Essays on banks' risk

Tese de Doutoramento

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RESUMO

As instituições bancárias são pilares fundamentais dos sistemas financeiros globais, cuja complexidade e ligação com os mercados financeiros faz com que estejam expostas a diversos tipos de riscos, alguns dos quais subestimados até recentemente. Em resposta, foram implementadas reformas regulatórias para mitigar estes riscos e garantir a estabilidade financeira. Estas reformas têm sido, desde então, analisadas pela literatura empírica, levando a alguns resultados contraditórios.

Esta tese tem como objetivo avaliar o efeito de vários fatores sobre o risco dos bancos. Iniciamos esta análise com o efeito das leis de proteção dos investidores sobre a resposta dos bancos a políticas macroprudenciais mais rigorosas. Concluímos que ao aumentar os níveis de proteção, é possível aumentar o nível de participação dos investidores no capital dos bancos, reduzindo a sua influência individual e o risco dos bancos. No entanto, os resultados apontam para o facto dos bancos adotarem comportamentos de *risk-shifting*, quando existem proteções implícitas governamentais.

Posteriormente, analisamos o efeito das medidas de regulação macroprudenciais adotadas nos pacotes pós-pandemia. Os resultados apontam para uma redução no nível de risco dos bancos com o relaxamento das medidas de capitais, embora este mesmo comportamento tenha o efeito contrário em anos de crise sistémica ou anos normais. Demonstramos ainda um mau uso das restantes políticas macroprudenciais ao evidenciar que o seu relaxamento, durante a crise pandémica, levou a um aumento do risco.

De seguida, analisamos se a disciplina imposta pelos investidores pode ser usada como complemento das políticas macroprudenciais, com vista a contrariar os comportamentos de *risk-shifting* e *moral hazard*. Concluímos que os bancos sujeitos a um nível maior de disciplina de mercado reduzem o seu risco perante a adoção ou agravamento das medidas macroprudenciais. No entanto, este efeito só é visível em países avançados e com maior magnitude nos Estados Unidos da América.

Por fim, investigamos o efeito das políticas financeiras climáticas sobre o risco, demonstrando que a sua adoção reduz o risco total, conseguida através da melhoria da reputação destas instituições. No entanto, estas medidas levam a uma degradação da qualidade da carteira de créditos através do aumento do crédito malparado.

Palavras-chave: Crise; Disciplina de mercado; Políticas verdes; Políticas macroprudenciais; Risco dos bancos.

ABSTRACT

In the global financial system, banks stand as fundamental pillars, whose inherent complexity and interconnectedness with the financial markets, make them susceptible to several risks some of which have been overlooked until recently. In response, policymakers have implemented several types of regulatory reforms to mitigate these risks and assure financial stability. These regulatory reforms have been analyzed by empirical literature, leading to some contradictory results.

The aim of this thesis is to investigate how several factors influence banks' risk. We start by analyzing how investor protection laws can influence banks' response to macroprudential policies. We find that higher levels of investor protection lead to an increase in the effectiveness of macroprudential policies, as individual shareholders have less power to influence banks' decisions. However, when there are safety nets in place, banks tend to engage in risk-shifting behaviors to regain lost profitability.

Furthermore, we analyze if the macroprudential framework deployed during the pandemic was effective. We find that loosening capital-aimed policies during the pandemic lead to less risky banks, while this same behavior would translate into higher risk in years of systemic crisis and normal years. Moreover, we provide evidence of some countries contributing to riskier banks during the pandemic through the misuse of the remaining macroprudential policies.

We then expand our analysis in an effort to evaluate if market discipline could solve the moral hazard and risk-shifting behaviors induced by macroprudential policies. Our results show that banks subjected to higher levels of market discipline were less risky when faced with a tighter macroprudential framework. However, we show that this effect is only visible in advanced economies and more so in the United States of America.

Finally, we expand our analysis towards green financial policies, which have become increasingly adopted in the last few years. On this subject, we find that while implementing green policies could lead to less risky banks in terms of total risk, due to enhanced market reputation, this is not the case in terms of credit quality as it leads to higher non-performing loans and, consequently higher credit risk.

Keywords: Bank risk; Crisis; Green policies; Macroprudential policies; Market discipline.

DEDICATION

To Beatriz. For the love, the laughter,

and the endless encouragement.

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STATEMENT OF AUTHORSHIP

I hereby testify that this thesis was made of my own initiative and especially developed to this purpose. All scientific articles throughout this PhD thesis and herein presented, except for the one displayed in chapter V, were submitted, peer-reviewed and published in indexed scientific journals as the following research articles:

Matos, T. F. A., Teixeira, J. C. A., and Dutra, T. M. (2023). The contribution of macroprudential policies to banks' resilience: Lessons from the systemic crisis and the COVID-19 pandemic shock. *International Review of Finance*, 1-37. https://doi.org/10.1111/irfi.12424. [JCR Q3]

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As these studies were carried out in collaboration with other authors, I also declare that I was the main responsible for the conceptualization, carrying out the data treatment and subsequent software run, as well as interpreting the results, composing the manuscripts, and submitting the research papers for publication as the first author.

Tiago Filipe Almeida Matos

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LIST OF ACRONYMS

AE – Advanced Economies
BIS – Bank for International Settlements
COP16 – 16th Conference of the Parties to the United Nations Framework Convention on Climate Change
CRFP – Climate-related Financial Policies
EMDE – Emerging Markets and Developing Economies
EU – European Union
GFC – Great Financial Crisis
IMF – International Monetary Fund
MLE – Maximum Likelihood Estimation
MPPI – Macroprudential Policies Index
OECD – Organization for Economic Co-operation and Development
OLS – Ordinary Least Squares
sGMM – System Generalized Method of Moments
USA – United States of America

CHAPTER I - INTRODUCTION

The Lehman Brothers' default and the subsequent 2007–08 Great Financial Crisis (GFC) served as a stark reminder that no bank is exempt from defaulting and causing financial distress to the economy and to the financial market, as it demonstrated that microprudential supervision alone is not enough to ensure the soundness of the financial system when confronted with systemic risk (Constâncio et al., 2019). Therefore, the post-GFC agenda prompted central banks and policymakers worldwide to rethink financial regulation to deal with this systemic dimension of risk.

The macroprudential framework was introduced as one of the post-GFC regulatory reforms. Overall, the main objective of this framework is to reduce the banks' systemic exposure either by controlling their credit portfolio (Altunbas et al., 2018; De Schryder & Opitz, 2021) or increasing their resilience during times of economic distress (Constâncio et al., 2019; Lim et al., 2011).

Since the implementation of these policies, there has been extensive literature analyzing its effectiveness. Claessens et al. (2013), Cerutti et al. (2017), Akinci and Olmstead-Rumsey (2018), Alam et al. (2019), Poghosyan (2020) and De Schryder and Opitz (2021) show that tightening macroprudential policies leads to a reduction in the banks' credit growth, thus reducing its exposure to systemic risk. Additionally, Igan and Kang (2011) and Akinci and Olmstead-Rumsey (2018) demonstrate that the implementation of macroprudential policies aimed at the credit market not only reduces the household prices but also the number of transactions. On this line of thought, Dell'Ariccia et al. (2012) confirms that these policies are effective in containing credit booms. Finally, Altunbas et al. (2018) show that the macroprudential framework can be complementary to the monetary policy taken by central banks as it has the potential to reduce the risk-taking incentives arising from monetary decisions.

However, although there seems to be a consensus on the effectiveness of these policies, the results of the literature are heterogenous. Altunbas et al. (2018) and Ely et al. (2019) show that these policies are more effective in small, weakly capitalized banks, who have a higher share of wholesale funding. Gaganis et al. (2020) shows that beyond these bank-specific characteristics, the number of policies in force also influences the effectiveness of this framework. Overall, these findings indicate that analyzing the effectiveness of the macroprudential framework is not a straightforward process.

Laeven and Levine (2009) highlight that the banks' ownership structure is unaccounted for when analyzing the effectiveness of bank regulation, as it has the potential to influence banks' decisions, as standard agency theory suggests. These authors emphasize the implications of this gap as it might lead to different responses to regulation, according to the comparative power of shareholders within the structure of each bank.

In fact, the preliminary works of La Porta et al. (1997, 1998) shows that the countries institutional framework, *i.e.,* the protection given to both creditors and shareholders, can influence the level of participation on financial markets, as higher levels of protection creates incentives for investors to participate, leading to a diversification of the bank ownership structure and, consequently, reduced individual influence over banks' decisions. On the other hand, the level of protection of creditors can influence banks' willingness to lend (Houston et al., 2010; Haddad and Lobez, 2015; Teixeira et al., 2020), thus posing as an obstacle to the goal of some macroprudential policies.

Another important factor when evaluating the effectiveness of the macroprudential framework is the absence of recessions on the post-GFC era. However, when the COVID-19 pandemic struck, some countries were already exhibiting signs of economic slowdown which were heightened by the consequences of the pandemic.

During the pandemic, Beneditksdottir et al. (2021) shows that the main macroprudential policy taken was the easing of capital-aimed macroprudential policies as an effort to stabilize the banking system and stimulate the economy. However, the ECB (2021) demonstrates that there was a lack of "policy space" as few countries had forced banks to hold countercyclical capital buffers. Furthermore, banks were reluctant in diving into these capital buffers due to the impression it might have caused in the financial markets. Nonetheless, it is important to assess the effects of this policy easing during times of distress, in order to calibrate the prudential framework for future events.

Another central pillar of the post-GFC agenda was the strengthening of the market participants' disciplinary power, as a way of maintaining constant monitoring of the financial markets. In fact, economic theory suggests that market discipline can dissuade companies from engaging in risky behavior, as it would be perceived by market participants who would discipline them by increasing funding costs (Kato, 2021). Nonetheless, although considered a useful tool for policymakers, this mechanism has been considered in a very vague and undeveloped way.

Chen and Hasan (2011) and Oliveira and Raposo (2019) argue that market discipline could complement macroprudential policies, as the former could prevent banks from engaging in moral hazard and regulatory arbitrage behaviors that are induced by the latter. Surprisingly, the analysis of this relationship constitutes a gap in the literature as studies by Chen and Hassan (2011) and Flannery and Bliss (2019) only focuses on a theoretical perspective.

More recently, this debate on the safeguard of financial stability started integrating climate-related risks, as the damaging effects of climate change attracted the attention of policymakers. This has led to the conceptualization of financial regulation aiming at integrating sustainable practices in the financial markets. According to Shirai (2023), this is done to assure that banks include climate-related factors when assessing risk, as they are the main market player bridging demand and supply.

In this context, Cui et al. (2018) and Al-Qudah et al. (2022) show that banks engaging in green lending tend to increase the quality of their credit and reduce non-performing loans. Feng et al. (2024) demonstrates that this reduction is due to the increased banks' risk management abilities. However, these authors also show that the increase in green lending can lead to higher risk appetite by banks. Hence, even though extensive research has been done on the impact of green policies and its influence on green lending, there is a notable gap in the literature on the effects of these policies over banks' risk-taking behavior.

Although some recent single-country studies by An et al. (2023) and Al-Qudah et al. (2022) have established the relationship between green prudential policies and banks' risk-taking behavior, we believe that there are some important issues that remain unexplored.

This thesis aims to fill these gaps in the literature and provide answers to a series of questions. In Chapter II, we assess if the effectiveness of the macroprudential framework can be channeled through the countries' institutional framework, identifying the theories behind these effects. We find that macroprudential policies are only effective when creditors and shareholders are highly protected, while having the opposite effect in countries with poorer protection laws. However, by decomposing the macroprudential framework in indexes according to their goals, we demonstrate a moral hazard behavior in countries with highly protected shareholders, where banks tend to increase their risk exposure in response to a tighter macroprudential framework. Furthermore, when analyzing the two possible adjustments of macroprudential policies separately, *i.e.,* loosening and tightening, we demonstrate an asymmetric effect where a loosening event will always lead to a greater response by banks than a tightening event. This chapter contributes to the literature as it is the first study analyzing how the institutional framework can influence banks' response to macroprudential policies. Second, we contribute to a growing body of literature on the effectiveness of macroprudential policies, either aggregated or by policy type, and on banks' risk determinants.

In Chapter III, we analyze if the macroprudential regulatory framework alleviated banks' risk-taking behavior during the COVID-19 pandemic, comparing these results with the GFC. We find that loosening capital-aimed macroprudential policies during the pandemic proved to be effective, while this could translate in higher risk-taking during years of systemic crisis. Conversely, tightening the other macroprudential policies proved to be effective in both periods. Additionally, we provide evidence that the macroprudential framework tend to be more effective during systemic crises when comparing with "normal" times and the pandemic years. When decomposing in the individual policies, we show that these effects are driven by the capital requirement policy in both periods, albeit the conservation buffer and the leverage limit contributed for the ineffectiveness of these policies during the pandemic. Finally, we demonstrate that these policies are more effective in banks with higher leverage and lower loan growth. The study carried out in this chapter contributes to the literature in numerous ways. First, it contributes to the strand of the literature analyzing why some banks performed better than others during periods of crisis, as it uses the COVID-19 as a case study to evaluate the effectiveness of macroprudential policies during times of distress. Second, we contribute to the literature by providing evidence that the usage of the macroprudential framework is not linear according to all types of crises, by comparing its effectiveness during the pandemic and the systemic crisis years, contributing to a better understanding of how policymakers can help mitigate the economic impact of future crisis.

In Chapter IV, we analyze the connection between market discipline and macroprudential policies, supplying empirical evidence on how the former might complement the latter in controlling banks' risk-taking behavior, solve the moral-hazard problems that macroprudential policies can induce and, consequently, contribute to more stable financial institutions. We find that macroprudential policies are more effective in banks subjected to higher levels of subordinated debt, *i.e.*, market discipline. Moreover, we show that this effect is more pronounced in advanced economies and more so in the United States of America, compared with the remaining countries of our sample. The analysis carried out in this chapter brings several contributions to the literature. First, it contributes to the strand of the literature advocating to the usage of market discipline as a way of disciplining banks and preventing them from engaging in deviant behaviors. Second, it provides empirical evidence of the effectiveness of this mechanism, providing it to be a solution to the moral hazard behaviors that macroprudential policies can induce. Finally, it contributes to a better understanding of how market discipline can be enforced by policymakers through mandatory issuing of subordinated debt, attempting to settle the debate on this subject.

In Chapter V, we provide a comprehensive analysis of the impact of adopting climate-related financial policies on banks' risk-taking behavior and compare these results amongst developed and developing countries. On this topic, we find that stronger climate-related financial policies lead to a reduction in banks' risk channeled by increased social reputation of such banks. However, it comes with a cost as higher levels of commitment to green policies leads to an increase in non-performing loans and, consequently higher credit risk. Finally, we show that these effects are stronger in developing countries compared to advanced economies. Again, the contribution of this chapter is multifold. First, it contributes to the literature on the impact of climate-related financial policies on banks' risk. Second, it is the first study analyzing if the impact of these policies is transversal between developed and developing countries, comparing these results between normal times and crises. Ultimately, it provides further insights on how including green credit in the banks' loan portfolio might create fragilities during times of economic crisis.

Finally, in Chapter VI, we present a summary of the conclusions, providing a thorough analysis of their policy implications.

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CHAPTER II - MACROPRUDENTIAL REGULATION AND BANK RISK: THE ROLE OF SHAREHOLDERS' AND CREDITORS' RIGHTS[1]

[1] This chapter is based on the article Matos et al. (2024a):
Matos, T. F. A., Teixeira, J. C. A., and Dutra, T. M. (2024a). Macroprudential regulation, and banks' risk: The role of shareholders and creditors' rights. *Global Finance Journal*, 59, 100920. https://doi.org/10.1016/j.gfj.2023.100920

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Macroprudential regulation and bank risk: The role of shareholders' and creditors' rights

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A R T I C L E I N F O

JEL classification:
G01
G21
G28
G38

Keywords:
Banks' risk
Investors' protection
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A B S T R A C T

This paper analyzes whether the effect of macroprudential policies on bank risk is channeled through investors' protection using panel data from a sample of 624 banks from 40 countries. We show that investors' protection plays a significant role in the effect of macroprudential policies on bank risk, which translates into higher efficiency for macroprudential policies in countries with highly protected creditors, whereas there is a loss of effectiveness in countries where shareholders are highly protected. We provide further evidence that the impact of loosening a macroprudential policy is asymmetric (and more pronounced) compared with the adoption or tightening of a macroprudential policy.

1. Introduction

The 2007–08 Financial Crisis brought up an important concern—microprudential supervision alone may not be enough to ensure the soundness of the financial system when confronted with systemic risk (Constâncio et al., 2019). This led policymakers to acknowledge the importance of looking at the bigger picture and establishing a macroprudential framework to deal with this type of risk.

The macroprudential policies toolset is wide-ranging, with each policy aimed at a specific goal. Overall, however, these policies are set to reduce banks' risk either by forcing banks to limit their exposure to credit risk (Altunbas et al., 2018; Andries et al., 2018; De Schryder & Opitz, 2021), such as the loan-to-value policy or the debt-service-to-income ratio, or by enhancing banks' resilience to crises (Constâncio et al., 2019; Lim et al., 2011), such as the reserve ratio or the countercyclical capital buffer.

Although the extant literature, from the past few years, has analyzed the effectiveness of macroprudential policies on the economy itself, the housing market, and banks' performance, that literature fails to analyze how the effect of such policies on bank risk can be channeled through investors' protection. Because the 2007–08 crisis also shook public and investor confidence in the financial system (Rombouts, 2017), the European postcrisis regulatory agenda determined that investor protection is an essential pillar to regaining trust (European Capital Markets institute, 2010; Institute of International Finance, 2008). Therefore, ignoring the impact that this type of microprudential regulation might have on banks' decisions may lead to a flawed analysis of the effectiveness of bank regulation (Laeven & Levine, 2009).

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Abstract

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1. Introduction

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Empirical evidence presented by La Porta et al. (1997, 1998) suggests that increasing shareholders' protection leads to greater participation by investors in banks' capital, thus diminishing individual shareholder power and, consequentially, their ability to influence banks' decisions. This theory is based on the principal–agent problem, as later confirmed by Laeven and Levine (2009). Therefore, we might expect banks' reactions to a new macroprudential regulatory agenda to be channeled through the level of shareholders' protection, since the latter can induce changes in the shareholder structures of banks and, consequently, amplify or reduce shareholders' individual influences on banks' decision-making.

The other side of the institutional framework, i.e., creditors' rights, may also play a role in dictating the effect of macroprudential policies on banks' risk, since this type of investor protection can influence banks' willingness to lend. According to Houston et al. (2010), Haddad and Lobez (2015), and Teixeira et al. (2020a), increased levels of creditor protection can boost banks' lending to riskier costumers since creditors are safeguarded in case these credits become impaired. Therefore, we might expect this behavior to collide with the implementation of a new macroprudential agenda, especially for policies aimed at the credit market.

Alternatively, Acharya et al. (2011) and Cole and Turk Ariss (2018) support the idea that increased creditor protection can induce banks to provide fewer loans. According to Acharya et al. (2011), stronger creditor protection, especially in cases where managers can be dismissed in case of bankruptcy, will induce administrators to reduce cash-flow risk through more diversified acquisitions. At the banking level, Cole and Turk Ariss (2018) show that this behavior leads banks to borrow less, thus reducing the risk associated with such credits. Therefore, in line with this theory, a tighter credit protection framework could boost the effectiveness of macroprudential policies, especially those aimed at dampening the credit cycle.

Although the literature points to the importance of a country's institutional framework in the effectiveness of macroprudential policies for reducing banks' risk, the interaction between the institutional framework and macroprudential policies lacks a deep analysis. This study aims to fill this gap in the literature.

We formulate two hypotheses. First, macroprudential policies are less effective in countries with higher levels of shareholder protection due to the risk-shifting behavior of banks when shareholders are highly protected. Second, macroprudential policies are more effective in countries with higher levels of creditor protection due to increased diversification of banks' acquisitions and reduced lending.

We test these propositions using a sample of 624 banks from 40 countries during the 2006–2020 period. By applying the system generalized method of moments model, we find that macroprudential policies are only effective in reducing banks' risk in countries with higher levels of both creditors' and shareholders' rights while being ineffective in countries with poorer protection laws for both types of investors. However, when we decompose macroprudential policies by their main goal, we demonstrate the moral hazard behavior of banks, where tightening both macroprudential policies indexes, i.e., macroprudential policies aimed at dampening the credit cycle or aimed at enhancing the financial system resilience, in countries where shareholders are highly protected will induce higher risk-taking by banks. Furthermore, and focusing on the protection of creditors, we find that tightening both macroprudential policies indexes is only effective in countries with high levels of protection, while this same tightening event would translate to higher bank risk in countries with poorly protected creditors.

We then stretch our analysis to the two possible adjustments that macroprudential policies can suffer, concluding that loosening these policies will generate a greater increase in bank risk than the risk reduction generated by tightening the same policies, thus demonstrating the asymmetric effect of macroprudential policy adoption or lift.

Our paper contributes to the existing literature in several ways. First, to our knowledge, this is the first study to examine how the effect of macroprudential policies on bank risk may be channeled through investors' protection, thus contributing to the growing literature on the impact of macroprudential policies (e.g., Gaganis et al., 2020). We examine both sides of investor protection, namely shareholders' and creditors' rights, thus contributing to the literature on the interplay between macroprudential regulation and investor protection with new evidence and theory. Second, we analyze macroprudential policies through different scopes—aggregated by main goals and by type of events—to understand the full extent of macroprudential policy effects on bank risks and avoid the scenario where a tightening event and a loosening event in the same year would cancel each other out, therefore contributing to the literature that analyzes macroprudential policies either as a single index (Altunbas et al., 2018; Meuleman & Vander Vennet, 2020; Niţoi et al., 2019) or by main goal (Altunbas et al., 2018; Cerutti et al., 2017; Claessens et al., 2013; Fendoğlu, 2017; Kuttner & Shim, 2016). Third, this paper contributes to the literature on determinants of bank risk, as discussed in Laeven and Levine (2009), Lapteacru (2016), Altunbas et al. (2018), Niţoi et al. (2019), Gaganis et al. (2020), Meuleman and Vander Vennet (2020), Teixeira et al. (2020a), Di Tommaso and Pacelli (2022), and Tseng and Guo (2022).

The remainder of the paper is arranged as follows. Section 2.2 summarizes the various ways in which macroprudential instruments interact with investors' protection in shaping bank risk, providing us with a background discussion on interactions between these two factors. Section 2.3 describes the data and variables used and explains the empirical analysis. Section 2.4 discusses the results, providing additional robustness checks. Finally, Section 2.5 presents our final remarks and thus concludes this study.

2. Literature review and hypothesis development

This section discusses the theoretical and empirical literature that may explain the interplay between macroprudential policies and investor protection in determining banks' risk. To do so, we consider two different types of investor protection, (1) shareholder protection and (2) creditor rights. Based on this discussion, we formulate the main hypotheses of our study.

2.1. Interplay between macroprudential policies and shareholders' rights

The importance of investor protection laws in the financial development of countries was first introduced in the works of La Porta et al. (1997, 1998). Many other studies followed, explaining the possibilities of better financial development through more effective enforcement mechanisms.

The economic theory emanating from the works of La Porta et al. (1997, 1998) suggests that when levels of shareholder protection increase, there is an incentive for more investors to participate in financial markets, thus increasing the diversification of bank owners and, consequentially, diminishing their individual power. Along this line of thought, we might expect that poor shareholder protection laws supporting large bank owners lead banks to increase their risks, as suggested by the principal–agent problem presented by Laeven and Levine (2009), whereas stronger shareholder protection leads to a more diversified shareholder structure and, consequently, diminished individual power, which reduces banks' risk since the individual shareholder will not be able to influence banks' decisions when adjusting to a tighter prudential framework.

This behavior is supported by empirical evidence presented by Shleifer and Vishny (1986) and Laeven and Levine (2009), who show that shareholders with greater voting and cash-flow rights have correspondingly greater power and incentives to shape corporate behavior than smaller owners do.

This conditional effect is also supported by the findings of the International Monetary Fund (2014, 2016), who shows that emerging markets' resilience and improved market liquidity can be achieved through better corporate governance and investor protection laws. This is accomplished through reduced information asymmetries, the ultimate cause of principal–agent and moral hazard problems, and by encouraging trading activity and investor participation. These arguments contribute to our theory that the effect of macroprudential policies on banks' risk can be amplified through stronger shareholder protection.

Another strand of the literature suggests the harming effect of stronger shareholder protection on banks' risk-taking behavior. This theory is based on banks' risk-shifting behavior and the moral hazard problem, where financial firms and agents are able, to some extent, to transfer risk to others when there are safety net arrangements or when shareholders are highly protected (Llewellyn, 1999).

Finally, Gaganis et al. (2020) show a relationship between macroprudential policies and investor protection using shareholders' rights as a proxy for corporate governance in robustness checks, concluding that shareholder protection influences macroprudential policy effectiveness, negatively affecting banks' risk when few macroprudential policies are in force, which then turns into a positive effect as the number of macroprudential policies in place increases.

Given this array of conclusions, we can assume that achieving the perfect balance between macroprudential policies and investor protection poses a challenge in itself. Therefore, we test the hypothesis that macroprudential policy effects on bank risk are strengthened or mitigated by the level of shareholders' protection, contributing to the literature with new evidence and theory.

2.2. Interplay between macroprudential policies and creditors' rights

Another dimension of the investor protection set is creditors' rights. La Porta et al. (1998) demonstrates the complexity of this type of investor protection, as it may generate conflicts of interest for various types of creditors. Moreover, corporate finance and banking literature provide abundant evidence of the importance of creditor rights in influencing bank and firm risk-taking (Acharya et al., 2011; Houston et al., 2010; Jayaraman & Thakor, 2013) and lending decisions (Djankov et al., 2007; González, 2016; Qian & Strahan, 2007), especially through credit growth.

Houston et al. (2010), Haddad & Lobez (2015), and Teixeira et al. (2020a) find that stronger creditor rights translate into greater bank risks channeled through the increased confidence by banks to lend to riskier clients. This view is consistent with the moral hazard problem mentioned before and supported by Jayaraman & Thakor (2013), who find that increased bank risk-taking behavior originating from increased creditor rights is only feasible in countries where governments implement safety nets, *i.e.*, where creditors are highly protected.

According to Djankov et al. (2007), the ratio of private credit to gross domestic product is positively related to both stronger creditor rights and legal protection and the level of information sharing. Therefore, in a scenario where the macroprudential authority implements a set of instruments aimed at dampening the credit cycle, the effectiveness of such deployment could in theory be countered by the effects of strong institutional rights that pull in the opposite direction, more specifically by increased lending to riskier debtors.

Another strand of the literature supports the view that enhancing creditor rights may lead to greater banking system stability and, consequently, reduced bank risk. According to Acharya et al. (2009, 2011), stronger creditor rights, especially in the case where there is control over whether a manager is dismissed in case of bankruptcy, will prompt managers to act with self-interest in corporate decisions, leading to greater diversification of acquisitions and reduced cash-flow risk. Cole and Turk Ariss (2018) complement this theory by showing that in these cases, a stronger creditor protection framework will prompt banks to provide fewer loans and, consequently, reduce their individual risk. Furthermore, Matos et al. (2024b) demonstrate that banks' responses can be influenced by the level of disciplinary power of market participants, with greater disciplinary power exerting pressure on banks to avoid moral hazard behavior when responding to adjustments in macroprudential capital policies.

Given the lack of consensus in the literature on the conditional effect, we test the hypothesis that the effect of macroprudential policies on bank risk is influenced either positively or negatively by the level of creditors' rights.

3. Data, sample and methodology

3.1. Data and sample

To conduct this analysis, we combine bank- and country-level data from various sources. The primary source for the bank data is the Bankscope database provided by Bureau van Dijk. We focus on publicly listed commercial banks and bank holding companies, collecting market and financial data for 624 banks over the 2006–2020 period. The sample is diversified in terms of geographical areas and levels of economic development of each country, comprising 40 countries, 23 of which are considered Advanced Economies (AEs) and 17 considered Emerging Markets and Developing Economies (EMDEs). The division of the sample according to the level of economic development of the country follows the literature, namely Alam et al. (2019). In AE countries have seen growing use of macroprudential policies since the Great Financial Crisis, while these policies were already part of the policy paradigm of EMDE countries before the crisis. The distribution of the sample by country and year is shown in Table 1.

As shown in Table 1, the final sample is organized in an unbalanced panel data format where some banks were not active for some years in the period. We also exclude banks with negative equity for the corresponding year and winsorize all bank-level data at 1% and 99% to ensure that our results are not driven by outliers.

Table 1. Sample distribution by country and year

Distribution of the 345 banks composing the sample by the country they are headquartered and year.

Country	**Type of Country**	**Year**															**Total**
		2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
Austria	AE			4	4	4		5	5	5	5	5	5	6	7	7	**62**
Belgium	AE	1	1	1		1	1	1	1	1	1			1	1		**11**
Brazil	EMDE					2		10		11	8	8	10	9	12	13	**83**
Bulgaria	EMDE						2	1	2	3	3	3	3	4	3	3	**27**
Chile	EMDE					2	2								2		**6**
China	EMDE		5		7		9	8	9	15							**53**
Colombia	EMDE			2	2	1		3	3	3	3		3	2	2	2	**26**
Cyprus	AE					1								1			**2**
Czech Republic	AE				1	1	1	1				1	2	2	1	1	**11**
Denmark	AE	2	3		4	4	10	11	13	12					14	13	**86**
Finland	AE							1	1	1	1	1	1	5	4	4	**19**
France	AE	3	3	5	6	4	4	5	5	6	5	5	4	5	5	5	**70**
Germany	AE	2	3	3	3	3	5	5	6	8	7	7	6	6	7	8	**79**
Greece	AE		1		1		1					5		5	5		**18**
Hungary	EMDE												1	1		1	**3**
India	EMDE	5	6	7	6	9	10	10	12	11	15	18		19	23	17	**168**
Indonesia	EMDE		6	5	5	4	12	10	13	16	18	25	25				**139**
Ireland	AE								1	1		1	4	4	4	4	**19**
Italy	AE	2	3	3	4	2	6	6	5	5	6	6	5	8	11	14	**86**
Japan	AE	17	20	16	31	21	22	25	18	20	17	20	26	22	19	21	**315**
Lithuania	AE							1	1				1		1	1	**5**
Mexico	EMDE		2	2	2		8				9						**23**
Netherlands	AE		1	1	1	1	1			1		1	2			2	**11**
Norway	AE							7	11	11						23	**52**
Peru	EMDE							1				4			1		**6**
Philippines	EMDE	3	5	4	2					9	9				11		**43**
Poland	EMDE	1	1	1	4			4	5	4	3	5	4	5	4	5	**46**
Portugal	AE							1	1	1	1	1	2	1	1	1	**10**
Republic of Korea	AE									3	1	1	3		2		**10**
Romania	EMDE							2	3	3	3	4	3		3	3	**24**
Russian Federation	EMDE			1									9	9	8		**27**
Slovakia	AE			1	2	1		2			2	1		1	1		**11**
Spain	AE	4	4	5	5	5	4	5	6	5	5	6	6	6	6	5	**77**
Sweden	AE			3	3			3	3	3						6	**21**
Switzerland	AE							6	5	6	6	6	5	6	7	6	**53**
Thailand	EMDE	2	2														**4**
Turkey	EMDE	2		2	5												**9**
Ukraine	EMDE							2						1	3	2	**8**
United Kingdom	AE	6	7	9		9		7		7	8			15	15		**83**
United States of America	AE			142	151	157	169	193	196	209	213	216	224	222	229	228	**2549**
Total		**50**	**73**	**217**	**249**	**232**	**267**	**336**	**325**	**380**	**349**	**350**	**354**	**366**	**412**	**395**	**4355**

3.2. Methodology

To estimate whether and how macroprudential policies interact with investor protection laws in shaping banks' risk-taking behavior, we start with the commonly used model in the literature, which takes the following form:

$$Risk_{i,j,t} = \alpha + \beta_1 Risk_{i,t-1} + \beta_2 MPPI_{j,t} + \beta_3 InvestorsProtection_{j,t} + \beta_4 (MPPI \times InvestorsProtection)_{j,t} + \beta_5 BankControl_{i,t} + \beta_6 CountryControl_{j,t} + Year_t + \varepsilon_{i,j,t}, \quad (1)$$

where the dependent variable *Risk* $_{i,j,t}$ is an indicator of risk for bank *i,* located in country *j* in year *t*, *MPPI* is an index of country-specific macroprudential policy adjustments in country *j* in year *t*, and *InvestorsProtection* is an indicator of the investors' protection level in country *j* in year *t*. The set of *BankControl* and *CountryControl* includes several bank-specific and macroeconomic and external variables typically used in the literature as control variables. We also add the variable $Year_t$ to capture time-specific fixed effects (temporal patterns), which allows us to control for the exogenous increase in the dependent variable not attributed to independent variables. In addition, given that we are using a dynamic model, we include a one-period lagged dependent variable to account for banks' risk persistence over time due to intertemporal risk smoothing and competition and in reaction to banking regulation (Delis & Kouretas, 2011).

As shown in the above equation, we also include the interaction term *MPPI* × InvestorsProtection to analyze if and how macroprudential policies interact with the investors' protection in shaping banks' risk. With this interaction, we can evaluate the full extent of macroprudential policy effects on bank risk both directly (β_2) and indirectly (β_4, subject to the level of investors' protection) as follows:

$$\frac{\partial Risk_{i,j,t}}{\partial MPPI_{j,t,m}} = \beta_{2,m} + \beta_{4,m,n} InvestorsProtection_{j,t,n}. \quad (2)$$

The above effect properly demonstrates the need to evaluate the joint magnitude of macroprudential policies and investors' protection, since the overall effect of macroprudential policies on banks' risk may shift from positive to negative, or *vice versa*, according to the range of investors' protection.

One big concern about the dynamic panel data setting above is the endogeneity issues that might arise between banks' risk and the macroprudential policies.[2] In addition, the commonly used models such as the ordinary least squares or the maximum likelihood estimation only hold their consistency when T and N tend to infinity. To deal with these problems, we use an autoregressive model based on the system generalized method of moments (sGMM) formulated by Arellano and Bover (1995) and Blundell and Bond (1998). This model uses assumptions, which we call moment conditions, based on specific moments of the random variables instead of assumptions about the entire distribution. This model is especially effective in a scenario where we have a large N and short T (Blundell & Bond, 1998; Roodman, 2009).

Nevertheless, the consistency of the sGMM estimator depends on the validity of two assumptions: the absence of serial correlation among the errors and the absence of instrument proliferation. To analyze these assumptions, we use two diagnostic tests: the Hansen test of overidentifying restrictions and the autoregressive test. The former focuses on testing the global validity of the instruments through an analysis of the moment conditions we mentioned earlier. The latter is suggested by Arellano and Bond (1991) and tests the hypothesis that the term error ε is not serially correlated. Failing to reject the null hypothesis of both tests validates our model.

3.3. Dependent variable

Macroprudential policies are set to reduce systemic risk through individual bank risk-taking behavior (Beirne & Friedrich, 2013; Borio, 2011). Therefore, ideally, we should measure the effect of macroprudential policies and investors' protection laws on systemic risk since the prior are specifically designed to address such risk. Although there have been developments in creating variables to reflect systemic risk, which Bisias et al. (2012) document quite extensively, these are still very rudimentary (Altunbas et al., 2018).

Taking this into account, and since the effect of macroprudential policies will also reflect on banks' risk due to its contribution to the systemic prospect (Altunbas et al., 2018), we analyze these effects on a bank's individual risk, measured by its asset risk. This approach is consistent with the studies of Laeven and Levine (2009), Altunbas et al.

[2] Although we study individual bank risk, where there is much less chance of endogeneity since it is unlikely that a macroprudential policy adjustment may occur in response to individual bank behavior due to the fact that each bank only represents a small part of the financial system (Claessens et al., 2013). Nonetheless, we use the sGMM estimator to deal with any residual endogeneity.

(2018), Niţoi et al. (2019), Gaganis et al. (2020), and Meuleman and Vander Vennet (2020), where these authors also measure the impact of macroprudential policies on banks' individual risk-taking behavior.

Following Gropp and Heider (2010), Claessens et al. (2013), and Teixeira et al. (2014), we calculate the banks' asset risk by the standard deviation of asset returns which reflects the yearly standard deviation based on the daily stock price returns multiplied by the total market value of the banks' equity over the market value of the bank. This variable perfectly reflects banks' risk since it incorporates the two components of risk: idiosyncratic risk and market risk.

The literature often considers several measures of banks' risk. Laeven and Levine (2009), Houston et al. (2010), Lapteacru (2016), Altunbas et al. (2018), Niţoi et al. (2019), Ashraf et al. (2020), Gaganis et al. (2020), and Dutra et al. (2023b) use the Z-score as a proxy for banks' risk. Therefore, to validate the robustness of our results, we repeat the same regressions using Z-score as the dependent variable. These results are presented and analyzed in section 2.4.4.

3.4. Macroprudential policies

We obtain the macroprudential policy data from the integrated Macroprudential Policy database (iMaPP) introduced by Alam et al. (2019). This database is particularly significant because it incorporates five existing databases and additional information obtained through International Monetary Fund (IMF) country documents and official sources (Alam et al., 2019). Therefore, following Choi et al. (2021) and Venter (2022), we obtain data for 16 macroprudential policies in the 2006–2020 period more specifically the adjustments these policies suffered over the years (tightening events and loosening events). Also, and considering that this database allows us to examine each direction of the macroprudential policy adjustments individually, we test the hypothesis that the impact across macroprudential policies tightening, and loosening events is asymmetric.

Following Meuleman and Vander Vennet (2020) and considering that this database has a monthly frequency, we aggregate the monthly data over the year to obtain a yearly adjustment of the macroprudential policy. This approach is in line with Akinci and Olmstead-Rumsey (2018) and Cerutti et al. (2017), who also use cumulative measures on a panel data setting since macroprudential policies not only affect the risk in the month of the announcement but also in subsequent months.

The baseline specification is estimated considering different groupings for the macroprudential policies. First, and following Boar et al. (2017), Fendoğlu (2017), Akinci and Olmstead-Rumsey (2018), Niţoi et al. (2019), and Gaganis et al. (2020), we estimate the effects of macroprudential policies by aggregating them in a single equally weighted index, which allows us to evaluate the overall interaction effect of macroprudential policies. This approach has a drawback since we aggregate multiple adjustments in both directions a tightening event and a loosening event in the same year would cancel each other out.

Considering this and the fact that the interaction effect between macroprudential policies and investor protection can be channeled through different ways since each macroprudential policy has a specific goal, we follow the literature by grouping the policies according to their main goals: to enhance the financial system resilience and to dampen the credit cycle (Altunbas et al., 2018; Borio, 2011; Claessens et al., 2013; Houston et al., 2010; Meuleman & Vander Vennet, 2020).

Finally, we analyze each adjustment direction by itself, disaggregating the previous index in tightening and loosening events. This approach is based on the empirical evidence presented by Claessens et al. (2013), Kuttner and Shim (2016), and Altunbas et al. (2018), where these authors find evidence that tightening a macroprudential policy has a larger magnitude than a loosening event.

