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Zbigniew Korzeb
Politechnika Białostocka, Polska, https://orcid.org/0000-0001-9690-3842 z.korzeb@pb.edu.pl
Marcin Gospodarowicz
Szkoła Główna Handlowa w Warszawie, Polska, https://orcid.org/0000-0001-5011-3247 mgospo@sgh.waw.pl
Paweł Niedziółka
Szkoła Główna Handlowa w Warszawie, Polska, https://orcid.org/0000-0002-1659-7310 pniedz@sgh.waw.pl
Antonio de la Torre Gallegos
University of Seville, Spain, https://orcid.org/0000-0001-7839-0385 atorre@us.es

Climate risk and capital requirements – findings for the Polish banking sector based on empirical research

Ryzyko klimatyczne a wymogi kapitałowe – wnioski dla polskiego sektora bankowego na podstawie badań empirycznych

Abstract

This article addresses the consequences for Polish commercial banks of modifying capital requirements by adding an environmental factor. Applying a simulation method, CRISK and MCRISK estimation, and a linear ordering method, the following conclusions were drawn: (i) while it is reasonable to consider the way(s) in which climate risk may impact credit, market and operational risks in scenario analyses, the lack of reliable historical data makes any calibration of GSF and BPF very difficult; (ii) simulating the implementation of adjustments to the calculation of capital adequacy ratios by GSF and BPF should not significantly lower the Tier 1 ratio for the largest banks; (iii) large retail banks are characterised by relatively high rankings reflecting a combination of financial characteristics (financial performance) and environmental (taxonomy) disclosures; and (iv) climate risk does not currently (2023) pose an immediate threat to the Polish banking sector, although the risk of climate transformation is a factor of significant importance.

Keywords: bank, linear ordering, capital adequacy, banking sector, climate risk.

JEL: G21, Q51, Q54, Q58

Streszczenie

Celem artykułu jest odpowiedź na pytanie o konsekwencje dla polskich banków komercyjnych modyfikacji wymogów kapitałowych o czynnik środowiskowy. Stosując metodę symulacyjną, estymację CRISK i MCRISK oraz metodę porządkowania liniowego, sformułowano następujące wnioski: i) o ile zasadne jest uwzględnianie ryzyka klimatycznego w kontekście wpływu na ryzyko kredytowe, rynkowe oraz operacyjne w analizach scenariuszowych, o tyle ze względu na brak wiarygodnych danych historycznych trudno jest aktualnie kalibrować GSF oraz BPF ii) symulacja wdrożenia korekt kalkulacji współczynników adekwatności kapitałowej o GSF oraz BPF nie powinna istotnie obniżyć wskaźnika Tier 1 w odniesieniu do największych banków; iii) duże banki detaliczne odznaczają się relatywnie wysokimi pozycjami w rankingu odzwierciedlającym kombinację cech finansowych i wyników ujawnień środowiskowych, iv) ryzyko klimatyczne nie stanowi obecnie (2023) bezpośredniego zagrożenia dla polskiego sektora bankowego, jednak ryzyko transformacji klimatycznej jest czynnikiem o istotnym znaczeniu.

Słowa kluczowe: porządkowanie liniowe, bank, adekwatność kapitałowa, sektor bankowy, ryzyko klimatyczne.

JEL: G21, Q51, Q54, Q58

1. Introduction

One of the ways to achieve climate goals is to incentivise the financing of projects and entities whose environmental impact is positive, and conversely, to disincentivise the financing high-carbon enterprises. Incentives that would induce financial institutions to alter their lending and investment policies, so as to increase the share of 'green assets' in their portfolios are key here. Capital adequacy is foremost among the quantitative standards for banks. Dafermos and Nikolaidi (2022) distinguish three potential methods of incorporating environmental considerations into capital requirements:

- A micro-prudential approach, which involves adjusting the calculation of capital requirements at the level of individual credit institutions to correspond with climate risk;
- a weak macroprudential approach that emphasizes the exposure of financial institutions to systemic risks associated with specific sectors and geographic areas where climate risk materializes;
- a strong macro-prudential approach, according to which systemic risk is analysed by focusing on macro-financial feedback loops with double materiality (this refers to the mode of obtaining information).

Measuring climate risk in banks is a challenge. As Jung et al. (2022) point out, existing measures of climate risk are retrospective, static, and based on deterministic scenarios, in contradistinction to the way(s) that financial institutions measure the systemic risks of financial crises.

The present study intends to rectify this shortcoming by identifying and quantifying the impact of climate risk on the key characteristic of every bank, viz. its capital. In short, this paper proposes to determine the impact of climate risk on the capital of Polish banks, and to group these banks according to their environmental portfolio structure, in order to determine the similarities between the banks in the individual groups.

The first section is a literature review. This discusses the impact of climate risk on other bank risks, in particular those that have to be quantified in order to ensure that their capital requirement is met. The effect of climate risk on other bank risks, and consequently on bank stability, raises the question of how this risk should be incorporated into quantitative measures that assess overall bank risk. The next three sections are empirical and examine the leading Polish commercial banks. First, the expected capital shortfall resulting from climate risk is examined using CRISK and MCRISK. Next, selected ideas for implementing an environmental adjustment factor when calculating the capital adequacy ratio are presented in order to simulate the largest Polish commercial banks in terms of assets as of 31 December 2022. Whether the structure of their asset portfolios and their Tier 1 ratios threaten to reduce their regulatory capital can then be determined. In the next section, a linear ordering method was used to separate groups of banks based on the criterion of the strength of the relationship between their portfolio structure (decomposition due to taxonomic disclosures) and their financial condition.

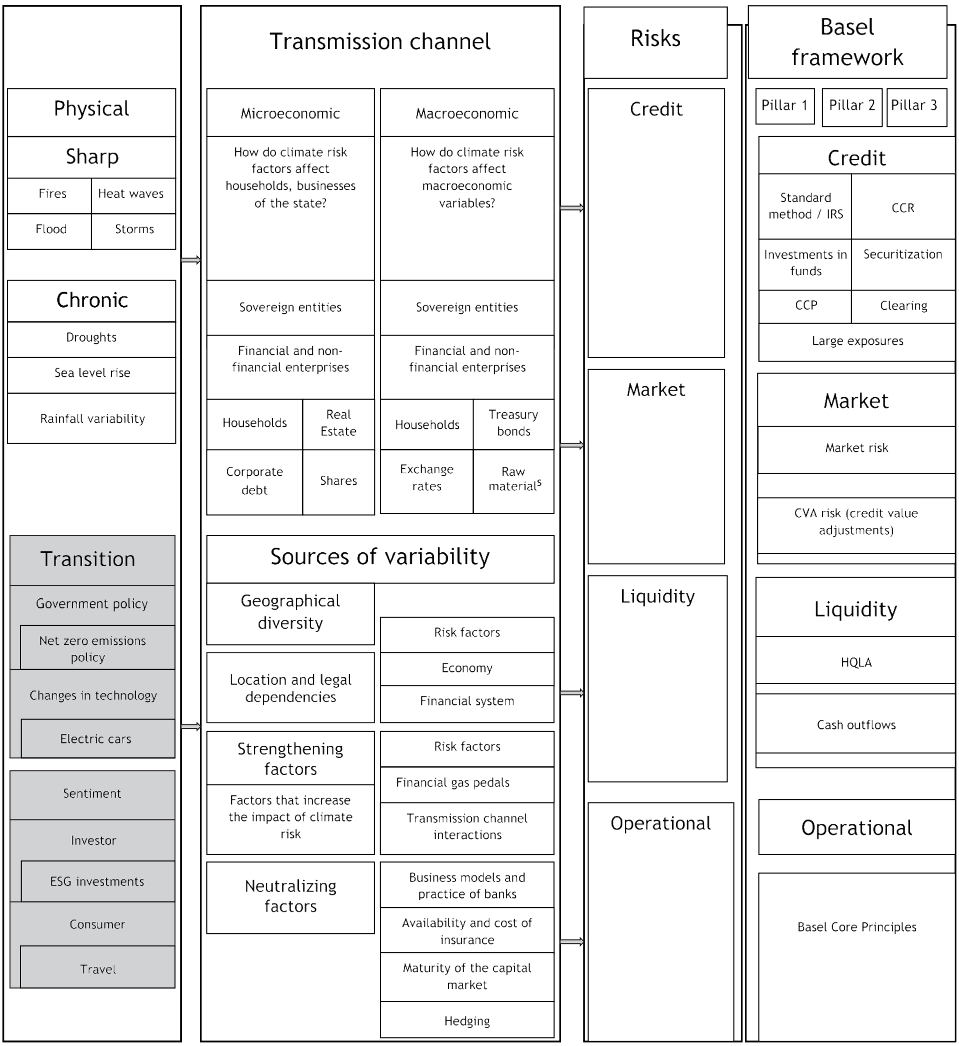
Despite the limitations described in the 'Conclusions' section, to the knowledge of the authors, the present study is the first attempt to estimate the impact of taxonomic disclosures on the banking sector of a specific country.

