CATÓLICA-LISBON School of Business and Economics

EPI Score effect on the Portuguese government bond yield spread

José Maria Amador Rodrigues de Freitas

Dissertation written under the supervision of Professor Diana Bonfim

Dissertation submitted in partial fulfilment of requirements for the Mestrado em Finanças, at the Universidade Católica Portuguesa, 02/01/2023.

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Abstract

This dissertation aims to understand if there is a relationship between environmental policies and the Portuguese cost of borrowing. I use a linear regression to estimate two models, one for the two years of government bond maturity to assess the relationship with the short-term cost of borrowing and the other for ten years of government bond maturity to estimate the association with the long-term cost of borrowing. The model controls for macroeconomic performance, fiscal conditions, foreign borrowing, inflation rate, labour productivity, demographic situation, global risk aversion, liquidity risk and, more importantly, the Environmental Performance Index. The results of the regressions estimated for the short-term maturity model and long-term model suggest that the EPI score has a positive relationship with the Portuguese government bond yield spread independently of the maturity of the bond. Furthermore, the EPI score is statistically significant for both maturities. This means that an EPI score increase is associated with an increase in the yield spread. The results of the analysis performed in this dissertation are that the environmental policies may have an opposite effect than the one expected (Capelle-Blancard, G., Crifo, P., Diaye, M.-A., Oueghlissi, R., & Scholtens, B. 2016), being associated with an increase (rather than a decrease) of the government cost of borrowing. That said, it is possible that these results are directly attributable to external factors that occurred during the time period studied (the introduction of the Euro, the subprime crisis and the government debt crisis).

Keywords: Environmental; Government bond yield spread.

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Resumo

Esta dissertação visa compreender se existe uma relação entre as políticas ambientais e o custo para o governo português de emitir obrigações. Utilizo uma regressão linear para estimar dois modelos, um para os dois anos de maturidade das obrigações do Estado para avaliar a relação com o custo a curto prazo e outro para os dez anos de maturidade das obrigações do Estado para estimar a associação com o custo a longo prazo. O modelo controla o desempenho macroeconómico, as condições fiscais, o endividamento externo, a taxa de inflação, a produtividade laboral, a situação demográfica, a aversão ao risco global, o risco de liquidez e, mais importante, o Índice de Desempenho Ambiental. Os resultados das regressões estimadas para o modelo de maturidade de curto prazo e modelo de longo prazo sugerem que a pontuação do EPI tem uma relação positiva com o spread da yield das obrigações do Estado português, independentemente da maturidade da obrigação. Adicionalmente, a pontuação do EPI é estatisticamente significativa para ambos os prazos de vencimento. Isto significa que um aumento da pontuação do EPI está associado a um aumento do spread da yield. Os resultados da análise realizada nesta dissertação são que as políticas ambientais podem ter um efeito contrário ao esperado, estando associadas a um aumento (e não a uma diminuição) do custo do emitir obrigações por parte do governo. Dito isto, é possível que estes resultados sejam diretamente atribuíveis a fatores externos que ocorreram durante o período estudado.

Palavras-chave: Ambiente; Spread da yield das obrigações do Estado.

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1 Introduction

According to a Swiss Re Institute report, if temperatures continue to rise and both the Paris Agreement and the 2050 net-zero emissions targets are not met by 2050, the world could lose 10% of its total economic value due to climate change.

The topic of environmental risks is increasingly gaining centre stage in global discussions due to the real impacts it can have on the countries' economies.

The World Economic Forum is one of the most important stages in the economic discussion process. Among the top leaders in business, politics, culture, and other fields of society, the WEF has a significant impact on shaping the agendas of global, regional, and industry events.

The Forum has been operating as a not-for-profit foundation since 1971 when it was established. As an independent, impartial, and unbiased body, it has no ties to any special interests or groups. The Forum states that "For more than 50 years, the Forum has engaged global Partners to drive significant impact – creating historical initiatives, industry breakthroughs, economical solutions and tens of thousands of projects and collaborations – improving the state of the world." (weforum.org/impact). Among the ten most severe risks that are expected to arise on a global scale in the next ten years, according to the 17th edition of the World Economic Forum report published in 2022, environment risks are identified as five of the ten most severe risks on a global scale.