3.5. Investor protections

The investors' protection variables were obtained from the World Bank Doing Business Dataset, as in Caprio et al. (2007), Teixeira et al. (2020b), and Dutra et al. (2023a). The shareholders' rights index measures the score for ease of shareholders' suits, *i.e.,* their capability to obtain evidence and recover legal expenses in cases of shareholders' legal actions. This index ranges from 0 to 100, where 0 represents countries with poor regulatory performance and 100 represents countries with the best regulatory performance, where shareholders are most protected.

Regarding creditors' rights, it is measured by the strength of the legal rights index, *i.e.,* whether certain features facilitate lending within the existing collateral and bankruptcy laws. This index also ranges from 0 to 100, where 0 represents the poorest regulatory performance, and 100 represents the best regulatory performance and creditors' protection.

3.6. Country- and bank-level control variables

The extant literature has identified several bank- and country-specific variables as important determinants of banks' risk-taking behavior. Following this literature, particularly Lee et al. (2014), Altunbas et al. (2018), Alam et al. (2019), Niţoi et al. (2019), Gaganis et al. (2020), and Teixeira et al. (2020a), *inter alios,* we identify several bank-specific (*BankControl*) and macroeconomic variables (*CountryControl*) that are introduced to capture time-invariant bank- or country-fixed effects that might impact banks' risk-taking behavior through other channels.

The bank control variables include leverage, size, profitability, operational efficiency (measured by the inverse of cost–income ratio), credit risk (measured by the inverse of credit quality), income diversity, and asset diversity, while the country-specific macroeconomic control variables include the inflation rate, the gross domestic product (GDP) growth rate, the level of interest rates, and the slope of the interest rates.

Appendix I summarizes the definition and sources of the variables.

3.7. Descriptive statistics

Descriptive statistics for the main regression variables are presented in Table 2. The dependent variable, the distribution of which can be analyzed through Figure 1, has a mean of 5.58% and a standard deviation of 10.79%. Through Figure 3.2, we can draw several interesting conclusions. First, we find that the average asset risk is higher in 2007 (5.09%) and 2008 (4.94%), matching the years of the GFC, while this average is lower in the post-GFC period. Furthermore, in the years following the GFC, we can observe two peaks in 2016 (7.00%) and in 2020 (9.85%). The high volatility in these years can be attributed to a series of shocks that hit global financial markets, namely Brexit (Quaye et al., 2016), the Shanghai market crash and the US–China tariff war (Shi et al., 2021) in 2016, and the COVID-19 pandemic in 2020 (Ganie et al., 2022; Matos et al., 2023; Shi, 2022).

Table 2. Descriptive statistics

Main descriptive statistics for the variables used in the models. The construction of each of these variables can be analyzed in Appendix I as well as the source of its data.

	N	Mean	St. Dev.	Min.	Max.	Distribution		
						10th	**50th**	**90th**
Banks' risk								
Asset risk (%)	4355	5.578	10.794	0.000	79.802	.299	1.687	12.226
Z-score		.016	.940	−3.274	3.228	−1.199	.127	1.112
Macroprudential variables								
Macroprudential policies index	4355	.827	2.195	−9	13	−1	1	3
Resilience MPP index	4355	.577	1.638	−8	7	0	0	2
Credit cycle MPP index	4355	.082	.780	−4	11	0	0	1
Investors' protection variables								
Shareholders' rights	4355	78.921	17.592	20.000	90.000	33.333	91.667	91.667
Creditors' rights	4355	71.624	26.055	20.000	90.000	50.000	90.000	90.000
Bank-specific variables								
Leverage (%)	4355	87.063	10.733	5.533	99.635	78.215	88.445	97.093
LOG size	4355	9.262	2.159	.047	14.854	6.939	8.875	12.499
Profitability (%)	4355	1.508	2.844	−16.936	72.844	.212	1.323	2.623
Cost–income ratio	4355	63.401	14.969	3.743	141.282	45.666	63.037	81.026
Income diversity	4355	.680	.467	−.219	2.450	.204	.564	1.375
Asset diversity	4355	.658	.398	.000	1.999	.277	.560	1.203
External variables								
GDP growth (%)	4355	1.654	2.415	−11.182	13.900	−2.300	2.000	3.400
Inflation (%)	4355	1.918	1.641	−1.700	13.300	.200	1.741	3.200
Level of interest rates (%)	4355	2.747	2.196	−0.294	5.087	.786	2.270	5.865
Slope of interest rates (%)	4355	1.339	4.587	−.579	31.313	.148	1.603	2.915
Concentration	4355	43.481	17.926	0.000	100.000	34.420	35.313	77.922
Crisis	4355	.169	.375	0	1	0	0	1

Figure 1. Distribution of the dependent variable (banks' risk).

Distribution of the main dependent variable, *i.e.,* the banks' risk as measured by its asset risk. This variable measures the annualized standard deviation of the daily stock price returns times the market value of equity over the market value of the bank.

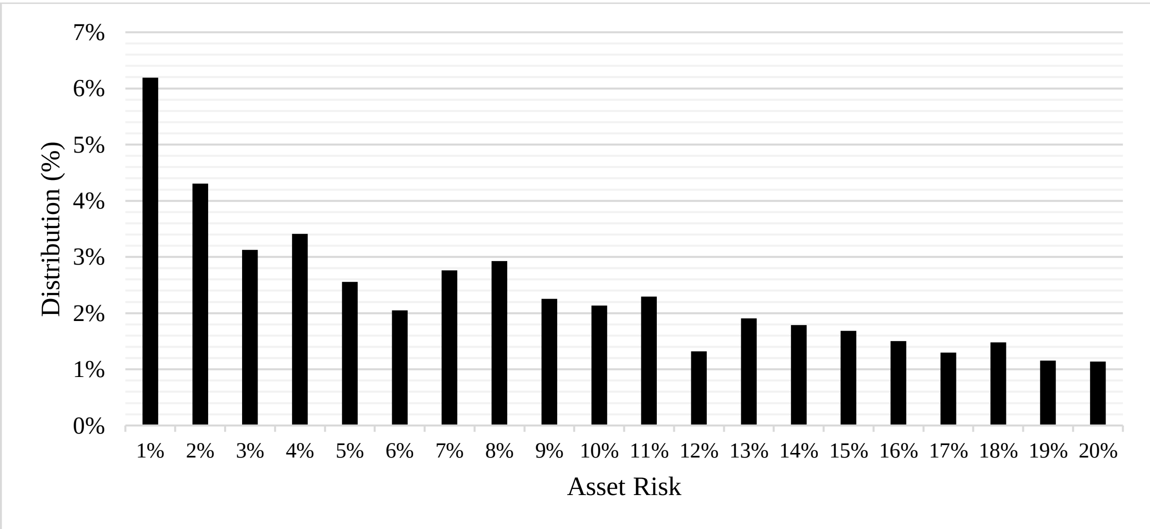
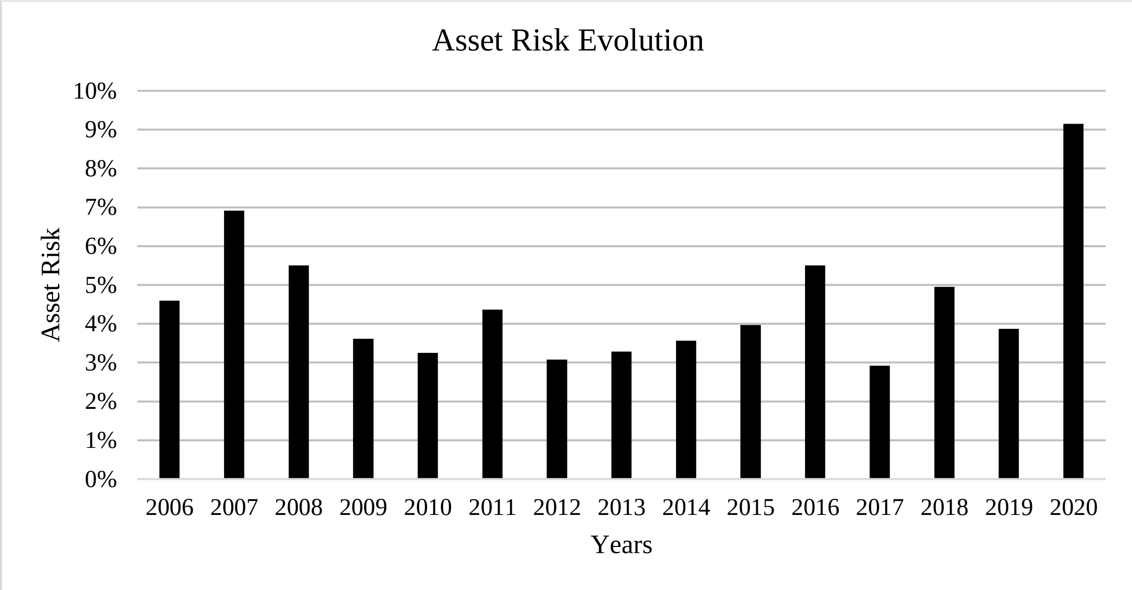


Figure 2. Yearly average of the dependent variable (banks' risk).

Yearly average of the banks' asset risk for the sample and its evolution throughout the period considered (2006–2020).



Regarding investors' protection, Table 2 shows that the means for creditors' rights (79.92) and shareholders' rights (71.62) are high since our database is composed of a set of 23 developed countries, which typically have higher investor protection levels and law enforcement (La Porta et al., 1997, 1998). However, as expected, we can identify a sign of heterogeneity across banks, evident by the high standard deviation of the shareholders' rights (17.59) and the wide range, from a minimum of 20.00 to a maximum of 90.00.

To further explore this matter, we split the sample according to the level of economic development of the country and present the corresponding descriptive statistics in Appendix II. As expected, investors are much more protected in developed countries, where the average country has a mean shareholder protection of 83.445, ranging from a minimum of 50.00 to a maximum of 90.00, while the average developing country has a mean of 55.09, with a wider range from 20.00 to 90.00. This same pattern is also exhibited in the creditors' rights variable where the average AE country has a mean of 76.52%, compared to the mean creditors' rights in EMDE countries of 45.85%. Nonetheless, for creditors' rights, the range is the same for both sets of countries.

In what concerns macroprudential policies, the average country has around one macroprudential policy tightening per year (0.83). It is important to state that the macroprudential policy index ranges from a minimum of −9 to a maximum of 13, i.e., each year, the maximum loosening events of the total 16 macroprudential policies analyzed was 9 (Czech Republic in 2020) and the maximum tightening events verified in a given year for these same policies was 13 (China in 2007).

When we look at the descriptive statistics for this variable according to the level of economic development of the country, depicted in Appendix II, we find that macroprudential policies have an average of 0.69 in AE countries, while this average is higher in EMDE countries (1.55). These results are in line with the literature, as it points to macroprudential policies being used more intensively in EMDE countries than in AE countries (Cerutti et al., 2017).

Regarding leverage and profitability, the average bank has a leverage of 87.06% and yearly mean profitability of 1.51%, similar to the 84.10% and 2.40%, respectively, presented by Teixeira et al. (2020a). In what concerns macroeconomic variables, we can characterize our average country as having a 1.65% GDP growth rate and a 1.92% inflation rate.

4. Empirical results

This section starts by analyzing the effect of macroprudential policies on banks' risk channeled through investors' protection, measuring macroprudential policies through the macroprudential policies index obtained from Alam et al. (2019). We then develop the same analysis but disaggregate the previous index into two subindexes, to analyze the effect of macroprudential policies according to their main goal. We then replicate this same analysis but take macroprudential policies one step further using two other subindexes, built from the same source, that measure each type of macroprudential policy adjustments (loosening or tightening) individually, to assess if the impact is symmetric across the two types of events. Finally, we check for the robustness of our results using a different proxy to measure banks' risk, namely the Z-score.

4.1. Interplay between macroprudential policies and investor protection: macroprudential policies measured by a single index

Starting with the model where we analyze macroprudential policies as a single index and measuring the total loosening and tightening events, we obtain the results of Models 1 and 2, presented in Table 3, where we analyze the interaction of macroprudential policies with shareholders' rights and creditors' rights, respectively.

The first conclusion we can draw from Table 3 reports the statistical significance of all variables at the 1% level. Moreover, the lagged dependent variable has a positive effect on banks' risk, which supports the hypothesis that there is a high level of persistence in banks' risk, as documented by Delis and Kouretas (2011), Louzis et al. (2012), Castro

(2013), and Baselga-Pascual et al. (2015), hence validating our choice of this dynamic model.

Table 3. Banks' risk model with banking regulatory and investors' protection variables.

The dependent variable, bank's asset risk, is given by the annualized standard deviation of daily stock price returns times the market value of equity over the market value of the bank. Models 1 and 2 include the interaction terms between macroprudential policies and shareholders' and creditors' protection, respectively. Models 3 and 4 expand the previous interaction by dividing the macroprudential policies according to their goals, *i.e.,* enhancing the financial system resilience and dampening the credit cycle. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively. The null hypothesis of the Hansen test states that all instruments are jointly exogenous and that the instruments used are not correlated with residuals. The null hypothesis of the autoregressive (AR) test states that there is not second-order serial correlation in the error term.

Dependent Variable: Asset Risk	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Lagged dependent variable	.794*** (.001)	.794*** (.001)	.813*** (.001)	.796** (.001)
Macroprudential Policies Index				
MPPI Index	.175*** (.008)	.371*** (.006)		
Resilience MPP Index			.128*** (.004)	.362*** (.003
Credit cycle MPP Index			.040*** (.008)	1.341*** (.008)
Investors protection variables				
Creditors rights	.016*** (.000)	.023*** (.000)	.018*** (.001)	.017*** (.000)
Shareholders protection	-.019*** (.000)	-.022*** (.000)	-.016*** (.000)	-.014*** (.000)
Interaction variable				
MPP Index x Shareholders protection	-.002*** (.000)			
MPP Index x Creditors rights		-.006*** (.000)		
Resilience MPP Index x Shareholders protection			.001*** (.000)	
Credit cycle MPP Index x Shareholders protection			.007*** (.000)	
Resilience MPP Index x Creditors rights				-.004*** (.000)
Credit cycle MPP Index x Creditors rights				-.019*** (.000)
Bank specific variables				
Profitability	-7.056*** (.140)	-7.605*** (.127)	-6.418*** (.112)	-7.554*** (.123)
Leverage	-.019*** (.001)	-.019*** (.001)	-.006*** (.004)	-.015*** (.000)
LOG Size	-.093*** (.002)	-.107*** (.003)	-.087*** (.002)	-.066*** (.002)
Cost-income ratio	-.018*** (.000)	-.017*** (.000)	-.023*** (.000)	-.017*** (.000)
Asset diversity	.143*** (.018)	.075*** (.014)	.319*** (.013)	.237*** (.013)
Income diversity	1.040*** (.016)	1.138*** (.023)	.992*** (.012)	.988*** (.016)
External variables				
Inflation	-.022*** (.003)	-.027*** (.003)	-.036*** (.001)	-.058*** (.002)
GDP growth	.363*** (.002)	.336*** (.001)	.320*** (.001)	.332*** (.001)
Level of interest rates	-.581*** (.004)	-.575*** (.004)	-.618*** (.002)	-.513*** (.002)
Slope of interest rates	.213*** (.002)	.234*** (.002)	.300*** (.002)	.339*** (.001)
Concentration	-.003*** (.000)	-.004*** (.000)	-.003*** (.000)	-.007*** (.000)
Crisis	.233*** (.005)	.087*** (.006)	.078*** (.006)	.309*** (.007)
Year dummies	Yes	Yes	Yes	Yes
Pre-validation tests				
Sargan-Hansen test	.265	.273	.769	.751
Arellano-Bond test for AR (2)	.768	.707	.735	.744

The estimated coefficients associated with the macroprudential policies variables have a positive impact on banks' risk, suggesting that the direct effect of tightening macroprudential policies induces growth in banks' risk-taking behavior. These results are consistent with the risk-shifting behavior and moral hazard behaviors adopted by banks, when adapting to a tighter prudential framework, supporting the empirical findings of Llewellyn (1999).

On what concerns investors' protection, the results show that the direct effect of creditors' rights on banks' risk is negative, while the direct effect of shareholders' rights is positive. Regarding the creditors' rights effect, this result supports the theory presented by Acharya et al. (2009, 2011) and Cole and Turk Ariss (2018), suggesting that stronger creditors' protection will lead managers to diversify their acquisitions and cause banks to reduce lending, translating into reduced risk-taking. Conversely, the positive effect of shareholders' rights supports the risk-shifting behavior and the moral hazard theory and the evidence presented by Llewellyn (1999), with the argument that when there are safety net arrangements, through higher shareholders' rights, banks will be able to transfer risk to others. Therefore, with these safety net arrangements in place, banks will be more prone to make riskier investments.

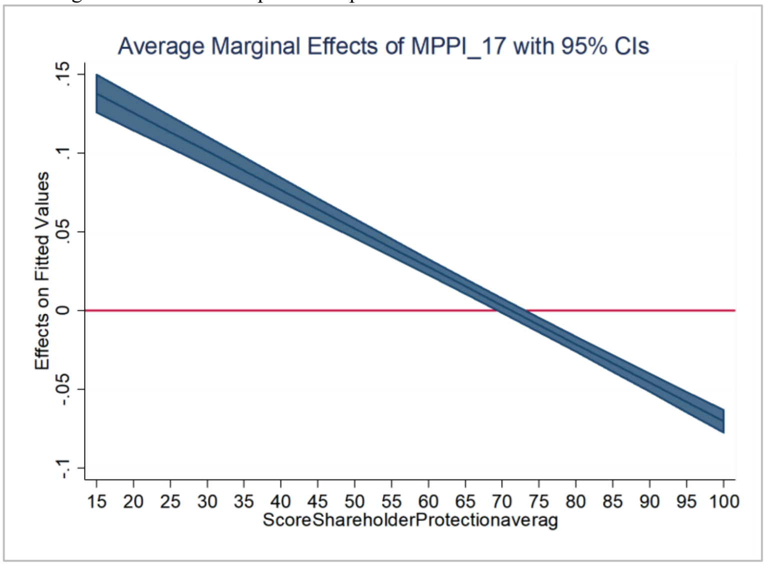
Regarding the interaction variables, which allow us to discuss the indirect effect of macroprudential policies on banks' risk, potentially channeled through investor protection, the results show that all estimated coefficients are statistically significant at the 1% level, which implies that the overall effectiveness of macroprudential policies on banks' risk is conditional on the level of investors' protection. Digging deeper into this conditional effect and using Figure 3 as assistance, we can graphically illustrate the marginal effect of macroprudential policies, conditional on the level of investors' protection.

As we can see in Panel A, the effect of macroprudential policies is only negative for higher values of shareholders protection, while being less effective in countries with lower levels of protection. For instance, tightening macroprudential policies in a country with a level of 90% shareholder protection will lead to a small reduction of 0.01% in banks' risk, while the same tightening event in a country with 20% shareholder protection will lead to an increase of 0.14%. Linking this effect to the dispersion of the investor protection variables, we can conjecture that in AE countries the high average shareholder protection level (83.45%) contributes to the effectiveness of macroprudential policies in reducing banks' risk, although with a negligible effect. On the contrary, in EMDE countries the low shareholder protection level (55.09% on average) reduces the effectiveness of macroprudential policies in reducing banks' risk, since the increased individual shareholder power allows these individuals to influence banks' decisions.

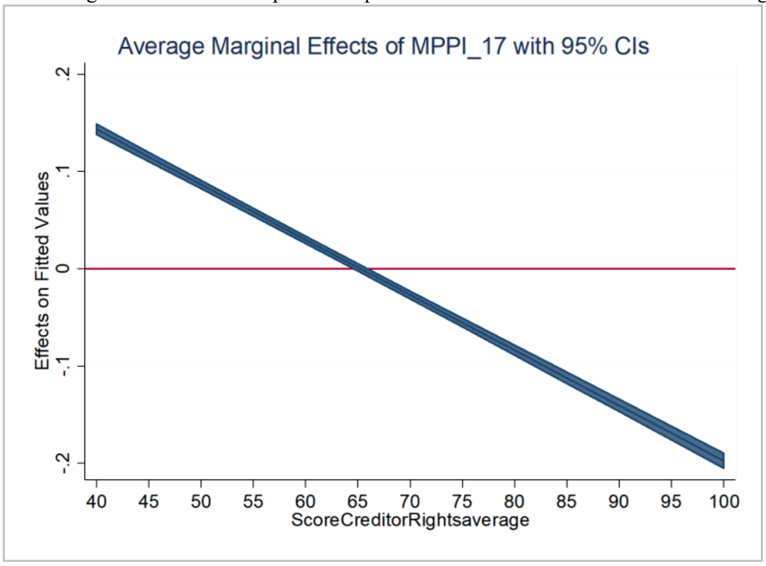
Figure 3. Marginal effects of macroprudential policies evaluated on all levels of investors' protection.

Marginal effects of the macroprudential policies index on banks' risk, evaluated at all values of creditors' rights (Panel A) and shareholders' rights (Panel B). These results are calculated using the derivatives of Equation 5.2 along with Model 1 and Model 2, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.

Panel A - Marginal effects of macroprudential policies evaluated on all levels of shareholders' rights.



Panel B - Marginal effects of macroprudential policies evaluated on all levels of Creditors' rights.



Regarding creditors' rights, through Panel B we can conclude that the effect of macroprudential policies exhibits a similar pattern, as the effectiveness of macroprudential policies is only present when creditors are highly protected. Therefore, strengthening creditors' rights intensifies the effect of macroprudential policies, making them more efficient at reducing banks' individual risk and, consequently, systemic risk, while this effect is the opposite in countries that have poorer creditor protection laws. In terms of economic impact, we might expect that in AE countries, where the average level of creditor protection is 83.45%, tightening macroprudential policies leads to a reduction of 0.12% in banks' risk level, while in EMDE countries, where the average level of creditor protection is 45.85%, the same tightening of macroprudential policies induces an increase of 0.12% in banks' risk level.

The results of the control variables show that profitability, leverage, size, and the cost-to-income ratio have a statistically significant negative effect on banks' risk in both Models 1 and 2, whereas asset diversity and income diversity have a positive effect. These results are aligned with the existing literature previously presented. In what concerns country-specific variables, banks tend to increase their risk in response to an increase of GDP growth, and interest rates slope. However, they tend to reduce their risk with higher inflation and interest rates.

Finally, regarding the crisis dummy variable, we can conclude that it has a statistically significant positive effect on banks' risk, which suggests that during crisis times, banks' risk tends to be higher.

The statistical tests in Table 3 show that the two-step GMM estimation approach was correctly applied since both prevalidation tests, the Hansen test and the autoregressive test, confirm the absence of instrument proliferation and second-order serial correlation for both Model 1 and Model 2.

4.2. Interplay between macroprudential policies and investor protection: decomposing macroprudential policies according to their targets

This section delves further into the interaction of macroprudential policies and investors' protection by splitting the first into two main goals: to enhance financial system resilience or dampen the credit cycle. This approach is in line with Kuttner and Shim (2016), Cerutti et al. (2017), and Altunbas et al. (2018), who analyze macroprudential policies with similar approaches, and aims to assess whether the conditional impact remains the same when we have macroprudential policies aiming at different goals. The division of the macroprudential policies into each goal follows the method presented in Borio (2011) and Claessens et al. (2013) and is indicated in Table 2. The results of this approach can be analyzed in Models 3 and 4, depicted in Table 3, which shows that all estimated coefficients are statistically significant at the 1% level.

Regarding the individual effects of the two subindexes of the macroprudential policies, we report some interesting results. Tightening both the macroprudential policies aiming at enhancing the financial systems' resilience and dampening the credit cycle leads to an increase in bank's risk. In other words, a tightening event in a macroprudential policy that aims at enhancing the financial system resilience will lead to an increase in banks' risk by 0.13% for Model 3 (0.36% for Model 4), while a tightening event of a macroprudential policy aiming at dampening the credit cycle will translate into an increase of 0.40% of banks' risk for Model 3 (1.34% for Model 4). These results might be explained by the theory we presented earlier, where tightening macroprudential policies leads banks to engage in risk-shifting to regain the lost profitability derived from the tighter macroprudential framework.

Concerning the interaction variables and starting with Model 3, where we analyze both the constitutive and interaction coefficient terms of the macroprudential policies subindexes and shareholders' rights, we can conclude that both are statistically significant, meaning that the overall effect of macroprudential policies on banks' risk-taking behavior is conditional on shareholders' rights. Digging even further into this conditional effect and analyzing how it performs for all values of shareholders' rights, we obtain Figure 4.

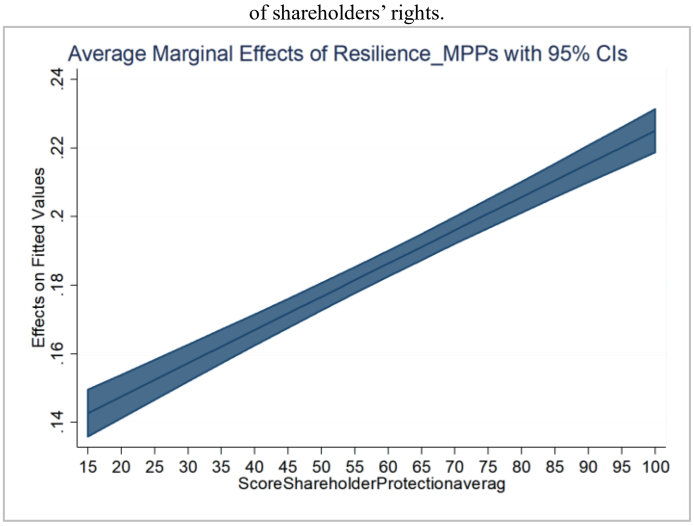
As shown in Panel C, the effect of macroprudential policies aimed at enhancing the financial systems' resilience is positive for all values of the shareholders' rights. However, this effect is more pronounced in countries with higher levels of shareholder protection than in countries with poorly protected shareholders. Once again, and since AE countries have typically higher shareholder protection levels when compared to EMDE countries, we can demonstrate a "dark side" for increased shareholder protection in AE countries and validate the moral hazard theory presented by Llewellyn (1999), as a higher level of protection leads banks to invest in riskier assets, since they are protected by safety net arrangements in case these assets do not perform as expected.

Looking at Panel D, we can analyze the marginal effect of the macroprudential policies subindex aimed at dampening the credit cycle with shareholders' rights. The results show a similar pattern, where the magnitude of the ineffectiveness of this type of macroprudential policy varies according to the level of protection, *i.e.,* a tightening event of a macroprudential policy aiming at dampening the credit cycle will lead to an increase in banks' risk for countries with higher shareholders' rights when compared with countries with lower levels of protection, where the risk increase is lower. Since the values of shareholders' rights level range from 20.00% to 90.00%, we conclude that in countries with lower shareholders' rights, typically EMDE countries, where the average shareholder protection is 55.09%, tightening a macroprudential policy aiming at dampening the credit cycle leads to a small increase of banks' risk (0.41%), whereas in countries with higher shareholders' rights, such as AE countries, where the average level of protection is 83.45%, the same tightening event causes a more pronounced increase in banks' risk (0.61%).

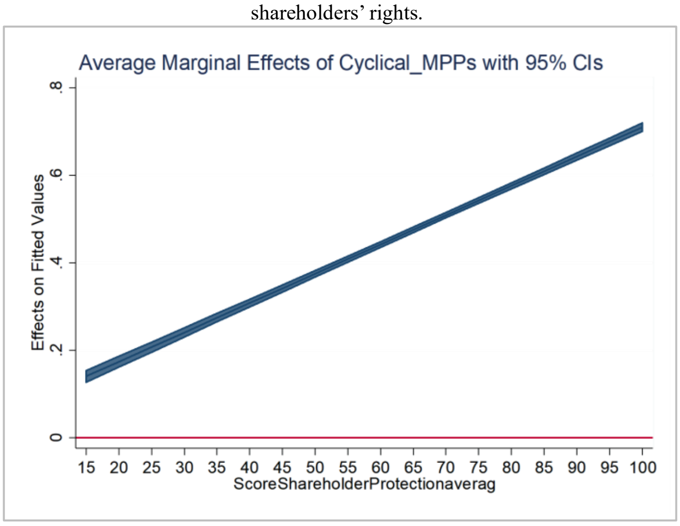
Figure 4. Marginal effects of macroprudential policies sub-indexes evaluated on all levels of shareholders' rights.

Marginal effects of the enhancing financial system resilience sub-index (Panel C) and dampening the credit cycle sub-index (Panel D) on banks' risk, evaluated at all values of shareholders' rights. These results are calculated using the derivatives of Equation 2 along with Model 3, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.

Panel C - Marginal effects of the macroprudential policies sub-index aimed at enhancing the financial system resilience on all levels of shareholders' rights.



Panel D – Marginal effects of the macroprudential policies sub-index aimed at dampening the credit cycle on all levels of shareholders' rights.



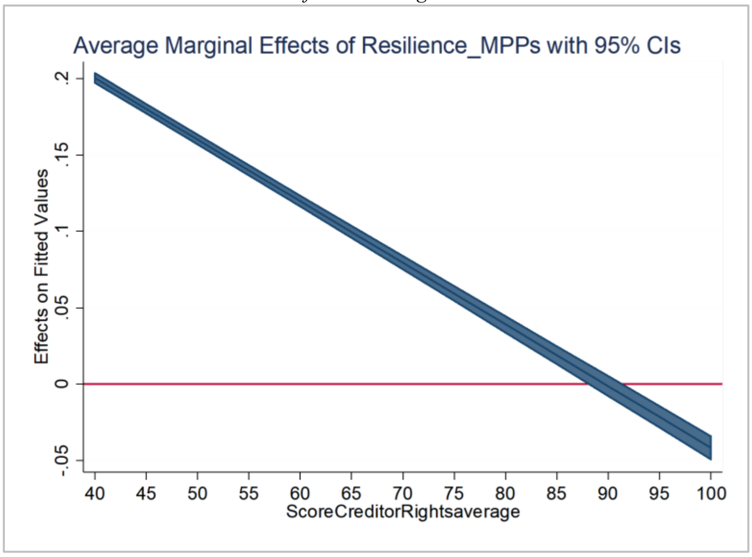
Overall, our results support the theory that when shareholders are highly protected, banks will tend to engage in a risk-shifting behavior when a tighter macroprudential framework is in place, leading to increased investment in riskier assets to regain the lost profitability, thus supporting the theory presented by Llewellyn (1999).

Taking a closer look at Figure 5, we can analyze the interplay of these subindexes with creditors' rights.

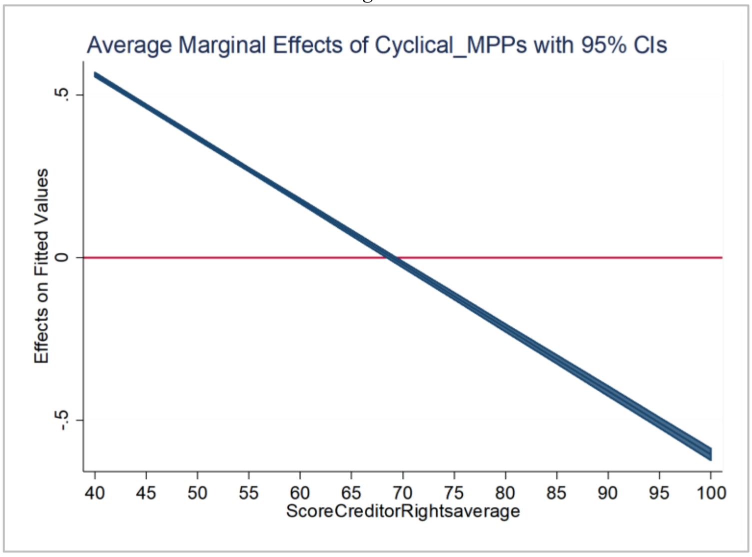
Figure 5. Marginal effects of macroprudential policies sub-indexes evaluated on all levels of creditors' rights.

Marginal effects of the enhancing financial system resilience sub-index (Panel E) and dampening the credit cycle sub-index (Panel F) on banks' risk, evaluated at all values of creditors' rights. These results are calculated using the derivatives of Equation 2 along with Model 4, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.

Panel E - Marginal effects of the macroprudential policies sub-index aimed at enhancing the financial system resilience on all levels of creditors' rights.



Panel F – Marginal effects of the macroprudential policies sub-index aimed at dampening the credit cycle on all levels of creditors' rights.



The results display an interesting pattern similar to those reported in Models 1 and 2. In Panel E we can observe that macroprudential policies are only effective in reducing banks' risk when creditors are highly protected. This same pattern is also present in Panel F, where the macroprudential policies aimed at dampening the credit cycle are only effective in countries with higher levels of creditor protection.

These results support the findings of Acharya et al. (2009, 2011) and Cole and Turk Ariss (2018), according to which higher levels of creditor rights, especially in situations where the manager can be dismissed in case of bankruptcy, prompt banks to diversify the acquisitions and reduce lending. Therefore, tightening macroprudential polices, especially those aiming at dampening the credit cycle, in countries with highly protected creditors, leads to increased effectiveness of these policies in reducing banks' risk.

4.3. Interplay between macroprudential policies and investor protection: the individual effect of tightening and loosening macroprudential policies

To shed more light on the magnitude of the effect of macroprudential policies when there is a tightening or loosening event, considering that the literature defines each event as having different dimensions (Alam et al., 2019; Araujo et al., 2020; Kuttner & Shim, 2016; McDonald, 2015; Poghosyan, 2020; Richter et al., 2019), we repeat the estimation of Models 1 and 2, using two categorical subindexes: a loosening subindex and a tightening subindex. These subindexes measure each type of event individually and allow us to quantify the magnitude of a tightening or loosening event for all values of shareholder and creditors' rights. The results are presented in Table 4 and graphically represented in Figure 6.

In Model 5, for all values of shareholders' rights, a loosening event will always lead to a reduction of banks' risk. However, in countries with stronger shareholders' rights, the risk reduction will be weaker than in countries with low shareholders' rights. In other words, a tightening event in a country with 90% of shareholder protection will lead to a reduction of banks risk of 0.28%, while the same tightening event in a country with 20% of shareholder protection will lead to a reduction of 0.35% in banks' risk. These results support our previous results and the risk-shifting position of banks when shareholders are highly protected.

Regarding Model 6, and for all values of creditors' protection, the same applies, where higher levels of creditors' protection will translate into a lower decrease in banks' risk for the same loosening event when compared with a country with poorly protected creditors.

Table 4. Banks' risk model with banking regulatory and investors' protection variables.

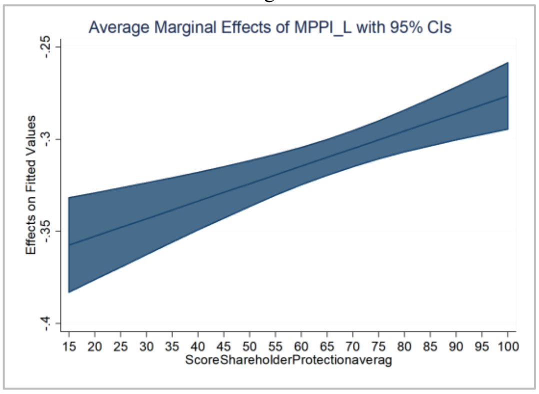
The dependent variable, bank's asset risk, is given by the annualized standard deviation of daily stock price returns times the market value of equity over the market value of the bank. Model 5 and 6 includes the interaction terms between macroprudential policies loosening sub-index and shareholders' and creditors' protection, respectively. Model 7 and 8 analyses the interaction between the macroprudential policies tightening sub-index and shareholders' and creditors' rights, respectively. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively. The null hypothesis of the Hansen test states that all instruments are jointly exogenous and that the instruments used are not correlated with residuals. The null hypothesis of the autoregressive (AR) test states that there is not second-order serial correlation in the error term.

Dependent Variable: Asset Risk	Model 5	Model 6	Model 7	Model 8
Lagged dependent variable	.810*** (.001)	.804*** (.001)	.795*** (.001)	.794*** (.001)
Macroprudential Policies Index				
MPPI Loosening Index	-.372*** (.016)	-.926*** (.013)		
MPPI Tightening Index			.481*** (.010)	-.149*** (.009)
Investors protection variables				
Creditors rights	.017*** (.000)	.010*** (.001)	.026*** (.000)	-.033*** (.001)
Shareholders protection	-.018*** (.000)	-.014*** (.001)	.001*** (.000)	-.149*** (.009)
Interaction variable				
MPP Loosening Index x Shareholders protection	..001*** (.000)			
MPP Loosening Index x Creditors' Rights		.007*** (.000)		
MPP Tightening Index x Shareholders protection			-.012*** (.000)	
MPP Tightening Index x Creditors' Rights				-.003*** (.000)
Bank specific variables				
Profitability	-7.160*** (.134)	-7.224*** (.208)	-3.795*** (.120)	-3.714*** (.154)
Leverage	-.024*** (.001)	-.018*** (.001)	-.009*** (.001)	-.010*** (.001)
LOG Size	.058*** (.003)	.016*** (.004)	-.128*** (.004)	-.130*** (.004)
Cost-income ratio	-.018*** (.001)	-.014*** (.001)	-.027*** (.001)	-.024*** (.001)
Asset diversity	-.323*** (.024)	-.105*** (.038)	.491*** (.022)	.379*** (.023)
Income diversity	.959*** (.028)	1.004*** (.040)	1.219*** (.026)	1.268*** (.030)
External variables				
Inflation	.024*** (.002)	.043*** (.004)	.105*** (.003)	.016*** (.006)
GDP growth	.354*** (.002)	.378*** (.003)	.360*** (.002)	.370*** (.002)
Level of interest rates	-.573*** (.005)	-.555*** (.008)	-.632*** (.006)	-.643*** (.008)
Slope of interest rates	.279*** (.002)	.326*** (.004)	.181*** (.003)	.216*** (.003)
Concentration	-.011*** (.000)	-.008*** (.000)	-.005*** (.000)	-.001*** (.000)
Crisis	.077*** (.010)	.231*** (.012)	.306*** (.009)	.219**** (.010)
Year dummies	Yes	Yes	Yes	Yes
Pre-validation tests				
Sargan-Hansen test	.096	.063	.219	.128
Arellano-Bond test for AR (2)	.807	.849	.773	.754

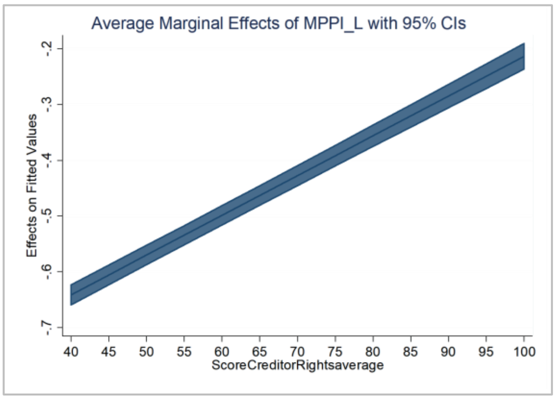
Figure 6. Marginal effects of macroprudential policies tightening and loosening sub-indexes evaluated on all levels of shareholders and creditors' rights.