2. Climate risk and its interactions with other bank risks: Literature review

Climate risk is defined as the potential for extreme weather events or long-term climate change to adversely affect ecosystems (Sheedy et al., 2017). This in turn can adversely affect life and health, general well-being, livelihoods and income levels, economic activity, investment, and consumption. Not surprisingly, an increase in the frequency and amplitude of weather events such as droughts, floods, storms and hailstorms, hurricanes, tornadoes, and earthquakes exacerbate economic, social and political tensions.

Climate risk is also becoming a major challenge for the banking sector, and has the potential to significantly disrupt financial markets (Nieto, 2019; Garmaise and Moskowitz, 2009). The potential impact of climate risk on the financial sector is subject to numerous decompositions. One of the most commonly used is the division into physical risk and transition risk. Physical risk is associated with the impact of violent weather events on the condition and value of assets that are indirectly (through shareholdings) owned by the bank, that serve as collateral for the bank, or that are critical to the operational activities of borrowers. Physical risk is characterized by a long-term horizon and is associated with such negative and usually irreversible effects as rising sea levels, changes in the chemical composition of sea water, increased air temperature, damage to the ozone layer, loss of biodiversity, or a decrease in the proportion of biologically active land (Batten et al, 2016; Bunten and Kahn, 2014; Bernstein et al, 2019). Physical risk can be acute, e.g., exposure to heatwaves or floods, or chronic, e.g., reduced water availability or rising sea levels (EBA, 2020). The European Banking Authority (EBA) (2020) emphasizes that the magnitude and decomposition of physical risk and transition risk depend on climate and environmental policies, technological developments, and changes in consumer preferences and market sentiment. Zioło (2020), on the other hand, points to a taxonomy of climate risk in the banking sector that includes direct risk (related to the direct impact of bank operations on the environment and climate) and indirect risk (resulting from supporting the transition of specific sectors to a low-carbon economy). The direct environmental impact of banks is measured by the consumption of utilities and office supplies, as well as the generation of municipal waste and air pollution. Indirect impacts result from lending and investment policies. Figure 1 shows the microeconomic and macroeconomic transmission channels of climate risk affecting risk in banking activities.

Figure 1.
Interactions between climate risk and financial risk



Source: BIS (2021), p. 4.

Climate risk primarily affects credit risk. The negative impact of climatic and weather phenomena directly or indirectly results in a reduction or loss of creditworthiness of bank customers, thereby increasing the probability of default. Dafermos et al. (2018) demonstrate that climate change, by contributing to the erosion of companies' capital and reducing their profitability, negatively affects liquidity. This poses a threat both to the financial sector and to non-financial entities. In addition to the direct impact of climate factors, i.e., the destruction of fixed assets, without which debtors are prevented or significantly hampered in their operations, debtors can be indirectly impacted. Andreoni and Miola (2015) point to disruptions in supply chains among borrowers as a result of extreme climate events. This can become a source of additional financial liabilities, some of which may have legal consequences. The creditworthiness of bank clients deteriorates, as the requirement to comply with energy transition regulations can generate additional, previously unplanned capital expenditures. Another negative consequence of climate risk for companies are sudden and significant changes in bank lending policies. In this context, Aslan et al. (2022) write that Turkish banks are scaling back their lending to entities located in more polluted provinces and are including climate risk in their credit write-off policies. Li et al. (2022), based on data from 174 countries, conclude that climate risk has a significant negative effect on the supply of credit to the private sector and a positive effect on the supply of credit to the public sector. The strength of this relationship is greater in high-income countries. This confirms research conducted by Faiella and Natoli (2018), which found that banks respond to climate risks by reducing lending.

Climate risk can also reduce the value of loan collateral, which will increase the LTV ratio of existing loans and increase the basis for calculating risk allowances. While most studies indicate that weather-related disasters do not fundamentally affect the stability of banking sectors in developed countries (Albuquerque and Rajhi, 2019; Klomp, 2014; Zhang et al., 2022), recent publications point to a change in this trend. For example, Noth and Schüwer (2018) emphasize that, independent of the status of a given economy, natural disasters threaten the solvency of borrowers, negatively affecting the stability of the banking sector, despite insurance payouts and public assistance programs. This is confirmed by significantly lower z-scores, higher probability of insolvency, a higher share of non-performing assets, a lower return on assets, and lower capital adequacy ratios reported within two years of a natural disaster. Birindelli et al. (2022), however, suggest that involvement in climate issues actually lowers a bank's credit risk. These authors contend that the greater commitment to climate protection in a given jurisdiction, the less the banks need to do to meet their climate goals. By contrast, Lee et al. (2022) not only examine climate risk transmission channels in the context of credit risk, but also in the context of market and liquidity risk. These authors contend that climate risk increases volatility in commodity prices (e.g., in the agricultural, food, and fuel and energy industries), thereby rendering the capital and derivatives markets more volatile, as reflected in the financial statements of banks active in these markets. Banks are naturally more interested in financing fossil fuel-based projects than green ones, as they deliver a higher expected rate of return while incurring lower risks (Sachs et al., 2019). However, this often comes at the cost of their reputation and ESG ratings.

This is confirmed by Niedziółka (2021), who claims that climate risk can increase a bank's reputational risk. Niedziółka contends that unsustainable activities that betray a lack of concern for the environment and the climate, and a preparedness to work with entities that do not comply with sustainability principles, can damage a bank's image in the eyes of investors, shareholders, customers, and other stakeholders.

Bernardelli et al. (2022) analysed the world's 60 largest banks, representing more than 70% of the assets of the global banking system, in 2020 and found that 33 of them increased their exposure to fossil fuel financing, at the cost of lower ESG ratings. However, banks compensate for reputation and credit risk with higher margins for climate risk exposures. The increase in lending rates was particularly pronounced for the mining sector. Loan spreads for these exposures grew by 54% in 2017–2020 compared with 2007-2010 (Zhou et al., 2021).

3. Measuring expected capital shortfall as a consequence of exposure to climate risk: The case of Polish commercial banks

The CRISK procedure outlines climate-related risk measures for global financial companies. These are updated on a regular basis. The CRISK measure is defined as the bank's expected capital shortfall (i.e., capital reserves set aside by the bank minus the value of the entity's equity) as a consequence of exposure to climate risk, and is estimated as follows:

$$CRISK_{it} = k \times D_{it} - (1 - k) \times W_{it} \times (1 - LRMES_{it}) \quad (1)$$

$$LRMES_{it} = 1 - \exp\left(\beta^{Climate} \log(1 - \Theta)\right)$$

Where:
D is the book value of the bank's liabilities;
W is its market capitalization;
LRMES (Long-Run Marginal Expected Shortfall) is the expected marginal loss of a firm's capitalization as a consequence of a reduction over a six-month horizon in the value of the *stranded assets* (*SA*) portfolio, i.e. constructed by Litterman (2023) and the World Wildlife Fund portfolio containing the assets of fossil fuel energy companies;
$\beta^{Climate}$ measures the sensitivity of the bank's stock returns to the climate factor;
Θ is the threshold decline in the value of the SA portfolio implicitly assuming a value of 50%; and
k is the prudential capital requirement of 8% of asset value. This is the level of equity required to survive in the event that the climate risk materialises (transition).

