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The link between financial development and environmental degradation in Portugal: a quantitative analysis

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Master´s Degree in Monetary and Financial Economics

Advisor: Professor Doctor Ricardo Barradas, Assistant Professor
ISCTE - University Institute of Lisbon

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Department of Political Economy

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Resumo

Esta dissertação utiliza o estimador autorregressivo de desfasamento distribuído (ARDL) para investigar a relação entre o desenvolvimento financeiro (crédito, oferta monetária e capitalização bolsista) e a degradação ambiental em Portugal de 1977 a 2023, ao mesmo tempo que contabiliza as influências do crescimento económico, abertura comercial, consumo de energia e urbanização. Os resultados demonstram que o desenvolvimento financeiro, medido através do crédito e da oferta monetária, exerce um efeito negativo significativo nas emissões de CO_2 a longo prazo, enquanto a capitalização bolsista não tem um impacto significativo nas emissões de carbono durante o mesmo período de tempo. No curto prazo, apenas o crédito e a oferta monetária continuam a influenciar as emissões. O crédito mantém um efeito negativo significativo, enquanto a oferta monetária apresenta um efeito positivo significativo. Para além disso, os resultados sugerem que, a longo prazo, o crescimento económico e a urbanização estão significativamente associados a um aumento da qualidade ambiental, enquanto a abertura comercial e o consumo de energia aumentam as emissões de carbono. Estas conclusões não só contribuem para a literatura existente como também têm implicações políticas significativas.

Palavras-chave: Desenvolvimento financeiro, Degradação ambiental, Emissões de CO_2, Séries temporais, Portugal

Abstract

This dissertation uses the autoregressive distributed lag (ARDL) estimator to investigate the relationship between financial development (credit, money supply, and stock market capitalization) and environmental degradation in Portugal from 1977 to 2023, while accounting for the influences of economic growth, trade openness, energy consumption, and urbanization. The results demonstrate that financial development, measured using credit and money supply, exerts a significant negative effect on CO_2 emissions in the long-term, whereas stock market capitalization does not significantly impact carbon emissions over the same period of time. In the short-term, only credit and money supply continue to influence emissions. Credit maintains a significant negative effect, while money supply exhibits a significant positive effect. Additionally, the results suggest that, in the long-run, economic growth and urbanization are significantly associated with an increase in environmental quality, whereas trade openness and energy consumption exacerbate carbon emissions. These findings not only contribute to the existing literature but also provide significant policy implications.

Keywords: Financial development, Environmental degradation, CO_2 emissions, Time-series, Portugal

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Glossary of Acronyms

2SLS - Two-Stage Least Squares

ADF - Augmented Dickey-Fuller

AMG - Augmented Mean Group

APEC - Asia-Pacific Economic Cooperation

ARDL - Autoregressive Distributed Lag

BRICS – Brazil, Russia, India, China, South Africa

CCEMG - Common Correlated Effects Mean Group

CCR - Canonical Correlation Regression

CO_2 – Carbon Emissions

DCCE - Dynamic Common Correlated Effects

DOLS - Dynamic Ordinary Least Squares

EC – Economic Growth

EEC - European Economic Community

EMDE´s - Emerging Market and Developing Economy Countries

FD – Financial Development

FDI – Foreign Direct Investment

FMOLS - Fully Modified Ordinary Least Squares

GDP – Gross Domestic Product

GHG - Greenhouse Gas

MENA - Middle East and North Africa

NARDL - Nonlinear Autoregressive Distributed Lag

OLS – Ordinary Least Squares

PECM - Periodic Error Correction Model

PP - Phillips-Perron

PVAR – Panel Vector Autoregression

QARDL - Quantile Autoregressive Distributed Lag

R&D - Research and Development

TO – Trade Openness

URB - Urbanization

VECM - Vector Error Correction Model

CHAPTER 1

Introduction

The study of climate change is one of today's most important issues, not only because it provides a better understanding of the impact of human activity on the planet, through its ecosystems, natural resources and biodiversity, but also because it provides a set of measures aimed at increasing environmental sustainability. The greenhouse effect is particularly relevant in this area, as it is the main driver of environmental degradation and its main contributor is carbon dioxide (CO_2) emissions resulting from human activity. Although it is a natural process, the exponential increase in greenhouse gas (GHG) emissions resulting from human activities jeopardizes the global climate balance by increasing the planet's temperature, as well as other phenomena such as melting ice, rising sea levels, heat waves and droughts, and other extreme events (torrential rains, hurricanes, typhoons, among other).

Portugal, in turn, is among the European countries most vulnerable to the impacts of climate change, according to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change published on February 28, 2022. This vulnerability is associated with some of the phenomena mentioned above, as well as a decrease in agricultural productivity, the spread of diseases by vectors (insects and snails), among others. Alongside these environmental issues, Portugal has undergone a series of significant economic and institutional transformations linked to the restructuring of its financial system, through privatizations, liberalizations and deregulations, especially since its entry into the European Economic Community (EEC), in order to comply with membership requirements (Barradas, 2020). In this sense, taking into account its growing financialization, as well as the risk to which it is exposed in climate terms, this dissertation aims to investigate the relationship between financial development and environmental degradation in Portugal, making it possible to trace the role of the Portuguese financial sector in the energy transition, as well as serving as a guide for the formulation of public policies that promote sustainable financial practices in line with national and European climate goals.

Financial development is now established as one of the main determinants of carbon emissions, although the existing literature does not converge on a common conclusion regarding its impact. The empirical literature is divided into three groups based on the results obtained, which vary according to the choice of sample and the indicators that proxy financial development. The first group shows that financial development leads to a decrease in emissions

(Shabaz et al., 2015; Shahbaz, Nasir and Roubaud, 2018; Zaidi et al., 2019; Godil et al., 2020; Khan, Khan and Muhammad, 2020; Rafique et al., 2020; Zhao and Yang, 2020; Khan and Ozturk, 2021; Habiba and Xinbang, 2022). The second group suggests that financial development exacerbates environmental degradation (Ali et al., 2018; Pata, 2018; Acheampong, 2019; Bui , 2020; Le and Ozturk, 2020; Shahbaz et al., 2020; Anwar et al., 2021; Ling et al., 2021; Shen et al., 2021). Finally, the third and last group indicates that financial development does not exert any significant impact on CO_2 emissions (Dogan and Turkekul, 2015; Omri et al., 2015; Jamel and Maktouf, 2017; Abokyi et al., 2019). Considering the results of these authors, this study aims to contribute to this debate and, simultaneously, to mitigate the scarcity of available literature focused on Portugal, by providing a more central and broader perspective on the impact of financial development on environmental degradation in Portugal. The analysis followed a time series econometric approach according to which environmental degradation, represented by CO_2 emissions per capita, depends on financial development (credit, money supply and stock market capitalization), as well as other control variables that have been shown theoretically and empirically to be determinants of carbon emissions (economic growth, energy consumption, trade openness and urbanization). The Autoregressive Distributed Lag (ARDL) estimator developed by Pesaran et al. (2001) was used due to the presence of a mixture of variables that are stationary in levels and variables that are stationary only in first differences.

The results show that, in the long-term, financial development has a negative impact on carbon emissions, as do economic growth and urbanization. On the other hand, trade openness and energy consumption lead to an increase in emissions in the same time frame. In the short-term, financial development, measured through credit, and economic growth have a negative impact on environmental quality, while trade openness leads to a decrease in emissions.

The rest of the dissertation is organized as follows. In the second section, the literature review is presented. The third section contains the model design and the main hypotheses, followed by a description of the data in the fourth section. The econometric approach that will be used is explained in the fifth section, followed by the presentation of the empirical results and discussions in the sixth section. The final section provides the main conclusions and some policy implications.

CHAPTER 2

Literature review

The effects of financial development on environmental degradation have been very debated in the literature. The primary theoretical perspectives are divided into two main groups.

The first group argues that financial development can enhance environmental quality through various channels. One of these channels is related to foreign direct investment (FDI) and technological innovation for sustainability, where scholars claim that financial development promotes FDI attraction and fosters research and development (R&D) activities, increasing environmental quality (Frankel and Romer, 1999; Tamazian et al., 2009; Khan et al., 2019). Furthermore, the financial sector development allows borrowers to have access to capital at a lower cost, which can help both public and private sectors to invest in energy-saving technologies, improving energy efficiency and reducing CO_2 emissions (Tamazian et al., 2009; Tamazian and Rao, 2010; Shahbaz et al., 2019). Another channel where financial development positively contributes to environmental quality is reported by Claessens and Feijen (2007), where they argue that financial development leads to good corporate governance and a more environmentally conscious approach to business.

On the other hand, the second group points that financial development negatively influences environmental sustainability. Some authors argue that financial development, by allowing to borrow money at cheaper levels, makes it easier for people to buy big-ticket items such as refrigerators, cars and houses, leading to higher energy consumption and CO_2 emissions. This effect can also be seen through a business perspective, where companies reduce their financing costs and expand their production levels, which in turn promotes more energy demand and higher levels of carbon emissions. Additionally, in result of the effects already mentioned comes a third one, the wealth effect, where a growing financial sector boosts consumer and business confidence, leading to higher consumption and investment, which consequently raises CO_2 emissions (Sadorsky, 2010, 2011; Zhang, 2011; Shabaz and Lean, 2012). At last, FDI is also seen as a potential catalyst of environmental degradation as it may accelerate industrial activities that rely on fossil fuels, worsening environmental degradation (Sadorsky, 2011; Zhang, 2011).

The empirical literature on this topic falls into three categories depending on their results, in a context in which they typically vary according to the choice of the sample of countries and indicators to proxy the financial development.