As a further explanation of how important environmental risks are for the economy, the report Climate Change and Sovereign Risk (Stampe, J., Volz, U., Ahmed, S., Anai, R., Ariyapruchya, S., et all (2020)) used a sample of 40 developed and emerging economies as a basis for the evaluation of the relationship between sovereign bond yields and climate risk vulnerabilities and climate risk resilience. According to the report, the cost of sovereign borrowing is particularly vulnerable to climate risk vulnerability, while resilience to climate risk has only a very small impact on sovereign bond yields in the long run.

It is the purpose of this dissertation to determine whether or not the environmental policies adopted by the Portuguese government can be rewarded by external investors through the yield spreads on government bonds issued by the Portuguese government. In order to calculate the Portuguese government bond yield spread, I use the German government bond yield as a benchmark. For measuring the environmental policies implemented by the Portuguese

government, I use the Environmental Performance Index produced by the collaboration of the Yale Center for Environmental Law and Policy (YCELP) and Yale Data-Driven Environmental Solutions Group, Yale University, Columbia University Center for International Earth Science Information Network (CIESIN), and the World Economic Forum (WEF).

Bearing in mind that the environmental policies are expected to have an impact on the medium to long term, I run the model for two-year and ten years maturity government bonds. My aim with this approach is to understand if the environmental policies are generating a larger discount on the long-term maturity government bond yields than on the short-term maturity government bond yields as a result of the environmental policies.

In order to have a more robust model for studying government bond yield spreads, I reviewed the literature on the determinants of government bond yield spreads and leverage on the study (Pinho, A., & Barradas, R., 2021). The authors identified the variables macroeconomic performance, fiscal conditions, foreign borrowing, inflation rate, labour productivity, demographic situation, global risk aversion and liquidity risk as statistically significant to explain the behaviour of the Portuguese government bond yields. In this dissertation, I added the variable Environmental Performance Index to the model to understand if the EPI score has an impact on the Portuguese government bond yield spreads. The analysis studies the time period from 1996 to 2020.

According to the results of the regressions conducted, both for the short-term maturity model and for the long-term maturity model, it appears that the EPI score is positively correlated with the Portuguese government bond yield spread, regardless of the bond's maturity period. Additionally, the data suggest that the variable EPI score is statistically significant for both maturities (two years and ten years). A rise in the EPI score may therefore mean that the yield spread will increase as a result of a rise in the EPI score. A detailed analysis and discussion of the results obtained are included in the results and discussion sections of this dissertation.

2 Literature Review

The relationship between the sovereign bond yield spreads and sustainable development is gaining more and more relevance due to the worldwide awareness of climate change and the impact it has on society. A study done by BCG has found that after the pandemic, people are more concerned about environmental challenges and willing to change their life choices to address them (Nicolas, K., Jesper, N., Adrien, P., & Florent, R. (2020).

The study (Capelle-Blancard, G., Crifo, P., Diaye, M.-A., Oueghlissi, R., & Scholtens, B. 2016) mentions that there are two different lines of research explaining why sustainability and sovereign bond spreads are related. According to the first line of research, despite the fact that returns and diversification are among the most significant motives for investing, investors are becoming increasingly aware of the importance of environmental, social, and governance performance (Bénabou & Tirole, 2010; Kitzmueller & Shimshack, 2012). In the second line of research, non-financial factors are considered in order to enhance profitability and risk management. The majority of the literature assessing the impacts of ESG performance on bonds are done at a corporate level and a small number of studies address the relationship on the ESG and sovereigns. This is mainly explained by the lack of reliable data on ESG and metrics to quantify ESG performance at the country level. In this dissertation, I used the Environmental Performance Index (EPI), which is the result of a collaboration between the Yale Center for Environmental Law and Policy (YCELP) and Yale Data-Driven Environmental Solutions Group, Yale University, Columbia University Center for International Earth Science Information Network (CIESIN), and the World Economic Forum (WEF), to assess the Portuguese environmental policies.