Marginal effects of the macroprudential policies loosening sub-index (Panel G and H) and the macroprudential policies tightening sub-index (Panel I and J) on banks' risk, evaluated at all values of shareholders and creditors' rights. These results are calculated using the derivatives of Equation 2 along with Models 5 to 8 respectively, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.

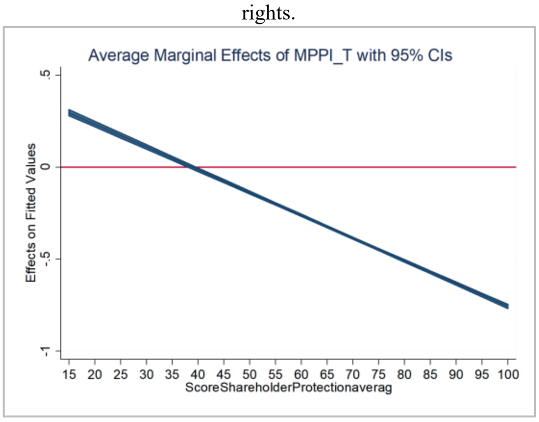
Panel G – Marginal effects of the macroprudential policies loosening sub-index (Model 5) on all levels of shareholders' rights.



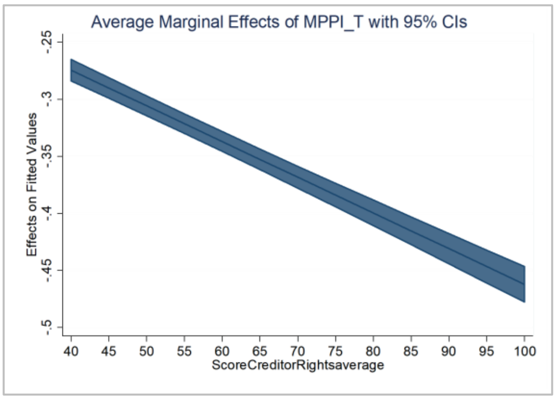
Panel H – Marginal effects of the macroprudential policies loosening sub-index (Model 6) on all levels of creditors' rights.



Panel I – Marginal effects of the macroprudential policies tightening sub-index (Model 7) on all levels of shareholders' rights.



Panel J – Marginal effects of the macroprudential policies tightening sub-index (Model 8) on all levels of creditors' rights.



When we look at the macroprudential policies tightening subindex, presented in Models 7 and 8, we get some interesting results. Tightening macroprudential policies will only lead to a decrease in banks' risk in countries with levels of shareholders' rights above 40%. Below that, a tightening policy is ineffective. These results support the capital participation theory presented by La Porta et al. (1997, 1998) and the idea that a more diversified shareholder structure and bigger capital participation can reduce the information asymmetry, the main cause of the principal–agent and moral hazard problems.

Looking at Figure 6 and delving deeper into Table 5, which reports the average marginal effects of Models 5 to 8, we can draw further interesting conclusions.

Table 5. Average marginal effects of the macroprudential tightening and loosening models

Average marginal effects of Model 5 to 8 (Table 3), with standard errors obtained by the Delta-method. The first column reports the values of Shareholders and Creditors' Rights, from the minimum observed to 100%, in increments of 5%, for each of the Investors' Protection variables. The columns 2, 4, 6 and 8 report the values of the marginal effects of macroprudential policies tightening and loosening subindexes on banks' risk, given the constant reported in the same row of the first column. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

	Loosening index (Model 5)		**Thightening index (Model 7)**		**Loosening index (Model 6)**		**Thightening index (Model 8)**	
c (in %)	dy/dx at Shareholders' Rights=c	Delta Method Standard Error	dy/dx at Shareholders' Rights=c	Delta Method Standard Error	dy/dx at Creditors' Rights=c	Delta Method Standard Error	dy/dx at Creditors' Rights=c	Delta Method Standard Error
15	-.357***	.013	.295***	.008				
20	-.353***	.012	.233***	.007				
25	-.348***	.011	.171***	.007				
30	-.343***	.010	.109***	.006				
35	-.338***	.009	.048***	.006				
40	-.334***	.008	-.014***	.005	-.641***	.009	-.275***	.005
45	-.329***	.007	-.076***	.004	-.605***	.009	-.290***	.005
50	-.324***	.006	-.138***	.004	-.570***	.009	-.306***	.004
55	-.319***	.006	-.200***	.003	-.534***	.009	-.321***	.004
60	-.315***	.005	-.262***	.003	-.499***	.009	-.337***	.004
65	-.310***	.005	-.324***	.003	-.463***	.009	-.353***	.005
70	-.305***	.005	-.386***	.003	-.427***	.009	-.368***	.005
75	-.300	.005	-.448***	.003	-.392***	.009	-.384***	.005
80	-.296***	.006	-.510***	.003	-.356***	.010	-.400***	.006
85	-.291***	.006	-.572***	.004	-.320***	.010	-.415***	.006
90	-.286***	.007	-.633***	.004	-.285***	.011	-.431***	.007
95	-.281***	.008	-.695***	.005	-.249***	.011	-.447***	.007
100	-.277***	.009	-.757***	.005	-.214***	.012	-.462***	.008

As we can see both graphically and in Table 5, for both investors' protection indexes, the impact on banks' risk is asymmetric since a loosening event will only lead to a bigger response from banks than the risk reduction verified when a macroprudential policy is adopted or tightened, in countries with poor shareholder (Models 5 and 7) and creditors' rights (Models 6 and 8). In other words, we can see that loosening macroprudential policies leads to a greater increase in banks' risk (in terms of magnitude) than the decrease verified when a macroprudential policy is tightened when investors are poorly protected. These asymmetries can be justified by the leakage in regulatory arbitrage that tends to hamper the effectiveness of tightening macroprudential policies but discard the loosening of macroprudential policies (BIS, 2018). This effect occurs because when a macroprudential policy is tightened, particularly one aimed at dampening the credit cycle, leakages can occur through (i) a shift in customer demand to nonbank credit institutions, not subject to the same macroprudential regulation as banks (Reinhardt & Sowerbutts, 2015) or (ii) a shift to foreign banks subject to the level of macroprudential regulation of home authorities (Aiyar et al., 2015). These results are also in line with Poghosyan (2020) who also reports a greater magnitude of the loosening events than tightening.

4.4. Robustness tests: Z-Score as the dependent variable

This section deploys additional robustness tests to validate our results. More specifically, we reestimate the previous models while using a different measure of banks' risk, namely the Z-score.

The literature often uses the Z-score as a measure of banks' risk.[3] Therefore, to validate our results, we reestimate Models 1 to 4 using the Z-score as our dependent variable to evaluate if the effect of macroprudential policies on banks' risk, conditional to the level of investors' protection, behaves in the same way as shown before. These results, consisting of Models 9 to 12, are reported in Table 6. We find that the relationship between macroprudential policies, as a single index or divided into two subindexes, and the two indexes of investor protection is statistically significant and with the expected signs regardless of the risk indicator in use.

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[3] This measure is used by Laeven and Levine (2009), Altunbas et al. (2018), Niţoi et al. (2019), and Gaganis et al. (2020), among others. It is calculated as the natural logarithm of $(ROA + Equity/Assets)/\sigma(ROA)$, where ROA represents the rate of return on assets and $\sigma(ROA)$ is the respective standard deviation of ROA. It is important to state that the Z-score has the inverse meaning of the standard deviation of return on assets used before, where lower values of Z-score represent a higher probability of banks' default and, consequently, higher banks' risk.

Table 6. Robustness Check: Prior banks' risk with the Z-Score as proxy for banks' risk.

Estimation of the baseline models (Model 1 to Model 4) using an alternative proxy for banks' risk: the Z-Score. Models 9 and 10 replicate Models 1 and 2, where we analyze the macroprudential policies as a single index, and Models 11 and 12 replicate Models 3 and 4, where the macroprudential policies are analyzed by their goal. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

Dependent Variable: Z-Score	Model 9	Model 10	Model 11	Model 12
Lagged dependent variable	.277*** (.001)	.285*** (.002)	.282*** (.002)	.177*** (.001)
Macroprudential Policies Index				
MPPI Index	-.048*** (.002)	-.044*** (.002)		
Resilience MPP Index			-.012*** (.003)	.009*** (.002)
Credit cycle MPP Index			.101*** (.005)	.023*** (.004)
Investors protection variables				
Creditors rights	.003*** (.000)	.003*** (.000)	.003*** (.000)	.004*** (.000)
Shareholders protection	-.003*** (.000)	-.003*** (.000)	-.001*** (.000)	-.014*** (.000)
Interaction variable				
MPP Index x Shareholders protection	.001*** (.000)			
MPP Index x Creditors rights		-.001*** (.000)		
Resilience MPP Index x Shareholders protection			-.001*** (.000)	
Credit cycle MPP Index x Shareholders protection			-.001*** (.000)	
Resilience MPP Index x Creditors rights				-.001*** (.000)
Credit cycle MPP Index x Creditors rights				.001*** (.000)
Bank specific variables				
Profitability	6.447*** (.100)	5.628*** (.176)	5.898*** (.147)	6.808*** (.132)
Leverage	.012*** (.000)	.010*** (.000)	.010*** (.000)	.011*** (.000)
LOG Size	-.044*** (.001)	-.046*** (.002)	-.048*** (.001)	-.054*** (.001)
Cost-income ratio	-.020*** (.000)	-.021*** (.000)	-.021*** (.000)	-.023*** (.000)
Asset diversity	-.127*** (.008)	-.111*** (.013)	-.121*** (.006)	-.220*** (.007)
Income diversity	.335*** (.005)	.321*** (.007)	.306*** (.007)	.458*** (.007)
External variables				
Inflation	-.026*** (.001)	-.026*** (.001)	-.036*** (.001)	-.020*** (.001)
GDP growth	.004*** (.001)	.003*** (.001)	.008*** (.001)	.010*** (.001)
Level of interest rates	-.099*** (.001)	-.102*** (.002)	-.098*** (.001)	-.113*** (.001)
Slope of interest rates	-.021*** (.001)	-.027*** /.001)	-.019*** (.001)	-.028*** (.001)
Concentration	.001*** (.000)	-.001*** (.000)	.001*** (.000)	.002** (.000)
Crisis	-.240*** (.004)	-.279*** .007)	-.289*** (.003)	-.413*** (.005)
Year dummies	Yes	Yes	Yes	Yes
Pre-validation tests				
Sargan-Hansen test	.595	.323	.541	.701
Arellano-Bond test for AR (2)	.160	.141	.183	.178

5. Conclusions

The 2007–08 financial crisis revealed the importance of looking at the bigger picture and defining a macro dimension of the prudential framework to deal with the risk derived from “herd behavior.” Despite the growing volume of academic research on the effect of macroprudential policies, both directly and indirectly, the literature ignores the link with the investors’ protection environment of each country. This study fills this gap by analyzing the interaction between macroprudential policies and investors’ protection in shaping banks’ risk.

Our results show that investor protections play a significant role in the effect of macroprudential policies on bank risk. Tightening macroprudential policies is only effective in reducing banks’ risk in countries with highly protected shareholders and creditors, while this same tightening event would induce greater risk-taking in countries with poorly protected investors. These results are explained by the greater capital participation theory when shareholders are highly protected, undermining the individual capacity of each shareholder to influence banks’ decisions, and by the increased transparency and reduced information asymmetry in countries with highly protected creditors, where the managers will be prompted to diversify the acquisitions and reduce lending, thus leading to reduced bank risk.

In addition, by analyzing macroprudential policies by their goals, we find that these policies are ineffective in curbing banks’ risk in countries with poorly protected creditors regardless of the goal of the macroprudential policy, while the same tightening event in a country with highly protected creditors leads to a reduction on banks’ risk. Moreover, in this analysis, we also find that macroprudential policies are ineffective for all values of shareholder protection, while higher levels of protection amplify this ineffectiveness.

By examining both directions of macroprudential policy adjustments individually, we conclude that the impact of macroprudential policies on banks’ risk is asymmetric. This means that loosening a macroprudential policy leads to a greater increase in banks’ risk (in terms of magnitude) than the decrease verified when a macroprudential policy is tightened or adopted. This disparity is more pronounced in countries with lower shareholders’ rights and in countries with higher levels of creditors’ rights.

Regarding the tightening or adoption of macroprudential policies, we find that while a loosening event will always lead to an increase in banks’ risk, such an increase is bigger in countries with highly protected creditors and shareholders when compared with countries with poorer investor protection. These results suggest that when safety nets are in place, and when investors are highly protected, banks are more likely to engage in risk-shifting behaviors to regain lost profitability due to a tighter macroprudential framework. This also reveals the absence of the policy makers' control while loosening macroprudential policies (which does not happen during a macroprudential policy tightening).

These results hold when we use the Z-score as a proxy for bank risk.

The present study has serious implications since it demonstrates that ignoring the relationship between macroprudential policies and investor protections may lead to misleading conclusions when evaluating the overall effectiveness of macroprudential policies. Our results also show the important role of shareholders and creditors in banks' risk-taking behavior when adapting to a new prudential environment.

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Appendix I

Variable sources and definitions.

Variable	Description	Source
Banks' risk		
Asset Risk	Annualized standard deviation of daily stock price returns times the market value of equity over the market value of the bank.	Thompson Reuters Datastream,Bankscope database and authors' calculations
Z-score	Natural logarithm of (ROA + E/A)/σ(ROA). ROA represents the rate of return on assets, E/A is the equity-to-assets ratio and σ (ROA) is the standard deviation of the rate of return on assets. A higher score suggests a lower probability of bank insolvency and, therefore, less risk.	Bankscope database and authors' calculations
Macroprudential Policy variables		
Macroprudential Policies Index	Sum of the total tightening (+1) and loosening (−1) events for the 16 macroprudential policies— Countercyclical capital buffers (CCB), Conservation, Capital Requirements, Leverage Limits (LVR), Loan Loss Provisions (LLP), Limits to credit growth (LCG), Loan Restrictions (LoanR), Limits on Foreign Currency (LFC), Limits on the Loan-to-Value ratio (LTV), Limits on the Debt-Service-to-Income ratio (DSTI), Tax Measures, Liquidity Requirements, Limits on the Loan-to-deposit ratio (LTD), Limits on Foreign Exchange positions (LFX), Reserve Requirements (RR), Systemically important financial institutions (SIFI), and Others-in year *t*	Integrated Macroprudential Policy (iMaPP) Database
Financial Systems' resilience-aimed macroprudential policies subindex	Sum of the total tightening (+1) and loosening (−1) events for the 6 macroprudential policies aiming at enhancing financial systems' resilience–Capital, LLP, CCB, Conservation, SIFI, and Liquidity.	Integrated Macroprudential Policy (iMaPP) Database and author's calculations
Credit Cycle-aimed macroprudential policies subindex	Sum of the total tightening (+1) and loosening (−1) events for the 6 macroprudential policies aiming at dampening the credit cycle-LCG, DSTI, LTV, RR, LFX, and LFC.	Integrated Macroprudential Policy (iMaPP) Database and author's calculations
Investors' protection variabls		
Shareholders' rights	Score-Ease of shareholder suits index from the World Bank Doing Business Data Set. The ease of shareholder suits index measures how likely shareholders plaintiffs are to access internal corporate evidence and recover legal expenses. It ranges from 0 to 100, where 0 represents the worst regulatory performance and 100 the best regulatory performance, *i.e.*, stronger shareholders' rights and protection.	World Bank Doing Business Data Set
Creditors' rights	Score-Strength of legal rights index from the World Bank Doing Business Data Set. The strength of legal rights index measures whether certain features that facilitate lending exist within the applicable collateral and bankruptcy laws. It ranges from 0 to 100, where 0 represents the worst regulatory performance and 100 the best regulatory performance, *i.e.*, stronger creditor's rights and protection.	World Bank Doing Business Data Set
Bank-specific variables		
Leverage	Book value of total liabilities over total assets, measured in market terms, *i.e.*, as the sum of the market value of equity and the book value of total liabilities.	Bankscope database and authors' calculations
Size	Natural logarithm of the book value of total assets.	Bankscope database and authors' calculations
Profitability	Profit after interest expenses over the book value of assets.	Bankscope database and authors' calculations
Cost–income ratio	Operating costs or noninterest costs over net operating income.	Bankscope database and authors' calculations
Income diversity	Measures the diversification across different sources of income and is given by 1 − [(net interest income − other operating income)⁄(total operating income)]	Bankscope database and authors' calculations
Asset diversity	Measures the diversification across different types of assets and is given by 1 − [(net loans − other earnings assets)⁄(total earnings assets)].	Bankscope database and authors' calculations
External variables		
GDP growth	Annual percentage change of GDP.	IMF's database
Inflation	Annual percentage change in the Consumer Price Index (CPI).	IMF's database
Level of interest rates	10-year yield rate on government bonds.	OECD database
Slope of interest rates	Difference between the 10-year yield rate and the 1-year yield rate on government bonds.	OECD database
Concentration	Measures the level of market competition in the banking sector and is given by the fraction of the assets of the three largest banks over the assets of all commercial banks in a country.	World Bank database
Crisis	Dummy variable that assumes the value 1 in the years of systemic banking crisis and 0 otherwise.	Laeven & Valencia (2020)

Appendix II

Descriptive statistics for the AE and EMDE subsamples.

	N	Mean	St. Dev.	Min.	Max.	Distribution		
						10th	50th	90th
AE subsample								
Banks' risk								
Asset risk (%)	3660	4.135	8.591	0.000	79.802	.386	1.671	8.225
Z-Score	3660	.625	.940	−3.273	3.228	−1.207	.119	1.101
Macroprudential variables								
Macroprudential policies index	3660	.689	2.021	−9	7	0	1	3
Resilience MPP index	3660	.511	1.555	−8	5	0	0	2
Credit cycle MPP index	3660	.066	.338	−3	4	0	0	1
Investors' protection variables								
Shareholders' rights	3660	83.445	12.111	50.000	90.000	60	90	90
Creditors' rights	3660	76.517	23.809	20.000	90.000	41.667	91.667	91.667
Bank-specific variables								
Leverage (%)	3660	87.751	8.833	7.093	99.635	79.987	88.381	97.134
LOG size	3660	9.354	2.125	3.984	14.854	7.073	8.865	12.696
Profitability (%)	3660	1.402	2.839	−16.936	72.844	.217	1.267	2.278
Cost–income ratio	3660	64.425	13.602	15.581	135.042	48.647	63.682	80.865
Income diversity	3660	.690	.474	−.219	2.450	.211	.566	1.427
Asset diversity	3660	.655	.396	.000	1.999	.284	.554	1.205
External variables								
GDP growth (%)	3660	1.204	1.932	−11.182	9.909	−2.300	1.900	2.700
Inflation (%)	3660	1.504	.905	−1.700	4.400	.180	1.502	2.721
Level of interest rates (%)	3660	2.065	1.199	−.219	5.087	.563	2.172	3.295
Slope of interest rates (%)	3660	1.317	4.983	−.579	31.313	.148	1.618	2.915
Concentration	3660	42.585	17.060	0.000	97.053	34.420	35.313	75.331
Crisis	3660	.199	.399	0	1	0	0	1
EMDE subsample								
Banks' risk								
Asset risk (%)	695	11.299	17.279	0.000	79.090	.046	2.139	39.019
Z-Score	695	.066	.919	−2.505	2.516	−1.169	.195	1.114
Macroprudential variables								
Macroprudential policies index	695	1.554	2.839	−5	13	−2	2	4
Resilience MPP index	695	.927	1.985	−5	7	−1	0	3
Credit cycle MPP index	695	.161	1.846	−4	11	−1	0	1
Investors' protection variables								
Shareholders' rights	695	55.094	22.179	20.000	90.000	20	70	80
Creditors' rights	695	45.854	21.886	20.000	90.000	16.667	50	75
Bank-specific variables								
Leverage (%)	695	83.445	17.198	5.533	99.625	64.361	88.717	96.939
LOG size	695	8.777	2.274	.047	14.836	5.944	8.909	11.424
Profitability (%)	695	2.068	2.803	−10.954	23.892	.163	1.743	4.303
Cost–income ratio	695	58.004	19.890	3.743	141.282	38.923	56.236	82.637
Income diversity	695	.626	.427	−.126	2.431	.160	.557	1.177
Asset diversity	695	.672	.410	.000	1.998	.208	.616	1.176
External variables								
GDP growth (%)	695	4.174	3.182	−6.022	13.900	−.227	4.939	7.300
Inflation (%)	695	4.244	2.620	−1.591	13.300	1.900	3.610	8.080
Level of interest rates (%)	695	6.333	2.712	.257	16.512	2.993	6.475	9.166
Slope of interest rates (%)	695	1.457	1.053	−.594	4.730	.148	1.364	3.019
Concentration	695	48.200	21.332	0	100.000	24.093	42.638	79.850
Crisis	695	.010	.100	0	1	0	0	1

CHAPTER III - THE CONTRIBUTION OF MACROPRUDENTIAL POLICIES TO BANKS' RESILIENCE: LESSONS FROM THE SYSTEMIC CRISES AND THE COVID-19 PANDEMIC SHOCK[4]

[4] This chapter is based on the article Matos et al. (2023):
Matos, T. F. A., Teixeira, J. C. A., and Dutra, T. M. (2023). The contribution of macroprudential policies to banks' resilience: Lessons from the systemic crisis and the COVID-19 pandemic shock. *International Review of Finance*, 1-37. https://doi.org/10.1111/irfi.12424

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ORIGINAL ARTICLE

The contribution of macroprudential policies to banks' resilience: Lessons from the systemic crises and the COVID-19 pandemic shock

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Abstract

This study examines the effectiveness of macroprudential policies in reducing the banks' risk during the COVID-19 pandemic and compares these results with the systemic banking crises years. Based on a sample of 624 banks across 40 countries during the period 2006–2020, we find that loosening capital-aimed macroprudential policies effectively reduced banks' risk during the COVID-19 pandemic, while this behavior led to increased risk during the systemic crises years. In contrast, tightening the remaining macroprudential policies during the systemic crises years and during the pandemic proved effective in reducing banks' risk. Furthermore, we show that the magnitude of the impact of macroprudential policies was stronger during the systemic crisis than that during the pandemic. Finally, we show that the results are driven by the capital requirement prudential policy, both during the systemic crisis and the COVID-19 pandemic, although the conservation buffer and the leverage limit also contributes to the ineffectiveness of these policies during the COVID-19 pandemic. The banks' leverage and loan growth also play an enhancing role of the effects of the macroprudential policies.

KEYWORDS

banks' risk, COVID-19, macroprudential policies, systemic crisis

JEL CLASSIFICATION

I1, G01, G21, G28

Abstract

This study examines the effectiveness of macroprudential policies in reducing the banks' risk during the COVID-19 pandemic and compares these results with the systemic banking crises years. Based on a sample of 624 banks across 40 countries during the period 2006–2020, we find that loosening capital-aimed macroprudential policies effectively reduced banks' risk during the COVID-19 pandemic, while this behavior led to increased risk during the systemic crises years. In contrast, tightening the remaining macroprudential policies during the systemic crises years and during the pandemic proved effective in reducing banks' risk. Furthermore, we show that the magnitude of the impact of macroprudential policies was stronger during the systemic crisis than that during the pandemic. Finally, we show that the results are driven by the capital requirement prudential policy, both during the systemic crisis and the COVID-19 pandemic, although the conservation buffer and the leverage limit also contributes to the ineffectiveness of these policies during the COVID-19 pandemic. The banks' leverage and loan growth also play an enhancing role of the effects of the macroprudential policies.

JEL classification: I1, G01, G21, and G28

Keywords: COVID-19, systemic crisis, banks' risk, macroprudential policies

1. Introduction

The post-Great Financial Crisis (GFC) agenda prompted central banks worldwide to implement a macroprudential framework to safeguard the stability of the global financial system during distress periods (Ampudia et al., 2021; BIS, 2021; Borri and Giorgio, 2022).

The use of macroprudential tools has increased globally, prompting a rapidly growing body of literature to analyze the impact of these policies on credit growth (Ghosh, 2015; Bonfim and Costa, 2017; Fendoglu, 2017; Schryder and Opitz, 2021), the housing market (Igan and Kang, 2011; Vandenbussche et al., 2015; Zhang and Zoli, 2016; Carreras et al., 2018; Poghosyan, 2020; Andries et al, 2021), the banking sector risks (Laeven and Levine, 2009; Lim et al., 2011; Blundell-Wignall and Roulet, 2013; Ghosh, 2014; Altunbas et al., 2018; Nitoi et al., 2019; Gaganis et al., 2020; Meuleman and Vennet, 2020; Matos et al., 2023), among others factors. However, as the incidence of recessions in the post-GFC era have been limited, broader adoption of these tools makes it a challenge to evaluate actual effectiveness.

The COVID-19 was declared a pandemic at a time when the global economy was already showing signs of a slowdown (Boissay and Rungcharoenkitkul, 2020; IMF, 2020; Miklaszewska et al., 2021), thus this unique crisis is the first event that is negatively affecting the global economy, providing the perfect opportunity to assess if the macroprudential framework implemented post-GFC was adequate to protect the financial system.

In this study, we analyze if the macroprudential regulatory framework, more precisely capital-aimed policies, alleviated banks’ risk-taking behavior during the COVID-19 pandemic. Using a sample of 846 banks across a set of 40 countries during the 2006–2020 period, we find that loosening capital-aimed macroprudential policies effectively reduced banks’ risk during the pandemic.

We extend our analysis by comparing two distinct crises situations, namely the GFC, commonly denoted as the systemic crisis that originated in the US housing market and spread worldwide due to linkages in the global banking system (Ramskogler, 2015; Allen and Gu, 2018), and the recent COVID-19 pandemic that triggered a humanitarian health crisis. We show that while loosening capital-aimed macroprudential policies during the pandemic proved effective, the same loosening would likely translate into greater risk-taking during the years of the systemic crisis. Conversely, successive tightening events on other macroprudential policies were effective during the systemic financial crises and the COVID-19 pandemic. Moreover, we show that macroprudential policies have a significant negative effect, that is, a greater magnitude on banks' risk during the systemic crises years than normal times or a pandemic. Furthermore, we show that the results are driven by the capital requirement prudential policy, both during the systemic crisis and the COVID-19 pandemic, albeit the conservation buffer and the leverage limit also contribute to the ineffectiveness of capital-aimed macroprudential policies during the COVID-19 pandemic. Finally, we demonstrate that the banks' leverage and loan growth play an enhancing role of the effects of the macroprudential policies.

Our study's contribution to the literature is multifold. First, our study relates and contributes to two strands of the literature. The first strand comprises studies on the effectiveness of macroprudential policies, and the second analyzes why some banks perform better than others during periods of distress. To the best of our knowledge, this is the first study that examines how macroprudential policies affect banks' risk during an actual negative event—more precisely, the COVID-19 pandemic. Second, we examine this relationship further and compare how the implications of macroprudential policies may differ during the GFC and the COVID-19 pandemic to assess if the origin of the crisis also plays an important role and should be considered when implementing such policies. Although Igan et al. (2022) analyze the impact of macroprudential policies adopted prior to the COVID-19 pandemic in alleviating banks' risk, they do so only by analyzing this isolated event. We extend this analysis by using a more robust dependent variable that measures not only the market risk but also the idiosyncratic risk, and by comparing two different crises to see if these results endure during the the systemic crisis period. Finally, this study contributes toward a better understanding of how policymakers can help mitigate the economic impact of a humanitarian health crisis in the future.

Our study, therefore, should be of interest to a broad audience of policymakers, politicians, and scholars as it uses the pandemic as an opportunity to assess how macroprudential policies can be used to increase banks' resilience and, ultimately, strengthen the global financial system, thus providing a perfect opportunity to calibrate this toolset for future events.

The remainder of this paper is organized as follows. Section 2 provides a brief review of the literature on how macroprudential policies may affect banks' risk-taking behavior differently during normal times, years of systemic crisis or during the COVID-19 pandemic. Section 3 describes the data and variables used in the empirical analysis.

Section 4 discusses the results and provides additional robustness checks. Finally, in section 5, we present our final remarks.

2. Literature review and hypothesis development

It is widely acknowledged that banks play an important role in the stability of financial markets and the economy itself. Afterall, the GFC served as a reminder that a single bank can contaminate and expose vulnerabilities in the entire financial system, even beyond borders. While macroprudential policies deal with this type of idiosyncratic risk and ultimately reduce financial instability, they do so by influencing banks' individual behavior.

The literature on the impact of macroprudential policies during different phases of the financial cycle comprises two strands. The first strand includes studies by Gauthier et al. (2012), Berger and Bouwman (2013) and Niţoi et al. (2019), among others, and focuses on the impact on individual banks' risk-taking behavior. The second strand, involving the studies of Qureshi et al. (2011), Jiménez et al. (2017), and Schroth (2021) evaluates the outcome of these policies on credit and real output for the entire economy. A consensus exists in these two strands of the literature that the pre-crisis implementation of capital macroprudential policies leads banks to reduce their default profitability and the credit crunch, thereby helping the economy recover faster. In other words, macroprudential policies are effective if implemented prior to the crisis than during the financial stress period.

The literature also shows that capital-aimed macroprudential policies, i.e. policies aiming at building a capital buffer, have an important role on these effects. Lim et al. (2011), Berger and Bouwman (2013), Claessens et al. (2014), Bitar et al. (2016), Altunbas et al. (2018), and Teixeira et al. (2020) show that capital-aimed macroprudential policies mitigate banks' individual risk and reduce externalities stemming from banking interconnectedness, or in other works reduce systemic risk.

However, there may be consequences beyond policymakers' intentions. As these policies are implemented with the goal of creating a monetary buffer that banks can use during turbulent times, avoiding default scenarios, as witnessed during the GFC, the "cost of macroprudential policy" theory indicates that this will reduce economic growth by constraining credit supply in the economy (Sanchez and Rohn, 2016; Richter et al., 2019; Belkhir et al., 2020; Ampudia et al., 2021). Therefore, restrictions on lending could potentially lead banks to engage in regulatory arbitrage by substituting credit with unsecured and less-regulated activities, potentially increasing banks' individual risk (Meuleman and Vennet, 2020). Banks can regain lost profitability by directly investing in riskier and unsupervised assets, thus increasing their individual risk.

Based on these theories, we test the hypothesis that the implementation or tightening of capital-aimed macroprudential policies during the period prior to the GFC and the COVID-19 pandemic had a significantly negative effect on banks' risk-taking behavior.

Comparing the GFC and the COVID-19 pandemic, although both these crises affected the financial markets, similarities stop there. While the GFC originated during a panic situation, following a sudden decline in asset prices and the global consequences of the financial contagion (Allen and Gu, 2018), the COVID-19 pandemic is the result of a public health emergency of international proportions. Some authors, such as Li et al. (2021) and Gunay and Can (2022), suggest that the COVID-19 pandemic has contracted global economic activities much more than the GFC.

In fact, during the COVID-19 pandemic, governments and central banks worldwide were urged to intervene in the economy to calm financial markets (Baret et al., 2020; European Central Bank, 2021). Policymakers have relaxed macroprudential policies to mitigate economic distress (Baret et al., 2020; Bergant and Forbes, 2021; Ćehajić and Košak, 2021; European Central Bank, 2021). According to Beneditksdottir et al. (2021), the main macroprudential policy adopted during the COVID-19 pandemic was the easing of capital requirements to stabilize the financial system and prevent a deeper economic crisis due to the lack of liquidity. In this context, the European Central Bank (ECB) allowed banks to temporarily operate below the capital adequacy requirements defined by Pillar II of the Basel Agreement, and governments implemented extraordinary measures such as public loan guarantees and direct support to firms to avoid a worst-case scenario (Beneditksdottir et al., 2021; ECB, 2021).

Hence, it is expected that banks in countries with loosened capital-aimed macroprudential policies will cope better with the COVID-19 crisis, as these policies are expected to increase banks' resilience (Ampudia et al., 2021) by building a monetary buffer that banks can use to absorb losses, avoid excessive deleveraging, and support lending during an economic crisis. In other words, by loosening previously developed capital buffers, banks can continue to allow credit to flow into the economy, thereby avoiding the worst-case scenario (Araujo et al., 2020; Nakatani, 2020).

The "cost of macroprudential policies" theory also explains this expected effect during a crisis period. According to Sanchez and Rohn (2016), Richter et al. (2019), Belkhir et al. (2020), and Ampudia et al. (2021), implementation or tightening of macroprudential policies hampers economic growth (i.e., the so-called cost of macroprudential policies). Therefore, the inverse may also apply, that is, loosening macroprudential policies, specifically capital-oriented strategies, will allow credit to flow back into the real economy (Araujo et al., 2020; Nakatani, 2020), thus undermining the economic consequences of the COVID-19 crisis, stimulating economic growth and reducing banks' risk.

According to Bergant and Forbes (2021), countries with more room to maneuver the implemented capital macroprudential policies, experienced less economic stress. However, data show that when the COVID-19 pandemic broke out, only seven countries in the European Union (EU) had countercyclical capital buffers above 0%, translating into little relief when loosening these policies (ECB, 2021). The lack of "policy space" was aggravated by the fact that banks were reluctant to use these buffers, primarily attributable to the stigma it could generate in the financial markets (ECB, 2021), thus limiting the potential of these policies.

In fact, thanks to Basel III and the post-GFC measures that policymakers had adopted, the banking sector was much better prepared when the COVID-19 pandemic broke out than it was before the GFC (BIS, 2021). Therefore, we test the hypothesis that during the COVID-19 pandemic, the release or loosening of capital-aimed macroprudential policies led to banks reducing their individual risk. In other words, we aim to check if macroprudential policies implemented during normal times are more effective than during a period of financial distress, and if the use of capital buffers reflects lower bank risk.

3. Data, Methodology, Variables and Summary Statistics

3.1. Data and Sample

Our empirical analysis focuses on publicly listed commercial banks and bank-holding companies during the period 2006–2020 whose data was collected from several sources. The BankFocus, a database of banks worldwide provided by Bureau van Dijk, which is the main source for bank-level data, while DataStream, a financial time series database by Refinitiv, was used to collect data for the country-level variables.

Our final sample comprises 624 banks from 40 countries, which are diversified in terms of geographical regions and levels of economic development. Table 1 presents details of the sample distribution by country and year.

Table 1 shows that our sample is in an unbalanced panel-data format because among the sampled 624 banks, not all were active during the 2006–2020 period. In addition, contributing to the unbalanced format is the fact that we winsorized the final sample at 1% and 99% of bank-level data, including banks with negative equity, to eliminate the influence of outliers from our results.

Table 1. Sample distribution by country and year

Country	Year															Total
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
Austria			4	4	4		5	5	5	5	5	5	6	7	7	62
Belgium	1	1	1		1	1	1	1	1	1			1	1		11
Brazil					2		10		11	8	8	10	9	12	13	83
Bulgaria						2	1	2	3	3	3	3	4	3	3	27
Chile					2	2								2		6
China		5		7		9	8	9	15							53
Colombia			2	2	1		3	3	3	3		3	2	2	2	26
Cyprus					1								1			2
Czech Republic				1	1	1	1				1	2	2	1	1	11
Denmark	2	3		4	4	10	11	13	12					14	13	86
Finland							1	1	1	1	1	1	5	4	4	19
France	3	3	5	6	4	4	5	5	6	5	5	4	5	5	5	70
Germany	2	3	3	3	3	5	5	6	8	7	7	6	6	7	8	79
Greece		1		1		1					5		5	5		18
Hungary												1	1		1	3
India	5	6	7	6	9	10	10	12	11	15	18		19	23	17	168
Indonesia		6	5	5	4	12	10	13	16	18	25	25				139
Ireland								1	1		1	4	4	4	4	19
Italy	2	3	3	4	2	6	6	5	5	6	6	5	8	11	14	86
Japan	17	20	16	31	21	22	25	18	20	17	20	26	22	19	21	315
Lithuania							1	1				1		1	1	5
Mexico		2	2	2		8				9						23
Netherlands		1	1	1	1	1			1		1	2			2	11
Norway							7	11	11						23	52
Peru							1				4			1		6
Philippines	3	5	4	2					9	9				11		43
Poland	1	1	1	4			4	5	4	3	5	4	5	4	5	46
Portugal							1	1	1	1	1	2	1	1	1	10
Republic of Korea									3	1	1	3		2		10
Romania							2	3	3	3	4	3		3	3	24
Russian Federation			1									9	9	8		27
Slovakia			1	2	1		2			2	1		1	1		11
Spain	4	4	5	5	5	4	5	6	5	5	6	6	6	6	5	77
Sweden			3	3			3	3	3						6	21
Switzerland							6	5	6	6	6	5	6	7	6	53
Thailand	2	2														4
Turkey	2		2	5												9
Ukraine							2						1	3	2	8
United Kingdom	6	7	9		9		7		7	8			15	15		83
United States of America			142	151	157	169	193	196	209	213	216	224	222	229	228	2549
Total	**50**	**73**	**217**	**249**	**232**	**267**	**336**	**325**	**380**	**349**	**350**	**354**	**366**	**412**	**395**	**4355**

3.2. Methodology

The empirical specification that we used to investigate if and how the effect of macroprudential policies may differ according to the financial cycle or during the COVID-19 pandemic takes the following form:

$$Risk_{i,j,t} = \alpha + \beta_1 Risk_{i,t-1} + \beta_2 MPPI_{j,t} + \beta_3 Crisis\_Dummy_{j,t} + \beta_4 (MPPI \times Crisis\_Dummy)_{j,t} + \beta_5 BankControl_{i,t} + \beta_6 CountryControl_{j,t} + Year_t + \varepsilon_{i,j,t} \ , \quad (1)$$

where the dependent variable *Risk* $_{ij,t}$ is an indicator of risk for bank *i,* located in country *j* in year *t*; *MPPI* is an index of country-specific macroprudential policy adjustments in country *j* in year *t*; and *Crisis_Dummy* is a set of dummy variables that takes the value of 1 if country *j* in year *t* is going through a crisis, either the systemic crisis or the COVID-19 crisis, and 0 otherwise. The *BankControl* variables are a set of idiosyncratic bank characteristics, and the *CountryControl* variables include a set of macroeconomic and external variables typically used in the literature as control variables. The variable $Year_t$ captures time-specific fixed effects (measure of temporal patterns), allowing us to control for the exogenous impact on the dependent variable that is not attributed to the endogenous variables. Finally, given the fact that we are using a dynamic model, we include the one-period lagged dependent variable for measuring banks' risk persistence over time due to the inter-temporal risk smoothing and competition and in response to banking regulations (Delis and Kouretas, 2011).

The interaction term *MPPI×Crisis_Dummy* is also included to analyze if the impact of the macroprudential policies changes during a crisis in shaping banks' risk. With this interaction, we can evaluate the full extent of the impact of macroprudential policies on banks' risk, both directly (β_2) and indirectly (β_4, subject to the phase of the financial cycle), as follows:

$$\frac{\partial Risk_{i,j,t}}{\partial MPPI_{j,t,m}} = \beta_{2,m} + \beta_{4,m} Crisis\_Dummy_{j,t} \ . \quad (2)$$

Equation 2 demonstrates the need to evaluate the magnitude of macroprudential policies considering the phase of the financial cycle, as the overall effect of macroprudential policies on banks' risk may shift from positive to negative or *vice versa* if country *j* is experiencing a crisis or the COVID-19 pandemic.