The first category indicates that financial development negatively affects CO_2 emissions (Table 1). For example, Khan, Khan and Muhammad (2020) investigated the effect of financial development on CO_2 emissions in 184 countries applying seemingly unrelated regression (SUR), two-step difference, and the system-generalized method of moments (sys-GMM) model. Their results, based on the two-step difference and the system GMM model, showed that financial development measured using domestic credit to the private sector by banks and financial institutions decreases CO_2 emissions. Similarly, Khan and Ozturk (2021) used a two-step difference and system GMM model to examine the direct and indirect effects of financial development on CO_2 emissions in 88 developing countries. The direct effects of financial development on CO_2 emissions are negative, as are the indirect effects of financial development through income, trade openness, and foreign direct investment (FDI), suggesting that financial development moderates the adverse effects of these variables on pollution emissions. Additionally, Habiba and Xinbang (2022) by employing the two-stage system GMM revealed that financial market development measured using the IMF indices and its sub-indices (FM-access, FM-depth, and FM-efficiency) negatively impacts CO_2 emissions in 22 developed and 24 emerging countries. The same outcome was observed regarding the impact of financial institutions development and its sub-indices (FI-access, FI-depth, and FI-efficiency) in developed countries. In the case of 17 Asia Pacific Economic Cooperation (APEC) countries, Zaidi et al. (2019) found that financial development (domestic credit to the private sector as a share of GDP) reduces CO_2 emissions. Using data from Pakistan, Godil et al. (2020) employed a quantile autoregressive distributed lag (QARDL) model to examine the effects of financial development, information and communication technology, and institutional quality on CO_2 emissions. Their results suggest that financial development (domestic credit by the financial sector as a share of GDP) has a negative impact on carbon emissions in almost all quantiles, which means that an increase in financial development will reduce CO_2 emissions, regardless of their current level, whether high or low. In another study, Shabaz et al. (2015) investigated the multivariate Granger causality between CO_2 emissions, energy intensity, and economic growth in Portugal using the vector error correction model (VECM) Granger causality approach and ARDL bounds approach to test the existence of a long-term relationship between the variables. The findings indicate that financial development, measured by real domestic credit to the private sector per capita, contributes to a reduction in long-term carbon emissions. The existence of an inverted U-shaped relationship between financial development and CO_2 emissions is also confirmed. Similarly, Shahbaz, Nasir and Roubaud (2018) employed the bootstrapping ARDL cointegration approach and bootstrapping ARDL-based Granger causality to examine the effects of FDI, financial development, and energy innovations on environmental degradation in France. They used data from the period 1955-2016 and found that financial development (real domestic credit to the private sector – constant local currency) reduces energy consumption, which subsequently leads to a decrease in carbon emissions. Additionally, Rafique et al. (2020) explored the effects of FDI, technological innovation, and financial development on CO_2 emissions in BRICS (Brazil, Russia, India, China, and South Korea) utilizing augmented mean group (AMG) and fully modified ordinary least squares (FMOLS) estimators. The outcome suggests that financial development has a significantly negative effect on carbon emissions. In the case of China, Zhao and Yang (2020) employed between-dimension, group-mean FMOLS and dynamic ordinary least squares (DOLS) estimators, periodic error correction model (PECM) Granger causal test and a panel vector autoregression (PVAR) model to investigate the influence of financial development on CO_2 emissions in China´s provinces. Financial development is represented by an index resulting from the application of principal component analysis (PCA) on indicators such as the ratio of total credit to provincial gross domestic product (GDP), ratio of credit to deposit, ratio of FDI to provincial GDP, ratio of stock market capitalization to provincial GDP, and ratio of stock traded value to provincial GDP. The results indicate that financial development negatively impacts CO_2 emissions at the regional level, although this negative influence does not apply to the provinces of Zhejiang, Fujian, Sichuan, Yunnan, Shaanxi, and Xinjiang from an individual perspective, where financial development increases carbon emissions.

Table 1 – Summary of the empirical literature where financial development leads to a decrease in emissions

Author	**Study period**	**Countries**	**Methodology**	**Indicator for financial development**	**Findings**
Khan, Khan and Muhammad (2020)	1990-2017	184 countries worldwide	Dynamic Seemingly Unrelated Regression (DSUR) Two-step GMM Two-step System GMM	Domestic credit to the private sector by bank and financial corporations as a percentage of GDP	CO2 emissions as a dependent variable: - Financial development negatively impacts CO2 emissions Energy consumption as a dependent variable: - Financial development increases energy consumption (CO2 emissions increase)
Khan and Ozturk (2021)	2000–2014	88 developing countries	Difference GMM System GMM	Financial system deposits to GDP Domestic credit provided by financial sector (% of GDP) Domestic credit to private sector (% of GDP) Total bank deposits to GDP (%) Liquid liabilities (M3) as a % of GDP	Direct effects of financial development on CO2 emissions are negative. Indirect effects of financial development on CO2 emissions through income, trade openness and FDI are also negative.

Habiba and Xinbang (2022)	2000–2018	22 developed and 24 emerging countries	Two-stage System GMM	IMF index (Overall Financial Markets Development and Overall Financial Institutions Development): - OFM Development (FM - access, FM-depth, FM - efficiency) - OFI Development (FI - access, FI - depth, FI - efficiency)	Overall financial institution development and its sub-indices have a significant negative impact on CO2 emissions in developed countries. The effect of these indices on CO2 emissions in emerging countries is positive. The relationship between financial markets development and CO2 emissions is negative in both groups of countries (developed and emerging).
Zaidi et al. (2019)	1990-2016	17 Asia Pacific Economic Cooperation countries (APEC) countries	Westerlund panel cointegration test CUP-FM CUP-BC Dumitrescu and Hurlin causality Granger causality	Domestic credit issued to private sector (% of GDP)	Financial development decreases CO2 emissions. Bidirectional causality between financial development and CO2 emissions according to Dumitrescu and Hurlin´s causality analysis.
Godil et al. (2020)	1995-2018	Pakistan	QARDL	Domestic credit by the financial sector (% of GDP)	Financial development has a significant negative impact on CO2 emissions at almost all quantiles.
Shabaz et al. (2015)	1971-2011	Portugal	ARDL bounds testing approach to cointegration VECM Granger causality	Real domestic credit to private sector per capita	Financial development condenses CO2 emissions. Inverted U-shape relationship between financial development and CO2 emissions. Unidirectional causal relationship from financial development to CO2 emissions. Financial development Granger causes energy intensity.
Shahbaz, Nasir and Roubaud (2018)	1955-2016	France	Bootstrapping ARDL cointegration approach Bootstrapping ARDL-based Granger causality	Real domestic credit to private sector (constant local currency)	Financial development leads to a decline on CO2 emissions. Financial development causes foreign direct investment, economic growth, energy consumption, and public expenditure on energy R&D and CO2 emissions.
Rafique et al. (2020)	1990-2017	BRICS countries	AMG FMOLS DOLS Dumitrescu and Hurlin panel causality	IMF index (Overall Financial Markets Development and Overall Financial Institutions Development): - OFM Development (FM - access, FM-depth, FM - efficiency) - OFI Development (FI - access, FI - depth, FI - efficiency)	Negative and significant influence of financial development on CO2 emissions. Bidirectional causal relationship between GDP, financial development, technological innovation, trade openness, urbanization, energy use, and CO2 emissions.
Zhao and Yang (2020)	2001-2015	China	Between-dimension, group-mean FMOLS and DOLS PECM Granger causal test PVAR	PCA (ratio of total credit to provincial GDP, ratio of credit to deposit, ratio of FDI to provincial GDP, ratio of stock market capitalization to provincial GDP, ratio of stock traded value to provincial GDP)	Financial development negatively affects CO2 emissions. This negative impact does not apply to Zhejiang, Fujian, Sichuan, Yunnan, Shaanxi and Xinjiang provinces, from an individual perspective, where positive influence arises. Two-way causal relationship between financial development and CO2 emissions in the long-term.

The second category of studies points out that financial development has a positive influence on CO_2 emissions (Table 2). Bui (2020) utilized two-stage least squares (2SLS) and three-stage least squares (3SLS) estimators to investigate the transmission channels between financial development and CO_2 emissions from a global perspective (a sample of 100 countries).

