Scientific Research Publishing

Journal of Financial Risk Management, 2026, 15(3), 309-334
https://www.scirp.org/journal/jfrm
ISSN Online: 2167-9541
ISSN Print: 2167-9533

Capital Minimum Requirements under Basel II in the Waemu: The Contribution of Internal Rating Methods

Mamadou Bakayoko

Institut National Polytechnique Félix Houphouët-Boigny, LADEG-Laboratoire de Droit, Economie et Gestion, Yamoussoukro, Côte d'Ivoire
Email: mamadou.bakayoko@inphb.ci

How to cite this paper: Bakayoko, M. (2026). Capital Minimum Requirements under Basel II in the Waemu: The Contribution of Internal Rating Methods. *Journal of Financial Risk Management, 15,* 309-334.
https://doi.org/10.4236/jfrm.2026.153018

Received: February 11, 2026
Accepted: September 20, 2026
Published: September 23, 2026

Abstract

This paper compares the two approaches to calculating capital minimum requirements under Basel II, the standardised approach and the internal ratings-based approach, and their effect on credit risk. We use data from 72 banks in the WAEMU region from 2016 to 2020. Our lending equation is based on a banking business model operating in an environment of uncertainty and on a credit market characterised by imperfect competition. This lending equation, which draws on the work of Monti-Klein, is estimated using the three-stage least squares method. The main results after simulation indicate that the IRB approach provides a more granular assessment of risk than the standardised approach. Furthermore, borrowers with a lower risk profile will benefit from lower interest rates when borrowing from banks that use the IRB approach. By focusing on less risky borrowers, banks using the IRB approach will be able to achieve capital savings. These results suggest the use of internal rating methods as a complement to the standardised approach. The coexistence of banks adopting different approaches could lead to specialisation based on the risk of their borrowers.

Keywords

Basel Accords, Minimum Capital Requirements, Internal Ratings, WAEMU

1. Introduction

The most significant change in the Basel II agreement, however, was the option for a bank to deviate from the use of rigid risk weightings. In addition to the traditional or standardised approach, the possibility to use internal rating-based approach (IRB) to calculate capital adequacy requirements was introduced. This requires the bank to use internal risk weights, which it determines itself on the basis of available historical data, relying on sufficiently long time series and statistical models specifically developed for this purpose.

This article is based on incentive theory (Giammarino et al., 1993; Besanko & Katanas, 1996). This approach has shown that the regulator does not have the necessary information about the quality of the assets initially held by the bank (adverse selection) and about the bank's choices to change its risk profile (asset substitution). To overcome these shortcomings, the regulator (principal) must define an optimal disclosure mechanism to get the bank (agent) to reveal its information. This theory marks the introduction of the obligation to disclose all information to the regulator in order to protect depositors, which is the concept of market discipline.

Studies have shown that adopting internal rating methods enables banks to be more competitive. For example, Cucinelli et al. (2018) show that banks adopting the IRB approach were better able to contain the increase in credit risk induced by the macroeconomic slowdown than banks using the standardised approach. Furthermore, Cave et al. (2003) show that adopting the IRB approach leads to a significant reduction in the capital requirements applicable to commercial credit, compared with the framework set out in Basel I. According to Repullo and Suarez (2004), the IRB approach treats loans with a low level of risk more favourably. Similar conclusions emerge in the work of Ruthenberg and Landskroner (2008). On the other hand, Hakenes and Schnabel (2011) show that adopting the IRB approach can improve the efficiency of regulatory capital requirements, provided that it is applied uniformly across all banks and that its implementation costs remain reasonable. However, allowing institutions to choose between the standardised approach and the IRB approach is likely to confer a competitive advantage on large banks. Similarly, Albaity and Toobaee (2017) note that banks which have adopted the Basel II framework are subject to lower minimum capital requirements than those which have continued to apply the Basel I framework.

Along the same lines, Stewart (2021) shows that the IRB approach allows for a more nuanced differentiation of risk levels across different exposures. It thus leads to a more proportionate allocation of regulatory capital, with higher requirements for the riskiest exposures and lower requirements for those presenting a lower risk. Mascia et al. (2016) show that during the economic recession following the 2007-2008 global financial crisis, European banks using IRB models shifted their lending away from the riskiest borrowers towards those with a lower risk profile. This finding suggests that the IRB approach enabled them to improve borrower selection and limit the excessive accumulation of credit risk. According to Resti (2016), IRB models are used more widely by large banks with strong capitalisation. They are also adopted more frequently in countries where banks have greater influence over the supervisory authorities, particularly where the banking sector is highly concentrated and banking assets account for a large share of GDP.

Currently, many international banks have applied IRB models for risk measurement and management. Around 50% of the capital requirements for banks in the European Union are determined by IRB models, with corporate and retail loan portfolios alone accounting for more than 75% of these requirements (Resti, 2016). In the WAEMU, only the standardised approach remains in force. Internal rating models are not permitted at this time. The question we ask here is whether there are advantages to adopting internal rating models in the WAEMU. Are these models more risk-sensitive? What is their effect on banks' lending behaviour? This issue is of particular importance to banks in the WAEMU, given that lending is their main source of business and revenue.

The aim of this research is to assess the benefits that the adoption of internal rating models could bring to the banking sector in the WAEMU. We will first assess the risk sensitivity of internal rating models and then examine their impact on banks' risk-taking behaviour. We put forward the general hypothesis that banks which adopt the internal ratings-based approach perform better in managing credit risk. Specifically, we formulate the following hypotheses: 1) IRB approach is more sensitive to credit risk than standardised approach; 2) banks adopting IRB approach will specialise in low-risk loans.

This study is both interesting and important. Indeed, following the publication of the Basel II agreement, the debate over the standardised approach's particularly high capital requirements, as well as the appropriateness of using internal rating methods to assess credit risk, has intensified. However, to the best of our knowledge, no study has yet examined these issues in the specific context of the WAEMU. Most of the work in the zone has been carried out within the framework of Basel I (Dannon & Lobez, 2014; Gammadigbé, 2018; Amadou & Mbengue, 2021). Our research therefore aims to help fill this gap in the literature on the WAEMU region. The findings deserve particular attention as they should benefit both supervisors and bank managers. The research methodology is based on the Monti-Klein loan equation. Due to the inherent simultaneity of the analysis, the lending rate and the demand for credit are estimated jointly using the three-stage least squares method. Based on these results, we carry out a simulation of the interest rates that banks are likely to charge their customers following the adoption of the IRB approach set out in Basel II.

The remainder of the paper is structured as follows. Section 2 presents a review of the literature on IRB models. Section 3 examines the stylised facts relating to the structure of the banking market in the WAEMU zone. Section 4 describes the methodology adopted and the sample selected. Section 5 sets out the main results obtained and discusses their implications. Finally, the last section summarises the main conclusions of the study.

2. Literature Review on the Internal Rating Approach

Since its introduction, the IRB approach has been the subject of ongoing debate amongst researchers, practitioners and supervisory authorities, particularly with regard to its effectiveness and reliability. This section therefore provides a review of the key research on these models.

2.1. Adverse Effects of IRB Models

With the implementation of Basel II, banks focused on developing internal rating models that would reduce risk-weighted assets (RWA) in order to save on capital. This situation led to mistrust of internal rating models, and researchers began to view "RWA adjustments" as a rather suspicious practice. The credibility of internal rating models has gradually eroded, to the point where The Economist magazine has described them as "DIY capital" (The Economist, 2012).

IRB models have been criticised for their high level of complexity and the considerable discretion they allow banks in their implementation. Empirical studies indicate that such discretion, combined with the possibility of achieving capital savings, encourages regulatory arbitrage and manipulation of capital requirements, particularly for undercapitalised banks (Plosser & Santos, 2018; Montes et al., 2018; Ferri & Pesic, 2017; Berg & Koziol, 2017; Mariathasan & Merrouche, 2014). In this sense, Benink and Kaufman (2008) argue that allowing banks to use their own internal models to assess risk is tantamount to "putting prisoners in charge of the prison".

Similarly, Hellwig (2010) emphasises that model-based capital regulation has its limitations, insofar as a large proportion of risks is determined endogenously rather than exogenously. Acharya et al. (2014) also question the predictive power of risk weights, as these are based on accounting data, can only be revised retrospectively and may, furthermore, be subject to manipulation by banks. Along the same lines, Erdinç and Gurov (2016) find that IRB models have a significant negative impact on asset quality at the national level.