Endogeneity issues may be derived from the response of banks' risk and macroprudential policies in the dynamic panel data setting we use.[5] Moreover, models such as ordinary least squares (OLS) or maximum likelihood estimation (MLE), which are commonly used in the literature, maintain their consistency when the number of observations in the sample is very large and tends to infinity. To address these issues, we choose an autoregressive model based on the system generalized method of moments (sGMM), as established by Arellano and Bover (1995) and Blundell and Bond (1998). Instead of drawing assumptions about the entire distribution, this model focuses on the specific moments (called moment conditions) of the random variables. This approach is particularly effective when there is a large N and short T scenario (Blundell and Bond, 1998; Roodman, 2009).

To ensure the consistency of the sGMM estimator, we previously check the validity of two assumptions: the absence of serial correlation among the errors, and the absence of instrument proliferation. For this, we rely on two diagnostic tests, namely the Hansen test of over-identifying restrictions and the autoregressive test. The first test analyzes the aforementioned moment conditions to assess the global validity of the instruments. The second test, proposed by Arellano and Bond (1991), checks if the term error ε is serially correlated. Therefore, failure to reject the null hypothesis in both tests validates our model.

3.3. Dependent variable

Although macroprudential policies are intended to reduce systemic risks, we follow the argument that these policies are set to do so by influencing individual bank's risk-taking behavior (Beirne and Friedrich, 2014; Altunbas et al., 2018). As this change in behavior is reflected in the financial market information (Acharya et al., 2017), we measure banks' individual risk by using their asset risk, calculated by the standard deviation of asset returns, which reflects the yearly standard deviation based on the daily stock price returns multiplied by the total market value of a bank's equity over its market value. This variable, also used by Claessens et al. (2014) and Dutra et al. (2023a), perfectly reflects banks' risk as it incorporates the two components of risk, namely idiosyncratic and market risk.

[5] The possibility of endogeneity issues is highly unlikely as policymakers are not expected to adjust macroprudential policies in response to a single bank's risk-taking behavior, as a single bank only represents a small part of the entire financial system (Claessens et al., 2014). Nonetheless, we use the sGMM estimator to address any residual endogeneity.

Other measures of banks' risk are considered in the literature, such as the Z-score (Laeven and Levine, 2009; Houston et al., 2010; Lapteacru, 2016; Altunbas et al., 2018; Niţoi et al., 2019; Ashraf et al., 2020; Gaganis et al., 2020, Dutra et al., 2023b), loan loss reserves to total loans ratio (Bitar et al., 2016), and credit growth (Claessens et al., 2014; Ghosh, 2014; Cerutti et al., 2017). Therefore, we repeat the same regressions using a different indicator for banks' risk, namely, the Z-score. The results are presented and discussed in Section 3.4.2.1.

3.4. Macroprudential Policies

The data for the macroprudential policies were retrieved from the integrated macroprudential policy database (iMaPP) by the International Monetary Fund (IMF), organized and documented by Alam et al. (2019). We opt for this database because it has been updated until 2020, incorporating new evidence from the COVID-19 pandemic, thus enabling us to effectively analyze how the macroprudential framework shifted during the pandemic and how this may have influenced banks' risk-taking behavior.

The data in this database were organized at a monthly frequency. Therefore, following Meuleman and Vennet (2020), we aggregated the monthly data to obtain a yearly index of the total adjustment of each policy. This approach also follows the theory presented by Cerutti et al. (2017) and Akinci and Olmstead-Rumsey (2018), who state that the impact of macroprudential policies affects banks' risk-taking behavior during the month the announcement is made and also in the subsequent months.

Although there are several types of macroprudential policies, we focus on capital-aimed macroprudential policies, as policymakers centered on these policies when responding to the pandemic economically depressing effects (Beneditksdottir et al., 2021; Behncke, 2022). Therefore, following the literature (e.g., Alam et al., 2019), our capital-aimed index includes four macroprudential policies: leverage limits, countercyclical capital buffers, conservation buffers, and capital requirements. The remaining 12 macroprudential policies are aggregated into a single index to assess if these policies influence banks' risk-taking behavior and how they do so.

3.5. Systemic crisis and COVID-19 dummy variables

China's officially reported its first case of the coronavirus disease 19 (COVID-19) to the World Health Organization (WHO) on December 31, 2019. The literature points out that the first effect of the economic contraction due to the pandemic was observed at the beginning of 2020 (Baret et al., 2020; Boissay and Rungcharoenkitkul, 2020; Barro et al., 2020; IMF, 2020; Correia et al., 2022; Gunay and Can, 2022), and policymakers responded by loosening macroprudential policies during the same year (Beneditksdottir et al., 2021; Behncke, 2022). Therefore, based on these studies, we considered the COVID-19 pandemic dummy variable as taking the value of 1 in 2020, and 0 otherwise.

Regarding the systemic crisis dummy variable, not all countries in our sample experienced such events at the same time or with the same intensity. Therefore, we used the database presented by Laeven and Valencia (2020), allowing us to adjust our systemic crisis variable accordingly. For instance, the systemic crisis in the United States (US) and the United Kingdom (UK) started in 2007 and lasted until 2011, while in Austria, Belgium, Greece, Hungary, Ireland, Spain, and Portugal, it started in 2008 and ended in 2012. Another set of countries, namely Denmark, France, Germany, Italy, the Netherlands, and Sweden, experienced a shorter crisis from 2008 to 2009.

It is important to account for this variable because there is consensus in the literature that during crises periods, banks tend to increase their risk-taking behavior (Chen et al., 2017; Tanna et al., 2017). Also, this database does not consider the effects of the COVID-19 pandemic, justifying the use of this database to measure the systemic crisis.

3.6. Country- and bank-level control variables

Our baseline regression also includes six idiosyncratic bank characteristics known as important predictors of a bank's risks. Following the literature, specifically, Altunbas et al. (2018), Alam et al. (2019), Niţoi et al. (2019), Gaganis et al. (2020), and Dutra et al. (2023a), we include as bank-control variables (*BankControl*) the bank's leverage, size, profitability, operational efficiency (measured by the inverse of cost-income ratio), credit risk (measured as the inverse of credit quality), income diversity, and asset diversity. We also consider five country-level control variables (*CountryControl*), namely inflation rate, GDP growth rate, market concentration, level of interest rates, and the slope of interest rates. These two sets of control variables are introduced to capture the different channels through which banks' risk may shift and that is not attributable to macroprudential policies or the crisis period.

Table 2 summarizes the definitions and sources of all the variables.

Table 2. Variable sources and definitions

Variable	Description	Source
Banks' risk		
Asset Risk	Annualized standard deviation of daily stock price returns times the market value of equity over the market value of the bank.	Thompson Reuters Datastream, Bankfocus database and authors' calculations
Z-score	Natural logarithm of (ROA + E/A)/σ(ROA). ROA represents the rate of return on assets, E/A is the equity-to-assets ratio and σ (ROA) is the standard deviation of the rate of return on assets. A higher score suggests a lower probability of bank insolvency and, therefore, less risk.	Bankfocus database and authors' calculations
Macroprudential policy variables		
Capital-aimed macroprudential policies index	Sum of the total tightening (+1) and loosening (-1) events for the 4 macroprudential policies aiming at building a financial cushion, namely the leverage limit, the countercyclical capital buffer, the conservation buffer, and the capital requirements in year t.	Author's calculations based on the Integrated Macroprudential Policy (iMaPP) Database
Other macroprudential policies index	Sum of the total tightening (+1) and loosening (-1) events for the remaining 12 macroprudential policies - Loan Loss Provisions , Limits to credit growth, Loan Restrictions, Limits on Foreign Currency, Limits on the Loan-to-Value ratio, Limits on the Debt-Service-to-Income ratio, Tax Measures, Liquidity Requirements, Limits on the Loan-to-deposit ratio, Limits on Foreign Exchange positions, Reserve Requirements, Systemically important financial institutions and Others- in year t	Author's calculations based on the Integrated Macroprudential Policy (iMaPP) Database
Crisis dummy variables		
Crisis	Dummy variable that assumes the value 1 in the years of systemic banking crisis and 0 otherwise.	Laeven and Valencia (2020)
COVID-19 Crisis	Dummy variable that assumes the value 1 in the year of 2020 and 0 otherwise.	Author's calculations
Bank specific variables		
Leverage	Book value of total liabilities over total assets, measured in market terms, *i.e.*, as the sum of the market value of equity and the book value of total liabilities.	Bankfocus database and authors' calculations
Size	Natural logarithm of the book value of total assets.	Bankfocus database and authors' calculations
Profitability	Profit after interest expenses over the book value of assets.	Bankfocus database and authors' calculations
Cost-income ratio	Operating costs or non-interest costs over net operating income.	Bankfocus database and authors' calculations
Credit risk	Provisions for loan losses to total loans.	Bankfocus database and authors' calculations
Income diversity	Measures the diversification across different sources of income and is given by 1-[(net interest income-other operating income)⁄(total operating income)]	Bankfocus database and authors' calculations
Asset diversity	Measures the diversification across different types of assets and is given by 1-[(net loans-other earnings assets)⁄(total earnings assets)].	Bankfocus database and authors' calculations
Macroeconomic variables		
GDP growth	Annual percentage change of Gross Domestic Product (GDP).	Bloomberg database
Inflation	Annual percentage change in the Consumer Price Index (CPI).	Bloomberg database
Level of interest rates	10-year yield rate on government bonds.	Bloomberg database
Slope of interest rates	Difference between the 10-year yield rate and the 1-year yield rate on government bonds.	Bloomberg database
Concentration	Measures the level of market competition in the banking sector and is given by the fraction of the assets of the three largest banks over the assets of all commercial banks in a country.	World Bank database

3.7. Descriptive Statistics

As a preliminary way to explore our data, we present the graphical and descriptive evidence for the main regression variables in Table 3.

Table 3. Descriptive Statistics

	N	Mean	St. Dev.	Min.	Max.	Distribution 10th	50th	90th
Banks' risk								
Asset risk (%)	4355	5.278	10.793	0.000	79.802	0.299	1.687	12.226
Z-score	4355	0.016	0.940	-3.274	3.228	-1.199	0.127	1.112
Macroprudential Variables								
Capital-aimed MPP Index	4355	0.324	1.014	-4	6	0	0	2
Other Macroprudential Policies Index	4355	0.501	1.557	-7	13	-1	1	2
Crisis Dummy Variables								
Systemic Crisis	4355	0.169	0.375	0	1	0	0	1
COVID-19 Crisis	4355	0.091	0.287	0	1	0	0	1
Bank specific variables								
Leverage (%)	4355	87.063	10.733	5.533	99.635	78.215	88.445	97.093
LOG Size	4355	9.262	2.160	0.047	14.854	6.939	8.875	12.450
Profitability (%)	4355	1.508	2.844	-16.937	72.844	0.213	1.323	2.623
Cost-income ratio (%)	4355	63.401	14.969	3.743	141.282	45.666	63.037	81.026
Credit risk (%)	4355	2.572	4.149	0.069	81.664	0.550	1.389	5.323
Income diversity	4355	0.680	0.467	-.219	2.450	0.204	0.564	1.375
Asset diversity	4355	0.658	0.398	0.000	1.999	0.277	0.560	1.203
External variables								
GDP growth (%)	4355	1.654	2.415	-11.182	13.900	-2.300	2.000	3.400
Inflation (%)	4355	1.918	1.641	-1.700	13.300	0.200	1.741	3.200
Level of interest rates (%)	4355	2.747	2.196	-0.579	31.313	0.786	2.270	5.865
Slope of interest rates (%)	4355	1.339	4.587	-294.075	5.087	0.148	1.603	2.915
Concentration	4355	43.481	17.926	0.000	100.000	34.420	35.313	77.921

Considering the distribution of the dependent variable, which can be analyzed through Figure 1, we can observe that our sample has a mean of 5.278% and a standard deviation of 10.793%. When we examine the yearly mean in Figure 2, we can see that the asset risk presents a higher mean during the years preceding the GFC, while the average asset risk is lower in the years following the global economic crisis.

Figure 1. Distribution of the dependent variable (banks' risk).

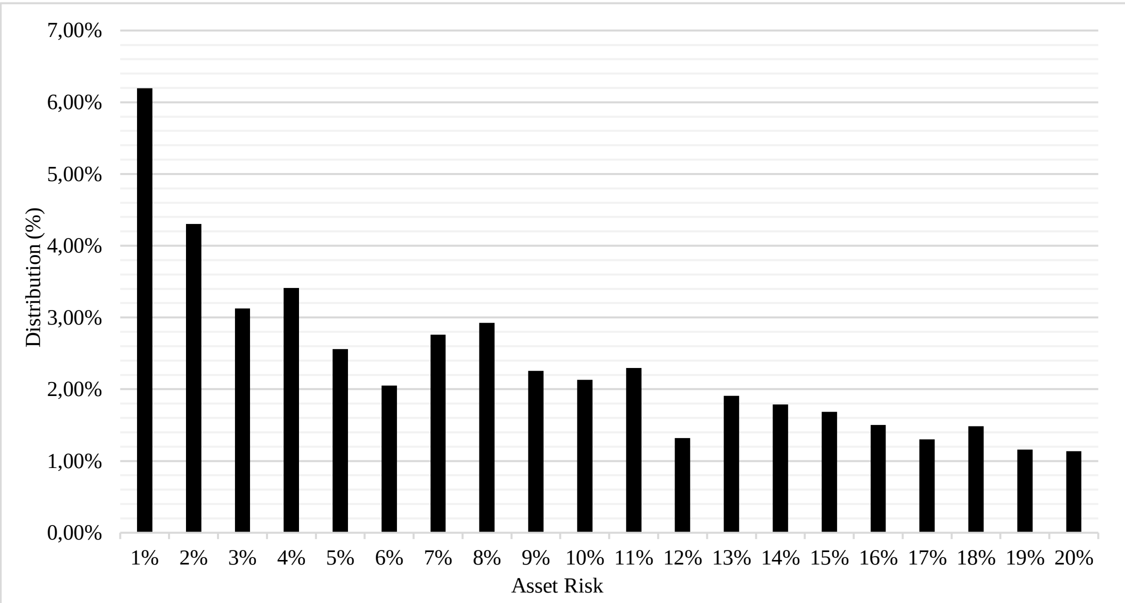
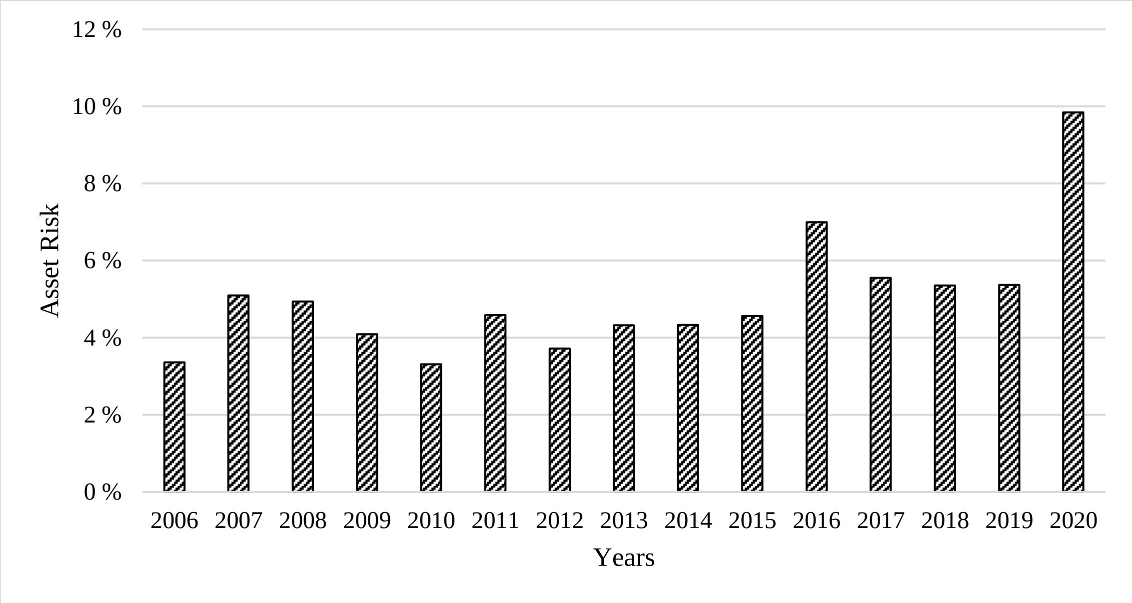


Figure 2. Yearly average of the dependent variable (banks' risk).



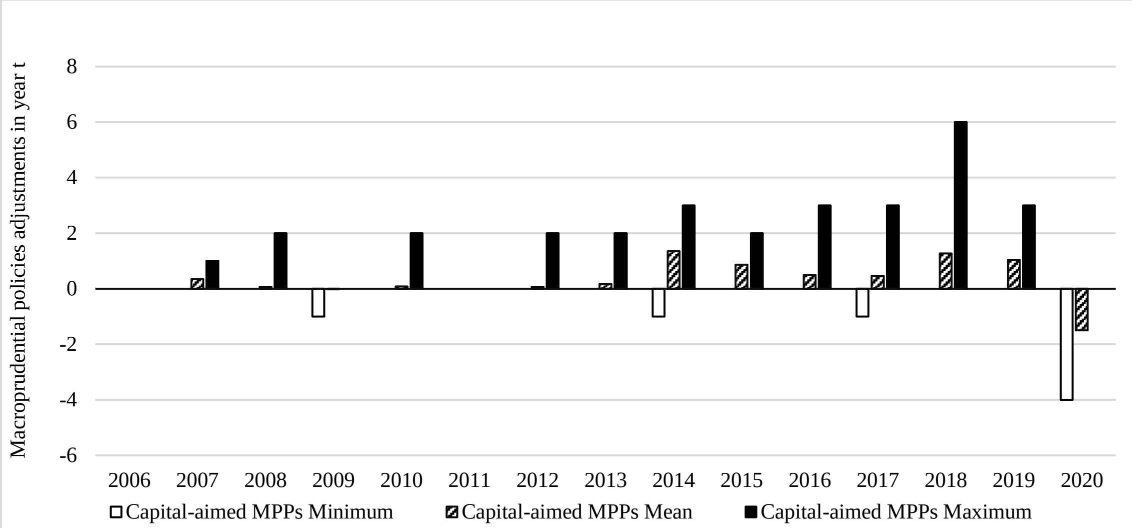
This variable presents an average asset risk of 6.995% in 2016, and an average of 9.846% in 2020. The peak verified in 2016 may be explained by the series of macroeconomic events that led to greater uncertainty and higher volatility in the global financial markets, such as Brexit (Quaye et al., 2016), the Shanghai market crash, and the US–China tariff war (Shi et al. 2021), among other factors. The peak verified in 2020 may be derived from the fact that many stock markets worldwide witnessed a period of sharp decline in March 2020 due to the COVID-19 pandemic, followed by a period of growth after the announcement of stimulus packages by governments (Vasileiou, 2021; Vasileiou et al., 2021; Ganie et al., 2022; Shi, 2022).

Next, we focus on the evolution of the macroprudential regulation scenario over the years, as shown in Figure 3.

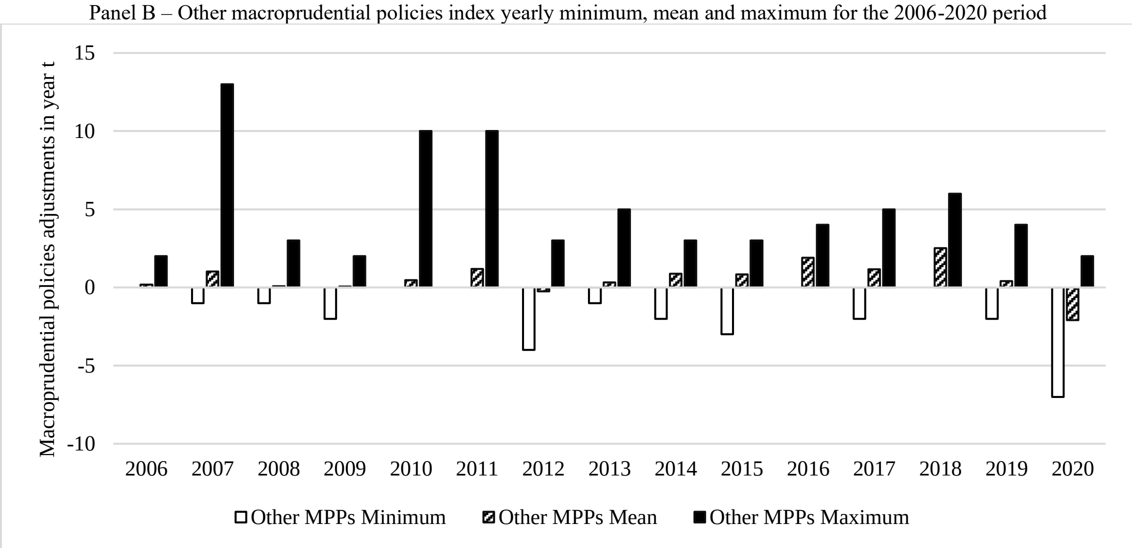
Overall, the post-GFC period was marked by the adoption or tightening of macroprudential policies. In Panel A, we see that capital-aimed macroprudential policies were increasingly adopted or tightened in 2018, reaching a maximum of six; during the pandemic, however, this policy was largely relaxed (minimum of minus four) to support the banking system. The other macroprudential policies index, represented in Panel B, shows a similar behavior, with a peak of thirteen tightening events in 2007 and a relaxation of seven policies in 2020. However, we can also see that some countries tightened these policies in 2020. In the next section, we analyze the nexus between the tightening or loosening of these policies and their impact on banks' risk during the pandemic.

Figure 3. Yearly minimum, mean and maximum of the macroprudential policies indexes.

Panel A – Capital-aimed macroprudential policies index yearly minimum, mean and maximum for the 2006-2020 period.



Panel B – Other macroprudential policies index yearly minimum, mean and maximum for the 2006-2020 period



For the remaining variables, our sample is characterized by a mean leverage of 87.06% and a yearly mean profitability of 1.51%. As for the macroeconomic variables, the average country had a GDP growth of 1.65% and an inflation rate of 1.92 %.

4. Empirical results

We present the main results based on Equation 1, beginning with a comparison of the impact of macroprudential policies during the systemic crisis and the COVID-19 pandemic. We then check for the robustness of the results using a different measure of banks' risk, specifically the Z-score, and by interacting with both macroprudential indexes simultaneously. We also confirm the results on the impact of macroprudential policies during the pandemic using a propensity score matching approach. Moreover, we check for the effect of several bank characteristics on the effectiveness of the results, namely the bank leverage, loan growth and country where the bank is located. Finally, we check for the effects of the bank and country specific variables by interacting them with the systemic crisis and COVID-19 shock dummy variables.

4.1. Systemic crisis vs COVID-19 pandemic: Does the origin matter?

Table 4 presents the baseline results for the specification in which we interact the macroprudential policy indexes with the dummy variables for the systemic crisis and the COVID-19 pandemic.

All the variables are statistically significant at the 1% level. The coefficient of the lagged dependent variable is positive, indicating that the risk tends to persist over time, consistent with the results of Castro (2013) and Pascual et al. (2015).

The coefficients of capital-aimed macroprudential policies are both significant and positive, indicating that this type of macroprudential policy *per se* is ineffective in lowering banks' risk. This supports the findings of Laeven and Levine (2009) and Franch et al. (2021) and the theory that managers will adapt to a tighter macroprudential framework by shifting banks' investments toward riskier assets, thereby increasing banks' risk.

The direct effect of other macroprudential policies index is negative, except in Model 4, suggesting that these policies are effective in reducing banks' risk. These results are consistent with those reported by Altunbas et al. (2018), Niţoi et al. (2019), Gaganis et al. (2020), and Meuleman and Vennet (2020).

Examining the crisis variables, we obtain some interesting results. First, as expected, the variable associated with the systemic crisis has a positive coefficient, implying that banks' risk is greater during the systemic crisis period. The COVID-19 crisis variable has a positive effect with a substantial magnitude over banks' risk. This result is consistent with the scenario that marked the global financial markets at the onset of the pandemic, when there was a dramatic collapse in stock value (Mishra and Mishra, 2022; Ganie et al., 2022).

Table 4. Banks' risk model with macroprudential regulation and crisis dummy variables.

The dependent variable, bank's asset risk, is given by the annualized standard deviation of daily stock price returns times the market value of equity over the market value of the bank. Model 1 and Model 2 includes the interaction terms between the systemic crisis variable and the macroprudential policies sub-indexes. Model 3 and Model 4 replicate the previous models using the COVID-19 variable in the interaction instead. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively. The null hypothesis of the Hansen test states that all instruments are jointly exogenous and that the instruments used are not correlated with residuals. The null hypothesis of the autoregressive (AR) test states that there is not second-order serial correlation in the error term.

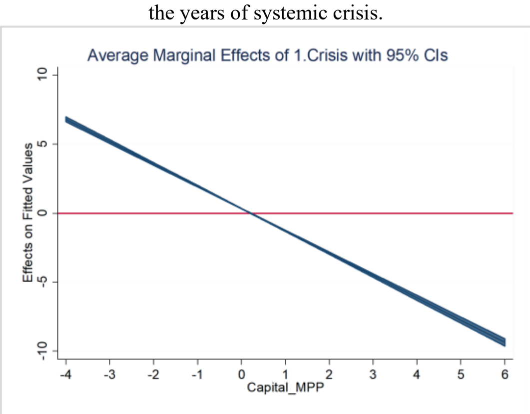
Dependent Variable: Asset Risk	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Lagged dependent variable	.784*** (.000)	.784*** (.000)	.776*** (.000)	.779*** (.000)
Macroprudential Policies Index				
Capital-aimed MPP Index	.204*** (.003)	.227*** (.003)	.136*** (.003)	.169*** (.003)
Other MPP Index	-.177*** (.002)	-.107*** (.002)	-.191*** (.002)	.039*** (.002)
Crisis Dummy variables				
Systemic Crisis	.292*** (.008)	.655*** (.009)	.386*** (.008)	.441*** (.007)
COVID-19 Crisis	9.343*** (.019)	9.653*** (.022)	1.875*** (.006)	.760*** (.004)
Interaction variable				
Capital-aimed MPP Index x Systemic Crisis dummy	-1.616*** (.022)			
Other MPPs Index x Systemic Crisis dummy		-1.654*** (.011)		
Capital-aimed MPP Index x COVID-19 Crisis dummy			.586*** (.012)	
Other MPPs Index x COVID-19 Crisis dummy				-.697*** (.008)
Bank specific variables				
Profitability	.008*** (.001)	.007*** (.001)	.001*** (.000)	.006*** (.001)
Leverage	.012*** (.000)	.009*** (.000)	.005*** (.000)	.009*** (.000)
LOG Size	-.157*** (.002)	-.158*** (.002)	-.137*** (.002)	-.144*** (.002)
Cost-income ratio	-.042*** (.000)	-.040*** (.000)	-.040*** (.000)	-.039*** (.000)
Asset diversity	-.067*** (.015)	-.067*** (.013)	-.131*** (.015)	-.278*** (.012)
Income diversity	1.623*** (.014)	1.459*** (.014)	1.510*** (.014)	1.689*** (.013)
Credit risk	0.071*** (.001)	0.081*** (.001)	.090*** (.001)	.086*** (.001)
External variables				
Inflation	.015*** (.001)	.059*** (.002)	.046*** (.002)	.006** (.001)
GDP growth	.381*** (.001)	.389*** (.001)	.382*** (.001)	.374*** (.001)
Level of interest rates	-.619*** (.002)	-.592*** (.003)	-.641*** (.002)	-.677*** (.002)
Slope of interest rates	.167*** (.001)	.130*** (.002)	.153*** (.001)	.205*** (.001)
Concentration	-.016*** (.000)	-.017*** (.000)	-.018*** (.000)	-.018*** (.000)
Year dummies	Yes	Yes	Yes	Yes
Pre-validation tests				
Sargan-Hansen test	.998	.999	.998	.998
Arellano-Bond test for AR (2)	.742	.733	748	.758

Focusing on the interactions and beginning with Models 1 and 2, which analyze the interaction between the two macroprudential policy indexes and the systemic crisis variable, we find that all the variables are statistically significant at the 1% level. Analyzing further and using Figure 4 for support, we can graphically represent the impact of macroprudential policies during the systemic crisis and the COVID-19 pandemic based on the evaluation and adjustments of each index.

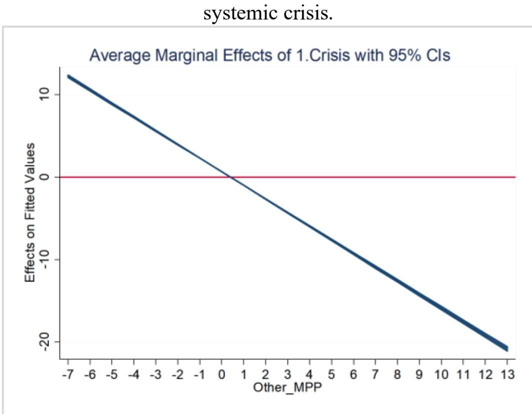
Figure 4. Marginal effects of capital-aimed and other macroprudential policies indexes during years of systemic crisis (Panel C and D) and during the pandemic (Panel E and F), evaluated on all values of the adjustments made to these policies.

Marginal effects of the capital-aimed macroprudential policies index (Panel C and E) and the other macroprudential policies index (Panel D and F) on banks' risk, evaluated at all values of the adjustments verified to these indexes during the systemic crisis and COVID-19 shock. These results are calculated using the derivatives of Equation 2 along with Models 1 to 4 respectively, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.

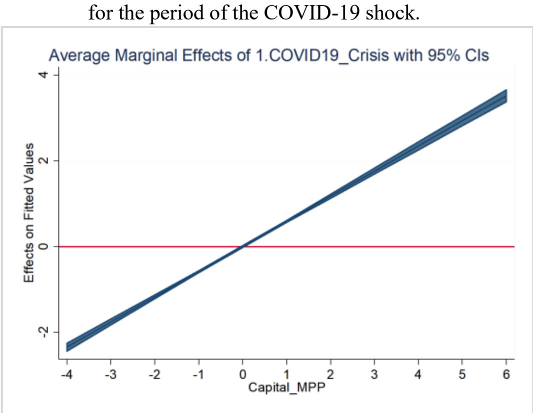
Panel C - Marginal effects of the capital -aimed macroprudential policies on all values of the adjustments, for the years of systemic crisis.



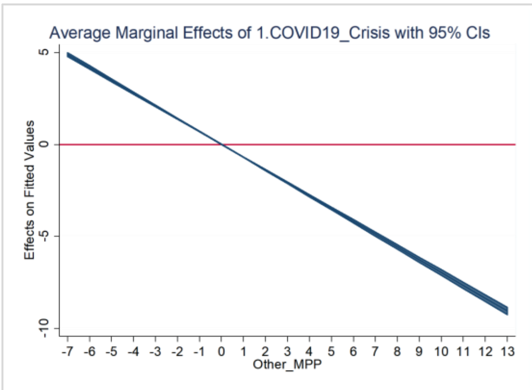
Panel D – Marginal effects of the other macroprudential policies on all values of the adjustments, for the years of systemic crisis.



Panel E - Marginal effects of the capital -aimed macroprudential policies on all values of the adjustments, for the period of the COVID-19 shock.



Panel F – Marginal effects of the other macroprudential policies on all values of the adjustments, for the period of the COVID-19 shock.



Model 1, which is represented in Panel C, shows that tightening capital-aimed macroprudential policies during systemic crises eases banks' risk, while a loose policy has the opposite effect. The efficiency of capital-aimed macroprudential policies is consistent with the theory that a tight prudential framework mitigates banks' individual risk by reducing the externalities stemming from banking interconnectedness and supports the findings of Ostry et al. (2012), Bitar et al. (2016), and Altunbas et al. (2018). These results also support the theory that a tight capital-aimed prudential framework leads banks to strengthen the requirement for supervising creditors, thereby reducing the risk associated with such credits (Fang et al., 2014).

Examining the interaction of the other macroprudential policies index with the systemic crisis variable presented in Model 2 and graphically depicted in Panel D, we find a similar pattern. During a systemic crisis, tightening macroprudential policies compels banks to reduce their risk, while loosening these policies induces reverse behavior.

When we examine the interaction with the COVID-19 variable, the inferences are quite different. Starting with the capital-aimed macroprudential policies represented in Model 3 and graphically shown in Panel E, loosening these policies can effectively help banks reduce their risk. These results validate the pandemic agenda adopted by policymakers and central banks, leading us to conclude that countries that relaxed capital-aimed policies during the pandemic helped banks mitigate the adverse impact of this event, thereby reducing their individual risk by allowing them to dive into the previously built buffers to support losses and maintain credit flow in the economy.

This also supports the findings of Ampudia et al. (2021) and Beneditksdottir et al. (2021) and is consistent with the theory of Araujo et al. (2020) and Nakatani (2020). Conversely, tightening such policies during the pandemic could have increased banks' risk, thus supporting the regulatory arbitrage theory presented by Meuleman and Vennet (2020).

Regarding the index for other macroprudential policies, in Model 4 and Panel F, we find that tightening this type of policies was effective in curbing bank risk during the COVID-19 crisis, while loosening the prudential framework contributed toward a greater bank risk. These results contrast with the agenda adopted by most countries in our sample, as they opted for loosening the macroprudential policies included in this index rather than tightening them. In other words, countries that preferred to relax these policies, as part of the pandemic agenda, actually contributed to greater risk-taking behavior than countries that adopted or tightened these policies.

Another interesting conclusion concerns the magnitude of the impact of macroprudential policies, which are analyzed in detail in Table 5.

Table 5. Average marginal effects of the crisis three-way interaction models.
Average marginal effects of Models 1 to 4 (Table 4), with standard errors obtained by the Delta-method. The first column reports the values of Shareholders and Creditors' Rights, from the minimum observed to 100%, in increments of 5%, for each of the Investors' Protection variables. The columns 2 and 4 report the values of the marginal effects of three-way interactions on banks' risk, given the constant reported in the same row of the first column. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

c	Systemic crisis (Model 1)		Systemic crisis (Model 2)		COVID-19 crisis (Model 3)		COVID-19 crisis (Model 4)	
	dy/dx at Capital-aimed MPPs=c	Delta Method Std. Error	dy/dx at Other MPPs=c	Delta Method Std. Error	dy/dx at Capital-aimed MPPs=c	Delta Method Std. Error	dy/dx at Other MPPs=c	Delta Method Std. Error
-7			12.233***	.081			4.880***	.055
-6			10.579***	.070			4.183***	.047
-5			8.925***	.060			3.486***	.039
-4	6.791***	.092	7.271***	.049	-2.345***	.048	2.789***	.031
-3	5.175***	.070	5.617***	.038	-1.759***	..036	2.091***	.023
-2	3.559***	.047	3.963***	.028	-1.172***	.024	1.394***	.016
-1	1.943***	.025	2.309***	.018	-.586***	.012	.697***	.008
0	.327***	.006	.655***	.009	-	-	-	-
1	-1.289***	.021	-.999***	.009	.586***	.012	-.697***	.008
2	-2.905***	.043	-2.654***	.017	1.172***	.024	-1.394***	.016
3	-4.521***	.065	-4.308***	.027	1.759***	.036	-2.091***	.023
4	-6.137***	.088	-5.962***	.038	2.345***	.048	-2.789***	.031
5	-7.753***	.111	-7.616***	.049	2.931***	.060	-3.486***	.039
6	-9.369***	.133	-9.270***	.059	3.517***	.072	-4.183***	.047
7			-10.924***	.070			-4.880***	.055
8			-12.578***	.081			-5.577***	.062
9			-14.232***	.091			-6.274***	.070
10			-15.886***	.102			-6.971***	.078
11			-17.540***	.113			-7.668***	.086
12			-19.194***	.124			-8.366***	.094
13			-20.848***	.134			-9.063***	.101

As can be observed, banks' risk-taking behavior response toward changes in the macroprudential framework was much more intense during the systemic crisis period than during the pandemic or even "normal" years (β_2 coefficients). These results show the importance of macroprudential policies in taming banks' risk during crises and avoiding a deeper economic recession.

Finally, with respect to either the bank or country level, we find that the signs and magnitudes of the control variables are as expected.

4.2. Robustness checks

To demonstrate the relevance of our findings on the effectiveness of macroprudential policies during the systemic crisis years and the COVID-19 pandemic, we employ a different measurement for banks' risk, namely the Z-score. We then employed a propensity score matching method to confirm the impact of macroprudential policies during the pandemic.

4.2.1 Different measure of banks' risk - The Z-Score

The literature on banks' performance uses the Z-Score as a measure of banks' risk. This variable measures the variability in banks' returns that can be absorbed by banks' capital, without such banks becoming insolvent. Therefore, higher Z-score levels indicate a less risky bank. We now estimate Models 5 to 8 using the Z-score as the dependent variable. Table 6 presents the results.

The results show that the estimated coefficients associated with the two macroprudential policy indices are statistically significant and according to expectations. These results validate our previous findings on how policymakers should calibrate the macroprudential framework during times of distress.

Table 6. Robustness Check: Prior banks' risk models with the Z-Score as proxy for bank risk.

Estimation of the baseline models (Model 1 to Model 4) using an alternative proxy for banks' risk: the Z-Score. Models 5 and 6 replicate Models 1 and 3.2, where we analyze the macroprudential policies interaction with the systemic crisis dummy variable, and Models 7 and 8 replicate Models 3 and 4, where the macroprudential policies are analyzed interacting with the COVID-19 dummy variable. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

Dependent Variable: Z-Score	**Model 5**	**Model 6**	**Model 7**	**Model 8**
Lagged dependent variable	.181***	.185***	.179***	.184***
	(.001)	(.001)	(.001)	(.001)
Macroprudential Policies Index				
Capital-aimed MPP Index	-.042***	-.041***	-.029***	-.041***
	(.001)	(.002)	(.001)	(.002)
Other MPP Index	-.015***	-.015***	-.016***	-.008***
	(.001)	(.001)	(.001)	(.001)
Crisis Dummy variables				
Systemic Crisis	-.238***	-.230***	-.240***	-.234***
	(.006)	(.006)	(.004)	(.005)
COVID-19 Crisis	-.873***	-.881***	-.778***	-.807***
	(.005)	(.006)	(.007)	(.006)
Interaction variable				
Capital-aimed MPP Index x Systemic Crisis dummy	.121***			
	(.012)			
Other MPPs Index x Systemic Crisis dummy		-.029***		
		(.006)		
Capital-aimed MPP Index x COVID-19 Crisis dummy			-.120***	
			(.005)	
Other MPPs Index x COVID-19 Crisis dummy				.032***
				(.002)
Bank specific variables				
Profitability	.070**	.071***	.070***	.072***
	(.001)	(.001)	(.001)	(.001)
Leverage	.012***	.013***	.012***	.013***
	(.000)	(.000)	(.000)	(.000)
LOG Size	-.061***	-.060***	-.061***	-.059***
	(.001)	(.001)	(.001)	(.001)
Cost-income ratio	-.023***	-.023***	-.023***	-.023***
	(.000)	(.000)	(.000)	(.000)
Asset diversity	-.257***	-.269***	-.260***	-.286***
	(.006)	(.009)	(.006)	(.006)
Income diversity	.480***	.494***	.487***	.505***
	(.006)	(.006)	(.007)	(.005)
Credit risk	-.011***	-.011***	-.011***	-.011***
	(.000)	(.000)	(.000)	(.000)
External variables				
Inflation	-.019***	-.020***	-.022***	-.021***
	(.001)	(.001)	(.001)	(.001)
GDP growth	.007***	.009***	-.008***	.008***
	(.001)	(.001)	(.001)	(.001)
Level of interest rates	-.083***	-.082***	-.084***	-.085***
	(.001)	(.001)	(.001)	(.001)
Slope of interest rates	-.032***	-.030***	-.031***	-.029***
	(.001)	(.001)	(.001)	(.001)
Concentration	.0004***	.000	.0002***	.000
	(.000)	(.000)	(.000)	(.000)
Year dummies	Yes	Yes	Yes	Yes
Pre-validation tests				
Sargan-Hansen test	.992	.998	.989	.948
Arellano-Bond test for AR (2)	.174	.158	.195	.189

4.2.2. Different approaches and specifications

4.2.2.1. Propensity-score matching

To confirm the previous results regarding the impact of capital-aimed macroprudential policies and other macroprudential policies indexes during the pandemic, we employed propensity-score matching as an alternative method. This approach was used in prior studies such as Hasan et al. (2020) and Trihn et al. (2022).