It was concluded in the article "Environmental, Social and Governance (ESG) performance and sovereign bond spreads: an empirical analysis of OECD countries" that higher ESG performance leads to lower sovereign bond spreads for both one year and ten years maturities.

In this dissertation, the aim is to determine if the Portuguese policies between 1996 and 2020, as measured by the Environmental Performance Index, have had any impact on the cost of borrowing for the Portuguese government between 1996 and 2020.

A few studies have linked natural disasters to sovereign defaults, including Mallucci, E. (2020), the author concludes with the study that the increase in environmental risk has a detrimental effect on the capacity of the government to issue debt, and that with the increasing climate risk

in global scale, expose the most vulnerable countries that may suffer even more restrictions in the future.

There is a lot of literature on the main factors that affect the cost of sovereign debt (Cordogno et al. (2003), Bernoth et al. (2006), Mangnelli and Wolswijk (2009)). The paper (Afonso, A., Arghyrou, M. G., & Kontonikas, A. (2015)) studied a panel of euro area countries to identify the determinants of long-term sovereign bond yields spreads over the period of 1991 to 2010. The paper concluded that the drivers of government bond spreads in the eurozone have changed dramatically over time, and that, in addition to fundamentals, changes in bond price sensitivity to fundamentals are also essential for explaining yield changes throughout the crisis period. Market pricing behaviour has undergone a significant change not just since the beginning of the global financial crisis in summer 2007, but also in the years preceding and after the crisis, most notably the period before and after spring 2009. More precisely, they found that macroeconomic and fiscal fundamentals are often insignificant in explaining spreads during the pre-crisis period. There has been a consistent relationship between macroeconomic and fiscal fundamental variations since the summer of 2007, however, and these variations seem to explain spread movements very well and are consistent with theoretical assumptions. Additionally, since spring 2009, the catalogue of fundamentals that look statistically relevant in explaining spreads has been expanded, implying that markets are now pricing risks that they weren't taking into account earlier, even during the crisis period. In addition, unlike in the pre-crisis period, the size, liquidity, and maturity of debt issuances are now valued by markets.

In the paper released in 2012 (Ichiue, H., & Shimizu, Y. (2012)), the authors assessed the determinants of long term forward rates using a cross country panel data analysis. In this analysis the authors reached the conclusion that when the government debt is financing is done externally the forward rate rise is almost double of the rise than when the financing is funded by borrowing from internal sources. The authors also concluded that aging population has an impact on the forward rate, in US and in Japan the aging of the population lead to a decrease in the forward rate this is explaining by the increase in the government’s costs and the elder trend to look for financial assets which lead to a reduction in inflation.

The paper published at journal of financial risk management (Gill, N. (2018)) studied the eurozone bond market and the determinants of sovereign bond yields. The study conducted used a sample of 6 countries France, Germany, United Kingdom, Greece, Italy and Spain in a time period between January 1,2005 and November 31, 2017, to assess the determinants which

impact directly the sovereign bond yields spread. According to the author, there are several significant determinants of the Gross Domestic Product rate of growth, including the Interest Rate, the Inflation rate, the Debt to Gross Domestic Product ratio, the Deficit to Gross Domestic Product ratio, and the VSTOXX index. Similarly, in accordance with other literature, the author also concludes that the main factors that affected the government bond yield spreads prior to the financial crisis were different from the main factors that affected the government bond yield spreads post-crisis.

I used the main determinants of sovereign bond yield already studied for Portugal (Pinho, A., & Barradas, R., 2021) as control variables to understand if there is a relation between the EPI score and the Portuguese sovereign borrowing cost.

As a measure of sovereign borrowing cost, I use the government bond yield spread of the government bonds using the German government bond as the “risk-free” rate. In order to compare the impacts of the EPI score on the Portuguese cost of borrowing, I choose different maturities, two years and ten years bonds from Portugal and German sovereign bonds. With this approach, I aim to understand if the investments in environmental policies that are expected to have results in the medium to long term have different impacts on each of the maturities.