Furthermore, Arroyo et al. (2012) show that the high degree of sophistication of IRB models complicates both risk assessment and the comparison of RWAs across banks. Such a comparison can only be truly meaningful if a very detailed set of information is available, much of which is not generally accessible to the public (Ledo, 2011; Cannata et al., 2012). Some authors argue that complex and sophisticated rules may be less effective than simpler, more easily enforceable regulations (Glaeser & Shleifer, 2001). Indeed, regulatory complexity entails significant implementation costs for society and may encourage regulated entities to seek ways of circumventing regulatory requirements.

Behn et al. (2022) add to this literature by pointing out that simpler and more transparent rules, leaving banks limited scope for manoeuvre, could prove more effective in reducing the distortions that may encourage excessive leverage in the banking sector. The complexity of the rules and the difficulties this creates in terms of supervision can indeed undermine the effectiveness of financial regulation. Similarly, Barucci and Milani (2018) find that internal ratings-based approaches, in particular the advanced IRB approach, can be used by banks to adjust, or even manipulate, their risk weights. The results indicate that risk weights are mainly underestimated for domestic loans, as well as for loans granted to businesses and households, that is, in segments characterised by significant information asymmetry. The authors show, however, that this underestimation does not appear to stem from a poor specification of the banks' internal models. Rather, they interpret it as consistent with the regulatory capture hypothesis, according to which national supervisory authorities may be influenced by the banks they are responsible for supervising.

In March 2016, the Basel Committee on Banking Supervision proposed a reform designed to limit the excessive variability in risk-weighted assets resulting from banks' use of their own rating models (BCBS, 2016). This reform provides, in particular, for the removal of IRB approaches where defaults are too infrequent, notably exposures to financial institutions and large corporates, to allow for sufficiently reliable calibration of the models. It also aims to provide a tighter framework for internal models by imposing constraints on estimation methods as well as minimum values for certain risk parameters "input floors". In addition, the Committee also envisages the introduction of an "output floor", whereby capital requirements calculated using IRB models could not fall below a specified threshold, ranging from 60% to 90% of the requirements that would have been obtained by applying the standardised approach, which is intended for banks that do not have approved internal models.

According to Resti (2016), the introduction of floors is a technically flawed response to what is nonetheless a real problem. Whilst IRB models may indeed have been used opportunistically to reduce capital requirements rather than to provide an objective assessment of risk, it is nevertheless difficult to see how their sensitivity to risk could be improved by systematically subjecting them to predefined values and mandatory minimum thresholds. Consequently, any reform aimed at addressing the limitations of IRB models should instead seek to strengthen their ability to correctly identify risks and translate them into capital requirements proportionate to the level of risk incurred.

2.2. Advantages of IRB Models

Despite the criticism they face, Resti (2016) points out that IRB models offer several advantages over the standardised approach. Firstly, they allow for a more nuanced and graduated assessment of risk. Thus, a small increase in a borrower's probability of default results in a proportional rise in capital requirements, unlike the standardised approach, which can lead to sudden changes in these requirements following a downgrade in credit rating, thereby creating "cliff effects". Secondly, IRB models encourage banks to develop more robust and sophisticated risk management systems. Thirdly, as these models are largely integrated into internal credit management processes, particularly in borrower selection, pricing, loan monitoring and provisioning, their use in determining regulatory requirements helps to align regulatory capital more closely with economic capital.

Cucinelli et al. (2018) assess the ability of IRB models to measure credit risk using a panel of 177 Western European banks observed over the period 2008-2015. Their results show that banks using the IRB approach were better able to contain the increase in credit risk associated with the macroeconomic slowdown than those applying the standardised approach. The authors argue that this finding suggests that the introduction of the IRB approach under Basel II helped to strengthen risk management practices within banks, in line with the objectives of the supervisory authorities.

In the same vein, Repullo and Suarez (2004), using a model of perfect competition in the bank credit market, show that low-risk borrowers benefit from lower lending rates when they turn to banks using the IRB approach. Conversely, higher-risk borrowers are better off turning to banks applying the standardised approach, which is less sensitive to risk, in order to avoid an increase in their borrowing costs. Wan et al. (2006) also show that the adoption of the IRB approach by large banks is likely to give them a competitive advantage over smaller institutions. Ruthenberg and Landskroner (2008) analyse these mechanisms within a framework of imperfect competition in the credit market. Despite this difference in modelling, their results are consistent with those of Repullo and Suarez (2004). In particular, they show that firms and households with a high-risk profile benefit from lower lending rates from large banks that have adopted the IRB approach. By contrast, riskier borrowers tend to turn to small banks applying the standardised approach, whose requirements are less directly sensitive to the level of risk.

Furthermore, Hakenes and Schnabel (2011) examine the link between the size of banks and their risk-taking behaviour under the Basel II capital framework. Using a model incorporating imperfect competition and moral hazard, they show that adopting the IRB approach can enhance the effectiveness of regulatory capital requirements when it is applied uniformly across all banks and its implementation costs remain under control. However, the ability of institutions to choose between the standardised approach and the IRB approach confers a competitive advantage on large banks. The resulting intensification of competition encourages small banks to increase their risk-taking, which may ultimately lead to an increase in the overall level of risk in the banking sector.

Albaity and Toobaee (2017) show that, for a given level of portfolio risk, banks that had adopted Basel II had, prior to the crisis, lower minimum capital requirements than those applying Basel I. They also corroborate previous findings, according to which exposures with a low level of risk receive more favourable treatment under the IRB approach. Similarly, Stewart (2021) shows that the IRB approach allows for a more precise differentiation of risk across different exposures, thereby leading to higher capital requirements for risky exposures and lower ones for those with lower risk.

Resti (2016) offers an important nuance by showing that the effects of IRB models may differ depending on economic conditions and the type of regulatory approach used. When GDP growth slows and banks reallocate their assets towards less risky investments, such as government bonds, risk-weighted assets decrease for institutions that primarily use the standardised approach. By contrast, this trend may differ for large banks using IRB models, whose internal rating systems enable them to reflect changes in borrowers' risk profiles more quickly. Furthermore, several studies show that, during the recession that followed the global financial crisis, European banks that had adopted the IRB approach shifted their lending away from the riskiest borrowers towards those with a lower risk profile (Mascia et al., 2016; Behn et al., 2016). These findings support the hypothesis that IRB models enable banks to improve their borrower selection and limit the accumulation of credit risk.

Drawing on a sample of European banks, Bruno et al. (2017) observed that institutions using IRB approaches reduced their outstanding corporate loans to a greater extent, or at least saw them increase to a lesser extent. However, the authors found no evidence of a reallocation of these loans toward sovereign exposures. The shift of banks toward government bonds during the European sovereign debt crisis thus appears to be driven by other factors, notably the mechanism of "financial repression".

Majnoni et al. (2005) point out that the capital requirements under Basel II are calibrated so as to remain, on average, close to 8% under the standardised approach, whilst they may be lower under the IRB approach. Similarly, Cipovová and Dlasková (2016) show that switching from the standardised approach to the IRB approach enables banks to achieve substantial savings in capital. However, Behn et al. (2022) show that these savings may result, at least in part, from strategic under-reporting of risks: banks may optimise their internal models in order to reduce their capital requirements, particularly where the associated gains are significant. The authors thus find that loans classified under the IRB approach exhibit lower probabilities of default and lower RWAs, whilst displaying higher realised default and loss rates. This finding is consistent with the hypothesis of an underestimation of regulatory risk. Nevertheless, the fact that these loans carry higher interest rates despite their low estimated probabilities of default suggests that IRB models retain strong discriminatory power and effectively differentiate between levels of risk. Thus, the under-reporting of risk can coexist with the IRB models' high capacity to measure and distinguish risk. Similarly, Mariathasan and Merrouche (2014), using data on 115 banks across 21 OECD countries, show that undercapitalised banks report RWA figures that do not reflect their actual level of risk. They attribute this under-reporting, however, to strategic manipulation of risk weights rather than to inherent flaws in the IRB models. Therefore, the limitations observed appear to be more closely linked to the strategic behaviour of banks and the difficulties in monitoring them than to the ability of the IRB models to measure and distinguish between different types of risk.

Our research forms part of the ongoing debate on the regulatory use of IRB models. Given that the use of these models is subject to prior approval by the supervisory authorities, we argue that approved IRB models should demonstrate a high level of accuracy and effectiveness in risk assessment, in line with the regulators' objectives of reliability and rigour.