SA return is a proxy for transition risk. It is composed of a 30% long position in the energy ETF, a 70% long position in the coal ETF, and a short position in the market (approximated by the MSCI All Country World Index). An underperformance of the SA portfolio is treated as an increase in transition risk (V-Lab, 2023).

The level of CRISK is a function of the entity's capital structure, its size, and the level of climate β. The derivative of CRISK is the marginal risk measure MCRISK, i.e., the difference between the CRISK level (at the current value of Θ) and the CRISK zero climate risk scenario (Θ=0). MCRISK enables the impact of climate risk, adjusted for the current capital shortfall, to be assessed.

$$MCRISK_{it} = (1 - k) \times W_{it} \times LRMES_{it} \tag{2}$$

CRISK and MCRISK values for selected entities in the Polish banking sector (both current and past) are available on Stern University's V-Lab website. These data are presented for monthly frequency. An analysis of CRISK levels for 12 large listed entities over the period 2011-2020 (including, four that have since ceased independent operations) shows that the aggregate CRISK level of the sector surged in 2020, reaching a value of around PLN 50 billion, which can be linked to the sharp decline in fossil fuel energy prices, and later declined to negative values, suggesting capital resilience to climate risk at the sector level (Figure 2). At the same time, a number of significant institutions in the sector, including Alior Bank, Bank Millennium, mBank, and Bank Pekao, registered positive CRISK levels in 2021-2023 (in the range of PLN 0 to about PLN 10 billion), which suggests that these entities are sensitive to climate transition risk. At the same time, it should be noted that the first three of these banks are most sensitive to climate risk. This is confirmed by the degree of capital consumption and the impact that the analysed risk, if materialised, is expected to have on capital adequacy ratios. Based on data from the end of 2022 (own funds and capital adequacy ratios), three scenarios of risk materialisation are analysed: (i) the maximum CRISK level for the entire study period (2011-2023); (ii) the maximum CRISK level for the two years prior to 30 September 2023; (iii) the CRISK from 30 September 2023 (current value). In scenarios (i) and (ii), in the case of Alior Bank, Bank Millennium and mBank, there is both a significant reduction in own funds (over 40%) and a reduction in capital adequacy ratios below the required levels. This effect is absent in the case of the other banks surveyed. None of them would have experienced a reduction in capital adequacy ratios below the required minimum. The maximum decrease in own funds would have been 30% for Bank Pekao. By contrast, the implementation of scenario (iii) would not have resulted in capital adequacy ratios falling below the required value for any of the surveyed banks.

Table 1 shows the selected diagnostic variables.

Table 1.
Variable definitions.

Variable	Definition	Source
Leverage Ratio (LR)	Tier 1 capital over a bank's total exposure measure, which consists of on-balance sheet as well as off-balance sheet assets	Notoria database
ROA	Bank return on assets (%, after tax)	Notoria database
C_FA	CRISK scaled by bank's financial assets (IFRS9)	V-Lab/Notoria database
MC_FA	MCRISK scaled by bank's financial assets (IFRS9)	V-Lab/Notoria database
Tier 1 Capital (T1)	The ratio of a bank›s core equity capital to its total risk-weighted assets (RWA)	Notoria database

Variable	Definition	Source
Net interest margin (NIM)	Bank's investment income minus its interest expenses divided by average earning assets	Notoria database
Bank Z-Score - ZSCORE	ROA+(equity/assets))/sd(ROA)	Notoria database
Bank›s total assets (natural logarithm)- LR_A	Natural logarithm of total assets	Notoria database
Liquidity ratio (LIQR)	Total assets over (total liabilities – conditional reserves)].	Notoria database
Cost/Income ratio (C/I)	Operating expenses divided by the operating income.	Notoria database
Capital adequacy ratio - CAR	Percentage of a bank›s risk-weighted credit exposures	Notoria database
Earnings per Share - EPS	Net income (profits or earnings) divided by available shares	Notoria database
–Net profit margin – NPM	percentage of profit a company produces From total revenue. It measures the amount of net profit a company obtains per dollar of revenue gained.	Notoria database

Source: own elaboration based on Notoria and V-Lab database data.

Table 2 shows the descriptive statistics of the variables listed above.

Table 2.
Descriptive statistics of explanatory variables.

	LR	ROA	LN_A	TIER1	NIM	Z_SCORE	LIQR.	C/I	CAR	EPS	NPM
Average	7.775	1.0129	5.021	15.53	72.353	14.875	7.035	42.646	16.87	2.40	21.150
Std dev	3.56	0.726	0.607	2.84	22.2	17.3	4.25	51.7	5.63	5.43	49.5
Min	1.118	-1.6732	3.689	1.57	6.592	-6.250	1.212	3.236	2.00	-53.1287	-37.372
Max	13.632	3.1944	6.776	23.00	97.512		95.839	782.651	25.39	19.4336	595.262

	C_FA	MC_FA
Average	-20.694	-9.698
Std dev	22.3	7.94
Min	-128.873	-7.326
Max	17.827	39.374

Source: own elaboration based on Notoria and V-Lab database data.

Using a fixed-effects panel regression model for quarterly data of 8 entities of the Polish banking sector from 2011 to 2023 (a total of 233 observations), a regression analysis was carried out between the CRISK and MCRISK measures of climate risk and a set of bank financial characteristics belonging to the categories of measures of capital adequacy, profitability, liquidity, cost, size and overall risk (Table 3).

Table 3.
Fixed-effects panel regression parameter estimates for models with the dependent variables CRISK (C_FA) and MCRISK (MC_FA)