The results indicate that financial development (domestic credit provided by the financial sector as a share of GDP) exerts a positive influence on carbon emissions through both direct and indirect mechanisms. Indirect impact occurs via two distinct transmission channels. The first channel pertains to energy consumption, suggesting that financial development enhances the demand for energy, which subsequently leads to an increase in CO_2 emissions. The second channel is related to income inequality, where the results show that financial development can reduce income inequality but in exchange for more CO_2 emissions. Similarly, Le and Ozturk (2020) examined the impacts of globalization, financial development, government expenditures, and institutional quality on CO_2 emissions in 47 Emerging Market and Developing Economies (EMDEs) using the common correlated effects mean group (CCEMG), augmented mean group (AMG), and dynamic common correlated effects (DCCE) estimators and found that financial development (ratio of domestic credit to the private sector as a share of GDP) leads to an increase in carbon emissions. In another study, Acheampong (2019) researched the direct and indirect effects of financial development on CO_2 emissions in 46 sub-Saharan African countries employing the system-generalized method of moments (GMM). The results regarding direct effects suggest that financial development measured by broad money, domestic credit to the private sector, and domestic credit to the private sector by banks increases CO_2 emissions, whereas financial development measured by indicators such as FDI, liquid liabilities, and domestic credit to the private sector by the financial sector has no significant impact on carbon emissions in sub-Saharan African countries. On the other hand, the analysis of the indirect effects revealed that financial development serves as a moderating factor in the relationship between economic growth, energy consumption, and their collective impact on CO_2 emissions. Additionally, the findings reveal that FDI moderates the impact of economic growth on carbon emissions, resulting in a reduction in carbon emissions. Conversely, broad money, domestic credit to the private sector by banks, and domestic credit to the private sector contribute to environmental degradation by increasing carbon emissions, while complementing economic growth. Thus, broad money, domestic credit to the private sector from banks, domestic credit to the private sector from the financial sector, and domestic credit to the private sector augment energy consumption, leading to increased carbon emissions. Furthermore, FDI does not moderate the impact of energy consumption on carbon emissions. However, domestic financial development indicators, including broad money, domestic credit to the private sector by banks, domestic credit to the private sector by the financial sector, and domestic credit to the private sector, complement energy consumption and exert a significant positive effect on carbon emissions. Finally, it was found that the effects of financial development vary across regions. In the case of Nigeria, Ali et al. (2018) employed the autoregressive distributed lag (ARDL) bounds approach to investigate the influence of financial development, energy consumption, trade openness, and economic growth on CO_2 emissions between the 1971-2010 period. The results indicate that financial development (domestic credit to the private sector as a ratio of GDP) has a positive and significant relationship with carbon emissions in both the short and long term. Anwar et al. (2021), using data from 15 Asian economies from the 1990-2014 period applied FMOLS and DOLS estimators to explore the impact of financial development, urbanization, renewable energy consumption, agriculture, and economic growth. The outcome of the long-run estimation suggests that financial development (domestic credit to the private sector as a share of GDP) negatively affects environmental quality by contributing to an increase in long-term CO_2 emissions. Additionally, Shen et al. (2021) investigated the role of green investment, natural resources rent, energy consumption, and financial development in limiting carbon emissions in 30 provinces in China between 1995-2017. This study used a novel cross-sectionally augmented autoregressive distributed lags (CS-ARDL) methodology to examine the short- and long-term impact of the mentioned variables on CO_2 emissions. The results indicate that financial development – measured by domestic credit to the private sector as a share of GDP – leads to increased carbon emissions. Similarly, Ling et al. (2021) also conducted a study related to China where they examined the asymmetric and time-varying effects of globalization, natural resources, and financial development from a multidimensional perspective. They employed nonlinear autoregressive distributed lag (NARDL) and cross-wavelet modeling approaches to investigate the short- and long-run nonlinear and time-variant association between the variables above (globalization, natural resources, and financial development) from 1984 to 2017. Financial development, measured by domestic credit to the private sector as a share of GDP, was found to have a positive and significant impact on CO_2 emissions in the long term, leading to environmental degradation. In another study, Pata (2018) explored the short- and long-term relationships between GDP, CO_2 emissions, financial development, renewable energy consumption, hydropower consumption, alternative energy consumption, and urbanization. The author employed an ARDL bounds testing approach and Gregory-Hansen and Hatemi-J cointegration tests, FMOLS, and canonical correlation regression (CCR) estimators for the 1974-2014 period. Empirical evidence suggests that financial development, quantified by the ratio of domestic credit to the private sector to GDP, adversely affects environmental conditions. This conclusion was supported by three distinct models, each utilizing different proxies for renewable energy consumption: total renewable energy consumption per capita, hydroelectricity consumption per capita, and alternative energy consumption per capita. In all cases, the analysis revealed a long-term increase in carbon emissions associated with financial development. Shahbaz et al. (2020) analyzed the role of economic growth, R&D expenditures, financial development, and energy consumption in increasing CO_2 emissions in the United Kingdom. Using data from 1870 to 2017, the authors applied the ARDL bootstrapping bounds testing approach to examine short- and long-term relationships. The relationship between financial development (broad money) and carbon emissions was found to be positive, suggesting that an increase in financial development leads to environmental degradation.

Table 2 – Summary of the empirical literature where financial development leads to an increase in emissions

Author	Study period	Countries	Methodology	Indicator for financial development	Findings
Bui (2020)	1990-2012	100 countries worldwide	2SLS 3SLS	Total domestic credit to private sector (% of GDP)	Financial development is positively associated with CO2 emissions. Two transmitting channels from financial development to environmental quality. FD -> + EC -> + CO2 channel: financial development creates more demand for energy, leading to higher energy consumption which increases CO2 emissions. FD -> - GINI -> + CO2 channel: a financial system improvement reduces income inequality, but leads to an increase on CO2 emissions.
Le and Ozturk (2020)	1990-2014	47 Emerging Market and Developing Economies	Westerlund and Banerjee and Carrion-i-Silvestre cointegration tests CCEMG AMG DCCE	Domestic credit to the private sector (% of GDP)	Long-run relationships among globalization, financial development, government expenditures, institutional quality, energy consumption, economic growth, and CO2 emissions. Financial development raises CO2 emissions.
Acheampong (2019)	2000-2015	46 sub-Saharan Africa countries	System GMM	Foreign direct investment (net inflow as a share of GDP) Domestic credit to the private sector (% of GDP) Domestic credit to private sector by banks (% of GDP) Domestic credit to private sector by financial sector (% of GDP) Broad money (% of GDP) Liquid liabilities (M3)	Financial development measured using broad money, domestic credit to the private sector and domestic credit to private sector by banks increases CO2 emissions, while FDI, M3 and domestic credit to private sector by financial sector have no significant effect on CO2 emissions. Financial development moderates economic growth and energy consumption to influence CO2 emissions. Direct and indirect effects of financial development on CO2 emissions differ across regions and income groups.
Ali et al. (2018)	1971-2010	Nigeria	ARDL bounds test approach	Domestic credit to the private sector (% of GDP)	Long-run relationship between CO2 emissions, energy consumption, trade openness, economic growth, and financial development. Financial development has a positive and significant impact on CO2 emissions in the short- and long-term.
Anwar et al. (2021)	1990-2014	15 Asian economies	Impulse response function Variance	Domestic credit to private sector (% of GDP - constant 2010 USD)	In the long-run, financial development leads to environmental degradation by increasing CO2 emissions.

			decomposition techniques		
Shen et al. (2021)	1995-2017	China	CS-ARDL AMG CCEMG	Domestic credit to the private sector (per capita and local currency units)	Financial development is positively linked with CO2 emissions.
Ling et al. (2021)	1984-2017	China	NARDL	Domestic credit to the private sector (% of GDP)	Asymmetric association between globalization, financial development, natural resources and CO2 emissions. In the long-run, a positive shock of financial development has a statistically significant impact on CO2 emissions, leading to environmental degradation.
Pata (2018)	1974-2014	Turkey	Gregory-Hansen and Hatemi-J cointegration tests ARDL FMOLS CCR	Domestic credit to private sector (% of GDP)	Financial development increases per capita CO2 emissions in the long-run.
Shahbaz et al. (2020)	1870-2017	United Kingdom	ARDL FMOLS CCR OLS	Broad money	Financial development leads to an increase on CO2 emissions. U-shaped association between financial development and environmental pollution.

The third category of studies reports an insignificant impact of financial development on CO_2 emissions (Table 3). For example, Abokyi et al. (2019) investigated the dynamic linkage between fossil fuel consumption, industrial growth, financial development, and CO_2 emissions in Ghana from 1971 to 2014. They applied the Bayer-Hack joint cointegration technique and the ARDL bounds test approach with structural breaks. Their findings differed based on the employed technique, since causality tests suggest that financial development (domestic credit to the private sector as a share of GDP) has a significant relationship with carbon emissions, and according to the ARDL approach, this variable does not have any significant impact on emissions. In another study, Dogan and Turkekul (2015) explored the relationship between carbon emissions, energy consumption, GDP, trade openness, urbanization, and financial development in the USA for the period 1960-2010. Using the ARDL bounds testing approach and Granger causality test, they found that financial development (domestic credit to the private sector) has no causal impact on CO_2 emissions. Omri et al. (2015) analyzed the association between financial development, CO_2 emissions, trade openness, and economic growth of 12 Middle East and North Africa (MENA) countries from 1990 to 2011. Using domestic credit to the private sector as a proxy for financial development, no significant relationship was found between CO_2 emissions and financial development. Additionally, Jamel and Maktouf (2017) used the ordinary least squares (OLS) method on panel data from 40 European countries between the 1985-2014 period to examine the causal relationship across economic growth, carbon emissions, financial development, and trade openness. Their results found the neutrality hypothesis linking carbon emissions and financial development, measured as domestic credit provided by banks to the private sector, which means that no significant causal nexus was found between CO_2 emissions and financial development.

Table 3 - Summary of the empirical literature where financial development has no significant impact on emissions

Author	Study period	Countries	Methodology	Indicator for financial development	Findings
Abokyi et al. (2019)	1971-2014	Ghana	ARDL with structural breaks Bayer-Hanck joint cointegration approach	Domestic credit provided by the financial sector (% of GDP)	According to ARDL parameters, financial development has no significant impact on CO2 emissions. The Granger-causality tests suggest financial development has a significant relationship with CO2 emissions.
Dogan and Turkekul (2015)	1960-2010	USA	ARDL Granger causality test based on VECM	Domestic credit to private sector	Financial development has no causal impact on CO2 emissions.
Omri et al. (2015)	1990-2011	12 MENA countries	GMM Pedroni cointegration test Durbin–Wu–Hausman test	Domestic credit to private sector (% of GDP)	No significant relationship was found between CO2 emissions and financial development.
Jamel and Maktouf (2017)	1985-2014	40 European countries	Durbin–Wu–Hausman test OLS Granger causality	Domestic credit provided by banks to the private sector	No significant causal nexus was found between CO2 emissions and financial development.

Given the debate of the existing literature and the fact that it focuses essentially on countries with a high number of CO_2 emissions (per capita), such as the BRICS (Brazil, Russia, China, India, and South Korea) and the United States of America, for example, or in countries with poorly developed financial systems, such as some African countries and the Pacific region, it has become necessary to carry out new empirical studies relating to other countries, such as Portugal. Therefore, this study aims to provide a more central and broader perspective on the impact of financial development on CO_2 emissions in Portugal, placing it as the main explanatory variable in the model, and characterizing it through various indicators for the period between 1977 and 2023.

