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The Problem of Heterogeneity within Risk Weights: Does Basel IV contain the Solution?

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ABSTRACT

The article uses a bank's credit data to study the impact of the Basel IV regulations on risk weight density (RWD). The analysis of the simulated data shows mixed results, as the improvement of risk weight heterogeneity is restricted to optimistically valued portfolios. Conservatively valued portfolios are likely to be confronted with an RWD decrease. However, within these portfolios, risk weight heterogeneity usually does not play an important role. Out of all the analysed Basel IV rules, the output floor clearly has the biggest influence on risk weight density, while the effect of the input floors is very limited within optimistically valued portfolios and is even eliminated by the removal of the scaling factor within conservatively valued portfolios. The change in RWD will also lead to a concurrent change in risk-weighted assets and therefore also in the level of eligible capital. The findings within the retail portfolio confirm those of the EBA study, which already suggested that Basel IV and especially the output floor will lead to a significant increase of risk capital (European Banking Authority, 2018).

Introduction

The soundness and safety of the banking system are said to be achievable by requiring banks to hold a high level of capital. Due to this fact, capital regulation has become the centrepiece of bank regulation within the past decades and the Basel Committee on Banking Supervision (BCBS), which is known as the most important standard-setter within the field of bank regulation, has played an important role within this evolution. In 1988 it published the Basel Accord (Basel I), which represents the first attempt to set international risk-based standards for capital regulation (Bodellini, 2019; Thakor, 2018). Basel I was structured very simply and therefore was soon criticised as being risk insensitive (Bodellini, 2019; Pérez Montes, Trucharte Artigas, Cristófoli, & Lavín San Segundo, 2018).This shortcoming was addressed by the BCBS through the introduction of the internal ratings-based approach (IRBA) in the Basel II framework. Since then, banks are able to determine their risk weighted assets (RWAs), which provide the basis for the calculation of the eligible capital, by using complex internal models. These models use parameters like the probability of default (PD), the loss given default (LGD) and the exposure at default (EAD) for the determination of risk weights (RW). The probability of default indicates how probable it is that the debtor defaults, the loss given default represents the percentage of the exposure which the bank loses in case of the default of a debtor and the exposure at default is the maximum loss, which can occur in case of a default (Hull, Mader, & Wagner, 2014). The fact that these parameters are determined by the banks themselves, provides them with a high level of discretion in the calculation of the capital they are required to hold (Behn, Haselmann, & Vig, 2016a; Cucinelli, Di Battista, Marchese, & Nieri, 2018). In addition to that, the determination of these parameters requires a certain level of judgement, which potentially leads to heterogenous risk weights for identical assets (Turk-Ariss, 2017).

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On the one hand, heterogeneity of risk weights has natural causes such as different databases, variations in IRB models and differences in national and international implementation standards (Haselmann & Wahrenburg, 2016). On the other hand, this effect may also be due to manipulation: a study conducted by Mike Mariathasan and Ouarda Merrouche concluded that risk reported by banks is declining following the approval of IRB models and that this effect is particularly strong within weakly capitalised banks. The IRB approach thus offers banks the opportunity to report their risk at a lower level than it actually is and thus to overstate regulatory capital (Mariathasan & Merrouche, 2014). During the financial crisis it then became apparent, that capital requirements, which have been set by the regulator were too low and that the definition of them has been set too broadly (Haldane, 2013; Rossignolo, Fethi, & Shaban, 2013). That is why the BCBS then published 'Basel III: A global regulatory framework for more resilient banks and banking systems' in which it raised the amount and the quality of the regulatory capital required (Basel Committee on Banking Supervision, 2010). However, the BCBS did not reform the IRB approach or the calculation of risk-weighted assets, which led to the fact that Basel III remained somewhat as self-regulatory as Basel II (Haldane, 2013).

The reduction of the excessive variability of risk weights was one of the reasons for the revision of the Basel III framework. In December 2017 the BCBS published the final version of "Basel III: Finalising post-crisis reforms" in which it emphasises the necessity of a credible and prudent RWA calculation. This new regulatory framework, which is commonly referred to as Basel IV, primarily deals with the revision of the standardised approach and the restriction of the internal ratings-based approach. The constraint of the IRBA comes with the removal of the IRB-option for certain asset classes and the introduction of parameter floors and output floors (Basel Committee on Banking Supervision, 2017). The publication of Basel IV led to a huge debate in the banking industry and since then various consulting firms have been trying to quantify the impact of the new rules. A study by the European Banking Authority (EBA) based on figures of 134 banks in the European Economic Area shows an increase in risk capital at full implementation of Basel IV of 21.8%. This increase is largely due to the introduction of the output floor (6.3%) (European Banking Authority, 2018). Another study even refers to the regulations as a "game changer" for the European banking landscape (Schneider, Schröckl, Koch, & Schneider, 2017).

The topic of risk weight variability has already been addressed in numerous articles, but to my knowledge none of them analysed the implications of the Basel IV input and output floors on heterogeneity.

The aim of this article is to analyse the impact of Basel IV on the heterogeneity of risk weights and thereby to answer the following research questions:

- *Question 1: How can the impact of Basel IV on the heterogeneity of risk weights be simulated?*
- *Question 2: Do the new Basel-IV-regulations have the potential to reduce or even to eliminate the problem of heterogeneity within risk weights?*
- *Question 3: To what extent will the risk weight density be affected by the Basel IV input and output floors?*

In order to get an answer to the research questions, a simulation of the Basel IV framework for credit risk has been developed and performed using Microsoft Excel 2016. The simulation is based on the credit data provided by an IRB bank located in Western Europe, and therefore only analyses the impact of Basel IV on the IRB approach for credit risk. Due to data protection issues the dataset has been anonymised by the bank itself before transmission.

The rest of the article is organised as follows. Sections 2, 3 and 4 provide the basis about risk weighted capital regulation, the IRB-Approach itself and the Basel IV framework. Section 5 describes the dataset and the methods employed. Section 6 presents the results and Section 7 provides a conclusion from the results.

The Evolution of Risk Weighted Capital Regulation

Capital regulation represents the centrepiece of bank regulation and there is a consensus that an increased level of equity goes hand in hand with increased stability (Bodellini, 2019; Thakor, 2018). While there is unity in this area, there is disagreement within others – that is why the required level of bank capital as well as the valuation of banks' assets has changed numerous times over the years (Mariathasan & Merrouche, 2014).

The Basel Accord of 1988 is the first attempt to set international risk-based standards for capital regulation. It regulated the minimum capital requirements and required banks to exhibit a minimum ratio of capital to risk weighted assets (RWAs) of 8%. The risk weights which have been used for the calculation of RWAs were negligible as there were only four of them (Blundel-Wignall & Atkinson, 2010; Haselmann & Wahrenburg, 2016; Hull et al., 2014). Basel I was criticised at an early stage as the calculation of RWAs was perceived as being too crude and as it did not distinguish between the risks within each category (Pérez Montes et al., 2018).

Basel II, the succeeding framework to Basel I was published in 2004, with the aim of promoting stronger risk management within banks. It introduced the IRBA, which determines the risk weights using internal models that are based on the bank's data. The aim of the IRBA therefore was to tie the calculation of regulatory capital closer to the actual risks banks are facing (Basel Committee on Banking Supervision, 2004). What actually happened was that Basel II increased the level of complexity, it enabled banks to reduce their capital and thereby caused an enormous indebtedness which then led to the fact that banks entered the financial crisis with a level of equity that was far too low (Cabrera, Dwyer, & Nieto, 2018; Hellwig, 2010; Mariathasan & Merrouche, 2014). These facts have also been admitted by the BCBS when they introduced Basel III as they stated that the leverage which has been built up by banks as well as the low level and quality of capital and the insufficient liquidity were some of the reasons for the financial crisis (Basel Committee on Banking Supervision, 2010). The focus of Basel III was then put on the increase of the level and the quality of regulatory capital. In addition to that the BCBS introduced a leverage ratio, which should act as a protection against the failure of internal models and therefore represents a risk insensitive backstop (Pérez Montes et al., 2018). However, what Basel III did not reform was the calculation of RWAs under both the standardised approach (SA) as well as the much criticised IRB-approach (Blundel-Wignall & Atkinson, 2010; Sonali & Amadou N.R., 2012). These aspects were then taken up by the BCBS in their Basel IV framework and will be described in Section 4 (Basel Committee on Banking Supervision, 2017).

The IRB-Approach and its Up- and Downsides

As already mentioned in the previous section, the standardised approach has often been criticised because of its rough RWA calculation (Behn et al., 2016a; Pérez Montes et al., 2018). This approach uses standardised risk weights depending on the asset class and the credit risk of the debtor. In order to address this point of criticism, the BCBS introduced a new method to calculate the RWAs: the so-called IRB-approach. This new calculation method uses complex internal models which have to be approved by the regulatory authority to determine the amount of regulatory capital (Resti, 2016).

The IRB-Approach under Basel II

When banks decide on the implementation of the IRB-approach they have the possibility to choose between the Foundation Internal Ratings-Based Approach (FIRBA) and the Advanced Internal Ratings-Based Approach (AIRBA). The difference between these two approaches is that for the foundation approach the bank only needs to determine the probability of default on its own, whereas the remaining parameters, such as exposure at default, loss given default and maturity (M) are provided by the authority. For the advanced approach all parameters have to be determined by the bank (Basel Committee on Banking Supervision, 2004).