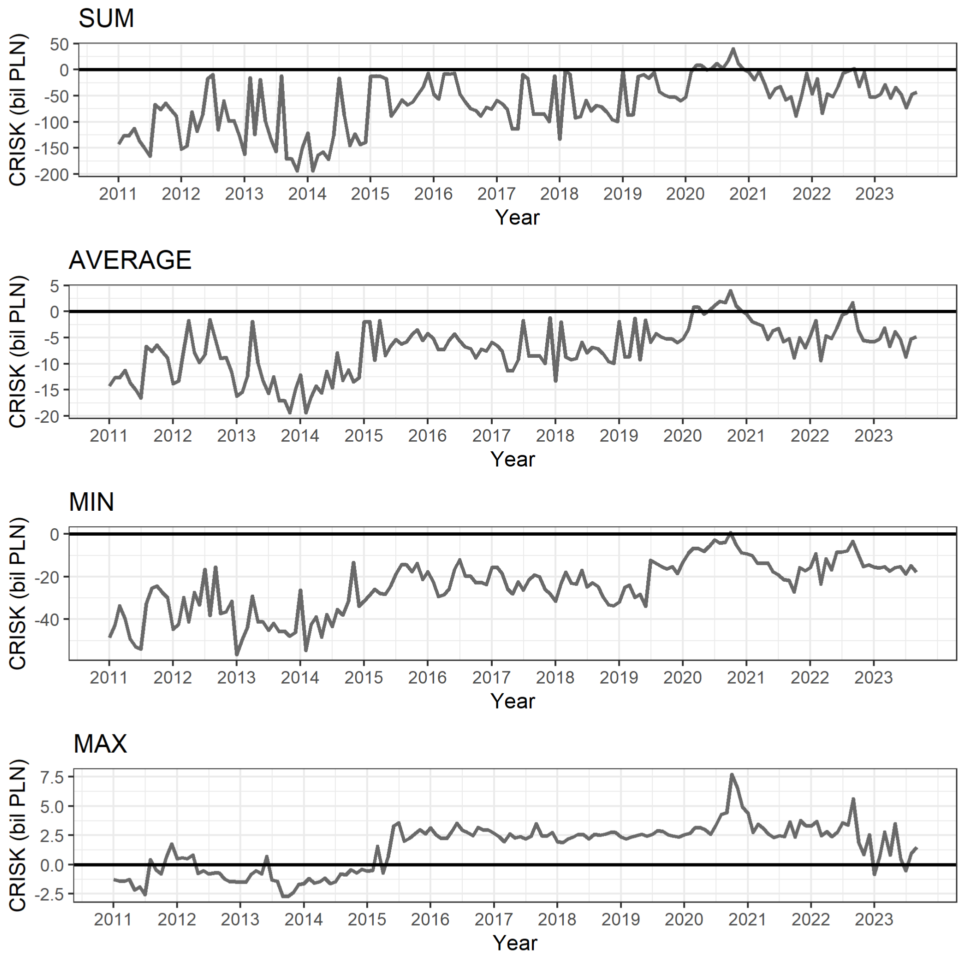
Specification	Dependent variable:	
Explanatory variable	C_FA	MC_FA
LN_A	17.042*** (5.135)	-6.349*** (2.053)
LR	-0.911** (0.380)	0.375** (0.152)
ZSCORE	-0.319*** (0.082)	0.044 (0.033)
NIM	-0.016 (0.054)	-0.013 (0.022)
ROA	-5.809** (2.388)	1.442 (0.955)
LIQR	-0.624* (0.351)	-0.123 (0.140)
CI	0.012 (0.030)	0.006 (0.012)
CAR	-0.093 (0.226)	-0.128 (0.090)
EPS	0.143 (0.238)	-0.075 (0.095)
NPM	-0.024 (0.032)	-0.025* (0.013)
T1	0.220 (0.458)	0.053 (0.183)
Statistics:		
# of observations	233	233
R2	0.305	0.213
Adjusted R2	0.246	0.147
F Statistic	8.530*** (df = 11; 214)	5.260*** (df = 11; 214)

Note: Significance level: *p<0.1; **p<0.05; ***p<0.01., standard errors in parentheses.
Source: Own elaboration based on Notoria and V-Lab database data.

The results indicate a marginally significant relationship between measures of climate risk and the bank's overall economic and financial characteristics. It can be shown that the size of the bank, the level of leverage of the entity, the overall risk expressed by the level of the z-score measure, and (to a limited extent) profitability and liquidity, are especially relevant. It can be conjectured that the reason for the limited dependence and influence of selected independent variables on the amount of risk is the nature of the selected risk proxies, in particular, their complex and non-linear nature.

Figure 2.

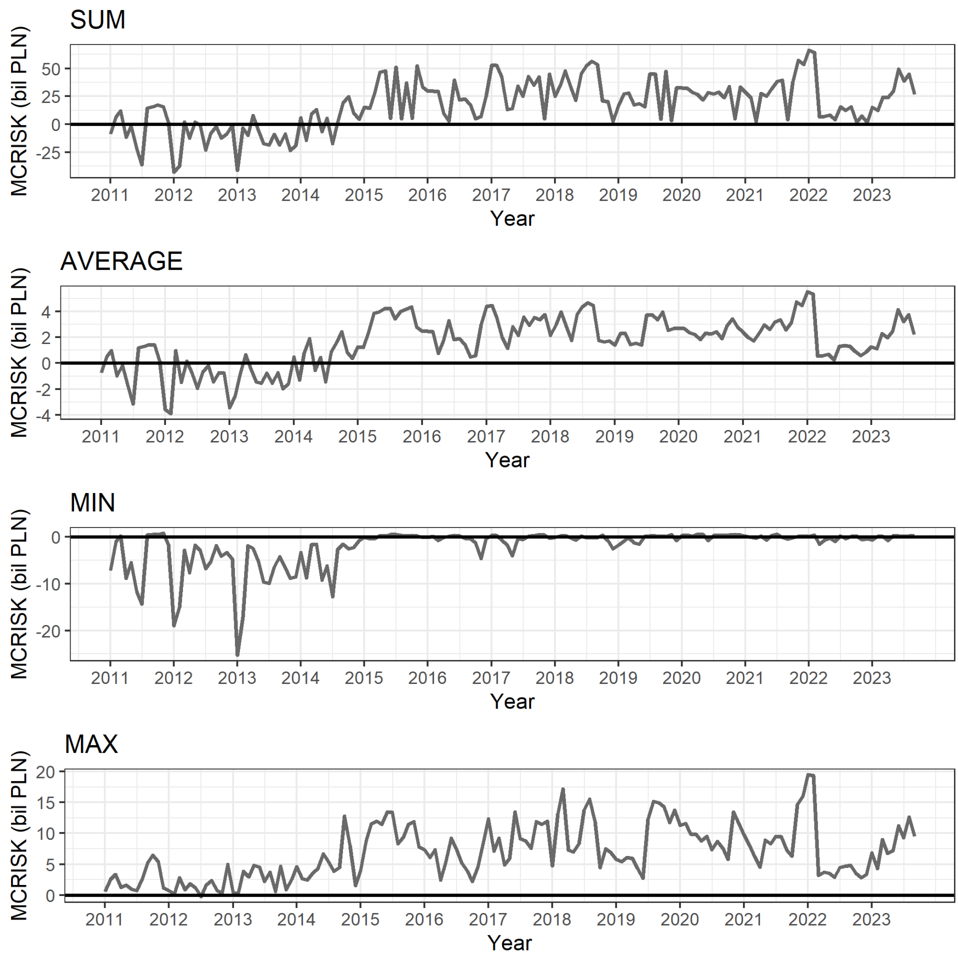
The value of CRISK in the Polish banking sector between 2011 and 2023



Source: own elaboration based on Notoria and V-Lab database data.

The above results suggest that climate risk does not currently (2023) pose an immediate threat to the Polish banking and financial system. At the same time, the analysis of the value of MCRISK (a forward-looking measure that isolates the level of systematic risk of an entity's assets) shows positive values at the aggregate level of the sector. This suggests that the future consequences of climate transition risk in the Polish banking sector are potentially significant in the event that the sector is undercapitalised. The aggregate value of MCRISK in 2022-2023 was approx. PLN 30-50 billion, which amounts to between 1/8 and 1/5 of the sector's capitalization. In this context, it is possible to think of the risk of climate transformation as a factor of significant importance, albeit one whose impact is steady and long-term rather than immediate and abrupt (Figure 3).

Figure 3.
The value of MCRISK in the Polish banking sector from 2011 to 2023



Source: own elaboration based on Notoria and V-Lab database data.