CHAPTER 3

Context analysis

The aim of this chapter is to provide an empirical framework for the relationship between financial development and environmental degradation in Portugal. Through a descriptive analysis of the primary economic, financial, energetic, and demographic factors, the purpose is to identify structural patterns, historical ruptures, and possible relationships between the events under consideration. In addition to demonstrating the research's applicability, this contextual exercise enables one to foresee interpretations and hypotheses that will be investigated in the empirical chapters.

Portugal's financial development is intricately connected to its integration into the European framework. Since the 1980s, and particularly following its accession to the European Economic Community (EEC) in 1986, the nation has undergone significant institutional and economic transformations. These changes have encompassed the restructuring of its financial system through privatizations, liberalizations, and deregulations of financial activities to meet the membership requirements (Barradas, 2020).

In line with other existing literature that studies the relationship between financial development and environmental degradation, and to enhance our understanding of the financial system's impact across its various dimensions, three different proxies are used to represent financial development: credit (Shabaz et al., 2015; Shahbaz, Nasir and Roubaud, 2018; Adams and Klobodu, 2018; Ali et al., 2018; Pata, 2018; Abokyi et al., 2019; Acheampong, 2019; Charfeddine and Kahia, 2019; Khan et al., 2019; Raheem, Tiwari and Balsalobre-Lorente, 2019; Zaidi et al., 2019; Bui, 2020; Godil et al., 2020; Khan, Khan and Muhammad, 2020; Le and Ozturk, 2020; Majeed et al., 2020; Shoaib et al., 2020; Anwar et al., 2021; Khan and Ozturk, 2021; Ling et al., 2021; Shen et al., 2021); money supply (Adams and Klobodu, 2018; Acheampong, 2019; Khan and Ozturk, 2021); and stock market capitalization (Shoaib et al., 2020).

Credit in Portugal, measured using total credit to private non-financial sector (% of GDP), experienced modest growth until the early 1980s, subsequently entering a phase of decline until the mid-1990s, after which there was a substantial rise, with the ratio surpassing 231% of GDP in 2012. From this point onwards, a pronounced downward trend emerged, signifying a deleveraging process in the private sector, with stability occurring between 140 to 150% of GDP in the final years of the analyzed period (Figure 1).

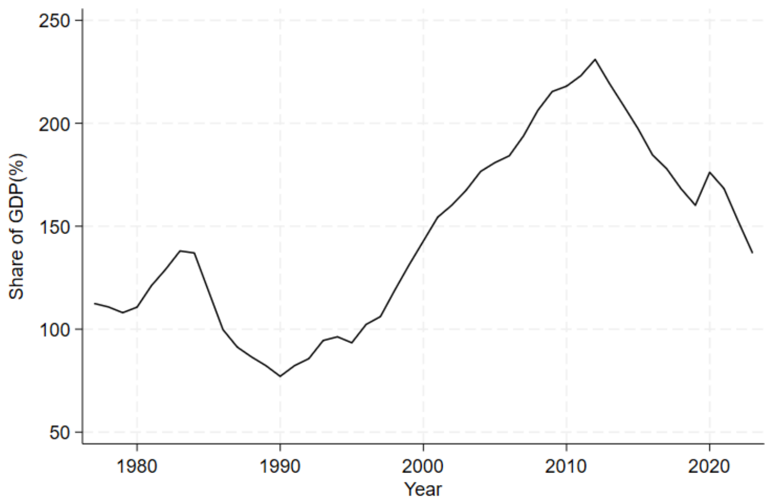

Figure 1 - Total credit to private non-financial sector (% of GDP)

Source: Fred St Louis

On the other hand, the evolution of money supply, represented by liquid liabilities (as a share of GDP), demonstrated a consistent upward trend from 1977 to 2023. Until the mid-1980s, there was rapid growth, reflecting the monetary expansion associated with economic development and stabilization of the financial system. From the 1990s onwards, growth was gradual and relatively stable, with annual record highs since the start of the covid-19 pandemic (Figure 2).

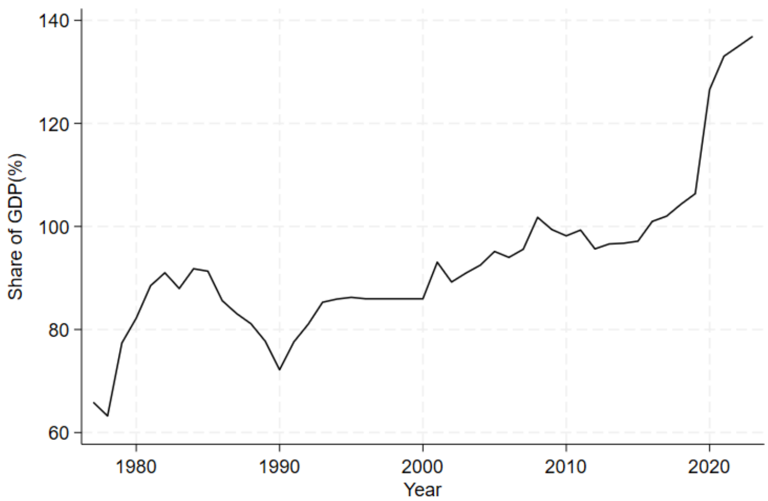

Figure 2 – Liquid liabilities (% of GDP)

Source: Fred St Louis

Finally, an analysis of the evolution of stock market capitalization in Portugal from 1977 to 2023 reveals notable shifts in the influence of the capital market on the national economy. In the initial phase (1977-1996), capitalization values were consistently low, with minor fluctuations remaining under 20% of GDP, except in 1987, when the value surged to approximately 30% of GDP. From the mid-1990s, there was a marked increase, with the capitalization ratio surpassing 50% of GDP by the end of the 20th century, a development linked to the liberalization of financial markets. The apex was reached in 2007, just before the global financial crisis, with values near 55% of the GDP. Following this, market capitalization experienced a steep decline and heightened volatility, indicative of the crisis's repercussions, reduced investment, and the depreciation of financial assets. Despite a partial recovery post-2008, the indicator has not returned to pre-crisis levels, stabilizing between 25% and 40% of the GDP by 2023 (Figure 3).

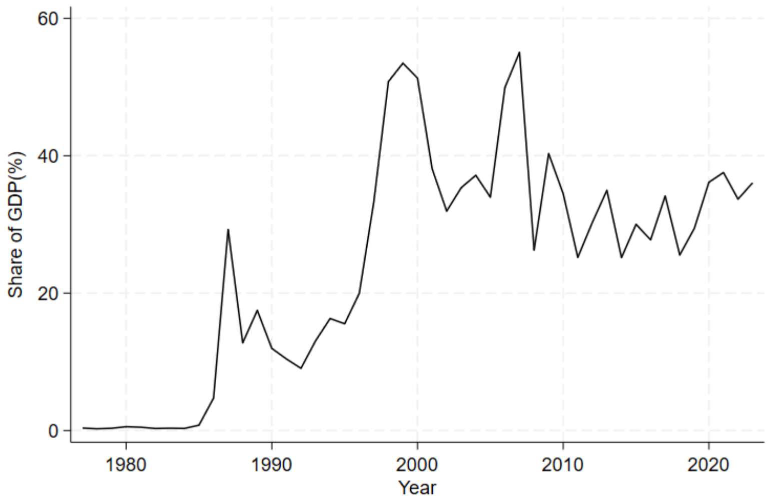

Figure 3 – Market capitalization of listed domestic companies (% of GDP)

Source: World Bank

Environmental degradation is represented in this study by CO_2 emissions, according with other empirical work on this topic (Shabaz et al., 2015; Adams and Klobodu, 2018; Ali et al., 2018; Shahbaz, Nasir and Roubaud, 2018; Pata, 2018; Abokyi et al., 2019; Acheampong, 2019; Charfeddine and Kahia, 2019; Khan et al., 2019; Nasir, Huynh and Tram, 2019; Raheem, Tiwari and Balsalobre-Lorente, 2019; Zaidi et al., 2019; Bui, 2020; Godil et al., 2020; Le and Ozturk, 2020; Khan, Khan and Muhammad, 2020; Majeed et al., 2020; Rafique et al., 2020; Shoaib et al., 2020; Zhao and Yang, 2020; Anwar et al., 2021; Ling et al., 2021; Lv and Li, 2021; Khan and Ozturk, 2021; Shen et al., 2021; Habiba and Xinbang, 2022).

The evolution of CO_2 emissions (tons per capita) in Portugal between 1977 and 2023 had different phases. In the first phase, there was a continuous increase in emissions until the mid-2000s. The turning point in this trend occurred around 2005 when there was a progressive reduction in emissions. The downward trend intensified after 2010 despite a brief growth cycle between 2014 and 2017. Finally, in 2023, the figure recorded is another example of a downward trend in CO2 emissions, corresponding to approximately 50% of the emissions recorded at the peak in 2005 (Figure 4).

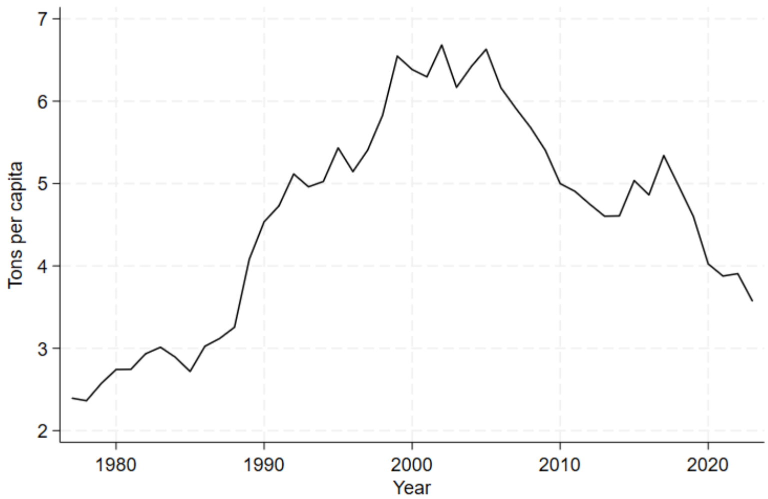

Figure 4 – CO_2 emissions (tons per capita)

Source: EDGAR

The situation in Portugal is analogous to that of other developed nations, including France, Italy, Russia, the United Kingdom, and Canada, where economic growth, coupled with increasing urbanization and industrialization, has adversely impacted environmental quality over time (Abid et al., 2021). In Portugal's case, an examination of environmental and financial trends indicates a potential correlation, as certain periods characterized by a rise in carbon dioxide emissions coincide with increases in some indicators of financial development. Notably, these periods include the time following Portugal's accession to the EEC, the late 20th century, and the early 2000s, up until the subprime crisis.