This technique assesses the variance in banks' risk attributed to each macroprudential index by matching a treated group of banks with a control group. Toward this, we control various bank and country characteristics that were previously presented and adopt a 1:1 matching condition based on the nearest neighbor approach to ensure that the treatment group, that is, a group of banks from countries where policymakers chose to loosen each type of macroprudential policy index, is sufficiently similar to the control group (*i.e.*, banks from countries that did not change the macroprudential framework during the pandemic).

The treatment variables were based on previous macroprudential indexes. These are dummy variables that take the value of 1 if the country loosened each type of macroprudential policy index during the pandemic, and 0 otherwise. Table 7 presents the results.

Table 7. Robustness Check: Propensity-Score Matching approach.
Propensity-score matching with a 1:1 matching condition, based on the nearest neighbor approach. The standard errors are corrected according to the work of Abadie and Imbens (2016). The "treatment" variables were constructed based on the previous indexes. These are dummy variables, taking the value of 1 if the country loosened each type of these macroprudential policies during the pandemic (year 2020), and 0 otherwise.

Dependend variable: Asset Risk	**Propensity-score matching with nearest neighbor**			
Number of obs: 390	**Average Treatment Effect on the Treated (ATET)**	**Standard Error**	**95% Confidence Interval**	**p-value**
Capital-aimed Macroprudenial Policies - Loosening	-11.414	.905	(-13.188, -9.639)	0.000
Other Macroprudential Policies - Loosening	3.808	1.661	(.552, 7.064)	0.022

The average treatment effect presented in Table 7 confirms our previous findings: loosening capital-aimed macroprudential policies during the pandemic contributed to less risk-taking by banks when compared to banks in countries where such loosening did not occur. This approach also validates previous results regarding the other macroprudential policies index; in other words, loosening this index contributed to an increase in banks' risk.

4.2.2.2. The simultaneous effect of both indexes of macroprudential policies

In this section, we re-estimate the main models considering the simultaneous interaction of both macroprudential policies indexes with the systemic crisis variable and the COVID-19 shock. This approach allows us to identify if the effect of the capital-aimed policies is being absorbed by the other policies index (or vice versa). The results are presented on Model 9 and 10, in Table 8.

Table 8. Robustness Check: Prior banks' risk models considering the interaction with both macroprudential policies indexes simultaneously.

Estimation of the baseline models in a specification where we interact the systemic crisis variable (Model 9) and the COVID-19 dummy variable (Model 10) with both indexes simultaneously. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

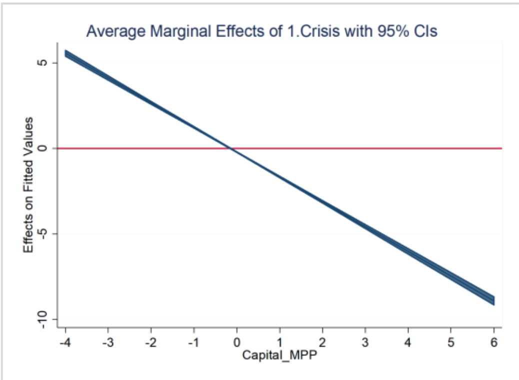
Dependent Variable: Asset Risk	**Model 9**	**Model 10**
Lagged dependent variable	.789*** (.000)	.786*** (.000)
Macroprudential Policies Index		
Capital-aimed MPP Index	.233*** (.003)	.104*** (.004)
Other MPP Index	-.026*** (.002)	-.055*** (.002)
Crisis Dummy variables		
Systemic Crisis	.527*** (.009)	.398*** (.007)
COVID-19 Crisis	9.787*** (.024)	9.643*** (.021)
Interaction variables		
Capital-aimed MPP Index x Systemic Crisis dummy	-1.447*** (.003)	
Other MPPs Index x Systemic Crisis dummy	-.026*** (.002)	
Capital-aimed MPP Index x COVID-19 Crisis dummy		.704*** (.013)
Other MPPs Index x COVID-19 Crisis dummy		-.769*** (.011)
Bank specific variables		
Profitability	.012*** (.001)	.010*** (.001)
Leverage	.012*** (.000)	.014*** (.000)
LOG Size	-.175*** (.002)	-.171*** (.002)
Cost-income ratio	-.042*** (.000)	-.041*** (.000)
Asset diversity	-.048*** (.013)	-.153*** (.014)
Income diversity	1.542*** (.013)	1.713*** (.013)
Credit risk	0.069*** (.001)	0.070*** (.001)
External variables		
Inflation	.056*** (.002)	-.005** (.002)
GDP growth	.382*** (.001)	.359*** (.001)
Level of interest rates	-.594*** (.002)	-.658*** (.003)
Slope of interest rates	.132*** (.002)	.203*** (.002)
Concentration	-.018*** (.000)	-.016*** (.000)
Year dummies	Yes	Yes
Pre-validation tests		
Sargan-Hansen test	.999	.997
Arellano-Bond test for AR (2)	.734	.769

Overall, we find that all the variables considered, including the interactions, maintain their statistical significance at the 1% level. Starting with the analysis of the effect of macroprudential policies during the systemic crisis (Model 9), we find that the individual effect of the macroprudential policies indexes validate our previous results. Regarding the interaction variables, graphically depicted in Figure15, we conclude that tightening both the capital-aimed macroprudential policies index (Panel G) or the other macroprudential policies index (Panel H), during years of systemic crisis, leads to decreased banks' risk, as previously determined.

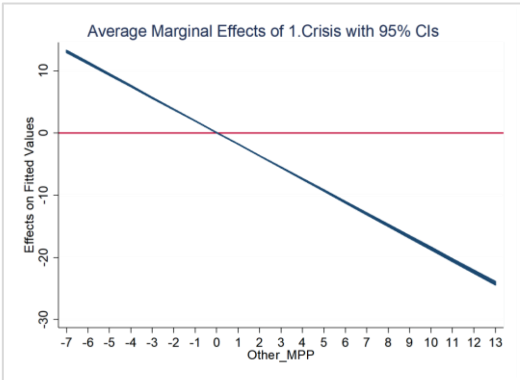
Figure 5. Marginal effects of capital-aimed and other macroprudential policies indexes during years of systemic crisis (Panel G and H) and during the COVID-19 shock (Panel I and J), evaluated on all values of the adjustments made to these policies, considering the simultaneous interaction.

Marginal effects of the capital-aimed macroprudential policies index (Panel G and I) and the other macroprudential policies index (Panel H and J) on banks' risk, evaluated at all values of the adjustments verified to these indexes during the systemic crisis and during the COVID-19 pandemic shock. These results are calculated using the derivatives of Equation 2 along with Models 9 and 10 respectively, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.

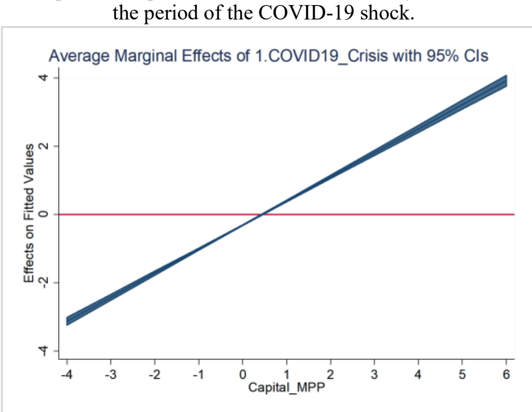
Panel G - Marginal effects of the capital-aimed macroprudential policies on all values of the adjustments, for the years of systemic crisis.



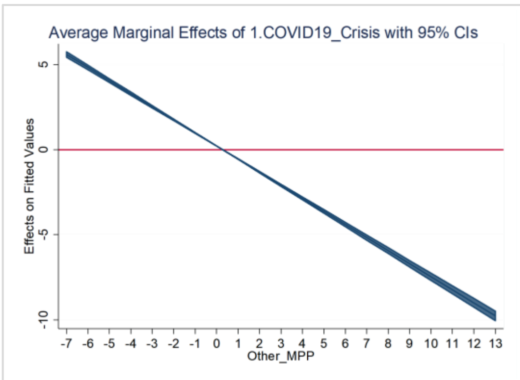
Panel H - Marginal effects of the other macroprudential policies on all values of the adjustments, for the years of systemic crisis.



Panel I - Marginal effects of the capital-aimed macroprudential policies on all values of the adjustments, for the period of the COVID-19 shock.



Panel J - Marginal effects of the capital-aimed macroprudential policies on all values of the adjustments, for the period of the COVID-19 shock.



Looking at the interactions of the macroprudential policies indexes with the COVID-19 shock variable (Model 10), and regarding the effectiveness of each macroprudential policies index, graphically depicted on Panels I and J, we find that the previous results still stand: tightening any of the capital-aimed macroprudential policies (Panel I) during the pandemic would translate in an increase of banks' risk, while tightening the other macroprudential policies index (Panel J) would lead to a reduction in banks' risk.

4.2.3. The role of bank-specific characteristics

The effectiveness of macroprudential policies might be impacted by several factors that are not identified in our analysis. To deal with this caveat, we interact the macroprudential policies indexes with different bank-specific variables, enabling us to assess if these play an important role of if they influence the results.

4.2.3.1. Banks' leverage

The literature shows that the banks' capital buffer play an important role on its' behavior and decision-making process during periods of crisis. By maintaining higher levels of capital buffers, *i.e.* more shareholder capital at risk, the banks will then also be more prudent and reduce their appetite for riskier investments (Thamae and Odhiambo, 2021). Furthermore, these increased buffers translate in a higher capacity to absorb unexpected losses and avoid default scenarios (Altunbas et al., 2018; Ampudia et al., 2021; Andries et al., 2021; Igan et al., 2022).

On this line of thought, we interact each of the macroprudential policies with the banks' leverage since this variable is closely related to the banks' capital ratio. These results are presented in Models 11 and 12 of Table 9.

As we can see, the previous results regarding the effectiveness of the macroprudential policies still stand. Furthermore, the banks' leverage plays an enhancing role of the effectiveness of the macroprudential policies, meaning that these policies are more effective in curbing banks' risk if the bank presents a higher leverage.

Again, these results stand out the importance of the macroprudential framework in controlling banks' risk, specifically for those with higher leverage.

Table 9. Robustness Check: Prior banks' risk models considering the interaction of the macroprudential policies with several bank-specific variables.

Estimation of the baseline models in a specification where we interact the macroprudential policies indexes with the leverage and the loan growth of the bank and with a dummy variable that takes the value of 1 if the bank is in the EU and 0 otherwise. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively. All models were previously validated for the Hansen test and the AR (2) test. For simplification purposes, we only present the coefficients for the variables of interest.

		Dependent Variable: Asset Risk	Coefficients
Leverage Effect	Model 11	**Macroprudential Policies Indexes**	
		Capital-aimed MPP Index	2.008*** (.069)
		Other MPP Index	-.130*** (.002)
		Bank-specific variable	
		Leverage	-.061*** (.001)
		Interaction variables	
		Leverage x Capital-aimed MPP Index	-.020*** (.001)
	Model 12	**Macroprudential Policies Indexes**	
		Capital-aimed MPP Index	.196*** (.006)
		Other MPP Index	-.259*** (.026)
		Bank-specific variable	
		Leverage	-.067*** (.001)
		Interaction variable	
		Leverage x Other MPP Index	-.005*** (.000)
Loan Growth Effect	Model 13	**Macroprudential Policies Indexes**	
		Capital-aimed MPP Index	.272*** (.008)
		Other MPP Index	.078*** (.000)
		Bank-specific variable	
		Loan Growth (%)	.009*** (.000)
		Interaction variable	
		Loan Growth x Capital-aimed MPP Index	-.013*** (.000)
	Model 14	**Macroprudential Policies Indexes**	
		Capital-aimed MPP Index	.250*** (.006)
		Other MPP Index	-.053*** (.000)
		Bank-specific variable	
		Loan Growth (%)	.009*** (.000)
		Interaction variable	
		Loan Growth x Other MPP Index	-.007*** (.000)
European Union Effect	Model 15	**Macroprudential Policies Indexes**	
		Capital-aimed MPP Index	.299*** (.010)
		Other MPP Index	-.176*** (.003)
		Region dummy variable	
		EU dummy variable	.369*** (.020)
		Interaction variable	
		EU dummy x Capital-aimed MPP Index	-.140*** (.009)
	Model 16	**Macroprudential Policies Indexes**	
		Capital-aimed MPP Index	.438*** (.008)
		Other MPP Index	.035*** (.004)
		Region dummy variable	
		EU dummy variable	1.314*** (.020)
		Interaction variable	
		Loan Growth x Other MPP Index	-1.129*** (.009)

4.2.3.2. Loan growth

The growth in loans, especially if abnormal, is regarded in the literature as an important source of banks' risk, mainly during times of distress (Foos et al., 2010; Altunbas et al., 2011; Köhler, 2012; Amador et al., 2013). Considering this, we interact the macroprudential policies indexes with the banks' loan growth to assess if the loans growth influence banks' risk response to a tighter macroprudential framework. The results are presented in Models 13 and 14 of Table 9.

Starting with the interaction with the capital-aimed macroprudential policies (Model 13), we find that higher levels of loan growth will increase the ineffectiveness of these policies and contribute to higher risk. Additionally, analyzing the effect of the loan growth over the other macroprudential policies (Model 14), we find the opposite behavior, where these policies will be more effective in curbing banks' risk for higher values of loan growth.

4.2.3.3. The European Union effect

Finally, we investigate potential regional differences effect on the main results. To do so, we interact the macroprudential policies indexes with a dummy variable that takes a value of 1 if the bank is in the EU or 0 otherwise. This specification allows us to assess if the regulatory differences between the EU and the remaining countries influence the effectiveness of the prudential framework. The results are presented on Models 15 and 16 of Table 9.

Starting with the interaction with the capital-aimed macroprudential policies (Model 15), we find that these policies are also ineffective in the EU. However, the risk increase verified when a capital-aimed policy is tightened in the EU (0.159) is lower than the same tightening event in the remaining countries (0.299).

Looking at the other macroprudential policies index (Model 16), we find some interesting results: These policies are ineffective in the remaining countries, while being effective in curbing banks' risk in the EU. Overall, our results show that the macroprudential framework is more effective in the EU when compared with the remaining countries composing the sample.

4.2.4. The capital-aimed macroprudential policies individual effect

It is important to assess if the results are driven by any particular macroprudential policy included in our index. To do so, we split the previously built capital-aimed macroprudential index in the four policies composing this index. This approach not only allows us to evaluate each macroprudential policy individual contribution, but also lets us deal with the cases where a tightening event is nulled by a loosening event in another policy when we use an aggregated index. The results are presented on Table 10, in Models 17 and 18.

Table 10. Robustness Check: Prior banks' risk models considering the interaction of the individual macroprudential policies with the systemic crisis and COVID-19 dummy variables.

Estimation of the baseline models but considering the simultaneous interaction of the individual capital-aimed macroprudential policies with the systemic crisis dummy variable (Model 17) and with the COVID-19 dummy variable (Model 18). The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively. Both models were previously validated for the Hansen test and the AR (2) test. For simplification purposes, we only present the coefficients for the variables of interest.

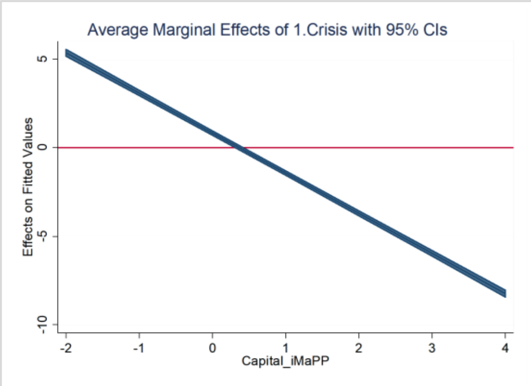
	Dependent Variable: Asset Risk	Coefficients
Model 17	**Individual Macroprudential Policies**	
	Capital requirement	.288*** (.005)
	Leverage limit	.031*** (.006)
	Conservation buffer	1.247*** (.007)
	Countercyclical capital buffer	-4.731*** (.021)
	Other MPP Index	-.157*** (.002)
	Interaction variables	
	Capital requirement x Systemic Crisis dummy	-2.265*** (.026)
	Leverage limit x Systemic Crisis dummy	omitted
	Conservation buffer x Systemic Crisis dummy	6.457*** (.744)
	Countercyclical Capital Buffer x Systemic Crisis dummy	omitted
Model 18	**Individual Macroprudential Policies**	
	Capital requirement	.292*** (.007)
	Leverage limit	-.172*** (.007)
	Conservation buffer	.533*** (.010)
	Countercyclical capital buffer	-2.320*** (.023)
	Other MPP Index	-.091*** (.002)
	Interaction variables	
	Capital requirement x COVID-19 Crisis dummy	.409*** (.033)
	Leverage limit x COVID-19 Crisis dummy	1.304*** (.022)
	Conservation buffer x COVID-19 Crisis dummy	6.483*** (.054)
	Countercyclical Capital Buffer x COVID-19 Crisis dummy	-5.238*** (.059)

Starting with the analysis of each policy during the systemic crisis (Model 17), we find that only the capital requirement and the conservation buffer policies are validated and statistically significant. To better evaluate the effectiveness of these two macroprudential policies, we graphically represent their marginal effects in Figure 6.

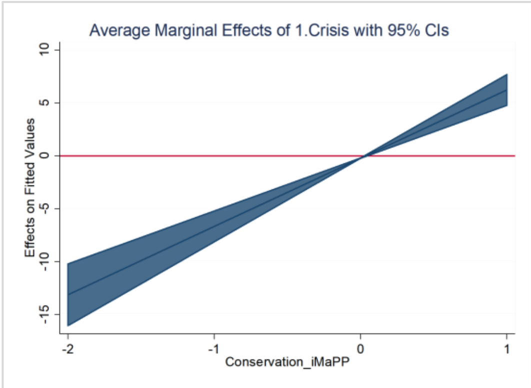
Figure 6. Marginal effects of the individual capital-aimed and other macroprudential policies during years of systemic crisis (Panel K and L), evaluated on all values of the adjustments made to these policies during this period.

Marginal effects of the capital requirement (Panel K) and the conservation buffer (Panel J) macroprudential policies on banks' risk, evaluated at all values of the adjustments verified to these policies during the systemic crisis. These results are calculated using the derivatives of Equation 2 along with Model 17, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.

Panel K - Marginal effects of the capital requirement macroprudential policy on all values of the adjustments, for the years of systemic crisis.



Panel L - Marginal effects of the conservation buffer macroprudential policy on all values of the adjustments, for the years of systemic crisis.



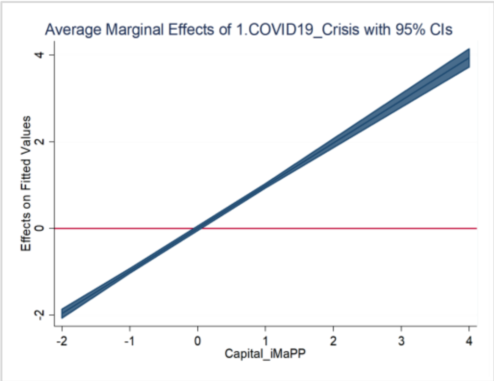
As we can see, the results regarding the effectiveness of the capital-aimed macroprudential policies during the systemic crisis are driven by the capital requirement macroprudential policy (Panel K), while tightening the conservation buffer (Panel L) would translate in an increase of banks' risk.

Focusing on Model 18, where we interact each of the capital-aimed macroprudential policies with the COVID-19 shock dummy variable, we obtain some interesting results. Using the marginal effect of each policy, presented in Figure 7 as support, we find that the macroprudential policies that contribute to the ineffectiveness of our index during the pandemic are the capital requirement (Panel M) and the conservation buffer (Panel O). Furthermore, our results show that tightening the leverage ratio (Panel N) and the countercyclical capital buffer (Panel P) could translate into risk reduction during this period.

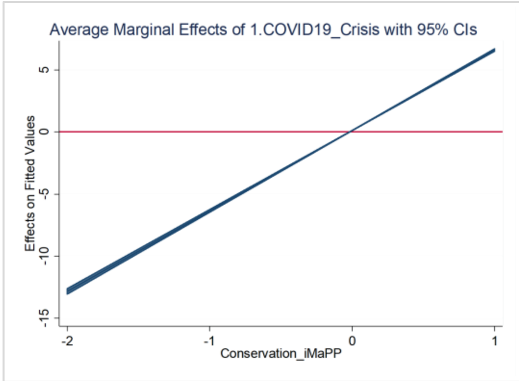
Figure 7. Marginal effects of the individual capital-aimed and other macroprudential policies during the COVID-19 pandemic (Panel M to P), evaluated on all values of the adjustments made to these policies during this period.

Marginal effects of the capital requirement (Panel M), the conservation buffer (Panel N), the the leverage limit (Panel O) and the countercyclical capital buffer (Panel P) macroprudential policies on banks' risk, evaluated at all values of the adjustments verified to these policies during the COVID-19 shock period. These results are calculated using the derivatives of Equation 2 along with Model 18, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.

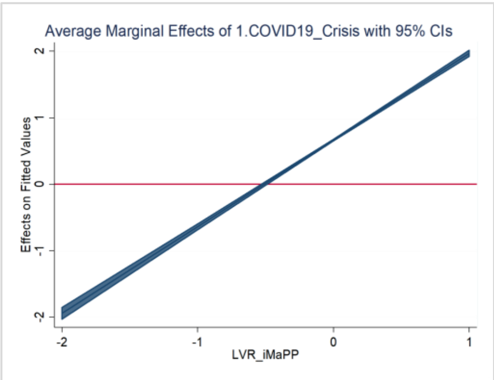
Panel M - Marginal effects of the capital requirement macroprudential policy on all values of the adjustments, for the period of the COVID-19 shock.



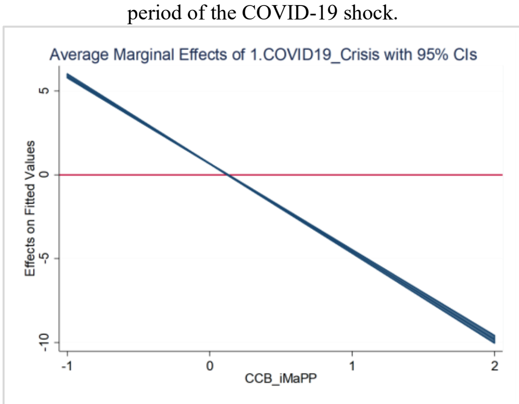
Panel N - Marginal effects of the conservation buffer macroprudential policy on all values of the adjustments, for the period of the COVID-19 shock.



Panel O - Marginal effects of the leverage limit macroprudential policy on all values of the adjustments, for the period of the COVID-19 shock.



Panel P - Marginal effects of the countercyclical capital buffer macroprudential policy on all values of the adjustments, for the period of the COVID-19 shock.



4.2.5. The role of the systemic crisis and the COVID-19 pandemic shock

Finally, we check if the systemic crisis and the COVID-19 pandemic shock influence the coefficients of all the variables considered in the analysis. Following Teixeira et al. (2014) and Nitoi et al. (2019), we re-estimate the main models interacting each variable with the systemic crisis dummy variable (Model 19) and then with the COVID-19 pandemic shock variable (Model 20). This approach allows us to evaluate the difference between the impact of each variable during 'normal times' and during a crisis or the pandemic, identifying the individual contribution of each variable to the behavior of banks' risk during times of distress. The results regarding the interaction with the systemic crisis dummy variable are presented below on Table 11.

Table 11. Robustness Check: Banks' risk model considering the interaction all the variables with the systemic crisis dummy variable.

Estimation of the baseline model but considering the interaction of all the bank-specific and country-specific variables with the systemic crisis dummy variable. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

Dependent Variable: Asset Risk	**Model 19**
Lagged dependent variable	.802*** (.000)
Macroprudential Policies Index	
Capital-aimed MPP Index	.227*** (.004)
Other MPP Index	-.006** (.003)
Crisis Dummy variables	
Systemic Crisis	.983*** (.246)
COVID-19 Crisis	9.723*** (.025)
Bank specific variables	
Profitability	-.013*** (.001)
Leverage	.021*** (.000)
LOG Size	-.177*** (.002)
Cost-income ratio	-.046*** (.000)
Asset diversity	.127*** (.022)
Income diversity	1.745*** (.019)
Credit risk	.065*** (.001)
External variables	
Inflation	.038*** (.003)
GDP growth	.363*** (.002)
Level of interest rates	-.494*** (.005)
Slope of interest rates	.148*** (.002)
Concentration	-.023*** (.000)
Interaction variables	
Capital-aimed MPP x Systemic Crisis dummy	-1.486*** (.035)
Other MPPx Systemic Crisis dummy	-3.426*** (.010)
Profitability x Systemic Crisis dummy	-.119*** (.007)
Leverage x Systemic Crisis dummy	-.068*** (.002)
LOG Size x Systemic Crisis dummy	-.068*** (.002)
Cost-income ratio x Systemic Crisis dummy	.060*** (.001)
Asset Diversity x Systemic Crisis dummy	.397*** (.045)
Income Diversity x Systemic Crisis dummy	-1.301*** (.038)
Credit Risk x Systemic Crisis dummy	-.591*** (.004)
Inflation x Systemic Crisis dummy	1.201*** (.009)
GDP Growth x Systemic Crisis dummy	.689*** (.007)
Level of interest rates x Systemic Crisis dummy	-.988*** (.009)
Slope of interest rates x Systemic Crisis dummy	-.345*** (.012)
Concentration x Systemic Crisis dummy	.053*** (.001)
Year dummies	Yes
Pre-validation tests	
Sargan-Hansen test	1.000
Arellano-Bond test for AR (2)	.804

We find that there are some variables whose effect shifts during the systemic crisis, namely the leverage, the cost-to-income ratio and the credit risk. Furthermore, and focusing on the macroprudential policies indexes, we observe that tightening capital-aimed macroprudential policies during the systemic crisis leads to a reduction of banks' risk, while it would lead to an increase of banks' risk during normal times. This pattern of increased effectiveness during the systemic crisis is also present on the other macroprudential policies, albeit these being effective in curbing banks' risk during normal times.

Finally, we analyze the interaction of all the variables with the COVID-19 shock dummy variable, presented on Table 12.

Again, Model 20 supports our previous findings: tightening capital-aimed macroprudential policies during the COVID-19 pandemic would have led to an increase of banks' risk, while loosening these policies would translate in an easing of banks' risk. Finally, and with regards to the other macroprudential policies, we find that tightening these policies during the COVID-19 shock leads to a reduction in banks' risk.

Table 12. Robustness Check: Banks' risk model considering the interaction all the variables with the COVID-19 dummy variable.

Estimation of the baseline model but considering the interaction of all the bank-specific and country-specific variables with the COVID-19 dummy variable. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

Dependent Variable: Asset Risk	**Model 20**
Lagged dependent variable	.788*** (.000)
Macroprudential Policies Index	
Capital-aimed MPP Index	.190*** (.003)
Other MPP Index	.156*** (.003)
Crisis Dummy variables	
Systemic Crisis	.088*** (.011)
COVID-19 Crisis	9.512*** (.024)
Bank specific variables	
Profitability	-.005*** (.001)
Leverage	-.015*** (.001)
LOG Size	-.031*** (.002)
Cost-income ratio	-.017*** (.000)
Asset diversity	-1.283*** (.017)
Income diversity	1.629*** (.016)
Credit risk	-.003*** (.001)
External variables	
Inflation	-.039*** (.002)
GDP growth	.182*** (.002)
Level of interest rates	-.448*** (.004)
Slope of interest rates	.415*** (.003)
Concentration	-.011*** (.000)
Interaction variables	
Capital-aimed MPP x COVID-19 dummy	2.548*** (.046)
Other MPPx COVID-19 dummy	-.359*** (.021)
Profitability x COVID-19 dummy	.320*** (.028)
Leverage x COVID-19 dummy	.026*** (.002)
LOG Size x COVID-19 dummy	.041** (.019)
Cost-income ratio x COVID-19 dummy	-.138*** (.002)
Asset Diversity x COVID-19 dummy	2.780*** (.084)
Income Diversity x COVID-19 dummy	1.540*** (.090)
Credit Risk x COVID-19 dummy	.353*** (.010)
Inflation x COVID-19 dummy	3.430*** (.037)
GDP Growth x COVID-19 dummy	1.548*** (.021)
Level of interest rates x COVID-19 dummy	-.334*** (.087)
Slope of interest rates x COVID-19 dummy	-3.756*** (.046)
Concentration x COVID-19 dummy	.074*** (.001)
Year dummies	Yes
Pre-validation tests	
Sargan-Hansen test	1.000
Arellano-Bond test for AR (2)	.819

5. Conclusions

The global financial crisis (GFC) highlighted the importance of using macroprudential policies to deal with risks stemming from the interconnectedness of the global financial markets. The aftermath of the SARS-CoV-2 pandemic presents a perfect opportunity to test if the use of these policies helped to prevent a bigger economic catastrophe.

This study analyzes the effectiveness of macroprudential policies during this new global crisis in the form of a pandemic and compares these results with those of the systemic crisis. We find that capital-aimed macroprudential policies are important and effective during systemic crises, where building capital buffers during these years leads to less risky banks.

When examining the COVID-19 period, where capital-aimed policies formed an important part of the post-pandemic toolbox, we found an inverse relationship. In other words, loosening such macroprudential policies is particularly effective in reducing banks' risk, although such behavior would have increased risk during a systemic crisis.

The remaining macroprudential policies, included in other macroprudential policies index, show a different type of behavior. Tightening these policies led to banks reducing their risk-taking behavior both during the systemic crisis and the pandemic.

Another interesting conclusion concerns the magnitude of the impact of macroprudential policies on banks' risk, which is much more sensitive to shifts in the macroprudential framework during the systemic crisis period than during the pandemic or normal years. These results confirm the importance of the macroprudential framework in controlling banks' risk during negative or disruptive events and contributing toward strengthening banks' resilience and rapid crisis resolution.

Given the possibility that banks' stock price volatility may be influenced by factors other than banks' risk-taking behavior, we replicate the same analysis using the Z-score as a proxy for banks' risk. With this approach, our previous results are still valid.

To confirm the effectiveness of macroprudential policies during the pandemic, we employed a propensity score-matching approach. This method confirmed the effectiveness of loosening capital-aimed macroprudential policies during the pandemic and the ineffectiveness of loosening other macroprudential policy indexes during this public healthcare shock. Our main results also hold when we re-estimate the main models considering both macroprudential policies index simultaneously.

By evaluating the effectiveness of the macroprudential policies considering several bank-specific characteristics, we find that both macroprudential policies indexes are more effective in banks with higher leverage and lower loan growth and for banks located in the EU, albeit the other macroprudential policies only being effective in curbing banks' risk in the EU.

Moreover, we show that the effectiveness of the capital-aimed policies during the systemic crisis is driven by the capital requirement, while tightening the conservation buffer would lead to an increase in banks' risk. Regarding the COVID-19 pandemic, we show that tightening the countercyclical capital buffer would be effective in reducing banks' risk, while tightening the capital requirements, conservation buffer, and the leverage limit would lead to an increase in banks' risk.

Finally, we find that the results still hold when interacting all the variables with the systemic crisis and the COVID-19 shock variables.

From this perspective, our results call for a careful calibration of the macroprudential framework, both during normal times and periods of distress, to avoid unintentional consequences and leverage the complete potential of macroprudential policies. In fact, our results show that the pandemic agenda showed mixed results, where countries that loosened their macroprudential policies, included in the other macroprudential policies indexes, increased banks' risk, contrary to countries that decided to tighten these policies.

Nonetheless, our results are limited by the fact that our indexes measure the total loosening or tightening of macroprudential policies in one year; that is, they do not reflect the magnitude of such loosening or tightening events. Therefore, it would be important and interesting to check if the extent of policy relaxation was sufficient to assure the effectiveness of our policies or if there was still room to maneuver, as suggested by the ECB (2021).

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CHAPTER IV - THE ROLE OF MARKET DISCIPLINE AND MACROPRUDENTIAL POLICIES IN ACHIEVING BANK STABILITY[6]

[6] This chapter is based on the article Matos et al. (2024b):
Matos, T. F. A., Teixeira, J. C. A., and Dutra, T. M. (2024b). The role of market discipline and capital prudential policies in achieving bank stability. *International Journal of Finance and Economics*, Forthcoming.

Abstract

This study examines whether forcing banks to hold subordinated debt and enforcing market discipline could enhance the effectiveness of capital macroprudential policies in reducing banks' risk and contribute to bank stability. Using the system generalized method of moments and based on a sample of 322 banks across 18 countries during the period 2006–2020, we find that a higher level of subordinated debt leads banks to avoid moral-hazard behaviors and engage in risk shifting when adapting to a tighter macroprudential framework, which in turn leads to a greater effectiveness of these policies. Furthermore, as robustness tests, we show that this effect is stronger in advanced economies and in the United States of America. These results also stand using a different proxy for banks' risk.

JEL Classification: G21, G28, G32 and E58

Keywords: Banks' risk, Macroprudential policies, Market discipline

1. Introduction

Banking institutions have become increasingly complex over the years (World Bank, 2020). This complexity, combined with the fact that bank supervisors are scarce compared with the number of banks operating in any economy, makes it a challenge for supervisors to effectively regulate these organizations. In this regard, since the mid-1970s, the role of short-term creditors in disciplining banks' behavior has been a central pillar of banking supervision (Crocket, 2002; Min, 2015).

However, the unprecedented government intervention during the Great Financial Crisis (GFC), along with the bailouts conducted over this period, discouraged market participants to effectively discipline banks because there were implicit government guarantees in place that secured banks in case of default due to the "too-big-to-fail" theory (Nier and Baumann, 2006). Therefore, the Basel Committee on Banking Supervision (2011) defined the importance of strengthening market discipline in Pillar 3 of Basel II and later in Basel III with increased disclosure requirements.

In the years following the GFC, policymakers' focus shifted toward capital-aimed macroprudential policies as a crucial mechanism to maintain the stability of the financial markets and, consequently, reduce the need for government bailouts, which are costly for taxpayers (Nieto, 2012). However, recent studies by Thamae and Odhiambo (2022) and Matos et al. (2024a) have shown that banks, when faced with a tighter regulatory framework, might engage in moral-hazard behaviors and shift banks' investments toward unsecured and riskier assets, thus undermining the goal of this type of regulation. Moreover, Kinateder (2016) shows that the capital-aimed macroprudential policies under Basel III only led to a reasonably small increase in the minimum capital requirements when compared with those under Basel II, which might translate into low efficiency of these policies in achieving banking stability.

Therefore, the post-GFC reform on market discipline could, in theory, complement macroprudential policies in controlling banks' response to a tighter prudential framework, as suggested by Nieto (2012), and even discourage banks from engaging in regulatory arbitrage and moral-hazard behaviors (Levonian, 2001; Chen and Hasan, 2011; Oliveira and Raposo, 2019). Although Flannery and Bliss (2019) extensively describe the role of market discipline and how the recent regulatory reforms might impact its effectiveness, these authors focus only on a theoretical perspective.

In this regard, Nieto (2012) analyzes the importance of market discipline in guaranteeing the quality of the balance sheet and market indicators that are used by macroprudential supervisors as structural measures of systemic importance. However, this author disregards how this relationship might influence banks' risk response toward adjustments to the macroprudential framework. Chen and Hasan (2011) also present a theoretical model that explains how market discipline can complement capital-aimed macroprudential policies in achieving financial stability and avoid value-destroying actions by bank managers. However, these authors fail to present any empirical evidence to support this theory. Finally, the connection between capital buffers and market discipline has been confirmed by Tarullo (2008), although this author admits that this relationship requires further investigation.

The present study aims to analyze this connection by supplying empirical evidence on how market discipline might complement capital macroprudential policies in controlling banks' risk-taking behavior, solve the moral-hazard problems that these policies can induce and, consequently, contribute to more stable financial institutions.

Using a sample comprising 322 banks across 18 countries during the 2006–2020 period, we find that tightening capital-aimed macroprudential policies per se is ineffective in curbing banks' risk-taking behavior. Furthermore, we show that issuing subordinated debt or, in other words, increasing market participants' disciplinary power is an effective mechanism to intensify the effectiveness of capital-aimed macroprudential policies and even overcome the moral-hazard problems that this type of bank regulation might create. Moreover, we find that this enhancing effect is stronger in advanced economies and in the United States of America (USA), when comparing with the remaining countries of the sample. These results also hold when we use an alternative measure of banks' risk.

This study's contribution to the literature is multifold. First, and to the best of our knowledge, this is the first study to examine how market discipline can influence banks' risk-taking response to adjustments to macroprudential policies. Although Chen and Hasan (2011) present a theoretical model to show how subordinated-debt regulation can be an effective mechanism to discipline banks and complement capital-prudential policies, we go even further by providing empirical evidence of and further theory on this effect. Second, the study contributes to a growing body of literature on how market discipline might impact banks' behavior and to another strand of the literature that analyzes the impact of macroprudential policies. Finally, this study contributes toward a better understanding of why policymakers should regulate and establish minimum levels of subordinated debt on banks' structures, as it attempts to settle the debate on this subject.

Therefore, our study should be of interest to a broad audience of scholars, policymakers, and banking supervisors as it sets the foundations for how these two mechanisms can join forces in assuring more robust and stable banking institutions and, consequently, financial markets.

The remainder of this paper is organized as follows: In Section 4.2 we review the related literature on how market discipline operates and how it might enhance the effectiveness of macroprudential policies in controlling banks' risk-taking behavior. In Section 4.3 we describe the data and the variables considered in the empirical analysis. In Section 4.4 we report and discuss the main results, and we provide additional robustness tests. Finally, in Section 4.5, we present concluding remarks.