3. Structure and Characteristics of the Banking Market in the WAEMU

In December 2020, the UEMOA region had 152 licensed credit institutions, compared with 138 in December 2016, reflecting an increase in the number of market participants. The degree of concentration in the banking sector is assessed using the Herfindahl-Hirschman Index (HHI), calculated on the basis of loans to customers. The trend in this index is shown in Table 1. Generally speaking, a high HHI value indicates a high degree of market concentration around a limited number of institutions, which is likely to favour oligopolistic structures and, consequently, reduce the intensity of competition.

Table 1. Evolution of the concentration index of the WAEMU banking system from 2016 to 2020.

Pays	2016	2017	2018	2019	2020
Benin	1427	1432	1344	1275	1261
Burkina	1285	1279	1261	1225	1245
Côte d'Ivoire	921	941	891	954	869
Guinea-Bissau	2971	2141	2199	2162	2074
Mali	1032	1009	1044	1104	1156
Niger	1456	1388	1354	1269	1174
Senegal	840	798	751	779	718
Togo	1269	1329	1342	1249	1225
WAEMU	192	197	194	197	190

Source: WAEMU Banking Commission (2020).

The results suggest that credit concentration within the banking sector is very high in Guinea-Bissau and rather low in Côte d'Ivoire and Senegal. It stands at an average level in the other countries of the Union. Between 2016 and 2020, the HHI declined in most countries as well as in the Union as a whole. Mali is the only country that has seen an increase in its HHI. Thus, concentration within the banking sector, although significant, is on a downward trend, linked in particular to the entry of new players into the market.

Another key feature of the WAEMU banking sector is the level of capital adequacy, which is a crucial indicator of the soundness of credit institutions. At the end of December 2020, the total solvency ratio stood at 12.4% in the Union, above the minimum regulatory threshold set at 9.5% for 2020. Overall, 107 credit institutions complied with the solvency standard at the end of December 2020. These institutions account for 87.8% of banking assets and 91.2% of risk-weighted assets. Table 2 shows the breakdown of the solvency ratio across the various WAEMU countries. The worrying level of this ratio in Guinea-Bissau is linked to the prudential situation of an institution with negative equity and a significant weighting in the national banking market. Togo also stood out for having a solvency ratio below the regulatory threshold of 9.5%, reflecting a shortfall in equity capital relative to the applicable prudential requirements.

Table 2. Minimum solvency ratio for credit institutions by country.

Benin	Burkina	Côte d'Ivoire	Guinea-Bissau	Mali	Niger	Senegal	Togo	UEMOA
14.5%	13.8%	11.6%	−3.6%	14.3%	15.6%	12.0%	7.4%	12.4%

Source: WAEMU Banking Commission (2020).

4. Description of the Simulation Model

Our analysis does not focus directly on the measurement of credit risk, but rather examines the relationship between minimum capital requirements and the level of credit risk. Methodologically, we draw on the approach developed by Ruthenberg and Landskroner (2008).

4.1. Specification of the Imperfect Competition Model

The model of optimal behaviour for a commercial bank adopted here is based on two assumptions: the bank's risk neutrality and the existence of imperfect competition in the banking sector. Indeed, the assumption of perfect competition may not seem entirely appropriate for the banking sector in the WAEMU, where there are significant barriers to entry. Moreover, **Table 1** shows that the sector is moderately concentrated in most countries of the Union. A model of imperfect competition (oligopoly) is probably more appropriate in this case.

The imperfect competition model we use here is based on the work of Monti-Klein[1]. In this model, the commercial bank acts on the primary market, where it takes deposits from the public and grants loans. It also operates in the secondary market in order to adjust its liquidity position by offsetting surpluses or shortfalls in reserves. To this end, it carries out transactions with other commercial banks, notably in the form of interbank deposits, with the central bank, through loans or deposits, and on the financial markets, for example by buying and selling government securities. Furthermore, the bank maintains a level of capital required by the banking supervisory authority, which acts as a buffer to absorb unexpected losses, particularly those likely to arise from its loan portfolio. In light of this description, the expected short-term profit of an individual commercial bank is expressed as:

$$\begin{aligned} E(\pi_i) = {} & (1-PD)*(1+R_C)*C_i(R_C,\tilde{\alpha}) - (1+R_D)*D_i(R_D,\tilde{\beta}) \\ & -(1+R)*Z - rk_i*K_i^*(C_i) - F_i \end{aligned} \tag{1}$$

where PD is the probability of default, $C(R_C,\tilde{\alpha})$ denotes the bank loan demand function, assumed to be decreasing with respect to the lending rate R_C and dependent on a fluctuation parameter $\tilde{\alpha}$. $D(R_D,\tilde{\beta})$ represents the public's

[1]Although this model is usually referred to as the "Monti-Klein model", it should be noted that it has its origins in the separate works of Klein (1971) and Monti (1972).

deposit supply function, assumed to be increasing with the interest rate paid on deposits R_D and dependent on a fluctuation parameter $\tilde{\beta}$. Z denotes the bank's activity in the secondary market, whilst R represents the interest rate associated with it. Finally, F corresponds to the bank's operating cost function, which we assume to be constant in the short run; rk denotes the cost of equity, i.e. the required rate of return, and K^* represents the regulatory capital requirements expressed in monetary units. We assume that capital requirements are determined in accordance with the provisions of the Basel II Accord.

The fluctuation parameter $\tilde{\alpha}$ captures several macroeconomic factors, notably changes in GDP, via the income effect, as well as conditions prevailing in the capital markets, via the substitution effect. It also allows for the influence of the business cycle on the demand for credit. Indeed, in theory, an improvement in economic activity, characterised by a phase of expansion, stimulates demand for loans and ultimately leads to an increase in the volume of credit granted. This relationship is consistent with the assumption of procyclicality in bank capital requirements under Basel II. Therefore,

$$\frac{\partial C}{\partial R_C} < 0, \quad \frac{\partial C}{\partial(\text{effet de revenu})} > 0 \quad \text{et} \quad \frac{\partial C}{\partial(\text{effet de substitution})} < 0$$

Equation (1) is based on the assumption of the bank's risk neutrality, according to which the bank is indifferent between two investment options: on the one hand, a risky investment, such as granting loans to the private sector, yielding an interest rate R_C that reflects the borrower's probability of default (PD); on the other hand, a risk-free investment, such as the purchase of government bonds, offering a rate of return R_0. The condition of the bank's risk neutrality can then be expressed as follows:

$$(1-PD)*(1+R_C) = (1+R_0) \quad \text{which is equivalent to} \quad R_C = \frac{(1+R_0)}{(1-PD)} - 1.$$

Therefore, $\frac{\partial R_C}{\partial PD} > 0$.

The last inequality highlights a positive relationship between the probability of the firm defaulting and the interest rate charged on the loan: the higher the risk of default, the higher the interest rate demanded by the bank.

Still in Equation (1), we define $Z = [C-(1-r)*D]$ as the bank's position in the secondary market, where r denotes the reserve requirement ratio applied to public deposits. The variable Z can take a positive, negative or zero value. When $Z > 0$, the bank faces a financing need in the primary market and must therefore raise funds in the secondary market at the rate R_A, notably by borrowing from the discount window or through interbank financing. Conversely, when $Z < 0$, the bank has a surplus of funds which it can place on the secondary market, for example in the form of deposits with the central bank or Treasury securities, remunerated at the rate R_B. In the rarer case where $Z = 0$, uses and resources on the primary market are in equilibrium, so that the bank does not need to intervene in the secondary market. Finally, we assume that the bank cannot act simultaneously as both a borrower and a lender in the secondary market.

Given the bank's position in the secondary market, we define the interest rate applicable in that market (R) as follows:

$$R = R_B + I\left(R_A - R_B\right), \text{ où } I = \begin{cases} 1, & \text{si } Z > 0 \\ 0, & \text{si } Z < 0 \end{cases}$$

In the short term, the individual commercial bank seeks to maximise its expected profit based on its decision variables, namely the volume of loans (C) and the amount of deposits (D).[2] By differentiating the expected profit $E(\pi)$ in Equation (1) with respect to C, and under the assumption $Z > 0$, an assumption that could also be formulated as $Z < 0$, we obtain the following first-order condition[3]:

$$\begin{aligned} \frac{\partial \pi}{\partial C} &= (1-PD)*(1+R_C)*\frac{\partial C(\cdot)}{\partial C} + C(\cdot)*(1-PD)*\frac{\partial(1+R_C)}{\partial C} \\ &\quad -(1+R_A)*\frac{\partial C(\cdot)}{\partial C} - rk*\frac{\partial K^*}{\partial C} \\ &= 0 \end{aligned} \tag{2a}$$

By rearranging the terms of Equation (2a), then treating all the banks as a single entity and assuming a Cournot-type oligopolistic market structure, we obtain the optimality condition whereby marginal revenue (Rm) equals marginal cost (Cm), namely:

$$\underbrace{(1-PD)*(1+R_C)*\left[1-\frac{H}{\eta}\right]}_{Rm} = \underbrace{(1+R_A)+rk*\frac{\partial K^*}{\partial C}}_{Cm} \tag{2b}$$

where $\eta = -\frac{\partial C}{\partial R_C}*\frac{R_C}{C}$ is the elasticity of demand for credit. $H = \sum_{i=1}^{n} s_i^2$ refers to the Herfindahl-Hirschman Index, which measures the degree of concentration in the credit market, whilst $s_i = (C_i/C)$ represents the market share held by bank i in that market.