CHAPTER 4

Specification of the model and hypotheses

The aim of this study is to examine the nexus between financial development and environmental degradation in Portugal. The carbon emissions function employed is modeled in accordance with Tamazian and Rao (2010), Shahbaz et al. (2016), among others. In our model, carbon emissions (CO_2) are expressed as a function of the financial development (*FD*) and other control variables, such as economic growth (*GDP*), trade openness (*TO*), energy consumption (*EC*), and urbanization (*URB*). A similar set of control variables is used by Shahbaz, Nasir and Roubaud (2018), Acheampong (2019), Khan et al. (2019), Bui (2020), Rafique et al. (2020), Shoaib et al. (2020), Zhao and Yang (2020), Lv and Li (2021), Khan and Ozturk (2021) and Habiba and Xinbang (2022), among others.

Accordingly, our model to estimate carbon emissions in Portugal takes the following specification:

$$CO_{2t} = \beta_0 + \beta_1 FD_t + \beta_2 GDP_t + \beta_3 TO_t + \beta_4 EC_t + \beta_5 URB_t + \epsilon_t \quad (1)$$

where t is the time period (years) and ϵ_t is the stochastic error term.

As discussed previously, both theoretically and empirically, the impact of the financial development on carbon emissions can be positive, negative, or insignificant, as the choice of the sample of countries and indicators to proxy the financial development significantly influences the results obtained in the literature.

Economic growth is anticipated to have a positive effect on carbon emissions due to the feedback mechanism between economic expansion and energy consumption. An increase in energy consumption consequently results in heightened CO2 emissions (Shahbaz, Nasir and Roubaud, 2018; Bui, 2020).

Trade openness is expected to exert a negative influence on CO_2 emissions, since the the so-called technical and composition effects of trade openness have a greater preponderance than the so-called scale effect. According to the scale effect, economic liberalization may cause trade openness to have an impact on economic activity, by increasing production and raising energy consumption, which in turn leads to more CO_2 emissions. The technique effect reflects how new environmental regulations, and the transfer and dispersion of new technology affects the quality of the environment. Trade openness encourages the use of cutting-edge, energy-efficient technology to boost domestic output. This suggests that stricter environmental restrictions aimed at improving environmental quality by reducing the intensity of carbon emissions are a result of energy-efficient technologies. The composition effect has to do with an economy's structural transition from the agricultural to the industrial and from the industrial to the service sectors. Compared to the latter, the former (industrial) uses more energy and therefore contributes more to the increase in emissions (Cole and Elliott, 2003; Stern, 2004; Pazienza, 2015a; Pazienza, 2015b; Shahbaz, Nasir and Roubaud, 2018; Habiba and Xinbang, 2022).

Finally, urbanization is expected to promote environmental degradation according to the ecological modernization theory, as the expansion of urbanization will increase energy consumption and consequently contribute to the rise of more carbon emissions (Poumanyvong and Kaneko, 2010; Habiba and Xinbang, 2022).

CHAPTER 5

Data

This study used annual data from 1977 to 2023 for Portugal, which represents a total of 47 observations. This is in line with the frequency and time period for which all variables were accessible. Most proxies were only available annually, and one of the proxies for financial development (stock market capitalization) was only available from 1977 onwards.

Environmental degradation was represented by CO_2 emissions per capita, measured in tons, and was obtained from the Our World in Data database.

Financial development was proxied by three different variables: credit, money supply, and stock market capitalization. Credit was measured using total credit to private non-financial sector as a percentage of the gross domestic product, which was collected from the Fred St Louis database. Money supply was proxied using liquid liabilities as a percentage of the gross domestic product, which is available on the Fred St Louis database[1]. Stock market capitalization was represented using market capitalization of listed domestic companies as percentage of the gross domestic product, which was collected from the World Bank database[2]. The use of different proxies of financial development allowed for a multidimensional analysis of the impact of the financial development on carbon emissions in Portugal through the estimation of three different models.

The annual growth rate of the real gross domestic product per capita was used to represent economic growth, and was obtained from the World Bank database.

Trade openness was measured using the sum of exports and imports as a percentage of the gross domestic product, which was collected from the World Bank database.

Energy consumption was represented using kg of oil equivalent per capita, which is available on the World Bank database.

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[1] This variable was only available between 1960 and 2021, so the values for 2022 and 2023 were calculated by applying the technique of linear extrapolation and assuming money supply growth at a similar average than the corresponding average from 1960 and 2021.

[2] The values for the period between 2019 and 2023 were obtained from the CEIC database.

Urban population as a percentage of total population was used to proxy urbanization, which was obtained from the World Bank database.

Figure 6 shows the plots of all variables and Table 5 compiles the definitions, units, and sources for all the variables. Table 6 presents the descriptive statistics for each variable, while Table 7 illustrates the correlations among all variables. Table 7 includes the standard augmented Dickey and Fuller (ADF) (1979) unit root test for each variable, and Table 8 provides the traditional Phillips and Perron (PP) (1988) unit root test for each variable.

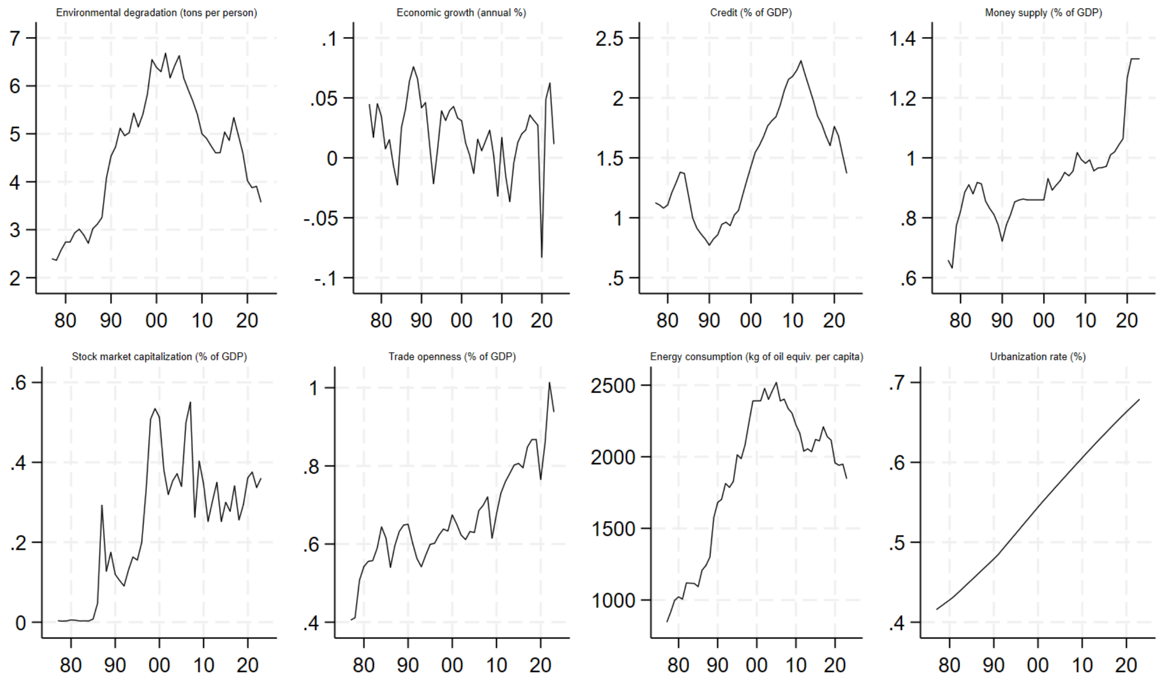

Figure 5 – Plots of all variables

Table 4 – Variables, proxies, units and sources for all variables

Variable	Proxy (units)	Source
Environmental degradation	CO_2 Emissions per capita (tons per capita)	Our World in Data
Economic Growth	GDP per capita growth (annual %)	World Bank
Credit	Total credit to private non-financial sector (% of GDP)	Fred St Louis
Money Supply	Liquid liabilities (% of GDP)	Fred St Louis
Stock Market Capitalization	Market capitalization of listed domestic companies (% of GDP)	World Bank
Trade Openness	Exports and imports of goods and services (% of GDP)	World Bank
Energy Consumption	Energy Consumption (kg of oil equivalent per capita)	World Bank
Urbanization	Urban population (% of total population)	World Bank

Table 5 – The descriptive statistics for each variable

Variable	Mean	Median	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis
Environmental Degradation	4.604	4.863	6.682	2.363	1.2922	-0.191	1.919

Economic Growth	0.019	0.020	0.076	-0.083	0.030	-0.52	4.655
Credit	1.455	1.380	2.310	0.771	0.453	0.231	1.833
Money Supply	0.928	0.910	1.330	0.632	0.151	1.089	4.745
Stock Market Capitalization	0.243	0.278	0.551	0.003	0.164	-0.053	2.011
Trade Openness	0.666	0.633	1.014	0.405	0.126	0.558	3.333
Energy Consumption	1852.590	2013.970	2519.139	845.369	508.535	-0.623	2.038
Urbanization	0.544	0.544	0.679	0.416	0.082	0.036	1.705

Table 6 – The correlations between all the variables

Variable	CO2	GDP	CRED	MS	SMC	TO	EC	URB
CO2	1.000							
GDP	-0.165	1.000						
CRED	0.380***	-0.513***	1.000					
MS	0.117	-0.260*	0.529***	1.000				
SMC	0.763***	-0.0930	0.536***	0.459***	1.000			
TO	0.230	-0.032	0.533***	0.846***	0.523***	1.000		
EC	0.943***	-0.221	0.578***	0.396*	0.863***	0.496***	1.000	
URB	0.490***	-0.259*	0.732***	0.816***	0.713***	0.883***	0.743***	1.000

Note: *** indicates statistical significance at 1% level, ** indicates statistical significance at 5% level and * indicates statistical significance at 10% level

There are no significant problems of multicollinearity among our variables, although it cannot be ruled out completely since some of the correlations between the variables exceed the traditional threshold of 0.8 in absolute terms (Studenmund, 2016). Despite the results, it was decided to keep all the variables in the model, as the relevance of their contribution to this issue has already been proven theoretically and empirically. The omission of a relevant variable could then lead to biased estimates, which represents a much greater problem than obtaining inefficient and not very robust estimates, although not biased, as a reflection of multicollinearity (Greene, 2003).