2. Literature review and hypothesis development

All companies are subject to market discipline one way or another (Emmons et al., 2001). If they need to obtain finance, businesses are subject to financial-market discipline, while if they want to sell goods or services, they are subject to product-market discipline. The banking industry is not oblivious to this. The theoretical foundation for this market-discipline theory rests on the fact that uninsured debtholders will discipline companies if they perceive them as being too risky and jeopardizing their investments (Kato, 2021).

Market participants' disciplinary power over banks has been a subject of debate among scholars and policymakers since the mid-1970s (Barth et al., 2004; Bertay et al., 2013; Elyasiani and Keegan, 2017; Flannery and Bliss, 2019). However, although the banking-supervision systems have acknowledged its theoretical importance, it has been considered in a very vague and undeveloped manner, thus limiting this mechanism's potential.

Market participants' supervisory role entails two different tasks: monitoring and influencing the market (Bliss and Flannery, 2002; Krishnan et al., 2005; Flannery and Bliss, 2019, World Bank, 2020). For this disciplinary action to work, three essential conditions must be met: (i) information must be adequate and timely; (ii) creditors must acknowledge that they are at risk; and (iii) market reaction must be observable (Crockett, 2002; Nier and Baumann, 2006; Nieto, 2012).

Market participants' influence can be exerted both directly and indirectly (Bliss and Flannery, 2002; World Bank, 2020). The direct corrective action may be employed through two different parties: (i) depositors can withdraw their deposits if they think that the bank is being too risky, thus increasing its risk of default, *i.e.*, depositors' discipline; and (ii) creditors may ask for a higher risk premium when they perceive a deviant behavior toward riskier actions (Crocket, 2002). Meanwhile, market participants can simply signalize third parties, such as supervising institutions or rating agencies, who will then engage in the corrective action against the bank, *i.e.*, the indirect channel of market discipline.

To enforce this market discipline, some empirical studies have advocated the need of a mandatory prudential policy to force banks to issue subordinated debt (Godspower-Akpomiemie and Ojah, 2021). However, there is no consensus on the literature on using this measure due to several drawbacks pointed out by Godspower-Akpomiemie and Ojah (2021). First, this type of market discipline requires developed financial markets without agency costs and externalities (Scott, 2004). Furthermore, market participants must have access to relevant and timely information to make informed decisions and exert their influence (World Bank, 2020). Finally, Ashraf (2008) show that runs by investors can destabilize banks and increase their risk of default, reducing their probability of recovering from distress.

Nonetheless, subordinated debt has been considered in the literature as an effective measure of market discipline since these debtholders are more exposed to risk and will swiftly discipline banks if they perceive their investments as being at risk. Iannotta (2011) find that these debtholders are in fact more risk sensitive than other liabilities and have increased incentives to discipline banks. Therefore, despite the sensitivity of this mechanism, subordinated debt can be an effective market discipline measure. Furthermore, Lang and Robertson (2002) demonstrate that issuing subordinated debt can increase banks' risk-sensitivity and have increased benefits as a market-trigger for regulatory action.

The GFC raised unprecedented governmental support to the banking industry both through bailout programs and extended deposit guarantees to stabilize the financial systems (World Bank, 2020). However, some researchers support the idea that these safety nets and bailout programs contributed to the destabilization of financial markets because not only did they significantly reduce market participants' incentives to discipline and monitor banks (Hadad et al., 2011; Ianotta, 2011; Anginer and Demirgüç-Kunt, 2018;

World Bank, 2020), but they also motivated banks to engage in moral-hazard and regulatory-arbitrage behaviors (Llewellyn,1999; Chen and Hasan, 2011; Schroth, 2021; Thamae and Odhiambo, 2021; Matos et al., 2024a).

In this regard, policymakers enhanced the regulatory power of market discipline, materialized in the Dodd-Frank Act (DFA, 2010), Pillar 3 of Basel II, and later in Basel III, through more extensive and frequent disclosure requirements (Nier and Baumann, 2006; Min, 2015; Godspower-Akpomiemie and Ojah, 2021). This regulatory change is explained by the first condition set by Nier and Baumann (2006) and Nieto (2012) to assure that market discipline works, namely, the adequate and timely information regarding a bank, as the increased disclosure requirements were set to reduce information asymmetry and increase transparency by supplying market participants with the relevant data to substantiate their informed market actions toward banks and punish riskier behaviors (Nieto, 2012; Kato, 2021).

The post-GFC regulatory reform also focused on intensifying the capital-aimed macroprudential framework (Thamae and Odhiambo, 2021). These policies were set to reduce banks' contribution to systemic risk, channeled through their individual risk taking, by forcing them to build a monetary buffer that could be used to cover unexpected losses, to deleverage, and to reduce abnormal credit growth (Andries et al., 2018; Ampudia et al., 2021; Igan et al., 2022; Kumar et al., 2022). The effectiveness of these policies has been confirmed in the literature (Sanchez and Rohn, 2016; Richter et al., 2019; Belkhir et al., 2020; Ampudia et al., 2021; Matos et al., 2023).

Moreover, sufficiently high capital requirements could potentially address the moral-hazard concerns. However, forcing banks to hold high levels of capital buffers could prove to be costly (Hellman et al., 2000; Chen and Hasan, 2011). In this regard, Chen and Hasan (2011) developed a theoretical model that explained how market discipline could be beneficial in complementing macroprudential policies in achieving this goal.

Although capital-aimed macroprudential policies and market discipline are different in nature, as the former are set to reduce shareholders' incentives to seek risk and the latter is set to motivate market participants to supervise banks and punish risky behaviors, these two supervision mechanisms could, theoretically, create synergies to achieve bank stability. This theory is based on the fact that when banks are subjected to higher levels of market discipline, managers will be less inclined to take value-destroying actions or even engage in risk shifting when adapting to tighter capital-aimed policies because these deviant actions could easily be perceived by market participants, who would punish the banks by requesting higher risk premiums for their investments.

Another strand of the literature shows a different channel through which market discipline can complement macroprudential policies. According to Fonseca and González (2010) and Ghosh (2017), when banks are subjected to higher levels of market discipline and if the banks' liabilities are unsecured, there will be incentives to maintain higher levels of capital buffers. This is explained by the fact that higher levels of market discipline will introduce incentives for banks to maintain capital buffers above the minimum requirements so that they can avoid higher costs of funding if market participants engage in corrective action. Therefore, because these higher levels of capital buffers will translate into more shareholder capital at risk, the banks will then also be more prudent and reduce their appetite for riskier investments (Thamae and Odhiambo, 2021). This theory is consistent with the idea presented by Flannery (2001) that uninsured investors have comparative advantage in monitoring banking institutions while banking supervisors have comparative advantage in influencing banks' behavior.

In this regard, we test the hypothesis that the presence of higher levels of subordinated debt, *i.e.*, market discipline, will enhance the effectiveness of a tighter capital-aimed framework by introducing incentives for bank managers to take prudent actions and by limiting the incentives for taking riskier and value-destroying actions. Furthermore, higher levels of market discipline will not only enhance banks' resilience but are also the key to solving the moral-hazard and regulatory-arbitrage problems created by government safety nets and banking regulation.

3. Methodology and variables

3.1. Empirical strategy

The main empirical strategy is to assess whether a bank's response to a change in the capital-aimed macroprudential framework shifts depending on the bank's level of market discipline. Therefore, we use the following empirical specification:

$$Risk_{i,j,t} = \alpha + \beta_1 Risk_{i,j,t-1} + \beta_2 MPPI_{j,t} + \beta_3 Market\_Discipline_{i,j,t} + \beta_4 (MPPI \times Market\ Discipline)_{i,j,t} + \beta_5 BankControl_{i,t} + \beta_6 CountryControl_{j,t} + Year_t + \varepsilon_{i,j,t} \, , \tag{1}$$

where the dependent variable, $Risk_{i,j,t}$, is an indicator of risk for bank *i,* located in country *j* in year *t*; *MPPI* is an index of adjustments to country *j*'s capital-aimed macroprudential policies in year *t*; and *Market_Discipline* is the ratio of subordinated debt to total liabilities for bank *i* located in country *j* in year *t*. The *BankControl* and *CountryControl* variables are, respectively, sets of idiosyncratic bank characteristics and macroeconomic/external variables typically used in the literature as control variables. The variable, $Year_t$, captures time-specific fixed effects (a measure of temporal patterns), allowing us to control for the exogenous impact on the dependent variable that is not attributed to the variables considered in the analysis. Finally, and because we are using a dynamic model, we include the one-period lagged dependent variable to measure banks' risk persistence over time due to the inter-temporal risk smoothing and competition and to capture the response to banking regulations (Delis and Kouretas, 2011).

To analyze the relationship between macroprudential policies and market discipline, we include the interaction term, *MPPI×Market_Discipline*, to verify whether the impact of capital prudential policies depends on whether banks are subjected to higher or lower levels of subordinated debt, *i.e.*, market discipline. This impact can be analyzed as follows:

$$\frac{\partial Risk_{i,j,t}}{\partial MPPI_{j,t,m}} = \beta_{2,m} + \beta_{4,m} Market\_Discipline_{i,j,t} \,. \tag{2}$$

Equation 2 demonstrates why we should consider the level of market discipline when analyzing the overall effectiveness of capital-macroprudential policies because the overall effect can be enhanced or diminished depending on the level of subordinated debt.

This dynamic panel-data specification might be prone to suffer from endogeneity issues, although it is highly unlikely for macroprudential authorities to adjust specific macroprudential policies in response to a single bank's behavior. Furthermore, models that are typically used, such as ordinary least squares (OLS) or maximum likelihood estimation (MLE), only maintain their consistency when the sample comprises an extremely large number of observations tending to infinity. These issues can be addressed by using an autoregressive model such as the system generalized method of moments (sGMM), established by Arellano and Bover (1995) and Blundell and Bond (1998). The key difference between these approaches lies in the fact that instead of drawing assumptions about an entire distribution, the sGMM focuses on the specific moments (called moment conditions) of the random variables. Moreover, this approach is particularly effective when there is a large N and short T scenario (Blundell and Bond, 1998; Roodman, 2009).

The consistency of the sGMM estimator has previously been determined by validating two assumptions: the absence of instrument proliferation and the absence of serial correlation among the errors. Thus, we rely on two diagnostic tests: the Hansen test of over-identifying restrictions, which analyzes the aforementioned moment conditions to assess the global validity of the instruments, and the autoregressive test to check if the term error, ε, is serially correlated, as proposed by Arellano and Bond (1991). Failure to reject the null hypothesis in both tests validates the model.

The remaining variables used in the above models are introduced in the following subsections.

3.2. Data and sample

The empirical analysis focuses on publicly listed commercial banks and bank-holding companies during the period 2006–2020, whose data were collected from several sources. We use BankFocus, a database on banks' information provided by Bureau van Dijk, as the main source for bank-level data, while DataStream, a financial time series database by Refinitiv, is used to collect data for country-level variables.

The final sample comprises 322 banks from 18 countries, which are diversified in terms of geographical regions and levels of economic development.

Table 1 presents details of the sample distribution by country and by year.

From Table 1, the sample is clearly in an unbalanced panel-data format. This is because among the sampled 322 banks, not all were active during the sample period. Furthermore, the fact that we winsorized the final sample at 1% and 99% of bank-level data, including banks with negative equity, contributes to this unbalanced format. Finally, to eliminate any potential bias of the results, we removed the banks from countries with less than four observations.

Table 1 Sample distribution by country and year

Distribution of the sample by country, year and by the level of economic development following Alam et al. (2019).

Country	Economic development level	Year															Total
		2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
Austria	AE			4	4	4		4	4	4	4	4	4	3	4	4	**47**
Brazil	EMDE							3		3	2	3	4	2	4	4	**25**
Bulgaria	EMDE						1	1	1	1	1				1	1	**7**
China	EMDE		2		3		5	4	7	10							**31**
Denmark	AE	2	3		4	4	9	8	8	5					12	10	**65**
Finland	AE							1	1	1	1	1	1	4	3	3	**16**
France	AE	3	3	5	6	4	4	5	4	4	4	3	2	3	3	3	**56**
Germany	AE	2	3	3	3	3	4	4	4	5	3	3	3	3	3	2	**48**
India	EMDE	4	5	2	3	5	7	7	7	6	8	11		10	7	3	**85**
Indonesia	EMDE		6	4	3	3	4	5	3	4	5	4	4				**45**
Italy	AE	2	2	1	2		5	4	5	5	4	4	3	6	7	8	**58**
Japan	AE	6	8	7	11	9	9	12	7	10	7	7	9	8	6	6	**122**
Norway	AE							5	8	9						18	**40**
Philippines	EMDE	2	3	3	1					4	4				4		**21**
Poland	EMDE		1	1	1			2	4	3	3	3	3	4	3	4	**32**
Russian Federation	EMDE			1									4	4	3		**12**
Slovakia	AE			1	1	1		1			1	1					**6**
Spain	AE	4	3	3	3	3	2	4	4	2	3	4	4	4	3	3	**49**
United Kingdom	AE	6	7	7		7		7		6	7			11	11		**69**
United States of America	AE			96	99	103	105	121	116	122	119	120	121	124	120	111	**1477**
Total		**31**	**46**	**138**	**144**	**146**	**155**	**198**	**183**	**204**	**176**	**168**	**162**	**186**	**194**	**180**	**2311**

3.3. Dependent variable

As mentioned earlier, for market discipline to work, market participants' disciplinary actions must be observable in the financial market (Nier and Baumann, 2006; Nieto, 2012). Therefore, since this behavior is reflected in the financial-market information, we measure banks' individual risk using their asset risk. This variable is computed by the standard deviation of asset returns, which reflects the yearly standard deviation based on the daily stock-price returns multiplied by the total market value of a bank's equity over its market value. This approach, also used by Chen and Hasan (2011), Claessens et al. (2014), and Dutra et al. (2023a), perfectly reflects banks' risk by incorporating the two components of risk, namely, idiosyncratic and market risk, an important factor that should be considered when analyzing the effect of market discipline.

The literature often considers different measures of banks' risk, such as the Z-score (Laeven and Levine, 2009; Houston et al., 2010; Lapteacru, 2016; Altunbas et al., 2018; Niţoi et al., 2019; Ashraf et al., 2020; Gaganis et al., 2020, Dutra et al., 2023b), loan-loss reserves to total loans ratio (Bitar et al., 2016), and credit growth (Claessens et al., 2014; Ghosh, 2014; Cerutti et al., 2017; Teixeira et al., 2020a). Therefore, we repeat the same regressions using a different indicator for banks' risk, the Z-score..

3.4. Market discipline

As mentioned before, market discipline may be employed by several market participants, which reflects the different ways of measuring such effects. For instance, the disciplinary action taken by other banking institutions can be measured using the interbank deposit ratio; depositors' disciplinary action may be measured using the growth of deposits; and bank self-discipline can be measured using the net present value of banks' future rents, *i.e.*, the charter value.

However, we focus on creditors' disciplinary action since our goal is to determine whether holding greater levels of subordinated debt would translate into significantly higher financial-market discipline by banks, as many economists suggest (Emmons et al., 2001; Nieto, 2012). Additionally, empirical evidence shows that the amount of uninsured and subordinated debt that banks carry on their balance sheets is associated with market discipline (Flannery and Sorescu, 1996; Sironi, 2003; World Bank, 2020). Therefore, following Krishnan et al. (2005), Baumann (2006), Nier and Baumann (2006), Haq et al.

(2016), and Oliveira and Raposo (2019), we measure market discipline using the ratio of subordinated debt to total liabilities.

3.5. Capital macroprudential policies

We use the integrated macroprudential-policy database (iMaPP) by the International Monetary Fund (IMF), organized and documented by Alam et al. (2019), to retrieve data on macroprudential-policy adjustments.

Since the data on this database are organized at a monthly frequency, we follow Meuleman and Vennet (2020) and aggregate the monthly adjustments to obtain a yearly index of the total adjustment for each policy. This approach is also supported by the fact that macroprudential policies affect banks' risk-taking behavior during the month the announcement is made as well as in the subsequent months, as indicated by Cerutti et al. (2017) and Akinci and Olmstead-Rumsey (2018).

Because the level of market discipline will theoretically influence the amount of capital held by banks (Fonseca and González, 2010; Ghosh, 2017), we focus on capital-aimed macroprudential policies. This index includes four macroprudential policies: the leverage limits, countercyclical capital buffers, conservation buffer, and capital buffers, as suggested by Alam et al. (2019).

3.6. Country- and bank-level control variables

There are other important bank characteristics and macroeconomic variables known in the literature as important predictors of a bank's risk. Therefore, following the literature, specifically, Altunbas et al. (2018), Alam et al. (2019), Niţoi et al. (2019), Gaganis et al. (2020), Teixeira et al. (2020b), Davis et al. (2022) and Dutra et al. (2023a), we include six idiosyncratic bank-control variables (*BankControl*): a bank's leverage, size, profitability, operational efficiency (measured by the inverse of the cost-income ratio), credit risk (measured as the inverse of credit quality), income diversity, and asset diversity. We also consider five country-level control variables (*CountryControl*): the inflation rate, GDP growth rate, market concentration, level of interest rates, and slope of interest rates. By introducing these two sets of control variables, we aim to capture the different channels through which banks' risk may shift and that are neither attributable to macroprudential policies nor to the level of market discipline.The expected effects of each of the bank-specific and macroeconomic control variables, and their respective empirical theory, is presented on Appendix I.

Table 2 summarizes the definitions and sources of all the variables.

Table 2. Variable sources and definitions

Variable	Description	Source
Banks' risk		
Asset Risk	Annualized standard deviation of daily stock price returns times the market value of equity over the market value of the bank.	Thompson Reuters Datastream, Bankfocus database and authors' calculations
Z-score	Natural logarithm of (ROA + E/A)/σ(ROA). ROA represents the rate of return on assets, E/A is the equity-to-assets ratio and σ (ROA) is the standard deviation of the rate of return on assets. A higher score suggests a lower probability of bank insolvency and, therefore, less risk.	Bankfocus database and authors' calculations
Macroprudential policy variables		
Capital-aimed macroprudential policies index	Sum of the total tightening (+1) and loosening (-1) events for the 4 macroprudential policies aiming at building a financial cushion, namely the leverage limit, the countercyclical capital buffer, the conservation buffer, and the capital requirements in year t.	Author's calculations based on the Integrated Macroprudential Policy (iMaPP) Database
Market Discipline variable		
Subordinated debt ratio	Ratio of subordinated debt over total liabilities.	Bankfocus database and authors' calculations
Bank specific variables		
Leverage	Book value of total liabilities over total assets, measured in market terms, *i.e.*, as the sum of the market value of equity and the book value of total liabilities.	Bankfocus database and authors' calculations
Size	Natural logarithm of the book value of total assets.	Bankfocus database and authors' calculations
Profitability	Profit after interest expenses over the book value of assets.	Bankfocus database and authors' calculations
Cost-income ratio	Operating costs or non-interest costs over net operating income.	Bankfocus database and authors' calculations
Credit risk	Provisions for loan losses to total loans.	Bankfocus database and authors' calculations
Income diversity	Measures the diversification across different sources of income and is given by 1-[(net interest income-other operating income)⁄(total operating income)]	Bankfocus database and authors' calculations
Asset diversity	Measures the diversification across different types of assets and is given by 1-[(net loans-other earnings assets)⁄(total earnings assets)].	Bankfocus database and authors' calculations
Macroeconomic variables		
GDP growth	Annual percentage change of Gross Domestic Product (GDP).	Bloomberg database
Inflation	Annual percentage change in the Consumer Price Index (CPI).	Bloomberg database
Level of interest rates	10-year yield rate on government bonds.	Bloomberg database
Slope of interest rates	Difference between the 10-year yield rate and the 1-year yield rate on government bonds.	Bloomberg database
Concentration	Measures the level of market competition in the banking sector and is given by the fraction of the assets of the three largest banks over the assets of all commercial banks in a country.	World Bank database
Crisis	Dummy variable that assumes the value 1 in the years of systemic banking crisis and 0 otherwise.	Laeven and Valencia (2020)

3.7. Descriptive statistics

As a preliminary exploration of the data, we present the summary statistics for the main variables used in the regression analysis in Table 3.

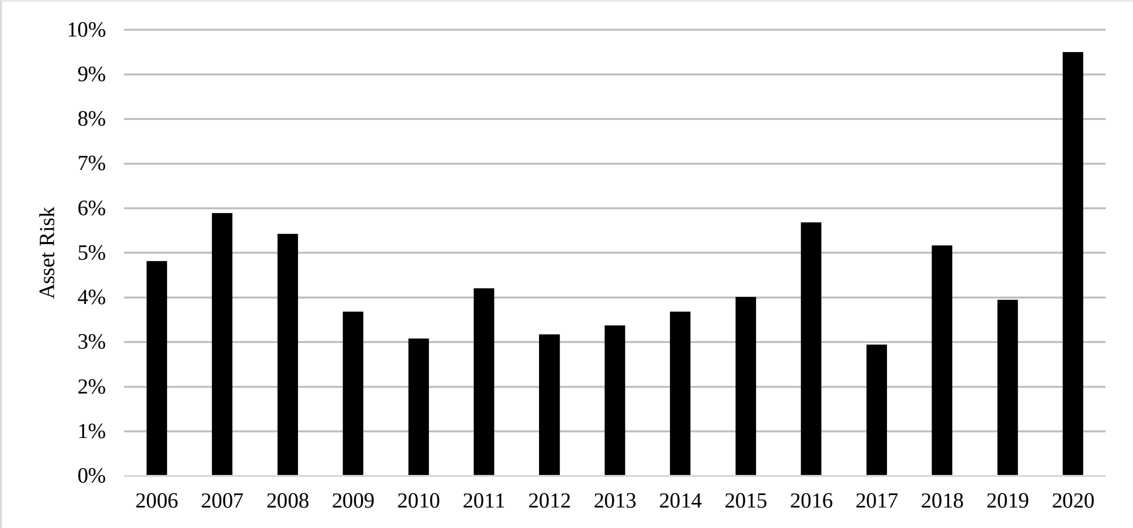
Table 3. Descriptive Statistics

						Distribution		
	N	**Mean**	**St. Dev.**	**Min.**	**Max.**	**10th**	**50th**	**90th**
Banks' risk								
Asset risk (%)	2298	4.489	8.465	.000	78.313	.375	1.812	10.000
Z-score	2298	.018	.952	-3.274	3.228	-1.220	.123	1.081
Macroprudential Variable								
Capital-aimed MPP Index	2298	.313	.974	-4	6	0	0	2
Market Discipline Variable								
Subordinated Debt ratio (%)	2298	1.599	1.247	0	11.934	.101	1.419	3.069
Bank specific variables								
Leverage (%)	2298	88.583	6.641	44.185	99.626	80.847	88.605	97.203
LOG Size	2298	9.808	2.137	4.328	14.836	7.453	9.332	10.402
Profitability (%)	2298	1.205	1.140	-11.637	6.610	.230	1.309	2.187
Cost-income ratio (%)	2298	62.677	12.484	19.207	135.042	47.212	62.541	77.617
Credit risk (%)	2298	2.055	2.197	.074	24.055	.601	1.360	4.144
Income diversity	2298	.667	.392	-.219	2.431	.255	.585	1.188
Asset diversity	2298	.671	.346	.011	1.998	.328	.580	1.176
External variables								
GDP growth (%)	2298	1.578	2.315	-8.900	13.900	-2.300	2.000	2.933
Inflation (%)	2298	1.881	1.478	-1.700	13.300	.400	1.741	2.962
Crisis	2298	.209	.407	0	1	0	0	1
Level of interest rates (%)	2298	1.442	6.068	-2.220	4.111	.143	1.618	3.028
Slope of interest rates (%)	2298	2.647	1.878	-.572	16.512	.916	2.20	4.305
Concentration	2298	42.531	16.085	.000	99.941	34.420	35.313	67.861

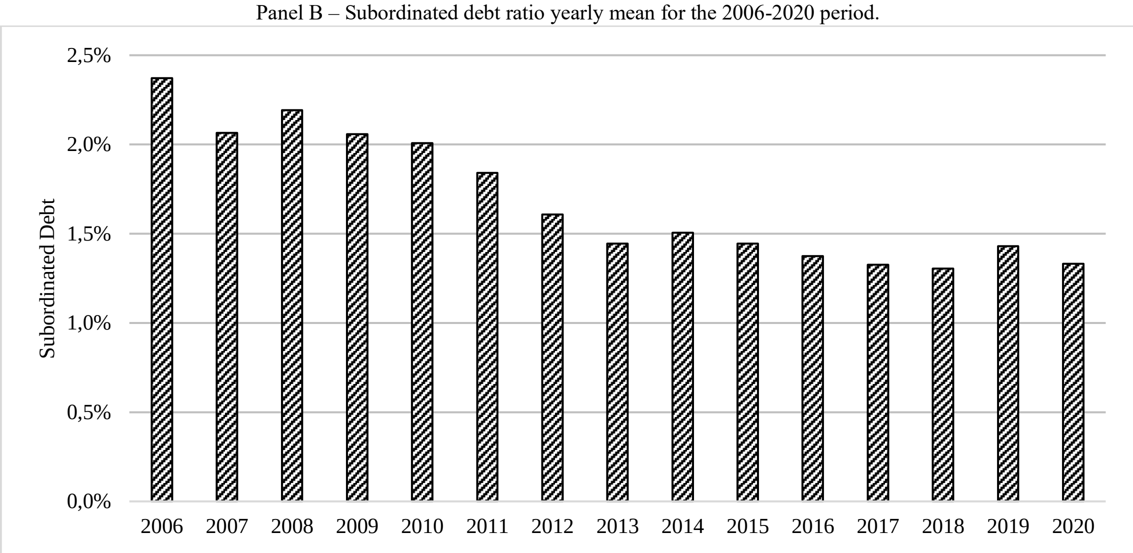
The average bank in the sample has an asset risk of 4.489% with a standard deviation of 8.465%. Considering this variable's yearly distribution, presented in Panel A of Figure 1, we perceive an interesting pattern. The average asset risk is higher in the years preceding the GFC and lower in the following years. This variable also presents two peaks in 2016 and 2020, which may be attributed to a set of events that affected the global economy, including Brexit (Quaye et al., 2016), the Shanghai market crash and US-China tariff war (Shi et al., 2021) in 2016, and COVID-19 pandemic (Ganie et al., 2022; Shi, 2022) during 2020.

Figure 1. Yearly average of the main variables

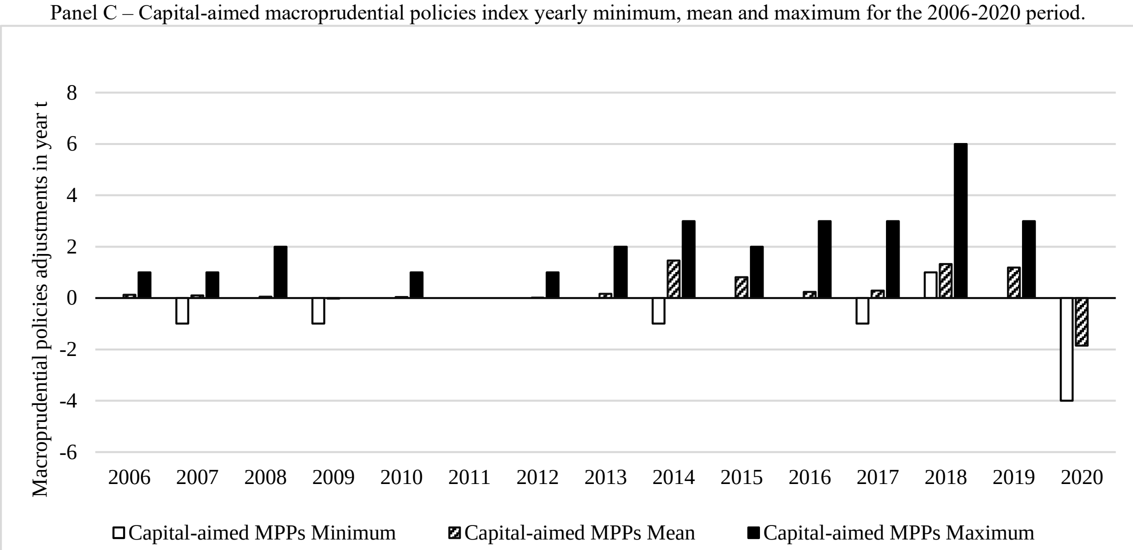
Panel A – Banks' risk yearly mean for the 2006-2020 period.



Panel B – Subordinated debt ratio yearly mean for the 2006-2020 period.



Panel C – Capital-aimed macroprudential policies index yearly minimum, mean and maximum for the 2006-2020 period.



Regarding the subordinated debt level, we can see that the average bank is subjected to 1.599% of subordinated debt, with a standard deviation of 1.247%. This variable's yearly evolution can be analyzed in Panel B of Figure 1. Clearly, this variable has been decreasing over the years, with the highest average in the years prior to the GFC.

Next, we focus on the evolution of the capital-aimed macroprudential framework over the years of the sample represented in Panel C. Overall, and as expected, these policies were extensively adopted in the post-GFC period, peaking in 2018 with a maximum of six adoptions and/or tightening. This growth tendency shifted in 2020 when these policies were relaxed (minimum of four) as part of the pandemic-support package for the banking system to allow banks to utilize the previously built buffers to cover unexpected losses (Matos et al., 2023).

Finally, we find that the average bank had a leverage of 88.583% and a profitability of 1.205%, while the average country had a GDP growth of 1.578% and an inflation rate of 1.881%.

4. Empirical results

Using Equation 1, we start by examining how the impact of capital-aimed macroprudential policies might change depending on the different levels of market discipline to which banks were subjected. We then test the robustness of the results by examining whether they depend on the level of economic development of the country or by the fact that the bank is located in the USA or not by applying Model 1 to subsamples for each of these cases. Finally, we employ a different measure of banks' risk, the Z-score, to confirm that these findings are not influenced by un-observed market conditions.

4.1. Market discipline and capital-aimed macroprudential policies

Table 4 presents the baseline results for the specification in which we interact market discipline with the capital-aimed macroprudential index.

The first conclusion drawn from the results relates to the statistical significance of all the variables used, except for Concentration, used as bank-specific control variable. Regarding the lagged dependent variable, the results show that banks' risk indeed tends to persist over time, consistent with Castro's (2013) and Pascual et al.'s (2015) conclusions.

Table 4. Banks' risk model with macroprudential regulation and market discipline variables.

The dependent variable, bank's asset risk, is given by the annualized standard deviation of daily stock price returns times the market value of equity over the market value of the bank. Model 13 includes the interaction term between the market discipline variable and the capital-aimed macroprudential policies index.

The reported coefficients and their robust standard errors (presented in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively. The null hypothesis of the Difference-in-Hansen test states that the subset of instruments, used in the level equations, are exogenous.The null hypothesis of the Hansen test states that all instruments are jointly exogenous and that the instruments used are not correlated with residuals. The null hypothesis of the autoregressive (AR) test states that there is not second-order serial correlation in the error term.

Dependent Variable: Asset Risk	**Model 1**
Lagged dependent variable	.428***
	(.005)
Macroprudential Policies Index	
Capital-aimed MPP Index	.219***
	(.043)
Market Discipline variable	
Subordinated debt ratio	-.064**
	(.037)
Interaction variable	
Capital-aimed MPP Index x Subordinated debt ratio	-.052***
	(.014)
Bank specific variables	
Profitability	-.125***
	(.029)
Leverage	-.203***
	(.008)
LOG Size	-.311***
	(.042)
Cost-income ratio	.053***
	(.004)
Asset diversity	5.066***
	(.277)
Income diversity	.576***
	(.181)
Credit risk	.130***
	(.012)
Inflation	.381***
	(.026)
GDP growth	.256***
	(.015)
Crisis	.570***
	(.109)
Level of interest rates	-1.306***
	(.048)
Slope of interest rates	.0.041**
	(.020)
Concentration	.002
	(.002)
Year dummies	Yes
Pre-validation tests	
Hansen test	.374
Difference-in-Hansen test	.000
Arellano-Bond test for AR (1)	.225
Arellano-Bond test for AR (2)	
Number of instruments	241
Number of observations	1830

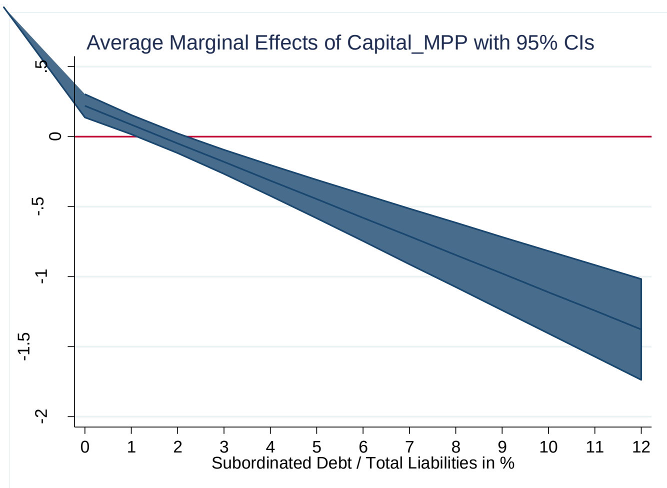
Considering the individual coefficients associated with the macroprudential policies index, we obtain some interesting results. First, we find that tightening these policies will lead to an increase in banks' risk. These results are consistent with the theory that tighter capital requirements induce banks to compensate for this loss of utility by increasing banks' investments towards riskier assets (Franch et al., 2021; Laeven and Levine, 2009). Regarding this point, Blundell-Wignall and Roulet (2013) demonstrate that the increase in capital-aimed macroprudential policies leads banks to increase the use of derivatives in off-balance sheet products and engage in regulatory arbitrage in order to compensate.

Considering the coefficient associated with the market-discipline variable, we find that, *ceteris paribus*, a 1% increase in subordinated debt will lead to a reduction of 0.064% in banks' risk. These results support Nier and Baumann's (2006), Emons et al.'s (2011), and Kato's (2021) findings, and they are explained by the fact that higher levels of market discipline preserve bank safety and soundness by directly or indirectly penalizing undue risks.

Focusing on the interaction between market discipline and the capital-aimed macroprudential policies index depicted in Model 1, we find that this coefficient is statistically significant at the 1% level. To investigate this relationship even further, and using Figure 2 to do so, we graphically represent the effect of a tightening event on any of the capital-aimed macroprudential policies considered in this index based on the level of subordinated debt to which banks are subjected.

Figure 2. Marginal effects of capital-aimed macroprudential policies index on banks' risk, evaluated on all values of market discipline.

Marginal effect of the capital-aimed macroprudential policies index on banks' risk, evaluated at all values of market discipline, as measured by the level of subordinated debt over total liabilities. These results are calculated using the derivatives of Equation 2 along with Model 1, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.



In Figure 2, we can see that tightening capital-aimed macroprudential policies leads to a reduction in banks' risk for values of market discipline above the 1.650% turning point, whilst being ineffective for inferior values. Furthermore, higher levels of subordinated debt translate into larger reductions in banks' risk. This effect is very clear on Table 5, which reports the average marginal effects of the previous model, where we can see that a bank without any subordinated debt will respond to a tightening of a capital-aimed macroprudential policy with an increase of 0.219% on banks' risk, whereas the same adjustment will cause a reduction of 1.377% in the level of risk of a bank with a ratio of 12% of subordinated debt.

Table 5. Average marginal effects of the interaction between market discipline and capital-aimed macroprudential policies.

Average marginal effects of Model 1 (Table 4), with respective standard errors obtained by the Delta-method. The first column reports the values of market discipline, measured by the subordinated debt ratio, from the minimum, 0%, to the maximum observed, 12%, in increments of 1%. The column 2 report the values of the marginal effects of interaction of market discipline and capital-aimed macroprudential policies on banks' risk, given the constant reported in the same row of the first column. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

c (in % of Sub. Debt)	**Capital-aimed macroprudential policies index (Model 1)**	
	dy/dx at Subordinated debt = c	Delta Method Standard Error
0	.219***	.042
1	.086**	.035
2	-.047	.036
3	-.180***	.044
4	-.313***	.056
5	-.446***	.070
6	-.579***	.086
7	-.712***	.101
8	-.845***	.117
9	-.978***	.134
1	-1.111***	.150
11	-1.244***	.167
12	-1.377***	.183

This enhancing effect is consistent with the theory that banks subjected to greater levels of market discipline, when faced with a more prominent and stringent capital-aimed macroprudential framework, will maintain buffers above the minimum requirements (Fonseca and González, 2010; Ghosh, 2017) to reduce the funding costs in the event that debt holders demand higher returns due to their increased risk. This behavior enhances the monetary build-up incentives of capital-aimed policies, increases banks' resilience and, consequently, their capability to cover unexpected losses and avoid default. Moreover, more of the banks' capital at risk will create incentives for managers to take more prudent decisions regarding the choice of investments (Thamae and Odhiambo, 2021) when adapting to a tighter macroprudential framework.

4.2. Robustness tests

4.2.1.The effect of countries' economic development: advanced economies vs emerging markets and developing countries

The effects of macroprudential policies and market discipline, and subsequently their joint impact, may differ between developed and developing countries. According to the literature, not only do emerging markets have more experience with macroprudential policies (Lim et al., 2011; Claessens et al., 2014), as these countries have more pronounced business and financial cycles, but they also have a different focus when considering which macroprudential policies to adjust.

Therefore, we apply the previous model to a sample composed solely by banks located in advanced economies. The results are presented in Table 6.

We observe that market discipline *per se* is effective in reducing banks' risk in advanced economies. These conclusions also apply to the individual effect of capital-aimed macroprudential policies, where tightening any of the capital-aimed macroprudential policies will lead to a reduction of 0.541% on banks' risk in advanced economies.

The interaction term between the macroprudential policies and the market discipline reveals a similar pattern, suggesting that the strengthening effect only exists in developed economies. This conditional effect of market discipline over the effectiveness of macroprudential policies can also be visualized in Figure 3.

As we can see, the conditional effect of subordinated debt over the effectiveness of capital-aimed macroprudential policies, in the advanced economies, is stronger for higher levels of market discipline, which validates our previous findings.

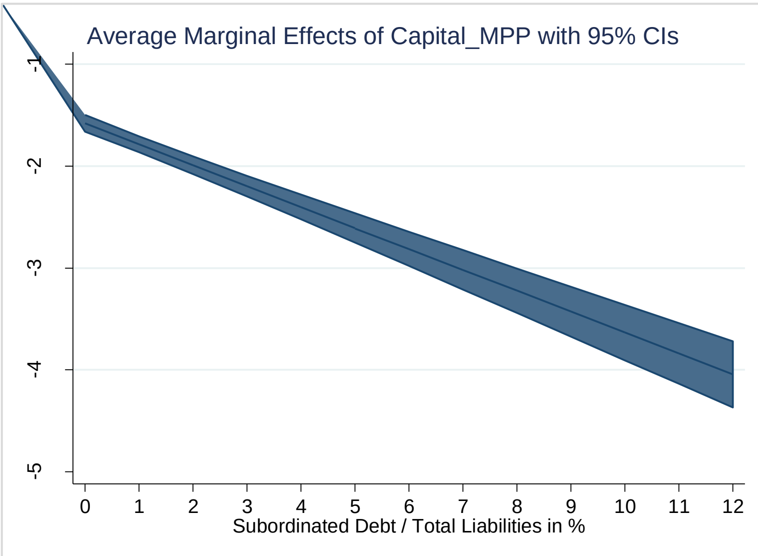
Table 6. Banks' risk model with macroprudential regulation and market discipline variables in the Advanced Economies subsample.