By substituting the condition of neutrality for risk, i.e.
$(1-PD)*(1+R_C) = (1+R_0)$, and then isolating $1+R_C$, we obtain the following expression:

$$(1+R_C) = \theta + (1+R_0)*\frac{H}{\eta} + (1+R_A) + rk*\frac{\partial K^*}{\partial C} \tag{3}$$

where $\theta = R_C - R_0$ represents the yield differential, corresponding to the risk premium, which can also be expressed as $PD*(1+R_C)$.

Equation (3) shows that the lending rate depends on several factors: the risk

[2]The bank's decision variables are C (the amount of loans granted) and D (the amount of deposits taken in), with the level of equity capital assumed to be given.

[3]It is assumed here that the exposure at default (EAD) is equal to the bank's outstanding loans, i.e. C. It follows that $\partial K^*/\partial C = K$, where K represents the capital requirements expressed as a percentage of the EAD.

premium (θ), the risk-free interest rate (R_0), such as the prime rate, the market power of the banking sector, measured by the concentration index (H), the elasticity of demand for credit in the market (η), the cost of funding in the secondary market (R_A), and the product of the cost of equity (rk) and the sensitivity of capital requirements to changes in the volume of loans granted ($\partial K^* / \partial C$).

In practical terms, the borrowing rate defined by Equation (3) can be expressed as follows:

$$R_c = f\big(\text{credit risk}, \text{market structure}(\text{"market power"}), \text{cost of debt}, \\ \text{cost of equity and sensitivity of equity to loans granted}\big)$$

As shown in Equation (1) relating to expected profit, the demand for loans depends on the lending rate (R_C) and a volatility parameter $\tilde{\alpha}$. Generally speaking, the credit demand function can be expressed as follows:

$$C^d = g\big(\text{interest rates on loans}, \text{income effect}(\text{"economic activity"}) \\ \text{and substitution effect}\big)$$

Writing these two equations as a system gives:

$$\begin{cases} R_C = f(\cdot) \\ C^d = g(\cdot) \end{cases} \tag{4}$$

Figure 1 illustrates the sensitivity of the volume of bank lending and lending rates to the product of the cost of equity (rk) and capital requirements ($\partial K^* / \partial C$), plus the cost of debt on the secondary market (R_A).

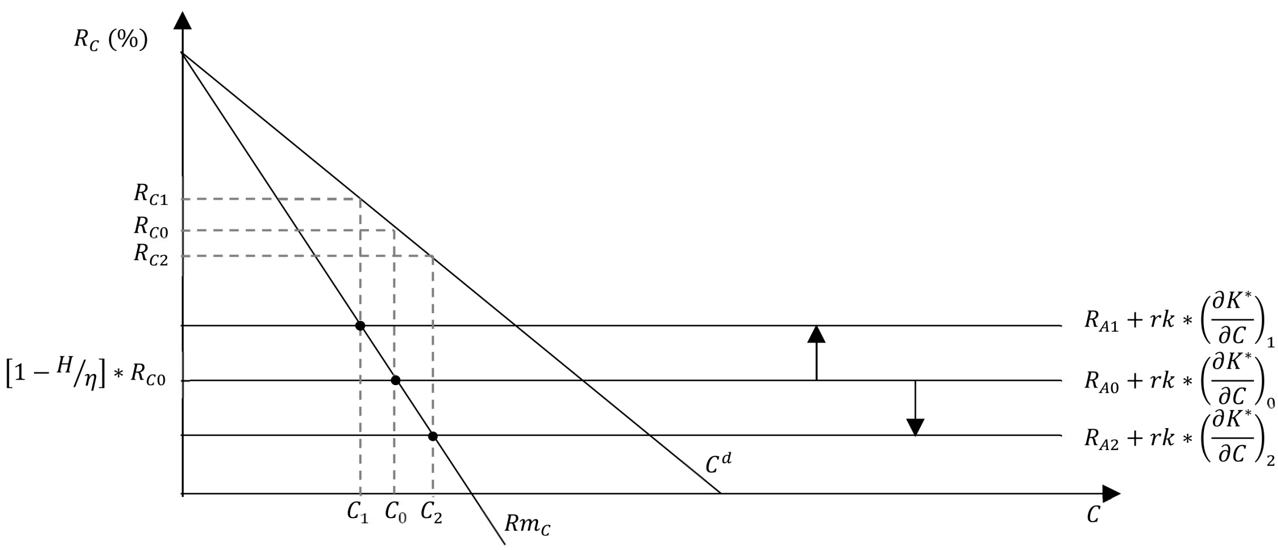

Figure 1. Determination of the lending rate (R_C) and the volume of loans (C) in an imperfectly competitive market, depending on changes in capital requirements. **Source:** Author, based on Ruthenberg and Landskroner (2008).

As illustrated in Figure 1, the lending rate (R_C), determined on the basis of the equality between marginal revenue and marginal cost (Equation (2b)), can vary between R_{C1} and R_{C2} . We therefore argue that, under the Basel II regulatory framework, the distribution of the lending rate R_C , all other things being equal, depends on the distribution of the probabilities of default (PD) associated with the loans granted by the bank to its customers.

The system of simultaneous equations presented in Equation (4) is estimated using the three-stage least squares method (3SLS). This estimation method is used because there is interdependence between the endogenous variables. As a result, this method provides robust parameter estimates. Furthermore, it is preferable to the two-stage least squares method (2SLS) because it is a full information technique, i.e., it allows all parameters to be estimated simultaneously. Moreover, 3SLS method takes into account inter-equation correlations. Therefore, using this technique, we obtain estimates that are asymptotically more efficient than those obtained by the 2SLS technique. This method, defined by Zellner and Theil (1962), incorporates the two stages of the 2SLS method and adds a third stage consisting of applying generalized least squares (GLS) to estimate all parameters simultaneously. The use of the 3SLS method is also justified by its ability to take account of any correlation between the error terms of the various equations in the structural form, which may also be correlated with the endogenous variables. The following section sets out how the variables are calculated, the data sources used, and the theoretically expected signs of their coefficients.

4.2. Analysis of Research Data

Data on the individual characteristics of banks are taken from the balance sheets and profit and loss accounts of banking institutions published by the BCEAO. This database provides series relating to banking activity. The data are collected annually and cover the period from 2016 to 2020. For macroeconomic variables, data are taken from the BCEAO database and World Bank Development Indicators. Market capitalization data comes from Global Financial Development Data. Our data set comprises 127 banks, excluding branches. In constructing our sample, we made several adjustments. Firstly, we excluded institutions for which data were missing for total assets, loans or total equity (46 banks). Secondly, to minimise the influence of extreme outliers, we excluded banks whose capital-to-total-assets ratio exceeded 100% (4 banks). Thirdly, we excluded all banks that had negative equity over the observation period (5 banks). This reduces the size of our sample from 127 to 72 banks. Although data cleaning procedures result in the exclusion of a significant number of observations, the banks thus excluded are generally very small. The institutions included in the sample account, on average, for 81% of the banking sector's total assets, which attests to the representativeness of the final sample of the WAEMU banking sector over the period under review.

The 72 banks in the sample are spread across the eight WAEMU countries. We recognise that this nested structure (banks nested within country-years) may give rise to a correlation in the error terms between banks in the same country that are subject to a common macroeconomic shock. If this dependence is not taken into account, it may lead to an underestimation of standard errors (Moulton, 1990) and, consequently, to an overestimation of the statistical significance of the estimated coefficients. To address this issue, we have re-estimated all our regressions by clustering the standard errors at the country-year level, which allows us to account for arbitrary correlation of the residuals within a given country-year whilst maintaining the assumption of independence between clusters. The results, presented in Table S1 in the appendix, confirm the robustness of our estimates following this adjustment. The coefficients retain their sign, magnitude and level of statistical significance, particularly in the lending rate equation, which forms the core of our empirical analysis.