4. Potential consequences of 'greening' banks' capital requirements

The following solutions for including climate risk in the calculation of a bank's capital requirement can be distinguished (Berenguer et al., 2020):

- Including a Green Supporting Factor (GSF) when estimating capital adequacy (CAR - Capital Adequacy Ratio) as follows (α is the risk weight of the exposure according to the current methodology):

$$CAR = \frac{Bank's\,total\,capital}{\alpha \cdot brown\ loans + (\alpha - GSF) \cdot green\ loans} \tag{3}$$

- Including a Brown Penalising Factor (BPF) when estimating capital adequacy as follows:

$$CAR = \frac{Bank's\,total\,capital}{(\alpha + BPF) \cdot brown\ loans + \alpha \cdot green\ loans} \tag{4}$$

- Including both a GSF and BPF when estimating capital adequacy as follows:

$$CAR = \frac{Bank's\,total\,capital}{(\alpha + BPF) \cdot brown\ loans + (\alpha - GSF) \cdot green\ loans} \tag{5}$$

- Including an Environment Risk Weighted Ratio (ERWR) when estimating CAR. This solution consists of weighting exposures with the existing risk weight, and then adjusting them with a factor that reflects pollution. The weights are to be in the range <0.5-1.5>, with weights below 1.0 assigned to exposures whose environmental impact is not negative. CAR is then calculated as follows:

$$CAR = \frac{Bank's\,total\,capital}{ERWR \cdot \alpha \cdot Loans} \tag{6}$$

- Including a Green Weighting Factor (GWF) when estimating capital adequacy - this solution distinguishes between financing for current needs and financing for a specific purpose. In the former case, the indicator is determined based on the customer's climate score or a score reflecting the customer's impact, while in the latter, it is a function of the environmental impact of the financed project. The indicators can then be used analogously to GSF and BPF.

It should be borne in mind, however, that the application of capital relief for the green portfolio, without prior justification and quantification of the positive impact of this feature (i.e. environmental friendliness) of the exposure on credit risk, could result in a significant increase in the share of green assets. This is of course desirable, but at the same time, could result in an underestimation of the capital-to-risk ratio which would be equivalent to an increase in systemic risk). Another threat is the escalation of credit and market risk that could result from a sharp reduction in exposures to industries whose impact on the environment and/or climate is harmful. This, in turn, will make their energy transition much more expensive, if not impossible, as they will be forced to seek financing outside the banking sector. This issue is discussed by, *inter alia*, Jondeau et al. (2021), who argue that the momentum toward greening the economy carries a transition risk. The expectation that other investors or lenders may exclude carbon-intensive companies from their portfolios creates the risk of a run on the brown asset market and ultimately increases systemic risk. A similar view is taken by Dafermos and Nikolaidi (2022), who emphasize that while the use of GSFs and/or BPFs can help reduce physical risk, they also increase transition risk. Dunz et al. (2021) are of a different opinion. These authors conclude that GSFs promotes green investment (but only in the short term), thus potentially contributing to financial stability. By contrast, Diluiso et al. (2021) find that introducing climate risk buffers can significantly reduce the severity of a financial crisis but prolongs the recovery phase. Thoma and Gibhardt (2019) examined the potential impact of introducing environmental factors (GSF and BPF) on capital reserves and the cost and availability of funding for green and brown exposures in European banks. The results show that compared to BPF, GSF has a limited impact on banks' capital requirements. This is mainly due to the relatively high share of brown assets in banks' portfolios. The estimated effect of introducing a GSF is a reduction in capital requirements of about EUR 3-4 billion, with a reduction in the cost of funding for green exposures ranging from 5 to 26 basis points. For brown assets, there would be a symmetrical increase in the cost of raising funding while reducing the availability of funding by about 8%. According to Oehmke and Opp (2022), who built a model describing the impact of the introduction of a GSF and a BPF on the structure of a bank's loan portfolio, capital requirements based on a borrower's environmental impact, while they allow for the management of climate-driven financial risks, do not necessarily lead to a reduction in greenhouse gas emissions. This is because the optimal solution for banks (despite the higher capital requirement) may be to increase the share of loans affected by climate-related financial risk, crowding out green loans (capital would be consumed by the BPF, reducing the green asset space). As long as carbon-intensive activities remain profitable and the profitability of financing these types of entities is satisfactory to banks, it may not be possible to remove loans financing these activities from the banking sector, or it may require lowering capital requirements for loans to environmentally positive companies to a level that does not reflect the actual risk of these exposures. It should be noted that some of these activities continue to be subsidized by individual countries, and companies engaged in such activities conduct extensive lobbying campaigns. This creates financial stability risks. Even if capital regulations that took the GSF and BPF into account brought about a reduction in the share of brown loans in banks' portfolios (which could happen in the case of banks with low capital adequacy ratios), they would do nothing to reduce GHG emissions, as the entities targeted by the regulations would seek financing outside the banking sector. The key, therefore, is to reduce the attractiveness of such companies by introducing mechanisms that reduce their profitability (e.g., a carbon tax). At the same time, if green capital requirements are implemented, it may be reasonable for governments to introduce or increase carbon taxes in order to provide capital support to banks exposed to stranded assets. Finally, climate risk is already affecting the economic and financial health of companies through at least two channels. First, companies bear the cost of CO2 allowances. Secondly, banks' climate policies are already limiting or even precluding financing for specific companies or industries whose environmental impact is negative, either now or in the foreseeable future. These effects would presumably be factored into banks' internal and external ratings. The introduction of a GSF and BPF would therefore mean that climate risk would be doubly taken into account in quantitative supervisory requirements for exposures with adverse environmental effects.

When considering whether to factor climate risk into the calculation of regulatory capital requirements, both the short-term and long-term perspectives should be taken account. In neither case should this make the calculation excessively complex. In the short term, energy efficiency certificates can be taken into account when valuing real estate collateral and qualitative assessment can be expanded to include ESG scoring. Concentration risk is not currently reflected in a separate capital requirement. However, it is worth considering introducing limits for industries and customers whose environmental impact is negative. Only in the long term (when reliable and extensive empirical data are available) can climate risk, or GSF and BPF be given due consideration (Zygierewicz, 2022).

The issue of adjusting capital adequacy requirements to take account of the environmental factor has been addressed by the EBA. Pursuant to the CRR II regulation, the EBA has been mandated to determine whether special prudential treatment of assets deemed important for meeting climate and social objectives can be justified. The EBA report is required to include an assessment of ESG risks and a recommendation as to whether they should be considered when calculating capital adequacy requirements. The report was to be submitted by 28 June 2025 and its recommendations were to be subjected to broad discussion (EBA, 2022). However, two years before the deadline (in connection with an intention to adopt CRR III), the EBA submitted a consultation paper to the relevant European Union bodies on the role of climate risk in banking activities (Zygierewicz, 2022; Marcinkowska, 2022). The EBA concluded that ESG risk has an impact on credit, market, operational, and concentration risk, although no noticeable impact on liquidity risk. Moreover, there is no rationale for including it in the definition of leverage ratio. Determining the difference in unexpected loss for exposures with a similar (except ESG) risk profile so as to adjust the capital requirement ratio is an extremely difficult task, if only because the materialisation horizon of ESG risks is much longer than that which is currently assumed when estimating the capital requirement. Moreover, there are no historical data on losses caused by ESG risks. For these reasons, there is no basis for recalibrating capital requirements and implementing the GSF and BPF concepts at present.

The year 2022 was the next reporting period for which banks were required to disclose the share of the Taxonomy-eligible exposures and exposures not eligible for Taxonomy in the total assets.. The Taxonomy provides a standard definition of environmentally sustainable activities to reduce greenwashing and lay the groundwork for a comparable monitoring and reporting system for portfolio decomposition based on sustainability goals. The aforementioned reporting obligations of banks stem from the following regulations:

- Regulation 2020/852 of the EU Parliament and Council of 18 June 2020 on establishing a framework to facilitate sustainable investment (EU Taxonomy);

- EU Commission Delegated Regulation 2021/2139 of 4 June 2021. (Technical eligibility criteria);
- EU Commission Delegated Regulation 2021/2178, dated 6 July 2021 (Disclosure Regulation);
- Accounting Act implementing Directive 2014/95/EU of the European Parliament and of the Council.

As regards corporate portfolio banks present the share of ineligible and separately eligible for the Taxonomy in the total assets. There are two alternative ways of estimating the abovementioned ratios: by turnover and capital expenditures. Most banks also provide data on the eligibility for the Taxonomy of retail exposures (loans secured by residential real estate, loans for building renovation, loans for photovoltaic installations, and loans for the purchase of transportation equipment other than motor vehicles).