Estimation of Equation 1 considering the interaction between the capital-aimed macroprudential policies index and the market discipline variable in a sample solely composed by banks from AE countries (Model 2). The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

Dependent Variable: Asset Risk	**Model 2**
Lagged dependent variable	.476*** (.005)
Macroprudential Policies Index	
Capital-aimed MPP Index	-.541*** (.033)
Market Discipline variable	
Subordinated debt ratio	-.117*** (.017)
Interaction variable	
Capital-aimed MPP Index x Subordinated debt ratio	-.121*** (.012)
Bank specific variables	
Profitability	-.336*** (.024)
Leverage	-.010* (.005)
LOG Size	-.571*** (.008)
Cost-income ratio	.024*** (.001)
Asset diversity	3.485*** (.084)
Income diversity	-.723*** (.087)
Credit risk	.133*** (.007)
External variables	
Inflation	.114*** (.022)
GDP growth	.528*** (.019)
Crisis	.186*** (.044)
Level of interest rates	-.467*** (.026)
Slope of interest rates	-.322*** (.021)
Concentration	-.008*** (.001)
Year dummies	Yes
Pre-validation tests	
Hansen test	.482
Difference-in-Hansen test	.000
Arellano-Bond test for AR (1)	.146
Arellano-Bond test for AR (2)	.476***
Number of instruments	228
Number of observations	1691

Figure 3. Marginal effects of capital-aimed macroprudential policies index on banks' risk, evaluated on all values of market discipline, in advanced economies.

Marginal effect of the capital-aimed macroprudential policies index on banks' risk, evaluated at all values of market discipline, as measured by the level of subordinated debt over total liabilities, in the advanced economies. These results are calculated using the derivatives of Equation 2 along with Model 2, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.



4.2.2. Robustness tests: The region effect on the relationship between market discipline and macroprudential policies

Another factor to consider when evaluating the joint effect of macroprudential policies and market discipline on banks' risk is the differences between the countries. For instance, Arnold et al. (2016) shows that German investors are more patient with troubled banks and slower in charging higher risk premiums, which could translate into a lower efficiency of the previous coefficients. Furthermore, Emmons et al. (2001) shows that in the USA, commercial banks are supervised by federal and state agencies, which limits bank managers' discretion and reduces market participants' disciplinary action.

Therefore, we establish whether the previous results hold when we consider the regulatory differences between the USA (Model 3) and the rest of the countries composing the sample by using the specification presented in Equation 1 in a sample solely composed by USA banks. These results are presented in Table 7.

Again, Model 3 validates our previous results and also shows us an interesting pattern: Market discipline is effective in reducing banks risk, while this effectiveness is higher in the USA compared to the other countries. The capital-aimed macroprudential policies, *per se,* also demonstrate this same pattern, with higher effectiveness in the USA.

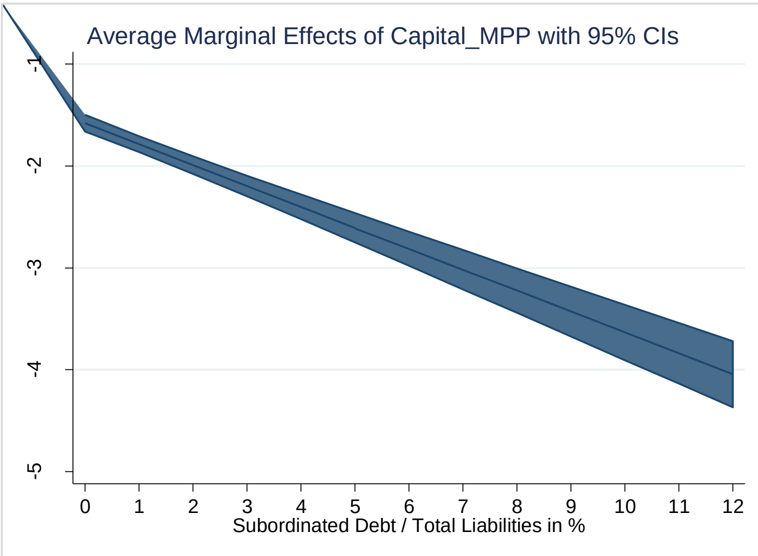
Table 7. Banks' risk model with macroprudential regulation and market discipline variables in the USA subsample.

Estimation of Equation 1 considering the interaction between the capital-aimed macroprudential policies index and the market discipline variable in a sample solely composed by banks from the USA (Model 3). The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

Dependent Variable: Asset Risk	**Model 3**
Lagged dependent variable	.274*** (.005)
Macroprudential Policies Index	
Capital-aimed MPP Index	-1.580*** (.042)
Market Discipline variable	
Subordinated debt ratio	-.050** (.022)
Interaction variable	
Capital-aimed MPP Index x Subordinated debt ratio	-.205*** (.014)
Bank specific variables	
Profitability	-.245*** .019)
Leverage	-.040*** (.006)
LOG Size	.235*** (.035)
Cost-income ratio	-.087*** (.004)
Asset diversity	2.394*** (.123)
Income diversity	1.614*** (.155)
Credit risk	.037 (.026)
Year dummies	Yes
Pre-validation tests	
Hansen test	.451
Difference-in-Hansen test	.527
Arellano-Bond test for AR (1)	.000
Arellano-Bond test for AR (2)	.107
Number of instruments	207
Number of observations	1308

Finally, the conditional effect of market discipline over capital-aimed macroprudential policies confirms our previous conclusions. Furthermore, we show that the magnitude of the strengthening effect is higher in the USA when compared with the other countries. This effect is pictured in Figure 4.

Figure 4. Marginal effects of capital-aimed macroprudential policies index on banks' risk, evaluated on all values of market discipline in the USA.
Marginal effect of the capital-aimed macroprudential policies index on banks' risk, evaluated at all values of market discipline, as measured by the level of subordinated debt over total liabilities, in the USA. These results are calculated using the derivatives of Equation 2 along with Model 3, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.



In Figure 4, we can visualize that a higher level of market discipline strengthens the effectiveness of capital-aimed macroprudential policies in reducing banks' risk, confirming our previous findings.

4.2.3. Robustness tests: Z-Score as the dependent variable

Finally, and following previous studies, we consider a different measure of banks' risk, namely the Z-Score. Because this variable measures the variability in banks' returns that can be absorbed by banks' capital without such banks becoming insolvent, higher values will indicate a less risky bank. We repeat Model 1 using the Z-score as the dependent variable. Table 8 presents the results.

The results show that the estimated coefficients in Model 4 are statistically significant and according to expectations. The marginal effects presented in Table 9 show that higher levels of subordinated debt will translate into a higher increase in the banks' Z-Score when facing a tightening of a capital-aimed macroprudential policy. These results validate the previous findings on how policymakers can use market discipline to complement the macroprudential framework in dealing with risky banks and overcome the moral-hazard problem.

Table 8. Robustness Check: Prior banks' risk models with the Z-Score as proxy for banks' risk.

Estimation of the baseline model (Model 1) using an alternative proxy for banks' risk: the Z-Score. Model 4 replicates Model 1, where we analyze the macroprudential policies interaction with the market discipline variable. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

Dependent Variable: Z-Score	**Model 4**
Lagged dependent variable	.112*** (.003)
Macroprudential Policies Index	
Capital-aimed MPP Index	.011** (.006)
Market Discipline variable	
Subordinated debt ratio	.046*** (.004)
Interaction variable	
Capital-aimed MPP Index x Subordinated debt ratio	.044*** (.004)
Bank specific variables	
Profitability	.476*** (.005)
Leverage	-.007*** (.001)
LOG Size	-.033*** (.002)
Cost-income ratio	-.008*** (.001)
Asset diversity	.078*** (.021)
Income diversity	.161*** (.014)
Credit risk	.014*** (.002)
External variables	
Inflation	.002 (.002)
GDP growth	-.014*** (.002)
Crisis	.183*** (.011)
Level of interest rates	-.169*** (.005)
Slope of interest rates	-.108*** (.003)
Concentration	.006*** (.001)
Year dummies	Yes
Pre-validation tests	
Hansen test	.374
Difference-in-Hansen test	.000
Arellano-Bond test for AR (1)	.408
Arellano-Bond test for AR (2)	.112***
Number of instruments	286
Number of observations	1830

Table 9. Average marginal effects of the interaction between market discipline and capital-aimed macroprudential policies considering the Z-Score as dependent variable.

Average marginal effects of Model 4 (Table 8), with standard errors obtained by the Delta-method. The first column reports the values of the market discipline, as measured by the level of subordinated debt, from the minimum, 0%, to the maximum observed, 12%, in increments of 1%. The column 2 report the values of the marginal effects of interaction of market discipline and capital-aimed macroprudential policies on banks' risk, measured by the Z-Score, given the constant reported in the same row of the first column. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

c (in % of Sub. Debt)	**Capital-aimed macroprudential policies index (Model 4)**	
	dy/dx at Subordinated debt = c	Delta Method Standard Error
0	.011*	.006
1	.055***	.004
2	.098***	.003
3	.142***	.004
4	.186***	.005
5	.229***	.007
6	.273***	.010
7	.316***	.012
8	.360***	.014
9	.404***	.016
1	.447***	.019
11	.491***	.021
12	.535***	.023

5. Conclusion

Assuring the soundness of banks and consequently protecting some claimants from the effects of banks' default has long concerned supervisors over the years. However, banks have incentives to take "excessive" risk at the expense of taxpayers due to the moral-hazard problems created by safety nets.

Although market participants' supervisory role has been discussed by academics and policymakers since the 1980s, it has been overlooked by policymakers as an effective regulatory mechanism. The present study is motivated by the recent, post-GFC regulatory reforms based on market participants' enhanced disciplinary power as well as by the regulatory reforms on macroprudential policies and how these two different mechanisms can complement each other and create synergies in achieving financial stability and dealing with moral-hazard problems at a lower cost.

The results show that there is a statistically significant interaction between market discipline and macroprudential policies in shaping banks' risk. That is, increased levels of market discipline, materialized through higher levels of subordinated debt on banks' structures, can enhance the effectiveness of capital-aimed prudential policies in reducing banks' risk. These results suggest that increasing market participants' disciplinary action can lead banks to avoid riskier investments and value-destroying actions as these would be easily perceived by market participants who would sanction this behavior by asking for a higher risk premium. Furthermore, increasing the level of subordinated debt on banks' structures will lead these institutions to hold more capital than the minimum required to avoid costly funding in case of disciplinary actions by creditors. This increase in capital buffers will also translate into a higher capacity to deal with unexpected losses and, consequently, reduce the banks' default probability.

Moreover, we show that this behavior is only present in advanced economies while being ineffective in emerging markets and developing economies. Additionally, we show that the conditional effect is stronger in the USA compared to the remaining countries composing our sample.

Finally, we show that these results hold when we consider an alternative variable for banks' risk, namely the Z-Score, and for the green financial policies.

These findings have important implications since they show that market participants' disciplinary power should not be ignored but should instead be enhanced, as it might be a cheaper mechanism to complement capital-aimed macroprudential policies in dealing with the moral-hazard problems created by the safety nets and bailouts imposed by governments. However, forcing banks to hold unsubordinated debt as a mechanism of enforcing market discipline has both boon and bane outcomes.

Market discipline can indeed act as an enforcing mechanism, guaranteeing constant supervision by market participants, as they will enforce their disciplinary power over banks when detecting any deviant or moral hazard behaviors. Moreover, theory suggests that due to this disciplinary power, banks will be prone to maintain higher capital levels to reduce funding costs. These increased capital buffers are another advantage as they increase the banks' resilience during crises.

Nonetheless, these effects do not come without consequences. First, it is necessary that timely and adequate information keeps flowing to the market to reduce information asymmetries considered one of the fragilities of market discipline. Furthermore, policymakers and governments must be specific about any safety nets in place and must commit not to bailout subordinated-debt owners, as this behavior would reduce the effectiveness of this supervisory mechanism, impairing the effectiveness of market discipline.

Another important implication is associated with the fact that market participants only account for short-term risks rather, ignoring the systemic perspective and long-run risks.

On this matter, although banking supervision indeed exists to account for these types of risk, the introduction of market discipline may lead to supervisors having a relaxed and careless behavior when supervising the market as they might perceive the role of market participants as enough to assure stability.

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Appendix I

Bank-specific and country-specific control variables used, their expected signals according to the empirical literature and empirical studies also using as control variables.

Control Variables	*Expected signal*	*Theory supporting the effects*	*Literature that uses as control variable*
Bank-specific variables			
Leverage	+ / −	Banks with higher leverage are more prone to increase their risk-taking by investing in riskier assets (Fatouh et al., 2023). On the other hand, under Basel III higher leverage will force banks to hold more capital, thus reflecting in higher loss-absorbing capacity and, consequently, reduced bank risk (Acosta-Smith et al., 2020; European Central Bank, 2015)	Baumann & Nier (2004), and Chan et al. (2024).
Size	+ / −	Larger banks are able to diversify their operations, thus realizing economies of scale and reducing inefficiencies, leading to reduced bank risk (Regehr and Sengupta, 2016). However, larger banks are riskier and create more systemic risk, due to their increased exposure to the financial markets. Nonetheless, other factors such as the level of capital and its funding also plays an important role on defining such effect (Laeven et al., 2014).	Baumann & Nier (2004), Bohachova (2008), Gaganis et al. (2020), Meuleman & Vennet (2022), and Belkhir et al. (2023).
Profitability	−	Higher profitability allows banks to build a monetary buffer that can be used to absorb losses, thus reducing its insolvency risk (Pascual et al., 2015).	Baumann & Nier (2004), Andrieş et al. (2021), and Belkhir et al. (2023)
Cost-income ratio	+ / −	According to the cost skimming theory, more efficient banks, who devote less costs to credit monitoring, will be subjected to higher future risk due to an increase in non-performing loans (Fiordelisi et al., 2010). On the other hand, the moral hazard theory shows a negative relation where bank managers have increased incentives to take on more risk when banks are less efficient (Fiordelisi et al., 2010).	Baumann & Nier (2004), Caprio et al. (2007), Boubakri et al. (2020), and Gaganis et al, (2020).
Credit risk	+	Credit risk is considered a key factor, that can influence the bank profitability and its contribution for the stability of the financial system (Ekinci and Poyraz, 2019). On this matter, it is expected that higher credit risk arising from non-performing loans, to lead to an increase in bank losses and reduced banks' performance thus leading to riskier banks (El Hokayem and El Kazzi, 2024).	Laeven & Levine, (2009), Kanagaretnam et al. (2014), Jin et al., (2013), Andrieş et al. (2021), and Belkhir et al. (2023).
Income diversity	+ / −	Income diversification can influence banks' risk through two different channels. Higher income diversification towards non-interest activities can reduce banks' risk through an increase in income stability (Berger et al., 1999; Campa and Kedia, 2002; Landskroner et al., 2005). On the other hand, it can also induce higher risk taking through increased exposure to volatility arising from non-interest activities (Lapteacru, 2016).	Bohachova (2008), Andrieş et al. (2021), and Chan et al. (2024).
Asset diversity	+ / −	Diversifying banks' activities away from lending activities can have an ambiguous effect. While it might reduce the banks' idiosyncratic risk and stabilize the banks' earnings (Gelman et al., 2022), it can also increase banks' contribution to systemic risk (Baele et al., 2007) and by diverging banks' investments towards riskier, unsecured and unsupervised investments, thus inducing higher volatility (Stiroh and Rumble, 2005; Stiroh, 2006) and, consequently, higher risk-taking. This positive relation is also supported by the agency theory.	Di Biase and D'Apolito (2012), Teixeira et al. (2020), and Radojičić and Marinković (2023).
Macroeconomic variables			
GDP growth	+	Banks are exposed to business cycle conditions. On this matter, risk tends to arise during periods of economic growth as banks lend more easily, thus increasing the potential losses of such credits which can be materialized during periods of distress (Bohachova, 2007).	Alam et al. (2019), Beirne & Friedrich (2014), Gaganis et al. (2020), Meuleman & Vennet (2022), and Chan et al. (2024).
Inflation	+	Increased levels of inflation threatens banks' profitability as it diminishes the banks' real rates of return of its assets. Furthermore, higher inflation can impair the earnings of the banks' borrowers, thus impairing the quality of such credits and, consequently, increasing banks' risk (Bohachova, 2008).	Bohachova (2008), Beirne & Friedrich (2014), Ashraf (2017), Gaganis et al. (2020), and Chan et al. (2024).
Level of interest rates	+ / −	Higher market interest rates will translate in an increase of the banks' returns. On the other hand, it threatens credit quality of said bank as it can be materialized in increased credit risk (Bohachova, 2007). Moreover, due to maturity mismatch, banks can be exposed to interest rate risk as banks' assets can decrease their value due to an increase in interest rates (Neely and Neely, 2023)	Ahmed and Khan (2022), Alam et al. (2019), and Gropp et al. (2007).
Slope of interest rates	+ / −	A steeper yield curve, indicating a larger difference between short-term and long-term interest rates, can enhance bank profitability in countries where bank loans are based on long-term interest rates thus reducing the banks' risk (Aydemir and Ovenc, 2016). This effect is due to the maturity mismatch, where banks borrow at lower short-term rates and lend at higher long-term rates, thus increasing their net interest margin and profitability (Fendoglu, 2023). However, this steeper yield curve can expose banks to increases interest rate risk, thus impacting its' net worth and, consequently, leading to riskier banks. (Neely and Neely, 2023).	Ahmed and Khan (2022), Teixeira et al. (2014), and Gropp et al. (2007).
Concentration	+ / −	Higher levels of banking competition leads to a decrease in profit margins, inducing banks to take on more risks to increase their returns (Berger et al., 2009). Moreover, concentrated market power leads banks to charge higher interest rates, which can impair the capacity of such borrowers to repay their loans, translating in higher risk (Boyd and De Nicolo, 2005; De Nicolo and Loukoianova, 2006). However, this concentration also boosts the banks' charter value, thus inducing in risk aversion (Bohachova, 2008).	Bohachova (2008), Baselga-Pascual et al. (2015), Gaganis et al. (2020), and Dutra et al. (2023a).
Crisis	+	Bank risk materializes during years of crisis (Altunbas et al., 2017). This effect comes not only from increased financial market volatility (Matos et al., 2024a) but also by greater exposure to credit risk, materialized through increased non-performing loans (World Bank, 2016) and decreased asset returns (Kuvshinov et al., 2022).	Ashraf (2017), Wang and Sui (2019), Matos et al. (2024a), and Chan et al. (2023).

CHAPTER V - GREEN FINANCIAL POLICIES AND BANKS' RISK-TAKING BEHAVIOR[7]

[7] This chapter is based on Matos et al. (2024c):
Matos, T. F. A., Teixeira, J. C. A., and Dutra, T. M. (2024c). Green financial policies and banks' risk-taking behavior. Under review at *Business Strategy and the Environment*.

Abstract

This study examines the impact of climate-related financial policies on banks' risk-taking behavior. Based on a sample of 614 banks across 37 countries from 2006 to 2020, we find that stronger green financial policies lead to a reduction in bank risk from a total risk perspective. Conversely, when examining credit risk, we find an inverse relationship in which higher levels of commitment to green policies induce an increase in non-performing loans, translating into higher credit risk. Finally, we complement this analysis by showing that the dampening effect of green policies on bank risk is stronger in developing countries and during crises. These results stand when using different proxies for bank risk and green financial policies.

JEL Classification: G01, G21, G28, Q58.

Keywords: Banks' risk, climate-related financial policies, green credit, sustainability.

1. Introduction

Climate change and environmental issues have garnered the attention of policymakers and researchers due to their impact on the overall economy, financial markets, and banking industry (Grippa et al., 2019; Shirai, 2023). This has urged the intervention of central banks and policymakers through the conception of financial regulations aimed at integrating sustainable practices in the financial industry (Carney, 2015; Shirai, 2023) and ensuring that banks incorporate climate-related factors in their risk assessment processes (Cigu et al., 2020). Since the banking sector plays a pivotal role in meeting the financial needs of the private sector by providing credit and private investments (Beck and Demirguc-Kunt 2006; Wang 2016; European Banking Federation, 2017; Scholtens and Klooster, 2019), it serves as a conduit for promoting private sustainable investments.

Many studies have analyzed the impact of these policies and green credit on bank performance and competitiveness (Luo et al. 2021; Galan and Tan, 2022), banks' non-performing loans (Cui et al., 2018; Al-Qudah et al., 2022), and the overall economy, with respect to carbon emissions (D'Orazio and Dirks, 2021) and other macroeconomic variables (Allen et al., 2020). Nevertheless, although the existing literature demonstrates a positive relationship between banks' performance and their environmental commitment, there is a notable gap in understanding how this complex relationship might influence banks' risk-taking dynamics (Scholtens and Klooster, 2019; An et al., 2023). Indeed, few empirical studies have focused on the effect of green credit on banks' risk, while the existing concentrate in the context of individual countries, such as China (Feng et al., 2014; Cui et al., 2018; Zhou et al., 2022; Liu and Huang, 2022; An et al. 2023) or the United Arab Emirates (Al-Qudah et al., 2022). Therefore, this study seeks to fill this gap by providing a comprehensive analysis of the impact of adopting climate-related financial policies on banks' risk-taking behavior.

Using a sample of 614 banks across 37 countries from 2006 to 2020, we find that stronger climate-related financial policies result in a reduction in bank risk from a total risk perspective. Additionally, from a credit risk perspective, we find an inverse relationship in which higher levels of commitment to green policies induce an increase in the bank's non-performing loans, translating into higher credit risk.

Further, extending our analysis by evaluating this dampening effect across developed and developing countries, we demonstrate that this effect is stronger in the latter. Furthermore, we show that stronger green financial policies can induce a greater reduction in bank risk during crises, associating such effects with the bank's increased social reputation when lending to sustainable projects.

The contributions of this study are multifold. First, it contributes to the literature on how green financial policies influence bank performance by focusing on banks' risk-taking channels. Second, to the best of our knowledge, this is the first empirical study to analyze how this relationship might influence banks located in developing countries differently and how these policies might influence banks' risk-taking behavior during crises. Finally, this study can help policymakers utilize green financial policies to reduce the banking system's exposure to environmental risks and even financial shocks, considering that our database contains many countries worldwide that are diversified both geographically and in terms of economic development. Further, it acts as a wake-up call considering the ramifications of these policies in terms of the exposure of the loan portfolio, which might prove to be fragile in times of economic uncertainty.

The remainder of this paper is organized as follows. Section 5.2 briefly reviews the literature examining how the implementation of green macroprudential policies can induce banks to increase their green credit allocation and examines its potential impact on banks' risk-taking behavior. Section 5.3 describes the data and variables used and explains the empirical analysis. Section 5.4 discusses the results and presents additional robustness tests. Finally, Section 5.5 summarizes the conclusions.

2. Literature review and hypothesis development

2.1. The effect of climate-related financial policies on bank risk

Climate change can influence monetary policies and financial regulations (Batten et al., 2016; Coeuré, 2018) due to shocks in supply prices and market volatility as a consequence of inflationary pressure on spreads, saving rates, and real interest rates arising from uncertainty (Pfister and Valla, 2021; D'Orazio and Popoyan, 2022). Since banks are as vulnerable as any other company (Thompson and Cowton, 2004), policymakers have started implementing a green prudential framework, aiming at increasing banks' green credit allocation to safeguard against any environmental or climate-related risks within the economy and financial system.

In this context, the literature refers to climate-related financial policies or green prudential policies as the guidelines or policies implemented by policymakers to promote sustainable and environmentally friendly practices in the banking sector (Chen et al., 2023), and increase green credit, that is, loans toward businesses or projects focusing on green, clean energy or environmental sustainability, including upgrades from traditional industries (Aizawa and Yang, 2010; Akomea-Frimpong et al., 2022).

The impact of climate change on the banking industry can materialize through two primary risks: physical risk, channeled through damage to property and infrastructure caused by natural disasters (Batten et al, 2016; Prudential Regulation Authority, 2018; Grippa et al., 2019; European Parliament, 2021); and transitional risk arising from regulatory changes, through which the late adaptation to a green policy framework can lead to greater risk due to increased consumer consciousness and market sentiment (Grippa et al., 2019; European Parliament, 2021) and, consequently, a decrease in the value of some assets (Prudential Regulation Authority, 2018; European Parliament, 2021). Furthermore, stranded assets, arising from transitional risk, can cause a “Minsky” moment, where a sudden collapse of the assets’ value can lead to financial instability, potentially causing a cascade effect throughout the entire financial system (Minsky, 1982; Carney, 2015; European Systemic Risk Board, 2016; Battiston et al., 2017).

The literature supports the idea that implementing green prudential policies and increasing banks’ green credit allocation can effectively reduce bank risk (Feridun and Güngör, 2020). This theory is based on the portfolio diversification theory, which states that banks can reduce their loan portfolio risk by diversifying toward green, renewable, and low-carbon industries, thus reducing the weight of common and traditional investments in their loan portfolios (Luo et al., 2021). Since these traditional investments have a higher environmental risk, banks can reduce their exposure and improve their asset quality (An et al., 2023) by increasing green lending.

Market sentiment also contributes to this dampening effect. In the past few years, investor interest in sustainability factors has increased, in addition to the traditional triad investment factors, that is, profitability, risk, and liquidity (Ambec and Lanoie, 2008; Rhodes, 2010). Therefore, by utilizing this growing public awareness of environmental issues, banks can attract deposits and investments from environmentally conscious investors by increasing their green credit allocation (Lingnau et al., 2022; Huang et al., 2023; Mirza et al., 2023). The empirical findings of Liu and Huang (2022) and Feng et al. (2024) also verify this effect by showing that an increase in banks’ activity with respect to green credit leads to an improvement in their social reputation and operating performance, as it enhances their financial risk management capabilities. Additionally, Ciciretti et al. (2014) and Wu and Shen (2013) show that higher levels of green credit allocation allow banks to reduce their funding costs for both debt and equity. Moreover, Jing et al. (2022) show that during the COVID-19 pandemic, companies with better sustainability levels were more resilient to shocks, associating this effect with increased stakeholder confidence.

Finally, since banks' performance depends on the financial health of their clients (Zhou et al., 2022), banks can reduce their credit risk in the long run by increasing green lending. This theory is based on the fact that some firms struggle to adapt sustainability activities and face a higher risk of default (Belloni et al., 2022). Therefore, although these difficulties might increase short-term bank risk (Godfrey, 2008), the surviving firms will eventually have better environmental performance, higher operational efficiency, innovation, and, consequently, better financial performance (Zhou et al., 2022), thus reducing the banks' credit risk associated with such lenders. Cui et al. (2018) and Al-Qudah et al. (2022) provide further evidence that an increase in green credit allocation can lead to a reduction in non-performing loans, thereby reducing credit risk. Moreover, Alogoskoufis et al. (2021) show that these short-term costs, which ultimately reduce the impact of transitional risk, are outweighed by the potential losses derived from sluggish implementation because it would imply an increase in physical risk in the long run as physical events causing these risks would become recurrent (Belloni et al., 2022).

Hence, we test the hypothesis that the early implementation of green macroprudential policies, triggering an increase in banks' green credit allocation, results in risk reduction, channeled through not only improved portfolio risk management but also enhanced social and market reputation, leading to an increase in deposits and, consequently, lowering funding costs.

2.2. The dark side of green financial policies

Another strand of the literature suggests that an increase in lending toward sustainable projects, due to the implementation of a green prudential framework, could lead to an increase in bank risk. According to Steckel et al. (2016) and Akomea-Frimpong et al. (2022), a lack of standardization in these industries can cause information asymmetry issues, which may cause banks to struggle to assess the risk of investing in such projects.

Furthermore, Chen et al. (2023) show that banks can deteriorate their credit quality by investing in green credit projects, as they are prone to environmental risks, thus impacting the banks' earnings and, consequently, increasing the risk of withholding loan repayments. The findings of Park and Kim (2020) also support this theory that increased green lending leads to banks taking more risks, from a credit risk perspective.

The empirical findings of Zhou et al. (2022) also support the damaging effects of an increase in banks' credit portfolio toward sustainable projects. They show that green projects require higher capital investments and human resources, leading to an increase in banks' operating costs and, consequently, reduced profitability.

Therefore, we analyze the hypothesis that enforcing green macroprudential policies and making banks increase their green credit allocation, can lead to a deterioration in their loan portfolio quality, translating into higher credit risk.

3. Methodology and variables

3.1. Empirical strategy

We assess whether implementing climate-related financial policies can reduce bank risk. To achieve this, we use the following empirical specifications:

$$Risk_{i,j,t} = \alpha + \beta_1 Risk_{i,j,t-1} + \beta_2 CRFP_{j,t} + \beta_3 BankControl_{i,t} + \beta_4 CountryControl_{j,t} + Year_t + \varepsilon_{i,j,t} \text{ ,} \quad (1)$$

where the dependent variable *Risk* $_{i,j,t}$ indicates risk for bank *i,* located in country j in year *t*; *and CRFP* is an index of climate-related financial policies for country j in year *t*. *BankControl* and *CountryControl* are sets of idiosyncratic bank characteristics and macroeconomic/external variables, respectively, which are typically used as control variables in the literature. The variable $Year_t$ captures time-specific fixed effects, allowing us to control for the exogenous impact on the dependent variable not attributed to the endogenous variables. Finally, since we use a dynamic model, the one-period lagged dependent variable is included to measure banks' risk persistence over time due to inter-temporal risk smoothing and competition and to capture the response to banking regulations, as proposed by Delis and Kouretas (2011).

Dynamic panel data specifications may face endogeneity issues. Furthermore, commonly used models such as ordinary least squares (OLS) or maximum likelihood estimation (MLE) only remain consistent when the sample comprises a large number of observations. We address these challenges by employing an autoregressive model, namely the system generalized method of moments (sGMM). This model differs from other approaches in that it focuses on specific moments, known as moment conditions, of random variables, instead of making assumptions about the entire distribution. Additionally, this approach is particularly effective in scenarios with a large N and a short T timeframe (Blundell and Bond, 1998; Roodman, 2009).

To assess the consistency of the sGMM estimator, we examine two key assumptions: the absence of serial correlation among errors and the absence of instrument proliferation. To do so, we rely on two diagnostic tests: the Hansen test of overidentifying restrictions and the autoregressive test. The first test evaluates the global validity of the instruments by analyzing the specified moment conditions, while the second test, proposed by Arellano and Bond (1991), checks for serial correlation in the error term, ε.

Finally, to evaluate whether the effects of green financial policies are consistent regardless of a country's economic development, we use the following interaction model:

$$Risk_{i,j,t} = \alpha + \beta_1 Risk_{i,j,t-1} + \beta_2 CRFP_{j,t} + \beta_3 EMDE\_Dummy_{j,t} + \beta_4 (CRFP \times EMDE\_Dummy)_{j,t} + \beta_5 BankControl_{i,t} + \beta_6 CountryControl_{j,t} + Year_t + \varepsilon_{i,j,t} \ . \quad (2)$$

The *EMDE_Dummy* variable, considered in Equation 8, is a dummy variable that takes the value of 1 if the bank is located in an emerging market/developing economy and 0 otherwise. This specification allows us to verify whether the impact of green financial policies depends on whether banks are located in developed or developing countries using the interaction term *CRFP×EMDE_Dummy*. This impact can be analyzed as follows:

$$\frac{\partial Risk_{i,j,t}}{\partial EMDE\_Dummy_{j,t,m}} = \beta_{3,m} + \beta_{4,m} CRFP_{j,t} \ . \quad (3)$$

This approach is also adopted when we analyze the effect of green financial policies during systemic crises, but by replacing the EMDE dummy variable with a crisis dummy variable that assumes a value of 1 in years of a systemic crisis and 0 otherwise.

3.2. Data and sample

To conduct this analysis, we combined data from numerous sources. We focused on publicly listed commercial banks and bank-holding companies, gathering data on 614 banks between 2006 and 2020 from the BankFocus database provided by Bureau van Dijk. For country-level variables, we collected data using DataStream, a financial time series database by Refinitiv.

Table 1 presents details of the sample distribution by country and year.

Table 1. Sample distribution by country and year.

Distribution of the sample by country, year and by the level of economic development following the distribution presented by Alam et al. (2019).

Country	Type of country	Year															Total
		2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	
Austria	AE			4	4	4		5	5	5	5	5	5	6	7	7	**62**
Belgium	AE	1	1	1		1	1	1	1	1	1			1	1		**11**
Brazil	EMDE					2		10		11	8	8	10	9	12	13	**83**
Bulgaria	EMDE						2	1	2	3	3	3	3	4	3	3	**27**
Chile	EMDE					2	2								2		**6**
China	EMDE		5		7		9	8	9	15							**53**
Colombia	EMDE			2	2	1		3	3	3	3		3	2	2	2	**26**
Cyprus	AE					1								1			**2**
Czech Republic	AE				1	1	1	1				1	2	2	1	1	**11**
Denmark	AE	2	3		4	4	10	11	13	12					14	13	**86**
Finland	AE							1	1	1	1	1	1	5	4	4	**19**
France	AE	3	3	5	6	4	4	5	5	6	5	5	4	5	5	5	**70**
Germany	AE	2	3	3	3	3	5	5	6	8	7	7	6	6	7	8	**79**
Greece	AE		1		1		1					5		5	5		**18**
Hungary	EMDE												1	1		1	**3**
India	EMDE	5	6	7	6	9	10	10	12	11	15	18		19	23	17	**168**
Indonesia	EMDE		6	5	5	4	12	10	13	16	18	25	25				**139**
Ireland	AE								1	1		1	4	4	4	4	**19**
Italy	AE	2	3	3	4	2	6	6	5	5	6	6	5	8	11	14	**86**
Japan	AE	17	20	16	31	21	22	25	18	20	17	20	26	22	19	21	**315**
Lithuania	AE							1	1				1		1	1	**5**
Mexico	EMDE		2	2	2		8				9						**23**
Netherlands	AE		1	1	1	1	1			1		1	2			2	**11**
Norway	AE							7	11	11						23	**52**
Peru	EMDE							1				4			1		**6**
Philippines	EMDE	3	5	4	2					9	9				11		**43**
Poland	EMDE	1	1	1	4			4	5	4	3	5	4	5	4	5	**46**
Portugal	AE							1	1	1	1	1	2	1	1	1	**10**
Russian Federation	EMDE			1									9	9	8		**27**
Spain	AE	4	4	5	5	5	4	5	6	5	5	6	6	6	6	5	**77**
Sweden	AE			3	3			3	3	3						6	**21**
Switzerland	AE							6	5	6	6	6	5	6	7	6	**53**
Thailand	EMDE	2	2														**4**
Turkey	EMDE	2		2	5												**9**
Ukraine	EMDE							2						1	3	2	**8**
United Kingdom	AE	6	7	9		9		7		7	8			15	15		**83**
United States of America	AE			142	151	157	169	193	196	209	213	216	224	222	229	228	**2 549**
Total		**50**	**73**	**216**	**247**	**231**	**267**	**332**	**322**	**374**	**343**	**344**	**348**	**365**	**406**	**392**	**4 310**

Table 1 shows that the sample has an unbalanced panel data format. This is because not all of the 614 banks sampled were active during the sample period. Furthermore, this unbalanced format was caused by the fact that we dealt with outliers by winsorizing the final sample at the 1% and 99% percentiles of the bank-level data and by excluding banks with negative equity.

3.3. Dependent variable

In line with the existing research, this study used banks' asset risk as a measure of their individual risk. Following Gropp and Heider (2010), Claessens et al. (2014), Teixeira et al. (2020), and Dutra et al. (2023a), we calculated the asset risk of a bank by the standard deviation of asset returns, which reflects the yearly standard deviation based on the daily stock price returns, multiplied by the total market value of the bank's equity over the market value of the bank. This approach allowed us to capture two distinct components of risk, idiosyncratic risk and market risk, thus measuring the market effect on bank risk arising from a changing climate-related prudential framework.

Furthermore, following Matos et al. (2023) and Saliba et al. (2023), we used the bank's credit risk, measured by the ratio of loan loss provisions to total loans, to capture the effects of climate-related financial policies on the bank's loan portfolio. In addition, following existing research (Zhou et al., 2022; An et al., 2023; Dutra et al., 2023b; Matos et al., 2024a), we used the Z-score as a proxy for total bank risk as a robustness check.

3.4. Green macroprudential policies

As a measure of countries' engagement in implementing climate-related policies, we used the Climate-Related Financial Policy (CRFP) index obtained from the novel database provided by D'Orazio (2023). This index measures five key areas: green prudential regulations, credit allocation policies, green financial principles, other disclosure requirements, and green bond taxonomy and issuing. It assigns a score based on the country's commitment and bindingness to the policies contained in these areas. This database presents four different specifications, in which D'Orazio (2023) assigns different weights to policy areas and considers the level of commitment. We chose to use index number one, where the policy areas are equally weighted, and the level of commitment to each policy is considered. In the robustness checks, we use index number 2, where the green prudential regulation and credit allocation areas have different weights. Overall, a higher score on both indexes indicates a higher commitment to climate-related policies.

This variable provides us with a comprehensive and standardized measure that can be used to assess banks' risk response to the level of engagement in each country.

3.5. Country- and bank-level control variables

The literature identifies bank-specific characteristics and macroeconomic variables as important determinants of banks' risk-taking behavior. Therefore, we included a set of bank-specific and macroeconomic variables to capture the time-invariant bank or country fixed effects that impact bank risk through different channels. The bank control variables include banks' profitability, leverage, size, operational efficiency (measured by the inverse of the cost-to-income ratio), income diversity, and asset diversity. As country control variables, we included the gross domestic product (GDP) growth rate, inflation rate, the macroprudential policies adjustments index and the level and slope of interest rates.

The source and definition of all these variables are summarized in Appendix I.

3.6. Descriptive Statistics

Table 2 reports the descriptive statistics for the main variables. Overall, the average bank in the sample presents a bank risk of 5.171% with profitability of 1.506% and leverage of 87.215%. The average country has a GDP growth of 1.640% and a 1.921% inflation.

Figure 1 graphically represents the average bank risk for a preliminary analysis of the evolution of bank risk over the study period. Overall, bank risk presents a higher average in the years preceding the great financial crisis, whereas this average is lower in the years prior to this crisis, albeit increasing in the years of global uncertainty in the financial markets, such as Brexit and the US-China tariff war in 2016 and the COVID-19 pandemic in 2020.

Next, we explored the evolution of the CRFP index, as shown in Figure 2. This variable shows a similar pattern, which is consistent with existing literature on this subject. In other words, these policies have been increasingly adopted over the past two decades, as shown in Panel A.

Table 2. Descriptive Statistics.

