DOCTORAL THESIS

ESSAYS ON THE EUROPEAN BANKS FINANCIAL STABILITY, PROFITABILITY, AND EFFICIENCY

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Título da tese: **Essays on the European Banks Financial Stability, Profitability, and Efficiency**

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Dna. **Ana Iglesias Casal**

En condición de: **Directora**

Título da tese: **Essays on the European Banks Financial Stability, Profitability, and Efficiency**

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ABSTRACT

As a result of the financial crisis of 2007-2008, all banking systems in Europe experienced a complete overhaul. These major changes justify the motives for this research, which has been based on a set of essays on the European banking sector. Firstly, we analyse the effects of bank competition on a bank's financial stability. Using a sample of 117 listed banks from 16 Western European countries from the period 2011 - 2018, the main findings indicate that an excessive increase in competition tends to generate financial instability, especially in countries where banking systems have low financial stability. Secondly, the effect of the implementation of negative interest rate policies on the profitability and risk of banks is evaluated. Considering a sample of 2,596 banks from 29 European countries in the period 2011- 2019, the results obtained have led us to conclude that the implementation of a negative interest rate policy reduces the net interest margin and the profitability of most banks, but it does not lead to the adoption of investment strategies with high-risk exposure. However, these conclusions do not apply to all banks, which differ according to the business models adopted by each bank. Finally, the impact of adopting socially responsible policies on banking efficiency is analysed. Based on a sample of 108 listed banks from 21 European countries during the period 2011 - 2019, it is concluded from the evidence of a U-shaped relationship between corporate social performance and banking efficiency that banks with good performance in the social area and with high-quality governance models are the most efficient.

KEY WORDS

Financial stability; bank competition; negative interest rates, profitability, corporate social responsibility, bank efficiency

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RESUMEN

Como resultado de la crisis financiera de 2007-2008, los diferentes sistemas bancarios en Europa sufrieron transformaciones considerables. Estas transformaciones justifican el presente trabajo de investigación, que se estructuró en torno a la realización de varios ensayos sobre el sector bancario europeo. En primer lugar, se analizan los efectos de la competencia bancaria sobre la estabilidad financiera de los bancos. Utilizando una muestra de 117 bancos cotizados de 16 países de Europa Occidental durante el período 2011 a 2018, los principales hallazgos indican que un aumento excesivo de la competencia tiende a generar inestabilidad financiera, especialmente en países con sistemas bancarios menos estables financieramente. En segundo lugar, se evalúa el efecto de la implementación de políticas de tipos de interés negativos sobre la rentabilidad y el riesgo de los bancos. Considerando una muestra de 2596 bancos, de 29 países europeos, en el período de 2011 a 2019, los resultados obtenidos permiten concluir que la implementación de una política de tipos de interés negativos redujo el margen financiero y la rentabilidad global de la mayoría de los bancos, pero no condujo a la adopción de estrategias de inversión con mayor exposición al riesgo. Sin embargo, estas conclusiones no son transversales para todos los bancos, difiriendo según el modelo de negocio utilizado por el mismo. Finalmente, se analiza el impacto de la adopción de políticas socialmente responsables sobre la eficiencia bancaria. Con base en una muestra de 108 bancos cotizados, de 21 países europeos, durante el período 2011 a 2019, se comprueba la existencia de una relación en forma de U entre desempeño social empresarial y eficiencia bancaria, y que los bancos con buen desempeño en el área social y con mejores modelos de gobernanza son los más eficientes.

PALABRAS CLAVE

Estabilidad financiera; competencia bancaria; tasas de interés negativas, rentabilidad, responsabilidad social corporativa, eficiencia bancaria.

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RESUMO

Em consequência da crise financeira de 2007-2008, os diferentes sistemas bancários da Europa foram objeto de consideráveis transformações. Estas transformações justificam o presente trabalho de investigação que foi estruturado em torno da realização de conjunto de ensaios sobre o setor bancário europeu. Primeiramente, analisam-se os efeitos da concorrência bancária sobre a estabilidade financeira dos bancos. Usando uma amostra de 117 bancos cotados, de 16 países da Europa Ocidental, no período de 2011 a 2018, as principais conclusões indicam que um aumento excessivo da concorrência tende a gerar instabilidade financeira, especialmente nos países com sistemas bancários menos estáveis financeiramente. De seguida, avalia-se o efeito da implementação de políticas de taxas de juro negativas sobre a rendibilidade e o risco dos bancos. Considerando uma amostra composta por 2596 bancos, de 29 países europeus, no período de 2011 a 2019, os resultados obtidos permitiram concluir que a implementação de uma política de taxas de juro negativas reduziu a margem financeira e a rentabilidade global da generalidade dos bancos, mas não levou à adoção de estratégias de investimento com uma maior exposição ao risco. Contudo, estas conclusões não são transversais a todos os bancos, diferindo consoante o modelo de negócio utilizado pelo banco. Finalmente, analisa-se o impacto da adoção de políticas socialmente responsáveis na eficiência bancária. Com base numa amostra de 108 bancos cotados, de 21 países europeus, durante o período de 2011 a 2019, concluiu-se pela evidência de uma relação em forma de U entre o desempenho social corporativo e a eficiência bancária e que os bancos com boa performance na área social e com melhores modelos de governação são os mais eficientes.

PALAVRAS-CHAVE

Estabilidade Financeira; concorrência bancária; taxas de juro de juro negativas, rendibilidade, responsabilidade social corporativa, eficiência bancária.

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RESUMO ALARGADO

Os sistemas bancarios de Europa, como noutros continentes, como consecuencia da crise financeira de 2007-2008, experimentaron cambios considerables nos últimos anos. Tras un longo período, caracterizado por unha desregulación crecente do sistema financeiro global e unha forte expansión da innovación e do proceso de globalización financeira, a referida crise veu a por de manifesto as debilidades de moitos dos bancos radicados no vello continente. Esa crise, combinada coa crise da débeda soberana dalgúns países da zona Euro, puxo en dúbida a estabilidade da case todos os sistemas bancarios europeos, o que provocou a desaparición de numerosas institucións bancarias e levou a múltiples intervencións públicas co fin de conter a propagación do risco sistémico. Xunto co apoio financeiro prestado polos distintos gobernos de Europa, nos anos pos-crise financeira, asístese igualmente a un reforzo da regulación prudencial, do que a aplicación do Acordo de Basilea III é un bo exemplo. É neste período, en concreto no 2014, cando asistimos ao nacemento da Unión Bancaria Europea asentada en dous piares fundamentais: os mecanismos únicos de supervisión e de resolución.

Os cambios substanciais acontecidos nos sistemas bancarios Europeos nos últimos anos, así como o feito de que o sector bancario estea en constante cambio e que constitúa unha peza esencial para o bo desempeño da economía, xustifica o presente traballo de investigación que está estruturado varios ensaios sobre o sector bancario europeo.

O primeiro capítulo presenta unha caracterización do sector bancario europeo despois da crise financeira, que abrangue o período 2008-2018. En particular, analizanse aspectos relacionados coa estrutura do mercado, a tipoloxía de activos e as fontes de financiamento empregadas polos bancos en Europa. Tamén abordanse os niveis de estabilidade financeira e rendibilidade destas institucións. Este capítulo inclue os obxectivos perseguidos e a metodoloxía a empregar no presente traballo investigación.

O segundo capitulo está dedicado ao estudo da relación entre a competencia e a estabilidade financeira na banca europea. Esta investigación distínguese das realizadas no pasado porque: (i) en primeiro lugar, analiza se esa relación é diferenciada segundo o banco opere nun sistema bancario máis ou menos estable no seu conxunto; (ii) en segundo lugar, considera unha nova medida de mercado para cuantificar o risco; e finalmente, (iii) utiliza un modelo de datos de panel dinámico, estimado polo método dos momentos xeneralizado, en lugar do modelo estático

tradicional, permitindo ter en conta a persistencia na relación entre a competencia bancaria e a toma de risco e utilizando estimadores máis eficientes.

Segundo a literatura existente, existen dúas visións diametralmente opostas sobre a relación existente entre a competencia bancaria e a estabilidade financeira dun banco. A literatura bancaria tradicional que apoia a hipótese da "competencia-fraxilidade", segundo a cal un aumento da competencia entre bancos reduce a marxe financeira e as comisións cobradas polos bancos nos servizos prestados, facendo presión á baixa sobre os resultados, aumentando a probabilidade de insolvencia dos bancos e, consecuentemente, poñendo en perigo a estabilidade do sistema bancario (Marcus, 1984; Keeley, 1990; Allen & Gale, 2004). Boyd e De Nicoló (2005) presentan argumentos que sustentan a hipótese da "competencia-estabilidade", segundo a cal nun mercado pouco competitivo os bancos tenderán a cobrar taxas de xuros máis elevadas, o que incentivará aos prestatarios a investir en proxectos de risco máis elevado aumentando a probabilidade de incumprimento destes, deteriorando a calidade da carteira de crédito dos bancos. Por tanto, segundo esta visión, un aumento da competencia, diminuirá a exposición dos bancos ao risco de crédito, aumentando a estabilidade do sistema bancario. Martinez-Miera e Repullo (2010) presentaron un modelo que pretende conciliar as dúas visións opostas sobre a relación entre a competencia e a estabilidade financeira, defendendo unha relación en forma de U.

A partir da revisión da literatura foron establecidas as seguintes hipóteses de investigación: H1: A competencia bancaria diminúe a estabilidade bancaria, o que apoia a visión "competencia-fraxilidade", e H2: Existe unha relación en forma de U entre competencia bancaria e a toma de risco dun banco. Coa finalidade de profundar no tema, analizouse se a relación obxecto de estudo podía diferenciarse segundo o banco actúase nun sistema bancario máis ou menos estábel en conxunto, resultando de aquí a terceira hipótese de investigación H3: A relación entre a competencia bancaria e a toma de risco dun banco diferénciase segundo o banco opere nun sistema bancario máis ou menos estable no seu conxunto.

Para cuantificar o risco individual dun banco foron consideradas dúas medidas de mercado, Distance-to-Default e Distance-to-Insolvency, e unha medida contable, o Z-score. Para medir a intensidade competitiva do mercado onde o banco opera considerouse o Índice de Lerner que permite medir a capacidade do banco para manter os seus prezos por enriba do custo marxinal.

En termos metodolóxicos, a relación foi estimada empregando un modelo de datos de panel dinámico e o estimador do método dos momentos xeneralizado, proposto por Arellano and Bover (1995) e Blundell and Bond (1998), co fin de controlar eventuais problemas de endoxeneidade. A análise empírica baseouse nunha mostra de 117 bancos cotizados, procedentes de 16 países de Europa Occidental, que abrangue o período comprendido entre 2011 e 2018. Os resultados obtidos permitiron concluír que o poder de mercado, medido polo Índice Lerner, aumenta a estabilidade financeira dun banco, o que corrobora a visión tradicional da "competencia-fraxilidade" e que a relación entre competencia e estabilidade financeira só é significativa en bancos que operan nun país cun sistema bancario menos estable. Tamén a evidencia permite concluír que os bancos con maior dimensión, mellor capitalizados e con fontes de ingresos máis diversificadas son máis estables.

As conclusións extraídas neste segundo capitulo permiten establecer algunhas recomendacións para as autoridades políticas e reguladoras do sector bancario en Europa. En primeiro lugar, as políticas públicas deben garantir un certo nivel de competencia bancaria, porque esta é esencial para o incremento do benestar da sociedade en xeral, mais limitando a asunción excesiva de riscos bancarios, especialmente en países con sistemas bancarios menos estables financeiramente. Isto significa que calquera medida que supoña aumentar a competencia na banca europea debe ir acompañada por regulamentación que garanta a estabilidade financeira dos bancos, por exemplo, a través do aumento dos requirimentos de capital e limitando a exposición a varios tipos de risco aos que a actividade bancaria está suxeita. En segundo lugar, o fomento de políticas que promovan a consolidación do sector bancario europeo, permitirá a formación de bancos máis sólidos e resistentes sen comprometer a competencia. Xuntamente coas fusións domésticas, as autoridades europeas e os distintos gobernos nacionais deben promover fusións transfronteirizas para afondar na integración e na construción dun sector bancario verdadeiramente europeo. Para acadar este obxectivo, a Unión Bancaria Europea, iniciada en 2014, pode desempeñar un papel esencial.

No terceiro capítulo analízase o efecto da aplicación de políticas de taxas de xuro negativas por parte dos bancos centrais sobre a rendibilidade e o risco da banca europea. Na última década, nun intento de evitar a deflación e estimular o crecemento económico, un número considerable de bancos centrais a nivel mundial aplicaron un conxunto de políticas monetarias expansionistas facendo uso de instrumentos non convencionais entre os cales destacan os

programas de compra de activos a gran escala e a cobranza de xuros negativos sobre os excedentes de reservas que as institucións de crédito manteñen depositadas nos seus respectivos bancos centrais. En Europa este tipo de políticas fíxose sentir con elevada intensidade xa que seis bancos centrais situaron as súas taxas de xuro oficiais en valores negativos, xustificando desta forma, a investigación do efecto que estas políticas poden ter sobre a rendibilidade e o risco da actividade bancaria. A principal contribución deste ensaio á literatura existente reside no feito de investigar se os efectos das taxas de xuros negativas sobre a rendibilidade e a asunción de riscos dos bancos son diferentes segundo o modelo de negocio adoptado polo banco.

Segundo a literatura revisada, a adopción de políticas de taxas de xuro negativas pode ter efectos contrarios sobre a rendibilidade e a estabilidade financeira dun banco. Taxas de xuro baixas ou menos negativas teñen un impacto positivo sobre a rendibilidade da banca vía ganancias de capital e redución das provisións para crédito vencido, dada a menor probabilidade de incumprimentos dos prestatarios (Boungou, 2019). Con todo, taxas de xuro baixas ou negativas, sobre todo por un prazo longo, poden tamén provocar unha baixada na marxe financeira afectando, desa forma, negativamente á rendibilidade do banco. Iso acontece porque a actividade de intermediación financeira está baseada na marxe financeira que ven dada pola diferenza entre as taxas de xuro dos préstamos e dos depósitos dos clientes. Cando as taxas de xuro se aproximan a cero, os bancos poden ter que axustar á baixa as taxas dos préstamos por cuestións de competencia, pero poden ser reacios a levar as taxas de xuro dos depósitos a valores negativos, sobre todo as dos depósitos minoristas, resultando de aí unha diminución da marxe financeira (Claessens et. al., 2018)). Estes argumentos permitiron formular as seguintes hipóteses de investigación; H1: A implementación de políticas de taxas de xuro negativas levou a un descenso na marxe financeira e da rendibilidade dos bancos na Europa, e H2: O efecto dunha variación das taxas de xuro sobre a marxe financeira e sobre a rendibilidade é máis pronunciado cando as políticas de taxas de xuro negativas están implementadas.

En canto aos efectos que a aplicación de políticas de taxas de xuro negativas poden ter sobre a estabilidade financeira dun banco, a literatura tamén presenta argumentos que apuntan en sentidos opostos. Por un lado, unha baixada das taxas de xuro de referencia afecta á percepción e/ou á tolerancia ao risco por parte dos xestores bancarios, aumenta o valor dos activos e das garantías asociadas aos préstamos, aumentando a capacidade dos bancos de asumir

riscos (Borio & Zhu, 2008). Por outro lado, se as taxas de xuros permanecen baixas ou negativas por un longo período, será grande a probabilidade dunha forte expansión do crédito, levando aos bancos a relaxar os seus estándares de concesión de préstamos e a aumentar o crédito a clientes con máis risco (Chen et al., 2017). Nun contexto de taxas de xuros baixas ou negativas, se os obxectivos de rendibilidade dos bancos son ríxidos, isto podería levar aos xestores bancarios a investir en activos de maior risco na "procura de rendemento" (Rajan, 2005). Estes dous últimos argumentos levaron á formulación das seguintes dúas hipóteses de investigación; H3: A implementación de políticas de taxas de xuro negativas levou a unha maior asunción de risco, e H4: O efecto dunha variación negativa das taxas de xuro sobre o aumento da asunción de risco é máis pronunciado cando as políticas de taxas de xuro negativas están implementadas.

Varios autores tamén suxiren que o efecto da implementación dunha política de taxas de xuro negativas na rendibilidade e na asunción de riscos por parte dun banco depende de características específicas do banco, como a súa dimensión, a súa estrutura de financiamento e investimento e liña de produtos e/ou servizos ofrecidos aos seus clientes. Así, é natural que un entorno de taxas de xuro baixas ou negativas teña afectado aos bancos de forma diferenciada segundo o seu modelo de negocio (Molyneux et al., 2019; Boungou, 2019). Este argumento permitiu, por último, formular as seguintes hipóteses de investigacións adicionais; H5: Os efectos da implementación de políticas de taxas de xuro negativas sobre a rendibilidade dun banco dependen do modelo de negocio adoptado, e H6: Os efectos da implementación de políticas de taxas de xuro negativas sobre a asunción de riscos dun banco dependen do seu modelo de negocio.

Para examinar as hipóteses de investigación enunciadas, a rendibilidade dos bancos foi medida mediante a marxe financeira e a rendibilidade do activo dos bancos, mentres que para cuantificar a asunción de riscos consideráronse tres indicadores: o Z-score, a ratio de incumprimento nos préstamos concedidos polo banco e finalmente a ratio entre os activos ponderados polo risco e o activo líquido do banco. O entorno das taxas de xuro foi recollido mediante unha taxa de xuro de curto prazo, o descenso da curva de rendementos e unha variable dummy para reflexar a implementación ou non dunha política de taxas de xuro negativas. Empregouse unha mostra de datos de panel composta por 2.596 bancos, de 29 países europeos, no período de 2011 a 2019, na que as variables endóxenas, rendibilidade e risco, foron regresadas, usando un estimador de efectos fixos, contra as variables que recollen o entorno das

taxas de xuro e outras variables de control. Para mitigar un posible nesgo causado pola endoxeneidade, foi considerado un modelo no que todas as variables explicativas foron desfasadas un período e incluídos efectos fixos para cada banco e para cada ano da mostra.

A identificación dos modelos de negocio existentes na banca europea foi feita mediante a análise de clusters, realizándose agrupacións en función da estrutura de activos e do financiamento de cada banco. Esta análise permitiu identificar catro modelos de negocio diferenciados na banca europea: un primeiro grupo de bancos con actividade orientada cara ao por menor, un segundo grupo con actividade baseada no mercado monetario interbancario e os dous últimos grupos orientados cara a actividade típica da banca de investimento.

As principais conclusións deste terceiro capítulo indican que a implementación dunha política de taxas de xuro negativas reduciu a marxe financeira e a rendibilidade global, medida pola rendibilidade do activo, da maioría dos bancos europeos. Tamén foi encontrada evidencia de que unha diminución das taxas de xuro de curto prazo provoca unha caída máis pronunciada na rendibilidade dos bancos cando as taxas de xuro xa se encontran en valores negativos. A análise permitiu igualmente concluír que a implementación dese tipo de políticas non levou á adopción de estratexias de investimento cunha maior exposición ao risco.

Non obstante, estas conclusións non son transversais a todos os bancos, diferindo segundo o modelo de negocio utilizado polo banco. Así, comprobouse que a marxe financeira dos bancos, cuxo modelo de negocio baséase no financiamento a través de depósitos captados no mercado minorista, viuse afectada mais negativamente pola aplicación de políticas de taxas de xuro negativas que nos restantes casos. En canto á toma de risco, concluíuse que os bancos pertencentes ao grupo que se financia no mercado monetario interbancario e a un dos grupos centrados na banca de investimento, adoptaron estratexias de investimento máis arriscadas, mentres que os bancos pertencentes ao grupo orientado ao por menor adoptaron estratexias de investimento menos arriscadas. Non obstante, a adopción de estratexias de investimento máis arriscadas non ten repercusións en termos de risco de crédito e estabilidade financeira en ningún dos modelos de negocio identificados.

Os resultados obtidos suxiren que as entidades de supervisión e regulación do sector bancario europeo controlen de preto os efectos dun entorno caracterizado por taxas de xuro

negativas que, a longo prazo, parece deprimir a rendibilidade dos bancos poñendo en risco a súa estabilidade financeira.

O cuarto capítulo analiza, no contexto europeo, o impacto da adopción de políticas socialmente responsables na eficiencia bancaria. Nun mercado global e competitivo, os bancos, como outras organizacións, buscan presentarse como organizacións socialmente responsables. Nun contexto de globalización empresarial, caracterizado pola contaminación ambiental nalgunhas partes do planeta e cada vez máis marcado pola escaseza de recursos, os bancos, como outras grandes empresas, son presionados para que xestionen os seus negocios de forma máis responsable socialmente (Gao, 2009). A crise financeira de 2007-2008 provocou que moitos gobernos de Europa inxectaran fondos dos contribuíntes para reforzar a solvencia dos bancos e conter a propagación do risco sistémico. Este feito fixo que a opinión pública pasase a examinar a actividade desenvolvida polos bancos dun xeito mais pormenorizado, xustificando pola súa banda maiores esforzos para recuperar a credibilidade corporativa e a confianza dos seus clientes (Pérez et al., 2013). A responsabilidade social corporativa converteuse nunha ferramenta esencial para que os bancos restablezan a súa reputación na sociedade en xeral. Como resultado, os bancos aumentaron as súas prácticas de responsabilidade social, reforzando a súa credibilidade e a confianza que seus stakeholders depositan neles (Coulson, 2009).

Esta crecente preocupación polo desenvolvemento de organizacións sostibles levou a moitos académicos a investigar se o desempeño social corporativo, como medida da responsabilidade social corporativa, ten un impacto positivo no desempeño financeiro da empresa. No sector bancario, os estudos existentes demostran que o desempeño social corporativo ten impacto no desempeño financeiro dos bancos (Esteban-Sanchez et al., 2017; Bätae et al., 2021), no valor de mercado das súas accións (Miralles-Quirós et al., 2019; Azmi et al., 2021) e no seu risco financeiro (Neitzert & Petras, 2019). Esta investigación, distínguese da maioría das anteriores, analizando o efecto do desempeño social corporativo, e de cada unha das súas dimensións (ambiental, social e governanza) considerada illadamente, sobre a eficiencia na banca europea.

A revisión da literatura levada a cabo permitiu concluír que existen dúas visións antagónicas sobre o efecto que o investimento en políticas socialmente responsábeis ten sobre o desempeño financeiro dunha organización. A Teoría Neoclásica defende que a empresa debe aplicar os seus recursos escasos en actividades que teñen como obxectivo a maximización do

beneficio, actuando de acordo coas regras básicas, leis e costumes xeralmente aceptadas pola sociedade (Friedman, 1970). Segundo esta visión, os accionistas son vistos como os principais stakeholders da empresa e, por iso, os recursos deben ser asignados para satisfacer a este grupo. A posición Neoclásica, por tanto, sostén que a xestión da empresa débese preocupar só dos intereses de seus propietarios ou accionistas (Miralles-Quirós et al., 2019). Segundo a Teoría da Axencia, a participación en actividades ligadas á responsabilidade social corporativa é unha responsabilidade da xestión sendo o custo soportado polos accionistas. Desde esta perspectiva, o investimento en actividades asociadas á responsabilidade social corporativa ten un impacto negativo no desempeño financeiro da empresa. No campo oposto encóntrase a Teoría dos Stakeholders, desenvolvida por Freeman (1984), segundo a cal unha empresa non pertence só aos propietarios/accionistas, debéndose ter en conta tamén os intereses dos restantes axentes que gravitan na súa esfera. Neste sentido, o obxectivo da empresa non debe ser maximizar o valor para os accionistas, senón crear valor para todas as partes interesadas incluíndo os empregados, os consumidores, as comunidades locais, os recursos naturais ou ambientais (Post et al., 2002). Con base nestas dúas visións antagónicas estableceuse a primeira hipótese de investigación do cuarto capítulo; H1: un bo desempeño social corporativo aumenta a eficiencia bancaria.

Como referido por Xie et al. (2019), as actividades ligadas á responsabilidade social corporativa son resultado das políticas de xestión e de obrigacións legais e comprenden distintas dimensións: a dimensión ambiental, a dimensión social e a dimensión asociada ao modelo de governanza. Naturalmente, estas tres dimensións teñen unha contribución distinta para o desempeño social corporativo e poden impactar de forma diferenciada sobre a eficiencia bancaria. Esta observación levounos a estabelecer as seguintes 3 hipóteses de investigación; H2: un bo desempeño na dimensión ambiental da responsabilidade social corporativa aumenta a eficiencia bancaria; H3: un bo desempeño na dimensión social da responsabilidade social corporativa aumenta a eficiencia bancaria; e H4: Os bancos con bo desempeño en termos de modelo de governanza son máis eficientes.

Nunha tentativa de reconciliación das dúas visións sobre o tema e en liña co defendido por Nollet et al. (2016) e Shabbir et al. (2020) foi formulada unha última hipótese de investigación a saber; H5: a relación entre o desempeño social corporativo (e cada un dos seus compoñentes considerado illadamente) e a eficiencia bancaria non é lineal.

Para analizar as hipóteses de investigación formuladas considerase unha mostra de datos de panel que contén 108 bancos cotizados, de 21 países europeos, durante o período de 2011 a 2019. En termos metodolóxicos, para medir o desempeño social corporativo, e cada unha das súas dimensións illadamente, construíronse catro índices empregando un modelo de análise envolvente de datos (DEA, Data Envelopment Analysis) sen inputs explícitos. No estudo da relación entre o desempeño social corporativo e a eficiencia bancaria, considerouse o método de estimación en dúas etapas proposto por Simar e Wilson (2007). Nunha primeira etapa, a técnica non paramétrica DEA foi utilizada para estimar as puntuacións de eficiencia, considerando un modelo con dous inputs (activos fixos e custo medio da man de obra) e dous outputs (préstamos e ingresos distintos da marxe financeira), asumindo que os bancos operan baixo a hipótese de rendementos variables a escala. Na segunda etapa, un modelo de regresión truncado foi estimado por medio do algoritmo II proposto por Simar & Wilson (2007), onde a puntuación de eficiencia, da primeira etapa, é regresada contra un conxunto de variables que potencialmente poderían explicar a eficiencia do banco, incluíndo a variable relativa ao desempeño social corporativo como un todo ou relativa a cada unha das súas tres dimensións consideradas illadamente.

As principais conclusións do cuarto capítulo permiten dicir que, en xeral, os bancos europeos presentan baixos niveis de eficiencia, cun valor de eficiencia técnica pura en torno ao 50%. Os resultados tamén nos permiten concluír que hai evidencia dunha relación en forma de U entre o desempeño social corporativo e a eficiencia dos bancos en Europa. En particular, constátase que os bancos con niveis intermedios de desempeño social corporativo son menos eficientes, mentres que os bancos con niveis baixos ou altos de actividades ligadas á responsabilidade social corporativa presentan mellores niveis de eficiencia. Considerando o efecto illado de cada dimensión do desempeño social corporativo, constátase que os bancos con boas performances nas áreas social e de governanza son máis eficientes. A dimensión ambiental das actividades ligadas a responsabilidade social corporativa non se revela estatisticamente significativa na explicación da eficiencia bancaria.

Os resultados obtidos teñen dúas implicacións para a xestión bancaria: (i) a primeira é que a adopción de prácticas ambientais para corrixir externalidades ou disfuncións que o mercado non consegue resolver debe limitarse, unha vez que non parecen influenciar a eficiencia dos bancos; (ii) a segunda é que as boas prácticas nas dimensións social e na asociada ao modelo

de governanza das actividades ligadas á responsabilidade social corporativa teñen un impacto positivo na eficiencia do banco, mais só no longo prazo.

O presente traballo remata coa presentación dunha síntese das principais conclusións dos ensaios realizados, limitacións presentes e futuras liñas de investigación sobre as temáticas abordadas.

À minha mulher, Paula

Aos meus filhos, Lucinda e Nelson

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JOSÉ FERNANDO DA SILVA NETO

July 2021

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LIST OF ACRONYMS/ABBREVIATIONS

CSP: Corporate Social Performance

CSR: Corporate Social Responsibility

DD: Distance-to-Default

DEA: Data Envelopment Analysis

DI: Distance-to-Insolvency

DMU: Decision Making Unit

ECB: European Central Bank

ESG: Environmental, Social and Governance

EU: European Union

GDP: Gross Domestic Product

GMM: Generalized Method of Moments

IMF: International Monetary Fund

NIRP: Negative Interest Rate Policy

NPL: Non-Performing Loans

ROA: Return on Assets

ROE: Return on Equity

RWA: Risk-Weighted Assets

VRS: Variable Returns to Scale

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INTRODUCTION

The process of financial deregulation, which began mainly in the 1980s, caused changes in the financial system of the more developed economic blocs, which include Europe. This process changed how financial institutions act, expanding financial disintermediation, which contributed to an expansion of financial innovations and the change in the architecture of the global financial system. With this, according to some authors, the process of financial deregulation increased the vulnerability of the US financial system, constituting itself as a structural cause of the subprime crisis.

The 2007-2008 financial crisis and later the Eurozone sovereign debt crisis shook the stability of the European banking system, leading to the disappearance of many credit institutions and numerous public interventions by the different European governments to contain the spread systemic risk. At the same time, in the post-financial crisis, there is a strengthening of prudential regulation, a good example of which is the implementation of the Basel III Accord, which obliges banks to increase their capital reserves to face future crises. In the European Union, in 2014, we witnessed the creation of the European Banking Union based on two essential pillars: the Single Supervisory Mechanism and the Single Resolution Mechanism.

The changes that have taken place will have had a positive impact on the financial stability of the European banking system, but they will also have changed the competitive conditions in which banks operate. Based on this idea, emerges the first essay of this thesis, which revisits the study of the relationship between competition in the banking sector and the financial stability of banks in Europe. The changes underwent by the European banking sector in the last decade, the fact that it plays a vital role in the good functioning of the economy, and facing new challenges, such as technological disruption, maintain interest in studying the relationship between competition and financial stability, justifying this research.

In the last decade, to combat the deflation scenario and simultaneously stimulate economic growth, some central banks worldwide have implemented a series of unconventional monetary policies that have brought interest rates to negative ground. In Europe, this phenomenon has been and continues to be particularly felt, with interest rates on the interbank money market and

public debt issued by most European countries remaining negative for a long period. This circumstance motivated the second investigation carried out in the present thesis. In the context of the European banking sector, we study the impact that a negative interest rate policy has on profitability and risk-taking in banks.

As already mentioned, the 2007-2008 financial crisis leads many European governments to provide public aids to contain the spread of a systemic crisis in the banking sector in their countries. These public aids and the need to recover corporate credibility and customers' trust led bank administrations to choose the adoption of socially and environmentally responsible policies as an essential tool for the development of their business. This raises the question of how it is the relationship between corporate social responsibility and banks' financial performance. In the context of the European banking sector, some studies have investigated the impact of corporate social performance on traditional financial measures such as profitability and the market value of banks. However, studies that assess the impact of corporate social performance on banking efficiency are scarce. This scarcity for the European banking sector motivated the third investigation of this thesis.

To carry out the essays identified about the European banking system, this document is structured as follows. The present introduction, followed by a chapter that characterizes the European banking sector after the financial crisis, defines the objectives of the thesis and the methodology employed. The next three chapters constitute the main body of the thesis, each corresponding to an essay. The thesis ends finally with the conclusion.

The first chapter presents a characterization of the European banking sector after the financial crisis, covering the period 2008-2018. In particular, aspects related to the market structure, the typology of assets and the sources of financing used by banks in Europe are analyzed. The levels of financial stability and profitability of these institutions are also addressed. This chapter includes the objectives pursued and the methodology that was used in the present research work.

In chapter 2 is analysed the relationship between competition and bank risk-taking in Europe. Based on the literature review, the competition-stability and competition-fragility views are hypothesized. It is also investigated the hypothesis that the relationship between competition and risk-taking in banking is given by a U-shaped relationship. This essay extends

the existing literature by investigating if that nexus is differentiated depending on whether the bank operates in a weaker or more stable banking system as a whole. To measure competition is considered the Lerner index, a measure of the bank's market power. Bank's risk-taking is proxied by distance-to-default, a market risk' measure, and Z-score, an accounting measure of risk. Because a market measure is used to quantify the bank's risk-taking, the sample utilized is made up of 117 listed banks from 16 European countries covering the period 2011-2018. To address the endogeneity problem between the bank competition measure and bank risk measures, the relationship between competition and bank's risk-taking is estimated considering a dynamic panel model with a 2-step GMM estimator. To control the effects of other variables in the bank's risk-taking is considered a set of variables at bank-level and some macroeconomic variables.

This is followed by Chapter 3, where the effect of negative interest rate policies on the profitability and risk-taking of European banks is investigated. After reviewing the literature, it is investigated (i) the effects of negative interest rates on the bank's net interest margin and the remaining components of banks' profitability; (ii) the effects of negative interest rates in bank's risk-taking; (iii) and lastly if the referred effects are differentiated according to the bank's business model. The main contribution to the related literature of this essay lies in the fact that it is investigated whether the effects of negative interest rates on banks' profitability and risk-taking are differentiated according to the business model adopted by the bank. Bank's margin and overall profitability are proxied by net interest margin and return on assets, respectively. To measure the bank's risk-taking three measures are considered: Z-score, as a measure of the overall bank risk, non-performing loans ratio as a measure of credit risk, and finally the risk-weighted assets to total assets ratio as a measure of the risk associated with the bank's investment strategy. The interest rate environment is characterized by a short-term interest rate, 3-month interbank money market interest rate, and the slope of the yield curve measured by the difference between 10-year Treasury yield and 3-month interbank money market interest rate. A sample of 2596 banks, from 29 European countries, over the period 2011-2019 is considered in the study. To test the research hypotheses, static panel models are estimated using a fixed-effect estimator, where all explanatory variables are lagged one period and bank and time fixed effects are included to mitigate a possible endogeneity bias. To identify the different business models existing in European banking are used k-medians clustering based on the asset and funding structure of each bank. The cluster analysis allowed us to identify four different

business models in European banking: a retail-oriented banks model, a lending-oriented banks model, and two investment-oriented banks models.

In chapter 4 is analysed the impact of corporate social performance on the bank's efficiency. The study was conducted to measure not only the global effect of corporate social performance but also the isolated effect of each of its three dimensions: environmental, social, and governance. Based on the literature review, we formulate five research hypotheses: in the first four, an attempt is made to investigate whether corporate social performance and its dimensions have a positive effect on bank efficiency. The fifth research hypothesis allows us to verify the possibility that the relationship between corporate social performance and banking efficiency is not linear as advocated by some authors. A sample of 108 European listed banks across 21 countries over the 2011-2019 period is considered to analyse the formulated hypotheses. To quantify the corporate social performance and each of their dimensions, four indexes are constructed using a data envelopment analysis model without explicit inputs. In the study of the relationship between corporate social performance and bank efficiency, Simar and Wilson's two-stage approach (2007) is applied. Specifically, at the first stage, the nonparametric data envelopment analysis technique is used data to estimate efficiency scores, considering a model with two inputs (fixed assets and average cost of labour) and two outputs (loans and non-interest income) and assuming that banks operate under the variable returns to scale hypothesis. At the second stage, a truncated regression model is estimated using algorithm II proposed by Simar & Wilson (2007), where the efficiency score, from the first stage, is regressed against a set of variables that could potentially explain the bank's efficiency, including the corporate social performance variable or one of each its three dimensions.

This work finishes with the main conclusions of the three essays, as well as the limitations presented in them and the opportunities for future research for the development of the three topics in the literature.

1. THE EUROPEAN BANKING SECTOR AFTER FINANCIAL CRISIS, OBJECTIVES AND RESEARCH METHODOLOGY

The banking sector plays a fundamental role in an economy as it ensures, among others, the function of financial intermediation between savers and investors, allowing a more efficient channelling of resources from the former to the latter and matching prices, terms, amounts, risks and guarantees. It is also a constantly changing sector that justifies being continuously studied and supervised by regulatory authorities to guarantee its financial stability, an essential condition for the positive contribution it can make to an economy.