We performed a logarithmic transformation on all variables in the equation system. Table 3 sets out the methods used to calculate the variables included in the system of equations, as well as the expected sign of their effect on the dependent variables. It should be noted that our "credit demand" variable does not correspond to the total demand for credit addressed to the bank, but rather to "the demand for credit granted by the bank". Indeed, regardless of the amount of outstanding credit, there is always unmet demand for credit.

Table 3. Description of model variables and expected effects.

Variable		Mesure	Abbreviation	Expected effect
Dependent variable	Loan demand	Average amount of loans granted to businesses and individuals	C^d	
Independent variables	Interest rate charged	Interest income and management fees as a proportion of the total amount of loans	R_c	Negative
	Income effect	Growth rate of gross domestic product per capita	GDP	Positive
	Substitution effect	Standard deviation of the inflation rate over 12 months	σ_{INFL}	Negative
		Market capitalization relative to GDP	SMC	Negative
Dependent variable	Interest rate charged	Interest income and management fees as a proportion of the total amount of loans	R_c	
Independent variables	Risk	Ratio of loan loss provisions to average loans	PPP	Positive
	Market power	Herfindahl-Hirschman Index for the banking sector (HHI)	PM	Positive
	Cost of funding on the secondary market	BCEAO repo rate	TPP	Positive
	Cost of equity sensitivity	Cost of equity (rk) multiplied by ($\partial K^* / \partial C$), assumed to be 11.5%	$rk * \frac{\partial K^*}{\partial C}$	Positive

Source: Author, based on literature review.

Table 4 presents the descriptive statistics for the variables included in the system of equations. It shows that banks devote on average more than 50% of their assets to lending, indicating that lending is the main activity of WAEMU banks. The table also shows that the average interest rate on loans for the entire sample is 9.098%. Although this interest rate remains relatively high, it should be noted that it has fallen compared to previous years, when it was in double digits. In addition, the low standard deviation of the lending rate indicates that all banks in the zone charge their customers almost the same level of interest rates. It also appears that the Central Bank's repo rate varies very little, inflation is moderate, and market capitalization is also low.

Table 4. Descriptive statistics for the variables used in the model.

Variable	Number of observations	Mean	Standard deviation	Median	25th percentile	75th percentile	Min	Max
Loan demand (% of total assets)	360	54.540	12.810	55.143	46.533	63.644	18.048	91.243
Interest rate charged (%)	360	9.098	2.683	8.670	7.529	10.385	3.762	26.621
Cost of equity (in %)	360	5.314	1.630	5.194	4.134	6.361	2.069	9.946
Loan loss provision ratio (%)	360	1.197	1.774	0.673	0.258	1.409	0.000	16.090
BCEAO repo rate (%)	5	3.997	0.455	3.927	3.500	4.500	3.500	4.500
Market capitalization (% of GDP)	5	25.223	8.192	25.776	14.571	33.114	13.837	37.792
Banking sector concentration index	40	1536.591	797.003	1246.603	1133.999	1614.930	957.651	5967.468
GDP growth rate per capita (%)	40	2.985	1.743	3.200	1.706	4.021	−1.670	6.225
Inflation rate (standard deviation)	40	0.636	0.272	0.638	0.466	0.786	0.139	1.362

Source: Author, based on data from the balance sheets and income statements of banks and financial institutions in WAEMU, 2016 to 2020.

5. Presentation and Discussion of the Results

This section shows the results of the estimates from the system of simultaneous equations, as well as the economic interpretations that may be drawn from them.

5.1. Results of the Estimation of the System of Simultaneous Equations

Table 5 summarises the main results of the estimation of the system of simultaneous equations. The tests of the appropriateness of the instruments and their validity are presented in Table S2 in the appendix. The F-statistic for the first stage ($F = 21.460$; $p = 0.000$) confirms the appropriateness of the instruments used. Hansen's over-identification test ($J = 1.415$; Chi2(3) $p = 0.234$) does not allow us to reject the null hypothesis of joint validity of the excluded instruments, which supports the validity of the instruments and reinforces the credibility of the model identification.

Table 5. Results of the three-step least squares regression.

		Coefficient	*p*-value
Loan	R_c	−0.876** (0.364)	0.016

Continued

	GDP	−0.513** (0.248)	0.033
	σ_{INFL}	−0.040* (0.024)	0.096
	SMC	−0.111* (0.062)	0.073
	Cons.	0.567*** (0.045)	0.000
Interest rate	*PPP*	0.127** (0.056)	0.024
	PM	0.061*** (0.015)	0.000
	TPP	1.803*** (0.219)	0.000
	$k*\left(\partial K^{*}/\partial C\right)$	0.280*** (0.064)	0.000
	Cons.	−0.038*** (0.012)	0.002

Note: The numbers in brackets are standard errors. *** (** and *) indicates the significance of the coefficient at a confidence level of 99% (95% and 90%). Source: Author, based on estimation results. Data from the balance sheets and income statements of WAEMU banks from 2016 to 2020.

The results of the estimates show that the coefficient associated with the lending rate (R_c) is negative and statistically significant, in line with theoretical predictions. The increase in the cost of borrowing discourages borrowers from seeking more credit. The negative and statistically significant coefficient for GDP growth per capita (GDP) suggests that, in WAEMU countries, an increase in average income is accompanied by a decrease in demand for bank credit. This counter-intuitive result could be explained by the fact that periods of economic growth in the WAEMU are frequently driven by major public works projects, extractive industries and foreign direct investment. These activities are frequently financed by budgetary resources, international donors or external funding, which limits the growth in demand for credit from commercial banks. Changes in the inflation rate (σ_{INFL}), as expected, have a negative effect on demand for credit. Indeed, inflation leads to high interest rates, which increase the cost of credit and discourage economic agents from borrowing. Market capitalisation (SMC) has a negative and statistically significant impact on the demand for credit. This finding suggests that, over the period under review, the development of the stock market and that of the banking sector constituted competing sources of finance, such that a deepening of the stock market is associated with lower demand for bank finance.

With regard to the lending rate equation, which is the main focus of this research, all the explanatory variables exhibit the theoretically expected signs and statistically significant coefficients. Provisions for loan losses relative to the amount of loans granted, which serve as a measure of credit risk in the interest rate equation and as an approximation of θ in Equation (3), have, in line with theoretical predictions, a positive and significant effect on the lending rate. Thus, an increase in credit risk results in a rise in the rate charged to borrowers. The bank's market share of total bank loans, used as a measure of the credit market structure and as an approximation of H in Equation (3), also has a positive and significant effect on the lending rate. This result suggests that the bank's market position influences its ability to set its lending rates. The BCEAO's repo rate (TPP), which corresponds to the rate at which commercial banks can obtain refinancing from the Central Bank, is used to measure the cost of funding in the secondary market (R_A in Equation (3)). In line with theoretical expectations, its coefficient is positive and statistically significant, indicating that a rise in the cost of refinancing is passed on to the lending rate. Finally, the sensitivity of the cost of equity, measured as the product of the cost of equity (rk) and the sensitivity of capital requirements to the volume of loans granted ($\partial K^* / \partial C$), also has, as expected, a positive and significant effect on the lending rate. This result implies that an increase in the cost of equity or in its sensitivity to loans granted leads banks to raise their lending rates in order to offset the additional cost associated with regulatory capital requirements.

Based on these results, we carry out a simulation, constituting an out-of-sample forecast, of the interest rates that WAEMU banks are likely to charge their customers following the adoption of the capital requirements set out in the Basel II agreement.

5.2. Out-of-Sample Prediction

The simulation was carried out in two stages. Firstly, we assumed that the explanatory variables, namely, provisions for loan losses, market share, the BCEAO's repo rate and the cost of equity, included in Equation (3) and presented in **Table 5** took on their average values over the period 2016-2020. Furthermore, the variable ($\partial K^* / \partial C$) is set to zero, which amounts to assuming a zero probability of default (PD) for customers. This assumption enables us to obtain the benchmark lending rates, from which their evolution as a function of PDs can be simulated. Based on these assumptions, the y-intercepts of the simulated loan rate trajectories are obtained by multiplying the mean values of the explanatory variables by their respective estimated coefficients, as shown in **Table 5**. The y-intercepts thus obtained are 5.790% for the IRB approach and 9.066% for the standardised approach. Secondly, starting from these two initial values, we assume that lending rates evolve in accordance with the capital requirements associated, alternately, with the IRB approach, as per Equation (5a) below, or with the standardised approach, based on the risk weights set out in **Table 6**.

Table 6. Bank asset weighting system established by the Basel II agreements.