Both approaches are based on the calculation of the Value at Risk (VaR), which is a commonly used measure for risk management. The VaR measures the maximum loss within a certain period of time and a given confidence level – therefore the VaR does not give any information about the loss below this threshold (Chen, Wang, & Zhang, 2019; Zoia, Biffi, & Nicolussi, 2018). The Basel regulations require banks to calculate their RWAs using the VaR at a confidence level of 99.9% (Basel Committee on Banking Supervision, 2004). Figure 1 shows the VaR-model, which includes the expected loss, which banks already incorporate in their interest rates dependent on their customers PD and the estimated LGD, and the unexpected loss, which they do not incorporate as they do not expect it to be incurred. Figure 1 is represented in formulas 5 and 7, which show the deduction of the expected loss (LGD x PD) from the total loss at the confidence level of 99.9% (Aikman et al., 2014).

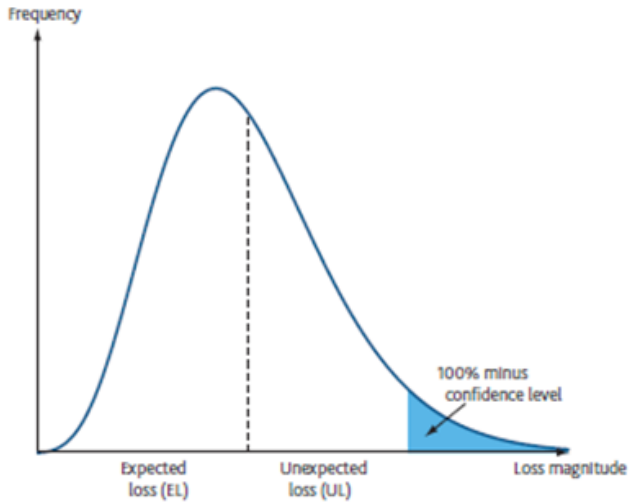

Figure 1. Value at Risk model for credit risk under Basel II

Source: Aikman et al. (2014)

The general formula for the calculation of risk weighted assets is shown in formula 1.

$$RWA=K \times 12{,}5 \times EAD \times 1.06 \quad (1)$$

In this formula the value of 12.5 represents the reciprocal of the minimum capital ratio which has been set at 8%. The scaling factor of 1.06 has been introduced by the BCBS in order to maintain a certain level of minimum capital requirements (Basel Committee on Banking Supervision, 2004). However, the calculation of the capital requirements (K), which will be described in the following paragraphs, differs between the individual exposures.

Calculation for Exposures to Corporates, Sovereigns and Banks

In order to be able to calculate the capital requirements, one firstly needs to determine the correlation (p) and the maturity adjustment (b). Basel II assumes an inverse relationship between the PD and the parameter for correlation (p) which it bases on empirical results (Lopez, 2002). If the solvency of a company decreases, its PD increases. This assumes that its probability of default gets more idiosyncratic and therefore it is less dependent on the overall market conditions (Hull et al., 2014).

$$p = 0.12\,\frac{1-\exp(-50\,x\,PD)}{1-\exp(-50)} + 0{,}24\left[1-\frac{1-\exp(-50\,x\,PD)}{1-\exp(-50)}\right] \quad (2)$$

The calculation of the correlation is slightly different for exposures to small- and medium-sized enterprises[1] (SMEs) as the formula also includes a firm-size adjustment in which S describes the annual turnover given in millions (Basel Committee on Banking Supervision, 2004):

$$p = 0.12\,\frac{1-\exp(-50\,x\,PD)}{1-\exp(-50)} + 0{,}24\left[1-\frac{1-\exp(-50\,x\,PD)}{1-\exp(-50)}\right] - 0{,}04\,x\,\frac{1-(S-5)}{45} \quad (3)$$

If Banks apply the FIRBA they must use 2.5 years as their effective term to maturity (M), if they apply the AIRBA they need to calculate M for every individual exposure (Basel Committee on Banking Supervision, 2004).

$$b = (0.11852 - 0.05478\,x\ln(PD))^2 \quad (4)$$

[1] SMEs = companies with an annual turnover of up to 50 million euros

After having calculated these parameters, the capital requirements (K) can be determined as follows:

$$K = \left[LGD\ x\ N\left\{N^{-1}(PD)\ x\ \sqrt{\frac{1}{1-p}}\ + N^{-1}(99.9\%)\ x\ \sqrt{\frac{p}{1-p}}\right\} - LGD\ x\ PD\right] x\ \frac{1+(M-2.5)+b(PD)}{1-1.5\ x\ b(PD)} \quad (5)$$

If the IRB-bank determines the parameters, which are incorporated in this formula, correctly, the calculated capital requirements should be large enough to ensure that the bank faces insolvency once every thousand years (Aikman et al., 2014).

Calculation for Retail Exposures

The calculation for retail exposures is a little simpler than the one before, as there is no maturity adjustment and the correlation is set to the fixed value of 0.15 for residential mortgage exposures, to 0.04 for qualifying revolving retail exposures and is determined by the following formula for all other retail exposures (Basel Committee on Banking Supervision, 2004):

$$p = 0.03\ \frac{1-\exp\ (-35\ x\ PD)}{1-\exp\ (-35)} + 0{,}16\ \left[1 - \frac{1-\exp\ (-35\ x\ PD)}{1-\exp\ (-35)}\right] \quad (6)$$

The calculation of the capital requirement is similar to the one for corporates, sovereigns and banks but does not include the maturity adjustment in the end:

$$K = \ LGD\ x\ N\left\{N^{-1}(PD)\ x\ \sqrt{\frac{1}{1-p}}\ + N^{-1}(99.9\%)\ x\ \sqrt{\frac{p}{1-p}}\right\} - LGD\ x\ PD \quad (7)$$

The Dark Side of the IRB-Approach

The IRB-approach has been introduced by the BCBS because they wanted to align the calculation of RWAs to the actual risks of the banks' portfolio. Banks, which decided for the implementation of the IRB-approach, are rewarded with more discretion in their risk assessment, a lower level of RWAs and therefore they are also able to reduce the amount of eligible capital they are required to hold (Barakova & Palvia, 2014; Cucinelli et al., 2018). Research indicates that the IRB model is superior to the SA model, as IRB banks are better placed to manage credit risk risk-sensitively. This is confirmed by the fact that IRB-banks reported a lower credit risk following the financial crisis (Cucinelli et al., 2018). According to a study which has been implemented by Barakova and Palvia (2014) the aim of increasing the risk sensitiveness of the Basel framework through the introduction of the IRBA has been reached: The results of their study show that under the AIRBA the alignment of capital with the banks' risk has improved. However, they could not foresee that there are also some other variations, which are not risk-related (Barakova & Palvia, 2014).

In the past years the IRB-approach has met with a great deal of criticism as researchers accused it of being self-regulatory, subject to manipulation and inferior to insensitive measures. The criticism of the excessive variability or heterogeneity within risk weights is one aspect that numerous articles together raised (Abbassi & Schmidt, 2018; Aikman et al., 2014; Cucinelli et al., 2018; Haldane, 2013; Hellwig, 2010; Mariathasan & Merrouche, 2014; Mayes & Stremmel, 2012; Sonali & Amadou N.R., 2012). This criticism refers to the fact, that the IRB-approach provides banks with a high level of discretion, as they are able to determine key parameters like PD, LGD and EAD on their own. As the determination of these parameters involves calibration and a certain level of judgement, it is possible that different banks assign different risk weights to the same asset. The problem of potential differences in risk weights is referred to as the problem of heterogeneity within risk weights (Turk-Ariss, 2017). All these criticisms will be addressed in the next few paragraphs.

Capital Optimisation and Risk Weight Manipulation

The right amount of equity is difficult to determine: a low level of capital may lead to an increase in the riskiness of banks' portfolios whereas a high level of capital may encourage banks to reduce their lending (Mariathasan & Merrouche, 2014). If banks estimated their internal risks properly, the only differences in their risk weights, which is calculated by dividing the RWAs by their total assets, should lie in the riskiness of their portfolios, the variation in

their modelling techniques and national implementation guidelines (Haselmann & Wahrenburg, 2016). However, it is expensive for banks to hold eligible capital and therefore they are encouraged to reduce it to a minimum. This fact is also referred to as Goodhart's law, which says: 'When a measure becomes a target, it ceases to be a good measure' (Plosser & Santos, 2018). Therefore, the IRBA might suffer from incentive problems (Behn et al., 2016a). Recent studies which have dealt with risk weight variability show that risk weight density decreases after the approval of the IRBA by the regulatory body (Mariathasan & Merrouche, 2014), that reported risk weights in general are significantly lower for IRB-banks than for SA-banks, but that actual default rates are higher for IRB-banks than for SA-banks. In addition to that, they show that the interest rates, charged by IRB-banks are higher than those charged by SA-banks, which indicates that banks were well aware of the risks within their portfolios but they just do not take this into account when calculating the risk weights (Barucci & Milani, 2018; Behn et al., 2016a). Some studies also show that these effects are particularly strong for weakly capitalised banks, which are found in countries where supervision is weak (Mariathasan & Merrouche, 2014; Plosser & Santos, 2018; Turk-Ariss, 2017). Another concern associated with the IRBA is the connection between risk weights and bank distress, which is statistically significant for SA-banks but insignificant for IRB-banks (Cizel, Rijken, Altman, & Wierts, 2017).