For the portfolio of exposures to retail customers, eligibility for the Taxonomy depends on product classification, while for the corporate portfolio, banks identify customers who are required to publish non-financial information under Article 19a or 29a of Directive 2013/34/EU. Pursuant to Article 7(3) of Delegated Regulation 2021/2178, exposures to corporates not required to submit non-financial statements are excluded from the numerator of key performance indicators.

When a company has not made its non-financial reports available, some banks will use information on types of business activities linked to PAC codes and other information at their disposal (obtained on a voluntary disclosure basis) to prejudge eligibility for systematics.

In addition to the previously signalled differences in reporting the eligibility of retail exposures, Polish banks employ two methods of determining the share of exposures that do not meet the taxonomy criteria:

- Recognizing that the portion of the portfolio that could not be assessed due to the lack of reporting obligations on the part of clients does not qualify for systematics (shares add up to 100%; a solution that is less frequently used; 'option 1'),
- to refer only to reportable customers and divide these exposures into those that qualify and those that do not qualify for the taxonomy. The Bank does not comment on the eligibility of exposures to customers who are not required to disclose non-financial information (shares do not add up to 100%; a more commonly used solution; 'option 2').

Based on data on the assets held by Poland's 9 largest banks (as of the end of 2022, these accounted for approx. 73.5% of the assets of the Polish banking sector, excluding cooperative banks and branches of foreign credit institutions), the impact of the capital adequacy ratio calculation adjustment was simulated. The simulation was predicated on the following assumptions:

- Green exposures are identified with exposures that qualify for the taxonomy, while brown exposures are identified with those that do not belong to the systematics. In order to determine the proportion of green exposures in the portfolio for the purpose of calculating the capital adequacy ratio, it is assumed that this proportion corresponds to the Green Asset Ratio (GAR). GAR was established by the European regulatory authorities and is defined in the EU Taxonomy Disclosures Delegated Act as a key performance indicator (KPI) for measuring the share of taxonomy-aligned on-balance-sheet exposure in the total assets of the credit institution (Brühl, 2023). The present study simplifies this by assuming that the GAR only uses balance sheet items and ignores risk weights. This implies that the capital adequacy ratio may be overestimated if the average risk weight for green exposures is higher than that for exposures not eligible for the taxonomy. It should be added that because some exposures (e.g., to sovereign entities) are not subject to the taxonomy, not all bank clients are obliged to disclose non-financial data, and because failure of an activity to qualify for the taxonomy is not synonymous with the related exposure being 'brown', the share of brown exposures should be treated as conservatively set. The use of GAR is justified provided that the taxonomy does not include exposures to the sovereign and that these exposures are assigned a zero-risk weight when calculating capital requirements. Thus, in both cases, there is an exclusion of exposures to sovereign entities. Due to the reluctance of supervisory institutions to reduce the capital requirement, option (W1), in which the weight for green exposures would be reduced *ceteris paribus*, was omitted.

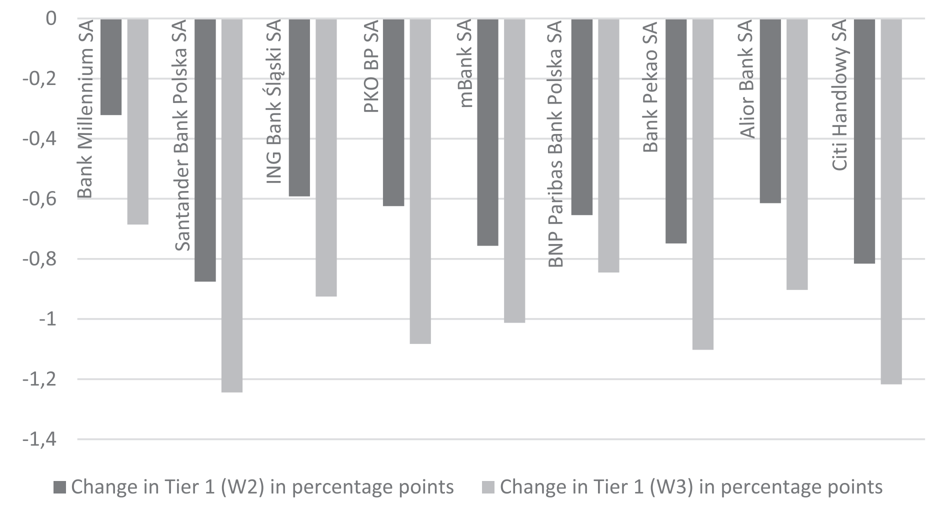
- The simulation includes two options: (i) introducing a GSF and BPF, each at 10%, i.e., reducing (GSF) or increasing (BFP) the risk weight by 10% (W2); and (ii) introducing a BPF at 10%, i.e., increasing the risk weight by 10% (W3) - basic simulation.
- in order to ensure comparability of source data, for the three banks that did not provide the share of exposures to households qualifying for the taxonomy, a market average value of 25% was adopted for the three banks that did not provide their share of exposures to households qualifying for the taxonomy, and a market average value of 2.23% was adopted for the bank using option 1.
- an additional simulation was carried out, based on a conservative assumption that coincides with the approach reflected in Option 1 - additional simulation (extreme variant). The values adopted for the simulation are on an expert method basis and are based on the past experience of commercial banks and the authors' knowledge of Taxonomy.

The results indicate:

- a relatively high resilience of the Tier 1 ratio in the case of additional (extreme) simulation, i.e., the ratio is reduced by a maximum of 0.88 pp. (W2) or by 1.24 pp. (W3). This high resilience is due to the fact that the minimum value of the Tier 1 ratio in the sample as of 31/12/2022 was 11.28%, which is significantly higher than the minimum value required by the FSC (6.00%) - see Figure 4 and Figure 5
- implementing W2 has a positive impact on the Tier 1 ratio (it increases for each bank) but the impact of implementing W3 was not significant (maximum reduction in the Tier 1 ratio is 0.1 pp.) - base simulation cf. Figure 6 and Figure 7.

Figure 4.

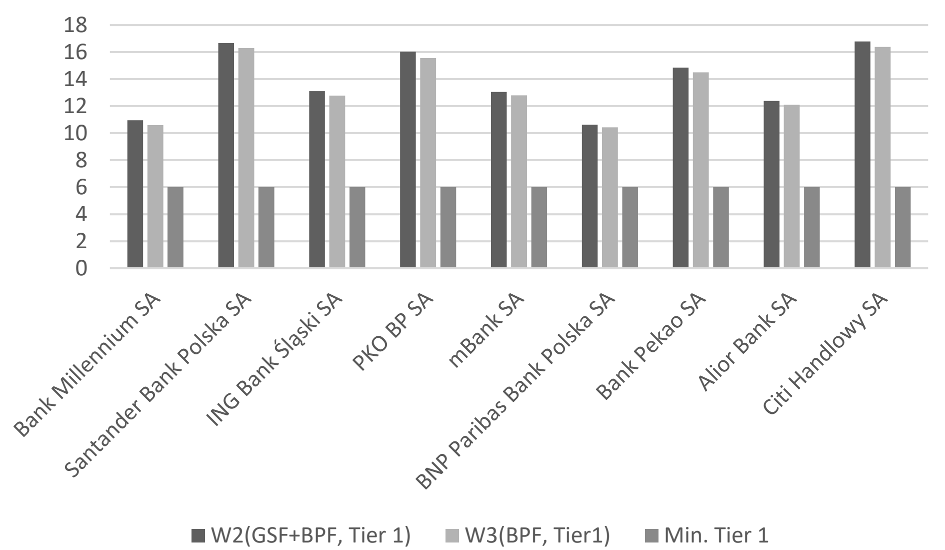
Change in Tier 1 as a result of W2 or W3 implementation - additional simulation (extreme)



Source: own compilation based on consolidated financial and non-financial statements of surveyed banks.