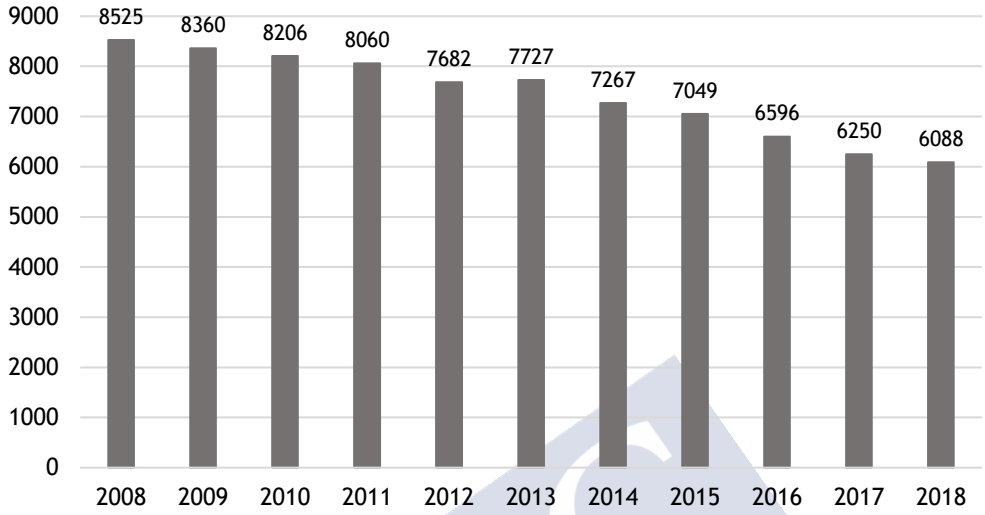
To carry out any study about the banking sector, in this case on the European continent, it is essential to start by making a characterization of it, to allow a better framing of the research hypotheses. Thus, in this first chapter, we begin by making a brief characterization of European banking in the period after the financial crisis of 2007-2008, which will allow us to have the necessary framework to carry out the three essays proposed in the scope of this research work. Then, the main objectives of the dissertation are defined and, finally, the chapter is closed by establishing the methodology to be used.

1.1. THE EUROPEAN BANKING SECTOR AFTER FINANCIAL CRISIS

As already mentioned in the introduction of this dissertation, the 2007-2008 crisis and later the sovereign debt crisis in the Eurozone had a strong impact on the financial stability of the European banking sector, leading to the disappearance of many credit institutions. According to the European Bank Federation report (2019), the number of credit institutions decreased an average annual rate of 3.3% between 2008 and 2018, from 8525 to 6088 (see Figure 1). Countries like the Netherlands, Spain, Greece, France and Denmark saw the number of credit institutions operating in their country decrease by more than 40% in the period considered. Among the countries with the smallest reduction in the number of credit institutions operating are the United Kingdom, Sweden, Belgium and Portugal with rates of decrease below 20%. As a result of the decrease in the number of credit institutions, in some countries, such as Greece, Italy and Spain, there was a strong growth in the market share of total assets of the five largest

credit institutions. Namely, according to European Bank Federation that share increase from 69,5% to 96,8% in Greece, from 31,2% to 45,6% in Italy and from 42,4% to 68,5% in Spain.

Figure 1 – Number of credit institutions in the EU-28 (2008-2018)



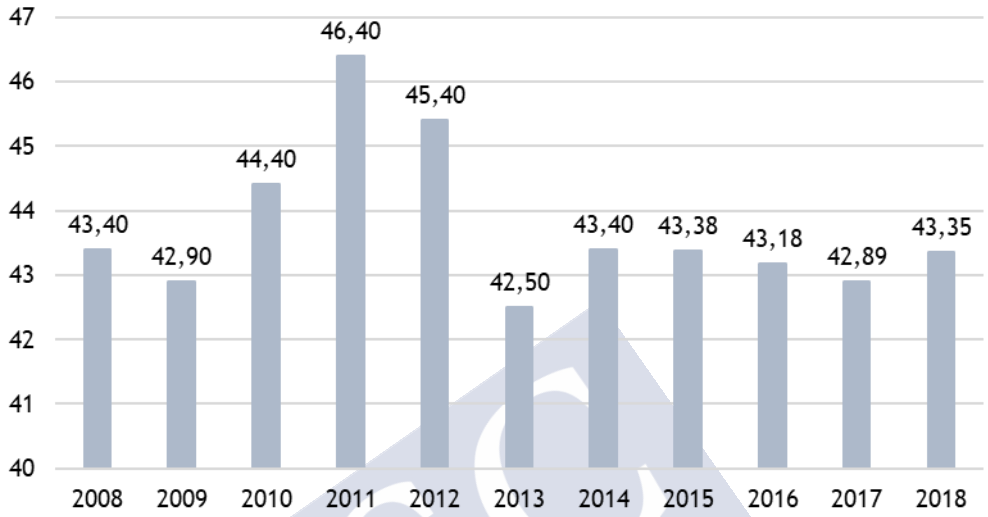
Source: Own production [using data collected from European Banking Federation (EBF)]

It should be noted that despite the structural changes that occurred, the value of assets under management of banks belonging to the EU-28 practically did not change, having gone from 43.40 trillion euros in 2008 to 43.35 trillion euros in 2018, recording a maximum of 46.40 trillion euros in 2011 (see Figure 2). It should be noted that at the end of 2018, banks in the United Kingdom, together with those in Germany and France, had under management around 60% of European banking assets, distributed more or less equally.

The value of domestic deposit liabilities in the EU-28 during the period 2008-2018 registered an upward trend rising from 21.1 to 23.5 trillion euros. This trend led to the percentage of deposits in the total assets of the EU-28 increasing from 48.7% in 2008 to 54.2% in 2018 (see Figure 3). In that period, all EU-28 countries saw the amount of bank deposits increase, except the United Kingdom, Cyprus and Greece, where they decreased by 10.6%, 26.5% and 23.6%, respectively. The value of bank loans in the EU-28 banks increased from 23.3 to 25.1 trillion euros between 2008 to 2018, implying that the share of loans in total assets increased from 53.7% to 57.9% (see Figure 3). However, this upward trend was not general, as there were countries that between 2008 and 2018 saw the value of bank loans decrease considerably. This is the case, among others, of Ireland, Latvia, Slovenia, Cyprus and Greece,

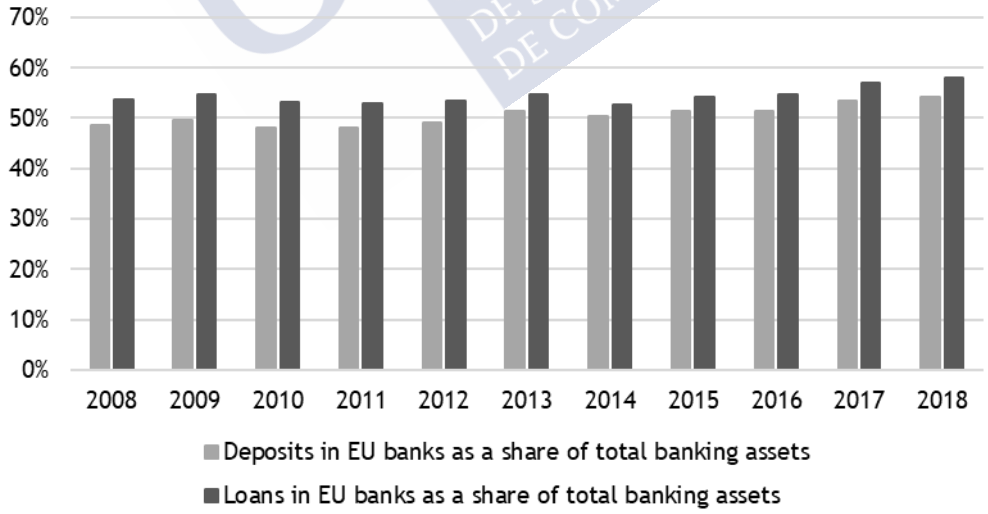
which in that period registered decreases in bank loans of 43.7%, 17%, 17%, 16.2% and 16.1%[1], respectively. In countries like France, Sweden, Finland and Lithuania the value of bank loans was more than duplicated.

Figure 2 – Total Assets of the EU-28 banks, in € trillions (2008-2018)



Source: Own production [using data collected from European Banking Federation (EBF)]

Figure 3 – Deposits and loans in EU-28 banks as a share of total banking assets (%) (2008-2018)



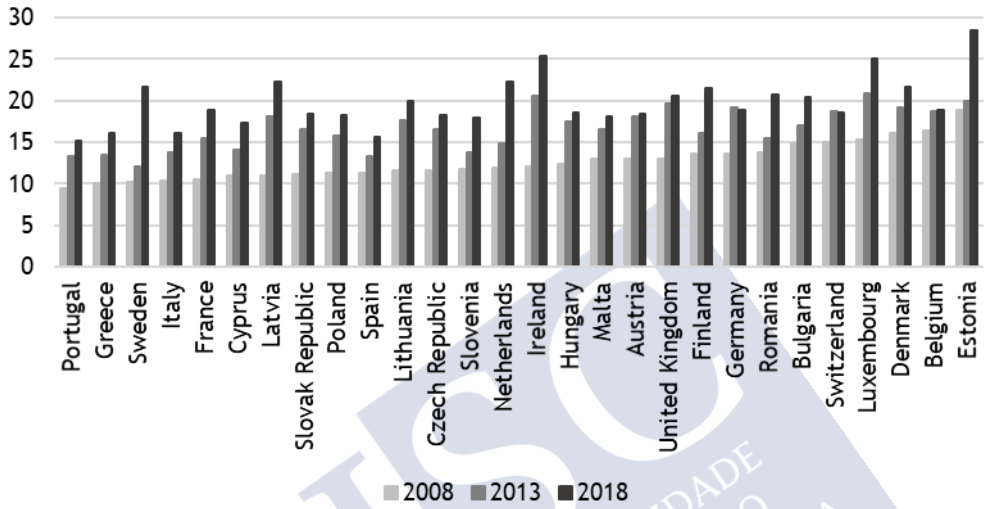
Source: Own production [using data collected from European Banking Federation (EBF)]

After the heavy losses incurred with the financial crisis of 2007-2008, European banks started to build a solid capital position, strengthening their balance sheets throughout 2018. The

[1] Own calculations based on data extracted from Statistical Data Warehouse from European Central Bank (ECB).

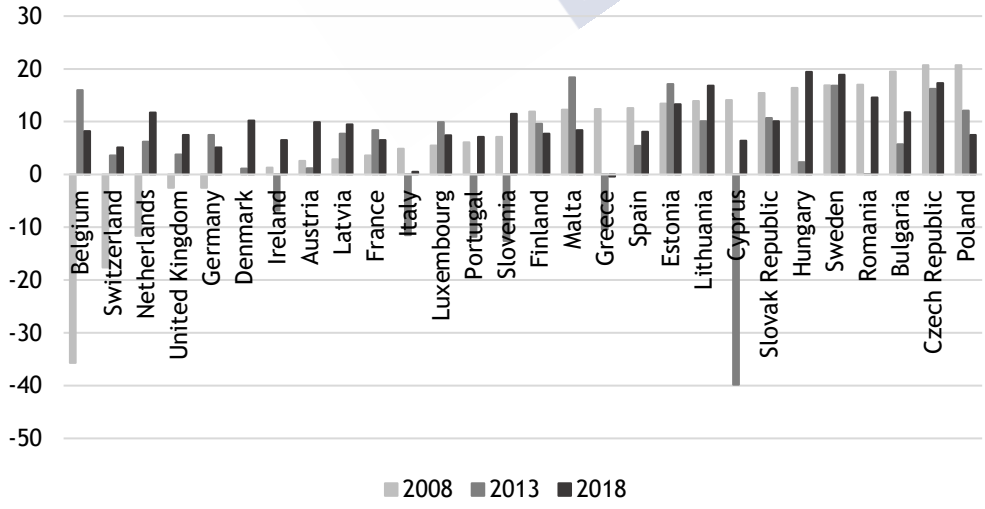
recapitalisation effort that European banks have made following the financial crisis made the European banking sector more resilient and robust. As can be seen from Figure 4, in all European countries there was a clear reinforcement of the Regulatory Capital to Risk-Weighted Assets (RWA) ratio in the period from 2008 to 2018, which is in line with what is established in the Basel III Accord about capital requirements.

Figure 4 – Bank Regulatory Capital to RWA in European banks (%)



Source: Own production [Financial Soundness Indicators of International Monetary Fund (IMF)]

Figure 5 – Return on Equity in European banks (%)



Source: Own production [Financial Soundness Indicators of International Monetary Fund (IMF)]

Despite some improvement in the profitability levels of European banking after the financial crisis of 2007-2008, the return on equity (ROE), a key indicator to assess the banking's

sector attractiveness for investors, has been slowly recovering. With the ECB and other central banks maintaining their ultra-low interest rates, profitability remains a key challenge facing European banks. The ROE of European banks was 6.1% in 2018 for EU 28, which compares with -6.5% in 2008 registered at the outbreak of the financial crisis. With the exception of Greece, in 2018, all banking sectors in different countries show a positive ROE, with 11 of them having a double-digit ROE (see Figure 5). On the positive side, the banks in Hungary, Sweden, the Czech Republic, Lithuania and Romania should be highlighted, with ROE of 19.4%, 18.9%, 17.3%, 16.8% and 14.6%, respectively. In the largest EU economies, banks' ROE in 2018, while positive, remains at much lower pre-crisis levels [Germany (5.1%), United Kingdom (5.1%), France (6.5%), Spain (8.1%) and Italy (0.5%)].

1.2. RESEARCH OBJECTIVES

After a brief characterization of the European banking sector in the post-financial crisis of 2007-2008, the aims of this dissertation are identified in this section, embodied in the realization of an innovative, deep and updated analysis of the implications that the financial crisis had on European banking, namely in terms of aspects related to its financial stability, profitability and efficiency.

The first objective is to understand to what extent the financial stability of European banks was affected by the change in the competitive conditions in which they operate due to the change in the different market structures existing in the European banking sector. In particular, it seeks to study whether the relationship between competition and financial stability is influenced by differences in the banking system as a whole.

The second objective of the dissertation is to determine whether the adoption of a policy of negative interest rates by some central banks of Europe led to a substantial reduction in the profitability levels of banks that are based in Europe and whether this led them to expose to riskier investment strategies, jeopardizing their financial stability. We also address this relationship taking into account the bank's business model, allowing us to identify differentiated effects in the relationship between banks' profitability and risk-taking and negative interest rate policies, representing an innovative research aspect.

The last objective of this research work is to study the determinants of banking efficiency in European banks. More specifically, it seeks to investigate the effect of adopting socially responsible policies, in its environmental, social and governance dimensions, on bank efficiency levels.

1.3. RESEARCH METHODOLOGY

To achieve the proposed objectives, the hypothetical-deductive method approach was applied by performing a set of essays in the European banking sector, that constitute the main body of this thesis. In this analysis, longitudinal samples from European banks, covering the period from 2011 to 2019 and parametric and non-parametric methodologies were utilized. In almost all of the essays about European banking performed in the thesis, panel data models were employed to test the research hypotheses formulated in the body of the research's work.

To achieving the first objective, about the relationship between financial stability and competitive conditions, the proposed model was estimated using the two-step "system GMM estimator" developed by Arellano and Bover (1995) and Blundell and Bond (1998), which proves to be suitable in situations of the possible presence of endogeneity. In robustness tests, the model was also estimated using a fixed and a random effect estimator with robust standard errors to account for the possible existence of autocorrelation and/or heteroscedasticity.

To estimate the proposed models, with the objective of analysing the impact of negative interest rate policies in the bank's profitability and risk-taking, a fixed effect estimator with robust standard errors was used to account for the possible existence of autocorrelation and/or heteroscedasticity. To identify the different business models adopted by European banks, cluster analysis was used. Namely, it was used k-medians clustering to assign each bank to a specific banking business model according to its asset and funding structure.

Lastly, to estimate the bank's efficiency scores a non-parametric technique was used, namely, data envelopment analysis (DEA), considering the BCC (Banker, Charnes and Cooper) model. We also used a DEA model without explicit inputs (DEA-WEI model) to estimate indices related to corporate social responsibility and each of its dimensions. The truncated regression model was estimated using algorithm II proposed by Simar & Wilson (2007). In

robustness tests, the model also was estimated using the two-step "system GMM estimator" of Arellano and Bover (1995) and Blundell and Bond (1998).

Further details on the computation of some variables, databases and the estimation methods used will be presented in the chapters of the three essays, which we will develop from now.

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2. COMPETITION AND FINANCIAL STABILITY IN THE EUROPEAN LISTED BANKS

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2.1. INTRODUCTION

The impact of bank competition on financial stability has been widely discussed in the academic and political communities over the last two decades and particularly since the 2007-2008 global financial crisis (Fu et al., 2014; Clark et al., 2018). During the decades of the seventies and eighties in the last century, there was an intensification of financial deregulation that promoted the globalization of financial markets and the financial innovation, which in turn led banks to adopt much more aggressive policies, increasing the degree of competition (Danisman & Demirel, 2019; Cuestas et al., 2020). For many, this excessive risk-taking behaviour by the banks was the key to the 2007-2008 crisis. This has led in Europe, as in the worldwide, in the past few years, a strengthening of prudential regulation via increased capital requirements and other obligations that incorporate aspects that can affect competition in the banking sector. Also, there was a reduction in the number of banks operating in most countries, with the troubled banks being bailed out by national governments or absorbed by other banks. These two phenomena may have modified the competitive conditions in which banks operate, relaunching the discussion about the relationship between competition in the banking sector and its financial stability in the scientific community.

While it is agreed at an academic level that greater competition in the banking sector leads to greater innovation and efficiency (Schaeck & Čihák, 2010; Turk Ariss, 2010), there is still no consensus as to whether the impact of competition on the banking sector will lead to greater

or lesser financial stability. The traditional banking literature supports a "competition-fragility" nexus. Under this hypothesis, bank competition will lower the net interest margin, eroding bank's profits, which will lead to an increased probability of bankruptcy, and consequently, the overall disruption of the financial system (Marcus, 1984; Keeley, 1990; Allen & Gale, 2004). More recently, Boyd and De Nicoló (2005) present arguments that support the competition-stability hypothesis, which states that banks with more market power tend to charge higher interest rates, which provides an incentive to borrowers to engage in riskier activities. So, under this theory, competition increases financial stability. Martinez-Miera and Repullo (2010) present a model that tries to reconcile the two opposing views on the relationship between competition and financial stability of banks.

Although this topic has already been investigated in the European context, this research is of particular interest because it analyses a sector in constant change and which is essential for the good functioning of the economy. The changes that took place in the different European banking sectors due to the 2007-2008 financial crisis and the regulatory changes to stabilize them have led in recent years to great restructuring that has altered the conditions of competition. This reason justifies our work, which presents the following distinctive aspects from those previously carried out. First, we emphasize the fact that the relationship between bank competition and risk-taking can be differentiated depending on whether the bank operates in a more or less stable banking system. Second, to measure the bank risk-taking, we considered a new market measure, computed with market data, and not obtained from data provider services. Finally, to account for the persistence in the relationship between banking competition and risk-taking, we consider a dynamic panel data model, instead of the traditional static model, estimated by a method that allows us to obtain more efficient estimators.

Initially, as a proxy for individual bank risk, two alternative measures are considered. These measures, which have been intensively used in previous empirical investigations, are the Z-score, an accounting measure, and the distance-to-default, a market measure. In robustness tests, we also considered a third measure, distance-to-insolvency, which, to the best of our knowledge, has never been used in previous empirical research to measure the bank's risk. To measure banking competition, we consider the Lerner index, which measures the bank's ability to keep its prices above its marginal costs.

Using a dynamic panel data model with a Generalized Method of Moments (GMM) estimator, to control for endogeneity, the empirical analysis is carried out for 117 banks, in 16 Western European countries, between 2011-2018. The findings indicate that market power increases the bank's financial stability, which corroborates the traditional "competition-fragility" view, and that relationship is only significant for countries with a less stable banking system. We also find evidence that banks with greater dimension, more well-capitalized and with more diversified earnings sources are more stable.

The remainder of the chapter is organized as follows. Subchapter 2.2. provides a review of the literature on competition and stability in banking and formulates the research hypotheses. Subchapter 2.3. describes the econometric methodology and the data used in the econometric tests. The results are reported and discussed in Subchapter 2.4. A set of robustness tests are conducted in Subchapter 2.5. and Subchapter 2.6. concludes.

2.2. Literature Review and Research Hypothesis

The literature on the study of the relationship between competition and stability in the banking sector is based on two different views: the competition-fragility view and the competition-stability view.

According to the traditional competition-fragility hypothesis, banks become more fragile when they operate in more competitive banking systems. Over time, several arguments have been suggested to support this hypothesis.

The first is based on the well-known "charter/franchise value" paradigm for bank risk-taking, which states that banks limit risk-taking to protect the quasi-monopoly rents granted by their governments' charters. Marcus (1984) and Keeley (1990) provide a theoretical framework that suggests in more competitive banking systems, due to lower charter/franchise value, the bankruptcy costs are lower, leading banks to adopt riskier investment strategies deteriorating thereby the quality of the bank's assets and the financial stability.

Another argument of the competition-fragility view rests on the market structure in which banks operate. More concentrated banking systems are composed by large banks that benefit from economies of scale and/or scope and have more diversified portfolios, lowering that way

the risk exposure (Williamson, 1986). This argument should be taken with caution as greater banking concentration does not necessarily mean less competition in the sector.

The competition-fragility hypothesis is also supported by the borrower-bank relationship. Several authors argue that in more competitive banking environments, the economic rents from intermediation decrease considerably, leading banks to reduce their screening of potential borrowers and, thus, overall portfolio credit quality declines (Chan et al., 1986; Marquez, 2002).

The competition-fragility hypothesis also finds support in the fact that the existence of deposit guarantee systems to mitigate liquidity risk introduces moral hazard by providing incentives to banks to engage in riskier activities, in more competitive banking environments (Matutes & Vives, 1996).

A last argument that supports the competition-fragility view is based on the fact that the stability of the banking system can also be affected by contagion. In a perfectly competitive market, banks are price takers and have no incentive to provide liquidity to troubled banks. If banks in difficulty eventually fail, this could have negative repercussions on the whole sector increasing the instability. In a more concentrated banking system, with a small number of large institutions, it is relatively easier to monitor banking activity by the supervisory authority and to obtain an agreement to rescue troubled banks, thus preventing contagion and increasing financial stability (Allen & Gale, 2000; Sáez & Shi, 2004).

The alternative and more recent competition-stability hypothesis states that more competitive and/or less concentrated banking systems are more stable. The main argument of this view is based on the risk-shifting effect introduced by Boyd and De Nicoló (BDN, 2005). They developed a model based on the argument that banks operating in markets with uncompetitive banking systems tend to charge higher interest rates on loans granted. This may encourage borrowers to invest in high-risk projects, increasing the probability of default on loans. Consequently, the volume of non-performing loans may increase, resulting in a higher probability of the bank's bankruptcy.

Another argument presented by proponents of the competition-stability hypothesis is related to the doctrine "too-big-to-fail". Mishkin (1999) and Barth et al. (2012) argue that in highly concentrated banking systems, largely made up of large banks, policymakers are more

likely to "save" these banks in case of bankruptcy. This creates a moral hazard problem, encouraging risk-taking behaviour by the bank managers and increasing financial fragility (Rosenblum, 2011; Demirgüç-Kunt & Huizinga, 2013).

Most of the empirical investigations found evidence supporting the view of competition-fragility. Beck et al. (2006), in a cross-country study of 69 countries over the period 1980-1997, using concentration ratio as a measure of competition and a dummy variable indicative of a systemic crisis, found evidence that in economies with more concentrated banking systems, crises are less likely, which supports the competition-fragility view. Using data at the bank level for 23 developed countries, over the period 1999-2005, Berger et al. (2009) conclude that banks with more market power, measured by the Lerner index, present riskier loan portfolios but the overall bank risk, measured by the Z-score index, is more reduced, which supports the competition-fragility view. Evidence of this view also can be found in more recent studies (Beck et al., 2013; Leroy & Lucotte, 2017; Danisman & Demirel, 2019).

Some but relatively fewer studies, using new measures for the competition, such as the Boone indicator, found evidence of the competition-stability view. Schaeck and Čihák (2010), using a panel data sample of banks from 10 European countries (covering the period 1995-2005) and a cross-section sample of U.S. local banks (for the year 2005), concluded that promoting competition improves banks' financial stability via efficiency channel, which supports the competition-stability view. Similar results were found by Clark et al. (2018) for a bank's panel data set from 10 Commonwealth of Independent States countries in the period 2005-2013. They concluded that there was a statistically significant negative relationship between the Lerner index and the Z-score, which supports the competition-stability view.

According to the European Banking Federation (EBF), since the financial crisis in 2008 until 2018, more than a quarter of credit institutions in the European Union have disappeared[2]. This downward trend gave rise to considerable bank consolidation processes in countries such as Spain, Italy and Greece. Consistent with this trend and the apparent stabilization of most banking systems in Europe in recent years, we expect, in line with the most recent empirical

[2] According to the EBF (2019), the number of credit institutions in the EU-28 decreased by 28.6% from 8525 in 2008 to 6088 in 2018. See Fig. 3, in Appendix of this chapter, for detailed information by country about change in the number of credit institutions between 2008 and 2018.

studies, to find results that support the competition-fragility view to the detriment of the competition-stability hypothesis. Based on this we formulate Hypothesis I below:

Hypothesis I: *Bank competition decreases the stability in banking, indicating the competition-fragility view.*

More recently Martinez-Miera and Repullo (MMR, 2010) developed a model, that assumes an imperfect correlation in the loan's probability of default, to demonstrate the existence of a U-shaped relationship between competition and risk. Increased competition in the banking sector leads to a decrease in loans interest rates which potentially has two opposite effects on financial stability. The first is the already mentioned risk-shifting effect of the BDN model that decreases the loan portfolio risk. The second effect, defined as a "margin" effect, leads to a decrease in banks' revenues, given the reduction of interest payments by firms, which potentially increase the bank risk. MMR demonstrated that the "risk-shifting" effect dominates in markets with greater banking concentration (monopolistic markets) so that the entry of new banks in the sector can improve bank risk measures. In already highly competitive banking markets, the "margin" effect dominates in such a way that the entry of new banking entities into the sector tends to worsen bank risk. This leads the authors to conclude that the lowest degrees of bank risk occur at moderate levels of competition and so a U-shaped relationship between competition and the risk of bank failure generally obtains.

In the context of European banking, despite the increase in banking concentration, quite different market structures still coexist. Countries such as Germany, Austria, Italy and France whose share of total assets of the five largest credit institutions does not exceed 50%, at the end of 2018, and countries like Greece, Netherlands and Finland where that value is greater than 80% (see Figure 8 presented in the appendix of this chapter). This diversity of market structures in European banking makes it possible to admit that both approaches, competition-fragility and competition-stability, may be appropriate, depending on the level of concentration and competition.

On the other hand, a nonlinear investigation could be useful from a policy point of view, as it allows an optimal threshold to be identified beyond which bank competition, or inversely a lack of competition, becomes dangerous for the stability of the banking sector.

Based on those arguments, we formulated the following hypothesis:

Hypothesis II: *There is a U-shaped relationship between competition and bank risk-taking.*

Some recent empirical studies found evidence of Hypothesis II. Jiménez et al. (2013), using a panel data sample of commercial and savings banks from Spain, in the period 1988-2003, concluded by a nonlinear relationship between competition in the loan market and bank risk-taking as in the MMR model. Empirical evidence of the U-shaped relationship between bank competition and risk-taking can also be found in the study of Cuestas et al. (2020) for banks operating in the Baltic countries over the period 2000–2014.

As previously mentioned, the 2007-2008 financial crisis and the eurozone sovereign debt crisis put many European banks under severe financial stress. This led the different European governments to adopt a set of measures to stabilize their countries' banking systems. Those set of measures can be grouped into three categories and, in general, they were implemented sequentially as the crisis worsened: i) guarantees, ii) capital injections and iii) asset restructuring/resolution. In countries with strong budgetary constraints and excessive levels of public debt, such as Italy, Portugal, and Greece, the implementation of steps ii) and iii) was avoided or delayed as much as possible, resulting in an even less stable banking system. In those countries, banks will tend to have poorer results, lower capitalization levels and a lower charter value. According to charter value hypothesis, banks with a lower charter value could be encouraged to take on more risk to benefit from the deposit insurance put option (Bakkar et al., 2020). So, in countries with less stable banking systems, we could expect that, increased competition may lead management to invest in riskier assets, amplifying the level of risk. In countries with more stable banking systems, where banks present higher charter value, more competition will not increase the incentive for risk-taking as much given the higher bankruptcy costs that banks can endure if they fail.

Motivated by these differences, in terms of financial stability, we investigate the influence of the stability of the banking system as a whole on the relationship between market power and bank risk-taking. In particular, we analyse the hypothesis that the relationship between competition and bank risk-taking is influenced by the fact that the bank operates in a more or

less stable banking system as a whole. Emphasizing the role of the banking environment in which each bank operates, we formulate Hypothesis III:

Hypothesis III: *The relationship between competition and bank risk-taking is differentiated depending on whether the bank operates in a less or more stable banking system as a whole.*

To the best of our knowledge, this hypothesis never had been investigated until today and this will be the major contribution of the present study to the recent state of the art.

2.3. METHODOLOGY AND DATA

This subchapter presents the methodology and the empirical model used to examine the effects of competition on the financial stability of listed banks in Europe. Measures of competition and financial stability are also presented and discussed.

2.3.1. Measuring Financial Stability

To measure individual bank risk, we used market-based and accounting-based risk measures. The market measure considered in this work was Distance-to-Default (DD) derived from Black and Scholes (1973) and Merton's (1974) model. In this model, the equity of a bank can be viewed as a call option on the bank's assets, with a strike price and maturity equals to the book value and average maturity of the bank's debt, respectively. At the maturity of debt, if the value of the bank's assets is greater than the book value of debt, equity holders exercise their option and pay off the debt holders. Otherwise, equity holders do not pay the debt and the bank goes bankrupt, and the value of equity is zero.

Formally, the DD of the bank i in a particular year t is defined as follow[3]:

$$DD_{it} = \frac{\ln\left(\frac{V_{A,it}}{D_{it}}\right) + \left(\mu_{A,it} - \frac{1}{2}\sigma_{A,it}^2\right)(T-t)}{\sigma_{A,it}\sqrt{(T-t)}} \tag{2.1}$$

[3] See Vassalou and Xing (2004) for a detailed formula's derivation.

where $V_{A,it}$ is the bank's assets market value, D_{it} is the book value of the bank's debt, $\mu_{A,it}$ is the expected return on assets, $\sigma_{A,it}$ is the standard deviation of market assets return (asset volatility), and $T-t$ is the time to maturity of the debt. In the expression (2.1) the variables $V_{A,it}$, $\mu_{A,it}$ and $\sigma_{A,it}$ are not observable and have to be estimated. For this proposal, we follow the approach used by Moody's KMV model, assuming that average maturity's debt is one year and that default point is equal short-term debt plus one half of long-term debt (Crosbie & Bonh, 2003). In this context, the DD can be defined as the difference between the current market value of a bank's assets and its estimated default point, weighted by the volatility of assets. An increase in the DD means that the bank is moving away from the default point and that bankruptcy becomes less likely.

In robustness tests, an alternative market measure, Distance-to-Insolvency (DI), proposed by Atkeson et al. (2017), was also considered, which is calculated as follows:

$$DI_{it} = \left(\frac{V_{A,it} - D_{it}}{V_{A,it}}\right)\frac{1}{\sigma_{A,it}} \tag{2.2}$$

where variables V_A and σ_A were estimated in the same way as described above. This ratio can be interpreted by the drop in asset value that would render the bank insolvent, measured in units of the firm's asset standard deviation.

As accounting measure of bank soundness, we considered the Z-score, originally introduced by Boyd and Graham (1986), which is widely used in the literature (e.g. Berger et al., 2009; Schaeck & Čihák, 2010; Beck et al., 2013; Leroy & Lucotte, 2017). The Z-score of the bank i in year t is defined as:

$$Z - score_{it} = \frac{E_{it}/A_{it} + ROA_{it}}{\sigma_{ROA,i}} \tag{2.3}$$

where E_{it}/A_{it} is the equity to total assets ratio, ROA_{it} represents the return on assets, measured by the ratio between net income and total assets, and $\sigma_{ROA,i}$ the volatility of return on assets. Because the sample period covered by the present investigation is relatively short, the estimate of the volatility of return on assets $\sigma_{ROA,i}$ is assumed constant and given by the standard deviation of the return on assets in the period under analysis.

It should be noted that Z-score is inversely related with the probability of the bank's insolvency, i.e., a lower Z-score implies a higher probability of insolvency. As noted by Schaeck and Čihák (2010), "the Z-score combines banks' buffers (capital and profits) with the risks they face (measured by the standard deviation of returns)". The Z-score measures the number of standard deviations a return realization must fall in order to deplete equity. Since Z-score is highly skewed, a natural logarithm transformation is used (Danisman & Demirel, 2019).

2.3.2. Measuring Competition

In this study, as a proxy of competition, it is considered the Lerner index, a measure based on non-structural approach. This indicator has been widely used in recent bank research (Fu et al., 2014; Leroy & Lucotte, 2017; Clark et al., 2018). It captures the capacity of price power by calculating the difference between price and marginal cost as a percentage of the price. It is an inverse proxy for bank competition, taking values between 0 and 1, with an index equal to 0 in the case of perfect competition and 1 in the case of monopoly. A low index indicates a high degree of competition, and a high index indicates a lack of competition.

The Lerner index presents several advantages when compared with other measures of competition. First, the Lerner index is the only time-varying measure of competition that can be computed at a disaggregated level, i.e., at the bank level. Second, the calculation of the Lerner index does not imply a definition of the market where the bank offers its services. Finally, a substantial empirical bank literature has suggested that structural measures, as the concentration indexes, are not reliable measures of competition.

Formally, the Lerner index of the bank i in year t is defined as

$$Lerner_{it} = \frac{P_{it} - MC_{it}}{P_{it}} \tag{2.4}$$

where P_{it} is the price of total assets proxied by the ratio of total revenues (interest and non-interest income) to total assets, MC_{it} is the marginal cost of total assets.

To obtain MC_{it}, we used the intermediation approach[4] (e.g. Berger et al., 2009; Fu et al., 2014; Beck et al., 2013; Clark et al., 2018**)**, estimating a translog cost function with three inputs and one output, for each country to better address differences in technology:

$$\ln TC_{it} = \alpha_0 + \beta_1 \ln TA_{it} + \frac{1}{2}\beta_2 (\ln TA_{it})^2 + \sum_{j=1}^{3} \alpha_j \ln w_{it}^j + \sum_{j=1}^{3} \phi_j \ln TA_{it} \ln w_{it}^j + \frac{1}{2}\sum_{j=1}^{3}\sum_{k=1}^{3} \theta_{jk} \ln w_{it}^j \ln w_{it}^k + \gamma_1 T + \frac{1}{2}\gamma_2 T^2 + \gamma_3 T \ln TA_{it} + \sum_{j=4}^{6} \gamma_j T \ln w_{it}^j + \varepsilon_{it} \quad (2.5)$$

where TC_{it} is the bank's total costs and is equal to the sum of interest expenses, commission and fee expenses, trading expenses, personnel expenses, administrative expenses, and other operating expenses, TA_{it} is the bank's output, measured by the total assets. w_{it}^j, for $j = 1,2,3$, are the prices of the inputs of production, defined as follow: w_{it}^1 is the price of purchased funds, measured by the ratio between interest expenses and the sum of total deposits and other sources of funding by debt, w_{it}^2 is the price of labour, measured by the ratio between personnel expenses and total assets, w_{it}^3 is the price of other inputs, measured by the ratio of administrative and other operating expenses to total assets. T is a time trend that captures the influence of technological changes that lead to shifts in the cost function over time and ε_{it} is the error term. We further imposed the following restrictions on regression coefficients to ensure homogeneity of degree one in input the prices: $\sum_{j=1}^{3} \alpha_j = 1$, $\sum_{j=1}^{3} \phi_j = 0$ and $\sum_{j=1}^{3}\sum_{k=1}^{3} \theta_{jk} = 0$.