Simplicity versus Complexity

Another much criticised aspect of the IRBA is the high complexity involved in the calculation which makes it difficult to monitor (Tarullo, 2014). Although very complex models have already been used prior to the financial crisis, they still were not able to predict nor to prevent it. Since then the models have become even more complex as more and more information is taken into account (Aikman et al., 2014). However, some studies point out that risk insensitive models, like the leverage ratio which has been introduced with Basel III and represents a non-risk-weighted ratio, often outperform risk sensitive ones. Not only because these models are easier to enforce, but also because empirical evidence proves that simple ratios provide a better indication of potential bank distress (Barucci & Milani, 2018; Behn et al., 2016a; Estrella, Park, & Peristiani, 2000; Kiema & Jokivuolle, 2014). In addition to that, the global financial crisis showed that risk-weighted models were no good as predictors of the crisis itself (Mayes & Stremmel, 2012). Risk measurement models use data from the past to predict future defaults (Rajan, Seru, & Vig, 2015) and they are subject to model risk, as they use statistical models to estimate risk. There is a variety of statistical models, which all present different outcomes and therefore also variable risk weights – the difference between all of them represents the model risk, which tends to be low during financially stable periods, but high in times of financial distress (Danielsson, James, Valenzuela, & Zer, 2016). This indicates that sometimes "It's better to be roughly right than precisely wrong" as John Maynard Keynes already said.

Procyclicality

In comparison to the standardised approach, the IRB approach uses a large number of risk weights which are variable between banks and dependent on the counterparty's PD and LGD. This large amount of risk weights grants risk-sensitive capital regulation, which ties capital charges to the actual risks banks are facing. However, this might not only be positive, as it also causes a certain level of procyclicality: banks are encouraged to increase their lending during good times, as loans are perceived as being less risky and therefore less eligible capital is required, but they will also tend to reduce lending during bad times when it becomes riskier (Ben Naceur, Marton, & Roulet, 2018; Ly & Shimizu, 2018). The IRBA, which represents the most risk-sensitive form of capital regulation, is said to be amplifying this effect (Repullo & Suarez, 2012). This fact is also confirmed by a study which analyses the effects of the global financial crisis on the lending behaviour of German banks. This study shows that the reduction in lending was greater for IRB-banks than for SA-banks. The BCBS has already reacted to this effect, as Basel III introduced a capital conservation buffer, which is designed in a way that leads banks to build up a capital buffer during times of growth. This excess capital can then be used in times of recession (Behn, Haselmann, & Wachtel, 2016b).

The afore mentioned critics encouraged the BCBS to revise the Basel III framework and introduce Basel IV. The alterations to the existing framework will be described in the following section.

Basel IV's Implications on the Measurement of Credit Risk

In March 2016, the BCBS already responded to the afore mentioned criticism for the first time and drafted the consultative document 'Reducing variation in credit risk-weighted assets - constraints on the use of internal model

approaches' in which it made several proposals to reform the standardised approach and restrict the IRB approach. This paper restricts the application of the IRB approach to specific portfolios; it includes an input floor that provides a constraint on the parameters used for the calculation (PD, LGD, CCF, EAD), and an output floor, which links the IRB-RWAs to the SA-RWAs (Basel Committee on Banking Supervision, 2016). In December 2017, the BCBS then published its final paper 'Basel III: Finalizing post-crisis reforms', also commonly referred to as Basel IV. In it, the proposals of the consultative paper from 2016 were revised and finally fixed. The document contains a timetable which suggests an implementation of the regulations from 2022 onwards (Basel Committee on Banking Supervision, 2017).

Implications for the Standardised Approach

Although this article primarily deals with the effects of Basel IV on the IRBA, it is also necessary to describe its influence on the SA, as the RWAs which are calculated following this approach provide the basis for the output floor, which in turn is an important part of the Basel IV IRBA. Overall it can be said that the BCBS' revisions of the SA for credit risk are seen positively by the literature, as they lead to an increased risk-sensitivity (Joosen, 2016).

Within the exposures to corporates it is necessary to distinguish between specialised lending exposures and general corporate exposures. Basel IV gives banks the possibility to base the risk weights of its corporate exposures on the rating of their counterparty if this has been determined by an eligible credit assessment institution (ECAI) (Basel Committee on Banking Supervision, 2017). As the sample data does not provide any external ratings, this approach cannot be applied. Therefore, the rules for banks located in jurisdictions, which do not allow the application of the previously described approach, are described and applied in the simulation.

Concerning general corporate exposures, banks need to determine whether an exposure is to a normal corporation or whether it is to an SME. In cases where it is to a corporation, Basel IV distinguishes between investment grade exposures, which are risk weighted at 65% and normal exposures, which receive a risk weight of 100%. Exposures to SMEs are divided into regulatory retail exposures and general SME exposures. The definition of regulatory retail encompasses the following characteristics: the exposure needs to be revolving or a personal term loan or lease, it amounts to € 1,000,000 or less and the exposure to one individual cannot exceed the threshold of 0.2% of the total regulatory retail portfolio. In cases where an exposure fulfills all these requirements, it is risk weighted at 75%. For all other SME exposures a risk weight of 85% is applied (Basel Committee on Banking Supervision, 2017).

Basel IV recognises three different types of specialised lending exposures: project finance, object finance and commodities finance. The risk weights, which are applied to object and commodity finance exposures are generally 100%, whereas there are three potential risk weights for project finance exposures: 130% if the project is in its pre-operational phase, 100% if its in the operational phase and 80% if it is in the operational phase and deemed to be high-quality (Basel Committee on Banking Supervision, 2017).

Within the retail portfolio, Basel IV defines two different types of exposure: the regulatory retail exposure and other retail exposures, which defines the remaining population and is risk weighted at 100% (Basel Committee on Banking Supervision, 2017).

As the bank's corporate and retail portfolio also contains real estate exposures, the adapted rules need to be explained in this article. Basel II allocated a risk weight of 35% to exposures, which were fully secured by residential real estate, but then risk-weighted commercial real estate exposures at 100% (Basel Committee on Banking Supervision, 2004). This regulation has been revised by the BCBS, as risk weights are now dependent on the Loan-to-Value-Ratio (LTV-Ratio) of the exposure. This ratio is calculated by dividing the amount of the loan by the value of the property. The calculated LTV-Ratio then leads to individual RWs, which also depend on whether they are residential or commercial real estate and whether the repayment is materially dependent on the cashflows generated by the property or not (Basel Committee on Banking Supervision, 2017). The changes within the real estate portfolio are seen as the most significant ones within the revision of the SA, as they bring more sophistication and more risk sensitivity (Joosen, 2016).

Removal of the IRB Option for Certain Exposures

Basel IV removes the possibility to apply the IRBA for certain asset classes, which exhibit modelling difficulties due to the small number of defaults. The exposures which are affected are shown in table 1. This restriction reflects certain critical voices like Amorello (2016), who argued that Basel III did not address the questionable reliability of the IRBA and that banks therefore were still incentivised to calculate their regulatory capital based on internal models

and parameters. Still, there are also adverse comments from the banking industry, which state that they fear a disproportionate increase of capital requirements for banks within the European Union, and that certain variations within the RWAs are desirable as they reflect differences in portfolios (Strickland, 2017). As the bank, which provided the data for the simulation applies the AIRBA on its retail portfolio and the FIRBA on its corporate portfolio and its equity portfolio, which then again has been excluded from the simulation due to insignificance, the effects of the removal of the IRB-option are not analysed in this article.

Table 1. Available Approaches under Basel II and IV

Exposure	Approaches under Basel II	Approaches under Basel IV
Corporates (consolidated revenue > 500 MEUR)	AIRB, FIRB, SA	FIRB, SA
Banks & other financial institutions	AIRB, FIRB, SA	FIRB, SA
Equities	AIRB, FIRB	SA

Source: Basel Committee on Banking Supervision (2017)

Input Floor for Model Parameters

The parameters used for the RWA calculation of exposures which can still be measured using the IRBA will be subject to the introduction of input floors for the PD, the LGD and the EAD (Basel Committee on Banking Supervision, 2017). The bank which provided the credit data, determine their RWAs for the corporate portfolio using the FIRBA and their RWAs for the retail portfolio using the AIRBA. Under the FIRBA banks only determine the PD on their own, whereas the other parameters are prescribed by the regulator (Basel Committee on Banking Supervision, 2004). Due to that only the PD-Floor has been considered in the simulation of the corporate portfolio, whereas all other floors have been taken into account in the simulation of the retail portfolio.