From the 1980s to the early 2000s, Portugal saw a marked rise in environmental degradation, which then noticeably decreased over the past twenty years. This pattern coincided with moderate fluctuations in economic growth, a continuous increase in money supply and credit until the global financial crisis, heightened energy consumption, ongoing urbanization, and a gradual opening of the economy to international trade (Figure 6). These developments imply that the trajectory of environmental degradation during this time is closely linked to the substantial growth in energy use, the cycle of credit expansion, rising urbanization, and increased trade openness. The strong positive correlations between environmental degradation and factors such as energy consumption, stock market capitalization, credit, and urbanization underscore the significant influence of these structural and financial dynamics on environmental pressures in the country (Table 6). On the other hand, the lack of a significant correlation between economic growth and environmental degradation, along with the weak link to money supply, suggests that economic growth and monetary expansion alone are not direct contributors to emissions in this context. Interestingly, trade openness also exhibits a moderate positive correlation with environmental degradation, potentially indicating the effects of globalized production and transport chains on emissions. The high intercorrelations among urbanization, credit, trade openness, and energy consumption suggest that these factors may interact in complex ways, intensifying environmental impacts.

Table 7 – *P-values* of the ADF unit root test for each variable

Variable	Level			First Difference		
	Intercept	*Trend and Intercept*	*None*	*Intercept*	*Trend and Intercept*	*None*
CO2	0.416	0.993*	0.711	0.000	0.000*	0.000
GDP	0.000*	0.002	0.000	0.000	0.000	0.000*
CRED	0.060	0.343*	0.512	0.060	0.163	0.005*
MS	0.949	0.913	0.991*	0.000*	0.000	0.000
SMC	0.248	0.257*	0.434	0.000	0.000	0.000*
TO	0.948	0.667*	0.994	0.000*	0.000	0.000
EC	0.358	0.996*	0.648	0.305	0.000*	0.046
URB	0.252	0.488*	0.691	0.083*	0.810	0.767

Note: The lag lengths were selected automatically based on the AIC information criteria and * indicates the exogenous variables included in the test according to the AIC information criteria

Table 8 - *P-values* of the PP unit root test for each variable

Variable	Level			First Difference		
	Intercept	*Trend and Intercept*	*None*	*Intercept*	*Trend and Intercept*	*None*
CO2	0.457	0.989*	0.661	0.000	0.000*	0.000
GDP	0.000*	0.002	0.000	0.000	0.000	0.000*
CRED	0.651	0.927	0.628*	0.056	0.155	0.004*
MS	0.917	0.768	0.984*	0.000*	0.000	0.000
SMC	0.288	0.264*	0.434	0.000	0.000	0.000*
TO	0.681	0.164*	1.000	0.000*	0.000	0.000
EC	0.233	0.993*	0.831	0.000	0.000*	0.000
URB	0.997	0.092*	1.000	0.123	0.830*	0.796

Note: * indicates the exogenous variables included in the test according to the AIC information criteria

The results of the ADF and PP unit root tests (Tables 7 and 8) show that we are dealing with a set of integrated variables of order zero (stationary in levels) and integrated variables of order one (stationary only in first differences). More specifically, at the traditional significance levels, economic growth is stationary in levels according to the results of both tests. Environmental degradation, credit, money supply, stock market capitalization, trade openness and energy consumption are only stationary in the first differences in agreement with the results of both tests. Urbanization is stationary only in the first differences by the ADF test but stationary in levels according to the PP test. In this sense, none of the variables under analysis is integrated of order two (stationary only in the second differences) in accordance with the results of the ADF and PP tests.

CHAPTER 6

Econometric approach

The econometric analysis was conducted using the ARDL (Autoregressive Distributed Lag) estimator proposed by Pesaran et al. (2001), as it is the most appropriate method for handling datasets that include a combination of variables that are integrated of order zero and integrated of order one. The choice of the ARDL approach is supported by its four key advantages. First, it accommodates variables integrated of order zero and one, or cointegrated, reducing the reliance on potentially unreliable unit root test outcomes - especially in small samples (Harris and Sollis, 2003; Mills and Narkellos, 2008). Second, the ARDL model has superior small-sample properties compared to traditional cointegration techniques (e.g., Engle and Granger, 1987; Johansen, 1988; Johansen and Juselius, 1990; Gregory and Hansen, 1996; Saikkonen and Lütkepohl, 2000), providing consistent and unbiased estimates even with more limited data (Pesaran and Shin, 1997; Phillips, 2018). Third, the ARDL estimator can address situations involving potential endogeneity among explanatory variables (Im, Pesaran and Shin, 2003; Harris and Sollis, 2003). Finally, it allows all variables to enter the model in levels, regardless of their integration order, which facilitates a more straightforward interpretation of the estimated coefficients (Romão and Barradas, 2024). The estimations were performed using Stata software (version 18) applying the command 'ardl' produced by Kripfganz and Schneider (2023).

The ARDL estimator elucidates the dynamics of environmental degradation by considering its lagged values alongside the contemporaneous and lagged values of the independent variables, namely economic growth, credit, money supply, stock market capitalization, trade openness, energy consumption, and urbanization. In this context, the application of the ARDL estimator encompasses the following five steps.

First, the appropriate number of lags to be included in the ARDL model for generating estimates was determined. This decision was guided by the AIC criteria, which is recommended for small samples comprising fewer than sixty observations (Liew, 2004), as is the case in this study.

Second, the bound tests developed by Pesaran et al. (2001) were employed to evaluate the presence of a cointegration relationship among the variables. Pesaran et al. (2001) provided asymptotically critical values for the upper and lower bounds, which are applicable only to larger samples exceeding one thousand observations. This limitation of the ARDL estimator was addressed by using the critical values for finite samples provided by Kripfganz and Schneider (2020), given the relatively small sample size. Consequently, the null hypothesis of no cointegration can be rejected if the F-statistic exceeds the upper critical value, while it cannot be rejected if the F-statistic falls below the lower critical value. The results are inconclusive regarding cointegration if the F-statistic lies between the upper and lower critical values.

Third, a series of diagnostic tests were carried out to assess the validity and robustness of the estimated models. The Breusch-Godfrey serial correlation LM test, the Skewness and Kurtosis test, the Breusch-Pagan-Godfrey test, the Ramsey RESET test and the CUSUM test were used to ascertain that the residuals are devoid of serial correlation, exhibit normality, and maintain homoscedasticity, thereby ensuring that the models are appropriately specified in their functional forms and validating the stability of the estimates along with the absence of structural breaks. If the models fail at least one of the diagnostic tests, measures must be taken to correct the respective econometric problems and to ensure the reliability of the estimates.

Fourth, the long-term and short-term determinants of environmental degradation in Portugal were presented. The estimations were obtained using the default ARDL specification, which includes an intercept, but excludes deterministic time trends, as this configuration is appropriate given that the majority of the variables were stationary in first differences in accordance with the ADF and PP unit root tests (Tables 7 and 8).

Fifth, the economic effects of the long-term estimates were examined to assess the contribution of each significant determinant in explaining the impact of financial development on carbon emissions in Portugal from 1977 to 2023.

CHAPTER 7

Empirical results and discussion

The first step was to determine the number of optimal lags to include in the ARDL models to generate the estimates (Table 9). Considering the small size of the sample, lags ranging from zero to three were evaluated, as estimating an ARDL model with four lags for both dependent and independent variables is not feasible. Under these circumstances, it was decided to use three lags in the ARDL models as a result of the conclusions obtained by the AIC, which is more suitable for small samples (Liew, 2004). It is also worth mentioning that the Stata software generated the estimates for each ARDL model by automatically selecting the number of lags for each variable, within the maximum limit of three lags.

Table 9 - Values of the information criteria by lag

Financial Development	Lag	LR	FPE	AIC	SC	HQ
Credit	0	n.a.	1.0e-06	3.21044	3.45374	3.30067
	1	829.3	3.4e-14	-14.0009	-12.2978*	-13.3693
	2	129.36	1.0e-14*	-15.3045	-12.1416	-14.1315*
	3	78.805*	1.1e-14	-15.4592*	-10.8365	-13.7448
Money Supply	0	n.a.	6.2e-08	0.435115	0.678413	0.525341
	1	728.31	2.1e-14	-14.4811	-12.778*	-13.8495
	2	111.79	9.3e-15*	-15.3855	-12.2226	-14.2125*
	3	83.017*	9.4e-15	-15.6358*	-11.0132	-13.9215
Stock Market Capitalization	0	n.a.	9.2e-08	0.822188	0.912415	1.06549
	1	686.77	8.0e-14	-13.1498	-12.5182	-11.4467*
	2	100.64	4.6e-14*	-13.8007*	-12.6277*	-10.6378
	3	55.868*	8.5e-14	-13.434	-11.7197	-8.81135

Note: * indicates the optimal lag order selected by the respective information criteria. LR = Likelihood-Ratio information criteria; FPE = Final prediction error; AIC = Akaike information criteria; SC = Schwarz information criteria; SC = Schwarz information criteria; HQ = Hannan-Quinn information criteria

Subsequently, the presence of a cointegration relationship among the variables was examined by applying the bounds test procedure to each of the three ARDL models (Table 10). In all cases, it was found a strong evidence of cointegration, as the calculated F-statistics exceeded the upper bound critical values at conventional significance levels.