Counterparty rating		AAA à AA−	A+ à A−	BBB+ à BBB−	BB+ à BB−	B+ à B−	Below B−	Not rated
Sovereigns		0%	20%	50%	100%	100%	150%	100%
Banks	Option 1	20%	50%	100%	100%	100%	150%	100%
	Option 2	20%	50%	50%	100%	100%	150%	100%
	Option 2 (short term)	20%	20%	20%	50%	50%	150%	20%
Corporate		20%	50%	100%	100%	150%	150%	100%
Retail customers	75%							
Secured real estate loans	40%							
Secured consumer loans	100%							
Securitised assets		20%	50%	100%	350%	Withdrawal from equity		
Other assets	100%							

Source: Author, based on information from the 2016 version of the Standardised Approach for credit risk.

The formula for determining capital requirements (K), expressed as a percentage of exposure at default (EAD), is based on Gordy's (2003) invariant portfolio model[4] and on the assumption of a normal distribution of the borrower's probability of default, in accordance with Vasicek's (2002) model. It is expressed as follows:

$$K\left(LGD, PD, M\right)=\left[LGD\times N\left(\frac{N^{-1}\left(PD\right)+\sqrt{\rho}N^{-1}\left(\alpha\right)}{\sqrt{1-\rho}}\right)-\left[PD\times LGD\right]\right]\times A^{*}\left(M,\ PD\right) \quad (5a)$$

As an alternative to Equation (5a), the unexpected loss (UL), or capital requirements (K) expressed as a percentage of EAD, can be expressed as follows:

$$\frac{UL}{EAD}=K=\left[\frac{VaR}{EAD}-\left[PD\times LGD\right]\right]$$

If we denote the unexpected losses, expressed in monetary terms, by K^{*}, the equation can be rewritten as follows:

$$K^{*}\left(LGD, PD, EAD, M\right)=K\times EAD \quad (5b)$$

The PD parameter represents the probability of default by rating class, i.e. the average percentage of borrowers defaulting within that class (generally over a

[4]Portfolio invariance means that the capital requirements associated with a given loan depend solely on its own risk characteristics (PD, LGD and EAD) and not on the risk profile of the portfolio to which that loan belongs. This assumption is a key element in the calculation and application of the IRB framework, as set out in Equation (5a). Otherwise, the calculation of capital requirements (K) would also need to incorporate the diversification effects associated with the composition of the loan portfolio.

one-year period); LGD refers to the loss given default, i.e. the percentage of the exposure that the bank is likely to lose in the event of borrower default, i.e. (1 − recovery rate); EAD refers to the exposure at default, i.e. an estimate of the outstanding loan amount at the time of the borrower's default.

In the absence of a reliable estimate of recovery rates for bank loans in the WAEMU, this study adopts an LGD of 75%, in line with the Basel Committee's regulatory parameters for subordinated claims under the IRB approach[5]. The effective maturity is set at 2.5 years, in line with the benchmark value adopted by the Basel Committee under the IRB approach. In the absence of detailed information on the residual maturity of bank exposures in the WAEMU, this assumption constitutes an approximation in line with international prudential standards. It ensures the comparability of results whilst avoiding an underestimation or overestimation of credit risk associated with the use of an extreme maturity. In the expression for K given by Equation (5a), $N(x)$ denotes the cumulative distribution function of the standard normal distribution, whilst $N^{-1}(x)$ represents its quantile function (or inverse cumulative distribution function).

The Basel Committee emphasised the importance of setting capital requirements to cover unexpected losses, assuming an adverse realisation of the systematic risk factor with a 99.9% confidence interval. α therefore takes the value of 0.999, which is equivalent to $N^{-1}(0.999) \approx 3.09$. Furthermore, ρ represents the correlation coefficient between the various exposures, that is to say, between the various loans making up the portfolio. Determined by the Basel Committee, this parameter reflects the extent to which the value of one borrower's assets depends on that of another borrower's assets[6]. Finally, A^* is an adjustment factor that takes account of the effective maturity (M) and the probability of default (PD).[7] It can then be shown that the capital requirements K increase with

[5]This conservative assumption aims to limit the risk of underestimating losses in the event of default. It is also justified by the characteristics of the institutional context of the WAEMU, which is characterised by recovery procedures that are often lengthy and costly, varying effectiveness of mechanisms for enforcing collateral, and limited liquidity of recovered assets–all factors likely to increase the final losses incurred by banking institutions. Many authors use ad hoc values for LGD. For example, Tarashev et al. (2010) set this rate at 55% without giving a reason. Gauthier et al. (2012) use 50%. Puzanova and Düllmann (2013) use a maximum loss rate of 100%. Degryse and Nguyen (2007) explain why the statistical estimation of $LGDs$ can be difficult.

[6]The equation for ρ is: $\rho(PD) = 0.12 \times \left[\frac{1-e^{(-50\times PD)}}{1-e^{(-50)}}\right] + 0.24 \times \left[1 + \frac{1-e^{(-50\times PD)}}{1-e^{(-50)}}\right]$. This function is modified by an adjustment factor that takes into account the amount of turnover in the case of small and medium-sized enterprises.

[7]The component A^* is specified as follows: $A^*(M,PD) = \frac{(1+(M-2,5)\times b(PD))}{(1-1,5\times b(PD))}$, where the coefficient b is determined by the Basel Committee according to the relationship $b = \left[(0.11852) - 0.05478 \times \log(PD)\right]^2$. Theoretical foundations and empirical findings suggest that long-term loans carry a higher level of risk than short-term loans. Consequently, capital requirements (K) should increase with effective maturity (M); $\frac{\partial K}{\partial M} > 0$.

PD, LGD and EAD [8]:

$$\frac{\partial K}{\partial PD} > 0; \quad \frac{\partial K}{\partial LGD} > 0 \quad \text{et} \quad \frac{\partial K}{\partial EAD} > 0.$$

The following section presents the results of the simulation, along with the economic interpretations that follow from them.

5.3. Simulation Results and Discussions

The results of the simulations are shown in **Figure 2**. For the sake of clarity, both approaches are plotted on the same graph, with the horizontal axis covering both the probabilities of default for the IRB approach and the credit ratings for the standardised approach. The results show that the IRB approach allows for a more granular assessment of risk than the standardised approach. Indeed, under the IRB approach, a slight increase in the borrower's probability of default leads to a gradual rise in the lending rate and, consequently, in capital requirements. Conversely, the standardised approach is characterised by "jumps" in lending rates, and thus in capital requirements, when the borrower's credit rating deteriorates and crosses a specified threshold.

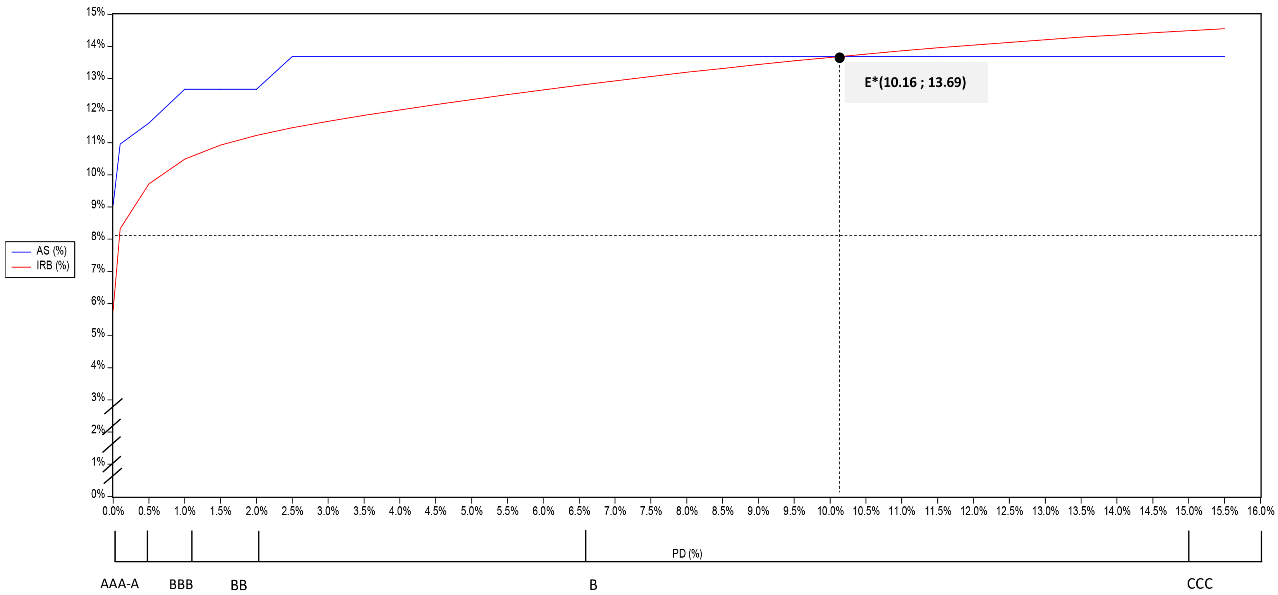

Figure 2. Changes in the lending rate under the standardised and IRB approaches of Basel II. Source: Author, based on simulation results. Data from the balance sheets and income statements of WAEMU banks from 2016 to 2020.