The minimum value for the PD of an exposure to a corporation amounts to 0.05%. The minimum PDs for retail exposures have been set at 0.05% for mortgages, qualifying revolving retail transactors and for other retail exposures, while exposures which come within qualifying revolving retail exposures (QRRE) were set at 0.1%. Under the AIRBA the minimum value for the LGD depends on whether the exposure is secured or unsecured. For unsecured exposures the LGD input floor has been set at 25% for corporates, at 50% for QRRE and at 30% for other retail exposures. The LGD of secured loans has to amount to at least 5% for mortgages and is dependent on the collateral type for corporate and other retail exposures: financial collaterals allow banks to set the LGD at 0%, receivables and commercial or residential real estate at 10% and other collaterals at 15%. In addition to the floor, which requires a minimum level of LGDs and has been introduced for exposures under the AIRBA, the determination of the LGD in the FIRBA has also been reformed. The LGD for unsecured exposures has been reduced from 45% to 40% if the counterparty is a corporation. The LGD of the collateral depends on the exposure weighted average of the unsecured and the secured LGD and is determined using formula 8. The secured LGD amounts to 0% for eligible financial collateral, 20% for eligible receivables and real estate and 25% for other eligible physical collateral. In addition to these LGDs a haircut has to be applied: this amounts to 40% for eligible receivables, real estate and other physical collateral and to 100% for ineligible collateral (Basel Committee on Banking Supervision, 2017).

$$LGD\ Floor = LGD\ Floor_U\ x\ \frac{E_U}{E\ (1+H_E)} +\ LGD\ Floor_S\ x\ \frac{E_S}{E\ (1+H_E)} \quad (8)$$

Where:
LGD FloorU - LGD floor for the secured portion of the exposure
EU - Unsecured portion of the other retail exposure
HE - Haircut of the collateral
LGD FloorS - LGD floor for the secured portion of the other retail exposure
ES - Secured portion of the other retail exposure

Under the AIRBA banks also need to determine their EAD measures. Basel IV now prohibits the application of internal EAD estimation and requires banks to determine their off balance sheet exposure using the credit conversion factors (CCF) which are also used under the standardised approach (Resti, 2016). In addition to that the BCBS also introduced a floor to the EAD, which is the sum of the entire on balance exposure plus 50% of the off balance exposure (Basel Committee on Banking Supervision, 2017).

Output Floor

The output floor will affect not only the RWAs resulting from credit risk but also all other risk types. In respect of credit risk, banks will need to determine their RWAs according to the standardised approach also for their IRB-portfolios. The output floor determines that the final IRB-RWAs must be at least 72.5% of the SA-RWAs by 2027 (Basel Committee on Banking Supervision, 2017). This floor replaces the previously applicable Basel I floor and serves as a backstop that links the RWAs calculated under the IRBA to the RWAs calculated under the SA. This introduction should ensure that a level playing field between IRB- and SA-banks is maintained (Bodellini, 2019). However, it is also seen critically as the leverage ratio already serves as a risk-insensitive backstop (Haselmann & Wahrenburg, 2016; Pérez Montes et al., 2018). Basel IV also includes transitional measures which include a phase-in arrangement for the output floor from 2022 to 2027. Within this period of time the Basel IV output floor gradually increases from 50% to 72.5%. The simulation includes the application of all percentages, but only the results of the final 72.5% output floor will be presented in this article. Due to these and the afore mentioned alterations to the IRBA, the BCBS decided that it is no longer necessary to apply the scaling factor of 1.06 in the RWA calculation (Basel Committee on Banking Supervision, 2017).

Methodology

The aim of this article is to show the impact of Basel IV on the heterogeneity of risk weights. This aspect has already been addressed in numerous studies, but to my knowledge none of them analysed the implications of the Basel IV input and output floors on heterogeneity. Most articles used RWA density, which is calculated by dividing RWAs by total assets, as a measure of heterogeneity: Beltratti and Paladino (2016) used it to show that banks perform capital optimisation through the usage of the IRBA, Mariathasan and Merrouche (2014) showed that RWA density decreased considerably after the regulatory approval of the IRBA and Vallascas and Hagendorff (2013) exhibited that there is an ill-calibration in the context of RWAs and portfolio risk with the usage of risk weight density. Due to the fact that RWA density has already been used by researchers to address numerous aspects, all in connection with risk weight heterogeneity, this ratio will also be used in this article.

The data analysis relies on a simulation as an inductive data driven instrument. Some research articles have previously already used a simulation for showing diverse aspects dealing with the Basel framework: Andersen (2011) used it to show Basel II's procyclical implications, Peura and Jokivuolle (2004) simulated the Basel stress tests for capital adequacy and Bellotti (2010) used it to compute the expected loss distributions of Basel II based on a credit card portfolio. The simulation itself has been applied using Microsoft Excel 2016. This choice can be justified with the fact that it allows the user to have full control over the applied parameters and maximum freedom in the analysis as well as the presentation of the data. The simulation was applied using advanced formulas and the data analysis tool.

Description of the Sample

The data was provided by a small IRB-bank located in Western Europe. The bank's total assets amount to less than 10 billion euros and the management controls the bank conservatively. The simulation is based on the bank's credit data and therefore only analyses the impact of Basel IV on the IRB approach for credit risk. As credit risk makes up about 80% of the total risk-weighted assets (Berg & Koziol, 2017), it is considered appropriate to exclude alterations in other risk types which are due to Basel IV from this thesis. Table 2 shows that the bank applies the AIRBA on its retail portfolio, whereas it applies the FIRBA on its corporate portfolio, on equities and investment certificates. In addition to that it can also be stated that the bank clearly focuses on retail exposures. As the data stems from a small regional bank, the results are very likely to differ from the results of large multinational banks. Nevertheless, the data is considered to be appropriate for simulation, as it represents a typical regional bank within Europe. Another aspect, which made the usage of the data very appealing, was the fact that small banks usually hold a rather small number of

syndicated loans, which could distort the simulation results. Therefore, this sample probably includes much clearer data within the corporate portfolio.

Table 2. EAD, RWA and RWD of the sample

	EAD	RWA	RWA Density
IRB Advanced Approach	**55.85%**	**22.18%**	**0.208**
Retail	55.85%	22.18%	0.208
IRB Foundation Approach	**44.15%**	**77.82%**	**0.924**
Equities	0.75%	4.26%	2.973
Corporates	43.24%	72.44%	0.879
Investment Certificates	0.16%	1.13%	3.700
Total	**100.00%**	**100.00%**	**0.524**

As the retail and corporate exposures already make up 99.09% of the total EAD and 94.62% of the RWA of the IRB-portfolio respectively, and these are the only asset classes which show a RWA density from below one, only these two asset classes are included in the simulation. The RWA density, which has been calculated by dividing the RWA by the EAD, of the overall IRB portfolio, amounts to 0.524 which suits the mean RWA density shown in table 3, which has been observed by Mariathasan and Merrouche (2014) during the period from 2004 to 2010 based on the data of 115 IRB-banks in 21 OECD-countries. The RWA density observed by Mariathasan and Merrouche (2014) is calculated on the basis of the entire portfolio of the banks being included. As a banks credit data provides the basis for this article, it is possible to analyse the RWA density more exactly. Therefore it is possible to calculate the RWA density for each asset class – this calculation shows that the RWA density of the retail portfolio lies clearly below the mean, as it amounts to 0.208, whereas the RWA density of the corporate exposure amounts to 0.879 and therefore lies above the mean observed by Mariathasan and Merrouche (2014).

Table 3. RWD according to Mariathasan and Merrouche (2014)

	Minimum	Mean	Maximum
RWA Density	0.024	0.516	0.965

For both portfolios, the maximum PD amounts to 22.77%. The minimum LGD and PD of the total corporate portfolio account for 0%, which is caused by the fact that specialised lending exposures are also included in the sample. For these exposures, the RW is not determined by the usage of the IRB-formula but is set by the Basel regulations. The minimum LGD of the remaining corporate portfolio amounts to 35%, which also represents a predefined parameter, as the FIRBA is used for this portfolio.

Table 4. PD and LGD of the sample

Asset Class	PD_{min}	PD_{av}	PD_{max}	LGD_{min}	LGD_{av}	LGD_{max}
Retail	0.03%	2.17%	22.77%	5.00%	35.23%	80.14%
Corporates	0.00%	2.01%	22.77%	0.00%	41.87%	45.00%

As the Basel framework requires banks to apply different formulas to their asset classes, the simulation was split into two parts: the simulation of the corporate portfolio, which is described in 0 Corporate Portfolio and the simulation

of the retail portfolio, which is shown in 0 Retail Portfolio. Before the separation into these portfolios it had to be determined whether an exposure falls into Basel IV's regulatory retail class, as this applies for the retail as well as for the corporate portfolio. Therefore, exposures within the corporate portfolio which were categorised as SMEs, amounted to a maximum value of € 1.000.000 and were not categorised as specialised lending were added to retail exposures, which were defined as qualifying revolving retail by the bank itself. After grouping these exposures together, each one was analysed as to whether it amounts to more than 0.2% of the overall regulatory retail portfolio (Basel Committee on Banking Supervision, 2017). If the exposure was smaller than 0.2% of the regulatory retail portfolio it remained in this portfolio, if it was higher it was excluded – the categorisation was then used in the determination of risk weights, which will be described later on.

Corporate Portfolio

The simulation of the corporate portfolio is divided into three steps: the simulation of the standardised approach under Basel IV, the simulation of the Basel IV input floors and the simulation of the Basel IV output floors.

Simulation of the Basel IV Standardised approach

For the simulation of the standardised approach it was necessary to divide the corporate portfolio into general corporate exposures and specialized lending exposures. This categorisation has already been given by the bank itself as it splits its corporate portfolio into general corporates, real estate finance, project finance and object finance.

