

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table compares the results of our three different risk measures and both of our competition measures. The samples for the regressions by risk measure consist of 58, 39 and 30 public banks in the Eurozone, respectively. The dependent variable for the first three columns is the logged unlevered monthly standard deviation of daily stock returns for bank j and time t, ranging from January 2013 to February 2015. The dependent variable for the fourth to sixth column is the logged monthly CDS-spread return for bank j and time t, ranging from January 2013 to February 2015. The dependent variable for the seventh to ninth column is the quarterly percentage change in the ratio of risk-weighted assets over total assets, which is based on accounting numbers that are used to measure the riskiness of a bank's asset composition when determining its capital requirements. HHI is the Herfindahl-Hirschman Index from 2013 based on total bank assets, which varies at the country level. Top5 is the market share by total assets in 2013 of the top five banks in a given country. The deposit ratio is a bank's total deposits over its total assets in 2013. After(06/2014) is a dummy variable for the time period starting in June 2014. Robust standard errors are clustered at the bank level. A few observations are dropped when we include country-month-year fixed effects as we only have one bank for a few countries in our sample. It is not possible to estimate country-month-year fixed effects for these countries. See Figure 3 on page 26 for the full distribution of banks by country.

Table 13: Comparison of Risk Measures - Extended Time Window

	$\ln(\sigma(Stock\ Return_j)^{1m})$			$\ln(CDS\ return_j)^{1m}$			$\% - change\ RWA\ Density_j^{3m}$		
Deposit ratio × After(06/2014)	0.559***	0.634**	1.049**	0.0865*	0.122**	0.277***	0.0909*	0.374**	0.695**
	(3.61)	(2.01)	(2.14)	(1.84)	(2.56)	(4.21)	(1.86)	(2.77)	(2.67)
HHI × Deposit ratio × After(06/2014)		-6.095***			-2.531***			-8.228***	
		(-3.36)			(-4.06)			(-3.19)	
Top5 × Deposit ratio × After(06/2014)			-0.0175**			-0.00647***			-0.0168***
			(-2.10)			(-5.35)			(-2.88)
Bank FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Month-year FE	Y	N	N	Y	N	N	Y	N	N
Country-month-year FE	N	Y	Y	N	Y	Y	N	Y	Y
Observations	2084	2048	2048	1404	1368	1368	345	313	313

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table compares the results of our three different risk measures and both of our competition measures using the extended time window to December 2015, which includes the ECB's public sector purchase program launched in March 2015. The samples for the regressions by risk measure consist of 58, 39 and 30 public banks in the Eurozone, respectively. The dependent variable for the first three columns is the logged unlevered monthly standard deviation of daily stock returns for bank j and time t, ranging from January 2013 to December 2015. The dependent variable for the fourth to sixth column is the logged monthly CDS-spread return for bank j and time t, ranging from January 2013 to December 2015. The dependent variable for the seventh to ninth column is the quarterly percentage change in the ratio of risk-weighted assets over total assets, which is based on accounting numbers that are used to measure the riskiness of a bank's asset composition when determining its capital requirements. HHI is the Herfindahl-Hirschman Index from 2013 based on total assets, which varies at the country level. Top5 is the market share by total assets in 2013 of the top five banks in a given country. The deposit ratio is a bank's total deposits over its total assets in 2013. After(06/2014) is a dummy variable for the time period from June 2014 onwards. Robust standard errors are clustered at the bank level. A few observations are dropped when we include country-month-year fixed effects as we only have one bank for a few countries in our sample. It is not possible to estimate country-month-year fixed effects for these countries. See Figure 3 on page 26 for the full distribution of banks by country.

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