[8] It can also be shown that, within the relevant range of values, $\frac{\partial K}{\partial \rho} > 0$. This positive relationship between ρ and K can be explained intuitively by the fact that a low correlation between the components of the loan portfolio (borrowers or sectors) promotes portfolio diversification and thus reduces the risk of concentration of losses. Unexpected losses are therefore less likely to occur simultaneously, leading to lower capital requirements to cover them. Conversely, when the correlation between the various components of the portfolio increases, risks become more likely to materialise simultaneously, reducing the benefits of diversification and leading to an increase in the capital requirements needed to cover unexpected losses.

Furthermore, we observe that, for a PD values below 10.16%, the borrowing rate simulated using the IRB approach is lower than that obtained using the standardised approach. This result suggests that relatively low-risk borrowers, characterised by a PD of less than 10.16%, would benefit from more favourable borrowing rates from banks adopting the IRB approach. Conversely, higher-risk borrowers, with a PD above 10.16%, would be better off obtaining finance from banks applying the standardised approach. This finding is consistent with the results of Repullo and Suarez (2004) and Hakenes and Schnabel (2011), according to whom low-risk exposures are treated more favourably under the IRB approach. It is also likely that large banks are more likely to adopt this approach, given the significant fixed costs associated with setting up and validating internal rating systems. Adopting the IRB approach could therefore lead these banks to attract a client base comprising a higher proportion of high-quality borrowers, whilst smaller banks, which are more likely to retain the standardised approach, may see their portfolios become more concentrated on relatively risky borrowers.

Overall, these findings are consistent with those of Ruthenberg and Landskroner (2008) and support the hypothesis that adopting the IRB approach may give large banks a competitive advantage over smaller banks using the standardised approach.

Similarly, the simulation results presented in **Figure 2** indicate that a PD of 10.16% corresponds to an interest rate of 13.69%. Furthermore, **Table 4** of the descriptive statistics shows that the average interest rate in the WAEMU zone is around 9%, which is well below 13.69%. This suggests that companies and individuals in the WAEMU region could, on average, benefit from more favourable financing terms from banks adopting the IRB approach. This is because the application of a single method based on the standardised approach increases the cost of credit in the zone and, as a result, limits access to credit. It is not certain that this increase in lending rates will affect economic activity, but it may result in lower-quality borrowers and thus increase financial instability (Martynova, 2015). These results show that there are advantages to adopting internal rating methods in the WAEMU zone.

6. Conclusion

In this study, we compared the two approaches to determining capital requirements under Basel II, the standardised approach and the internal ratings-based approach, and examined their effects on credit risk. To this end, we derived an equation for a commercial bank's lending rate, assuming that the bank is risk-neutral and operates in a market characterised by imperfect competition. The analysis covers a sample of 72 banks in the WAEMU observed over the period 2016-2020. The results of the simulations indicate that companies and individuals with a low level of risk could benefit from lower lending rates by borrowing from banks adopting the IRB approach. Conversely, high-risk borrowers could avoid an increase in their lending rates by turning to banks applying the standardised approach. Overall, these results highlight the potential benefits of adopting internal rating-based approaches in the WAEMU region, particularly in terms of risk differentiation and credit pricing.

In light of our findings, we can expect WAEMU banks to adopt internal rating systems in response to their advantages. However, a few caveats are in order. Firstly, the implementation of an effective internal risk-measurement model requires significant organisational effort, substantial investment and advanced technical expertise. Consequently, only large banks generally have the necessary resources to develop and maintain such systems. This situation may give rise to competitive distortions, insofar as some banks apply the standardised approach whilst others determine their capital requirements using internal models. Secondly, the IRB approach can be difficult for the general public to understand due to the complexity of the models used to measure risk. Finally, it raises an important issue of transparency, as banks' internal models rely on parameters and calculation methods that are not necessarily accessible to external parties. This lack of transparency may create a risk of opportunistic use of IRB models, as banks may be tempted to adjust their risk parameters in order to reduce their capital requirements rather than seeking as objective a measure of risk as possible.

In this respect, our findings support the recent efforts of the regulatory community, through the Basel III agreements, to restrict banks' discretion in their choice of modelling approaches and to limit the extent of the reduction in capital requirements permitted under the IRB approach. We suggest that internal models be subject to a set of constraints relating to estimation practices and to minimum values for risk parameters, known as "input floors". We also support the Basel Committee's proposed reform (2016) to introduce an "output floor" whereby the capital requirements generated by IRB models could not fall below a certain percentage, to be set within a range of 60% to 90%, of the capital requirements resulting from the standardised approach.

Finally, within the context of the WAEMU, supervisory authorities should pay particular attention to the validation, monitoring and ongoing oversight of internal rating systems. The initial validation should, in particular, focus on data quality, the relevance of assumptions, the robustness of estimation methods and the predictive power of the models. A system of regular monitoring also appears necessary to ensure that the models remain reliable over time and are not used opportunistically to artificially reduce capital requirements.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

Acharya, V., Engle, R., & Pierret, D. (2014). Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights. *Journal of Monetary Economics, 65,* 36-53. https://doi.org/10.1016/j.jmoneco.2014.04.014

Albaity, M., & Toobaee, M. (2017). The Risk-Sensitivity of Bank Capital Requirements: The

Moderating Effects of Capital Regulation and Supervisory Power. *International Journal of Economics and Financial Issues, 7,* 94-102.

Amadou, B., & Mbengue, M. L. (2021). L'efficacité de la règlementation prudentielle à la lumière des accords de Bâle: Cas des banques de la zone UEMOA. *Revue Internationale des Sciences de Gestion, 4,* 732-759.

Arroyo, J. M., Colomer, I., Baena, R. G., & Mosquera, L. Á. G. (2012). Comparing Risk-Weighted Assets: The Importance of Supervisory Validation Processes. *Estabilidad Financiera, 22,* 9-29.

Barucci, E., & Milani, C. (2018). Do European Banks Manipulate Risk Weights? *International Review of Financial Analysis, 59,* 47-57. https://doi.org/10.1016/j.irfa.2018.07.002

Basel Committee on Banking Supervision (BCBS) (2016). *Reducing Variation in Credit Risk-Weighted Assets—Constraints on the Use of Internal Model Approaches*. Bank for International Settlements and Basle Committee on Banking Supervision Publications.

Behn, M., Haselmann, R., & Vig, V. (2022). The Limits of Model-Based Regulation. *The Journal of Finance, 77,* 1635-1684. https://doi.org/10.1111/jofi.13124

Behn, M., Haselmann, R., & Wachtel, P. (2016). Procyclical Capital Regulation and Lending. *The Journal of Finance, 71,* 919-956. https://doi.org/10.1111/jofi.12368

Benink, H., & Kaufman, G. (2008). Turmoil Reveals the Inadequacy of Basel II. *Financial Times*.

Berg, T., & Koziol, P. (2017). An Analysis of the Consistency of Banks' Internal Ratings. *Journal of Banking & Finance, 78,* 27-41. https://doi.org/10.1016/j.jbankfin.2017.01.013

Besanko, D., & Kanatas, G. (1996). The Regulation of Bank Capital: Do Capital Standards Promote Bank Safety? *Journal of Financial Intermediation, 5,* 160-183. https://doi.org/10.1006/jfin.1996.0009

Bruno, B., Nocera, G., & Resti, A. (2017). *Are Risk-Based Capital Requirements Detrimental to Corporate Lending? Evidence from Europe (CEPR Discussion Paper No. 12007). Centre for Economic Policy Research.* https://hdl.handle.net/11565/3999451

Cannata, F., Casellina, S., & Guidi, G. (2012). *Inside the Labyrinth of Basel Risk-Weighted Assets: How Not to Get Lost*. Bank of Italy Occasional Paper.

Cave, J., Feid, J., French, G., & Stark, W. (2003). *Risk-Based Capital Requirements for Commercial Lending: The Impact of Basel II.* US Federal Deposit Insurance Corporation.