Basel IV includes project finance, object finance and commodities finance in its framework for specialised lending exposures. The risk weights which are applicable for these exposures are dependent on the sub portfolio they belong to: object and commodity finance exposures generally receive a risk weight of 100% whereas project finance exposures have to be separated into exposures during the pre-operational phase, which receive a risk weight of 130% and exposures during the operational phase, which are generally risk weighted at 100% unless they are deemed to be high quality, then they receive a risk weight of 80% (Basel Committee on Banking Supervision, 2017). As the data did not include any information about the phase they are currently in and the quality of them, it was assumed, that 60% of the entire portfolio are in the operational phase whereas 40% are in the pre-operational phase. Due to simplification reasons there was no assessment of the quality of the exposure, so all project finance exposures, which are in their operational phase were risk weighted at 100%. It must be noted that this further categorisation would only have an insignificant influence on the overall result, as the project finance portfolio only amounts to 7.93% of the entire RWAs of the corporate portfolio.

The Basel IV framework also includes new rules for banks' real estate exposures: Basel IV differentiates between the collateralisation by commercial and residential real estate, and whether repayment is materially dependent on the cash flows which are generated by the property or not (Basel Committee on Banking Supervision, 2017). For reasons of simplicity, it was assumed that all real estate exposures within the corporate portfolio are secured by commercial real estate. The bank includes its real estate exposures in its specialised lending exposures, as it defines them as income-producing real estate (IPRE) under the IRBA. The Basel IV definition of IPRE exposures contains the requirement that the repayment of these loans needs to materially depend on the cash flows generated by the property (Basel Committee on Banking Supervision, 2017). Due to that, it was assumed that there exists a material dependence on the cash flows of the property for the entire real estate exposure. Therefore the risk weights depend on the Loan-to-Value-Ratio (LTV-Ratio) of the respective exposure. This ratio is calculated by dividing the amount of the loan by the value of the property – the applied risk weights are shown in formula 9.

$$W = \begin{Bmatrix} LTV \leq 60\% = 70\% \\ 60\% < LTV \leq 90\% \\ LTV > 80\% = 110\% \end{Bmatrix} \quad (9)$$

Within the general corporate exposures there is a distinction between regulatory retail exposures, general SME exposures, investment grade exposures and all other corporate exposures. Regulatory retail exposures within the corporate portfolio must be to SMEs, amount to up to € 1,000,000 and not exceed 0.2% of the overall regulatory retail portfolio. This allocation has already been made during the data preparation and has been described under **Fehler! Verweisquelle konnte nicht gefunden werden. Fehler! Verweisquelle konnte nicht gefunden werden.**. The exposures which are categorised as regulatory retail are risk weighted at 75%, whereas the remaining exposures which are to SMEs receive a risk weight of 85% (Basel Committee on Banking Supervision, 2017). Based on the information

provided by the bank, it was not possible to assess whether an exposure can be allocated to the investment grade portfolio. Due to that reason the remaining corporate portfolio was risk weighted at 100%. After having determined the risk weights for all exposures, it was possible to calculate the RWAs under the Basel IV standardised approach. The results of this calculation will be needed for the calculation of the output floor.

Simulation of the Basel IV Input and Output Floors

Basel IV introduced a parameter floor for the probability of default which amounts to 0.05% (Basel Committee on Banking Supervision, 2017) - therefore all exposures to corporates, which showed a smaller PD, were floored at this percentage. As the bank, which provided the data for the simulation, applies the foundation approach on its corporate exposure, the effect of the PD floor is the only one that can be simulated, as the other parameters are fixed by the standard setter and therefore not affected by any floors. Basel II required banks to apply a risk weight of 45% on unsecured senior claims and 75% on unsecured subordinated ones under the FIRBA. The LGD for the secured part of the exposure depended on the type of collateral and amounted to 35% at a minimum (Basel Committee on Banking Supervision, 2004). Basel IV now requires banks to apply an LGD of 40% on unsecured senior claims for exposures to corporates, whereas the risk weight for unsecured subordinated exposures remains the same. The LGD for the secured portion of the exposure needs to be calculated as the exposure weighted average of the unsecured and the secured LGD using formula 8. As already mentioned, the LGD of the unsecured portion amounts to 40%. The LGD of the secured portion amounts to 0% for eligible financial collateral, 20% for eligible receivables and real estate and 25% for other eligible physical collateral. In addition to these LGDs, a haircut has to be applied: this amounts to 40% for eligible receivables, real estate and other physical collateral and to 100% for ineligible collateral (Basel Committee on Banking Supervision, 2017). As the sample data did not comprise any information about the type of collateral, the secured LGD was fixed at 20%, as this applies for two out of four collateral types. In addition to that the haircut was fixed at 40%, as this applies for three out of five categories.

After the determination of the Basel IV LGDs and PDs it was possible to calculate the correlation (p), the capital requirements (K) and the RWAs by using the formulas stated in 0 Calculation for Exposures to Corporates, Sovereigns and Banks.The results of this calculation represent the RWAs following the Basel IV rules for input floors. The simulation of the output floor was done by multiplying the RWAs, which have been determined by applying the Basel IV rules for the standardised approach, with the applicable percentages of 50% in 2022 to 72.5% in 2027 (Basel Committee on Banking Supervision, 2017).

Retail Portfolio

Like the simulation of the corporate portfolio, the simulation of the retail portfolio is divided into three steps: the simulation of the standardised approach under Basel IV, the simulation of the Basel IV input floors and the simulation of the Basel IV output floors.

Simulation of the Basel IV Standardised approach

The simulation of the Basel IV SA required the segmentation of the retail portfolio into the real estate exposure, the regulatory retail exposure and other retail exposure. The segmentation criteria have already been partially provided by the bank itself as it splits its retail portfolio into three Basel sub categories: residential mortgages, qualifying revolving retail and other retail. For the purpose of the simulation it has been assumed that the bank's residential mortgage portfolio meets Basel IV's criteria for the real estate exposure, which includes the following requirements: the property needs to be fully completed, the claim has to be legally enforceable, the bank holds a first lien, the borrower needs to be able to repay, the value of the property has to be determined in a prudential way and all required information needs to be documented. In addition to that it is assumed that the bank's qualifying revolving retail exposure fulfills Basel IV's requirements for regulatory retail, which say that the exposure needs to be revolving or a personal term loan or lease, it amounts to € 1,000,000 or less and that the exposure to one individual cannot exceed the threshold of 0.2% of the total regulatory retail portfolio. The remaining exposures have been determined as 'other retail' by the bank and will therefore be treated as other retail under Basel IV (Basel Committee on Banking Supervision, 2017).

The risk weights for the regulatory retail portfolio amount to 75% and to 100% for the other retail portfolio under the Basel IV standardised approach. The determination of risk weights is a little more complicated for real estate

exposures as it depends on the fact of whether the repayment is materially dependent on the cash flows which are generated by the property or not and on the Loan-to-Value-Ratio (LTV-Ratio) of the loan itself.(Basel Committee on Banking Supervision, 2017). As the data did not comprise any information about the material dependence on the cash flows of the property, it was assumed that there exists a material dependence if the counterparty is occupied in the real estate sector. This is due to the fact that debtors, whose ability to repay depends substantially on the cash flows of the property, are usually involved in real estate development. The risk weights for loans whose repayment is not materially dependent on the cash flows of the property are shown in formula 10, whereas the ones for loans whose repayment is materially dependent are shown in formula 11. After the determination of risk weights it was possible to simulate the calculation of risk-weighted assets under the Basel IV standardised approach. The results of this simulation provide a basis for the simulation of the Basel IV output floor, which will be described later on.

$$RW = \begin{Bmatrix} LTV \leq 50\% = 20\% \\ 50\% < LTV \leq 60\% = 25\% \\ 60\% < LTV \leq 80\% = 30\% \\ 80\% < LTV \leq 90\% = 40\% \\ 90\% < LTV \leq 100\% = 50\% \\ LTV > 100\% = 70\% \end{Bmatrix} \quad (10)$$

$$RW = \begin{Bmatrix} LTV \leq 50\% = 30\% \\ 50\% < LTV \leq 60\% = 35\% \\ 60\% < LTV \leq 80\% = 45\% \\ 80\% < LTV \leq 90\% = 60\% \\ 90\% < LTV \leq 100\% = 75\% \\ LTV > 100\% = 105\% \end{Bmatrix} \quad (11)$$

Simulation of the Basel IV Input and Output Floors

As already described under **Fehler! Verweisquelle konnte nicht gefunden werden. Fehler! Verweisquelle konnte nicht gefunden werden.**, Basel IV introduced parameter floors for LGD, PD and EAD. The LGD floor for mortgages is fixed to 5% and the one for QRREs to 50%. The LGD floor for the retail class 'other retail' depends on whether the loan is secured or not and in the case where it is secured, also on the type of collateral. As most of the loans within the other retail portfolio are not fully but only partially secured, the LGD floor has to be determined using formula 8. The unsecured LGD floor (LGD $Floor_U$) for other retail exposures is fixed to 30% whereas the secured one (LGD $Floor_S$) depends on the collateral type and lies between 0% and 15%.(Basel Committee on Banking Supervision, 2017) As the sample does not include any information about the collateral type, it is assumed that the minimum LGD amounts to 10% for the secured portion of this retail class as this percentage applies to two out of four collateral types. As the haircut for these two collateral types amounts to 40%, this percentage is used for the calculation of the entire other retail portfolio. As already mentioned under 0 Simulation of the Basel IV Standardised approach, the bank already splits its retail portfolio into residential mortgages, qualifying revolving retail and other retail. This information was used for the determination of the applicable PD floor. The application of input floors was simulated in Microsoft Excel by using an IF formula, which is shown in formula 12 for the PD-floor and in formula 13 for the LGD floor. This formula says that in the case where the PDs or LGDs, which have been provided by the bank, undercut the respective LGD- or PD-floor, the LGD- or PD-floor must be used for the RWA calculation. In the case where they exceed the floors, the LGDs or PDs provided by the bank can be used. The EAD floor was simulated by using a CCF of at least 50% for all off balance exposures.