Figure 5.

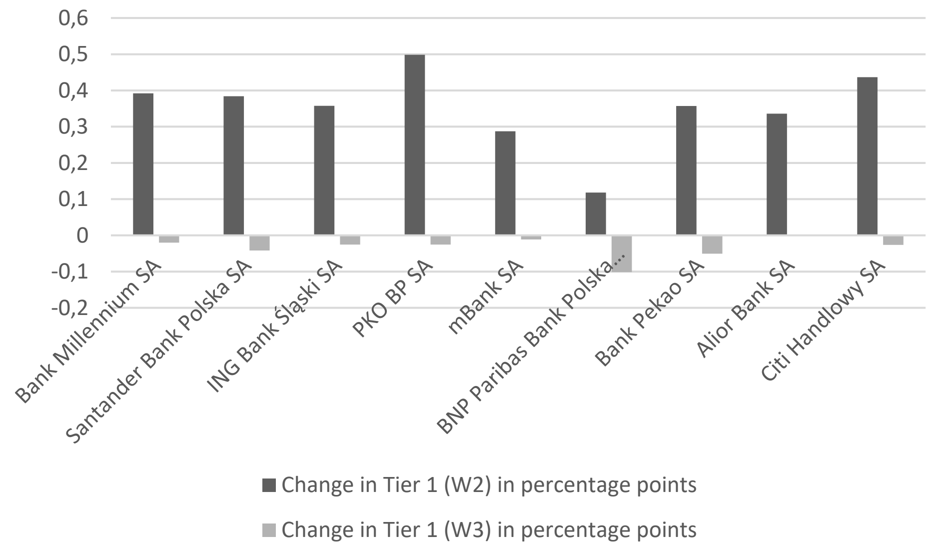
Tier 1 as a result of implementing W2 or W3 against the minimum requirement-Additive simulation (extreme)



Source: own compilation based on consolidated financial and non-financial statements of surveyed banks.

Figure 6.

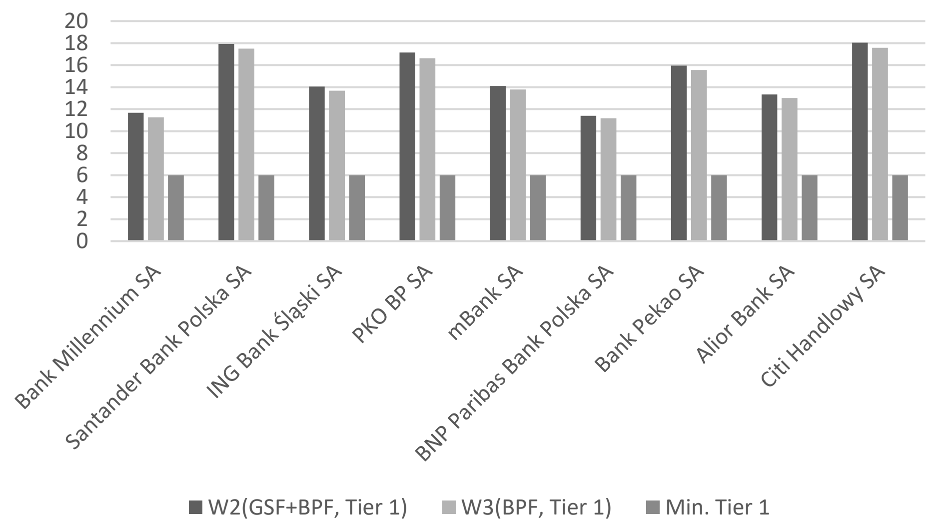
Change in Tier 1 as a result of implementing W2 or W3 - baseline simulation



Source: own compilation based on consolidated financial and non-financial statements of surveyed banks.

Figure 7.

Tier 1 as a result of implementing W2 or W3 against the minimum requirement - baseline simulation



Source: own compilation based on consolidated financial and non-financial statements of surveyed banks.

5. Classification and grouping of Polish banks based on the criterion of environmental portfolio structure using the linear ordering method

The study sample included the 9 largest commercial banks operating in the Polish banking sector. These are the same banks that were analysed in the previous section. The data reported by individual banks in their original form are in some cases the result of different methodologies. Solutions aimed at making the indicators describing the shares of each bank's portfolios comparable (whether consistent or inconsistent with the taxonomy) have therefore been applied. Note that: (i) each bank's KPI refers to the percentage of assets eligible for systematisation according to the Capex KPI (non-financial corporates); (ii) exposures to households secured by residential real estate and exposures to households for building renovation were included in the indicator describing the share of assets compliant with the taxonomy - in 3 cases (banks, which did not provide this information), an average (from the data provided by the other banks) of the value of this indicator (25%) was used; and (iii) for each bank, the share of exposures to non-financial entities in non-taxonomy-eligible activities in assets was provided.

The banks were analysed using linear ordering methods, and classified into Multiple-Criteria Decision Making (MCDM). This led to the banks being ranked on the adopted ordering criterion. For this purpose, the Hellwig method (1968) and the TOPSIS method of Hwang and Yoon (1981) were used. These are aggregation methods that consist in determining the distance of individual objects from a certain defined model object (Table 4):

Table 4.
Hellwig and TOPSIS synthetic measure constructs

Name of the method	Standardization	Pattern coordinates	Distances of objects from the pattern	Values of the aggregate variable
Hellwig	$z_{ij} = \frac{x_{ij} - \overline{x}_j}{S_j}$	$z_j^+ = \max_i \{z_{ij}\}$	$d_i^+ = \sqrt{\sum_{j=1}^{m} \left(z_{ij} - z_j^+\right)^2}$	$q_i = 1 - (d_i^+) / d_0$ whereby: in general $q_i \in [0; 1]$; $\max_i \{q_i\}$ - best object; $\min_i \{q_i\}$ - worst object; $d_0 = \overline{d}_0 + 2S_d$; $d_0 = \frac{\sum_{i=1}^{n} d_i^+}{n}$; $S_d = \sqrt{\frac{\sum_{i=1}^{n} \left(d_i^+ - \overline{d}\right)^2}{n}}$.

Name of the method	Standardization	Pattern coordinates	Distances of objects from the pattern	Values of the aggregate variable
TOPSIS	$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$	$z_j^+ = \max_i \{z_{ij}\}$ $z_j^- = \max_i \{z_{ij}\}$	$d_i^+ = \sqrt{\sum_{j=1}^{m} \left(z_{ij} - z_j^+\right)^2}$ $d_i^- = \sqrt{\sum_{j=1}^{m} \left(z_{ij} - z_j^-\right)^2}$	$q_i = \frac{d_i^-}{\left(d_i^+ + d_i^-\right)}$, whereby: $q_i \in [0 ; 1]$; $\max_i \{q_i\}$ – best object; $\min_i \{q_i\}$ – worst object.

Source: own elaboration based on Hellwig (1968), Hwang and Yoon (1981) and Kukuła and Luty (2018).

In the first step of the multivariate comparative analysis, diagnostic characteristics were selected (Table 5 and Table 6).

Table 5.

Selected diagnostic variables

Symbol	Specification	The nature of the variables
Z1	ROE - return on equity	S -stimulant
Z2	RWA/TA - risk-weighted assets to total assets	S - destimulant
Z3	Cost of risk (basis points)	D - destimulant
Z4	core capital ratio	S - stimulant
Z5	Taxonomy (KPIs of capital expenditures).	S - stimulant
Z6	% of portfolio that does not meet taxonomy criteria	D - destimulant
Z7	Has the bank disclosed taxonomy information for the retail portfolio? (If yes, 1, otherwise 0)	S - stimulant

Source: own elaboration.

Table 6.