Cipovová, E., & Dlasková, G. (2016). Comparison of Different Methods of Credit Risk Management of the Commercial Bank to Accelerate Lending Activities for SME Segment. *European Research Studies Journal, 19,* 17-26. https://doi.org/10.35808/ersj/577

Cucinelli, D., Battista, M. L. D., Marchese, M., & Nieri, L. (2018). Credit Risk in European Banks: The Bright Side of the Internal Ratings Based Approach. *Journal of Banking & Finance, 93,* 213-229. https://doi.org/10.1016/j.jbankfin.2018.06.014

Dannon, P. H., & Lobez, F. (2014). La régulation bancaire dans l'Union économique et monétaire ouest-africaine est-elle efficace? *Revue d'économie financière, 116,* 279-304. https://doi.org/10.3917/ecofi.116.0279

Degryse, H., & Nguyen, G. (2007). Interbank Exposures: An Empirical Examination of Contagion Risk in the Belgian Banking System. *International Journal of Central Banking, 3,* 123-171.

Erdinç, D., & Gurov, A. (2016). The Effect of Regulatory and Risk Management Advancement on Non-Performing Loans in European Banking, 2000-2011. *International Advances in Economic Research, 22,* 249-262.

https://doi.org/10.1007/s11294-016-9591-y

Ferri, G., & Pesic, V. (2017). Bank Regulatory Arbitrage via Risk Weighted Assets Dispersion. *Journal of Financial Stability, 33,* 331-345. https://doi.org/10.1016/j.jfs.2016.10.006

Gammadigbé, V. (2018). Survie des banques de l'UEMOA: Les nouvelles exigences de fonds propres sont-elles pertinentes. *Revue Économique et Monétaire de la BCEAO, 24,* 9-47.

Gauthier, C., Lehar, A., & Souissi, M. (2012). Macroprudential Capital Requirements and Systemic Risk. *Journal of Financial Intermediation, 21,* 594-618. https://doi.org/10.1016/j.jfi.2012.01.005

Giammarino, R. M., Lewis, T. R., & Sappington, D. E. M. (1993). An Incentive Approach to Banking Regulation. *The Journal of Finance, 48,* 1523-1542. https://doi.org/10.1111/j.1540-6261.1993.tb04766.x

Glaeser, E. L., & Shleifer, A. (2001). A Reason for Quantity Regulation. *American Economic Review, 91,* 431-435. https://doi.org/10.1257/aer.91.2.431

Gordy, M. B. (2003). A Risk-Factor Model Foundation for Ratings-Based Bank Capital Rules. *Journal of Financial Intermediation, 12,* 199-232. https://doi.org/10.1016/s1042-9573(03)00040-8

Hakenes, H., & Schnabel, I. (2011). Bank Size and Risk-Taking under Basel II. *Journal of Banking & Finance, 35,* 1436-1449. https://doi.org/10.1016/j.jbankfin.2010.10.031

Hellwig, M. F. (2010). Capital Regulation after the Crisis: Business as Usual? *CESifo DICE Report, 8, 40-46.*

Klein, M. A. (1971). A Theory of the Banking Firm. *Journal of Money, Credit and Banking, 3,* 205-218. https://doi.org/10.2307/1991279

Ledo, M. (2011). Towards More Consistent, Albeit Diverse, Risk-Weighted Assets across Banks. *Estabilidad Financiera, 21,* 41-61.

Majnoni, G., Powell, A., Correa, P., & Brock, P. (2005). Reforming Bank Capital Requirements: Implications of Basel II for Latin American Countries. *Economía, 5,* 105-149. https://doi.org/10.1353/eco.2005.0019

Mariathasan, M., & Merrouche, O. (2014). The Manipulation of Basel Risk-Weights. *Journal of Financial Intermediation, 23,* 300-321. https://doi.org/10.1016/j.jfi.2014.04.004

Mascia, D. V., Keasey, K., & Vallascas, F. (2016). Did Basel II Affect Credit Growth to Corporate Borrowers during the Crisis? In *Contributions to Economics* (pp. 83-94). Springer. https://doi.org/10.1007/978-3-319-17413-6_6

Montes, C. P., Artigas, C. T., Cristófoli, M. E., & San Segundo, N. L. (2018). The Impact of the IRB Approach on the Risk Weights of European Banks. *Journal of Financial Stability, 39,* 147-166. https://doi.org/10.1016/j.jfs.2016.11.004

Monti, M. (1972). Deposit, Credit, and Interest Rate Determination under Alternative Bank Objective Function. In G. P. Szegö, & K. Shell (Eds.), *Mathematical Methods in Investment and Finance* (pp. 431-454). North-Holland.

Moulton, B. R. (1990). An Illustration of a Pitfall in Estimating the Effects of Aggregate Variables on Micro Units. *The Review of Economics and Statistics, 72,* 334-338. https://doi.org/10.2307/2109724

Plosser, M. C., & Santos, J. A. C. (2018). Banks' Incentives and Inconsistent Risk Models. *The Review of Financial Studies, 31,* 2080-2112. https://doi.org/10.1093/rfs/hhy028

Puzanova, N., & Düllmann, K. (2013). Systemic Risk Contributions: A Credit Portfolio Approach. *Journal of Banking & Finance, 37,* 1243-1257. https://doi.org/10.1016/j.jbankfin.2012.11.017

Repullo, R., & Suarez, J. (2004). Loan Pricing under Basel Capital Requirements. *Journal of Financial Intermediation, 13,* 496-521. https://doi.org/10.1016/j.jfi.2004.07.001

Resti, A. (2016). Bank Internal Ratings: Are Capital Floors a Suitable Tool to Restore Their Credibility? *Journal of Financial Management, Markets and Institutions, 4,* 179-194.

Ruthenberg, D., & Landskroner, Y. (2008). Loan Pricing under Basel II in an Imperfectly Competitive Banking Market. *Journal of Banking & Finance, 32,* 2725-2733. https://doi.org/10.1016/j.jbankfin.2008.07.009

Stewart, R. (2021). Improving Regulatory Capital Allocation: A Case for the Internal Ratings-Based Approach for Retail Credit Risk Exposures. *Journal of Financial Regulation and Compliance, 29,* 317-335. https://doi.org/10.1108/jfrc-08-2020-0076

Tarashev, N. A., Borio, C. E., & Tsatsaronis, K. (2010). *Attributing Systemic Risk to Individual Institutions*. Bank for International Settlements Working Paper.

The Economist (2012). DIY Capital: An Edifice of Modern Bank Regulation Comes under Scrutiny. *The Economist*.

Vasicek, O. (2002). The Distribution of Loan Portfolio Value. *Risk, 15,* 160-162.

Wan, N., Li, C., & Huang, J. (2006). *An Analysis of Loan Pricing under Basel II.* https://papers.ssrn.com/sol3/papers.cfm?abstract_id=937890

Zellner, A., & Theil, H. (1962). Three-Stage Least Squares: Simultaneous Estimation of Simultaneous Equations. *Econometrica, 30,* 54-78. https://doi.org/10.2307/1911287

Supplementary

Table S1. Robustness of the estimates to the panel structure (country-year clustering).

		Original model	Cluster model
C^d	R_C	−0.877** (0.364)	−0.877** (0.428)
	$TCPIBH$	−0.532** (0.248)	−0.532** (0.264)
	σ_{INFL}	−0.040* (0.024)	−0.040 (0.026)
	SMC	−0.112* (0.062)	−0.112 (0.070)
	$Const.$	0.568*** (0.045)	0.568*** (0.054)
R_C	PPP	0.127** (0.056)	0.127** (0.058)
	PM	0.061*** (0.015)	0.061*** (0.020)
	TPP	1.803*** (0.219)	1.803*** (0.258)
	$k*\left(\partial K^*/\partial C\right)$	0.280*** (0.064)	0.280*** (0.080)
	$Const.$	−0.039*** (0.012)	−0.039*** (0.013)

Note: The numbers in brackets are standard errors. *** (** and *) indicates the significance of the coefficient at a confidence level of 99% (95% and 90%). **Source:** Author, based on estimation results. Data from the balance sheets and income statements of WAEMU banks from 2016 to 2020.

Table S2. Validity and relevance diagnostics for the instruments in the 3SLS model.

F (4, 503) = 21.460***   Prob > F = 0.000
Hansen J = 1.415   chi2(3) Prob = 0.234

Source: Author, based on estimation results. Data from the balance sheets and income statements of WAEMU banks from 2016 to 2020.