Under these conditions, we can use the coefficient estimates from the translog cost function to estimate the marginal cost for each bank i at year t:

$$MC_{it} = \frac{\partial TC_{it}}{\partial TA_{it}} = \left[\beta_1 + \beta_2 \ln TA_{it} + \sum_{j=1}^{3} \phi_j \ln w_{it}^j + \gamma_3 T\right] \frac{TC_{it}}{TA_{it}} \quad (2.6)$$

As referred by Turk Ariss (2010), one potential problem associated with the conventional Lerner index is that it assumes full bank efficiency, neither employing too many scarce

[4] In the intermediation approach, a bank is considered as an intermediary between depositors and borrowers. A bank employs labor and physical capital to attract deposits, which are used to fund loans. In addition to labor and physical capital, deposits are considered as an input. Bank output is often defined as total assets, or total loans.

resources (technical efficiency) nor allocating resources in suboptimal proportions given prices (allocative efficiency). Ignoring both cost and profit inefficiency at the same time, the conventional Lerner index calculation will be biased. In robust testing, to deal with both cost and profit inefficiencies in the empirical measurement of the Lerner index, we used the efficiency-adjusted Lerner index, proposed by Koetter et al. (2008), which is estimated using stochastic frontier analysis[5] to account that banks are not fully efficient. The efficiency-adjusted Lerner index is obtained as follows:

$$E - Lerner_{it} = \frac{AR_{it} - MC_{it}}{AR_{it}} \tag{2.7}$$

where AR_{it} denotes average revenues, which is obtained by the ratio between expected total revenues $(\widehat{TR}_{it})$ and total assets (TA_{it}). To estimate the total revenues, we considered the fact that $\widehat{TR}_{it} = \widehat{TP}_{it} + \widehat{TC}_{it}$, where TP_{it} represents the total profits and TC_{it} represents the total costs. TC_{it} was estimated from Eq. (2.5) and the TP_{it} was estimated from an alternative profit function which is equal to Eq. (2.5) but where the dependent variable is now $\ln TP_{it}$.

2.3.3. Empirical Model and Estimation Method

In order to investigate the effects of competition on the financial stability of listed banks in Europe, we follow Beck et al. (2013) and Fu et al. (2014) who argue that in studies of panel data, a dynamic model should be used to estimate the time persistence in the bank risk. Thus, the equation of a dynamic linear model:

$$\begin{aligned} risk_{it} = {} & \beta_0 + \beta_1 * risk_{it-1} + \beta_2 * Competition_{it} + \beta_3 * Competition_{it}^2 \\ & + \sum_{k=1}^{s} \gamma_k Bank\ Control_{k,it} + \sum_{j=1}^{m} \delta_j Macro\ Control_{j,t} + \mu_i + \phi_t + \varepsilon_{it} \end{aligned} \tag{2.8}$$

where i and t are bank and time indicators, respectively, $risk_{it}$ represents alternatively one of the measures of risk stated above, $Competition_{it}$ represents one of the measures of bank competition described above, $Bank\ Control_{k,it}$ represents a bank-level controls variables, $Macro\ Control_{j,t}$ represents macroeconomic variables, μ_i and ϕ_t represent a bank-specific effect and time fixed effect, respectively, and ε_{it} is a disturbance with mean zero and not serially

[5] See Koetter et al. (2008) for details how to estimate the translog cost and profit functions using stochastic frontier analysis.

correlated. Following the literature (Berger et al., 2009; Turk Ariss, 2010; Cuestas et al., 2020), the quadratic term of the measure of bank competition is included in the model to account for the potential U-shaped relationship between competition and risk-taking (MMR, 2010). To test the U-shaped relationship formally, we use the U-shape test developed by Lind and Mehlum (2010), noting that the test is only valid if the estimates of the coefficients associated with the linear and quadratic term present opposite signs, that is, a positive sign and a negative sign.

The first bank-level variable considered is the ratio of equity to assets, as a measure of bank capitalization. Because banks are expected to trade-off higher levels of equity capital for risk assets, we considered this variable as being endogenous (Delis & Kouretas, 2011).

Second, we control the bank's size, measured by the natural logarithm of the total assets. The relationship between risk-taking and size is unclear because, on one hand, managers of large banks may be tempted to adopt higher-risk policies in the case that governments are prepared to bail-out large problematic banks (Demirgüç-Kunt & Huizinga, 2013) and, on the other hand, larger banks can achieve economies of scale that allow them to be more stable than small banks (Williamson, 1986). Third, we considered the non-interest income share, measured as the percentage of non-interest income in total operating revenues, to proxy the composition of bank revenues. It is expected that more diversified revenues imply less risk exposure. To account for the bank's debt structure, we considered the share of wholesale funding in total funding. While the wholesale funding includes money market funding plus other borrowings, total funding is calculated as a sum of wholesale funding plus total deposits. To measure bank's exposure to liquidity risk, we also include, as a control bank-level variable, the ratio between liquid assets and total assets. Finally, we control for asset composition, using the loans-to-assets ratio and for inefficiency using the cost-to-income ratio.

In terms of macroeconomic variables, we have considered two variables. First, GDP growth, to monitor the effect of fluctuations in the business cycle and the trend of economic growth in general in the bank risk-taking. In the previous literature, it has been already found evidence that economic growth encourages banks to reduce financial restrictions to increase lending, generating more risk (Berger & Udell, 2004). Given this, we expect a negative sign for the relationship between economic growth and banking stability. Second, as suggested in the work of Demirgüç-Kunt and Huizinga (2010), we also control for inflation. According to these

authors, a higher inflation rate makes banks achieve a high return on assets but also carries a high level of risk. So, we expect that a higher inflation rate reduces the bank's stability.

Examining whether market power influences the bank's risk-taking raises the question of endogeneity bias. Indeed, Schaeck and Čihák (2010) argued that the level of risk-taking could affect competition between banks, which could then influence our measures of market power. When banks face a high probability of default, they might have an incentive to change the price of their products to access new financial resources and attract new customers, affecting the existing market power. To address the endogeneity problem between the bank competition measure and bank risk measures, as well as capitalization levels, we estimate the Eq. (2.8) using the Generalized Method of the Moments (GMM). Namely, we use the System GMM method who estimates two equations, one in differences and one in levels, including lagged values in levels as instruments of the endogenous variables in first differences and additionally lags of the first differences in the endogenous variables as instruments for the equations in levels. In this research, we use the two-step "system GMM estimator" developed by Arellano and Bover (1995) and Blundell and Bond (1998), with Windmeijer (2005) corrected standard errors[6].

2.3.4. Sample Description and Data Statistics

To evaluate the effects of bank competition on financial stability in Europe after the global financial crisis, we considered an unbalanced panel data set constituted by listed European banks, that covers the period from 2011 to 2018, from the following countries: Austria(AU), Belgium(BE), Denmark(DK), Finland(FI), France(FR), Germany(GE), Greece(GR), Ireland(IR), Italy(IT), Netherlands(NL), Norway(NO), Portugal(PT), Spain(SP), Switzerland(CH), Sweden(SE) and the United Kingdom(UK)[7]. Accounting and stock market information of the banks is obtained from BankFocus Database by Bureau van Dijk and Datastream, respectively (all monetary data has been converted into euros). Real GDP growth and inflation rate are obtained from the World Economic Outlook Database of International Monetary Fund. After excluding banks with (1) missing, negative or zero values for the cost

[6] We use the two-step GMM estimator, instead one-step GMM estimator, because is more efficient.

[7] We considered Western European listed banks for which balance-sheet and market data are available over the period of study. We only considered commercial banks, savings banks, cooperative banks, and bank holdings & holding companies, with at least 3 of years consolidated accounts available.

function needed to calculate the Lerner index, (2) missing data to estimate distance-to-default, and (3) missing Z-score values, we obtain a final sample that includes unbalanced panel data for 117 banks, with 860 bank/year observations.

In the estimation of the Lerner Index (and efficiency-adjusted Lerner index) the sample used was different. As discussed previously, the translog cost function was estimated for each country to better address differences in technology. To increment the number of observations that allowed the estimation of Eq. (2.5) by country, we extended our sample to all listed and non-listed European banks for which we have consolidated data.

The statistics of the variables that are used in the main regression are reported in Table 1.

Table 1 - Sample descriptive statistics of variables used in the main model (2011-2018)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Dependent variables:					
Distance-to-default	860	3.837	3.030	-2.280	16.669
Ln Z-score	860	3.515	0.927	1.215	5.278
Distance-to-insolvency	860	3.502	2.422	-1.038	15.888
Independent variables:					
Lerner index	860	0.140	0.211	-0.959	0.440
E-Lerner index	860	0.236	0.212	-0.746	0.605
Capitalization	860	0.083	0.034	0.017	0.174
Size	860	10.425	2.224	5.788	14.529
Non-interest income share	860	0.428	0.167	0.060	0.919
Share of wholesale funding	860	0.380	0.192	0.007	0.763
Liquidity	860	0.185	0.128	0.023	0.607
Asset composition	860	0.608	0.186	0.133	0.875
Inefficiency	860	0.628	0.157	0.314	1.216
Real GDP growth	860	0.012	0.015	-0.040	0.045
Inflation	860	0.013	0.011	-0.011	0.036

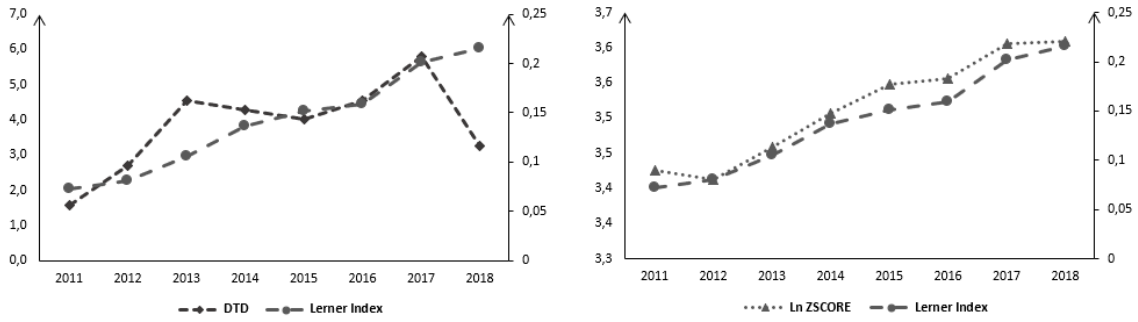
Source: Own production

Considering the results obtained for the financial stability measures, it is verified that banks included in our sample present average values of 3.837 and 3.515 for the distance-to-default and the Ln Z-score indicators, respectively. These values are substantially higher than those obtained by Leroy and Lucotte (2017) which is explained by the fact that their sample period was characterized by the occurrence of subprime crises. The sample average value of distance-to-insolvency is slightly lower than the value of the distance-to-default. Regarding the measures of bank competition, we observed mean values of 0.140 for the conventional Lerner index and

0.236 for the efficiency-adjusted Lerner index, which indicates relatively low market power by the banks included in our sample.

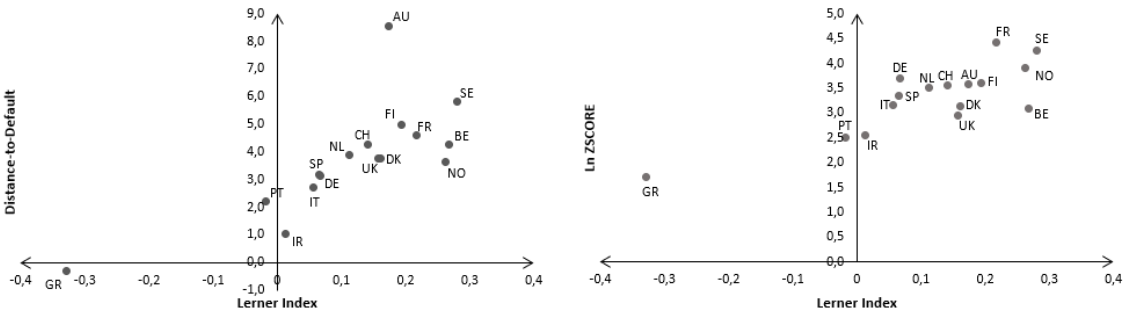
Between 2011 and 2018, the financial stability of the banks included in our sample improved considerably, with the average value of distance-to-default increasing, during the entire period, about 109% from 1.56 to 3.26, while the average value of Z-score registered a more modest growth (see Figure 6). Regarding the evolution of the bank's market power, the trend for the conventional Lerner index is ascending suggesting an increase in pricing power of the European banks of our sample.

Figure 6 - Distance-to-default, Ln Z-score and Lerner index (average) 2011-2018



Source: Own production

Figure 7 - Distance-to-default and Ln Z-score against Lerner index (average) by country



Source: Own production

Comparing bank financial stability by country, using distance-to-default, we concluded that on average, listed banks of our sample that operate in Greece, Ireland and Portugal are the most fragile, while the Austrian and Swedish banks are the most stable (see

Figure ***7***). If we considered Z-score the French and the Swedish banks are the most stable. Looking for bank's market power, comparisons lead to conclude that Greek, Irish and

Portuguese banks present the lowest Lerner indexes, while at the opposite extreme, with the highest pricing power, are the banks of Sweden, Belgium and Norway. We also observe a positive relationship between the average values of the measures of financial stability and market power.

2.4. EMPIRICAL RESULTS AND DISCUSSION

Columns (2) and (4) of Table 2 present the estimation results of Eq. (2.8), by alternatively considering distance-to-default and Ln Z-score as measures of financial stability. Results, for both the financial stability measures, do not support, for our sample, the U-shaped relationship between competition and risk (Hypothesis II) of MMR (2010). Although the signs of coefficient estimates associated with the Lerner index and its square indicate the possibility of an inverse U-shaped relationship between the Lerner Index and the measures of financial stability, the U-shape test of Lind and Mehlum (2010) does not allow us to reject the null hypothesis of a monotone relationship in the model of column (2) and indicate a turning point outside the sample range of the Lerner index for the model of column (4).

Given these results, we re-estimated Eq. (2.8) excluding the quadratic term of the Lerner index [see columns (1) and (3) of Table 2]. For both market and accounting-based stability measures, we find a positive and significant relationship with the Lerner index, which confirms the competition-fragility view (Hypothesis I).

The obtained results allow us to conclude that an increase in the competition encourages individual bank risk-taking of European listed banks, which confirms our Hypothesis I and the evidence found in the recent studies for European banking systems (Leroy & Lucotte, 2017).

Discussing now the impact of the other control variables on bank stability, we found a positive and statistically significant relationship between the Ln Z-score and the levels of capitalization, size, non-interest income share and asset composition [see columns (3) and (4)]. These results indicate that largest banks, best-capitalized, with higher loans-to-assets ratio, and with more diversification of their sources of income, are more financially stable. For the distance-to-default model [see columns (1) and (2)] only non-interest income share and real GDP growth are significant at 5% level of significance. We highlight the negative sign and the magnitude of the estimate of the coefficient associated with real GDP growth, indicating that

the economic growth encourages banks to reduce financial restrictions to increase lending, generating more risk and consequently less stability.

Table 2 - Bank financial stability and competition (whole sample)

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Dependent variable (t-1)	0.401***	0.417***	0.914***	0.908***
	(0.053)	(0.056)	(0.019)	(0.018)
Dependent variable (t-2)	0.248***	0.274***		
	(0.047)	(0.043)		
Lerner index	3.036***	1.791*	0.249***	0.146
	(0.927)	(0.976)	(0.093)	(0.113)
Lerner index squared		-2.659**		-0.010
		(1.246)		(0.143)
Capitalization	6.087	2.966	0.750*	0.720**
	(4.964)	(4.591)	(0.382)	(0.343)
Size	0.051	-0.012	0.015***	0.012*
	(0.051)	(0.051)	(0.005)	(0.006)
Non-interest income share	1.444**	1.411**	0.147*	0.182**
	(0.630)	(0.626)	(0.080)	(0.083)
Share of wholesale funding	0,096	0.564	-0.013	0.027
	(0.441)	(0.472)	(0.052)	(0.057)
Liquidity	0.663	0.415	0.067	0.127**
	(1.110)	(1.043)	(0.050)	(0.060)
Asset composition	1.448*	0.894	0.186**	0.194**
	(0.849)	(0.799)	(0.080)	(0.097)
Inefficiency	-0.000	-0.775	-0.109	-0.193*
	(0.913)	(0.897)	(0.084)	(0.105)
Real GDP growth	-29.388***	-24.878***	-0.409	-0.198
	(8.814)	(9.118)	(0.696)	(0.749)
Inflation	13.489	13.241	0.752	0.603
	(10.098)	(9.241)	(0.744)	(0.759)
Constant	-0.972	0.747	-0.019	0.049
	(1.381)	(1.439)	(0.111)	(0.160)
U-Shape test		0.300		Extremum
p-value [U-Shape test]		[0.384]		outside
Turning point		0.337		interval
Number of observations	619	619	737	737
Number of banks	115	115	117	117
Number of instrumental variables	80	102	87	107
F-Test	58,71***	55.84***	1512.00***	1349.86***
RHO(1) Test	-5,643	-5.699	-3.741	-3.692
p-value [RHO(1) Test]	0.000	0.000	0.000	0.000
RHO(2) Test	1.195	1.045	1.427	1.199
p-value [RHO(2) Test]	0.232	0.296	0.154	0.230
Hansen's J Test	70.328	91.774	72.820	95.272
p-value [Hansen's J Test]	0.219	0.239	0.353	0.280

Note: The table reports the dynamic panel regression results. The two-step system GMM estimator (Arellano & Bover, 1995) is used with Windmeijer (2005) corrected standard errors. Some regressions include an additional lag of dependent variable as explanatory variable to remove second-order autocorrelation. Time Dummies are included. Robust standard errors are reported in parentheses below their coefficient estimates. The U-shape test is based on

Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. Arellano-Bond test is used to test serial correlation, where RHO(1) and RHO(2) are the estimated coefficients of first- and second order correlation and apply to residuals in differences. To analyse the validity of instruments we used the Hansen's (1982) *J* Test for overidentification. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

To test Hypothesis III, we divided our sample into two sub-samples, one containing banks that are based in countries with less stable banking systems and the other with banks that belong to countries with more stable banking systems. For this purpose, using Z-score data extracted from the World Bank's Global Financial Development Database, we calculated the average of that indicator, for each country, in the period 2011-2017[8]. Then the countries were ranked in ascending order of the Z-score and split into two sub-samples: the first group, of the countries with less stable banking systems, which includes banks from the 8 countries with a lower average Z-score (Italy, Portugal, Finland, United Kingdom, Netherlands, Norway, Ireland, Greece) and a second group, of countries with more stable banking systems, which includes banks from the 8 countries with a higher average Z-score (Austria, Germany, France, Spain, Denmark, Belgium, Switzerland, Sweden).

It is interesting to note that countries such as Finland, the United Kingdom, the Netherlands, and Norway, which traditionally have sustainable public finances, are part of the group of countries with less stable banking sectors, based on Z-score. On the contrary, countries like Spain and Belgium, which in the recent past had some problems with the sustainability of public finances, are part of the group of countries with more stable banking sectors. This finding allows us to conclude that the stability of a country's banking sector is not necessarily influenced by that country's public finances, reinforcing the hypothesis that the relationship between competition and risk-taking can be differentiated depending on whether the bank operates in a banking system more or less stable.

The estimation results of Eq. (2.8), with and without the Lerner Index quadratic term, for the two sub-samples, are reported in Table 3[9]. The results confirm a linear and positive relationship between market power and bank's financial stability, confirming the competition-fragility view (Hypothesis I), in the countries with less stable banking systems. The same conclusion cannot be drawn for countries with more stable banking systems, where the

[8] 2018 was not considered, because at the time of the investigation, that year was not yet available.

[9] The complete estimation results can be consulted in the Table 4 and Table 5 of the appendix of this chapter.

relationship between market power and financial stability is not statistically significant at a 5% level of significance. In both sub-samples, there was no evidence of the U-shaped relationship between competition and risk.

Table 3 - Bank financial stability and competition: less vs more stable banking systems

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Less stable banking systems:				
Lerner index	5.700***	2.078	1.098***	0.486
	(2.031)	(1.446)	(0.182)	(0.360)
Lerner index squared		-0.955		-0.994
		(1.620)		(0.665)
Number of observations	364	364	305	305
Number of banks	58	58	57	57
U-Shape test		Extremum		0.420
p-value [U-Shape test]		outside		[0.338]
Turning point		interval		0.244
More stable banking systems:				
Lerner index	2.062	10.785*	-0.456	-0.721*
	(4.245)	(5.449)	(0.319)	(0.405)
Lerner index squared		9.509		-0.279
		(6.239)		(0.636)
Number of observations	314	314	373	373
Number of banks	58	58	59	59
U-Shape test		0.730		Extremum
p-value [U-Shape test]		[0.235]		outside
Turning point		-0.567		interval

Source: Own production

2.5. ROBUSTNESS TESTS

We test the robustness of our results in several ways. First, we considered an alternative measure of the Lerner index: the efficiency-adjusted Lerner index as outlined in section 2.3.2. The estimation results, for the whole sample and sub-samples of less and more stable banking systems, are reported in Table 6, Table 7 and Table 8 of the appendix of this chapter, respectively. Second, we used distance-to-insolvency, described in section 2.3.1, as a measure of a bank's financial stability in estimating Eq. (2.8). The estimation results, for the whole sample and sub-samples of less and more stable banking systems, are reported in Table 9, Table 10 and Table 11 of the appendix of this chapter, respectively. Finally, we estimate a static version of Eq. (2.8) using the fixed effects model and the random effects model. In these models, to consider the endogeneity issue, all explanatory variables are lagged one period. Estimation results for fixed effects model, for the whole sample and sub-samples of less and

more stable banking systems, are reported in Table 12, Table 13 and Table 14 of the appendix of this chapter, respectively. For the random effects model, the results are reported, similarly, in Table 15, Table 16 and Table 17.

In general terms, the results obtained were the same, supporting the "competition-fragility" view for the whole sample and for the sub-sample of the banks that belongs to countries with less stable banking systems. There is no evidence of the U-shaped relationship between competition and risk in the whole sample and in the two sub-samples considered. For banks based in countries with more stable banking systems, market power does not appear to influence risk-taking.

2.6. CONCLUSIONS

The beginning of the 21st century was marked by serious financial crises, such as the global financial crises and Eurozone sovereign debt crises, which severely decreased the financial stability of banks worldwide. This forced the governments of several countries to adopt measures to rescue the banks, and thus, prevent the propagation of a systemic risk crisis. This set of public interventions has probably changed the relationship between competition and financial stability, which motivated this study. This work investigated the competition-stability nexus in the European banking systems using a sample of listed banks. We extend the existing literature by investigating if that nexus is differentiated depending on whether the bank operates in a more stable or less stable banking system as a whole.

We proxy competition with the Lerner index and focused on overall risk measures, such as distance-to-default, distance-to-insolvency and Z-score, for bank risk-taking. To deal with the persistence of bank risk-taking over time, we used a dynamic panel data model, which was estimated by a 2-step GMM estimator to address the endogeneity problem between the bank competition measure and capitalization levels and the bank risk-takings measures. The results obtained do not confirm the U-shaped relationship between competition and bank risk-taking as predicted by MMR (2010). We find support for the competition-fragility view in European banking as a whole, indicating that additional market power decreases the individual risk-taking behaviour of a bank. Perhaps because the competitive environment in European banking systems is already high, the "margin" effect dominates the risk-shifting effect. However, the

competition-fragility view appears only to be valid in countries with less stable banking systems. In countries with more stables banking systems, the relationship between market power and financial stability did not prove to be statistically significant.

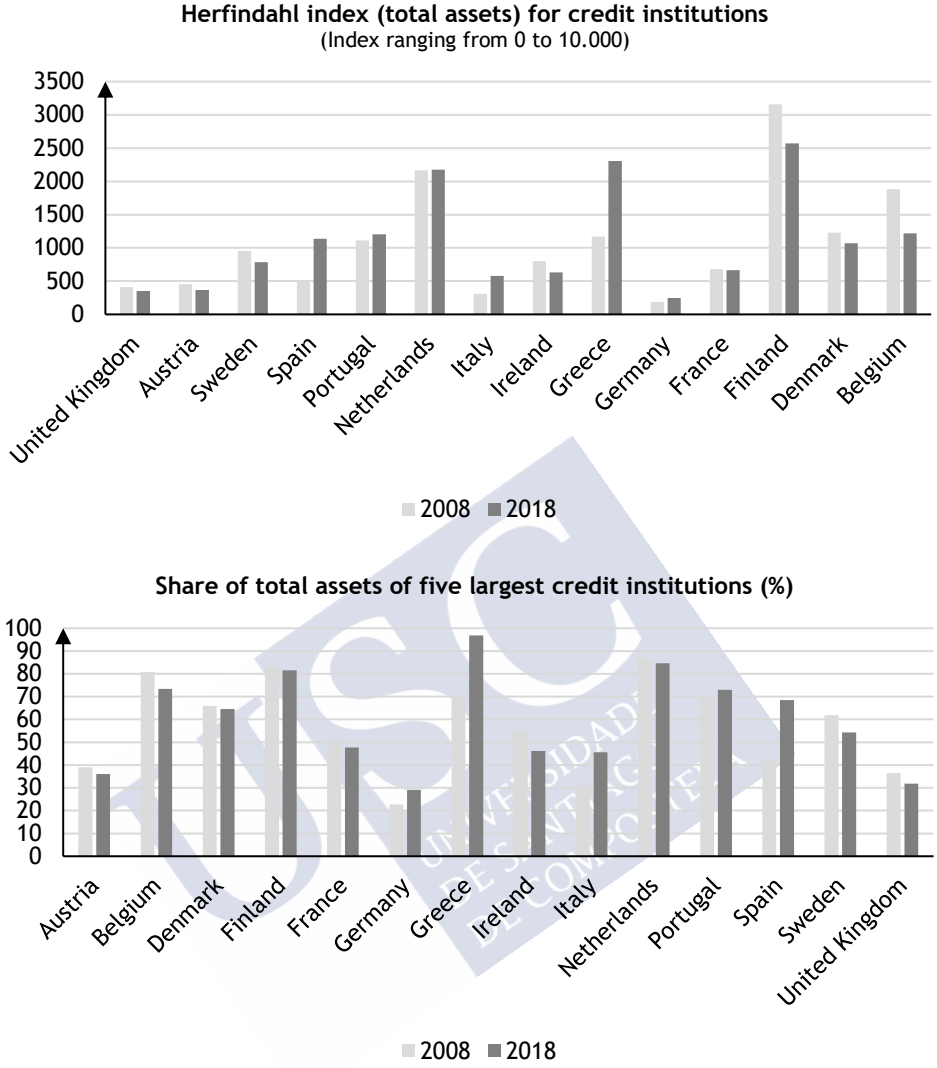
These results remained unchanged even when we considered the efficiency-adjusted Lerner index as a measure of competition, distance-to-insolvency as a measure of bank risk-taking or when we estimated a static panel data model with fixed effects or random effects.

Our findings highlight several issues for policymakers and regulators. Public policies must guarantee banking competition, for welfare reasons, but limiting excessive bank risk-taking, especially in countries with less financially sound banking systems. This means that any attempt to increase competition in European banking should be accompanied by regulation that guarantees bank stability, for example by increases in capital standards and limiting the risk exposure.

Consolidation of the European banking industry can lead to stronger and more resilient banks without compromising competition. However, this process of consolidation in Europe has a significant number of obstacles due to political, economic, regulatory, and cultural factors. Although the European Banking Union was created in 2014 to stimulate this integration, it remains unfinished and European banks - especially retail banks - still mostly operate on a national basis. Along with domestic mergers, European authorities and different national governments should promote cross-border mergers to deepen the integration and construction of a truly European banking sector. Cross-border banks would be able to offset losses in one country with income from other countries and would be better prepared to face the challenges posed by technological disruption.

2.7. APPENDIX

Figure 8 - European Union structural financial indicators



Source: Own production

Table 4 - Bank financial stability and competition (sub-sample of the less stable banking systems)

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Dependent variable (t-1)	0.248***	0.260***	0.571***	0.535***
	(0.082)	(0.082)	(0.181)	(0.112)
Dependent variable (t-2)			0.362***	0.381***
			(0.068	(0.075)
Lerner index	5.700***	2.078	1.098***	0.486
	(2.031)	(1.446)	(0.182)	(0.360)
Lerner index squared		-0.955		-0.994
		(1.620)		(0.665)
Capitalization	-2.478	-8.646	7.154	5.649**
	(11.369)	(9.063)	(5.632)	(2.409)
Size	0.075	-0.012	0.056	0.029
	(0.097)	(0.088)	(0.051)	(0.023)
Non-interest income share	1.476	2.397***	-0.045	-0.071
	(0.911)	(0.868)	(0.303)	(0.212)
Share of wholesale funding	-0.703	-0.596	0.277	0.335
	(1.138)	(1.276)	(0.238)	(0.251)
Liquidity	-2.916	-1.806	-0.337	-0.319
	(2.032)	(2.350)	(0.442)	(0.302)
Asset composition	-0.658	-1.072	0.262	-0.016
	(1.127)	(1.127)	(0.163)	(0.273)
Inefficiency	1.671	-1.471	0.947**	0.430
	(2.239)	(1.488)	(0.471)	(0.372)
Real GDP growth	-5.022	5.360	-6.903	-4.779*
	(12.555)	(12.249)	(4.400)	(2.452)
Inflation	55.898***	66.258***	-2.269	1.363
	(14.134)	(13.184)	(4.351)	(2.377)
Constant	-0.947	2.240	-1.588	-0.666
	(3.333)	(2.535)	(1.607)	(0.747)
U-Shape test		Extremum		0.420
p-value [U-Shape test]		outside		[0.338]
Turning point		interval		0.244
Number of observations	364	364	305	305
Number of banks	58	58	57	57
Number of instrumental variables	27	39	23	26
F-Test	26.24***	36.50***	92.01***	92.14***
RHO(1) Test	-4.367	-4.358	-2.401	-2.344
p-value [RHO(1) Test]	0.000	0.000	0.016	0.019
RHO(2) Test	1.078	1.408	-0.545	0,323
p-value [RHO(2) Test]	0.281	0.159	0.586	0.747
Hansen's J Test	13.708	21.663	6.228	9.78
p-value [Hansen's J Test]	0.133	0.361	0.285	0.201

Note: The table reports the dynamic panel regression results. The two-step system GMM estimator (Arellano & Bover, 1995) is used with Windmeijer (2005) corrected standard errors. Some regressions include an additional lag of dependent variable as explanatory variable to remove second order autocorrelation. Time Dummies are included. Robust standard errors are reported in parentheses below their coefficient estimates. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. Arellano-Bond test for RHO(1) and RHO(2) is used to investigate the presence of serial correlation of order one and two, respectively. To analyse the validity of instruments we used the Hansen's (1982) *J* Test for overidentification. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 5 - Bank financial stability and competition (sub-sample of the most stable banking systems)

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Dependent variable (t-1)	0.369***	0.447***	0.949***	0.947***
	(0.089)	(0.084)	(0.047)	(0.054)
Dependent variable (t-2)	0.228***	0.196**		
	(0.078)	(0.083)		
Lerner index	2.062	10.785*	-0.456	-0.721*
	(4.245)	(5.449)	(0.319)	(0.405)
Lerner index squared		9.509		-0.279
		(6.239)		(0.636)
Capitalization	14.911	20.529	0.835	0.833
	(21.093)	(20.562)	(0.969)	(0.788)
Size	0.024	0.267	0.006	0.000
	(0.227)	(0.295)	(0.015)	(0.016)
Non-interest income share	0.499	-0.621	0.068	0.058
	(1.634)	(1.435)	(0.087)	(0.091)
Share of wholesale funding	-0.530	-1.095	-0.027	-0.024
	(1.252)	(1.167)	(0.072)	(0.090)
Liquidity	-1.402	-0.609	0.067	0.033
	(3.005)	(2.395)	(0.143)	(0.194)
Asset composition	-1.158	0.789	0.005	-0.045
	(2.573)	(2.349)	(0.197)	(0.310)
Inefficiency	-1.639	7.307	-0.559**	-0.797***
	(3.232)	(4.869)	(0.264)	(0.253)
Real GDP growth	-72.569***	-75.789***	0.421	0.238
	(17.861)	(23.433)	(0.745)	(0.705)
Inflation	19.158	44.062	-1.523	-2.173
	(24.351)	(41.507)	(1.837)	(1.633)
Constant	3.769	-7.606	0.490	0.818*
	(4.162)	(8.638)	(0.285)	(0.417)
U-Shape test		0.730		Extremum outside interval
p-value [U-Shape test]		[0.235]		
Turning point		-0.567		
Number of observations	314	314	373	373
Number of banks	58	58	59	59
Number of instrumental variables	50	34	30	35
F-Test	38.02***	19.57***	1097.78***	896.04***
RHO(1) Test	-4.100	-4.632	-3.502	-3.710
p-value [RHO(1) Test]	0.000	0.000	0.000	0.000
RHO(2) Test	0.840	1.354	-0.390	-0.190
p-value [RHO(2) Test]	0.401	0.176	0.697	0.849
Hansen's J Test	42.013	21.718	16.326	16.174
p-value [Hansen's J Test]	0.111	0.115	0.177	0.441

Note: The table reports the dynamic panel regression results. The two-step system GMM estimator (Arellano & Bover, 1995) is used with Windmeijer (2005) corrected standard errors. Some regressions include an additional lag of dependent variable as explanatory variable to remove second order autocorrelation. Time Dummies are included. Robust standard errors are reported in parentheses below their coefficient estimates. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. Arellano-Bond test is used to test serial correlation, where RHO(1) and RHO(2) are the estimated coefficients of first- and second order correlation and apply to residuals in differences. To analyse the validity of instruments we used the Hansen's (1982) *J* Test for overidentification. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 6 - Bank financial stability and competition measured by E-Lerner index (whole sample)

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Dependent variable (t-1)	0.383***	0.394***	0.923***	0.907***
	(0.059)	(0.063)	(0.020)	(0.024)
Dependent variable (t-2)	0.262***	0.236***		
	(0.045)	(0.046)		
E-Lerner index	2.897***	2.647**	0.182**	0.146
	(0.890)	-1.077	(0.090)	(0.120)
E-Lerner index squared		-1.260		0.095
		-1.775		(0.162)
Capitalization	6.196	5.673	0.554	0.739**
	(4.585)	-4.930	(0.383)	(0.364)
Size	-0.005	-0.025	0.009*	0.009*
	(0.051)	(0.053)	(0.005)	(0.006)
Non-interest income share	1.256**	1.572**	0.150*	0.169**
	(0.618)	(0.664)	(0.084)	(0.085)
Share of wholesale funding	0.053	0.404	-0.026	0.011
	(0.463)	(0.553)	(0.054)	(0.066)
Liquidity	1.350	0.484	0.091*	0.129*
	(0.947)	-1.123	(0.051)	(0.066)
Asset composition	1.596*	0.888	0.158*	0.190*
	(0.831)	(0.942)	(0.083)	(0.103)
Inefficiency	-0.292	-0.666	-0.184**	-0.198*
	(0.732)	(0.933)	(0.090)	(0.116)
Real GDP growth	-29.813***	-24.031***	-0.320	-0.248
	(7.650)	-7.651	(0.671)	(0.859)
Inflation	16.929*	16.212*	0.648	0.539
	(9.535)	-9.301	(0.554)	(0.751)
Constant	-0.571	0.358	0.104	0.078
	(1.334)	-1.601	(0.124)	(0.152)
U-Shape test		Extremum		Extremum
p-value [U-Shape test]		outside		outside
Turning point		interval		interval
Number of observations	619	619	737	737
Number of banks	115	115	117	117
Number of instrumental variables	92	106	96	95
F-Test	54,81***	56.57***	1292.52***	1356.37***
RHO(1) Test	-5.450	-5.491	-3.702	-3.630
p-value [RHO(1) Test]	0.000	0.000	0.000	0.000
RHO(2) Test	0.976	1.212	1.253	0.986
p-value [RHO(2) Test]	0.329	0.226	0.21	0.324
Hansen's J Test	86.585	97.234	79.979	82.216
p-value [Hansen's J Test]	0.150	0.213	0.417	0.293

Note: The table reports the dynamic panel regression results. The two-step system GMM estimator (Arellano & Bover, 1995) is used with Windmeijer (2005) corrected standard errors. Some regressions include an additional lag of dependent variable as explanatory variable to remove second order autocorrelation. Time Dummies are included. Robust standard errors are reported in parentheses below their coefficient estimates. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. Arellano-Bond test is used to test serial correlation, where RHO(1) and RHO(2) are the estimated coefficients of first- and second order correlation and apply to residuals in differences. To analyse the validity of instruments we used the Hansen's (1982) *J* Test for overidentification. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 7 - Bank financial stability and competition measured by E-Lerner index (sub-sample of the less stable banking systems)