Table 10 – Bounds test for cointegration analysis

Financial Development	F-statistic	Critical Value	Lower Bound Value	Upper Bound Value
Credit	**49.687**	1%	4.106	6.148
		5%	2.899	4.486
		10%	2.396	3.789
Money Supply	**5.599**	1%	4.104	6.225

		5%	2.885	4.522
		10%	2.380	3.811
Stock Market Capitalization	**4.878**	1%	4.112	5.917
		5%	2.940	4.378
		10%	2.445	3.722

Note: Critical values for the lower bound and upper bound are from Kripfganz and Schneider (2020)

Afterwards, in order to confirm that none of the three ARDL models suffered from any econometric problems, some diagnostic tests were carried out (Table 11). According to the results obtained, it can be assured that the residuals of all models exhibit no serial correlation, follow a normal distribution, and display homoscedasticity. Additionally, the three models are correctly specified in terms of their functional forms and produce stable estimates, with no evidence of structural breaks detected (Figures 6, 7 and 8).

Table 11 – *P-values* of the diagnostic tests for the ARDL models

Financial Development	Diagnostic Test	*P-value*
Credit	**Breusch-Godfrey**	0.5014
	Skewness and Kurtosis	0.3319
	Breusch-Pagan-Godfrey	0.9417
	Ramsey's RESET	0.7013
Money Supply	**Breusch-Godfrey**	0.2246
	Skewness and Kurtosis	0.8798
	Breusch-Pagan-Godfrey	0.5888
	Ramsey's RESET	0.5873
Stock Market Capitalization	**Breusch-Godfrey**	0.2220
	Skewness and Kurtosis	0.0948
	Breusch-Pagan-Godfrey	0.5493
	Ramsey's RESET	0.1489

Note: Breusch-Godfrey tests were conducted with 3 lags and Ramsey's RESET tests were performed with 1 fitted term, albeit results do not change if we had used more lags and more fitted terms, respectively

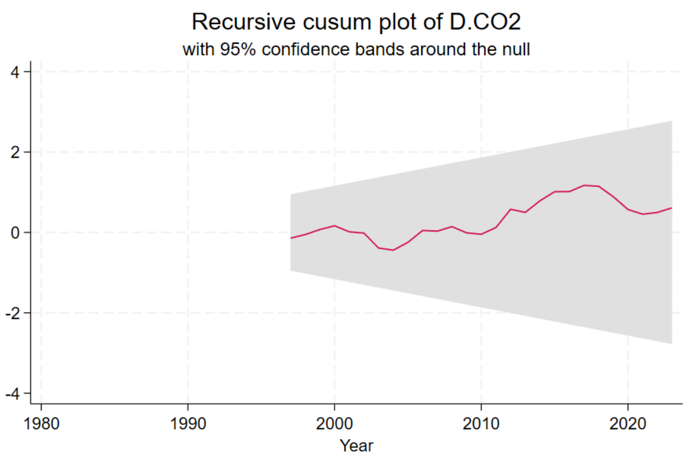

Figure 6 - Plot of the recursive CUSUM for the credit ARDL model

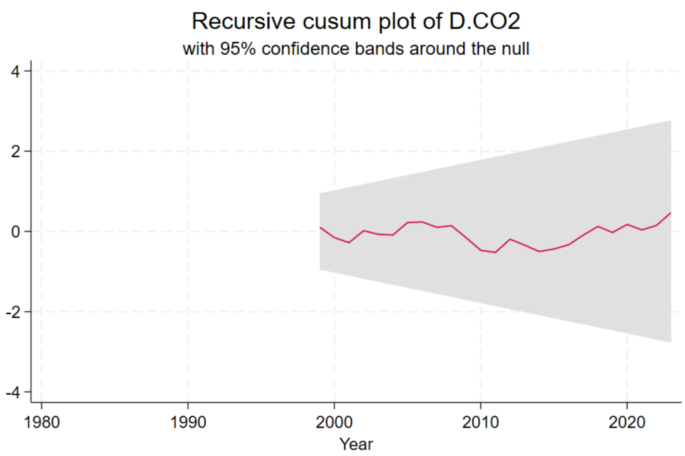

Figure 7 - Plot of the recursive CUSUM for the money supply ARDL model

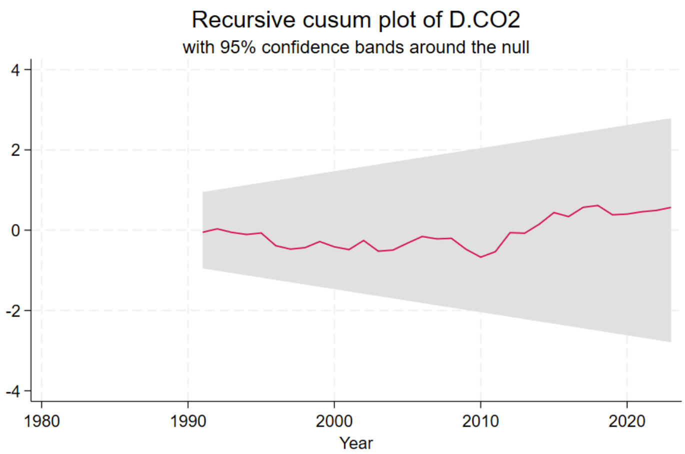

Figure 8 - Plot of the recursive CUSUM for the stock market capitalization ARDL model

Before examining the long-term and short-term estimates of the ARDL models, it is important to emphasize that the models provide a strong explanation of the impact of financial development and control variables on environmental degradation in Portugal, as demonstrated by their high *R-squared* (and adjusted *R-squared*) values. The model that incorporates credit as proxy for financial development explains around 94% (90%) of the variations in CO_2 emissions in Portugal, the model that uses money supply explains around 95% (91%), and the model that incorporates stock market capitalization explains around 92% (89%).

Table 12 - Long-term and short-term estimates

Variable	Credit	Money Supply	Stock Market Capitalization
Long-term Estimates			
Economic Growth$_t$	-9.602***(1.901)[-5.03]	-6.724***(1.655)[-4.06]	-2.480**(1.268)[-1.95]
Financial Development$_t$	-0.222**(0.081)[-2.75]	-1.689**(0.622)[-2.72]	-0.469(0.287)[-1.63]
Trade Openness$_t$	1.463**(0.643)[2.27]	3.119**(1.219)[2.56]	-0.321(0.811)[-0.40]

Energy Consumption$_t$	0.004***(0.000)[19.47]	0.003***(0.000)[26.70]	0.003***(0.000)[20.77]
Urbanization$_t$	-10.106***(1.597)[-6.33]	-9.676***(1.877)[-5.16]	-5.044***(1.707)[-2.96]
Short-term Estimates			
Error Correction Term$_t$	-1.080***(0.082)[-13.16]	-0.900***(1.655)[-4.06]	-0.721***(0.142)[-5.09]
ΔEnvironmental Degradation$_t$	n.a.	n.a.	n.a.
ΔEnvironmental Degradation$_{t-1}$	0.232***(0.082)[2.85]	0.161**(0.090)[1.80]	0.211***(0.071)[2.99]
ΔEnvironmental Degradation$_{t-2}$	0.120**(0.81)[2.48]	0.155**(0.086)[1.81]	0.169**(0.071)[2.37]
ΔEnvironmental Degradation$_{t-3}$	n.a.	n.a.	n.a.
ΔEconomic Growth$_t$	6.219***(1.551)[4.01]	3.640**(1.49)[2.45]	n.a.
ΔEconomic Growth$_{t-1}$	3.289***(1.120)[2.93]	3.323***(1.137)[2.92]	n.a.
ΔEconomic Growth$_{t-2}$	n.a.	3.054***(0.995)[3.07]	n.a.
ΔEconomic Growth$_{t-3}$	n.a.	n.a.	n.a.
ΔFinancial Development$_t$	-0.044(0.347)[-0.13]	1.352**(0.686)[1.97]	n.a.
ΔFinancial Development$_{t-1}$	-0.153(0.425)[-0.36]	2.345***(0.585)[4.01]	n.a.
ΔFinancial Development$_{t-2}$	-1.239***(1.120)[2.93]	0.908(0.641)[3.07]	n.a.
ΔFinancial Development$_{t-3}$	n.a.	n.a.	n.a.
ΔTrade Openness$_t$	n.a.	-1.493(0.906)[-1.65]	0.630(0.472)[1.33]
ΔTrade Openness$_{t-1}$	n.a.	-1.205**(0.554)[-2.18]	n.a.
ΔTrade Openness$_{t-2}$	n.a.	-1.276**(0.644)[-1.98]	n.a.
ΔTrade Openness$_{t-3}$	n.a.	n.a.	n.a.
ΔEnergy Consumption$_t$	n.a.	0.000(0.001)[1.39]	0.002***(0.000)[3.21]
ΔEnergy Consumption$_{t-1}$	n.a.	n.a.	n.a.
ΔEnergy Consumption$_{t-2}$	n.a.	n.a.	n.a.
ΔEnergy Consumption$_{t-3}$	n.a.	n.a.	n.a.
ΔUrbanization$_t$	-24.955(100.908)[-0.25]	n.a.	n.a.
ΔUrbanization$_{t-1}$	113.264(129.14)[0.88]	n.a.	n.a.
ΔUrbanization$_{t-2}$	-238.35**(94.746)[-2.52]	n.a.	n.a.
ΔUrbanization$_{t-3}$	n.a.	n.a.	n.a.
Observations	44	44	44
R-squared	0.939	0.950	0.919
Adjusted R-squared	0.903	0.913	0.894

Note: Standard errors in (), t-statistics in [], D is the operator of the first differences, *** indicates statistically significance at 1% level, ** indicates statistically significance at 5% level and * indicates statistically significance at 10% level

The long-term estimates show that all variables are statistically significant at the conventional significance levels, with the exception of stock market capitalization. This seems to contradict the results obtained by Shoaib et al. (2020), where stock market capitalization, as a proxy for financial development, had a positive and significant impact on long-term emissions, suggesting that the increased market valuation of Portuguese companies tends to make them more energy efficient, probably due to pressure from both their consumers and regulatory institutions.