	N	Mean	St. Dev.	Min.	Max.	Distribution		
						10th	50th	90th
Banks' risk								
Asset Risk	4 310	5.171	10.476	.000	79.802	.311	1.700	11.982
Credit Risk	4 310	2.493	3.959	.069	81.664	.546	1.381	5.102
Z-Score	4 310	.016	.939	-3.274	3.228	-1.191	.129	1.112
Climate-related Financial Policies Indexes								
CRFPI 1	4 310	27.454	17.243	.000	86.667	.000	33.333	46.667
CRFPI 2	4 310	19.840	18.252	.000	92.500	.000	18.500	44.400
Bank specific variables								
Profitability (%)	4 310	1.506	2.839	-16.936	72.844	.218	1.323	2.610
Leverage (%)	4 310	87.215	10.142	6.320	99.635	78.493	88.445	97.046
LOG Size	4 310	9,287	2.149	.047	14.854	6.972	8.896	12.535
Cost-income ratio	4 310	63.358	14.843	3.743	141.282	45.798	62.979	80.908
Asset diversity	4 310	.656	.395	.000	1.999	.278	.559	1.195
Income diversity	4 310	.677	.465	-.219	2.450	.204	.564	1.363
Macroeconomic variables								
GDP Growth	4 310	1.640	2.410	-11.182	13.900	-2.300	2.000	3.282
Inflation	4 310	1.921	1.641	-1.700	13.300	.200	1.741	3.103
Macroprudential policies index	4 310	.819	2.190	-9	13	-1	1	3
Level of interest rates (%)	4 310	1.337	4.610	-294.075	5.087	.148	1.603	2.915
Slope of interest rates (%)	4 310	2.741	2.202	-.579	31.313	.786	2.270	5.865
Concentration	4 310	43.261	17.848	.000	100	34.420	35.313	77.864
Crisis	4 310	.171	.376	0	1	0	0	1

Figure 1. Banks' risk yearly mean for the 2006-2020 period.

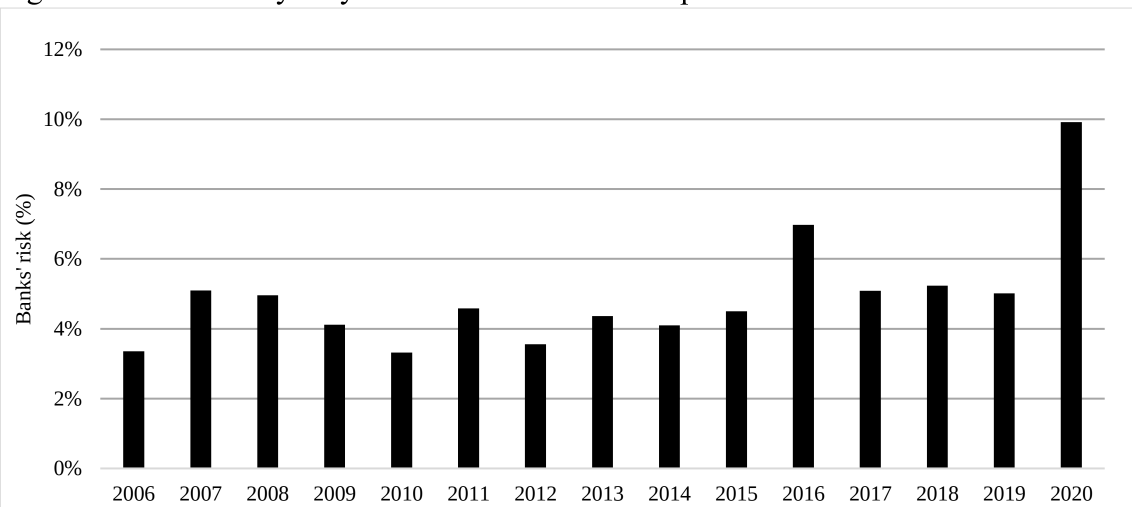
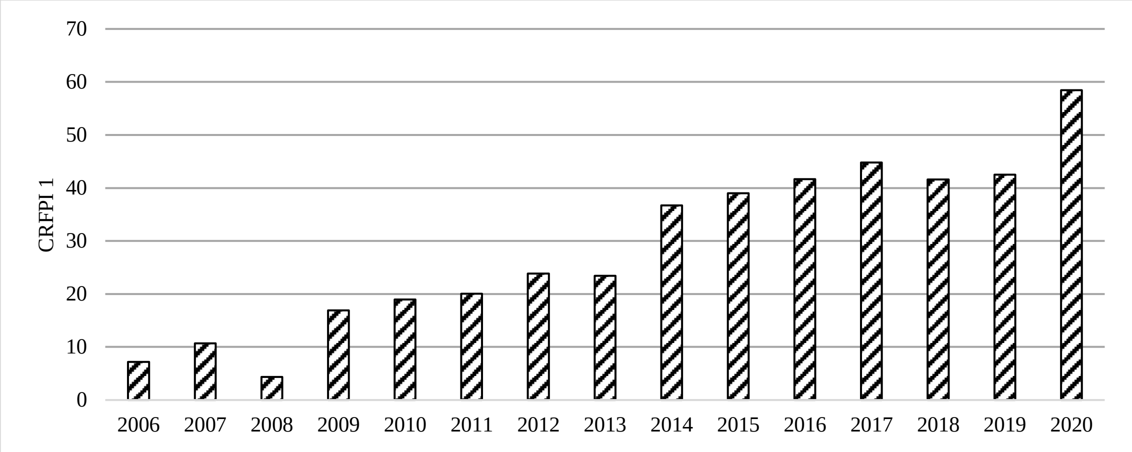
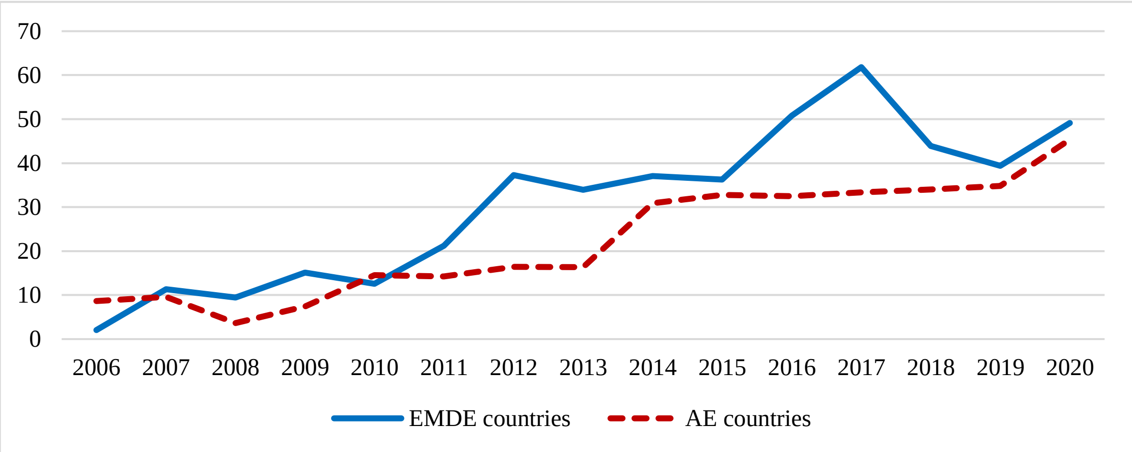


Figure 2. Climate-related financial policies index yearly mean for the 2006-2020 period.

Panel A – Climate-related financial policies index yearly mean, for the 2006-2020 period, for the whole sample.



Panel B – Climate-related financial policies index number 1 yearly mean, for the 2006-2020 period, divided by the AE and EMDE countries.



We further examined this variable by decomposing the sample according to the level of economic development of a country, that is, emerging markets and developing economies (EMDE) and advanced economies (AE), as graphically depicted in Panel B. From the figure, both groups of countries showed similar behavior regarding the growing implementation of climate-related financial policies in the 2006-2010 period. However, in 2008, the level of engagement with these policies decreased. This might be attributed to the focus of policymakers on addressing immediate financial stability problems arising from the Great Financial Crisis rather than focusing on the climate aspect, which also occurred during the COVID-19 Pandemic (Quatrini, 2021).

Furthermore, since 2010, EMDE countries have increased the implementation of these policies beyond the levels of AE countries. This behavior is consistent with the empirical evidence of the Organization for Economic Cooperation and Development (OECD, 2018) and D'Orazio (2022), who pointed out that after the 16th Conference of the

Parties to the United Nations Framework Convention on Climate Change (COP16) in 2010, national funds have been flowing from developed countries to developing economies to enhance the engagement of the latter in policies aimed at tackling climate change. Therefore, we expect a boost in developing countries' engagement with climate-related financial policies after 2010.

4. Empirical Findings

We start by analyzing how adopting climate-related financial policies can influence bank risk. We then develop this analysis by specifying the effects according to the level of economic development of a country and by checking whether these effects are transversal to years of crises and regular years. Finally, we check the robustness of the results using different proxies for bank risk, namely the Z-score, and for the climate-related financial policies.

4.1. The impact of green macroprudential policies on bank risk

Table 3 presents the benchmark regressions used to analyze the effect of climate-related financial policies on bank risk.

The first conclusion considers the statistical significance of all variables at the 1% level. Furthermore, the results show that bank risk tends to persist over time, because the lagged dependent variable is statistically significant, supporting the empirical findings of Delis and Kouretas (2011), Castro (2013), and Baselga-Pascual et al. (2015).

Focusing on the effects of climate-related financial policies on bank risk, we find that greater engagement in green financial policies leads banks to reduce their risk. This effect is supported by the theory of Luo et al. (2021), according to which banks can reduce their portfolio risk and exposure to physical risks in the long run by diversifying their loan portfolios toward green projects and reducing the weight of common investments.

Furthermore, since our measure of bank risk captures market risk, we can conclude that market sentiment affects how green policies influence bank risk. In other words, when banks increase their green credit allocation, they can boost their social reputation (Huang et al., 2023; Feng et al., 2024), attract environmentally conscious investors (Lingnau et al., 2022; Huang et al., 2023; Mirza et al., 2023), thereby reducing their debt and equity funding costs (Ciciretti et al., 2014).

Table 3. Banks' risk models with the climate-related financial policies.

Model 1 presents the effect of the climate-related financial policies on the banks' risk as measured by the bank's asset risk, calculated as the annualized standard deviation of daily stock price returns times the market value of equity over the market value of the bank. Model 2 represents the effect of climate-related financial policies over the banks' risk, as measured by its' credit risk. The banks' credit risk is measured as the loan loss provisions to the total loans ratio. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively. The null hypothesis of the Hansen test states that all instruments are jointly exogenous and that the instruments used are not correlated with residuals. The null hypothesis of the autoregressive (AR) test states that there is no second-order serial correlation in the error term.

	Model 1	Model 2
Dependent variable	**Asset Risk**	**Credit Risk**
Lagged dependent variable	.586***	.218***
	(.010)	(.007)
Climate-related financial policies index		
CRFPI 1	-.045***	.051***
	(.004)	(.002)
Bank-specific variables		
Profitability	-.342***	-.068***
	(.046)	(.004)
Leverage	-.092***	-.023***
	(.014)	(.003)
LOG Size	-.759***	-.380***
	(.094)	(.014)
Cost-income ratio	-.021***	-.032***
	(.006)	(.002)
Asset Diversity	2.898***	.094
	(.464)	(.091)
Income Diversity	1.430***	1.348***
	(.247)	(.074)
Macroeconomic variables		
GDP Growth	.756***	.609***
	(.022)	(.007)
Inflation	.035***	.211***
	(.004)	(.016)
Concentration	-.031***	-.054***
	(.004)	(.001)
Macroprudential Policies Index	-.148***	-.099***
	(.025)	(.011)
Level of interest rates	-1.434***	-1.156***
	(.058)	(.017)
Slope of interest rates	.633***	.775***
	(.053)	(.016)
Crisis	.706***	.717***
	(.146)	(.039)
Year dummies	Yes	Yes
Pre-validation tests		
Sargan-Hansen test	.370	.272
Arellano-Bond test for AR (2)	.210	.175

4.2. Additional Analyses

4.2.1. The effect of climate-related financial policies on banks' credit risk

Based on the prior conclusions, it is important to evaluate whether adopting climate-related financial policies can influence bank credit quality. We repeat the same regression using banks' credit risk as the dependent variable. The results are presented in Model 2 in Table 3.

As we can see, all variables remain statistically significant except for the banks' asset diversity. Furthermore, we can again visualize risk persistence over time because the lagged dependent variable remains statistically significant, thus further validating the choice of this model.

By examining the CRFP index, we find that when countries increase their engagement in green policies, especially when increasing the level of enforcement of such policies, banks' credit risk increase, materialized through an increase in their loan loss provisions. These results are consistent with the evidence presented by Godfrey (2008), Park and Kim (2020), and Chen et al. (2023) that an increase in green credit allocation can lead to an increase in banks' short-term credit risk. However, this effect is expected to be countered in the long term because the surviving firms will have higher operational efficiency and financial performance (Zhou et al., 2022), reflecting a reduction in credit risk.

4.2.2. The effect of the economic development level of a country: advanced economies vs emerging markets and developing countries

The empirical literature indicates that engagement in global green policies varies from country to country (Network for Greening the Financial System, 2019; Official Monetary and Financial Institutions Forum, 2020; D'Orazio and Popoyan, 2022). Meanwhile, Pauw and Pegels (2013) and La Rovere et al. (2018) show that the public initiatives of developing countries toward green finance is very poor due to the low returns associated with these investments, although they increased substantially in the past decade due to the pledge made by the countries at COP16 (Organization for Economic Cooperation and Development, 2018). Therefore, it is important to evaluate whether these effects are transverse between these two groups of countries.

To do so, we estimated the previous model by applying the specification presented in Equation 1 and interacting the green financial policy index with the dummy variable related to developing economies (EMDE Dummy). The results are presented in Model 3 in Table 4 and graphically depicted in Figure 3.

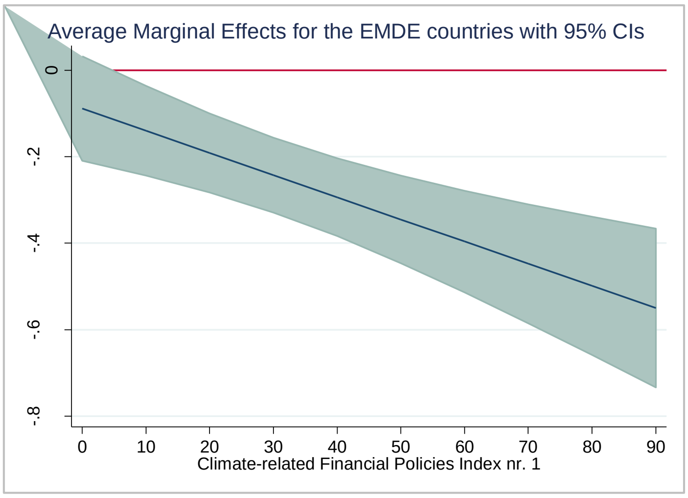
Table 4. Banks' risk models with the climate-related financial policies and the EMDE and Crisis dummy variables.

The dependent variable, the bank's asset risk, is given by the annualized standard deviation of daily stock price returns times the market value of equity over the market value of the bank. Models 3 and 4 include the interaction term between the climate-related financial policies index and the EMDE and systemic crisis dummy variables, respectively. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively. The null hypothesis of the Hansen test states that all instruments are jointly exogenous and that the instruments used are not correlated with residuals. The null hypothesis of the autoregressive (AR) test states that there is no second-order serial correlation in the error term.

Dependent Variable: Asset Risk	Model 3	Model 4
Lagged dependent variable	.747*** (.001)	.749*** (.001)
Climate-related financial policies index		
CRFP 1	.003*** (.001)	.006*** (.001)
Interaction variable		
EMDE Dummy x CRFP 1	-.006*** (.001)	
Crisis Dummy x CRFP 1		-.031*** (.001)
Bank-specific variables		
Profitability	-.073*** (.003)	-.063*** (.002)
Leverage	-.021*** (.002)	-.025*** (.001)
Size	-.054*** (.009)	-.056*** (.006)
Cost-income ratio	-.034*** (.001)	-.038*** (.001)
Asset Diversity	-.488*** (.052)	-.141*** (.033)
Income Diversity	2.061*** (.043)	1.703*** (.037)
Macroeconomic variables		
GDP Growth	.423*** (.006)	.375*** (.004)
Inflation	-.010* (.005)	-.590*** (.010)
Level of interest rates	-.582*** (.012)	-.590*** (.010)
Slope of interest rates	.307*** (.007)	.260*** (.006)
Concentration	-.027*** (.001)	-.026*** (.001)
Crisis	.177*** (.021)	.942*** (.038)
EMDE Dummy	.386*** (.062)	
Pre-validation tests		
Sargan-Hansen test	.466	.517
Arellano-Bond test for AR (2)	.310	.234

Figure 3. Marginal effects of the climate-related financial policies index on banks' risk, for the EMDE countries.

Marginal effect of the climate-related financial policies index on banks' risk, for the EMDE countries. These results are calculated using the derivatives of Equation 3 along with Model 3, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.



The results show that this effect is stronger in developing countries than in developed countries. This effect is validated by Mua (2017), who points out that green financial policies are particularly effective in developing countries because they reduce their exposure to international financial shocks, which are considered their main vulnerability (Alam et al., 2019). Furthermore, in Figure 6.3, we find an interesting pattern in which higher levels of engagement in green financial policies for EMDE countries amplify the effectiveness of these policies in reducing bank risk.

4.2.3. The effect of the crisis: the systemic crisis vs the COVID-19 pandemic

During the recent COVID-19 pandemic in 2020, investments in the green economy were overlooked, and public interest in these investments decreased (Quatrini, 2021; Nguyen et al., 2023). It is therefore important to assess whether these effects persist during periods of economic uncertainty. To do so, we applied the specification presented in Equation 2 while interacting the green financial policies index with the dummy variable that takes the value of one in years of systemic crises. The results are displayed in Model 4 in Table 4 and illustrated in Figure 4.

Overall, all variables remained statistically significant. Furthermore, using Figure 4, we find that during crises, higher levels of engagement in green financial policies lead to a greater reduction in bank risk. From Table 5, which reports the marginal effects of this model through the delta method, this effect is only visible in countries with higher levels of green financial policy adoption, whereas countries below the turning point (*i.e.*, with a CRFP index below 30.39%) experience the opposite effect.

Figure 4. Marginal effects of the climate-related financial policies index on banks' risk, for the systemic crisis period.

Marginal effect of the climate-related financial policies index on banks' risk, for the interaction with the systemic crisis dummy variable. These results are calculated using the derivatives of Equation 6.3 along with Model 6.4, a methodology used by Brambor et al. (2006) and Berry et al. (2012). The dashed lines provide the 95% confidence intervals.

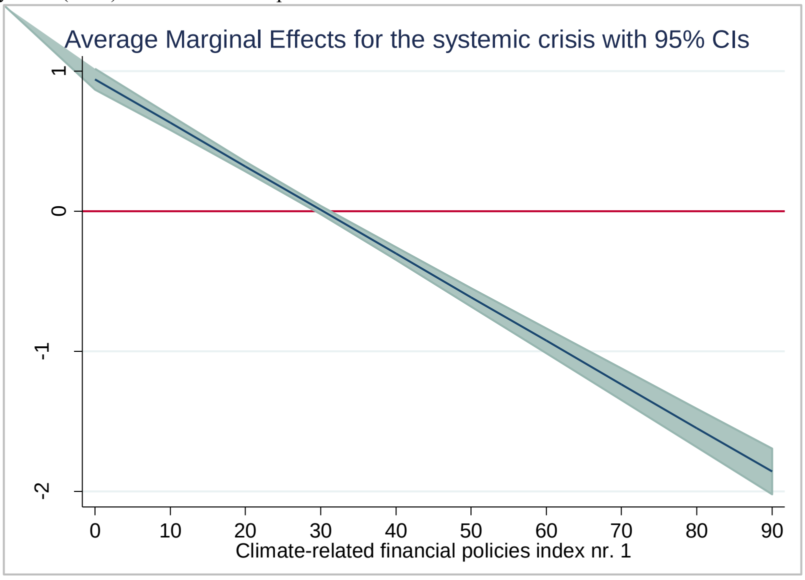


Table 5. Average marginal effects of the interaction between the climate-related financial policies index and the systemic crisis dummy variable, considering the Asset risk as the dependent variable.

Average marginal effects of Model 4 (Table 4), with standard errors obtained by the Delta method. The first column reports the values of the climate-related financial policies index, from the minimum, 0, to the maximum observed, 90, in increments of 10. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

c (CRFP Index)	**Climate-related financial policies index (Model 4)**	
	dy/dx at CRFP=c	Delta Method Standard Error
0	.942***	.038
10	.631***	.027
20	.320***	.018
30	.009	.016
40	-.302***	.023
50	-.613***	.033
60	-.924***	.045
70	-1.235***	.058
80	-1.546***	.070
90	-1.857***	.083

These results are consistent with the empirical findings of Jing et al. (2022), who found that during the COVID-19 pandemic, companies with higher sustainability performance (*i.e.*, green firms) performed better and were more resilient than companies operating in traditional industries. This effect is associated with stakeholder theory, in which higher engagement in sustainable investments can lead to increased stakeholder confidence and reduced company risk (Dhaliwal et al., 2011; El Ghoul et al., 2011).

4.3. Robustness checks

4.3.1. Z-Score as the dependent variable

To further confirm our results, following Bhagat et al. (2015), Danisman and Tarazi (2020), Lee et al. (2024), and Matos et al. (2024b), we used a different measure of bank risk, namely, the Z-score. This variable measures the variability in banks' returns that can be absorbed by banks' capital without such bank becoming insolvent. Therefore, higher values indicate less risky banks. We repeat Model 6.1 and present the results in Table 6.

Overall, Model 5 validates our previous results, where higher levels of engagement in climate-related financial policies lead to an increase in banks' Z-score, thus reducing bank risk.

Table 6. Robustness Check: Prior banks' risk model with the Z-Score as a proxy for banks' risk and with the climate-related financial policies index number two as alternative proxy for green financial policies.

Estimation of the baseline model (Model 1) using as an alternative proxy for banks' risk: the Z-Score. Models 5 and 6 replicates Model 1, where we analyze the macroprudential policies' interaction with the CRFPI 1 and CRFPI 2, respectively. The reported coefficients and their robust standard errors (in parentheses) clustered at country levels are obtained using the Arellano and Bover (1995) and Blundell and Bond (1998) two-step System GMM estimator. ***, ** and * represent statistical significance at 1%, 5% and 10% levels, respectively.

	Model 5	Model 6
Dependent variable	**Z-Score**	**Asset Risk**
Lagged dependent variable	.193*** (.014)	.634*** (.011)
Climate-related financial policies index		
CRFPI 1	.006*** (.001)	
CRFPI 2		-.036*** (.005)
Bank-specific variables		
Profitability	.091*** (.011)	-.349*** (.045)
Leverage	-.009*** (.002)	-.102*** (.014)
Size	-.045*** (.013)	-.744*** (.095)
Cost-income ratio	-.042*** (.002)	-.022*** (.006)
Asset Diversity	-.193** (.080)	3.040*** (.452)
Income Diversity	.270*** (.065)	1.342*** (.252)
Macroeconomic variables		
GDPGrowth	.027*** (.008)	.717*** (.024)
Inflation	-.032*** (.012)	-.041* (.024)
Macroprudential policies index	.028*** (.009)	-.157*** (.021)
Concentration	.020*** (.001)	-.030*** (.004)
Level of interest rates	-.103*** (.016)	-1.354*** (.062)
Slope of interest rates	-.067*** (.013)	.545*** (.052)
Crisis	-.394*** (.060)	.488*** (.137)
Pre-validation tests		
Sargan-Hansen test	.379	.302
Arellano-Bond test for AR (2)	.147	.210

4.3.2. Robustness checks: Different weighting for the policy areas

Finally, since the database introduced by D'Orazio (2023) provides three additional differentiated indexes[8] where the policy areas are differently weighted, we used index number two, where the prudential and credit allocation areas are differently weighted. This approach allowed us to test the sensitivity of our results to the weighting of each of the policy areas considered. The results are presented in Model 6 in Table 6.

Again, Model 6 confirms our earlier findings, indicating that higher levels of engagement in climate-related financial policies result in reduced bank risk.

5. Conclusion

The banking sector plays a vital role in the transition to a greener economy by providing capital to all economic sectors and bridging supply and demand. Therefore, policymakers have focused on implementing prudential policies aimed at increasing investments in green and sustainable projects. While the existing literature has analyzed the effects of climate risk on the overall economy, it has largely overlooked the impact of these policies on bank risk. This study aims to fill this research gap.

Our results provide evidence that the effects of implementing green financial policies is twofold. First, from an asset risk perspective, it causes a decline in bank risk by reducing the weight of traditional loans, which tend to be more exposed to climate risk in banks' loan portfolios. Furthermore, by increasing green lending, banks can boost their social reputations, exploit market sentiment, attract environmentally conscious investors, and reduce their debt and equity funding costs.

Second, from a credit risk perspective, adopting green financial policies and encouraging banks to invest in greener projects can increase banks' credit risk. This is channeled through increased lending to sustainable investments that are traditionally riskier in the short term and have lower profitability, leading to an increase in banks' loan loss provisions.

In terms of the implications of these effects, the risk-dampening effect is found to be more expressive in developing countries, associating these results with the fact that an increase in banks' green lending can reduce exposure to international financial shocks, which is considered the main cause of concern in such countries.

[8] We conduct additional robustness checks by regressing Model 6.1 against the two remaining CRFP indexes presented by D'Orazio (2023). The results of these models validate our previous findings. Therefore, for simplification purposes, we do not present these regressions in this paper.

Moreover, we find evidence that during crises, tightening green prudential policies can reduce bank risk. This effect can be achieved through the above-mentioned stakeholder theory, where banks that lend to green firms are considered less risky by investors and, therefore, can take advantage of increased stakeholder confidence and reduce their exposure to shocks and funding costs.

These results hold when we use the Z-score as the dependent variable and when we consider a differentiated index where the green policy areas are differently weighted.

Our research has vital implications for policymakers and banks as it demonstrates that although implementing green policies can lead to a reduction in bank risk from a market perspective, it may cause fragilities in terms of non-performing loans, which can be damaging during crises. Nonetheless, our findings provide evidence that investing in green and sustainable firms can be a channel through which banks can reduce their risk and funding costs by exploiting their improved social reputation.

However, notably, we do not consider the level of green investment in the loan portfolios of individual banks, which is an important limitation of this study. Thus, it is important to evaluate whether the level of green loans in bank portfolios is a driver of bank risk, both during normal years and, more importantly, during crises.

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Appendix I

Variable sources and definitions.

Variable	Description	Source
Banks' risk		
Asset Risk	Annualized standard deviation of daily stock price returns times the market value of equity over the market value of the bank.	Thompson Reuters Datastream, Bankfocus database, and author's calculations
Credit risk	Provisions for loan losses to total loans ratio.	Bankfocus database, and author's calculations
Z-score	Natural logarithm of (ROA + E/A)/σ(ROA). ROA represents the rate of return on assets, E/A is the equity-to-assets ratio and σ (ROA) is the standard deviation of the rate of return on assets. A higher score suggests a lower probability of bank insolvency and, therefore, less risk.	Bankfocus database, and author's calculations
Climate-related financial policies		
Climate-related financial policies index number 1	Composite index measuring the country's bindingness in five climate-related policy areas namely five key areas, namely green prudential regulations, credit allocation policies, green financial principles, other disclosure requirements, and green bonds taxonomy and issuing. The five policy areas are equally weighted	D'Orazio (2023)
Climate-related financial policies index number 2	Composite index measuring the country's bindingness in five climate-related policy areas namely five key areas, namely green prudential regulations, credit allocation policies, green financial principles, other disclosure requirements, and green bonds taxonomy and issuing. The green prudential regulation and green credit allocation policy areas are differently weighted.	D'Orazio (2023)
Bank specific variables		
Leverage	Book value of total liabilities over total assets, measured in market terms, *i.e.*, as the sum of the market value of equity and the book value of total liabilities.	Bankfocus database, and author's calculations
Size	Natural logarithm of the book value of total assets.	Bankfocus database, and author's calculations
Profitability	Profit after interest expenses over the book value of assets.	Bankfocus database, and author's calculations
Cost-income ratio	Operating costs or non-interest costs over net operating income.	Bankfocus database, and author's calculations
Income diversity	Measures the diversification across different sources of income and is given by 1-[(net interest income-other operating income)⁄(total operating income)]	Bankfocus database, and author's calculations
Asset diversity	Measures the diversification across different types of assets and is given by 1-[(net loans-other earnings assets)⁄(total earnings assets)].	Bankfocus database, and author's calculations
Macroeconomic variables		
GDP growth	Annual percentage change of Gross Domestic Product (GDP).	Bloomberg database
Inflation	Annual percentage change in the Consumer Price Index (CPI).	Bloomberg database
Level of interest rates	10-year yield rate on government bonds.	Bloomberg database
Slope of interest rates	Difference between the 10-year yield rate and the 1-year yield rate on government bonds.	Bloomberg database
Concentration	Measures the level of market competition in the banking sector and is given by the fraction of the assets of the three largest banks over the assets of all commercial banks in a country.	World Bank database
Crisis	Dummy variable that assumes the value 1 in the years of the systemic banking crisis and 0 otherwise.	Laeven & Valencia (2020)
EMDE dummy variable	Dummy variable that assumes the value of 1 for the emerging markets and developing economies and 0 otherwise.	Alam et al. (2019)

CHAPTER VI – CONCLUSION

In the wake of the 2007-08 GFC, banks came under intense scrutiny due to their role in this crisis. This event exposed the systemic vulnerabilities inherent to the financial sector, highlighting the importance of implementing robust regulatory measures to safeguard financial stability against systemic risk. Additionally, over the recent years, the spotlight on banks has been propelled by a series of events such as systemic crises, geopolitical tensions, and most recently, the unprecedented challenges posed by the COVID-19 pandemic. This has created a need to assess how banks' risk responds to these events and evaluate whether the regulatory policy reforms taken post-GFC were enough to avoid more severe crises.

This thesis provides a comprehensive analysis of the impact of recent regulatory reforms on banks' risk, drawing important conclusions that allow us to fill a series of gaps in the literature.

In Chapter II, we analyzed the impact of macroprudential policies on bank risk considering the investor protection laws in place and found that investor protections play a significant role in determining the effectiveness of macroprudential policies. Tightening macroprudential policies is only effective in reducing banks' risk in countries with highly protected shareholders and creditors, while it would lead to greater risk-taking in countries with poorly protected investors.

These results are explained by the greater capital participation theory, according to which when shareholders are highly protected their individual capacity to influence banks' decisions is undermined. Furthermore, in countries with highly protected creditors, increased transparency and reduced information asymmetry leads to managers diversifying acquisitions and decreasing lending, thus reducing bank risk.

When analyzing macroprudential policies by their goals, we found that these policies are ineffective in curbing bank risk in countries with poorly protected creditors, regardless of the macroprudential policy's goal. However, the same tightening event in a country with highly protected creditors leads to a higher reduction in bank risk. Moreover, macroprudential policies are ineffective for all levels of shareholder protection, while higher levels of protection amplify this ineffectiveness.

By examining both directions of macroprudential policy adjustments individually, we conclude that the impact of macroprudential policies on banks' risk is asymmetric.

Loosening a macroprudential policy leads to a greater increase in bank risk than the decrease verified when a macroprudential policy is tightened or adopted. This disparity is more pronounced in countries with lower shareholder rights and higher levels of creditors' rights. Furthermore, a loosening event will always lead to an increase in bank risk significantly higher in countries with highly protected creditors and shareholders. These results suggest that when safety nets are in place and investors are highly protected, banks are more likely to engage in risk-shifting behaviors. Our results also reveal the absence of policymakers' control while loosening macroprudential policies, contrarily to when these policies are tightened.

Our results have serious policy implications as we show that ignoring the relationship between macroprudential policies and investor protection may lead to misleading conclusions when evaluating the overall effectiveness of macroprudential policies.

This chapter makes a significant contribution to the existing literature by being a pioneer study to examine the relationship between the institutional framework and its impact on banks' response to macroprudential policies. Additionally, it adds to the empirical literature on the effects of macroprudential policies, both in aggregate and by specific policy types, as well as on the factors influencing banks' risk-taking behavior.

In Chapter III, we highlight the relevance of capital-aimed macroprudential policies in minimizing risk during crises. We find that strengthening capital buffers during systemic crisis and normal years can lead to less risky banks. However, during the COVID-19 pandemic, the reverse applies, where loosening capital-aimed policies was particularly effective in reducing banks' risk, as intended by the post-pandemic agenda. On the other hand, tightening the other macroprudential policies both during the pandemic and in years of systemic crisis, led to a reduction in banks' risk.

Our study also found that banks' risk-taking is much more sensitive to shifts in the macroprudential framework during the systemic crisis period than in normal years or during the pandemic. These results underscore the importance of the macroprudential framework in controlling banks' risk during disruptive events and promoting banks' resilience.

By evaluating the effectiveness of the macroprudential policies based on several bank-specific characteristics, we found that both macroprudential policy indexes were more effective in banks with higher leverage and lower loan growth, and for banks located in the EU, albeit the other macroprudential policies only being effective in curbing banks' risk in the EU.

Moreover, we show that the effectiveness of the capital-aimed policies during the systemic crisis is driven by the capital requirement, while tightening the conservation buffer would lead to an increase in banks' risk. Regarding the COVID-19 pandemic, we show that tightening the countercyclical capital buffer would be effective in reducing banks' risk, while tightening the capital requirements, conservation buffer, and leverage limit would lead to an increase in banks' risk.

The analysis carried out in this chapter contributes to the empirical literature in several ways. First, it adds to the strand of literature examining the reasons behind the differences in banks' performance during crisis, by using the COVID-19 outbreak as a case study to assess the efficacy of macroprudential policies amidst this turmoil. Furthermore, it contributes to the literature by demonstrating that the macroprudential framework does not follow a linear pattern across all crises, as evidenced by our findings.

From this perspective, our results call for a careful calibration of the macroprudential framework, both during normal times and periods of distress, to avoid unintentional consequences and leverage the complete potential of macroprudential policies. Our results show that the pandemic agenda showed mixed results, where countries that loosened their macroprudential policies, included in the other macroprudential policies indexes, increased banks' risk, contrary to countries that decided to tighten these policies.

In Chapter IV, we examine whether market discipline can enhance the effectiveness of macroprudential policies in reducing banks' risk. Our analysis revealed that there is a statistically significant correlation between market discipline and macroprudential policies in shaping banks' risk. In other words, increased levels of market discipline, materialized through higher levels of subordinated debt on banks' structure, can enhance the effectiveness of capital-aimed prudential policies in reducing banks' risk. This suggests that increasing market participants' disciplinary action can discourage banks from engaging in riskier investments and value-destroying actions as these would be detected by market participants who would sanction this behavior by asking for a higher risk premium. Furthermore, increasing the level of subordinated debt on banks' structure will lead these institutions to hold higher capital buffers to avoid costly funding in case of disciplinary actions by creditors. This increase in capital buffers will also translate into a higher capacity to deal with unexpected losses and consequently reduce the banks' default probability.

However, our results show that this behavior is only present in advanced economies while being ineffective in emerging markets and developing economies. Additionally, we show that the conditional effect is stronger in the USA than in the other countries comprising our sample.

These findings have important implications as they show that market participants' disciplinary power should not be ignored but instead be enhanced, as it can be a cheaper mechanism to complement capital-aimed macroprudential policies in dealing with the moral hazard problems created by the safety nets and bailouts imposed by governments. However, enforcing market discipline by forcing banks to hold unsubordinated debt has both boon and bane outcomes.

On the one hand, market discipline can act as an enforcing mechanism, ensuring constant supervision by market participants and encouraging banks to maintain higher levels of capital, which are useful to increase banks' resilience during crises. On the other hand, timely and adequate information must be provided to the market to reduce information asymmetries considered a fragility of market discipline. Moreover, policymakers must be specific about any safety nets in place and must commit not to bailout subordinated debt owners, as this would reduce the effectiveness of this supervisory mechanism.

Another important implication is associated with the fact that market participants only account for short-term risks, ignoring the systemic perspective and long-run risks. While banking supervision exists to account for these types of risks, the introduction of market discipline may lead to supervisors having a relaxed and careless attitude towards supervising the market as they might perceive the role of market participants as enough to assure stability.

This analysis makes significant contributions to the literature advocating for the use of market discipline as a means of regulating banks. Also, it offers empirical evidence supporting the effectiveness of this mechanism, by showing that it can prevent the moral hazard tendencies induced by macroprudential policies. Lastly, it enhances comprehension of how policymakers can enforce market discipline through mandatory issuance of subordinated debt.

Finally, in Chapter V, we analyze the impact of climate-related financial policies on banks' risk and provide evidence that implementing green financial policies has two different effects. First, from an asset risk perspective, it causes a decline in bank risk by reducing the weight of traditional loans, which tends to be more exposed to climate risk in banks' loan portfolios. Also, by increasing green lending, banks can boost their social reputations, exploit market sentiment, attract environmentally conscious investors, and reduce their debt and equity funding costs. Second, from a credit risk perspective, adopting green financial policies and encouraging banks to invest in greener projects can increase banks’ credit risk. This is channeled through increased lending to sustainable investments that are traditionally riskier in the short term and have lower profitability, leading to an increase in banks’ loan loss provisions.

Our research shows that this risk-dampening effect is more significant in developing countries. We associate these results with the fact that an increase in banks’ green lending can reduce exposure to international financial shocks, which is a significant concern in such countries.

Moreover, we find evidence that during crises, tightening green prudential policies can reduce bank risk. This effect can be achieved due to the above-mentioned stakeholder theory, where banks that lend to green firms are considered less risky by investors and can take advantage of increased stakeholder confidence to reduce their exposure to shocks and funding costs.

Again, our results have vital implications for policymakers and banks. Although it that implementing green policies can lead to a reduction in bank risk from a market perspective, it may cause fragilities in terms of non-performing loans, which can be damaging during crises.

The contribution of this chapter is multifold. First, it contributes to the literature analyzing the effects of climate-related financial policies on banks' risk. Second, it is the first study examining whether these policies' impact is consistent across developed and developing countries, contrasting results between stable periods and crises. Finally, it offers insights on how integrating green credit into banks' loan portfolios could potentially expose vulnerabilities during economic downturns.

Therefore, from a global perspective, this thesis contributes to the empirical literature on bank risk determinants by providing further evidence that the effect of a stricter regulatory framework is not linear and can even lead banks to engage in deviant behaviors. Nonetheless, this serves as a wake-up call to policy makers when evaluating the implementation of such policies, as we provide evidence that there are other factors that must be considered, such as the institutional framework, in order to evaluate if these policies are effective. Moreover, we show that there are undeveloped mechanisms, such as the market discipline, that can be used to dissuade banks from engaging in risky behaviors. Although the importance of this mechanism has been acknowledged in the

Basel III Agreement, we believe that it can be developed even further to leverage its full potential.

APPENDIX

Author statement

I hereby declare that this thesis reflects my original work and intellectual contribution. Overall, my contribution to the papers presented in this thesis were the following:

Matos, T. F. A., Teixeira, J. C. A., and Dutra, T. M. (2023). The contribution of macroprudential policies to banks' resilience: Lessons from the systemic crisis and the COVID-19 pandemic shock. *International Review of Finance*, 1-37. https://doi.org/10.1111/irfi.12424: Conceptualization, Methodology, Software Run, Data Treatment, Writing.

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