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Dependent variable (t-1)	0.263***	0.237***	0.601***	0.583***
	(0.086)	(0.079)	(0.107)	(0.097)
Dependent variable (t-2)			0.313***	0.298**
			(0.088)	(0.119)
E-Lerner index	5.633**	4.142**	0.624***	0.382
	(2.514)	(2.038)	(0.233)	(0.374)
E-Lerner index squared		0.499		0.288
		(2.183)		(0.376)
Capitalization	2.563	-3.706	2.302	1.964
	(12.614)	(11.715)	(1.994)	(2.430)
Size	0.004	-0.060	0.013	0.007
	(0.087)	(0.090)	(0.020)	(0.026)
Non-interest income share	1.281	1.870*	0.062	0.169
	(1.100)	(0.938)	(0.248)	(0.242)
Share of wholesale funding	-0.140	0.108	0.029	0.061
	(1.037)	(1.171)	(0.199)	(0.312)
Liquidity	-2.574	-2.451	0.011	0.252
	(1.800)	(1.905)	(0.282)	(0.328)
Asset composition	-0.566	-0.702	0.254*	0.310*
	(1.122)	(1.198)	(0.134)	(0.179)
Inefficiency	0.844	0.005	0.143	0.002
	(2.131)	(2.064)	(0.319)	(0.417)
Real GDP growth	-3.049	-2.112	-2.689	-1.994
	(13.055)	(12.744)	(2.801)	(2.885)
Inflation	55.619***	60.421***	-0.287	0.451
	(15.456)	(14.385)	(2.405)	(3.480)
Constant	-0.810	0.717	-0.326	-0.227
	(3.451)	(3.388)	(0.728)	(0.937)
U-Shape test		Extremum		0.120
p-value [U-Shape test]		outside		[0.451]
Turning point		interval		-0.664
Number of observations	364	364	305	305
Number of banks	58	58	57	57
Number of instrumental variables	27	39	29	38
F-Test	20.85***	34.20***	183.27***	182.13***
RHO(1) Test	-4.150	-4.200	-2.300	-3.703
p-value [RHO(1) Test]	0.000	0.000	0.022	0.000
RHO(2) Test	1.205	1.313	0.281	-0.737
p-value [RHO(2) Test]	0.228	0.189	0.779	0.461
Hansen's J Test	14.373	24.177	16.123	24.064
p-value [Hansen's J Test]	0.110	0.235	0.137	0.194

Note: The table reports the dynamic panel regression results. The two-step system GMM estimator (Arellano & Bover, 1995) is used with Windmeijer (2005) corrected standard errors. Some regressions include an additional lag of dependent variable as explanatory variable to remove second order autocorrelation. Time Dummies are included. Robust standard errors are reported in parentheses below their coefficient estimates. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. Arellano-Bond test is used to test serial correlation, where RHO(1) and RHO(2) are the estimated coefficients of first- and second order correlation and apply to residuals in differences. To analyse the validity of instruments we used the Hansen's (1982) *J* Test for overidentification. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 8 - Bank financial stability and competition measured by E-Lerner index (sub-sample of the most stable banking systems)

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Dependent variable (t-1)	0.399***	0.392***	0.974***	0.962***
	(0.094)	(0.089)	(0.045)	(0.031)
Dependent variable (t-2)	0.206**	0.268***		
	(0.078)	(0.075)		
E-Lerner index	3.205	-0.609	-0.465	-0.419
	(4.766)	(8.002)	(0.387)	(0.453)
E-Lerner index squared		11.579		-0.043
		(11.591)		(0.541)
Capitalization	13.212	25.780*	0.374	-0.420
	(20.070)	(15.218)	(1.139)	(1.199)
Size	-0.044	0.066	0.011	-0.003
	(0.251)	(0.164)	(0.016)	(0.017)
Non-interest income share	-0.092	-0.298	0.127	0.147
	(1.755)	(1.459)	(0.092)	(0.112)
Share of wholesale funding	-0.622	-1.605*	-0.017	0.057
	(1.137)	(0.920)	(0.065)	(0.077)
Liquidity	-1.186	0.351	0.123	0.054
	(2.804)	(2.516)	(0.108)	(0.146)
Asset composition	-1.016	-0.477	0.062	-0.018
	(2.381)	(2.503)	(0.139)	(0.213)
Inefficiency	-0.793	1.050	-0.603**	-0.648**
	(3.403)	(2.341)	(0.284)	(0.263)
Real GDP growth	-73.211***	-76.213***	0.878	0.300
	(17.357)	(20.161)	(0.903)	(0.607)
Inflation	29.110	12.867	-0.176	0.395
	(28.812)	(31.481)	(1.760)	(1.506)
Constant	3.592	0.227	0.359	0.654*
	(4.913)	(4.759)	(0.363)	(0.373)
U-Shape test		0.720		Extremum outside interval
p-value [U-Shape test]		[0.237]		
Turning point		0.026		
Number of observations	314	314	373	373
Number of banks	58	58	59	59
Number of instrumental variables	50	54	36	55
F-Test	37.19***	17.65***	661.93***	710.17***
RHO(1) Test	-4.132	-4.051	-3.530	-3.582
p-value [RHO(1) Test]	0.000	0.000	0.000	0.000
RHO(2) Test	1.034	0.819	-0.530	-0.372
p-value [RHO(2) Test]	0.301	0.413	0.596	0.710
Hansen's J Test	40.42	44.015	20.338	38.850
p-value [Hansen's J Test]	0.146	0.141	0.314	0.343

Note: The table reports the dynamic panel regression results. The two-step system GMM estimator (Arellano & Bover, 1995) is used with Windmeijer (2005) corrected standard errors. Some regressions include an additional lag of dependent variable as explanatory variable to remove second order autocorrelation. Time Dummies are included. Robust standard errors are reported in parentheses below their coefficient estimates. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. Arellano-Bond test is used to test serial correlation, where RHO(1) and RHO(2) are the estimated coefficients of first- and second order correlation and apply to residuals in differences. To analyse the validity of instruments we used the Hansen's (1982) *J* Test for overidentification. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 9 - Bank financial stability, measured by distance-to-insolvency, and competition (whole sample)

Dependent variable	Distance-to-insolvency (DI)	
	(1)	(2)
Dependent variable (t-1)	0.508***	0.531***
	(0.072)	(0.065)
Dependent variable (t-2)	0.292***	0.304***
	(0.056)	(0.054)
Lerner index	2.062***	1.428**
	(0.465)	(0.565)
Lerner index squared		-1.637**
		(0.778)
Capitalization	3.944	3.861
	(4.729)	(4.462)
Size	0.048	0.028
	(0.043)	(0.047)
Non-interest income share	0.388	0.046
	(0.390)	(0.381)
Share of wholesale funding	0.443	0.650**
	(0.273)	(0.281)
Liquidity	0.479	0.696
	(0.648)	(0.703)
Asset composition	0.999**	0.917*
	(0.446)	(0.524)
Inefficiency	0.997*	0.656
	(0.523)	(0.576)
Real GDP growth	-8.889	-9.109
	(7.562)	(6.963)
Inflation	7.397	4.338
	(5.543)	(4.318)
Constant	-1.502	-0.871
	(1.074)	(1.214)
U-Shape test		0.010
p-value [U-Shape test]		[0.496]
Turning point		0.436
Number of observations	619	619
Number of banks	115	115
Number of instrumental variables	92	102
F-Test	86.48***	87.28***
RHO(1) Test	-4.847	-5.001
p-value [RHO(1) Test]	0.000	0.000
RHO(2) Test	0.582	0.618
p-value [RHO(2) Test]	0.561	0.536
Hansen's J Test	87.993	98.556
p-value [Hansen's J Test]	0.127	0.117

Note: The table reports the dynamic panel regression results. The two-step system GMM estimator (Arellano & Bover, 1995) is used with Windmeijer (2005) corrected standard errors. Some regressions include an additional lag of dependent variable as explanatory variable to remove second order autocorrelation. Time Dummies are included. Robust standard errors are reported in parentheses below their coefficient estimates. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. Arellano-Bond test is used to test serial correlation, where RHO(1) and RHO(2) are the estimated coefficients of first- and second order correlation and apply to residuals in differences. To analyse the validity of instruments we used the Hansen's (1982) *J* Test for overidentification. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 10 - Bank financial stability, measured by distance-to-insolvency, and competition (sub-sample of the less stable banking systems)

Dependent variable	Distance-to-insolvency (DI)	
	(1)	(2)
Dependent variable (t-1)	0.308**	0.346*
	(0.127)	(0.202)
Lerner index	3.923***	3.332
	(1.079)	(3.172)
Lerner index squared		1.865
		(3.581)
Capitalization	-3.714	-1.292
	(10.012)	(6.204)
Size	0.031	0.056
	(0.079)	(0.065)
Non-interest income share	0.417	1.234**
	(0.575)	(0.555)
Share of wholesale funding	-0.211	-0.255
	(0.634)	(0.591)
Liquidity	-1.069	-0.982
	(1.054)	(1.136)
Asset composition	-0.247	-0.020
	(0.574)	(0.705)
Inefficiency	1.874	1.289
	(1.170)	(2.352)
Real GDP growth	0.885	4.506
	(7.110)	(8.774)
Inflation	25.904***	28.517**
	(7.245)	(11.520)
Constant	-0.143	-0.848
	(2.248)	(2.301)
U-Shape test		0.060
p-value [U-Shape test]		[0.475]
Turning point		-0.893
Number of observations	364	364
Number of banks	58	58
Number of instrumental variables	24	27
F-Test	27.89***	50.06***
RHO(1) Test	-4.227	-3.334
p-value [RHO(1) Test]	0.000	0.001
RHO(2) Test	1.511	1.481
p-value [RHO(2) Test]	0.131	0.139
Hansen's J Test	8.244	10.126
p-value [Hansen's J Test]	0.221	0.256

Note: The table reports the dynamic panel regression results. The two-step system GMM estimator (Arellano & Bover, 1995) is used with Windmeijer (2005) corrected standard errors. Time Dummies are included. Robust standard errors are reported in parentheses below their coefficient estimates. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. Arellano-Bond test is used to test serial correlation, where RHO(1) and RHO(2) are the estimated coefficients of first- and second order correlation and apply to residuals in differences. To analyse the validity of instruments we used the Hansen's (1982) *J* Test for overidentification. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 11 - Bank financial stability, measured by distance-to-insolvency, and competition (sub-sample of the most stable banking systems)

Dependent variable	Distance-to-insolvency (DI)	
	(1)	(2)
Dependent variable (t-1)	0.529***	0.597***
	(0.070)	(0.073)
Dependent variable (t-2)	0.327***	0.301***
	(0.086)	(0.062)
Lerner index	0.719	2.314
	(1.977)	(1.935)
Lerner index squared		1.348
		(2.389)
Capitalization	-1.615	-5.068
	(12.366)	(12.763)
Size	-0.097	-0.079
	(0.164)	(0.154)
Non-interest income share	-0.603	-1.204
	(1.012)	(1.263)
Share of wholesale funding	0.666	0.554
	(0.886)	(0.909)
Liquidity	-0.810	-0.046
	(1.448)	(1.554)
Asset composition	-0.960	-0.102
	(1.276)	(1.448)
Inefficiency	-0.538	1.022
	(1.523)	(1.650)
Real GDP growth	-40.473***	-39.712***
	(12.045)	(14.682)
Inflation	16.902	6.930
	(22.298)	(25.153)
Constant	4.113	2.376
	(3.861)	(3.680)
U-Shape test		0.080
p-value [U-Shape test]		[0.469]
Turning point		-0.858
Number of observations	314	314
Number of banks	58	58
Number of instrumental variables	56	46
F-Test	60.45***	91.20***
RHO(1) Test	-3.800	-4.028
p-value [RHO(1) Test]	0.000	0.000
RHO(2) Test	-0.540	-0.269
p-value [RHO(2) Test]	0.590	0.788
Hansen's J Test	48.008	36.441
p-value [Hansen's J Test]	0.128	0.106

Note: The table reports the dynamic panel regression results. The two-step system GMM estimator (Arellano & Bover, 1995) is used with Windmeijer (2005) corrected standard errors. Some regressions include an additional lag of dependent variable as explanatory variable to remove second order autocorrelation. Time Dummies are included. Robust standard errors are reported in parentheses below their coefficient estimates. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. Arellano-Bond test is used to test serial correlation, where RHO(1) and RHO(2) are the estimated coefficients of first- and second order correlation and apply to residuals in differences. To analyse the validity of instruments we used the Hansen's (1982) *J* Test for overidentification. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 12 - Bank financial stability and competition (whole sample) – Fixed Effects (FE) Model

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Lerner index	0.482	0.733	0.138*	0.165***
	(0.589)	(0.779)	(0.074)	(0.055)
Lerner index squared		0.441		0.047
		(1.052)		(0.113)
Capitalization	2.648	2.775	2.653***	2.666***
	(7.037)	(7.121)	(0.671)	(0.675)
Size	-1.277**	-1.268**	-0.177***	-0.176***
	(0.610)	(0.610)	(0.049)	(0.049)
Non-interest income share	-0.399	-0.401	-0.064	-0.064
	(1.212)	(1.213)	(0.107)	(0.107)
Share of wholesale funding	1.858	1.898	-0.018	-0.014
	(1.696)	(1.696)	(0.115)	(0.112)
Liquidity	-0.809	-0.815	-0.067	-0.068
	(2.043)	(2.050)	(0.138)	(0.138)
Asset composition	-6.886***	-6.888***	-0.068	-0.068
	(1.575)	(1.584)	(0.142)	(0.141)
Inefficiency	-0.517	-0.378	0.058	0.073
	(0.683)	(0.822)	(0.093)	(0.090)
Real GDP growth	-14.348**	-14.265**	-0.368	-0.359
	(7.149)	(7.089)	(0.624)	(0.624)
Inflation	26.994***	26.592***	-0.325	-0.368
	(9.132)	(9.021)	(0.662)	(0.651)
Constant	19.230***	18.980***	5.119***	5.092***
	(6.676)	(6.751)	(0.545)	(0.551)
U-Shape test		0.070		Extremum
p-value [U-Shape test]		[0.473]		outside
Turning point		-0.831		interval
Number of observations	737	737	737	737
Number of banks	117	117	117	117
F-Test	27.945***	26.451***	21.069***	24.873***

Note: The table reports the static panel regression results for the fixed effects model. To consider the endogeneity issue, all explanatory variables are lagged one period. Robust standard errors clustered at the bank level are reported in parentheses below their coefficient estimates. Time Dummies are included. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 13 - Bank financial stability and competition (whole sample) – Random Effects (RE) Model

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Lerner index	1.356***	2.194***	0.171**	0.229***
	(0.488)	(0.842)	(0.079)	(0.055)
Lerner index squared		1.570		0.099
		(1.150)		(0.114)
Capitalization	7.118	7.199	3.129***	3.173***
	(5.126)	(5.042)	(0.735)	(0.732)
Size	-0.257**	-0.244**	-0.072**	-0.069**
	(0.102)	(0.101)	(0.031)	(0.031)
Non-interest income share	0.126	0.115	-0.025	-0.024
	(0.994)	(1.005)	(0.116)	(0.117)
Share of wholesale funding	2.582***	2.529***	0.153	0.172
	(0.865)	(0.859)	(0.111)	(0.109)
Liquidity	0.028	-0.029	-0.024	-0.023
	(1.739)	(1.738)	(0.153)	(0.153)
Asset composition	-3.481***	-3.454***	0.006	0.010
	(1.239)	(1.251)	(0.156)	(0.158)
Inefficiency	-0.294	0.199	0.075	0.106
	(0.624)	(0.782)	(0.099)	(0.093)
Real GDP growth	-6.148	-6.239	-0.042	-0.009
	(6.376)	(6.348)	(0.658)	(0.662)
Inflation	34.077***	32.565***	-0.085	-0.171
	(8.995)	(8.691)	(0.618)	(0.628)
Constant	5.023**	4.463**	3.787***	3.708***
	(2.162)	(2.236)	(0.377)	(0.379)
U-Shape test		0.500		Extremum outside interval
p-value [U-Shape test]		0.309		
Turning point		-0.699		
Number of observations	737	737	737	737
Number of banks	117	117	117	117
Chi2-Test	488.861***	479.766***	319.756***	423.175***

Note: The table reports the static panel regression results for the random effects model. To consider the endogeneity issue, all explanatory variables are lagged one period. Robust standard errors clustered at the bank level are reported in parentheses below their coefficient estimates. Time Dummies are included. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 14 - Bank financial stability and competition (sub-sample of the less stable banking systems) – FE Model

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Lerner index	-0.182	0.511	0.187**	0.249***
	(0.437)	(0.762)	(0.089)	(0.072)
Lerner index squared		1.122		0.100
		(0.751)		(0.145)
Capitalization	-0.086	0.053	2.109**	2.121**
	(6.808)	(7.035)	(0.904)	(0.900)
Size	-1.323**	-1.291**	-0.176***	-0.173***
	(0.629)	(0.626)	(0.057)	(0.056)
Non-interest income share	0.402	0.488	-0.142	-0.135
	(0.767)	(0.775)	(0.146)	(0.150)
Share of wholesale funding	-0.067	0.078	0.093	0.106
	(2.034)	(2.052)	(0.160)	(0.153)
Liquidity	2.152	2.084	-0.228	-0.234
	(2.284)	(2.303)	(0.153)	(0.153)
Asset composition	-7.421***	-7.342***	0.065	0.072
	(1.995)	(2.026)	(0.190)	(0.191)
Inefficiency	-1.069	-0.693	0.087	0.120
	(0.734)	(0.751)	(0.107)	(0.109)
Real GDP growth	2.271	2.627	0.890	0.922
	(7.859)	(7.755)	(0.904)	(0.899)
Inflation	47.985***	46.203***	-0.095	-0.254
	(11.791)	(11.738)	(0.807)	(0.786)
Constant	19.407***	18.613***	4.703***	4.632***
	(6.948)	(6.968)	(0.629)	(0.630)
U-Shape test		1.110		Extremum
p-value [U-Shape test]		0.136		outside
Turning point		-0.227		interval
Number of observations	364	364	364	364
Number of banks	58	58	58	58
F-Test	19.177***	18.204***	18.648***	18.064***

Note: The table reports the static panel regression results for the fixed effects model. To consider the endogeneity issue, all explanatory variables are lagged one period. Robust standard errors clustered at the bank level are reported in parentheses below their coefficient estimates. Time Dummies are included. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 15 - Bank financial stability and competition (sub-sample of the less stable banking systems) – RE Model

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Lerner index	0.899**	1.835**	0.218**	0.296***
	(0.455)	(0.870)	(0.093)	(0.072)
Lerner index squared		1.687*		0.125
		(0.949)		(0.148)
Capitalization	-3.198	-2.740	2.138**	2.154**
	(5.825)	(5.954)	(0.929)	(0.921)
Size	-0.236**	-0.217**	-0.130***	-0.127***
	(0.109)	(0.108)	(0.044)	(0.043)
Non-interest income share	1.327**	1.429**	-0.087	-0.075
	(0.652)	(0.664)	(0.145)	(0.150)
Share of wholesale funding	0.434	0.474	0.152	0.171
	(1.320)	(1.332)	(0.152)	(0.144)
Liquidity	1.780	1.736	-0.133	-0.138
	(2.518)	(2.536)	(0.177)	(0.176)
Asset composition	-2.264**	-2.089*	0.054	0.063
	(1.128)	(1.113)	(0.207)	(0.209)
Inefficiency	-1.037	-0.456	0.116	0.159
	(0.674)	(0.734)	(0.109)	(0.110)
Real GDP growth	16.720**	15.756**	1.249	1.294
	(7.831)	(7.717)	(0.930)	(0.928)
Inflation	59.842***	56.144***	0.414	0.222
	(9.773)	(9.823)	(0.757)	(0.767)
Constant	4.350**	3.502	4.116***	4.030***
	(2.111)	(2.210)	(0.526)	(0.532)
U-Shape test		1.240		Extremum outside interval
p-value [U-Shape test]		0.108		
Turning point		-0.544		
Number of observations	364	364	364	364
Number of banks	58	58	58	58
Chi2-Test	485.355***	513.712***	279.345***	310.345***

Note: The table reports the static panel regression results for the random effects model. To consider the endogeneity issue, all explanatory variables are lagged one period. Robust standard errors clustered at the bank level are reported in parentheses below their coefficient estimates. Time Dummies are included. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 16 - Bank financial stability and competition (sub-sample of the most stable banking systems) – FE Model

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Lerner index	0.796	-0.703	0.004	-0.002
	(1.973)	(1.731)	(0.092)	(0.080)
Lerner index squared		-3.504		(0.016)
		(2.347)		(0.125)
Capitalization	44.001**	42.792**	3.180***	3.174***
	(18.109)	(17.456)	(1.014)	(1.013)
Size	0.241	0.254	-0.164*	-0.164*
	(1.023)	(0.988)	(0.092)	(0.092)
Non-interest income share	-5.133*	-4.683	0.058	0.060
	(2.941)	(2.919)	(0.137)	(0.138)
Share of wholesale funding	4.718	4.380	-0.136	-0.138
	(3.106)	(3.106)	(0.155)	(0.156)
Liquidity	-7.992**	-7.937**	0.087	0.087
	(3.057)	(2.995)	(0.250)	(0.250)
Asset composition	-13.547***	-13.204***	-0.101	-0.100
	(3.400)	(3.374)	(0.212)	(0.215)
Inefficiency	1.001	0.365	-0.134	-0.136
	(1.955)	(1.957)	(0.167)	(0.166)
Real GDP growth	-25.556**	-25.578**	-1.679**	-1.680**
	(10.348)	(10.576)	(0.818)	(0.819)
Inflation	14.625	11.125	-1.925*	-1.941*
	(17.937)	(17.517)	(1.144)	(1.135)
Constant	6.020	6.525	5.455***	5.458***
	(11.994)	(11.583)	(1.054)	(1.050)
U-Shape test		1.230		0,110
p-value [U-Shape test]		0,112		0.455
Turning point		-0.100		-0.073
Number of observations	373	373	373	373
Number of banks	59	59	59	59
F-Test	23.844***	23.128***	19.733***	18.932***

Note: The table reports the static panel regression results for the fixed effects model. To consider the endogeneity issue, all explanatory variables are lagged one period. Robust standard errors clustered at the bank level are reported in parentheses below their coefficient estimates. Time Dummies are included. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 17 - Bank financial stability and competition (sub-sample of the most stable banking systems) – RE Model

Dependent variable	Distance-to-default (DD)		Ln Zscore	
	(1)	(2)	(3)	(4)
Lerner index	2.352	1.693	0.006	0.026
	(1.546)	(1.385)	(0.094)	(0.086)
Lerner index squared		-1.561		0.047
		(2.623)		(0.118)
Capitalization	19.905**	20.482**	4.936***	5.058***
	(9.334)	(9.458)	(0.772)	(0.767)
Size	-0.328	-0.330	-0.007	-0.002
	(0.252)	(0.254)	(0.043)	(0.042)
Non-interest income share	-3.571	-3.491	0.016	0.007
	(2.349)	(2.341)	(0.156)	(0.160)
Share of wholesale funding	2.485**	2.566**	0.001	0.021
	(1.213)	(1.221)	(0.127)	(0.129)
Liquidity	-6.760*	-6.732*	0.050	0.048
	(3.470)	(3.474)	(0.288)	(0.289)
Asset composition	-8.703***	-8.669***	-0.061	-0.058
	(3.120)	(3.133)	(0.244)	(0.249)
Inefficiency	1.179	0.856	-0.140	-0.133
	(1.664)	(1.702)	(0.174)	(0.171)
Real GDP growth	-24.882***	-24.806***	-1.636**	-1.626**
	(8.835)	(9.051)	(0.796)	(0.795)
Inflation	21.420	19.782	-1.652	-1.599
	(21.006)	(21.043)	(1.225)	(1.201)
Constant	10.713*	10.974*	3.531***	3.450***
	(5.893)	(5.855)	(0.557)	(0.548)
U-Shape test		Extremum		0.270
p-value [U-Shape test]		outside		0.392
Turning point		interval		-0.282
Number of observations	373	373	373	373
Number of banks	59	59	59	59
Chi2-Test	355.893***	356.670***	320.634***	335.307***

Note: The table reports the static panel regression results for the random effects model. To consider the endogeneity issue, all explanatory variables are lagged one period. Robust standard errors clustered at the bank level are reported in parentheses below their coefficient estimates. Time Dummies are included. The U-shape test is based on Lind and Mehlum (2010) and "Extremum outside interval" means that the extremum point (i.e. the turning point) is outside the interval, then we cannot reject the null hypothesis of a monotone relationship. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

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3. EFFECTS OF NEGATIVE INTEREST RATE POLICY IN BANK PROFITABILITY AND RISK-TAKING: EVIDENCE FROM THE EUROPEAN BANKS

3.1. INTRODUCTION

In the last decade, some central banks around the world, in an attempt to avoid low inflation rates and stimulate economic growth, resorted to a set of unconventional monetary policy instruments, such as a large scale asset purchase in the form of quantitative easing, the implementation of negative interest rate policies (NIRP's) as well as policy rate forward guidance. After, in July 2012, Danmarks Nationalbank lowered, for the first time, its policy rate to negative values, several central banks from other countries (Euro Area, Hungary, Norway, Sweden, Switzerland, Bulgaria, and Japan) adopted the same behaviour.

The implementation of NIRP means that central banks are now charging interests (instead of paying) on the excess reserves that commercial banks have deposited there, encouraging them to take them back on the balance sheet. This is expected to have positive effects on economic activity through the increased supply and demand for loans due to the decline in funding costs for both banks and borrowers (Cœuré, 2016).

However, the effect that NIRP can have on banks' profitability is not so clear (Boungou, 2019). Low or negative interest rates help to improve banks' balance sheets and performance, leading to capital gains and a reduction in loan loss provisions. However, low or negative interest rates also can mean lower net interest margins. This is because bank intermediation is a spread business, based on the difference between interest rates on loans and deposits. When market interest rates fall, becoming low or even negative, banks may have to adjust loan interest rates down but are very reluctant to lower deposit rates for negative levels, especially for retail depositors, compressing the net interest margin (Claessens et al., 2018). Banks know that a negative deposit interest rate would lead their customers to withdraw their deposits for other banks. Refusing to pass negative interest rates on customer deposits, bank's profitability related to maturity transformation will be negatively affected eroding their equity capital and deteriorating their financial stability (Zimmermann, 2019). Banks can compensate the margin

decline by increasing fees and commissions and reducing operating expenses (Scheiber et al., 2016).

The implementation of NIRP also impacts the bank's risk-taking. First, a decline in the reference interest rate affects banks' perception and/or tolerance to risk. Lowering interest rates drive up the value of assets and collateral and subsequently banks' income, thus raising banks' risk-taking capacity (Borio & Zhu, 2008). If interest rates remain low or negative for long periods, there will be a high probability of a credit boom, leading banks to loosen their lending standards and increase credit to more risky clients (Chen et al., 2017). In a context of lower or negative interest rates, if the bank's return target is sticky, induce bank's managers to hold an increasing amount of risky assets in the "search for yield" (Rajan, 2005).

Several authors also advocate that the NIRP effect on bank's profitability and risk-taking depends on bank-specific characteristics such as size, funding structure, assets repricing and product-line specialization and that banks adjust their business models in response to this new environment (Molyneux et al., 2019; Boungou, 2019).

Considering the above scenario, the objective of this research is to study the impact of negative interest rates on the profitability and risk-taking of European banks. In particular, the intention is to investigate: (i) the effects of negative interest rates on the bank's net interest margin and the remaining components of banks' profitability; (ii) the effects of negative interest rates in bank's risk-taking; (iii) and lastly, if the referred effects are differentiated according to the bank's business model.

The contribution of this study is three-fold. First, there are still very few studies, some of them with contradictory results, that study the impact of central banks in some countries having adopted NIRP's on bank's profitability and risk-taking. Second, it is verified whether the impact of changes in interest rates on bank's profitability and risk-taking is differentiated when interest rates are positive or negative. Third, and for the first time that is of our knowledge, we investigate if the impact on bank's profitability and risk-taking resulting from NIRP's implementation is differentiated according to the business model adopted by the bank.

Bank's margin and overall profitability are proxied by net interest margin and return on assets, respectively. We use three measures for bank risk-taking: Z-score, as a measure of the

overall bank risk, non-performing loans (NPL) ratio as a measure of credit risk and finally the risk-weighted assets (RWA) to total assets ratio as a measure of the risk associated with the bank's investment strategy. To characterize the interest rate environment is considered a short-term interest rate, proxied by a 3-month interbank money market interest rate, and the slope of the yield curve measured by the difference between 10-year Treasury yield and 3-month interbank money market interest rate.

We use an unbalanced panel data dataset of 2596 banks, with 15119 bank/year observations, operating in 29 European countries, over the period 2011-2019. In the sample period considered, 6 central banks have adopted NIRP's. To investigate the effects of the NIRP's adoption on the bank's profitability and risk-taking two equations are estimated using a fixed-effect estimator and, to mitigate a possible endogeneity bias and the possibility of omitted variables, explanatory variables are lagged one period and bank and time fixed effects are included. To identify bank's business models in European banking and investigate the effects of the NIRP's adoption on the bank's profitability and risk-taking, we use k-medians clustering to assign each bank to a specific banking business model given its asset and funding structure. Based on cluster analysis, we identify four different business models: investment-oriented banks (type I), retail-oriented banks, investment-oriented banks (type II) and interbank lending-oriented banks.

The main findings indicate that NIRP implementation lowered the net interest margin and the overall profitability of European banks that are affected by that policy. We also find evidence that a decrease in short-term interest rates lower net interest margin and the ROA in a more pronounced way when interest rates are already negative. Considering the whole sample, we do not find evidence that European banks increase risk-taking with NIRP's adoption. The results also allow us to conclude that the effects of the implementation of NIRP's affect banks' profitability and risk-taking in a different way. Net interest margins of bank business models whose main source of finance is retail deposits are more negatively affected by NIRP's implementation. Banks' financial stability and credit risk, across different bank business models, has not been affected by negative interest rates. Lastly, we conclude that investment-oriented banks (type I) and interbank lending-oriented banks adopted more risky investment strategies, while retail-oriented banks have adopted less risky investment strategies.

The remainder of the chapter is organized as follows. Subchapter 3.2. provides a review of the literature on the relationship between a low or negative interest rate environment and bank's profitability and risk-taking. Subchapter 3.3. describes the econometric methodology and the data used in the econometric tests. The results are reported and discussed in subchapters 3.4., 3.5. and 3.6. Finally, subchapter 3.7. concludes and highlights political implications.

3.2. LITERATURE REVIEW AND RESEARCH HYPOTHESIS

In this subchapter, we briefly review the literature on the relationship between a low or negative interest rate environment and bank behaviour. In the first section of this subchapter, we present the literature that analyses the relationship between interest rates and the bank´s profitability. In the second section, we expose the one between low or negative rates and bank's risk-taking. The last section presents the reasons that may lead to the effects of NIRP's adoption on profitability and risk taking to be differentiated according to the business model adopted by the bank.

3.2.1. Negative Interest Rates and Bank Profitability

How changes in interest rates affect the bank's performance of banks is a subject that in recent years has received increased attention both from a practical and an academic point of view. The existing literature argues that the effect of interest rates on bank's profits will vary by bank, depending on their interest rate exposures, in turn, a function of their degree of maturity transformation and the use of risk management techniques, including derivatives (Claessens et al., 2018). According to Borio et al. (2017) changes in the levels of interest rates and the slope of the yield curve affects the various components of bank profitability, that is, net interest margin, non-interest income and loan loss provisions.

Most of the theoretical and empirical studies suggest that banks' net interest margins are lower when interest rates are low. According to Claessens et al. (2018), this is because, for many types of deposits and other liabilities, banks are reluctant to lower interest rates below a certain level as depositors and other creditors can switch to cash forms of savings. When short-term interest rates become negative, there is a reduction in banks' net interest margin since banks are unable to pass through these interest rates to their clients' applications, given the

possibility and the high probability that clients will invest their savings in other alternative financial instruments. With deposit rates facing a floor, as interest rates decline, bank margins will compress if banks must still pass on lower rates on the asset-side of their balance sheet (Claessens et al., 2018). This market imperfection leads banks to compensate those losses by selling complementary products and services in a cross-selling policy and increased commissions, together with a reduction in costs and an increase in credit volume.

The slope of the yield curve could also influence the net interest margin (Borio et al., 2017). Specifically, a flat yield curve has a negative effect on banks' net interest margin. Typically, a bank in its maturity transformation activity is financed with short-term liabilities and invests in assets with longer maturities. If the term premium is close to zero or even negative, the net interest margin will be compressed. Changes in the slope of the yield curve will also have quantity effects, notably influencing the volume of banks' fixed-rate mortgages.

Low or negative interest rates could also impact non-interest income and loan loss provisions. Borio et al. (2017) argue the existence of a negative relationship between interest rates and non-interest income through two effects: valuation effects on securities, and fees and commissions. As interest rates rise, the bank's ability to generate profits from the net interest margin between loans to applications increases, and as interest rates decrease, the greater the need for the banks to generate profits from non-interest income. The relationship between interest rates and loan loss provision is presented with a concave shape: higher rates induce variable-rate loans, increasing stock and the debt service burdens; nevertheless, this relationship is attenuated as rates increase.

As referred by Boungou (2019), currently, there is no consensus of the interest rate effects on bank profitability. On the one hand, several studies show that low-interest rates have a negative effect on banks' net margin and overall profitability. Borio et al. (2017) analysed the influence of monetary policy on bank profitability through the influence on the interest rate structure. The authors find a concave relationship between the level of interest rates and the slope of the yield curve, associated with higher net income. This relationship is particularly strong at very low levels of nominal rates. The same authors also find a negative relationship between interest rates and non-interest income, which seems to indicate a kind of search for alternative channels that ensure bank profitability. Claessens et al. (2018), using a sample of 3385 banks from 47 countries from 2005 to 2013, find that low-interest rates have a

significantly greater impact on bank's net interest margin than high-interest rates. The impact is greater on interest income than on interest expense, and banks with short maturity balance sheets are more affected than those with long maturity balance sheets. The effects on banks' profitability are not so pronounced because banks mitigate the negative effect of low-interest rates on net interest margin by cutting costs and generating more non-interest income such fees and commissions and valuation gains. Similar conclusions are drawn from studies of Genay & Podjasek (2014), Busch & Memmel (2017) and Bikker & Vervliet (2018).

On the other hand, some authors find opposite effects of low (negative) interest rates on bank profitability. Scheiber et al. (2016), in an investigation of the profitability of banks in three European countries (Denmark, Sweden and Switzerland) during a period of very low and negative interest rates (2010 to 2015), conclude that negative interest rates have so far not resulted in a significant reduction of bank profitability and particularly of net interest margin. Similar results are founded in Madaschi & Pablos Nuevo (2017) for Swedish and Danish banks. Altavilla et al. (2017) analyse Eurozone banks, covering the period 2000-2016, and conclude that monetary policy easing – a decrease in short-term interest rates and/or a flattening of the yield curve – is not associated with lower bank profits. Their analysis indicates that the main components of bank profitability are asymmetrically affected by accommodative monetary conditions, with a positive impact on loan loss provisions and non-interest income largely offsetting the negative one on net interest income. Finally, a reference for the study of Lopez et al. (2020), that using data on 5200 banks from 27 advanced European and Asian countries, 2010–2017, conclude that banks offset interest income losses under negative rates with lower deposit expenses and gains in non-interest income, including fees and capital gains. However, the authors emphasize that there is no guarantee that the gains to non-interest bank income are sustainable over long periods.