Basic characteristics of selected diagnostic variables

Specification	Z1	Z2	Z3	Z4	Z5	Z6	Z7
Max	0.2400	0.6300	151	0.1760	0.3537	0.0867	1
Min	-0.1750	0.4195	30	0.1128	0.1943	0.0015	0
Average	0.0623	0.5082	65.5556	0.1450	0.2600	0.0223	0.6667
Median	0.0970	0.5257	59.0000	0.1381	0.2560	0.0172	1.0000
standard deviation	0.1176	0.0713	37.0240	0.0247	0.0478	0.0251	0.5000
coefficient of variation	1.8887	0.1402	0.5648	0.1704	0.1839	1.1280	0.7500

Source: own elaboration based on annual reports of analysed banks.

Linear ordering methods require that quantitative weights be calculated for individual variables (Ma et al. (1999), Choo and Wedley (1985), Schoemaker and Waid (1982)). Two criteria were used to select variables in the present study:

- system w1 - equal weights were assumed for all variables, i.e.:

  $w_k = \frac{1}{m}$ where: k - indicator number (k = 1, 2, ..., m);

- system w2 - weights were determined based on the expert method - the highest weights were given to three diagnostic features: Z1, Z2 and Z4 - 0.20, and the features Z3, Z5, Z6 and Z7 were given weights - 0.10.

In order to assess the relationship between climate risk disclosures and bank health, the values of each bank's relative proximity to the ideal solution were determined, and bank rankings were constructed using both the Hellwig and TOPSIS methods, using the two weight construction procedures. In this way, 4 rankings were obtained. These were then used to build the final classification of banks (Table 7).

Table 7.

Ranking of banks obtained using TOPSIS and Hellwig method

RANKING	TOPSIS				HELLWIG			
	weight w1		weight w2		weight w1		weight w2	
	value	Position	value	position	value	position	value	position
Bank Millennium SA	0.469	8	0.313	9	0.305	7	0.147	8
Santander Bank Polska SA	0.733	2	0.721	2	0.494	3	0.563	3
ING Bank Śląski SA	0.709	4	0.680	4	0.514	2	0.515	4
PKO BP SA	0.742	1	0.690	3	0.624	1	0.587	2
mBank SA	0.566	7	0.439	8	0.326	6	0.354	6
BNP Paribas Bank Polska SA	0.455	9	0.477	7	0.002	9	0.050	9
Bank Pekao SA	0.639	5	0.620	6	0.424	5	0.483	5
Alior Bank SA	0.597	6	0.635	5	0.156	8	0.261	7
Citi Handlowy SA	0.725	3	0.820	1	0.485	4	0.680	1

Source: own elaboration based on annual reports of analysed banks.

The results obtained using both the Hellwig method and the TOPSIS method (even with two different weighting factors) are very similar and clearly indicate the banks with the strongest relationships between taxonomic disclosures and financial parameters and those with correspondingly weaker relationships. These results do not explain the effect of shareholding structure (domestic vs. foreign) on the ranking positions, although the three banks owned by foreign shareholders were ranked last. At the same time, the same category (with the highest ranking positions) includes large banks with a predominantly retail segment. The second group includes medium-sized banks, primarily with a mixed (corporate-retail) business model.

6. Conclusions

The Polish banking sector went through something of a stress test in 2020, when the highest ever aggregate and individual CRISK values were recorded. Banks, despite struggling with the escalation of the COVID-19 pandemic, passed this test. At the same time, it should be emphasised that resilience to the risk of climate change varies from bank to bank. The largest banks are relatively resilient. Only Pekao SA reported a shortfall in the last period, but it was not significant in view of the bank's size. Medium-sized banks, which in the past have faced capital problems due to the quality of credit risk management or legal risks (portfolio of foreign currency mortgages and foreign currency options) are noticeably less resilient. The materialisation of these risk factors adversely affected their profitability, which was attempted to be rebuilt through dynamic lending where the key parameters were credit risk, price and capital consumption. Each of these banks is currently characterised by capital adequacy ratios that considerably exceed the regulatory requirement. This division according to the scale of the climate risk borne by a group of large and medium-sized banks was corroborated by the linear ordering method.

The results of the present study suggest that the climate risk will not have an immediate negative impact on the stability of the banking sector in Poland. MCRISK indicates that the impact of climate risk on the banking sector and its capitalization (up to 20%) is potentially significant. However, this impact is expected to be steady and long-term and not have immediate and abrupt consequences.

The present study compels the conclusion that modifying the algorithms that calculate capital adequacy ratios, so as to factor in the environmental impact of the exposure or customer, is premature, and cannot reasonably be considered until more extensive data on the impact of climate risk on financial system stability are available. .Additionally, any modification of the capital adequacy ratio with an environmental factor is bound to come with limitations and caveats that cannot be ignored. Implementing the GSF risks undervaluing regulatory capital and creating a green bubble. The BPF may contribute to cutting off bank financing to high-carbon entities, thereby preventing them from transitioning to green energy and driving them into the realm of shadow banking. Global supply chains are such as to make the ERWA mechanism difficult to calibrate. It therefore cannot guarantee capital neutrality. For its part, the GSF will not necessarily lead to green assets growing faster than their brown counterparts (Berenguer et al., 2020). For the time being, the EBA (2023) recommends including environmental risk as a component of stress testing under the Internal Ratings Based (IRB) approach, as well as the Internal Model Approach (IMA) under the Fundamental Review of the Trading Book (FRTB). The EBA also calls for a review of valuation methodologies for real estate collateralising bank exposures towards incorporating environmental risk. Environmental risk concentrations should be reported. The EBA additionally points out that CRA methodologies need to be reviewed in light of the requirement to have ESG factors included in the algorithms that determine credit ratings. This is particularly relevant for financial systems in the USA and the British Commonwealth, but not so much for continental systems, such as Poland. At the same time, GSF and BPF hold so much promise and are so farsighted that it is well worthwhile to continue working on them and using systematic aggregated data to calibrate them. For these reasons, the present article simulated the introduction of environmental coefficients in the calculation of capital adequacy for Polish banks. This led to the conclusion that such a recalibration should not produce a significant capital gap. As already mentioned, the results are predicated on conservative assumptions regarding the share of 'brown' exposures in banks' portfolios. For this reason, the study should be considered as a stress test. Expanding the spectrum of entities obliged to report non-financial information should increase the share of 'green' assets. Assuming no differentiation of the underlying risk weights for 'green' and 'brown' exposures, it should be expected that a possible adjustment of the algorithm for calculating the capital adequacy ratio by a GSF or BPF will not lead to a significant decrease in the coverage of loan portfolios by regulatory capital. Implementing the EBA's recommendations (EBA, 2023) does not necessitate abandoning the idea of adding a GSF or BPF, as in line with the rationale for introducing the leverage ratio, a parallel implementation of a uniform methodology that allows for the impact of environmental risk on regulatory capital is desirable. For the time being, the EBA's recommendation to include environmental risk in stress testing gives far-reaching flexibility in defining the strength and channels of the impact of environmental risk on those risks for which regulatory capital is estimated.

At the same time, an attempt was made to determine the regularities governing the relationship between taxonomic disclosures and bank profiles. The linear ordering used for this purpose revealed that large retail banks are characterized by relatively high rankings reflecting a combination of financial characteristics (financial performance) and environmental disclosure performance. The above research was conducted in an environment of relatively narrow taxonomic disclosures, in the absence of complete knowledge of the structure of loan portfolios built on taxonomic criteria, and with the use of data that were not wholly comparable (retail portfolio disclosures and the treatment of exposures to entities not yet required to disclose non-financial obligations).

The extent of mandatory reporting by bank customers, together with the heterogeneity of the approach used by individual banks, indisputably impose further limitations on the results. The authors contend that these limitations will be systematically removed as disclosure obligations expand. This area therefore remains a direction for further research.

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