As for the other variables, certain results also appear to contradict the expected effects on the evolution of CO_2 emissions. Economic growth has a negative influence on carbon emissions, which contrasts with the findings of Shahbaz, Nasir, and Roubaud (2018) and Bui (2020), who identified a feedback mechanism between economic growth and energy consumption that resulted in an increase in emissions. Therefore, the results obtained seem to suggest that the development of economic activity in Portugal is associated with the adoption of more sustainable practices in energy consumption.

On the other hand, energy consumption contributes significantly to an increase in emissions, which corroborates the conclusions provided by Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018), Acheampong, A. (2019), Khan, M. A., Khan, M. J., & Muhammad, N. (2020), Le, T. H., & Ozturk, I. (2020) and Shoaib, M., et al. (2020).

With regard to the other financial development proxies, both credit and money supply exhibit a significant negative impact on the long-term trajectory of emissions. The results related to credit support the findings made by Shabaz, M., et al. (2015), Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018), Zaidi, S. A., et al. (2019), Godil, D. I., et al. (2020) and Khan, M. A., Khan, M. J., & Muhammad, N. (2020), suggesting that the allocation of financial resources by the Portuguese non-financial private sector is directed towards environmental protection initiatives, while also supporting organizations and industries that have a sustainable approach to the way they operate. In turn, the results of money supply are inconsistent with the findings of Acheampong, A. (2019), who argues that money supply, represented by liquid liabilities (M3), is not a determinant of environmental degradation.

Trade openness exerts a significant positive effect on CO_2 emissions in two of the three models, contrary to the assertions made by Cole and Elliott (2003), Stern (2004), Pazienza (2015a, 2015b), Shahbaz, Nasir, and Roubaud (2018), and Habiba and Xinbang (2022). These authors argue that the technical and composition effects of trade openness are more substantial than the scale effect, which implies that trade openness would lead to a reduction in emissions due to technological advancements and a shift in production to cleaner industries. However, the findings of this study suggest that the scale effect, likely attributable to the increase in imports and the associated rise in the transportation of goods and services, which subsequently elevates emissions, may be more pronounced in the Portuguese context[3].

Finally, the results regarding urbanization demonstrate a significant negative effect on the long-term emissions, contrary to the ecological modernization theory supported by

[3] Trade openness is represented by the sum of exports and imports. Given that an increase in exports is associated with an increase in production which, according to the results obtained, leads to a decrease in emissions, the effect shown by trade openness seems to be explained by the influence of imports in this context.

Poumanyvong and Kaneko (2010) and Habiba and Xinbang (2022), which indicates that the expansion of urbanization leads to more carbon emissions. Thus, our results suggest that urban growth may be associated with enhanced energy efficiency and the implementation of more effective environmental policies. This reflects the increased capacity of urban areas to mitigate emissions through the adoption of ecologically optimized infrastructures and improved access to cleaner technologies.

Regarding the short-term estimates, several conclusions should be drawn. First, the error correction terms are all statistically significant at conventional significance levels, negative, and their coefficients range from 0 to –2. This indicates that the ARDL models return to the long-term equilibrium whenever a short-term shock or disturbance occurs. The adjustment speed for any short-term shock is fully corrected within a year, with corrections of approximately 101%, 90%, and 72% for the models of credit, money supply, and stock market capitalization, respectively. Second, CO_2 emissions exhibit a high degree of persistence, as past emissions significantly influence current emission levels in a positive direction. Third, economic growth, both current and past, exerts a positive effect on emissions in the short-term, which contrasts with its long-term influence. Fourth, only two proxies for financial development have a short-term impact on carbon emissions: credit and money supply. Credit shows the same impact as for the long-term. Money supply, however, has as significant positive effect in the short-term. Fifth, trade openness leads to a decrease in emissions in the short-term. Sixth, the remaining variables exhibit similar effects as in the long-term, suggesting that CO_2 emissions in Portugal are influenced by these variables in a comparable way across both the short- and long-term.

Table 13 - Economic effects of financial development in Portugal

Financial Development	Variable	Long-term coefficient	Actual cumulative change	Economic effect
Credit	Economic growth$_t$	-9.602	0.019	-0.182
	Financial Development$_t$	-0.222	0.005	-0.001
	Trade Openness$_t$	1.463	0.028	0.041
	Energy Consumption$_t$	0.004	0.025	0.000
	Urbanization$_t$	-10.106	0.013	-0.131
Money Supply	Economic growth$_t$	-6.724	0.019	-0.128
	Financial Development$_t$	-1.689	0.022	-0.037
	Trade Openness$_t$	3.119	0.028	0.087
	Energy Consumption$_t$	0.003	0.025	0.000
	Urbanization$_t$	-9.676	0.013	-0.126
Stock market capitalization	Economic growth$_t$	-2.480	0.019	-0.047
	Energy Consumption$_t$	0.003	0.025	0.000
	Urbanization$_t$	-5.044	0.013	-0.066

Note: The long-term coefficient corresponds to the estimated coefficient, the actual cumulative change corresponds to the average of the annual growth rates of the corresponding variable from 1977 to 2023 and the economic effect represents the multiplication of the long-term coefficient by the actual cumulative change.

Lastly, analyzing the economic effects of our long-term estimates enables us to identify the primary factors driving carbon emissions in Portugal from 1977 to 2023 (Table 13). The findings are notably consistent across the three models. In the first model, where financial development is represented by credit, economic growth and urbanization emerge as the main contributors to the reduction in carbon emissions, accounting for an average annual decrease of 18.2% and 13.1%, respectively. Credit also contributed to a reduction in CO_2 emissions, although its impact was almost zero, as it was responsible for an average annual decrease of 0.1%. On the other hand, trade openness was found to be the main trigger for the increase of carbon emissions, accounting for an average annual increase of 4.1%. In the second model, where financial development is proxied by money supply, economic growth and urbanization were also the main contributors to the reduction in emissions, accounting for an average annual decrease of 12.8% and 12.6%, respectively. Money supply was responsible for an average annual decrease of 3.7%, while trade openness was responsible for an average annual increase of carbon emissions of 8.7%. In the third model, where financial development is represented by stock market capitalization, economic growth and urbanization continued to be the main triggers that explain the reduction in emissions, although their impact was found to be significant lower compared to the results of the other models, accounting for an average annual decrease of 4.7% and 6.6%, respectively. Energy consumption was found to have no economic effect on carbon emissions in all three models.

CHAPTER 8

Conclusion

This study applied the ARDL estimator developed by Pesaran et al. (2001) to investigate the relationship between financial development and environmental degradation by conducting a time-series econometric analysis focused on Portugal from 1977 to 2023, while controlling for the impact of economic growth, trade openness, energy consumption and urbanization. In order to enhance a more comprehensive understanding of financial development and its relationship with environmental degradation, three indicators of financial development (credit, money supply, and stock market capitalization) were employed to examine their impact on carbon emissions.

The results obtained revealed that financial development measured using credit and money supply exert a significant negative effect on CO_2 emissions in the long-term, while stock market capitalization has no significant impact on carbon emissions for the same period of time. In the short-term, only credit and money supply continue to have an impact on emissions. Credit maintains a significant negative effect, while money supply now has a significant positive effect. The results also indicate that, in the long-run, economic growth and urbanization are found to be significantly associated with a reduction in CO_2 emissions, whereas trade openness and energy consumption exert an exacerbating effect on emissions in Portugal.

Despite what the results indicate, they should be interpreted with prudence for some reasons. First, the study´s findings have limited applicability to other countries. These countries may possess distinct economic, social and institutional contexts that could influence the relationship between financial development and environmental degradation, as seen in other empirical studies. Second, although the variables used to represent financial development are appropriate and have shown valid results, the scarcity of data, in temporal terms of other potential proxies, especially with regard to financial markets (total value of stocks traded as a share of GDP, turnover ratio of domestic shares, for example), ends up limiting the number of conclusions that can be drawn.

Finally, this study not only contributes to the existing literature but also provides significant policy implications, as its findings support the claims made by Acheampong, A. (2019) that suggest that excluding financial development from models of carbon emissions may lead to a distorted portrayal of true carbon emissions, thereby undermining the success and sustainability of strategies aimed at improving environmental quality. Therefore, based on the results obtained, policymakers should advocate for policies that incentivize the financing of companies committed to adopting clean technologies and environmentally responsible practices through tax incentives or by facilitating access to credit for these organizations, particularly for projects associated with environmental protection or those with minimal environmental impact. Additionally, the promotion of the energy transition must persist, as the implementation of more sustainable practices and the advancement of low-carbon technologies are instrumental in mitigating the environmental impact of energy consumption. The relationship between urbanization and carbon emissions indicates that urban expansion is linked to enhancements in energy efficiency and the implementation of more effective environmental policies. Consequently, policymakers should aim to extend the urban policies implemented to the national level, promoting the construction of sustainable infrastructure and the development of a low-emission public transportation network.

Future research could seek to expand this study to a continental scale by utilizing panel data econometric analysis or examining whether other variables, such as institutional development and technological advancement, influence the relationship between financial development and environmental quality.

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