Considering the difficulty that the banks have in obtaining non-interest income under a negative interest rate scenario, that compensates the interest income losses, the following hypotheses is formulated:

Hypothesis I: *The NIRP lead to a lower in the bank's net interest margin and profitability.*

Hypothesis II:*The effect of a decrease in interest rates in the bank's net interest margin and profitability is most pronounced when a NIRP is implemented.*

3.2.2. Negative Interest Rates and Risk-Taking

Unconventional monetary policies, including Quantitative Easing as well as policy rate guidance promoted by central banks to provide economic stimulus in an economic stagnation environment, have led to negative interest rates with impacts on bank's risk-taking. The relationship between low-interest rates and bank's risk-taking has been presented in the literature under a risk-taking channel that means the way that changes in monetary policy affect risk perceptions or risk tolerance of finance intermediaries (Rajan, 2005; Borio & Zhu, 2008; Adrian et al., 2010). The risk-taking channel may operate i) through the way banks measure risk, through their impact on valuations, incomes and cash-flows (Borio & Zhu, 2008; Adrian & Shin, 2009), and ii) through an increase in "search for yield" (Rajan, 2005). Analysing the way banks measure risk, low-interest rate provides an increase in the asset values and collateral values, decreasing the risk perception by the reduction in asset price volatility. Adrian & Shin (2009) emphasize the fact that after an unusually long period of low interest rates, in which leveraged positions may have built up, small changes in the monetary policy stance will have an amplified impact on the "repricing of risk" and on "liquidity conditions". "Search for yield" is related to the commitment to produce certain levels of nominal rates of return that cannot be assured with low or even negative interest rates environment and low returns on government bonds.

Rajan (2005) justifies the willingness to take more risks by asset managers for three reasons: contractual, behavioural, and institutional. The author states that, when interest rates are low, the yields on risk-free assets are also low and banks tend to invest in risky assets, providing a higher yield. This behaviour is reinforced by replication of investment decisions by peers, a process known as herding phenomena. This phenomenon is complemented to the so-called money illusion, according to which investors may ignore the fact that nominal interest rates may decline to compensate for lower inflation.

Andries et al. (2015) emphasize the dual effect of monetary policy on the credit supply of banks, the credit channel presented by Arteta et al. (2016): i) the increase of collateral and cash-flows of borrowers provided by low interest rates through the balance-sheet channel, that allows increases on supply loans, and ii) the search of other financing sources by banks, responding the threat of deposit withdrawals under low interest rates. The higher cost related to this other financing sources implies an extra cost that has the consequence of reducing the credit supply.

Altunbas et al. (2014) states, in addition, that bank risk may also be influenced by communication policies, with a moral hazard problem. Ease monetary policy perception in bad economic outcomes could lower the expectations of large downside risks and encourage liquidity risk-taking. This leads to the low-interest rates paradox introduced by Maddaloni & Peydró (2011) according to which when interest rates are low, credit risk and liquidity risk increase and so do the likelihood of a financial crisis. The interaction between finance, behavioural finance and macroeconomics associated to the risk-taking channel of monetary policy, have been justified because it captures the measurement and managing risk, the effects of monetary policy on bank's risk perceptions and incentives and because excessive bank risk-taking has effects on the general equilibrium, respectively (Andries et al., 2015). In complement of the moral hazard problem, monetary policy would impact on the adverse selection problem, considering the reducing incentive to screen and monitor loan applicants by weakening banks (Dell'Ariccia et al., 2011; Dell'Ariccia et al., 2014).

Considering the empirical studies, Jiménez et al. (2014) test the existence of a risk-taking channel for Spain. According to the authors, low interest rates affect the risk of the loan Spanish Bank's portfolio, as follows: i) in short term, low interest rates reduce the probability of default of the outstanding loans; ii) in the medium term banks tend to take more risk, softening their lending standards, and lending to borrowers with bad credit history. Ioannidou et al. (2009) have reached the same conclusion, investigating the impact of changes in the monetary policy rates on loan pricing in Bolivia. They state a negative relationship between the interest rate and loans' risk. They also conclude that banks increase the number of new risky loans and reduce the rates they charge to riskier borrowers, relative to less risky ones. Heider et al., (2018), using loan-level information for Europe, covering the period from January 2013 to December 2015, conclude that the introduction of negative policy rates by the European Central Bank in mid-2014 leads to more risk-taking and less lending by euro-area banks, which can pose a risk to financial stability if lending is done by high-deposit banks. Basten & Mariathasan (2018) analyse the effect of negative monetary policy rates on banks, using detailed supervisory information from Switzerland, namely, comparing changes in the behaviour of banks that had different fractions of their central bank reserves exempt from negative rates. They conclude that more affected banks reduce costly reserves and bond financing while maintaining non-negative deposit rates and larger deposit ratios. With higher fee and interest income, banks compensate for squeezed liability margins but increase credit and interest rate risk. Boungou (2020) analyse

for the first time that it is known, the effects of negative rates on the risk-taking of banks operating on the 28 member countries of the European Union. The author concluded that negative interest rates contributed to a reduction in banks' risk-taking. During the implementation period of negative rates, banks took less risk, in particular by reducing the share of non-performing loans. Boungou (2019) does not find encourage from banks to take more risk, despite a reduction in interest margins.

Several studies in the risk-taking literature tend to explain how the interest rate structure would encourage excessive risk-taking by banks. For some authors, the effects of interest rates on risk-taking depend on the profitability level of banks (Repullo, 2004; Martynova et al., 2019), and for others, on the bank's capitalization level (Jiménez et al., 2014; Dell'ariccia et al., 2017). Studies that investigate the effects of the NIRP on bank risk-taking are still limited and the results obtained are contradictory. Those contradictory results justify the present investigation and considering the explained above, the following hypotheses are formulated to test:

Hypothesis III: *The NIRP lead to a greater bank risk-taking.*

Hypothesis IV: *The effect of a decrease in interest rates on bank risk-taking increase is most pronounced when a NIRP is implemented.*

3.2.3. Negative Interest Rates and Bank's Business Model

Some authors emphasize the fact that the impact of low (negative) interest rates on profitability varies depending on a set of bank's characteristics. Molyneux et al., (2020) reinforce the existence of specific characteristics that significantly influence the relationship between the negative interest rate and bank margins. The characteristics are presented as follows: bank's size, funding structure and the business model, including assets repricing, and product-line specialization. The bank's size could explain the reduced elasticity of net interest margin to interest rate volatility. The funding structure is important, because, when policy rates turn negative, banks that rely on deposit funding are reluctant to reduce deposit rates, trying to keep their funding base, avoiding passing negative rates onto depositors. The business model can provide different degrees of sensitivity to interest rate risk. This risk is different from a real estate mortgage specialist bank, comparing to a bank that holds mostly floating interest rate

loans. Because the evidence shows that the effect of adopting a NIRP on profitability can be differentiated depending on the bank's business model, we still formulated the following hypothesis:

Hypothesis V: *The effect of a NIRP on profitability depends on the business model adopted by the bank.*

Lucas et al., (2019) in an empirical study of 208 European banks between 2008Q1–2015Q4, identify six distinct business model and conclude that changes in the slope in the yield curve changes in average business model characteristics. So it is expected that, depending on the business model adopted by a bank, its risk response will be differentiated (Schwaab, 2017). This led us to formulate the last research hypothesis:

Hypothesis VI: *The effect of a NIRP on bank risk-taking depends on the business model adopted by the bank.*

3.3. METHODOLOGY AND DATA

In this subchapter, we introduce the methodology and empirical models that allow analysing the impacts of the adoption of NIRP's by some central banks on profitability and risk-taking in European banks. For this purpose, profitability and risk-taking measures are defined and discussed. The variables used to characterize the interest rate environment are also specified. To investigate whether these impacts are differentiated according to the business model adopted by the bank, we also describe the methodology that allows us to allocate banks to different business models.

3.3.1. Profitability and Risk-Taking Measures

To measure banks' profitability two main indicators were considered: net interest margin, defined as the difference between interest-earning assets and interest-bearing liabilities divided by total earning assets, and return on assets (ROA), a commonly used performance measure, defined by the ratio of net income over total assets[10]. Because monetary policy also has an

[10] Similar measures are considered by Borio et al. (2017) and Boungou (2019).

impact on other components of profit (Borio et al. 2017), in addition to net interest margin, we also study the effect of NIRP on net fee & commission, net trading income, other operating revenues and finally on loan loss provisions[11].

Considering the different risk channels of the monetary policy identified in the literature review, we consider three measures of risk (e.g. Boungou, 2020). The non-performing loans (NPL) ratio, defined as the non-performing loans divided by gross loans, as a measure of credit risk. A riskier loan portfolio increases the credit risk and the need to constitute more provisions. The ratio of risk-weighted assets (RWA) over total assets. In a context of reduced interest rates, the "search for yield" effect, leads the banks to adopt more risky investment strategies, increasing their exposure to risk and consequently this ratio. Lastly, we consider the ratio Z-score[12] as a measure of overall banking risk. This ratio is estimated as the sum of current ROA with equity-to-asset (E/A) ratio divided by the standard deviation of ROA (σ_{ROA})[13]. The idea behind the Z-score is that a bank becomes insolvent when its current losses exhaust all bank's equity. Thus, a lower bank's Z-score implies a greater risk of insolvency (Ngambou Djatche, 2019).

3.3.2. Interest Rate Environment Measures

This study is concerned with the impact that the adoption of NIRP by some central banks in Europe has on banks' profitability and risk-taking. To this end, the following variables are considered: a short-term interest rate, the slope of the yield curve and a dummy variable reflecting the adoption or not of a NIRP.

As a short-term interest rate, we take the 3-month interbank money market interest rate (e.g. Delis & Kouretas, 2011; Bikker & Vervliet, 2018). We prefer an interbank money market interest rate to the central bank's policy rate because the former reflects more appropriately the adoption of unconventional monetary policy measures. Making the same assumption as in the literature that the short-term interest rate reflects the general interest rate level, we expect that

[11] All those variables are considered in our models as a percentage of total assets.

[12] Because literature indicates that the Z-score is highly skewed, we use a natural logarithm transformation.

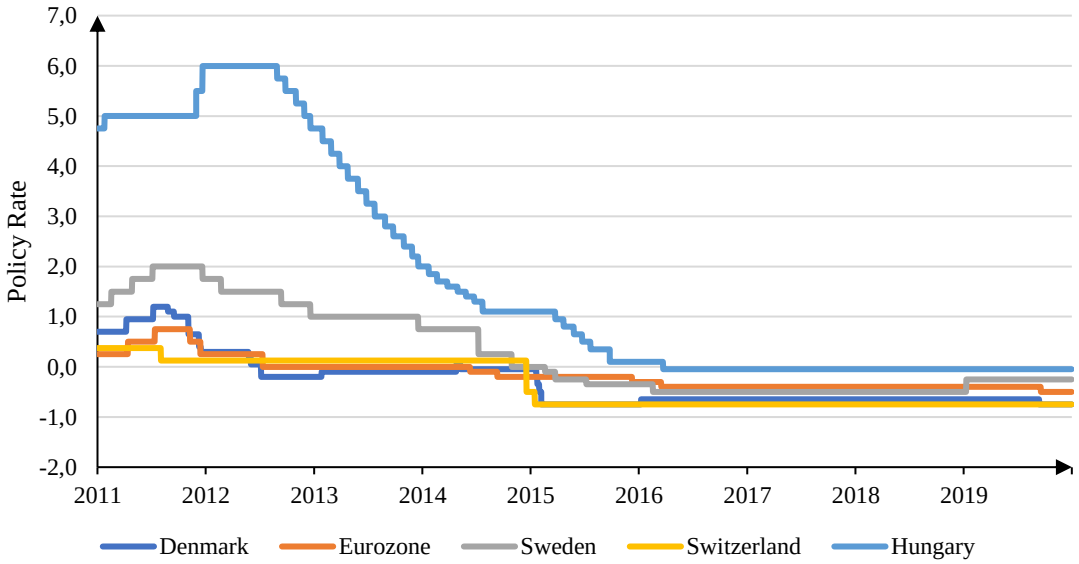
[13] Because the sample period covered by the present investigation is relatively short, we assumed that σ_{ROA} is constant and given by the standard deviation of the return on assets in the period under analysis.

lower interest rates impair the bank's net margin and increase risk exposure and that this impact is stronger when interest rates are already low or negative.

The slope of the yield curve, that also helps control the effects of unconventional monetary policy measures, is approximated by the difference between 10-year treasury yield and 3-month interbank money market interest rate (e.g. Borio et al., 2017; Claessens et al., 2018). As a result of the maturity transformation function performed by banks, a positive correlation is expected between the banks' profits or net interest margins and the slope of the yield curve (Alessandri & Nelson, 2015).

Finally, to characterize the interest rate environment, we consider a dummy variable to reflect if the central bank of the country where the bank is based adopted or not a NIPR. Figure 9 shows the evolution of the central bank's policy rate[14] in European countries that have adopted NIRP's.

Figure 9 - Evolution of the central bank's policy rate in European countries that have adopted NIRP



Source: Own production

[14] Refers to the main deposit policy rate in most cases, and the main refinancing rate for the Riksbank. No historical data is reported for Bulgaria due to its unavailability.

3.3.3. Model Specifications and Estimation Method

To study the effects of interest rates on banks' profitability and risk-taking as a result of the adoption of NIRP's, we consider the following models:

$$y_{it} = \beta_0 + \beta_1 * ir_{t-1} + \beta_2 * slope_{t-1} + \beta_3 * NIRP_{t-1} + \gamma_1 * X_{it-1} + \gamma_2 * W_{t-1} + \mu_i + \delta_t + \varepsilon_{it} \quad (3.1)$$

$$y_{it} = \alpha_0 + \alpha_1 * ir_{t-1} + \alpha_2 * slope_{t-1} + \alpha_3 * NIRP_{t-1} * ir_{t-1} + \alpha_4 * NIRP_{t-1} * slope_{t-1} + \gamma_1 * X_{it-1} + \gamma_2 * W_{t-1} + \mu_i + \delta_t + \xi_{it} \quad (3.2)$$

where i and t are bank and time indicators, respectively, y_{it} represents alternatively one of the bank's profitability or risk-taking measures defined above, ir_t represents the short-term interest rate, $slope_t$ represents the slope of the yield curve and $NIRP_t$ takes the value of 1 if in the country where the bank is based adopted a NIRP in year t and 0 otherwise. X_{it} and W_t represents a vector of bank-specific and macroeconomic variables, respectively. μ_i and δ_t represent a bank-specific effect and time fixed effect, respectively. In all regressions, we follow Borio et al. (2017) and Leroy & Lucotte (2017), and explanatory variables are lagged one period and we include bank and time fixed effects in order to mitigate a possible endogeneity bias. Both equations are estimated using a fixed-effect estimator and in the statistical inference robust standard errors clustered at the bank level are used to consider the existence of autocorrelation and/or heteroscedasticity.

For profitability models, we expect that $\beta_3 < 0$, meaning that the adoption of NIRP's will put pressure on banks' net interest margin and profitability (Hypothesis I). According to Hypothesis II, it expected $\alpha_3 - \alpha_4 > 0$, meaning that a decrease in the short-term interest rates lead to a negative change in banks' net interest margin and profitability more pronounced when a NIRP is implemented. For risk-taking models, according to Hypothesis III, it is expected that $\beta_3 < 0$ if the risk measure used is Z-score, and $\beta_3 > 0$ if the risk is measured by the NPL ratio or the ratio of RWA over total assets. According to Hypothesis IV, we expect that $\alpha_3 - \alpha_4 > 0$ if the risk measure used is Z-score, and $\alpha_3 - \alpha_4 < 0$ if the risk is measured by the NPL ratio or the ratio of RWA over total assets.

To control possible effects of other determinants of the bank's profitability and risk-taking, we include the following bank-specific variables in vector X_{it}. First, we consider the bank's size, measured by the natural logarithm of the total assets. According to Goddard et al. (2004),

the bank's size influences positively its profitability through the realisation of economies of scale. However, as suggested by Demirgüç-Kunt et al. (2004), large efficient banks could apply lower spreads to customers through increasing returns to scale. So, the effect of the *bank's size* on profitability is unclear. The same conclusion can be drawn regarding the relationship between the bank's size and risk. On one hand, managers of large banks may be tempted to adopt higher-risk policies in the case that governments are prepared to bail-out large problematic banks (Demirgüç-Kunt & Huizinga, 2013) and, on the other hand, larger banks can achieve economies of scale that allow them to be more stable than small banks (Williamson, 1986). We employ several variables to control for bank risk aversion, credit risk and bank operating efficiency. We use *capitalization*, measured by the ratio of equity over total assets, to proxy bank risk aversion. Given their risk aversion, we expect that better-capitalized banks will require higher margins and take less risk (Berger, 1995; Bikker & Vervliet, 2018). Credit risk is measured by the *non-performing loans (NPL) ratio*. We expect that banks with higher credit risk apply a premium to margins (Philip Molyneux et al., 2019) and shows a higher overall risk[15]. Bank's management *inefficiency* is measured using the cost-to-income ratio. As referred by Molyneux et al. (2019), inefficient management of a bank translates into lower margins and profits and consequently more risk. In order to control for the impact of bank business models, we also consider as a determinant of a bank's profitability and risk-taking the *asset composition*, measured by the loans-to-asset ratio, its funding structure, measured by the *share of wholesale funding* and the diversity of its incomes, measured by the *non-interest income share* (Bikker & Vervliet, 2018 and Molyneux et al., 2019).

The banking literature suggests that the macroeconomic environment in which banks operate may have effects on their behaviour. Thus, both the structure of the banking sector and the economic environment can affect banks' profitability and risk-taking. Like Boungou (2019) we considered real GDP growth and the inflation rate to characterize the macroeconomic conditions. To measure the impact of market structure on the bank's profitability and risk-taking, we use the Herfindahl-Hirschman Index (HHI) (Chen et al., 2017), which is measured as the sum of the squares of individual bank's market share in total banking assets, to proxy the

[15] In the risk-taking model in which the dependent variable is the NPL ratio, for methodological reasons, this variable was not considered as an explanatory variable.

average concentration level of the banking sector. A Herfindahl-Hirschman Index close to one indicates more concentration.

In Table 25 of the Appendix of this chapter, we present a detailed description of all the variables used in the present investigation as well as the different sources of information used.

To analyse research hypotheses V and VI, we need, first, to identify the different business models existing in European banking and, second, allocate each bank in our sample to one of the previously identified business models. For this purpose, following the methodology adopted by Hryckiewicz & Kozłowski (2017) and Roengpitya et al. (2017), we use k-medians[16] clustering to assign each bank to a specific banking business model given its asset and funding structure. The objective of this k-medians clustering is to group banks with similar asset and funding structures into the same cluster and those with different characteristics into different clusters. The k-medians approach identifies a cluster by minimizing the differences between the individual financial variables of different banks using Manhattan distance:

$$S = \sum_{k=1}^{K} \sum_{x_i \in C_k} \left| x_{ij} - med_{kj} \right| \tag{3.3}$$

where K is the number of clusters, x_{ij} are the observation of the j financial variable for the bank i used in cluster analysis, C_k is the cluster k and med_{kj} is the median on cluster k. For our analysis, we perform the grouping based on earning assets structures and liability sources. Among bank asset structures, we distinguish the following positions: loans to customers, loans and advances to banks and trading securities, all scaled by bank total assets. Among bank funding sources, we distinguish between customer deposits and wholesale funding[17]. Additionally, because the NIRP's adoption may have caused a bank to change its business model, we allow our sample banks to modify their banking business models throughout the sample period.

To ensure a good compromise between the homogeneity within each cluster and the number of clusters selected, the pseudo F-index, proposed by Calinski & Harabasz (1974), is

[16] We prefer k-medians clustering to k-means clustering because medians are less sensitive to outliers than means.
[17] This item includes bank deposits, debt securities, repurchase agreements and subordinated liabilities.

used to help us decide[18]. To evaluate the goodness of clustering by considering how well the clusters are separated and how compact the clusters are, we use the silhouette coefficient. This measure ranges from -1 to +1, where a high value indicates that the bank is well matched to its cluster and poorly matched to neighbouring clusters (Rousseeuw, 1987).

3.3.4. Sample Description and Data Statistics

In our investigation, an unbalanced panel data of European banks is used, covering the period from 2011 to 2019, from the 29 following countries: 18 countries that, at the end of 2019, belonged to the Eurozone[19], Bulgaria, Croatia, the Republic Czech, Denmark, Hungary, Norway, Poland, Romania, Sweden, Switzerland, and the United Kingdom. In those countries, 6 central banks have adopted NIRP's. Table 18 summarizes information on the date and level of the policy rate at which the 6 central banks first adopted a NIRP.

Table 18 - Negative interest rate policy (NIRP) announcements

Country	Central Bank	Policy rate	Date	Rate
Bulgaria	Central Bank of Hungary	Overnight deposit rate	Jan 2016	-0.30%
Denmark	Danmarks Nationalbank	1-week certificate of deposit rate	July 2012	-0.20%
Eurozone	European Central Bank	Overnight deposit facility rate	June 2014	-0.10%
Hungary	Magyar Nemzeti Bank	Overnight deposit rate	March 2016	-0.05%
Sweden	Sveriges Riksbank	1-week repo rate	February 2015	-0.10%
Switzerland	Swiss National Bank	Overnight sight deposit rate	December 2014	-0.25%

Source: Own production and based on information collected from Central Banks

Specific information about bank variables is obtained from Moody's Analytics BankFocus, with all data converted to euros[20]. Historical information about the short-term interest rate, the 10-year treasury yield, the GDP growth rate and the inflation rate has been taken from Thomson Datastream. Finally, the Herfindahl-Hirschman Index is computed using data of the bank's total assets available from Moody's Analytics BankFocus database.

After excluding banks with missing data or with unplausible data for the variables used, we obtain a final sample that includes an unbalanced panel data sample for 2596 banks[21], with

[18] We should select the number of clusters that maximize the pseudo F-index.

[19] We do not include the Banks of Estonia because some macroeconomic data is not available.

[20] We considered all commercial banks, savings banks, real estate & mortgage banks, cooperative banks, and bank holdings & holding companies, with at least 2 years of information. We considered consolidated accounts when available and unconsolidated accounts for individual banks. We excluded all domestic bank subsidiaries (to avoid duplication of data) and holding companies with residual bank activity.

[21] A note to mention that the sample used is dominated by German banks that represent 48.57% of the total number of banks, followed by Italian banks with 16.80%.

15119 bank/year observations, where 8743 correspond to the period after the implementation of the NIRP by central banks.

The descriptive statistics of the variables that are used in the main regressions are reported in Table 19 , distinguishing the pre-NIRP period from the NIRP period. As we can see, as a result of the adoption of NIRP's by several central banks in Europe, there has been a considerable decrease in short-term interest rates. Namely, on average, short-term interest rates fell by 143.1 b.p. from 1.142% to -0.289%. There was also a sharp decline in long-term interest rates from the pre-NIRP period to the NIRP period, smoothing the yield curve, with its slope's mean value decreasing from 2.456 to 1.375. This latter movement can be explained by the various asset purchase programs implemented by several central banks during the period under analysis.

As a result of the decrease in short-term interest rates and the slope of the yield curve, the mean value of net interest margin decreased by 39.9 b.p. from the pre-NIRP period to the NIRP period from 2.289% to 1.890%. The mean value of the ROA registered, from one period to the other, only a slight decrease from 0.386% to 0.342%. This less pronounced decrease in ROA may be explained in part by a less severe loan loss provisions policy and an increase in the mean value of other operating revenues: the mean value of loan loss provisions relatively to total assets decreased from 0.365% in the period pre-NIRP to 0.204% in the NIRP period, while the other operating revenues in total assets increased from 0.223% to 0.360%.

Looking at risk-taking measures, we can conclude that banks, in the NIRP period, took less risk. From the pre-NIRP period to NIRP period the mean value of the natural logarithm of Z-score, a proxy for the overall bank risk, increased from 4.283 to 4.737. The mean value of the NPL ratio, a proxy of credit risk, decreased from 6.759% in the pre-NIRP period to 5.343% in NIRP period. Lastly, the mean value of the ratio RWA/Total Assets also decreased which indicates that, on average, banks adopted less risky investment strategies, in the NIPRP period. Thus, the preliminary evidence does not seem to allow us to conclude that banks' risk-taking has increased with the implementation of NIRP's.

Table 19 - Descriptive Statistics

Variables	Pre-NIRP period					NIRP period					T-test
	Obs.	Mean	Std.Dev.	Min	Max	Obs.	Mean	Std.Dev.	Min	Max	
Panel A: Bank profitability measures											
Net interest margin	6376	2.289	0.842	0.190	8.400	8743	1.890	0.669	0.150	8.440	-31.345***
Return on assets (ROA)	6376	0.386	0.677	-7.650	7.070	8743	0.342	0.792	-9.450	57.910	-3.684***
Net fee & commission	6376	0.670	0.885	-1.852	38.416	8743	0.683	0.651	-0.681	21.429	0.977
Net trading income	6376	0.168	0.469	-1.891	13.193	8743	0.117	0.385	-2.271	11.452	-7.025***
Other operating revenues	6376	0.223	0.427	-2.364	9.731	8743	0.360	5.050	-3.851	401.989	2.529***
Loan loss provisions	6376	0.365	0.746	-5.060	10.450	8743	0.204	0.515	-2.99	17.12	-14.873***
Panel B: Bank risk-taking measures											
Ln Z-score	6376	4.283	1.784	-2.407	41.686	8743	4.737	1.871	-2.305	41.734	15.122***
NPL ratio	6376	6.759	7.195	0.000	58.730	8743	5.343	7.376	0.000	100.000	-11.820***
RWA/Total Assets	6376	56.787	14.484	0.040	99.870	8743	53.066	13.648	5.880	97.880	-15.980***
Panel C: Interest rate environment measures											
Short-term interest rate	146	1.142	1.243	-0.027	6.867	109	-0.289	0.178	-0.955	-0.013	-13.724***
Slope of yield curve	146	2.456	2.794	-0.569	23.064	109	1.375	1.468	0.070	10.252	-3.993***
Panel D: Bank-specific variables											
Size	6376	7.097	2.044	2.944	14.588	8743	6.904	1.880	2.398	14.588	
Capitalization	6376	9.577	3.622	0.180	69.300	8743	10.189	3.655	0.900	67.540	
Inefficiency	6376	65.752	13.337	6.430	99.930	8743	69.745	12.267	13.700	100.000	
Liquidity	6376	20.961	15.314	0.230	94.680	8743	19.936	15.651	0.310	87.320	
Share of wholesale funding	6376	25.398	17.757	0.000	96.030	8743	18.805	14.936	0.000	99.130	
Asset composition	6376	62.198	15.637	2.540	97.830	8743	61.461	14.943	4.850	98.230	
Non-interest income share	6376	32.608	12.639	0.030	98.800	8743	37.243	12.714	0.200	99.090	
Panel E: Country variables											
Real GDP growth	146	1.637	2.532	-9.132	8.706	109	2.852	2.788	-0.438	25.163	
Inflation	146	1.719	1.487	-1.545	5.789	109	0.955	1.016	-1.736	3.723	
Herfindahl-Hirschman Index	146	0.105	0.064	0.027	0.388	109	0.125	0.070	0.025	0.316	

Note: The table shows descriptive statistics for variables. While Panel A provides information on bank profitability, Panel B contains information on bank risk-taking, Panel C includes information about short-term interest rates and yield curve and Panel D report bank-specific variables. Panel D shows the information on country-specific variables. The T-test refers to the sample value of the test statistic for comparing means in the two periods analysed. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

3.4. THE EFFECTS OF NEGATIVE INTEREST RATES ON BANK PROFITABILITY

In this subchapter, we present the estimation results of equations (3.1) and (3.2) that allow us to analyse the effects of adopting NIRP's on the profitability of European banks. Table 20 shows the results for net interest margin and ROA. The analysis of columns (1) and (3) allows us to conclude that in the European countries where the NIRP's are implemented the banks' net interest margin as well as their overall profitability, measured by ROA, suffer a substantial reduction, corroborating our research hypothesis I. We can conclude that in NIRP period the net interest margin and the ROA decreased 14.5 b.p. and 18.5 b.p., respectively, which are in line with results obtained by Campmas (2020).

Looking for the other components that influence the overall profitability [see columns (1) and (3) of Table 26 and Table 27 presented in the Appendix of this chapter], we can conclude that the adoption of NIRP's raised the weight of fees and commissions charged by banks. Contrary to our expectations, in countries where NIRP's were implemented, the weight of net trading income in the total assets decreased and the weight of loan loss provisions increased. These results could be a consequence of a tightening in the regulation rules by the European regulatory authorities in the last decade, requiring greater provisioning and less risky investment strategies. The adoption of a NIRP has not been shown to have a statistically significant impact on the weight of other operating revenues in a bank's total assets.

Turning our attention now to the effect that changes in short-term interest rates can have on net interest margin and overall profitability, we can conclude the following: a decrease in short-term interest rates has a more pronounced negative effect on the net interest margin and overall profitability when a NIRP is implemented than when it is not [see columns (2) and (4) of Table 20]. This validates our research hypothesis II and these results are in line with those obtained by Claessens et al. (2018) in a study on the effect of short-term interest rates on net interest margin and ROA, distinguishing between low and high-interest rate environments. For a representative bank, a one-percentage-point decrease in the short-term rate is associated with a 5 b.p. (0.031+0.019) decrease in net interest margin in a positive-rate environment versus a 16.9 b.p. (0.031+0.019+0.132-0.013) decrease in net interest margin in a negative-rate environment, an 11.9 b.p. difference. That difference is 44.4 b.p. for ROA.

Table 20 - Effect of interest rates and NIRP on net interest margin and return on assets

	Net interest margin		Return on assets	
	(1)	(2)	(3)	(4)
Short-term interest rate	0.043	0.031	-0.300**	-0.337**
	(0.033)	(0.035)	(0.146)	(0.157)
Slope of the yield curve	-0.025**	-0.019**	0.051**	0.068**
	(0.010)	(0.010)	(0.023)	(0.027)
NIRP	-0.145***		-0.185***	
	(0.026)		(0.062)	
NIRP * Short-term interest rate		0.132**		0.529***
		(0.067)		(0.188)
NIRP * Slope of the yield curve		0.013		0.085
		(0.009)		(0.059)
Size	-0.325***	-0.329***	-0.298***	-0.297***
	(0.052)	(0.053)	(0.085)	(0.084)
Capitalization	0.003	0.003	0.010	0.012
	(0.007)	(0.007)	(0.010)	(0.011)
Inefficiency	-0.004***	-0.005***	0.001	0.000
	(0.001)	(0.001)	(0.003)	(0.003)
NPL ratio	0.005***	0.005**	-0.007	-0.009*
	(0.002)	(0.002)	(0.006)	(0.005)
Share of wholesale funding	-0.007***	-0.007***	0.001	0.002
	(0.001)	(0.001)	(0.005)	(0.005)
Asset composition	0.010***	0.010***	-0.011***	-0.010***
	(0.001)	(0.001)	(0.003)	(0.002)
Non-interest income share	-0.014***	-0.014***	-0.002	-0.002
	(0.001)	(0.001)	(0.002)	(0.002)
Real GDP growth	0.018***	0.018***	0.016*	0.009
	(0.005)	(0.005)	(0.009)	(0.011)
Inflation	0.033***	0.034***	-0.001	-0.005
	(0.007)	(0.007)	(0.021)	(0.024)
HHI	-0.518**	-1.256***	0.575	-0.620
	(0.248)	(0.208)	(0.576)	(0.422)
Constant	4.526***	4.519***	3.251***	3.163***
	(0.418)	(0.420)	(0.716)	(0.694)
Research hypothesis:				
Hypothesis I $[\beta_3 = 0]$	-5.475***		-2.966***	
Hypothesis II $[\alpha_3 - \alpha_4 = 0]$		1.735**		2.269**
Number of observations	12050	12050	12050	12050
Number of Banks	2562	2562	2562	2562
R-Squared	0.497	0.492	0.027	0.030
F-Test	206.66***	191.44***	5.71***	5.10***

Note: This table shows the results of the effects of the adoption of NIRP and interest rates on bank net interest margin and return on assets. In all regressions, explanatory variables are lagged one period and we include bank and time fixed effects to soften eventual endogeneity issues. Section "Research hypothesis" report the t-statistics for the respective hypothesis. Robust standard errors clustered at the bank level are reported below their coefficient estimates. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

For the other components that influence overall profitability, we can conclude that a decline in short-term interest rates has a more significant impact (positive) on the variation in the weight

of fees and commissions and loan loss provisions in a negative interest rate environment than in a positive interest rate environment [see columns (2) and (4) of the Table 26 and Table 27 presented in the Appendix of this chapter]. The impact's difference is not statistically significant for the other components considered in the study (net trading income and other operating revenues).

Discussing now the impact of the other control variables on bank profitability, we found a negative and statistically significant relationship between the net interest margin and ROA with bank's size, indicating that larger banks present lower levels of profitability. We also concluded that the less efficient banks, where the wholesale funding share is greater and that have a high diversification in their income sources, have lower net interest margins, which is in line with our expectations. Banks with a higher level of credit risk exposure, as expected, have higher net interest margins. The asset composition, measured by the weight of loans to costumers in the total assets, positively influences the net interest margin but negatively influences the ROA. This means that banks that are more oriented towards lending to their customers have a lower ROA.

In terms of the effects that macroeconomic variables have on banks' net interest margin, it is concluded that both economic growth and inflation have, as expected, a positive effect on the net interest margin. We find that in countries with higher levels of bank concentration, the net interest margin is lower, which means that higher concentration levels do not necessarily mean less competition. The macroeconomic variables considered in the study do not show to have a statistically significant influence on overall profitability.

3.5. The Effects of Negative Interest Rates on Bank Risk-Taking

Table 21 presents the estimation results of equations (3.1) and (3.2) that allow analysing the effect of the adoption of NIRP's on the bank's risk-taking. As can be seen, whatever the risk-taking indicator considered, we can conclude that the adoption of NIRP's in some European countries did not have any impact on risk-taking. Regardless of the risk-taking indicator considered, we verify that the adoption of NIRP's in some European countries did not have any impact on the bank's risk-taking. This conclusion is sustained by the estimation results of columns (1), (3) and (5) in Table 21, where the one-lag dummy variable NIRP never got over

statistically significant. These results do not allow us to validate our research hypothesis III, indicating that the adoption of NIRP's in some countries in Europe did not lead banks to adopt more risky investment strategies. This conclusion is in line with that obtained by Boungou (2020) and Bikker & Vervliet (2018) in a context of low-interest rates.

The analysis of the estimation results presented in columns (2), (4) and (6) in Table 21 allows drawing the following conclusions:

(i) In the pre-NIRP period, a decrease in short-term interest rates has a positive effect on the Z-score and a negative effect on the NPL ratio, both of which are statistically significant at a 5% significance level[22]. In the same period, the short-term interest rate does not have a statistically significant effect on the RWA/TA ratio. This means that in an environment of low but positive interest rates, further decreases in short-term interest rates decrease the probability of default by borrowers on bank loans, decreasing the credit risk, as measured by the NPL ratio and the overall risk of the bank measured by the Z-score. In this context, there seems to be no evidence of the so-called "search-for-yield" effect and a softening lending standard.

(ii) In the NIRP period, a decrease in short-term interest rates has no statistically significant effect on the Z-score, NPL ratio and RWA/TA ratio[23]. This means that in an environment of negative interest rates, additional decreases in short-term interest rates do not lead banks to take more risk.

The conclusions above referred allow us to conclude that there is no statistical evidence to support our research hypothesis IV.

[22] The null hypothesis $\alpha_1 - \alpha_2 = 0$ was tested in the columns (2), (4) and (6) and were obtained p-values of 0.040, 0.0003 and 0.3528, respectively.
[23] The null hypothesis $\alpha_1 - \alpha_2 + \alpha_3 - \alpha_4 = 0$ was tested in the columns (2), (3) and (4) and were obtained p-values of 0.9493, 0.1144 and 0.4145, respectively.