$$PD\ Basel\ IV = \begin{Bmatrix} PD_{Mortgages} \leq 0.05\% = 0.05\% \\ PD_{Mortgages} > 0.05\% = PD_{Mortgages} \\ \\ PD_{QRRE} \leq 0.10\% = 0.10\% \\ PD_{QRRE} > 0.10\% = PD_{QRRE} \\ \\ PD_{Other\ Retail} \leq 0.05\% = 0.05\% \\ PD_{Other\ Retail} > 0.05\% = PD_{Other\ Retail} \end{Bmatrix} \quad (12)$$

$$LGD\ Basel\ IV = \begin{Bmatrix} LGD_{Mortgages} \leq 5\% = 5\% \\ LGD_{Mortgages} > 5\% = LGD_{Mortgages} \\ \\ LGD_{QRRE} \leq 50\% = 50\% \\ LGD_{QRRE} > 50\% = LGD_{QRRE} \\ \\ LGD_{Other\ Retail} \leq LGD\ Floor_{Other\ Retail} = LGD\ Floor_{Other\ Retail} \\ LGD_{Other\ Retail} > LGD\ Floor_{Other\ Retail} = LGD_{Other\ Retail} \end{Bmatrix} \quad (13)$$

After the determination of the Basel IV LGDs, PDs and EADs it was possible to calculate the correlation (p), the capital requirements (K) and the RWAs by using the formulas stated in **Fehler! Verweisquelle konnte nicht gefunden werden. Fehler! Verweisquelle konnte nicht gefunden werden.**. The result of this calculation represents the RWAs following the Basel IV rules for input floors. The simulation of the output floor was done by multiplying the RWAs, which have been determined by applying the Basel IV rules for the standardised approach, with the applicable percentages of 50% in 2022 to 72.5% in 2027 (Basel Committee on Banking Supervision, 2017).

Empirical Findings

In order to anonymise the data, the findings will only be presented as percentages or ratios.

Corporate Portfolio

As the bank uses the FIRBA for the valuation of its corporate portfolio, it only estimates the PDs of its exposures but uses fixed parameters, which are provided by the regulator for its LGDs and EADs. (Basel Committee on Banking Supervision, 2004) Due to that, it was only possible to analyse the effects of the PD floor and the output floor on the RWD of the corporate portfolio.

The analysis of the bank's credit data shows that the valuation of its corporate portfolio is rather conservative as the RW density amounts to 0.879, which is close to the maximum RW density, which has been observed by Mariathasan & Merrouche (2014). It can therefore be said, that heterogeneity does not represent a big problem within this portfolio. After the simulation of Basel IV, it was possible to split the corporate portfolio into the element which is affected by the Basel IV PD floor and the element, which is not. This more detailed analysis shows that the RW density of exposures, which are not affected by the PD-Floor amounts to 1.018 and therefore even lies above the maximum RW density, which has been observed by Mariathasan & Merrouche (2014). In contrast, the RW density of exposures, which are affected by the PD floor only amounts to 0.164. The composition of this portfolio already suggests that the alterations of the Basel framework on the IRB approach for credit risks might not have huge effects on the RW density, as the exposures which are affected by the PD floor only make up 3.04% of the entire RWAs of the corporate portfolio.

Table 5. Composition of the corporate portfolio prior simulation

	EAD	**RWA**	**RWD**
Not affected by PD Floor	83.68%	96.96%	1.018
Affected by PD Floor	16.32%	3.04%	0.164
Total	**100.00%**	**100.00%**	**0.879**

The application of the Basel IV SA on the credit data led to a significant RWA increase of the PD floor affected exposure by 507.18%, while it led to a slight decrease of 1.90% within the remaining portfolio. The increase does not come as a surprise, as the applied risk weights within the SA are all near (regulatory retail: 75%, other SMEs: 85%) or even at 100% (general corporates). As the majority of the PD-floor-affected exposures fall into the group of general corporates, which are risk weighted at 100%, the RWD increases from 0.164 to 0.993. The development of

the exposures which are not affected by the PD floor was rather unexpected, but is also comprehensible as this effect is caused by specialised lending exposures:

- The greatest RWA reduction is observed within the project finance portfolio, as it amounts to -41.78%. This development is caused by the fact, that the Basel IV SA connects the risk weights to the project phase and not to the solvency of the exposure as the IRBA does. Therefore, the risk weights lie between 80% for high quality projects and 130% for projects in their pre-operational phase within the SA, but between 70% and 250% within the IRBA (Basel Committee on Banking Supervision, 2017).
- The RWAs of the real estate portfolio decline by 39.22%, which is due to the fact that they were risk weighted at an average of 173% within the IRBA, but received a lower risk weight within the standardised approach because of the dependence on LTV-ratios.
- The RWAs of object finance exposures decrease by 13.04%, as these exposures are generally risk weighted at 100% within the standardised approach, whereas they all received a risk weight of 115% (category: satisfactory) under the IRBA.

The general corporate exposure, which is not affected by the PD-Floor, shows an RWA increase of 6.90%, which is caused by the fact, that the SA usually leads to higher risk weighted assets than the IRBA, as the risk weights are fixed by the regulator and tend to be higher (Cucinelli et al., 2018).

The application of the new Basel IV regulations concerning the IRBA for credit risk does not show the expected results, as it leads to an RWA decrease of the exposure, which is not affected by the PD floor, by 23.95% and even the PD floor affected exposure by 1.44%. Overall the RWA reduction amounts to 18.90% and results in an RWD of 0.713. This development shows, that the application of the new Basel IV rules has a negative impact on risk weight heterogeneity, as it reduces the RWD by 0.166. The reasons for this development can clearly be attributed to the lower LGD (reduction of unsecured LGD from 0,45 to 0,40 and exposure weighted average LGD for the secured exposure) and the removal of the scaling factor of 1.06. These parameters fully affect the not PD floor affected exposure but are attenuated for the PD floor affected portfolio through the PD floor, which leads to an increase of the PD at least.

The impact of the output floor on the RWAs and the RWDs, which is shown in tables 6 and 7, is calculated by using the final percentage of 72.5%, which will be applicable from 2027 onwards. This percentage is displayed in the RWD itself, as it amounts to 0.724, which is caused by the RWDs, which amount to almost 1.000 under the SA. There is only a little difference between the RWDs after the application of the Basel IV input floors and after the application of the output floor. Compared to the initial RWD, both floors lead to a significant RWD reduction. Still, the final RWDs lie clearly above the mean, which has been observed by Mariathasan & Merrouche (2014). In addition to that, it has already been determined in the beginning, that risk weight heterogeneity is not such a big problem within this portfolio, as the initial RWD was already close to the maximum observed RWD by Mariathasan & Merrouche (2014).

Table 6. RWAs prior and after simulation

Exposure	**RWA Basel III IRBA**	**RWA Basel IV SA**	**RWA Basel IV IRBA – Input Floor**	**RWA Basel IV IRBA – Output Floor**
Not affected by PD Floor	96.96%	83.75%	96.31%	83.75%
Affected by PD Floor	3.04%	16.25%	3.69%	16.25%
Total	**100.00%**	**100.00%**	**100%**	**100%**

Table 7. RWD prior and after simulation

Exposure	RWD Basel III IRBA	RWD Basel IV SA	RWD Basel IV IRBA – Input Floor	RWD Basel IV IRBA – Output Floor
Not affected by PD Floor	1.018	0.999	0.820	0.724
Affected by PD Floor	0.164	0.993	0.161	0.720
Total RWD	**0.879**	**0.998**	**0.713**	**0.723**
Total Δ to Basel III	**-**	**0.119**	**-0.166**	**-0.156**

The major findings within the corporate portfolio can be summarised as follows:

- *Finding 1: The application of the Basel IV input and output floors can lead to an RWD decrease if they are applied to conservatively valued portfolios. This effect is primarily caused by a majority of PDs exceeding the PD floor.*
- *Finding 2: Due to the fact that the removal of the scaling factor applies to the entire portfolio, whereas the PD floor only applies to a certain part of it, the new regulations lead to an RWD reduction in the case of conservatively valued portfolios.*

These findings are summarised in Figure 2:

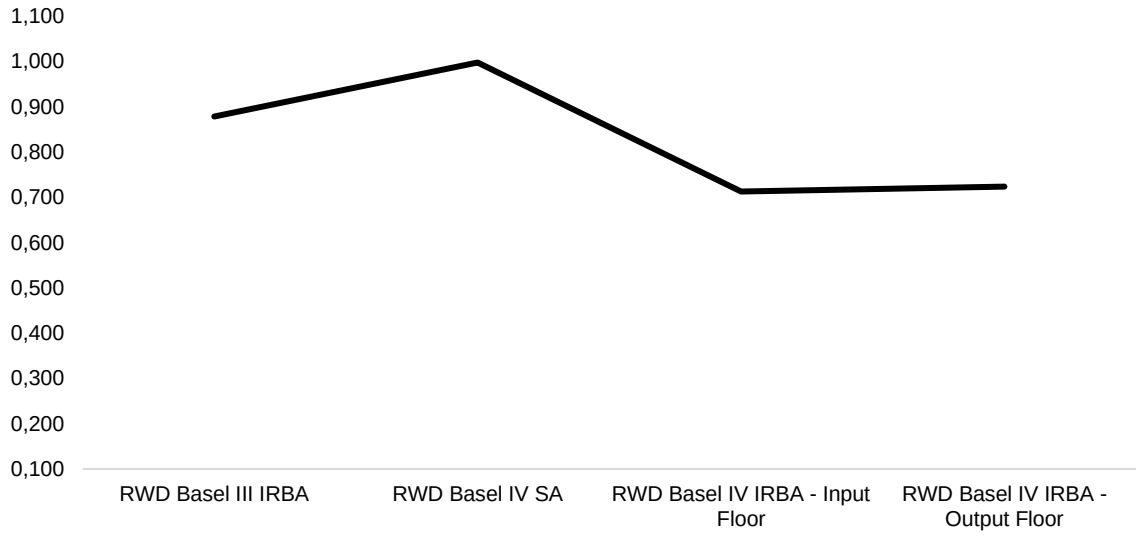

Figure 1. RWD Development Corporate Portfolio

Retail Portfolio

The bank, which provided the credit data, uses the advanced IRB approach for the calculation of its RWAs within the retail portfolio. Due to that it was possible to analyse the impact of the PD floor, the LGD floor, the EAD floor and the output floor on the risk weight density of the retail portfolio. The analysis of the transmitted data already showed that, compared to the corporate portfolio, the RWD of the retail portfolio is much lower. Still the overall RWD of the retail portfolio, which amounts to 0.208, is far from the minimum RWD (0.024) which has been observed by Mariathasan and Merrouche (2014).

The retail portfolio is divided into three sub-categories: qualifying revolving retail, other retail and residential mortgage, which already belongs to the real estate exposure class within Basel IV (Basel Committee on Banking Supervision, 2017). The analysis of these subcategories shows that the RWD calculated on the basis of the non-simulated data is rather similar, as it amounts to 0.221 for the qualifying revolving retail exposure, to 0.215 for the other retail and to 0.205 for the real estate exposures – still, the development of these ratios is different.

Qualifying Revolving Retail Exposures

Since the CCFs are rather high within this category, the QRRE is only affected by the parameter floors for PD and LGD. The division into exposures, which are affected by the input floors and those which are not, shows, that the affected exposures exhibit much lower RWDs throughout the simulation. The RWD of the exposures, which are affected by the PD floor even lies below the observed minimum of Mariathasan and Merrouche (2014). The application of the Basel IV standardised approach leads to an RWD increase to 0.750 for all sub-categories, which is caused by the fact, that the entire QRRE portfolio falls within the definition of regulatory retail and therefore receives a risk weight of 75%. The RWD after the application of the output floor of 72.5% which will be applicable from 2027 onwards amounts to 0.544 for all sub-categories. This uniform RWD is caused by the consistent SA-RWD and the multiplication with the fixed value of 72.5% (Basel Committee on Banking Supervision, 2017). The application of the Basel IV input floors leads to an interesting result, as it leads to an RWD increase for the first three sub-categories, but to a reduction for the exposures, which are not affected by the LGD floor. This RWD reduction is caused by the removal of the scaling factor and the fact that within this exposure only 5.21% of the Basel IV RWAs after the application of the input floor are affected by the PD floor. In contrast to that, the exposure which is not affected by the PD floor records an RWD increase due to the fact that 20.76% of the Basel IV RWAs after the application of the input floor are affected by the LGD floor.

Table 8. RWD within QRRE prior and after simulation

Exposure	**RWD Basel III IRBA**	**RWD Basel IV SA**	**RWD Basel IV IRBA – Input Floor**	**RWD Basel IV IRBA – Output Floor**
Affected by PD Floor	0.021	0.750	0.037	0.544
Not affected by PD Floor	0.312	0.750	0.314	0.544
Affected by LGD Floor	0.136	0.750	0.187	0.544
Not affected by LGD Floor	0.250	0.750	0.242	0.544

Residential Mortgage Exposures

The residential mortgage exposures are not affected by the application of the LGD floor, as the BCBS had already introduced a transitional 10% LGD floor for these exposures in 2006, which was then prolonged in 2009 because of the volatile mortgage portfolios faced during the financial crisis (Basel Committee on Banking Supervision, 2006). It is noticeable that the exposures, which are affected by parameter floors, all exhibit an RWD improvement, whereas all non-affected exposures exhibit an RWD reduction. The reason for the deterioration is again the removal of the scaling factor and the fact that this effect cannot be compensated by another floor. Within this sub-portfolio, the application of the output floor leads to an RWD improvement. However, it is not as strong as within the other retail sub-portfolios, which is attributable to the fact, that residential mortgage exposures usually receive a lower risk weight than QRRE or other retail exposures within the standardised approach.

Table 1. RWD within residential mortgage prior and after simulation

Exposure	RWD Basel III IRBA	RWD Basel IV SA	RWD Basel IV IRBA – Input Floor	RWD Basel IV IRBA – Output Floor
Affected by PD Floor	0.014	0.590	0.016	0.428
Not affected by PD Floor	0.217	0.594	0.204	0.431
Affected by EAD Floor	0.164	0.565	0.387	0.410
Not affected by EAD Floor	0.205	0.594	0.194	0.431

Other Retail Exposures

The risk-weight density under the Basel IV SA amounts to 1.000 for all exposures, as the uniform risk weight of 100% is applied to all exposures which come under other retail (Basel Committee on Banking Supervision, 2017). This fact is also the reason why the RWD after the application of the 72.5% output floor amounts to 0.725 for all exposures. This sub-category shows the same results as the residential mortgage portfolio: an improvement of the RWD for exposures, which are affected from certain floors and a deterioration of the RWD for the ones which are not affected. Again, this result can be attributed to the removal of the scaling factor and the little stake of exposures, which are affected by other floors, within the exposures, which are not affected by a certain floor.

Table 2. RWD within other retail prior and after simulation

Exposure	RWD Basel III IRBA	RWD Basel IV SA	RWD Basel IV IRBA – Input Floor	RWD Basel IV IRBA – Output Floor
Affected by PD Floor	0.025	1.000	0.028	0.725
Not affected by PD Floor	0.230	1.000	0.221	0.725
Affected by LGD Floor	0.057	1.000	0.074	0.725
Not affected by LGD Floor	0.238	1.000	0.226	0.725
Affected by EAD Floor	0.166	1.000	0.400	0.725
Not affected by EAD Floor	0.215	1.000	0.206	0.725

Since the volume of the retail exposures, which are not affected by any parameter floor exceeds the volume of the floor affected exposures by far, the overall RWD also decreases from 0.208 to 0.198 after the application of the Basel IV input floors. The biggest RWD improvement can be observed after the application of the output floor, as it increases by 0.300 and therefore harmonises the IRBA-RWDs to the SA-RWDs.

Table 3. Overall RWD prior and after simulation

Exposure	RWD Basel III IRBA	RWD Basel IV SA	RWD Basel IV IRBA – Input Floor	RWD Basel IV IRBA – Output Floor
Qualifying Revolving Retail	0.221	0.750	0.228	0.544
Residential Mortgage	0.205	0.594	0.194	0.431
Other Retail	0.215	1.000	0.207	0.725
Total RWD	**0.208**	**0.701**	**0.198**	**0.509**
Total Δ to Basel III	**-**	**0.493**	**-0.010**	**0.300**

The major findings within the retail portfolio can be summarised as follows:

- *Finding 3: The removal of the scaling factor eliminates the input floor's effect of increasing the RWD, as large parts of the portfolio are not affected by any input floor.*
- *Finding 4: The output floor leads to a significant RWD increase and an assimilation to the Basel IV SA RWDs.*

These findings are summarised in Figure 3:

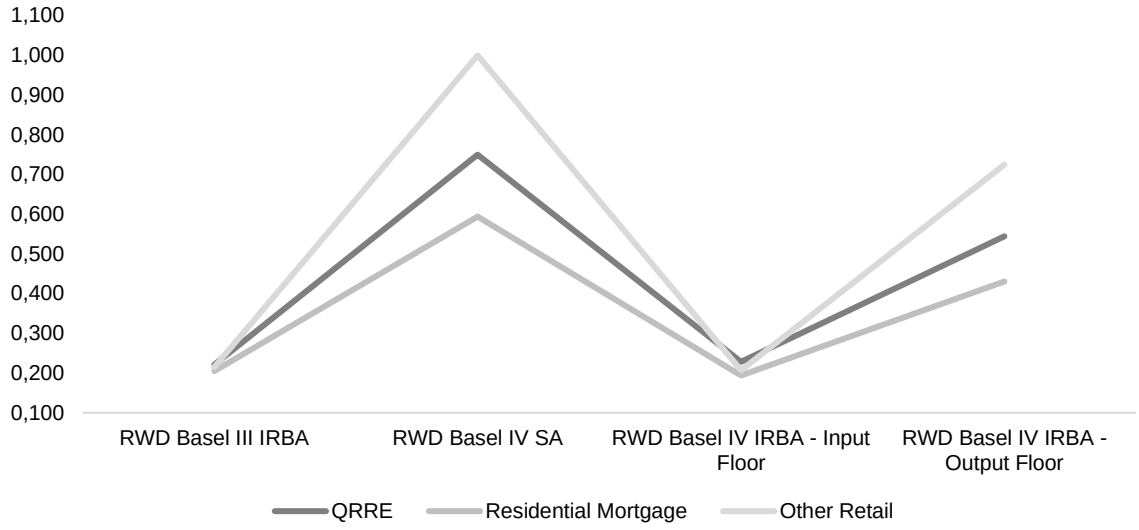

Figure 2. RWD Development Retail Portfolio

Discussion and Conclusion

As already mentioned, the aim of this article is to analyse the effects of the Basel IV input and output floors on the heterogeneity of risk weights. In this context, heterogeneity describes the fact that identical assets are assigned different risk weights (Turk-Ariss, 2017). This effect has been measured by researchers like Beltratti and Paladino (2016), Mariathasan and Merrouche (2014) and Vallascas and Hagendorff (2013) using the ratio of risk-weighted-assets to total assets, namely the risk weight density, which is also used in this article. In order to provide a comparison with other banks, the results of the simulation are compared with the findings of Mariathasan and Merrouche (2014) as they observed the RWD development of a sample of 115 IRB-banks in 21 OECD-countries.

The simulation of Basel IV results in mixed findings concerning the development of the risk weight density. The extent to which the RWD is affected by the Basel IV regulation is illustrated in Figure 4. The figure shows an overall RWD reduction for the corporate portfolio, but an RWD increase for the retail portfolio. In Section 6, these results have already been discussed in detail. In brief, Basel IV leads to an RWD increase for portfolios which are valued optimistically or exhibit a low Basel III RWD, and to an RWD decrease for the opposite. Moreover, the removal of the scaling factor leads to stronger effects than the input floor in case of conservatively valued portfolios and therefore might encourage an RWD reduction.

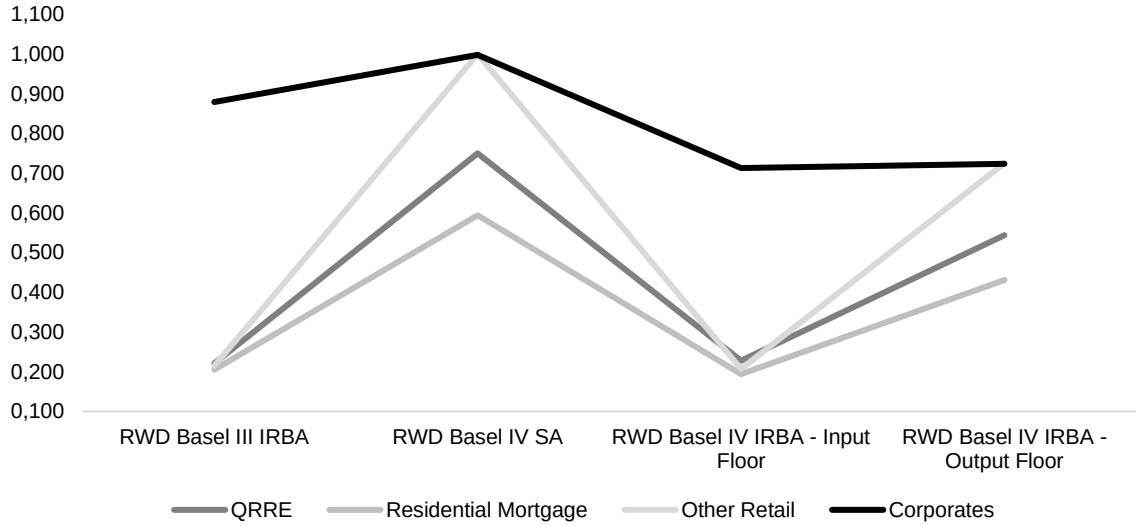

Figure 3. RWD Development Overall Portfolio

Following these results, there is only a two-part answer to research questions number two and three, which ask whether Basel IV is able to reduce the heterogeneity of risk weights and how the RWD is affected by the new rules: Taking into account findings one to three, which highlight the fact that the Basel IV rules might lead to an RWD decrease if they are applied to conservatively valued portfolios, suggests that Basel IV has a rather negative impact on risk weight variability. However, one also needs to consider the fact that conservatively valued portfolios are not usually affected by the problem of heterogeneity at all. This is also confirmed by the comparison of the Basel III RWD of the corporate portfolio (0.879) with the observed mean RWD (0.516) by Mariathasan and Merrouche (2014). On the contrary, finding number four clearly shows that the Basel IV regulations, especially the output floor, can lead to a significant RWD increase and therefore also to a reduction of risk weight heterogeneity. This statement can be confirmed by the fact that Basel IV results in an RWD of the retail portfolio that amounts to 0.509 and therefore almost matches the observed mean by Mariathasan and Merrouche (2014). Summarising it can be said, that the reduction of risk weight heterogeneity is reserved for optimistically valued portfolios, which exhibit a low RWD starting value, as conservatively valued portfolios show a counteracting effect. Within the observed portfolios, the input floors only have a very limited influence on the RWD, which can be attributed to the conservative valuation as well as the counteracting effect of the removal of the scaling factor. On the contrary, the Basel IV output floors can have a tremendous effect on RWD. The detailed effects of the Basel IV rules on RWD are shown in Section 6. The before mentioned aspects can be summarized in the following implications:

Implication 1 – The Basel IV regulations have the potential to reduce the problem of heterogeneity within risk weights in certain portfolios.

Implication 2 – The improvement of risk weight heterogeneity is reserved for optimistically valued portfolios. Conservatively valued portfolios, which usually do not face the problem of RW heterogeneity, are likely to be confronted with an RWD decrease.

Implication 3 – Out of all analysed Basel IV rules, the output floor clearly has the biggest influence on risk weight density. The input floors' effect is very limited within optimistically valued portfolios and is even eliminated by the removal of the scaling factor within conservatively valued portfolios.

Unfortunately, these implications do not come without criticism: In literature there is a consensus that the excessive variability of risk weights has to be addressed by the BCBS. However, some articles criticise the BCBS because of its willingness to introduce a 'system of floors', which is seen as a restriction of the primary advantage of the IRBA: risk sensitivity. Moreover, researchers remark that capital floors are similar to 'flat tax' regulations, which are not desirable as they impose high capital charges on low-risk exposures. This fact may encourage banks to invest into high-risk exposures again (Haselmann & Wahrenburg, 2016; Resti, 2016). The literature criticises the BCBS' approach of restricting the IRBA, but also admits that the reduction of RW heterogeneity is difficult to curb. An alternative solution to RW heterogeneity, which has been brought up by research, is the one of clarifying the concepts of standards and guidelines. The current regulations and definitions leave considerable space for interpretation, which lead to different ways of applying the IRBA and therefore also to variable results. The comparison of IRBA-RWAs and SA-RWAs is also suggested by researchers, but rather as a way of revealing the weaknesses of the IRBA than as a constraint of the approach itself. Moreover, a peer-review process, which should be accompanied by supervisory authorities is considered to be an appropriate way to disclose differences between banks and countries. An aspect that is clearly said to be the key to restore the credibility of the IRBA is transparency (Resti, 2016).

As already described, the findings are based on the simulation of Basel IV. By using a simulation technique, the effects of Basel IV on the overall credit portfolio but also on risk weight density can be displayed very well, as each influencing parameter can be steered individually. The simulation technique and Microsoft Excel 2016 complement each other very well, as Excel provides the possibility to analyse the data in detail: the drill down to the single datasets allows the user to find the origin of any change in the overall results and therefore a detailed analysis of the driving parameters. The detailed description of how the simulation was performed and therefore also the answer to research question number one are included in Section 3 and 5.

During the process of writing this article, the following aspects were identified as potential fields for future research:

1. The results of this simulation rely on the data of a conservative Western European IRB-bank. Therefore, this article does not contain any information about the effect of Basel IV on the heterogeneity of risk weights of large multinational banks. This aspect should be addressed by future research, as the results of this evaluation will probably look very different.
2. Another aspect, which has not been covered by this article, is the effect of the Basel IV regulations on corporate portfolios under the AIRBA. This article only analysed the impact of the PD-floor, but future research should also cover the LGD- and the EAD-floor.
3. It has already been mentioned multiple times that the bank, which provided the credit data, follows a rather conservative risk policy. For this reason, future research should also look at the bank's risk policy and its influence on RWD.

The contribution to the literature, which has been generated by condensing the afore mentioned implications, includes the information that Basel IV will definitely have an impact on RWD. Whether this impact is a positive or a negative one, depends on the preceding valuation of the portfolio. The change in RWD will also lead to a concurrent change in risk-weighted assets and therefore also in the level of eligible capital. The findings within the retail portfolio confirm those of the EBA study, which have already suggested that Basel IV and especially the output floor will lead to significant a increase of risk capital (European Banking Authority, 2018).

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