Table 21 - Effect of interest rates and NIRP on bank risk-taking

	Ln Z-score		NPL ratio		RWA/TA	
	(1)	(2)	(3)	(4)	(5)	(6)
Short-term interest rate	-0.045	-0.050	1.029**	1.117**	1.030**	1.131**
	(0.031)	(0.033)	(0.487)	(0.537)	(0.458)	(0.461)
Slope of the yield curve	0.018**	0.014**	-0.641***	-0.715***	0.977***	0.725***
	(0.007)	(0.007)	(0.149)	(0.167)	(0.207)	(0.185)
NIRP	-0.015		0.269		0.666	
	(0.014)		(0.320)		(0.417)	
NIRP * Short-term int.rate		0.037		-1.425*		-2.747***
		(0.040)		(0.824)		(0.912)
NIRP * Slope yield curve		-0.026***		-0.425***		-1.627***
		(0.007)		(0.164)		(0.254)
Size	-0.114***	-0.111***	0.132	0.129	0.412	0.491
	(0.027)	(0.027)	(0.493)	(0.498)	(0.853)	(0.866)
Capitalization	0.045***	0.043***	-0.042	-0.056	0.671***	0.615***
	(0.005)	(0.005)	(0.069)	(0.069)	(0.159)	(0.156)
Inefficiency	-0.001***	-0.001***	-0.029***	-0.028***	0.005	0.010
	(0.000)	(0.000)	(0.007)	(0.007)	(0.011)	(0.011)
NPL ratio	-0.004**	-0.003**			0.116***	0.153***
	(0.001)	(0.001)			(0.038)	(-0.04)
Share wholesale funding	0.001**	0.001	0.068***	0.064***	0.046**	0.028
	(0.001)	(0.001)	(0.011)	(0.011)	(0.020)	(0.020)
Asset composition	0.000	0.000	0.000	-0.003	0.274***	0.269***
	(0.001)	(0.001)	(0.014)	(0.014)	(0.028)	(0.027)
Non-interest income share	-0.001*	-0.001**	0.035***	0.034***	0.005	0.001
	(0.001)	(0.001)	(-0.01)	(-0.01)	(0.016)	(0.016)
Real GDP growth	0.002	0.005**	-0.174***	-0.134**	0.183**	0.326***
	(0.002)	(0.002)	(0.067)	(0.065)	(0.081)	(0.090)
Inflation	-0.002	0.000	-0.327***	-0.293***	0.020	(0.165)
	(0.004)	(0.004)	(0.092)	(0.097)	(0.140)	(0.141)
HHI	-0.373***	-0.240**	-17.632***	-14.218***	8.868*	22.062***
	(0.117)	(0.108)	(2.677)	(2.277)	(4.782)	(4.486)
Constant	5.091***	5.095***	5.906	6.371	21.499***	22.344***
	(0.222)	(0.223)	(3.966)	(4.023)	(7.425)	(7.586)
Research hypothesis:						
Hypothesis III $[\beta_3 = 0]$	-1.056		0,840		1.597	
Hypothesis IV $[\alpha_3 - \alpha_4 = 0]$		1.510		-1.181		-1.205
Number of observations	12050	12050	12050	12050	12050	12050
Number of Banks	2562	2562	2562	2562	2562	2562
R-Squared	0.204	0.209	0.182	0.186	0.238	0.252
F-Test	31.74***	36.73***	42.387***	44.126***	46.01***	48.41***

Note: This table shows the results of the effects of the adoption of NIRP and interest rates on bank risk-taking. In all regressions, explanatory variables are lagged one period and we include bank and time fixed effects to soften eventual endogeneity issues. Section "Research hypothesis" report the t-statistics for the respective hypothesis. Robust standard errors clustered at the bank level are reported below their coefficient estimates. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Looking at the effect of other control variables on banks' risk-taking, it can be concluded that smaller banks, better capitalized, more efficient, less exposed to non-interest income and credit risk show greater financial stability, measured by the Z-score, which is in line with our expectations. We also conclude that banks that operate in more concentrated market structures show less financial stability.

About the exposure to credit risk, as measured by the NPL ratio, it can be concluded that the most efficient banks have lower credit risk, while banks with a higher share of wholesale funding and non-interest income are more exposed to default's risk. Economic growth, inflation and increased banking concentration have a positive, statistically significant effect on credit risk, decreasing the NPL ratio.

Lastly, we can conclude that banks better capitalized, more exposed to credit risk, with high loan-to-asset ratios follow riskier investment strategies, measured by RWA/TA ratio. Higher economic growth and greater banking concentration also lead to greater bank's risk-taking.

3.6. EFFECTS OF A NEGATIVE INTEREST RATE POLICY ON DIFFERENT BANKS' BUSINESS MODELS

To study whether the effect of implementing a NIRP on profitability and risk-taking depends on the business model adopted by the bank, we use the methodology described in section 3.3.3. Based on the bank assets structures and their sources of financing, and using cluster analysis, it was concluded that the optimal number of business models to use in our sample was four. These four business models are characterized in Table 22 by a set of characteristics listed there.

We have designated the four business models as follows:

- **Investment-oriented banks type I (Model I):** Large banks, with funding sources diversified, having substantial trading activities and trading income has a relatively high weight on operational revenues;
- **Retail-oriented banks (Model II)**: Midsize banks, whose main source of financing is customer deposits, and which are highly oriented for lending to customers. Its major sources of operational revenues are net interest margin and net fees and commissions;
- **Investment-oriented banks type II (Model III)**: Small banks, whose main source of financing is customer deposits, having substantial trading activities. Its major sources of operational revenues are net interest margin and net fees and commissions;
- **Interbank lending-oriented banks (Model IV)**: Midsize banks, whose main source of financing is customer deposits, and which are highly oriented for lending to other banks.

Its major sources of operational revenues are net interest margin and net fees and commissions.

Table 22 - Business model identification based on bank assets structures and their sources of financing

Variable	Business Model			
	Model I	Model II	Model III	Model IV
Variables used in the cluster analysis (% of total assets):				
Loans to customers	63.62	76.60	53.03	51.41
Loans and advances to banks	8.40	5.58	7.26	31.45
Trading securities	22.11	13.45	35.25	12.04
Customer deposits	43.40	72.06	76.89	77.46
Wholesale funding	41.69	15.58	10.80	9.74
Other variables (% of operational revenues except for total assets):				
Total Assets (in millions €)	71320	8419	3715	6744
Net interest margin	61.10	67.96	64.03	60.94
Net fees and commissions	22.49	21.30	22.70	26.17
Net trading income	10.54	1.67	3.17	3.18
Other operacional revenues	5.87	9.07	10.11	9.71
Number of banks	**628**	**1288**	**1180**	**355**

Note: This table shows the mean values of the listed variables for each business model.

Source: Own production

After identifying the different bank business models in our sample, we study the effects of the implementation of the NIRP on the profitability and risk-taking of each one.

Regarding the effects of short-term interest rates and NIRP on profitability, Table 23 reports the (partial) estimation results of equations (3.1) and (3.2) for the net interest margin [columns (1) and (2)] and return on assets [columns (3) and (4)]. Looking at the effects of the implementation of the NIRP in some European countries, we can conclude that, except for investment-oriented banks (type I), all other banks see their net interest margin decrease. In particular, it appears that the banks where customer deposits have a greater weight in their financing, greater is the negative impact on banks' net interest margin. In the interbank lending-oriented banks, where the customer deposits represent, on average, 77.46% of funding sources and the loans and advances to banks represent 31,45% of the investments, the net interest margin reduced 32.2 b.p. as a result of the implementation of the NIRP. This happens because banks that adopt this business model are forced to lower interest rates on bank loans without being able to lower interest rates on customer deposits, given the reluctance of banks to lower

the latter to negative values. It can also be seen that, when interest rates are already on the negative ground, an additional fall in them puts greater pressure on the net interest margin of the retail-oriented and interbank lending-oriented banks. Analysing the effect of interest rates and NIRP on overall profitability, measured by ROA, there seem to be no differences between the pre-NIRP period and the NIRP period across different bank business models.

Table 24 reports the (partial) estimation results of equations (3.1) and (3.2) for the effects of short-term interest rates and NIRP on the bank's risk-taking. Looking at columns (1) and (2) of Table 24, it can be concluded that the adoption of NIRP's did not affect banks' financial stability, measured by the Z-score, regardless of their business model. Only for interbank lending-oriented banks, we conclude that when interest rates are already on the negative ground, an additional fall in them leads to a decrease in financial stability higher than that which would occur if interest rates were in positive territory. We also conclude that the adoption of NIRP's did not have a different impact on the credit risk of the different bank business models identified [see columns (3) and (4) of Table 24].

Lastly, looking at columns (5) and (6), we can conclude that in the NIRP period, the investment-oriented banks (type I) and interbank lending-oriented banks adopted more risky investment strategies, which is in line with the idea of "search for yield" presented by Rajan (2005). On the contrary, in the NIRP period, retail-oriented banks implemented less risky strategies. We also verify that when interest rates are already on the negative ground, an additional fall in them leads investment-oriented banks (type I) to increase their risk exposure.

From the analysis carried out, we can conclude for research hypotheses V and VI that the effect of a NIRP in the net interest margin and the investment strategies adopted depends on the business model adopted by the bank. Regarding to overall profitability, credit risk and financial stability, that dependency is not so evident.

Table 23 - Effect of interest rates and NIRP on net interest margin and return on assets by business model

Bank Business Model	Explanatory variables	Net interest margin		Return on assets	
		(1)	(2)	(3)	(4)
Model I	Short-term interest rate	0.129*	0.118	0.203**	0.223**
		(0.070)	(0.074)	(0.099)	(0.106)
	Slope of the yield curve	0.017	0.011	0.155***	0.148***
		(0.018)	(0.019)	(0.044)	(0.038)
	NIRP	0.095		-0.011	
		(0.058)		(0.082)	
	NIRP * Short-term interest rate		-0.066		-0.049
			(0.142)		(0.211)
	NIRP * Slope of the yield curve		0.029**		0.083**
			(0.014)		(0.038)
	Research hypothesis:				
	H1 $[\beta_3 = 0]$	1.639		-0.135	
	H2 $[\alpha_3 - \alpha_4 = 0]$		-0.661		-0.594
	Number of observations	2481	2481	2481	2481
Model II	Short-term interest rate	-0.041	-0.061	0.050	0.044
		(0.047)	(0.049)	(0.079)	(0.088)
	Slope of the yield curve	-0.016	-0.012	0.036	0.045
		(0.021)	(0.021)	(0.062)	(0.060)
	NIRP	-0.163***		-0.055	
		(0.032)		(0.052)	
	NIRP * Short-term interest rate		0.155***		0.162
			(0.063)		(0.121)
	NIRP * Slope of the yield curve		-0.033*		0.139
			(0.017)		(0.103)
	Research hypothesis:				
	H1 $[\beta_3 = 0]$	-5.110***		-1.070	
	H2 $[\alpha_3 - \alpha_4 = 0]$		2.817***		0.188
	Number of observations	4313	4313	4313	4313
Model III	Short-term interest rate	0.042	0.013	-0.218	-0.301
		(0.066)	(0.069)	(0.197)	(0.224)
	Slope of the yield curve	-0.048***	-0.031	0.028	-0.010
		(0.018)	(0.019)	(0.047)	(0.049)
	NIRP	-0.226***		-0.279	
				(0.205)	
	NIRP * Short-term interest rate		0.062		0.488
			(0.181)		(0.367)
	NIRP * Slope of the yield curve		0.040		-0.150***
			(0.027)		(0.048)
	Research hypothesis:				
	H1 $[\beta_3 = 0]$	-2.729***		-1.631	
	H2 $[\alpha_3 - \alpha_4 = 0]$		0.118		1.702*
	Number of observations	4305	4305	4305	4305

(continued)

Table 23 (continued) - Effect of interest rates and NIRP on net interest margin and return on assets by business model

Bank Business Model	Explanatory variables	Net interest margin		Return on assets	
		(1)	(2)	(3)	(4)
Model IV	Short-term interest rate	0.207***	0.176***	-0.211	-0.302
		(0.057)	(0.067)	(0.256)	(0.253)
	Slope of the yield curve	0.017	0.051*	0.124	0.156**
		(0.029)	(0.030)	(0.075)	(0.075)
	NIRP	-0.322***		-0.326	
		(0.114)		(0.740)	
	NIRP * Short-term interest rate		0.596***		1.045
			(0.244)		(0.655)
	NIRP * Slope of the yield curve		-0.103***		-0.040
			(0.020)		(0.057)
	Research hypothesis:				
	H1 $[\beta_3 = 0]$	-2.825***		-0.441	
	H2 $[\alpha_3 - \alpha_4 = 0]$		2.870***		1.638
	Number of observations	951	951	951	951

Note: This table shows the (partial) results of the effects of the adoption of NIRP and interest rates on bank net interest margin and return on assets by business model. In all regressions, explanatory variables are lagged one period and we include bank and time fixed effects to soften eventual endogeneity issues. Section "Research hypothesis" report the t-statistics for the respective hypothesis. Robust standard errors clustered at the bank level are reported below their coefficient estimates. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 24 - Effect of interest rates and NIRP on bank risk-taking by business model

Business model	Explanatory variables	Ln Zscore		NPL ratio		RWA/TA	
		(1)	(2)	(3)	(4)	(5)	(6)
Model I	Short-term interest rate	0.014	0.014	-1.032	-1.291	0.414	0.438
		(0.020)	(0.020)	(0.725)	(0.799)	-1.002	-1.000
	Slope of the yield curve	0.023*	0.024*	-1.811***	-1.803***	0.383	0.324
		(0.012)	(0.013)	(0.273)	(0.259)	(0.474)	(0.501)
	NIRP	-0.007		-0.066		2.780***	
		(0.031)		(0.618)		-1.008	
	NIRP * Short-term interest rate		-0.001		2.245		-5.882***
			(0.078)		-1.752		-2.579
	NIRP * Slope of the yield curve		-0.014		0.142		-0.681
			(0.014)		(0.274)		(0.477)
	Research hypothesis:						
	H3 $[\beta_3 = 0]$	-0.220		-0.108		2.757***	
	H4 $[\alpha_3 - \alpha_4 = 0]$		0.162		1.188		-1.997**
	Number of observations (Banks)	2481	2481	2481	2481	2481	2481
Model II	Short-term interest rate	0.026	0.027	0.088	0.013	1.311***	1.125*
		(0.018)	(0.021)	(0.418)	(0.493)	(0.641)	(0.682)
	Slope of the yield curve	0.022*	0.021*	-0.028	-0.041	0.835***	0.759**
		(0.013)	(0.012)	(0.325)	(0.329)	(0.360)	(0.363)
	NIRP	0.008		-0.136		-0.960*	
		(0.012)		(0.254)		(0.531)	
	NIRP * Short-term interest rate		-0.029		0.282		-0.064
			(0.025)		(0.640)		-1.035
	NIRP * Slope of the yield curve		-0.022*		-0.269		-1.983***
			(0.013)		(0.252)		(0.436)
	Research hypothesis:						
	H3 $[\beta_3 = 0]$	0.710		-0.536		-1.807*	
	H4 $[\alpha_3 - \alpha_4 = 0]$		-0.253		0.816		1.700*
	Number of observations	4313	4313	4313	4313	4313	4313

(continued)

Table 24 (continued) - Effect of interest rates and NIRP on bank risk-taking by business model

Business model	Explanatory variables	Ln Zscore		NPL ratio		RWA/TA	
		(1)	(2)	(3)	(4)	(5)	(6)
Model III	Short-term interest rate	-0.021	-0.042	1.089	1.307*	-0.488	-0.639
		(0.050)	(0.060)	(0.681)	(0.740)	(0.707)	(0.684)
	Slope of the yield curve	0.016	-0.004	-0.217	-0.265	1.421***	0.874**
		(0.012)	(0.012)	(0.305)	(0.321)	(0.404)	(0.409)
	NIRP	-0.070		0.896		-0.019	
		(0.058)		-1.107		(0.677)	
	NIRP * Short-term interest rate		0.031		-2.164		-2.150
			(0.099)		-2.086		-1.837
	NIRP * Slope of the yield curve		-0.073***		-0.121		-1.941***
			(0.013)		(0.284)		(0.431)
	Research hypothesis:						
	H3 $[\beta_3 = 0]$	-1.202		0.809		-0.028	
	H4 $[\alpha_3 - \alpha_4 = 0]$		1.014		-0.969		-0.118
	Number of observations (Banks)	4305	4305	4305	4305	4305	4305
Model IV	Short-term interest rate	-0.016	-0.029	3.942***	4.266***	0.501	2.091
		(0.053)	(0.056)	-1.937	-2.312	-1.379	-1.843
	Slope of the yield curve	0.057**	0.068**	-0.533	-0.468	2.170*	2.122*
		(0.026)	(0.027)	(0.488)	(0.489)	-1.121	-1.171
	NIRP	-0.107		-0.782		4.865**	
		(0.113)		-2.824		-2.246	
	NIRP * Short-term interest rate		0.207*		-2.387		-9.640
			(0.112)		-6.293		-6.132
	NIRP * Slope of the yield curve		-0.029**		-0.540		-1.471***
			(0.014)		(0.349)		(0.543)
	Research hypothesis:						
	H3 $[\beta_3 = 0]$	-0.953		-0.277		2.166**	
	H4 $[\alpha_3 - \alpha_4 = 0]$		1.994**		-0.294		1.338
	Number of observations	951	951	951	951	951	951

Note: This table shows the partial results of the effects of the adoption of NIRP and interest rates on bank risk-taking by business model. In all regressions, explanatory variables are lagged one period and we include bank and time fixed effects to soften eventual endogeneity issues. Section "Research hypothesis" report the t-statistics for the respective hypothesis. Robust standard errors clustered at the bank level are reported below their coefficient estimates. *, ** and *** indicate statistical sign. at 10%, 5% and 1% levels.

Source: Own production

3.7. CONCLUSIONS

Since 2012, several central banks implemented NIRP's intending to boost economic activity and fight low inflation rates by facilitating an increase in the supply of bank loans. These policies have generated controversy with the most sceptics pointing to several factors that might affect the bank's financial stability and raising doubts about the transmission mechanism from negative policy rates to higher bank lending.

This investigation studies the effect of negative interest rates on bank's profitability and risk-taking. Using a sample of 2596 banks from European countries, over the period 2011-2019, we conclude that NIRP implementation lowered the net interest margin of a representative bank by 14.5 b.p., in average. This finding combined with the results of chapter 2 allows to conclude that the increase in market power, measured by the Lerner index, of European banks, in the period analysed, cannot be explained by the behaviour of the banks' net interest margin, as it decreased in the period. The increase in market power may have been explained by the rise in fees and commissions charged and the cut in operating costs.

Despite the rise in the weight of fees and commissions charged by banks, the decrease of the weight of net trading income and the increase of the weight of loan loss provisions led the overall profitability of a representative bank, measured by ROA, to decrease 18.5 b.p. It is interesting to note that despite the decrease in ROA, banks' solvency risk, measured by the Z-score, decreased in a scenario of negative interest rates. This can be explained by the reinforcement of prudential rules, namely, in terms of capital requirements and/or a lower volatility in the returns.

We also conclude that a decrease in short-term interest rates lower net interest margin and the ROA in a more pronounced way when interest rates are already negative than when, they are positive. In a scenario of negative interest rates, banks try to compensate for the decrease in the net interest margin with a more pronounced increase in the net fees and commissions.

Despite the negative effect that the implementation of NIRP had on the net interest margin and the ROA, we do not find that European banks, on average, increased risk-taking. We also conclude that in an environment of negative interest rates, additional decreases in short-term interest rates do not lead banks to take more risk, that is, there is no evidence of the "search for

yield" effect. For this result, once again, the tightening of prudential regulation rules will have been decisive.

Based on the bank assets structures and their sources of financing and using cluster analysis, we identify four different business models: investment-oriented banks (type I), retail-oriented banks, investment-oriented banks (type II) and interbank lending-oriented banks. Our study leads us to conclude that, except for investment-oriented banks (type I), all other banks see their net interest margin decreased with the implementation of the NIRP. This is particularly true for those banks whose main source of finance is retail deposits. We also conclude that, when interest rates are already on the negative ground, an additional fall in them puts greater pressure on the net interest margin of the retail-oriented and interbank lending-oriented banks. Looking at the effect of interest rates and NIRP on ROA, we do not find differences between the pre-NIRP period and the NIRP period across different bank business models. The analysis carried out also make it possible to conclude that the implementation of NIRP did not affect banks' financial stability and credit risk, regardless of their business model. Lastly, we conclude that investment-oriented banks (type I) and interbank lending-oriented banks adopted more risky investment strategies, while retail-oriented banks have adopted less risky investment strategies.

The empirical results obtained in this study require that special emphasis be given, by the regulatory and supervisory entities of European banking systems, to the monitoring of the bank’s profitability and risk-taking that were most affected by the introduction of NIRP's.

3.8. APPENDIX

Table 25 - Variables definition and data source

Variable	Units	Description	Source
Bank profitability:			
Net interest margin	percentage	Difference between interest-earning assets and interest-bearing liabilities divided by total earning assets	BankFocus Database
Return on assets	percentage	Net income divided by total assets	BankFocus Database
Net fee & commission	percentage	Net fee & commission divided by total assets	BankFocus Database
Net trading income	percentage	Net trading income divided by total assets	BankFocus Database
Other operating revenues	percentage	Other operating revenues divided by total assets	BankFocus Database
Loan loss provisions	percentage	Loan loss provisions divided by total assets	BankFocus Database
Bank risk-taking:			
Ln Z-score	logarithm	Z-score is computed as the ratio between the sum of the expected return on assets and the equity to total assets ratio and the standard deviation of the return on assets	BankFocus Database and own calculations
NPL Ratio	percentage	Non-performing loans divided by gross loans	BankFocus Database
RWA / Assets	percentage	Risk-weighted assets divided by total assets	BankFocus Database
Bank-specific variables:			
Size	logarithm	Natural logarithm of total assets	BankFocus Database
Capitalization	percentage	Equity divided by total assets	BankFocus Database
Inefficiency	percentage	Cost-to-income ratio computed as the ratio of operating expenses on net operating income	BankFocus Database
Liquidity	percentage	Liquid assets divided by total assets	BankFocus Database
Share of wholesale funding	percentage	Wholesale funding divided by total funding	BankFocus Database
Asset composition	percentage	Loans and advance to customers divided by total assets	BankFocus Database
Non-interest income share	percentage	Non-interest income divided by operating revenues	BankFocus Database
Interest rate environment measures:			
Short-term interest rate	percentage	3-month interbank rate	Thompson Datastream
Slope of yield curve	percentage	Difference between 10-year Treasury yield and 3-month interbank rate	Thompson Datastream
NIRP	Dummy variable	Takes the value of 1 if a NIRP was adopted and 0 otherwise	Central Banks
Country variables:			
Real GDP growth	percentage	Yearly growth rate of real GDP	Thompson Datastream
Inflation	percentage	Yearly growth rate of the consumer price index	Thompson Datastream
Herfindahl-Hirschman Index (Assets)	units	Measure of market concentration	BankFocus Database and own calculations

Source: Own production

Table 26 - Effect of interest rates and NIRP on net fee & commission income and net trading income

	Net fee & commission		Net trading income	
	(1)	(2)	(3)	(4)
Short-term interest rate	0.012	0.025	0.027	0.027
	(0.014)	(0.015)	(0.020)	(0.021)
Slope of the yield curve	0.005	0.003	0.031***	0.017*
	(0.007)	(0.007)	(0.009)	(0.009)
NIRP	0.081***		-0.052***	
	(0.022)		(0.017)	
L.NIRP * Short-term interest rate		-0.134***		-0.125***
		(0.038)		(0.042)
NIRP * Slope of the yield curve		0.007		-0.106***
		(0.009)		(0.015)
Size	-0.055	-0.056*	0.043	0.045
	(0.034)	(0.034)	(0.050)	(0.048)
Capitalization	0.015	0.015	0.014**	0.010*
	(0.015)	(0.015)	(0.006)	(0.006)
L.Inefficiency	0.000	0.000	-0.002***	-0.002***
	(0.001)	(0.001)	(0.000)	(0.000)
NPL ratio	0.004**	0.004**	-0.004*	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)
Share of wholesale funding	-0.003**	-0.003**	-0.021***	-0.011**
	(0.001)	(0.001)	(0.005)	(0.004)
Asset composition	0.000	0.000	-0.003**	-0.003**
	(0.001)	(0.001)	(0.001)	(0.001)
Non-interest income share	0.001**	0.002**	0.005***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
Real GDP growth	0.007*	0.005	-0.021***	-0.011**
	(0.004)	(0.004)	(0.005)	(0.004)
Inflation	0.003	0.001	-0.030***	-0.019***
	(0.004)	(0.005)	(0.006)	(0.006)
HHI	-0.065	0.211	-0.538***	-0.123
	(0.257)	(0.194)	(0.163)	(0.138)
Constant	0.819***	0.829***	-0.122	-0.063
	(0.292)	(0.293)	(0.410)	(0.403)
Research hypothesis:				
Hypothesis I $[\beta_3 = 0]$	3.727***		-3.048***	
Hypothesis II $[\alpha_3 - \alpha_4 = 0]$		-3.723***		-0.458
Number of observations	12050	12050	12050	12050
Number of Banks	2562	2562	2562	2562
R-Squared	0.038	0.037	0.102	0.126
F-Test	11.83***	11.06***	23.71***	25.70***

Note: This table shows the results of the effects of the adoption of NIRP and interest rates on net fee & commission income and net trading income. In all regressions, explanatory variables are lagged one period and we include bank and time fixed effects to soften eventual endogeneity issues. Section "Research hypothesis" report the t-statistics for the respective hypothesis. Robust standard errors clustered at the bank level are reported below their coefficient estimates. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Table 27 - Effect of interest rates and NIRP on other operating revenues and loan loss provisions

	Other operating revenues		Loan loss provisions	
	(1)	(2)	(3)	(4)
Short-term interest rate	-0.121	-0.140	0.298***	0.342***
	(0.106)	(0.123)	(0.095)	(0.100)
Slope of the yield curve	-0.206	-0.222	-0.013	-0.041*
	(0.163)	(0.175)	(0.021)	(0.024)
NIRP	-0.321		0.103**	
	(0.239)		(0.049)	
NIRP * Short-term interest rate		-0.003		-0.748***
		(0.075)		(0.139)
NIRP * Slope of the yield curve		-0.176		-0.180***
		(0.131)		(0.057)
Size	-0.159*	-0.160*	0.259***	0.254***
	(0.082)	(0.082)	(0.082)	(0.080)
Capitalization	0.003	-0.003	0.008	0.003
	(0.005)	(0.009)	(0.012)	(0.013)
Inefficiency	0.003***	0.003***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
NPL ratio	0.001	0.004	0.000	0.004
	(0.002)	(0.003)	(0.006)	(0.005)
Share of wholesale funding	0.003	0.002	0.009***	0.007***
	(0.003)	(0.002)	(0.002)	(0.003)
Asset composition	0.000	-0.002	0.013***	0.012***
	(0.002)	(0.002)	(0.003)	(0.002)
Non-interest income share	0.001	-0.001	-0.001	-0.001
	(0.001)	(0.003)	(0.001)	(0.001)
Real GDP growth	-0.155	-0.136	-0.031***	-0.014*
	(0.119)	(0.105)	(0.007)	(0.008)
Inflation	0.087	0.109	-0.012	0.003
	(0.068)	(0.084)	(0.018)	(0.017)
HHI	8.890	8.530	-0.686*	0.636*
	(6.836)	(6.561)	(0.388)	(0.361)
Constant	1.265**	1.359**	-2.484***	-2.322***
	(0.597)	(0.655)	(0.695)	(0.669)
Research hypothesis:				
H1 $[\beta_3 = 0]$	-1.340		2.079**	
H2 $[\alpha_3 - \alpha_4 = 0]$		1.022		-4.145***
Number of observations	12050	12050	12050	12050
Number of Banks	2562	2562	2562	2562
R-Squared	0.007	0.008	0.095	0.123
F-Test	2.00***	2.02***	16.61***	16.69***

Note: This table shows the results of the effects of the adoption of NIRP and interest rates on other operating revenues and loan loss provisions. In all regressions, explanatory variables are lagged one period and we include bank and time fixed effects to soften eventual endogeneity issues. Section "Research hypothesis" report the t-statistics for the respective hypothesis. Robust standard errors clustered at the bank level are reported below their coefficient estimates. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

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4. DOES CORPORATE SOCIAL PERFORMANCE IMPROVE BANK'S EFFICIENCY? EVIDENCE FROM EUROPEAN BANKING

4.1. INTRODUCTION

In a global and competitive market, banks, like other companies, must present themselves as socially responsible organizations. Throughout the advent of globalization, environmental pollution, and scarcity of resources, banks and other large companies, are facing huge pressure to manage their business in a more socially responsible way (Gao, 2009). The financial crisis in 2008 also conducted to increasing attention to corporate social responsibility (CSR, henceforth), that is, the "company activities demonstrating the inclusion of social and environmental concerns in business operations, and in interactions with stakeholders, also according to the ambition levels of corporate sustainability'' (Islam et al., 2012). CSR is now considered as an essential tool to recover corporate credibility and customers' trust, what is called corporate reputation. The improvement of employees' motivation, the desire to be perceived as an innovative organization, or the establishment of beneficial relationships with stakeholders are other reasons for this concern (Pérez et al., 2013; Izquierdo & Vicedo, 2009).

According to Greenbaum & Thakor (2007), cited by Scholtens & Zhou (2008), banks act as financial intermediaries in our society: they price and value financial assets, they monitor borrowers, they manage financial risks and they organize the payment system. By carrying out these functions, banks have a huge impact on society and because of that, traditionally, face strong scrutiny, which justifies the big efforts to maintain corporate credibility and customers' trust (Pérez et al., 2013). As a result, banks are increasing their social responsibility practices, reinforcing their credibility and the trust that their stakeholders have in them (Coulson, 2009). These include the publication of sustainability reports following the Global Reporting Initiative (GRI) guidelines, the adoption of the Equator Principles and the Global Compact, and the inclusion of environmental risk assessments in their credit policies, among other practices. This is due, among other reasons, to the recommendations of the European Union (Miralles-Quirós et al., 2019).

This growing concern with the development of sustainable organizations has led many academics to investigate whether corporate social performance (CSP, henceforth), as a measure of CSR, can improve a firm's financial standing. In the banking industry, existing studies show that CSP has an impact on banks' financial performance (Esteban-Sanchez et al., 2017; Bătae et al., 2021), their market value (Miralles-Quirós et al., 2019; Azmi et al., 2021); and their financial risk (Neitzert & Petras, 2019). Some studies have concluded that CSP has a positive effect on banks' financial performance (Simpson & Kohers, 2002; Wu & Shen, 2013), others found a U-shaped relationship (Barnett & Salomon, 2012) and others concluded by an insignificant relationship (Graves & Waddock, 1999). Most of these studies analysed the relationship between CSP and traditional financial measures, such as ROA, ROE and stock price.

Our study, using a directional distance function approach, analyse the relationship between CSP and each of its dimensions with bank efficiency for European banking. We use an unbalanced panel data dataset of 108 listed banks, with 740 bank/year observations, operating in 21 European countries, over the period 2011-2019 and employed the semi-parametric two-stage double bootstrap method introduced by Simar & Wilson (2007) that enable us to obtain a more reliable measure of bank efficiency and identify their relationship with CSP.

As the main contributions of our work, we can highlight the following. First, unlike most studies that have focused on investigating the relationship between CSP and the bank's financial performance, our work focuses on the relationship between CSP and bank's efficiency, which is still very scarce. Second, considering that the different dimensions of the CSP can compensate each other, we analysed the individualized impact that each dimension has on banking efficiency. Third, at the methodological level, we used the two-stage double bootstrap DEA (data envelopment analysis) approach that allows us to obtain results more robust and reliable than the techniques traditionally used in this line of research. Finally, instead of using the CSP measures provided by some databases, which according to some authors suffers from some inaccuracy and subjectivity, we constructed CSP indexes using DEA models without explicit inputs, that according to our knowledge never been used so far in banking industry.

Our main results are as follows. We found a U-shaped relationship between CSP and efficiency, indicating that banks with lower or higher CSP levels are more efficient. At a disaggregated level, the same conclusion is drawn for the social and governance dimensions of

CRS activities. The environmental dimension seems does not to have any impact on the bank's efficiency.

The rest of the chapter is organized as follows. Subchapter 4.2. reviews the literature on CSP and efficiency. In Subchapter 4.3. is presented the methodology. Subchapter 4.4 describes the data and variables used. Subchapter 4.5 presents and discuss the main results. Subchapter 4.6 presents robustness tests and Subchapter 4.7. concludes.

4.2. Literature Review and Research Hypothesis

In this subchapter, we review the literature on the relationship between CSP in its three dimensions, environmental, social and governance (ESG, henceforth), and bank's financial performance.

The matter of whether banks should incorporate social responsibility practices into their management strategies designed to meet the expectations of their different stakeholders leads to two opposing theoretical positions, in favour and against (Miralles-Quirós et al., 2019). On the one hand, the trade-off view of CRS activity, that considers the investment in this type of activities as a potentially inefficient use of resources. This view is inspired by neoclassical economics and the majority of management theories that are based on the assumption that the key corporate objective is maximize the firm's value (Eccles et al., 2014). The neoclassical theory, established by Friedman (1970), argues that the company has the responsibility to employ its resources on activities aiming to maximize its profits, acting appropriately with the basic rules of society, law and ethical customs. In this view, shareholders are seen as the key stakeholders of the company and, by this, the resources are allocated to satisfy this group. Satisfying any other stakeholder groups would negatively impact firm performance (Brown & Caylor, 2006). In short, companies should maximize profit. When this is achieved, the contribution of the company to society will be optimized (Friedman, 1970). The neoclassical position, therefore, maintains that the management of the company should only be concerned with the interest of its owners or shareholders (Miralles-Quirós et al., 2019). Any other activity that obstructs the company from maximizing the value for the shareholder will be considered unacceptable since a misallocation of resources will be incurred.

According to the agency theory, when the interests of managers are not aligned with those of shareholders, the former invest in CRS activities in their own interest (Jensen & Meckling, 1976). In particular, because investment in this type of activity is well regarded by society in general, managers build a good image and reputation at the expense of the company. Jiraporn & Chintrakarn (2013) demonstrate that managers who are less entrenched are more likely to increase CSR activity than other CEOs. This is likely due to the private benefits and reputational benefits afforded by CRS activity.

In disagreement with the views presented, we find the stakeholder theory developed by Freeman (1984). This theory states that a company does not belong just to owners or shareholders, meaning that it must be considered the mass of agents involved in it. In this sense, the objective of the company should not be to maximize value for the shareholder, but instead, the company should create value for all the stakeholders including employees, consumers, local communities, natural or environmental resources. Some authors, such as Post et al. (2002), argue that companies should apply those social, environmental, and corporate governance aspects that are necessary, regardless of the costs incurred or the income they produce. Stakeholder theory suggests that environmental, social and governance practices are important issues for stakeholders. The conceptualization made by Carroll (1991) and Wood (1991) about CSR includes a stakeholder approach in which any party, including employees, customers, shareholders, environment, society, and investors, who might be affected by the business activities of organizations, should be considered as a stakeholder of an organization.

The resource-based view sees investment in CRS activities as being strategic that allow the company to gain competitive advantages by acquiring additional skills that are difficult to replicate (Russo & Fouts, 1997). This means that an increment in corporate social performance improves financial performance.

On the other hand, authors like Porter & Kramer (2011) claim that the company's objective as to be the maximization of shareholder value while, at the same time, trying to incorporate social, environmental and corporate governance measures into management, as a way to create shared value for the company and society. In other words, it is important to know whether these measures are profitable for the company, in the sense that they allow shareholder value to be maximized.

Miralles-Quirós et al., (2019), in their study about the relationship between ESG performance and shareholder value creation in the banking industry, presents a summary of the recent studies about this controversy, underlining that previous empirical evidence for the banking industry presents inconclusive results. Simpson & Kohers (2002) provided evidence of a positive and significant relationship between CSR activities and the performance of the company. Later, Soana (2011) showed that there is no statistically significant link between the two measures of performance for a sample of Italian banks. Wu & Shen (2013), with a sample of 162 banks from 22 countries covering the period 2003–2009, observed that CSR is positively associated with financial performance in terms of return on assets, return on equity, net interest income, and non-interest income. On the contrary, CSR is negatively associated with unproductive loans. Meanwhile, Cornett et al. (2016) analysed the relationship between CSR and financial performance in US banks during the financial crisis. Their results indicate that larger banks perform significantly more CSR activities than smaller banks. Mixed results were obtained by Esteban-Sanchez et al. (2017) when analysing the effect of different CSR dimensions on the financial performance of 154 banks in 22 countries, before and during the years of the financial crisis. Belasri et al. (2020), using an international sample of 184 banks in 41 countries over the 2009-2015 period, founds evidence that CSR has a positive impact on bank efficiency in developed countries, in countries where investor protection is high and in countries featuring a high degree of stakeholder orientation. Shah et al. (2019) using a sample of 45 banks from 14 countries for a period of nine years (2010-2018) founded evidence that sustainable banks are more efficient and productive. In a more recent study for 39 European banks, for the period from 2010–2019, Bătae et al. (2021) find mixed results for the relationship between the corporate financial performance and the different dimensions of CSR activities. They concluded by a positive relationship between emissions reductions and financial performance. The same cannot be concluded for its product quality and social responsibility policies. Regarding the corporate governance dimension, they concluded that an increase in its quality negatively affects the bank's financial performance.

Belasri et al. (2020) suggest that various reasons are pointing that ESG activities could have an impact on bank's inputs and outputs, and as a result on bank efficiency: CSR activities can help firms build a strong reputation (Branco & Rodrigues, 2006; Hillman & Keim, 2001) which can, in turn, provide many benefits such as an increased ability to attract and retain valuable employees (Branco & Rodrigues, 2006; Bătae et al. (2021). Increased employee

productivity and loyalty are associated with better management of human capital resources or, from an efficiency perspective, a better use (processing) of inputs. On the other hand, customers may be willing to accept a lower rate on their deposits if it comes from a bank with strong CSP (Wu & Shen, 2013). In the case of banks, a good reputation could therefore increase profit by enabling banks to attract new customers and charge higher interests on their loans. Also, a strong CSR-induced reputation can provide banks with the ability to charge higher fees and commissions on other services (Wu & Shen, 2013). This expected positive impact of CSR on both interest and non-interest income indicates that CSP could increase a bank's outputs. Consistent with these arguments and in line with stakeholder theory, we can formulate the following hypothesis:

Hypothesis I: *CSP has a positive impact on banking efficiency.*

4.2.1. CSP Dimensions and Bank's Efficiency

As noted by Xie et al. (2019), ESG activities are the result of management policies and legal obligations and comprise different dimensions. Naturally, these different dimensions have a different contribution to the CSP, depending on the activity of the company.

The environmental dimension of CSP is a highly researched subject, but the relationship between environmental practices and corporate efficiency remains inconclusive (Ambec et al., 2013). The neoclassical traditional view argues that environmental regulations represent an additional cost to the company that reduce profitability and lead to low efficiency (Friedman, 1970). In contrast, Porter & van der Linde (1995) argue that environmentally friendly regulation promotes technological innovation in companies, creating efficiencies that more than offset additional costs. Although banks are not seen as polluters in comparison, for example, with chemical or oil companies, banks use a considerable amount of resources such as energy and paper and generate indirect carbon emissions (Bătae et al., 2021). By investing in renewable energy for office buildings, offering eco-friendly services such as e-banking apps, switching paper by electronic documents, banks can reduce the operational costs improving their environmental performance.

According to the resource-based view on environmental practices, pollution prevention and product stewardship can become a source of competitive advantage, through differentiation or

cost savings (Hart, 1995). However, Finger et al. (2018) consider that in the banks of developed countries environmental management is a form of window-dressing in the sense that banks have already optimized their processes to the point that more environmental measures do not bring significant improvements in their sustainability performance.

In line with stakeholder theory, banks that implement environmentally responsible practices are more likely to create positive stakeholder perceptions, resulting in improved economic performance (Sila & Cek, 2017). Although some studies (e.g., Wagner et al., 2002) reported a negative relationship between these two variables, others (e.g., Bătae et al., 2021) found a positive relationship. In this study, we posit that environmental performance is positively related to bank's efficiency:

Hypothesis II: *Environmental performance is positively related to banking efficiency.*

Social performance refers to how the organization treats its employees, the community and the customers, through responsibility in their products and services (Miralles-Quirós et al., 2019). According to Rhouma et al. (2014), stakeholders greatly appreciate the implementation of different social practices by organizations. These practices are, among others, those related to employees' rights, their training and career development, issues related to customers and the support of social causes. Starting from within the organization, stable and fair relationships between employees and management will lead to higher personal satisfaction and loyalty (Birindelli et al., 2015), contributing to an increase in corporate efficiency.

In line with the Equator Principles, a socially responsible bank must optimize its credit portfolio to finance socially responsible investments. Wu & Shen (2013) argue that a bank that engages in CSR activities builds a strong loyalty with its customers that allows it to pay a lower interest rate on deposits, charge a higher interest rate on loans and higher fees and commissions on other services, improving the financial performance and efficiency. In this sense, we can highlight the works of Simpson & Kohers (2002) that observed that banks that are more involved with the community in which they operate achieve greater financial performance. Fombrun (2005) also refers those social practices can serve as a marketing tool for companies to increase demand for their products and services. Based on the referred arguments, we hypothesize that

Hypothesis III: *Social performance has a positive impact on banking efficiency.*

Corporate governance is defined as the organisation's code of conduct to ensure whether board members and executives actions are compatible with the stakeholder's interests (Esteban-Sanchez et al., 2017). Miralles-Quirós et al. (2019) refer to corporate governance as how the power is exercised and how decisions are made in a bank that guarantees that members of its board of directors and executives act in the best interest of their long-term shareholders. The scope of corporate governance also embraces business ethics, disclosure and accountability (Shakil et al., 2019). Strong corporate governance may influence the financial performance of banks. Esteban-Sanchez et al. (2017) find a significant positive relationship between corporate governance and bank financial performance in an international sample that includes most developed country banks. Besides, Soana (2011) also find a positive link between corporate governance and the performance of the assets of the Italian banks analysed. Based on the agency's theory, it is expected that in banks with better governance models, shareholders and managers interests are better aligned, resulting in higher levels of efficiency. This leads us to formulate the following research hypothesis:

Hypothesis IV: *The relationship between corporate governance quality and banking efficiency is positive.*

4.2.2. A Non-Linear Relationship Between CSP (and each of its dimensions) and Bank's Efficiency

In an attempt to reconcile the two opposing views on the relationship between CSP (and each of its dimensions) and banking efficiency and in line with the studies of Nollet et al. (2016) and Shabbir et al. (2020), we also test whether the relationship between those two variables it is non-linear. It seems reasonable to admit that for low levels of CSR activity, as it increases, bank efficiency decreases because CSR activity costs do not yet cover its benefits. However, it is expected that after a certain level of CSR activity, an increase in CSR activity will have a positive impact on bank efficiency. This means that the most efficient banks will have low or high levels of CSP. Banks with an intermediate level of CSP will be the least efficient. Based on this idea, we formulate the following research hypothesis:

Hypothesis V: *The relationship between CSP (and each its dimensions) and banking efficiency is non-linear.*

4.3. METHODOLOGY

To investigate the formulated hypotheses, we will have to measure bank efficiency. Over time, in operational research, several techniques, both parametric and nonparametric, have been used to measure corporate efficiency. Among non-parametric techniques, Data Envelopment Analysis (DEA) has been extensively used for the efficiency evaluation of banks. Radojicic et al. (2018) present an excellent review of research that uses the DEA technique in the study of bank efficiency. The efficiency measurement indicates whether a bank maximizes the output quantity by using the given quantity of inputs or minimize the quantity of inputs used to produce a given output quantity.

We apply Simar & Wilson (2007) method in a two-stage procedure to estimate bank efficiency and study its relationship with CSP and its components. In general, two major problems arise when the analysis is based on a conventional two-step procedure: (i) the lack of a well-defined data generating process (e.g., inappropriate censored regression) and (ii) misleading inference. To overcome these problems, Simar & Wilson (2007) proposed a double-bootstrap DEA approach that is grounded on a statistical theory. In the first stage, it combines the classical DEA model with the bootstrap procedure to estimate the relative efficiency scores and confidence intervals. In the second stage, efficiency estimates are regressed on a set of explanatory variables, including ESG variables, using the truncated regression with bootstrap. The authors proposed two algorithms to implement the two-stage procedure described. We use algorithm II, which is more involved and rests on bias-corrected DEA scores as the left-hand-side variable of the truncated regression from the second stage.

Stage 1: Estimation of Efficiency Scores

Using linear programming, the DEA technique allows to estimate the production frontier and calculate the efficiency score of a DMU (Decision Making Unit) to homogeneous entities. Our study focuses on European banking and assumes that the banks considered have similar characteristics and have a common production frontier: (i) common economic objective

(maximize the shareholder wealth), (ii) similar activities (most perform the typical activities of commercial banking), (iii) similar regulatory environment and (iv) similar legal form.

Since the original work of Charnes et al. (1978) many DEA models have been proposed in the literature (static or dynamic, with constant or variable returns to scale). The most popular are the CCR (Charnes, Cooper and Rhode, 1978) and the BCC (Banker, Charnes and Cooper, 1984) models. Both are based on radial efficiency measurements and can be carried out from both orientations (either input or output). The CCR model is based on the assumption of constant returns to scale (CRS) and the BCC model assumes that the evaluated entity may be operating under the variable returns to scale (VRS) hypothesis, implying that the relative efficiency of each DMU is obtained by comparing that DMU with those that are efficient and possess similar operational dimensions. The CRS assumption is only justifiable when all DMUs are operating at an optimal scale. However, banks or DMUs in practice might face either economies or diseconomies to scale, so in this work, following Grmanová & Ivanová (2018), we used the BCC model. The VRS assumption provides the measurement of pure technical efficiency, which is the measurement of technical efficiency devoid of scale efficiency effects (Řepková, 2014).

We considered the output orientation since banks usually aim to maximize profits with an adequate combination of productive factors (inputs).

For each period t (t = 1, 2, …,T), consider that exists n_t DMUs (i = 1, 2, …, n_t), for which we considered a set of q outputs (r = 1, 2,…,q) that produce $Y_{it} = \{y_{rit}\}$ and p inputs (s = 1, 2,…,p) that consume $X_{it} = \{x_{sit}\}$. The BCC model, with output orientation, maximizes the output keeping unchanged the inputs and can be mathematically represented as:

$$Max\ \theta_{0t} \tag{4.1}$$

subject to:

$$x_{s0t} - \sum_{i=1}^{n_t} \lambda_{it} x_{sit} \geq 0 \qquad s = 1, 2, \dots, p \tag{4.2}$$

$$\sum_{i=1}^{n_t} \lambda_{it} y_{rit} - \theta_{0t} y_{r0t} \geq 0 \qquad r = 1, 2, \dots, q \tag{4.3}$$

$$\sum_{i=1}^{n_t} \lambda_{it} = 1 \tag{4.4}$$

$$\lambda_{it} \geq 0 \qquad i = 1, 2, \ldots, n_t \tag{4.5}$$

where θ_0 is the efficiency score of DMU_0 and λ is the weight. More precisely, θ_0 represents how much all outputs must be multiplied, keeping inputs unchanged, for the DMU_0 to reach the efficient frontier. If θ_0 is equal to 1, the DMU_0 is efficient, if θ_0 is greater than 1, the DMU_0 is inefficient and higher values mean more inefficiency.

Because the empirical study was carried out on panel data, we estimate the value of θ for each bank using a one-year window, as suggested by Charnes et al. (1994).

One of the weaknesses of the DEA methodology is that it tends to generate biased estimates of θ. To correct this weakness, we use the procedure proposed by Simar & Wilson (2000) bootstrapping the initial efficiency scores and obtaining bias-corrected efficiency estimations $\hat{\hat{\theta}}_{it}$.

Stage 2: Estimation of Truncated Regression

Next, to determine the effect of CSP and each of its dimensions on the bank's efficiency, we estimate a truncated regression model using algorithm II proposed by Simar & Wilson (2007) where the efficiency score, from the first stage, is regressed against a set of variables that could potentially explain the bank's efficiency, including the CSP variable and its three dimensions.

The second stage regression is given by:

$$\hat{\hat{\theta}}_{it} = \delta CSP_{it} + \beta Z_{it} + \eta D_t + \varepsilon_{it} \tag{4.6}$$

where $\hat{\hat{\theta}}_{it}$ is the dependent variable, the bootstrapped bias-corrected efficiency score of bank i in year t; CSP_{it} is a variable that measures CSR of bank i in year t or one of each of its dimensions; Z_{it} is a vector of control variables that are expected to explain bank efficiency; D_t is a vector of year dummies; δ, β and η are the parameters to be estimated in the second stage;

ε_{it} is an independent error that follows the normal distribution with a zero mean and σ_ε^2 variance $N(0, \sigma_\varepsilon^2)$ with left-tail truncation $(1 - \delta CSP_{it} - \beta Z_{it} - \eta D_t)$.

To implement algorithm II proposed by Simar & Wilson (2007), we have to carry out the following steps:

1. For each year $t = 1, 2, \dots, T$, using original data of outputs, Y_{it}, and inputs, X_{it} (that are all positive), estimate DEA efficiency scores for each bank, $\hat{\theta}_{it}$;
2. Use the method of maximum likelihood to obtain estimates $\hat{\delta}$, $\hat{\beta}$ and $\hat{\eta}$ of δ, β and η, respectively, as well an estimate $\hat{\sigma}_\varepsilon$ of σ_ε in the truncated regression of $\hat{\theta}_{it}$ on CSP_{it}, Z_{it} and D_t in (4.6) using the observations when $\hat{\theta}_{it} > 1$;
3. For each $i = 1, 2, \dots, n_t$ and $t = 1, 2, \dots, T$, loop over the next four ([3.1.]-[3.4.]) steps L_1 times to obtain a set of bootstrap estimates $\mathfrak{B} = \{\hat{\theta}_{it}^b\}_{b=1}^{L_1}$:
   3.1. Generate the residual $\tilde{\varepsilon}_{it}$ from the normal distribution $N(0, \hat{\sigma}_\varepsilon^2)$ with left-truncation at $\left(1 - \hat{\delta} CSP_{it} - \hat{\beta} Z_{it} - \hat{\eta} D_t\right)$
   3.2. Compute $\tilde{\theta}_{it} = \hat{\delta} CSP_{it} + \hat{\beta} Z_{it} + \hat{\eta} D_t + \tilde{\varepsilon}_{it}$
   3.3. Set $X_{it}^* = X_{it}$ and $Y_{it}^* = Y_{it}\left(\hat{\theta}_{it}/\tilde{\theta}_{it}\right)$
   3.4. Use X_{it}^* and Y_{it}^* to estimate the pseudo-DEA efficiency scores $\hat{\theta}_{it}^b$;
4. For each $i = 1, 2, \dots, n_t$ and $t = 1, 2, \dots, T$, compute the bias-corrected efficiency as:

$$\hat{\hat{\theta}}_{it} = \hat{\theta}_{it} - \widehat{bias}_{it}$$

$\widehat{bias}_{it}$ is the bootstrap estimator of bias, according to Simar & Wilson (1998):

$$\widehat{bias}_{it} = \left(\frac{1}{L_1}\sum_{b=1}^{L_1} \hat{\theta}_{it}^b\right) - \hat{\theta}_{it}$$

5. Use the method of maximum likelihood to estimate the truncated regression of $\hat{\hat{\theta}}_{it}$ on CSP_{it}, Z_{it} and D_t to obtain estimates $\hat{\hat{\delta}}$, $\hat{\hat{\beta}}$ and $\hat{\hat{\eta}}$ of δ, β and η, respectively, as well an estimate $\hat{\hat{\sigma}}_\varepsilon$ of σ_ε;

6. For each $i = 1, 2, \dots, n_t$ and $t = 1, 2, \dots, T$, loop over the next three ([6.1.]-[6.3.]) steps L_2 times to obtain a set of bootstrap estimates $\mathfrak{D} = \left\{\hat{\hat{\delta}}^b,\ \hat{\hat{\beta}}^b, \hat{\hat{\eta}}^b, \hat{\hat{\sigma}}_\varepsilon^b\right\}_{b=1}^{L_2}$:

   6.1. Generate the residual $\tilde{\tilde{\varepsilon}}_{it}$ from the normal distribution $N\left(0, \hat{\hat{\sigma}}_\varepsilon^2\right)$ with left-truncation at $\left(1 - \hat{\hat{\delta}} CSP_{it} - \hat{\hat{\beta}} Z_{it} - \hat{\hat{\eta}} D_t\right)$

   6.2. Compute $\tilde{\tilde{\theta}}_{it} = \hat{\hat{\delta}} CSP_{it} + \hat{\hat{\beta}} Z_{it} + \hat{\hat{\eta}} D_t + \tilde{\tilde{\varepsilon}}_{it}$

   6.3. Use the maximum likelihood method to estimate the truncated regression of $\tilde{\tilde{\theta}}_{it}$ on CSP_{it}, Z_{it} and D_t to obtain estimates bootstrap estimates $\hat{\hat{\delta}}^b$, $\hat{\hat{\beta}}^b$ and $\hat{\hat{\eta}}^b$ of δ, β and η, respectively, and $\hat{\hat{\sigma}}_\varepsilon^b$ of σ_ε;

7. Calculate confidence intervals and standard errors for $\hat{\hat{\delta}}$, $\hat{\hat{\beta}}$, $\hat{\hat{\eta}}$ and $\hat{\hat{\sigma}}_\varepsilon$ from the bootstrap distribution of $\hat{\hat{\delta}}^b$, $\hat{\hat{\beta}}^b$, $\hat{\hat{\eta}}^b$ and $\hat{\hat{\sigma}}_\varepsilon^b$.

In the empirical investigation, a truncated regression including also a quadratic term of CSP_{it} was estimated to investigate the hypothesis of a non-linear relationship between CSP and bank efficiency (Hypothesis V).

To estimate regression (4.6), we need to obtain a measure for the bank's CSP and each of its dimensions. This concept is nowadays widely recognized in the academic and professional world as a multidimensional construct that essentially covers three aspects related to environmental, social and governance issues. This multidimensionality implies that a unidimensional quantitative index is needed to account for the simultaneous organizational aspects when assessing CSP (Belu & Manescu, 2013). In the past, many empirical studies frequently employed the Kinder, Lydenberg, Domini (KLD) data set which has become the standard measure of CSP in academic research (Mattingly, 2017). However, many researchers have questioned the weighting system used by the KLD and other indexes provided by CRS rating agencies in aggregating the different CSP dimensions into one single measure (Crane et al., 2017). According to Capelle-Blancard & Petit (2017), this aggregation process suffers from some inaccuracy and subjectivity and should not be the same across sectors.

To overcome these measurement issues, we resort to the DEA models without explicit inputs (DEA-WEI models)[24] initially proposed by Lovell & Pastor (1999). DEA-WEI models are suitable when input variables are not available and the focus of many evaluation activities lies in the performance rather than the efficiency of assessed DMUs (Lahouel et al., 2021). In our empirical analysis, we construct four DEA indexes (a global CSP index, an environmental index, a social index, and a corporate governance index), where no particular quantity is considered as an input and the different dimensions of CSP are the outputs. While it is obvious that achieving a given level of CSP might require material inputs, it is usually not clear how these are converted into CSP scores. So, we treat each as a stand-alone unit, without identifying the various inputs that are involved in obtaining the ESG–related accomplishments.

Considering that for each period t (t = 1, 2, …, T) exists n_t DMUs (i = 1, 2, …, n_t), with s attributes in terms of CSP (g = 1, 2, …, s) given by $Y_{it} = \{y_{git}\}$, the BCC-WEI model, with output orientation, that maximizes the performance in terms of CSP can be mathematically represented as:

$$Max\ \phi_{0t} \tag{4.7}$$

subject to:

$$\sum_{i=1}^{n_t} \lambda_{it} y_{git} - \theta_{0t} y_{g0t} \geq 0 \qquad g = 1, 2, \dots, s \tag{4.8}$$

$$\sum_{i=1}^{n_t} \lambda_{it} = 1 \tag{4.9}$$

$$\lambda_{it} \geq 0 \qquad i = 1, 2, \dots, n_t \tag{4.10}$$

where $\phi_0 \geq 1$ represents an index of performance in terms of CSP of DMU_0 and λ is the weight. Higher values of ϕ_0 means that DMU_0 performs worse than others DMUs in terms of CSP. As in determining the bank's efficiency, we estimate the value of ϕ for each bank using a one-year window and bootstrap the initial coefficients, using the procedure of Simar & Wilson (2000), to obtain bias-corrected estimations $\hat{\hat{\phi}}_{it}$.

[24] Belu & Manescu (2013) apply the same approach to construct a CSR index for a sample of 405 non-financial large publicly traded companies listed on the main international stock exchanges. Lahouel et al. (2021) apply this approach to airline industry.

4.4. DATA AND VARIABLES

Our dataset consists of an unbalanced panel data sample of 108 European listed banks observed over the period 2011–2019 for which ESG data were available in the Thomson Reuters Eikon Asset 4 ESG database. The sample consists of 740 bank/year observations and its distribution by country, in terms of the number of banks, is the following: Austria (3), Belgium (3), Czech Republic (2), Denmark (4), Finland (2), France (4), Germany (6), Greece (4), Hungary (1), Ireland (4), Italy (15), Liechtenstein (1), Netherlands (3), Norway (7), Poland (10), Portugal (2), Romania (2), Spain (8), Sweden (5), Switzerland (9) and United Kingdom (13). The bank's accounting data used in the present research was obtained in Moody's Analytics BankFocus database, with all data converted to euros. Macroeconomic data has been taken from Thompson Datastream.

4.4.1. DEA Specification for Bank's Efficiency

The estimation process of the DEA model starts with the selection of potential model variables, i.e., the combination of inputs and outputs. The selection could be based on three basic approaches to banking: intermediation approach, production approach and profitability approach (Titko et al., 2014). The intermediation approach emphasizes the role of financial intermediary played by banks, treating loans and securities as outputs and deposits, labour and capital as inputs (Barros et al., 2011). The production approach assumes that banks use capital and labour to offer different kinds of banking services including loans but also deposits (Staub et al., 2010). Finally, the profitability approach is quite similar to the production approach but with outputs oriented for profitability such as interest income and non-interest income (Avkiran, 2015).

Because we are interested in measuring the efficiency of the whole bank, not just the branches of the bank, the intermediation approach was used, and the following potential inputs and outputs were considered:

- Inputs: Personnel Expenses (I)PE, Deposits (I)DEP, Fixed Assets(I)FA, and Average Cost of Labour (I)ACL.
- Outputs: Loans (O)L, Earning Assets (O)EA and Non-Interest Income (O)NII.

To select which inputs and outputs to include in the final DEA model, many researchers have suggested several methods (see, e.g., Jenkins & Anderson, 2003). The simplified method to determine relevant variables is to omit highly correlated ones from the list (Luo et al., 2012).

Table 28 and Table 29 shows the descriptive statistics and Spearman rank correlation test, respectively, for the potential inputs and outputs, in the period 2011-2019 (monetary values in millions of euros).

Table 28 - Descriptive statistics of potential inputs and outputs for the efficiency model

	(I)PE	(I)DEP	(I)FA	(I)ACL	(O)L	(O)EA	(O)NII
Mean	2454.8	131250.1	2193.2	0.0776	172475.0	284659.8	3202.5
Median	667.5	37208.5	511.5	0.0713	48132.5	64448.5	847.5
Std. Dev.	3798.3	200466.2	4092.1	0.0465	242305.1	445305.6	5233.3
Min	9.0	77.0	1.0	0.0092	472.0	2056.0	0.0
Max	18279.0	1281035.0	34262.0	0.2957	1251085.0	2148107.0	41268.3
Obs.	740	740	740	740.0	740	740	740

Source: Own production

Table 29 - Spearman rank correlation coefficients

	(I)PE	(I)DEP	(I)FA	(I)ACL	(O)L	(O)EA	(O)NII
(I)PE	1						
(I)DEP	0.937***	1					
(I)FA	0.921***	0.916***	1				
(I)ACL	0.217***	0.117***	0.057	1			
(O)L	0.921***	0.938***	0.858***	0.314***	1		
(O)EA	0.930***	0.936***	0.860***	0.271***	0.991***	1	
(O)NII	0.941***	0.904***	0.851***	0.334***	0.843***	0.876***	1

*, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Based on the correlation analysis, we considered the inputs combinations in which the Spearman rank correlation coefficient is less than 0.9. This led us to consider the combinations between the input *Average Cost of Labour* and the other three inputs. Because it is theoretically not very plausible to consider a production function where the *Average Cost of Labour* and *Personnel Expenses* are both inputs, we exclude this combination. Looking at the correlation coefficients between the outputs, we can conclude that the *Earning Assets* are highly correlated with *Loans*. Because our sample is essentially formed by commercial banks, whose main output is loans, we considered as outputs of the DEA model the *Loans* and the *Non-Interest Income*. So, we considered the following two alternative models:

Model 1: (I)DEP, I(ACL), (O)L and O(NII)

Model 2: (I)FA, I(ACL), (O)L and O(NII)

The proposed models satisfy the isotonicity property, which requires that outputs do not decrease with an increase in the inputs, since the coefficient correlations between inputs and outputs are positive and significant (Bowlin, 1998).

4.4.2. Bank's CSP and each of its Dimensions Indexes

The CSP index is calculated using the DEA-WEI model described in Eq. (4.7) – (4.10). As the CSP index evaluates the efficiency of bank's management of their primary stakeholders, we follow Lahouel et al. (2021) and consider that the ten categories describing the three ESG pillars from the Thomson Reuters Eikon Asset 4 ESG database, presented in Table 30, would be the outputs of our DEA-WEI model.

To construct the indexes of different dimensions of CSP, we consider the following categories: Environmental index (Resource Use, Emissions, and Innovation), Social index (Workforce, Human Rights, Community, and Product Responsibility) and Governance index (Management, Shareholders, and CRS Strategy). Table 31 presents the statistics descriptive for the scores of the ten categories referred (ranging from 0 to 100), over the period 2011-2019.

Table 30 - Categories from Thomson Reuters Eikon Asset 4 ESG database used in the estimation of CSP and each of its dimensions indexes

Pillar	Category	Description
Environmental	Resource Use (RUS)	The resource use category reflects a company's performance and capacity to reduce the use of materials, energy or water, and to find more eco-efficient solutions by improving supply chain management.
	Emissions (ES)	The emission category measures a company's commitment and effectiveness towards reducing environmental emission in the production and operational processes.
	Innovation (EIS)	The innovation category reflects a company's capacity to reduce the environmental costs and burdens for its customers, and thereby creating new market opportunities through new environmental technologies and processes or eco-designed products.
Social	Workforce (WS)	The workforce category measures a company's effectiveness towards job satisfaction, a healthy and safe workplace, maintaining diversity and equal opportunities, and development opportunities for its workforce.
	Human Rights (HRS)	The human rights category measures a company's effectiveness towards respecting the fundamental human rights conventions
	Community (CS)	The community category measures the company's commitment towards being a good citizen, protecting public health and respecting business ethics.
	Product Responsibility (PRS)	The product responsibility category reflects a company's capacity to produce quality goods and services integrating the customer's health and safety, integrity and data privacy.
Governance	Management (MS)	The management category measures a company's commitment and effectiveness towards following best practice corporate governance principles.
	Shareholders (SS)	The shareholders category measures a company's effectiveness towards equal treatment of shareholders and the use of anti-takeover devices
	CSR Strategy (CSRS)	The CSR strategy category reflects a company's practices to communicate that it integrates the economic (financial), social and environmental dimensions into its day-to-day decision-making processes.

Adapted from Environmental, Social and Governance (ESG) Scores from REFINITIV (February 2021). Available at https://www.refinitiv.com/content/dam/marketing/en_us/documents/methodology/refinitiv-esg-scores-methodology.pdf

Source: Own production

Table 31 - Descriptive statistics of ESG scores used in the estimation of DEA-WEI model for CPS and each of its dimensions indexes

	RUS	ES	EIS	WS	HRS	CS	PRS	MS	SS	CSRS
Mean	55.55	56.05	47.45	71.92	37.95	51.13	46.48	57.88	52.54	47.78
Median	64.91	63.35	53.06	78.74	30.10	51.73	43.98	62.50	52.31	50.00
Std. Dev.	34.41	31.52	37.00	23.32	36.33	31.02	33.36	29.30	27.98	32.09
Min	0	0	0	0.54	0	0	0	1.04	0.39	0
Max	99.77	99.88	99.49	99.91	98.10	99.77	99.79	99.61	99.38	99.45
Obs.	740	740	740	740	740	740	740	740	740	740

Source: Own production

4.4.3. Other Determinants of Bank's Efficiency

To ensure that CSP and each of its dimensions do not replace the known effect of other variables on bank efficiency, we have considered a set of control variables previously identified in the literature. These control variables can be divided into two categories: bank-specific variables and country variables.

In the first category, we include the *bank's size*, measured by the natural logarithm of the total assets, the *revenue diversification*, measured by the ratio of non-interest income over operating revenues, the *Liquidity*, measured by the liquid assets over total assets. We also considered a measure of a *bank's rentability*, the return on assets, and a measure of the bank's leverage, the *equity to assets ratio*. To control the effect of the board composition on the bank's efficiency we also consider an indicator of *board independence* (percentage of the of independent directors in the board) and *board gender diversity* (percentage of women in the board).

In the second category, we include two macroeconomic variables, *real GDP growth* and *inflation rate*, to control the effect of the economic environment on banking efficiency and finally the *Herfindahl-Hirschman Index* (HHI), which is measured as the sum of the squares of individual bank's market share in total banking assets of a country, to proxy the market structure of banking sector (an HHI close to one indicates more concentration).

In Table 32, we present the statistics descriptive for the control variable over the period 2011-2019 (all variables are in percentage, except the size and HHI).

Table 32 - Descriptive statistics of control variables of banks' efficiency

	Obs.	Mean	Median	Std.Dev.	Min	Max
Size	740	11.47	11.19	1.64	7.78	14.72
Revenue diversification	740	42.55	39.85	23.70	-7.95	319.51
Liquidity	740	27.07	24.98	13.92	2.44	91.24
Return on assets	740	0.41	0.46	1.39	-13.41	6.29
Equity to assets ratio	740	8.42	7.03	7.92	-3.93	76.91
Board independence	740	54.95	57.14	24.24	0.00	100.00
Board gender diversity	740	23.48	23.53	13.94	0.00	60.00
HHI	740	0.09	0.07	0.06	0.02	0.39
Real GDP growth	740	1.69	1.67	2.76	-9.13	25.16
Inflation	740	1.24	1.14	1.23	-1.74	5.65

Note: All variables are in percentage, except Size and HHI.

Source: Own production

4.5. RESULTS AND DISCUSSION

4.5.1. Bank's Efficiency Scores and ESG Indexes

We apply the methodology described in subchapter 4.3., and estimate the BCC model, with output orientation, to obtain the estimates of the bank's efficiency score $(\hat{\theta})$ and the bias-corrected efficiency score $(\hat{\hat{\theta}})$ for models 1 and 2 proposed in section 4.4.1. Table 33 presents the mean values of the estimates of those coefficients, as well as the number of banks used in the estimation and the percentage of fully efficient banks for the two models.

Table 33 - Bank's efficiency score and bias-corrected efficiency score (means) by year based on the BCC model, with output orientation, using DEA

	Model 1 Inputs: I(DEP) and I(ACL) Outputs: O(L) and O(NII)			Model 2 Inputs: I(FA) and I(ACL) Outputs: O(L) and O(NII)			
Year	Efficiency Score	Bias-corrected efficiency score	% Efficient DMUs'	Efficiency Score	Bias-corrected efficiency score	% Efficient DMUs'	Number of banks
2011	2.177	2.569	13.89	2.022	2.395	12.50	72
2012	1.681	1.898	18.06	1.668	1.903	12.50	72
2013	1.701	1.925	13.70	1.585	1.789	13.70	73
2014	2.265	2.714	13.51	2.254	2.764	16.22	74
2015	1.843	2.135	13.92	1.614	1.817	17.72	79
2016	1.860	2.153	13.25	1.515	1.673	22.89	83
2017	2.231	2.667	11.36	2.161	2.581	22.73	88
2018	2.182	2.580	9.26	1.715	1.960	21.30	108
2019	2.053	2.410	8.79	1.550	1.761	21.98	91
2011-2019	2.011	2.355	12.57	1.781	2.062	18.38	740

Source: Own production

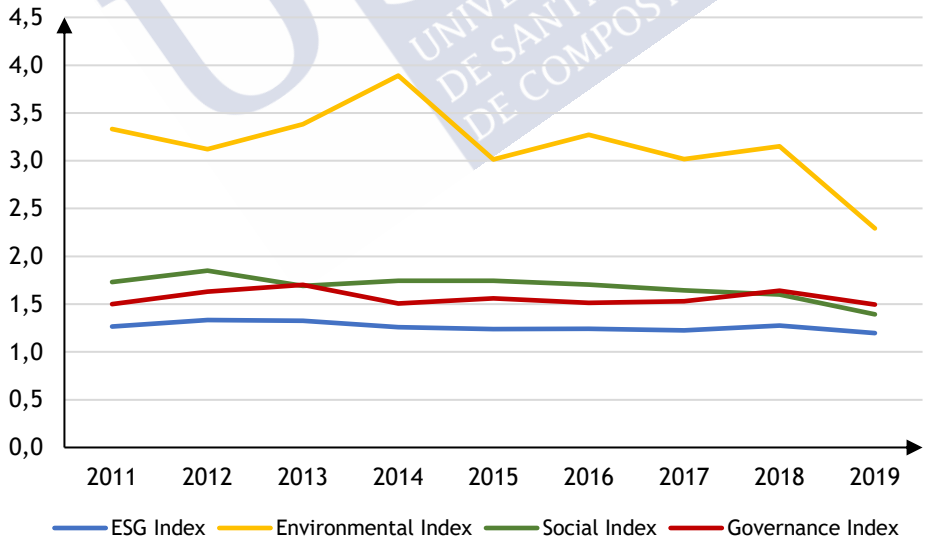
In general, in average terms, the level of the bank's efficiency in Europe of the period 2011-2019 was low. Considering the efficiency scores of models 1 and 2, we can conclude that, keeping the inputs unchanged, the outputs would have been multiplied, on average, by 2.011 and 1.781 times, respectively, for a given bank to reach the efficient frontier. These results are in line with those obtained by Neves et al. (2020) and Christopoulos et al. (2020) who reported low levels of efficiency in European banking in the periods of 2011-2016 and 2009-2015, respectively. These low levels of efficiency could be explained by activity restrictions and high

capital requirements imposed by the regulatory authorities during the European sovereign debt crisis (Bace & Ferreira, 2020).

Bias-corrected efficiency scores reported shows that the rankings do not change substantially, however, efficiency scores are generally augmented. Comparing the results obtained for models 1 and 2, we conclude that the average efficiency level and the percentage of fully efficient banks are higher in model 2[25], and for this reason, the bias-corrected efficiency scores of this model are used in estimating the truncated regression of the second stage.

To measure CSP, ESG indexes were estimated using the DEA-WEI model described in subchapter 4.3. and section 4.4.2. Figure 10 presents the evolution of the mean value of the bias-corrected index of ESG activity and each of its dimensions $\left(\hat{\hat{\phi}}\right)$[26]. As we can see, in the period 2011-2019, European banking presents good levels of performance at the level of ESG activity with the bias-corrected efficiency score to present an average value of 1.260, that is, very close to unity.

Figure 10 - Bank's ESG activity and each of its dimensions bias-corrected indexes (means)



Source: Own production

[25] Remember that a fully efficient bank will have a coefficient θ equal to one and a higher coefficient means that bank is less efficient.

[26] In Table 39 of the appendix of this chapter is presented detailed information about the evolution of ESG activity and its dimensions indexes, by year, using DEA-WEI model.

In the Social and Governance dimensions of the CSP, it can be concluded that European banking also has good levels of performance. The mean value of the corporate governance index ranged between a minimum value of 1.495 in 2019 and a maximum value of 1.702 in 2013. In the activities related to the social pillar, there is even an increase in performance, with the respective index decreasing from 1.731 in 2011 to 1.393 in 2019. The dimension of the CSP in which European banking has the worst performance is the environmental dimension, with an average index of 3.140 in the period 2011-2019. This result was somewhat expected as banking activity has, at least directly, little environmental impact. However, over the period studied, there was a significant increase in the performance of this dimension, with the Environmental index falling from 3.332 in 2011 to 2.292 in 2019.

In Table 34, we present the descriptive statistics of the variables of interest in our study and that will be used to test the hypotheses formulated in subchapter 4.2.: the bias-corrected efficiency score $\left(\hat{\hat{\theta}}\right)$ and the bias-corrected index of ESG activity and each of its dimensions $\left(\hat{\hat{\phi}}\right)$.

Table 34 - Descriptive statistics of banks' efficiency and CSP and each of its dimensions

	Obs.	Mean	Median	Std.Dev.	Min	Max
Bank Efficiency Score	740	2.997	2.457	1.798	1.086	13.860
ESG Index	740	1.260	1.090	0.537	1.013	9.267
Environmental Index	740	3.140	1.256	4.419	1.010	20.878
Social Index	740	1.668	1.172	1.726	1.012	17.822
Governance Index	740	1.565	1.246	1.114	1.011	19.761

Source: Own production

4.5.2. Truncated Regression Analysis for Bank's Efficiency

Table 35 presents the results for the truncated regression that allows us to analyse the effect of different variables, including those related to CSP, on the bank's efficiency. The results presented assume that the bank's efficiency is linearly related to the CSP and each of its dimensions. As already mentioned, to measure the bank's efficiency, we used the bootstrapped bias-corrected efficiency score $\left(\hat{\hat{\theta}}\right)$, and the CSP and each of its dimensions were measured by the ESG Index, Environmental Index, Social Index and Governance Index described in section 4.5.1. Column (1) presents the estimation results of Eq. (4.6), including only the bank-specific

and the macroeconomic control variables. In column (2)-(4), CSP's variables were included to investigate the effect of CSP and each of its dimensions on the bank's efficiency.

Table 35 - Results of bootstrap truncated regressions for determinants of bank's efficiency (linear relationship assumed between CSP and bank's efficiency)

	(1)	(2)	(3)	(4)	(5)
Size	-1.299***	-1.224***	-1.323***	-1.333***	-1.248***
	[-1.480,-1.087]	[-1.405,-1.009]	[-1.512,-1.107]	[-1.533,-1.117]	[-1.428,-1.033]
Revenue Diversificat.	-0.043***	-0.043***	-0.043***	-0.043***	-0.043***
	[-0.056,-0.030]	[-0.056,-0.031]	[-0.057,-0.030]	[-0.056,-0.030]	[-0.056,-0.030]
Liquidity	-0.017*	-0.019**	-0.017*	-0.016*	-0.019**
	[-0.035,0.002]	[-0.037,-0.001]	[-0.035,0.001]	[-0.036,0.003]	[-0.037,0.000]
Return on assets	-0.336***	-0.327***	-0.336***	-0.340***	-0.323***
	[-0.466,-0.184]	[-0.459,-0.178]	[-0.468,-0.184]	[-0.469,-0.193]	[-0.455,-0.184]
Equity to assets ratio	-0.076***	-0.072***	-0.077***	-0.078***	-0.071***
	[-0.139,-0.028]	[-0.132,-0.024]	[-0.142,-0.025]	[-0.141,-0.027]	[-0.130,-0.023]
Board independence	0.027***	0.027***	0.027***	0.026***	0.027***
	[0.018,0.036]	[0.017,0.036]	[0.017,0.036]	[0.017,0.036]	[0.018,0.036]
Board gender diversity	0.008	0.009	0.008	0.007	0.009
	[-0.010,0.025]	[-0.007,0.027]	[-0.010,0.025]	[-0.010,0.025]	[-0.009,0.026]
HHI	4.162**	3.751**	4.075**	4.107**	4.006**
	[0.638,7.506]	[0.212,7.109]	[0.468,7.504]	[0.478,7.601]	[0.352,7.172]
Real GDP growth	-0.110***	-0.116***	-0.106***	-0.107***	-0.116***
	[-0.193,-0.032]	[-0.201,-0.041]	[-0.195,-0.029]	[-0.195,-0.029]	[-0.198,-0.041]
Inflation	-0.564***	-0.552***	-0.563***	-0.583***	-0.560***
	[-0.841,-0.281]	[-0.819,-0.257]	[-0.853,-0.293]	[-0.853,-0.284]	[-0.859,-0.281]
ESG Index		0.547***			
		[0.229,0.856]			
Environmental index			-0.019		
			[-0.063,0.025]		
Social index				-0.093	
				[-0.224,0.026]	
Governance index					0.213***
					[0.058,0.353]
Constant	19.295***	17.892***	19.625***	19.897***	18.453***
	[16.857,21.552]	[15.412,20.005]	[17.026,22.015]	[17.244,22.42]	[15.96,20.77]
Sigma	1.898***	1.879***	1.899***	1.908***	1.881***
	[1.683,2.040]	[1.663,2.015]	[1.703,2.038]	[1.695,2.039]	[1.688,2.022]

Note: The table reports the estimation results for the truncated regression using algorithm II proposed by Simar & Wilson (2007). The dependent variable of all regressions is the bootstrapped bias-corrected efficiency score obtained considering in the first stage the BCC model, with output orientation, with two inputs [(I)FA, (I)ACL] and two outputs [(O)L, O(NII)]. All regressions were estimated with 740 observations. Time Dummies are included. The number of bootstrap replications for bias correction of DEA scores and for estimating confidence intervals (CI) for the regression coefficients was 2000. The 95% CI are reported in the squared brackets. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

Looking to column (1), we conclude that: (i) the coefficient associated with the bank's size is statistically significant, showing that a larger size implies higher levels of efficiency[27]; (ii) banks with more revenue diversification present more high levels of efficiency; (iii) better-

[27] Remember that a higher value of θ means that bank is more inefficient.

capitalized and more profitable banks are more efficient; (iv) banks that present a greater percentage of independents directors on the board are more inefficient; (v) banks that are based in countries with more concentrated banking sectors, with a higher HHI, are less efficient; and finally, (vi) in a context of economic and inflationary expansion, banks are more efficient. The gender diversity of the board seems does not to influence the bank's efficiency and the variable liquidity only are significant to a significance level of 10%.

Considering now the effect of ESG activities, measured by the ESG Index, on the bank's efficiency, we conclude that an increase in the ESG index increases the efficiency score (the sign of the estimate of the coefficient associated with the ESG Index variable in column (2) is positive and significant for 1% of significance level). This means that the statistical evidence supports Hypothesis I which states that banks with worse CSP are less efficient. These results are in line with those obtained by Belasri et al., (2020), who find evidence that CSR has a positive impact on bank efficiency in developed countries, and Shah et al. (2019) who found support in their study that sustainable banks are more efficient and productive. Looking at the results presented in columns (3) and (4), we do not find statistical evidence that banks with better social and environmental practices are more efficient since the coefficients associated with the Environmental Index and Social Index variables are not statistically significant. This means that our results do not support Hypotheses II and III of our study. However, we found evidence that supports Hypothesis IV. Looking at column (5), we could see that the estimate of the coefficient associated with the Governance Index is positive and statistically significant. This means that banks with good governance practices are more efficient. These first results seem to support what is advocated by the stakeholder theory, according to which banks with the best CSP will be the ones with the best levels of efficiency. However, the dimension linked to the bank's governance model seems to be the only one that contributes to that positive relationship. As suggested by agency theory, the banks that adopt governance practices that best align the interests of shareholders and managers will be the ones that will be most efficient.

Table 36 - Results of bootstrap truncated regressions for determinants of bank's efficiency (non-linear relationship assumed between CSP and bank's efficiency)

	(1)	(2)	(3)	(4)
Size	-1.178***	-1.283***	-1.274***	-1.224***
	[-1.365, -0.974]	[-1.467, -1.059]	[-1.456, -1.049]	[-1.402, -1.017]
Revenue Diversification	-0.044***	-0.043***	-0.044***	-0.044***
	[-0.056, -0.031]	[-0.057, -0.030]	[-0.057, -0.031]	[-0.056, -0.030]
Liquidity	-0.022**	-0.017*	-0.017*	-0.022**
	[-0.042, -0.003]	[-0.037, 0.001]	[-0.036, 0.001]	[-0.040, 0.001]
Return on assets	-0.319***	-0.337***	-0.342***	-0.308***
	[-0.457, -0.174]	[-0.477, -0.191]	[-0.482, -0.198]	[-0.444, -0.168]
Equity to assets ratio	-0.072***	-0.076***	-0.078***	-0.073***
	[-0.129, -0.027]	[-0.136, -0.025]	[-0.140, -0.027]	[-0.134, -0.025]
Board independence	0.027***	0.027***	0.026***	0.028***
	[0.018, 0.036]	[0.017, 0.036]	[0.016, 0.036]	[0.018, 0.037]
Board gender diversity	0.008	0.008	0.007	0.008
	[-0.009, 0.025]	[-0.010, 0.025]	[-0.010, 0.026]	[-0.010, 0.025]
HHI	3.590**	4.072**	3.994**	4.036**
	[0.008, 6.911]	[0.236, 7.401]	[0.425, 7.423]	[0.596, 7.386]
Real GDP growth	-0.122***	-0.111***	-0.110***	-0.124***
	[-0.210, -0.046]	[-0.198, -0.029]	[-0.193, -0.035]	[-0.207, -0.046]
Inflation	-0.549***	-0.561***	-0.574***	-0.567***
	[-0.828, -0.268]	[-0.841, -0.293]	[-0.859, -0.282]	[-0.846, -0.276]
ESG Index	1.375***			
	[0.496, 2.181]			
ESG Index squared	-0.111**			
	[-0.220, -0.003]			
Environmental index		0.142		
		[-0.069, 0.333]		
Environmental index squared		-0.009		
		[-0.019, 0.002]		
Social index			0.334	
			[-0.057, 0.771]	
Social index squared			-0.034**	
			[-0.073, -0.007]	
Governance index				0.507***
				[0.157, 0.813]
Governance index squared				-0.021*
				[-0.043, 0.002]
Constant	16.662***	18.976***	18.822***	18.875***
	[13.966, 19.058]	[16.269, 21.48]	[16.01, 21.26]	[15.301, 20.05]
Sigma	1.888***	1.904***	1.906***	1.894***
	[1.674, 2.016]	[1.690, 2.029]	[1.700, 2.036]	[1.692, 2.017]

Note: The table reports the estimation results for the truncated regression using algorithm II proposed by Simar & Wilson (2007). The dependent variable of all regressions is the bootstrapped bias-corrected efficiency score obtained considering in the first stage the BCC model, with output orientation, with two inputs [(I)FA, (I)ACL] and two outputs [(O)L, O(NII)]. All regressions were estimated with 740 observations. Time Dummies are included. The number of bootstrap replications for bias correction of DEA scores and for estimating confidence intervals (CI) for the regression coefficients was 2000. The 95% CI are reported in the squared brackets. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

To analyse the validity of the hypothesis of a non-linear relationship between bank efficiency and CSP (and each of its three dimensions) [Hypothesis V], equation (4.6) was re-estimated by additionally including the term CSP_{it}^2. The estimation results are shown in Table 36. Looking at column (1) of that table, we concluded that the coefficients associated with the ESG index and ESG index squared variables are both significant for a 5% significance level, which allows us to conclude by a non-linear relationship between the CSP and banks efficiency. Namely, considering the signals obtain for the estimates of the coefficients, we can conclude by a U-shaped relationship between the CSP and the efficiency of the banks. That is, banks with low or high CSP are the most efficient. Banks with intermediate levels of CSP are the most inefficient. These results are in line with those obtained by Nollet et al. (2016) and Shabbir et al. (2020) who also find a U-shaped relationship between CSP and financial performance. These results allow us to reconcile the two opposing theoretical views on the relationship between CSP and banking efficiency. In favour of the trade-off view of ESG activities we can point to the fact that if banks with low levels of CSP invest more money in CSR activities they will see their efficiency levels go down. In support of stakeholder theory, evidence is found that for banks with high levels of CSP, additional investment in ESG activities tends to improve efficiency levels.

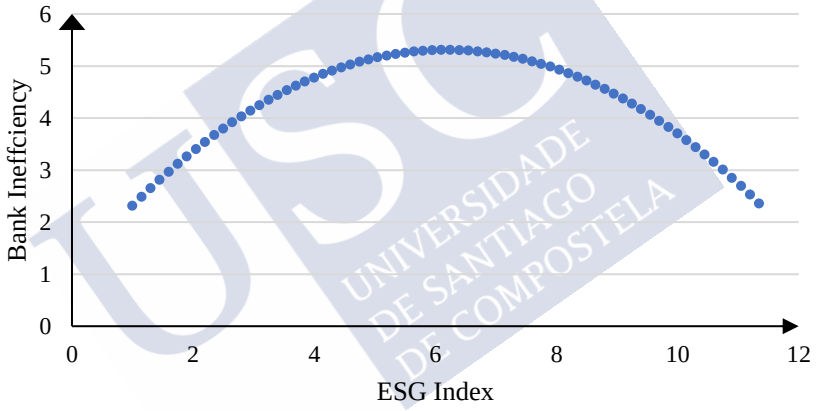
The results of columns (2)-(4) of Table 36 allow us to draw the same conclusion for the social and governance dimensions of ESG activities, that is, banks with low or high performance in those two dimensions are the most efficient. Banks with intermediate performance levels in social and governance dimensions of ESG activities are the least efficient. These results imply that if a bank decides to invest in socially responsible practices, it will have to do so in a sustained way to obtain high levels of performance, as only for these levels the investment is transformed into efficiency gains. As referred by Birindelli et al. (2015), stable and fair relationships between employees and management will lead to higher personal satisfaction and loyalty, contributing to an increase in corporate efficiency. Banks that sustainably engage with the local communities in which they operate can build an image of a good reputation that results in increased demand for their products and services increasing the bank's efficiency.

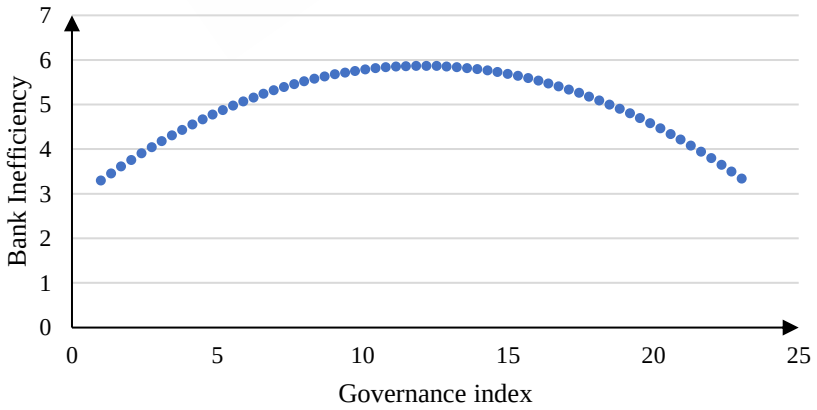
The environmental dimension of ESG activities continues to prove insignificant in explaining the efficiency of banks. These results corroborate the arguments of Finger et al.

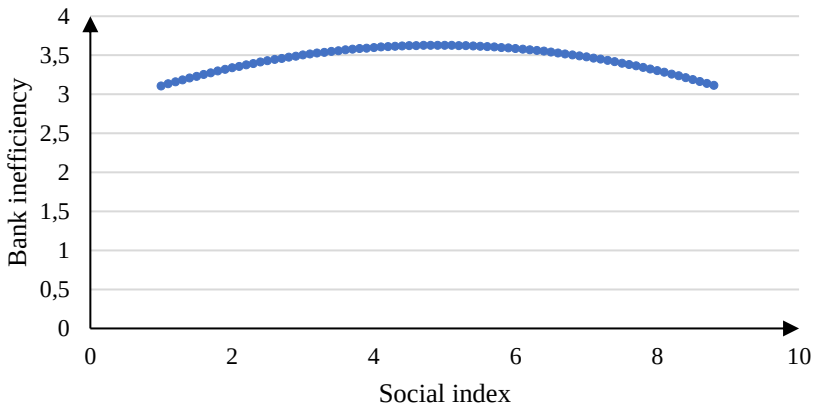
(2018) according to which banks of developed country have already optimized their processes in such a way that additional environmental measures do not result in efficiency gains.

Figure 11 shows the relationship between a bank's inefficiency and ESG performance and its social and governance dimensions for a bank representative of our sample (average values). We can conclude that a bank's inefficiency is maximum when the ESG index takes the value of 6.2, the Social index takes the value of 12.1 and the Governance index takes the value of 4.9. It is also noted that the U-shaped curve is less pronounced when the Social index is related to the bank's efficiency.

Figure 11 - Relationship between Bank's inefficiency and ESG, Social and Governance indexes for a representative bank







Source: Own production

4.6. ROBUSTNESS ANALYSIS

Several studies have highlighted that financial factors are crucial in explaining the adoption of CSR practices. The most efficient banks will be, a priori, better able to have these financial resources. Based on this idea, it is reasonable to assume that bank efficiency can itself influence CSP, resulting in a possible bidirectional relationship between CSP and bank efficiency. This means that an endogeneity problem arises when we estimate Eq. (4.6), given the simultaneity between the bank's efficiency and the CSP. To overcome the problem of endogeneity motivated by the simultaneity between bank efficiency and CSP and by possible correlation between the delayed endogenous variable and the unobservable effects, we use the System Generalized Method of Moments (GMM) proposed by Arellano & Bover (1995) and Blundell and Bond (1998), described in the chapter 2, to re-estimate the Eq. (4.6) including the term CSP_{it}^2 given the evidence of a non-linear relationship. This method combines the first differences in our regression equation with the level form, reducing any biases and imprecision associated with the first-difference GMM. We use the two-step GMM estimator, instead one-step GMM estimator, with Windmeijer (2005) corrected standard errors, because is more efficient. To satisfy the instruments' validity, we test for over-identifying restrictions using Hansen's (1982) *J* test and Arellano-Bond test to guarantee that second-order autocorrelation coefficient, RHO(2), is null.

The results presented in Table 37 are free from any endogeneity issues and using System GMM also allow us to control for persistence. The results obtained only confirm the non-linear relationship between the social dimension of ESG activities and the bank's efficiency. Given

these results, we re-estimate the model excluding the quadratic terms from the ESG index, Environmental index, Social index and Governance index. Results are presented in Table 38. The results indicate the existence of a significant and positive linear relationship between the efficiency of a bank and the CSP. At the disaggregated level, a good performance in the social and governance components improves the bank's efficiency.

Table 37 - Robustness test to non-linear relationship assumed between CSP and bank's efficiency

	(1)	(2)	(3)	(4)
L.Dependent variable	0.621***	0.579***	0.535***	0.618***
	(0.078)	(0.086)	(0.098)	(0.072)
Size	-0.495*	-0.443	-0.564**	-0.515*
	(0.269)	(0.274)	(0.288)	(0.287)
Revenue Diversification	0.003	0.003	0.003	0.003
	(0.003)	(0.002)	(0.003)	(0.003)
Liquidity	-0.006	-0.007	-0.003	-0.005
	(0.011)	(0.01)	(0.01)	(0.01)
Return on assets	0.124**	0.113**	0.105**	0.114**
	(0.051)	(0.051)	(0.044)	(0.044)
Equity to assets ratio	-0.074	-0.074	-0.061	-0.07
	(0.051)	(0.048)	(0.042)	(0.043)
Board independence	-0.007***	-0.011***	-0.008***	-0.009***
	(0.003)	(0.003)	(0.003)	(0.002)
Board gender diversity	-0.004	-0.005	-0.004	-0.005
	(0.007)	(0.007)	(0.005)	(0.006)
HHI	2.167	3.719	3.000	2.111
	(3.084)	(3.123)	(3.251)	(3.114)
Real GDP growth	0.022*	0.014	0.018	0.023*
	(0.013)	(0.01)	(0.011)	(0.012)
Inflation	-0.112	-0.141	-0.08	-0.102
	(0.105)	(0.108)	(0.079)	(0.103)
ESG Index	0.664**			
	(0.315)			
ESG Index squared	-0.057			
	(0.047)			
Environmental index		0.048		
		(0.056)		
Environmental index squared		0.001		
		(0.002)		
Social index			0.365**	
			(0.146)	
Social index squared			-0.021*	
			(0.011)	
Governance index				0.032
				(0.21)
Governance index squared				0.013
				(0.026)
Constant	7.061*	7.294*	8.081**	7.933**
	(3.674)	(3.795)	(3.553)	(3.782)
Number of instrumental variables	55	55	55	55
F-Test	187.00***	140.55***	130.51***	176.07***
RHO(1) Test	-4.92***	-4.03***	-3.98***	-4.64***
RHO(2) Test	-0.10	0.06	-0.10	0.04
Hansen's J Test	41.23	39.25	44.37	41.01
p-value [Hansen's J Test]	0.184	0.246	0.110	0.190

Note: All regressions were estimated with 632 observations. The dependent variable of all regressions is the bootstrapped bias-corrected efficiency score obtained considering in the first stage the BCC model, with output orientation. Time Dummies are included. Robust standard errors are reported in parentheses below their coefficient estimates. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels.

Source: Own production

Table 38 - Robustness test to linear relationship assumed between CSP and bank's efficiency

	(1)	(2)	(3)	(4)
L.Dependent variable	0.623***	0.579***	0.574***	0.619***
	(0.077)	(0.087)	(0.105)	(0.072)
Size	-0.513*	-0.430	-0.605**	-0.508*
	(0.262)	(0.268)	(0.291)	(0.288)
Revenue Diversification	0.002	0.003	0.003	0.003
	(0.003)	(0.003)	(0.003)	(0.002)
Liquidity	-0.005	-0.007	-0.004	-0.005
	(0.011)	(0.010)	(0.010)	(0.010)
Return on assets	0.130***	0.111**	0.101**	0.112**
	(0.050)	(0.050)	(0.047)	(0.044)
Equity to assets ratio	-0.079	-0.071	-0.062	-0.069
	(0.049)	(0.047)	(0.042)	(0.044)
Board independence	-0.008***	-0.011***	-0.009***	-0.008***
	(0.003)	(0.003)	(0.003)	(0.003)
Board gender diversity	-0.004	-0.005	-0.005	-0.005
	(0.006)	(0.007)	(0.006)	(0.006)
HHI	2.164	3.758	2.485	2.069
	(3.079)	(3.122)	(3.252)	(3.114)
Real GDP growth	0.022	0.013	0.018	0.023*
	(0.013)	(0.010)	(0.012)	(0.012)
Inflation	-0.116	-0.141	-0.117	-0.104
	(0.105)	(0.107)	(0.098)	(0.103)
ESG Index	0.362**			
	(0.171)			
Environmental index		0.009		
		(0.100)		
Social index			0.207***	
			(0.069)	
Governance index				0.120**
				(0.061)
Constant	7.582**	7.076*	9.146**	7.743**
	(3.493)	(3.686)	(3.893)	(3.832)
Number of instrumental variables	54	54	54	54
F-Test	153.56***	133.82***	138.65***	183.72***
RHO(1) Test	-5.23***	-4.63***	-4.51***	-5.32***
RHO(2) Test	-0.01	0.04	-0.04	0.00
Hansen's J Test	43.56	44.52	41.36	39.26
p-value [Hansen's J Test]	0.126	0.107	0.180	0.246

Note: All regressions were estimated with 632 observations. The dependent variable of all regressions is the bootstrapped bias-corrected efficiency score obtained considering in the first stage the BCC model, with output orientation. Time Dummies are included. Robust standard errors are reported in parentheses below their coefficient estimates. *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Source: Own production

4.7. CONCLUSION

The 2008's financial crisis and the need for several governments to adopt measures to rescue troubled banks, demanded that the banking sector adopt better social and environmental practices based on responsible governance principles. As a result, banks are increasing their social responsibility practices, reinforcing their credibility with different stakeholders. Since then, several investigations have studied the effects of the CRS activities on the banks' performance, namely on the profitability and the market value of the banks. However, very few studies have looked at the effects of CRS activities on bank efficiency.

Our research investigates the relationship between CSP and bank efficiency using a sample of European listed banks for the period 2011-2019. To measures the bank's efficiency, we use the well-known nonparametric DEA technique, under the variable returns to scale hypothesis (BCC model). The performance of CRS activities and their three different dimensions, environmental, social and governance, was estimated using a DEA model without explicit inputs and a set of ten indicators extracted from the Thomson Reuters Eikon Asset 4 ESG database. To study the relationship between bank efficiency and CSP and other control variables, is used algorithm II of the two-stage procedure proposed by Simar & Wilson (2007).

The main conclusions of our work for the proposed efficiency model indicate in general European banks presents low levels of efficiency, with a value for pure technical efficiency of around 50%. Our results also indicate, for European banking, a U-shaped relationship between CSP and efficiency. Banks with intermediate levels of CSP are less efficient. Banks with low or high levels of CRS activity show better levels of efficiency. At the disaggregated level, the same conclusion is drawn regarding the social and governance dimensions of CSR activities. The environmental dimension of CRS activities does not improve the bank's efficiency, not confirming the postulate by the stakeholder theory.

These results allow us to reconcile the neoclassical view with the stakeholder theory about the relationship between CSP and the bank's efficiency and are in line with those obtained by Nollet et al. (2016). However, robustness tests only allow to identify a positive linear relationship between the CRS activities and the bank's efficiency. The same conclusion was drawn regarding the social and governance dimensions of CSR activities.

Our results have two managerial implications. The first is that environmental practices to correct externalities/dysfunctions that the market could not address must be limited, as these do not seem to influence the bank's efficiency. The second is that good practices in the social and governance dimensions of CSR activities have a positive impact on the bank's efficiency, but only if these practices are sustained. In the short term, good performance in those two dimensions may even decrease efficiency because the costs are not yet covered by the benefits of such activities.

This study has some limitations. First, the sample only considers listed banks. In the future, this analysis may be extended to unlisted banks, which will imply the development of new indicators to measure performance in all dimensions of ESG activities. Second and last, the analysis carried out should be corroborated with a new framework by using new parametric and non-parametric approaches such as the stochastic frontier approach and the analytical hierarchical process.

4.8. APPENDIX

Table 39 - Bank's ESG activity and each of its dimensions indexes and bias-corrected indexes (means) by year based on DEA-WEI model

	ESG Index			Environmental Index			
Year	Efficiency Score	Bias-corrected efficiency score	% Efficient DMUs'	Efficiency Score	Bias-corrected efficiency score	% Efficient DMUs'	Number of banks
2011	1.241	1.266	43.06	3.298	3.332	6.94	72
2012	1.306	1.333	44.44	3.091	3.122	9.72	72
2013	1.299	1.326	38.36	3.350	3.384	8.22	73
2014	1.237	1.260	33.78	3.852	3.891	8.11	74
2015	1.213	1.237	31.65	2.981	3.012	6.33	79
2016	1.217	1.243	33.73	3.239	3.272	6.02	83
2017	1.194	1.224	36.36	2.988	3.018	9.09	88
2018	1.247	1.276	32.41	3.120	3.152	3.70	108
2019	1.167	1.197	34.07	2.267	2.292	4.40	91
2011-2019	1.233	1.260	36.08	3.108	3.140	6.76	740

	Social Index			Governance Index			
Year	Efficiency Score	Bias-corrected efficiency score	% Efficient DMUs'	Efficiency Score	Bias-corrected efficiency score	% Efficient DMUs'	Number of banks
2011	1.711	1.731	16.67	1.481	1.499	6.94	72
2012	1.830	1.850	9.72	1.611	1.631	9.72	72
2013	1.674	1.692	9.59	1.678	1.702	6.85	73
2014	1.726	1.745	14.86	1.489	1.508	10.81	74
2015	1.723	1.743	10.13	1.542	1.559	12.66	79
2016	1.684	1.704	8.43	1.493	1.512	9.64	83
2017	1.623	1.644	9.09	1.509	1.531	6.82	88
2018	1.580	1.601	12.04	1.618	1.640	9.26	108
2019	1.372	1.393	13.19	1.472	1.495	6.59	91
2011-2019	1.647	1.668	11.49	1.544	1.565	8.78	740

Source: Own production

CONCLUSIONS, IMPLICATIONS AND FUTURE RESEARCH LINES

The beginning of the 21st century was inevitably marked by the global 2007-2008's financial crisis. The period leading up to it can be characterized by very favourable economic conditions, namely an abundance of liquidity, low interest rates and increasing deregulation of the financial sector. This environment, supported by strongly expansionary monetary policies and some relaxation in credit policies, contributed to a considerable exponential increase in bank credit, giving rise to a price bubble in the North American housing market, which in turn triggered the already referred financial crisis.

This financial crisis, later exacerbated by the Eurozone sovereign debt crisis, put heavy pressure on the entire European banking system, in fact, as banking in general worldwide, leading to the disappearance of many credit institutions in countries such as the Netherlands, Spain, Greece, France, Denmark and Italy. According to data from the European Banking Federation (2019), the number of credit institutions in the EU-28 decreased by 28.6% between 2008 and 2018, with the market share of the 5 largest banks, in terms of assets, growing significantly in countries like Greece, Italy, Spain and even Germany. These profound changes in the market structure of the European banking sector, the numerous interventions by different national governments to save their banks, the significant strengthening of banking sector regulation in Europe and, finally, the unconventional expansionary monetary policies implemented by several central banks in Europe have motivated the three essays covered by this research work.

The first essay, covered in chapter 2 of this thesis, revisits the study of the relationship between competition and the bank's risk-taking in Europe, extend the existing literature by investigating if that nexus is differentiated depending on whether the bank operates in a weaker or more stable banking system as a whole. The competition was proxied by the Lerner index, a measure of the bank's market power, and for the bank's risk-taking was used overall risk measures such distance-to-default and Z-score. With a sample of 117 listed banks, from 16

European countries, covering the period between 2011-2018, and using a dynamic panel data model with a 2-step GMM estimator, to control endogeneity, we obtain the following results:

- Considering the sample with all banks, we found evidence that supports the competition-fragility view in detriment of the competition-stability view, which is in line with the results obtained by Leroy & Lucotte (2017), meaning that the banks with more market power adopt less risky investment strategies;
- We do not find evidence that confirms the U-shaped relationship between competition and bank risk-taking as predicted by MMR (2010); this result combined with the previous could mean that the level of competition between banks in Europe is already high enough that the "margin" effect dominates the risk-shifting effect;
- Distinguishing between banks that operate in less stable banking systems from those that operate in more stable banking systems, we only find evidence for the competition-fragility view in the first group; for banks located in countries with more stables banking systems, the relationship between market power and financial stability does not prove to be statistically significant;
- The results obtained remain unchanged even when we consider the efficiency-adjusted Lerner index as a measure of competition, distance-to-insolvency as a measure of bank risk-taking or when we use a static panel data model with fixed (or random) effects.

Our results imply that public and regulatory entities in the European banking sector must promote competition in the sector, essential for welfare reasons, together with a reinforcement of regulation that guarantees banking stability. For this purpose, it will be necessary to continue the process of consolidating the sector in Europe, started in 2014 with the creation of the European Banking Union, promoting domestic mergers and the emergence of stronger and more resilient pan-European banks, without compromising free competition.

The work carried out in this research has several limitations, related to the investigation process, and related essentially to the data. First, it will be convenient to analyse whether the results that we obtained remain unchanged if we include unlisted banks in the sample, which still constitute a large percentage of European banks. The main limitation of the inclusion of unlisted banks in the sample is that it is not possible to use market measures for banking stability. However, it also opens the door to the emergence and use of new ways of measuring bank stability.

The second essay, presented in the third chapter of this thesis, analyses the impact of negative interest rate policies on the profitability and risk-taking of European banks. In the last decade, some central banks in Europe, to avoid a deflationary scenario and stimulate economic growth, resorted to a set of unconventional monetary policy instruments, among which we highlight the large asset purchase programs and the implementation of negative interest rate policies (NIRP's). Some academics and experts have warned that such policies can put pressure on banks' profitability, motivating an increase in risk-taking, which could jeopardize the stability of the banking system. This concern motivated this second investigation. In particular, this work search to answer the following research questions: (i) The NIRP lead to a lower bank's profitability and a greater bank's risk-taking?; (ii) The effect of a change in interest rates in the bank's profitability and risk-taking is most pronounced when a NIRP is implemented?; and (iii) The effect of a NIRP on bank's profitability and risk-taking depends on the bank's business model?. Using a dataset of 2596 banks, from 29 European countries, over the period 2011-2019, and applying a static modelling approach, we conclude that:

- The NIRP implementation decreases, on average, banks' net margin by 14.5 b.p.; despite the increase in commissions, a decrease in net trading gains and an increase in the loan loss provisions led to the overall profitability, measured by ROA, to decrease, on average by 18.5 b.p.;
- A decrease in short-term interest rates lower net interest margin and the ROA in a more pronounced way when interest rates are already negative than when they are positive;
- The NIRP implementation does not increase risk-taking in the European banks; more, in an environment of negative interest rates, additional decreases in short-term interest rates do not lead banks to take more risk, which allows us to conclude that there is no evidence of the "search for yield" effect.

Using cluster analysis, we identify, in our sample, four different bank's business models: investment-oriented banks (type I), retail-oriented banks, investment-oriented banks (type II) and interbank lending-oriented banks. We conclude that the effects of the implementation of NIRP's influence banks' profitability and risk-taking in a different way depending on the business model adopted. In general, the implementation of the NIRP put downward pressure on the net interest margin of all banks except for investment-oriented banks (type I). Retail-oriented banks were particularly affected as their main source of financing was retail deposits.

However, there appear to be no differences in the overall profitability of different types of banks, measured by ROA, in the pre-NIRP and NIRP periods. Finally, we conclude that the implementation of NIRP did not affect banks' financial stability and credit risk, regardless of their business model. However, the investment-oriented banks (type I) and interbank lending-oriented banks adopted more risky investment strategies, while retail-oriented banks have adopted less risky investment strategies.

Our results imply that regulatory and supervisory entities of European banking systems must keep a close watch on the effect of a prolonged NIRP on the profitability and financial stability of European banks.

The third and last essay of this thesis analyse the influence of corporate social performance on banking efficiency. The financial crisis and public capital injections by most European governments have demanded that banks adopt better social and environmental policies based on responsible governance principles. The increase in investment in CSR activities by banks has led numerous studies to investigate its effect on bank performance, namely, on its profitability and market value. However, studies investigating the effect of corporate social performance on banking efficiency are still rare. This third investigation seeks to fill that gap in the literature.

Namely, we analyse the impact of corporate social performance on bank efficiency for a sample of 108 European listed banks across 21 countries over the 2011-2019 period. For this purpose, Simar and Wilson’s two-stage approach (2007) is applied. Specifically, we use data envelopment analysis (DEA) at the first stage to estimate efficiency scores and then use truncated regression estimation with double-bootstrap to test the significance of the relationship between bank efficiency and corporate social performance and its different dimensions: environmental, social and governance. The corporate social performance and its three dimensions were measured using a DEA model without explicit inputs. Our results can be summarized as follow:

- We find evidence of a U-shaped relationship between corporate social performance and efficiency, indicating that banks with lower or higher corporate social performance levels are more efficient;

- Considering the isolated effect of each of the three ESG activities, the same conclusion is drawn for the social and governance dimensions, while the environmental dimension does not show to have any effect on banking efficiency.

Our results have two managerial implications. First, CSR investments should be directed to social and governance dimensions of ESG activities because those components are the key drivers of the relationship between corporate social performance and bank's efficiency. The second and last is that good practices in those two dimensions of ESG activities only have a positive impact on the bank's efficiency in the long term. In the short term, good performance in those two dimensions may even decrease efficiency because the costs are not yet covered by the benefits of such activities.

Future investigations in this field should be extended to unlisted banks, which will imply the development of new measures for corporate social performance. Approaches such as the stochastic frontier approach and the analytical hierarchical process should be considered as alternative methodologies in the study of this relationship.

Having established the main conclusions and recommendations of the three essays carried out on European banking, we conclude hoping that the results here obtained will inspire decision-makers, including managers, political and regulatory authorities, to implement a set of practices and policies that allow definitively the construction of a true system European banking system, based on banking stability and socially and environmentally responsible principles.

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ANNEX

a. List of publications included in the thesis

The different chapters of this thesis resulted in articles that were or will be submitted to scientific journals, all evaluated by the JOURNAL CITATION REPORTS (JCR). To date, an article that resulted from Chapter 2 of the thesis has been published in SAGE Open, ISSN: 2158-2440 JCR (Impact Factor 2020: 1.356) Q3, and is presented below.

López-Penabad, M. C., Iglesias-Casal, A., & Neto, J. F. S. (2021). Competition and Financial Stability in the European Listed Banks. *SAGE Open*, *11*(3), 1–13. https://doi.org/10.1177/21582440211032645

b. Authorization of the journal/publisher for use of the publication in the thesis

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c. Specification of the doctoral student's contribution to the published work

The doctoral student had a fundamental role in the elaboration of the entire published article, namely, in the following aspects:

- Literature review and conceptualization;
- Definition of the methodology to be used;
- Data collection and calculation of variables of interest;
- Estimation and systematization of the results obtained; and
- Concluding.