2.1 Sovereign bond yield

Today, economies are increasingly dependent on external financing, as a result of which the cost of borrowing has become a larger burden on the state budgets of every country. In this thesis, we are focusing on Portugal, a country that has a large amount of public debt as a percentage of its GDP (125% in 2021, Pordata). There is a significant cost associated with sovereign debt as a result of this large external debt, and that cost inevitably affects the budget of the government.

As a means of calculating the Portuguese cost of borrowing, I used the literature that has been published in the past few years (Hilscher and Nosbuch, 2010, Crifo, Diaye, and Oueghlissi, 2017). It is explained in the literature that the cost of borrowing is made up of the "risk-free" rate and the spread. In the context of sovereign bonds, the yield spread between the interest rate paid by an external US dollar-denominated government bond and the rate offered by the US

Treasury on an external US dollar-denominated debt of comparable maturity is known as the sovereign bond yield spread. Based on the data available in Statista under Gross domestic product at current market prices of selected European countries in 2021 as part of this dissertation, I selected German government bonds as my benchmark since it is the most robust economy in European countries. My calculation of the sovereign bond yield spread for sovereign bonds is based on the end-of-year Portuguese government bonds and the German government bonds, where the German bond is treated as the "risk-free" rate. It should be noted that both of these values are taken from the arithmetic average for each year over a fixed term. As part of this dissertation, I analyse the effects of the EPI score for different maturities, specifically for two years and ten years bonds issued by the Portuguese and German sovereign governments.

As mentioned above, the cost of sovereign debt has a significant impact on the governmental budget, and that significant impact has motivated great interest in finding the determinants of sovereign bond yield, allowing governments to adjust their policies to have greater control of the borrowing costs. There have been an increasing number of studies that have examined these determinants of the cost of debt in Europe, such as Cordogno et al. (2003), Bernoth et al. (2006), Mangnelli and Wolswijk (2009).

As outlined in recent publications in this field, there are three primary factors that are responsible for driving spreads on yields: credit risk, liquidity indicators, and general changes in risk aversion and international risks.

Credit risk assesses the risk of a sovereign borrower's partial or total default using six different factors (Ichiue & Shimizu, 2012), namely macroeconomic performance, fiscal conditions, foreign borrowing, the inflation rate, labour productivity, and the demographic situation (ageing population). Liquidity risk quantifies the market's size and depth, capturing the possibility of capital losses due to early liquidation or significant price changes caused by a small number of transactions in the market. Global risk aversion assesses investors' risk appetite and perceived level of financial risk.

Several empirical studies have been conducted to assess the determinants of government bond yields, the study (Pinho, A., & Barradas, R., 2021) assessed the determinants of the one-year, five years, and ten years of Portuguese government bond yields were calculated using a time series econometric analysis from the first quarter of 2000 to the last quarter of 2016. Eight independent variables were used in the econometric models: macroeconomic performance,

fiscal conditions, foreign borrowing, inflation rate, labour productivity, demographic situation, global risk aversion, and liquidity risk.

The findings were that for ten years Portuguese government bond yields, all the variables were statistically significant, and the majority with the expected signs. The labour productivity, fiscal conditions and liquidity risk were statistically significant but did not have the expected signs.

In the case of fiscal conditions, the authors emphasise that their findings are rather contentious because they show that deterioration in fiscal conditions has a negative effect on Portuguese government bond yields. The authors' argument is consistent with (Ichiue & Shimizu, 2012), the latter of whom claim that the narrowing of governments bond yields occurs as a result of the weakening of fiscal conditions exerting disinflationary pressure through the belief that taxes are going to go up (and other fiscal consolidation measures).

Labour productivity was predicted to have a positive impact on government bond yields since it would contribute to pay increases, which would raise inflation expectations and, as a result, government bond yields. The authors explain the finding of a contrary sign by saying that the economic agent considers the increase in labour productivity as a sign of a growing economy causing a decrease in the government bond yields.

With regards to liquidity risk, the authors explain that their findings are in line with the findings of Arghyrou and Kontonikas (2011), who explain that a positive relationship between liquidity and government bond yields suggests a mispricing of liquidity risk.

For the five-year Portuguese government bond yields, the authors stated that the variable labour productivity loses statistical significance, and for the one-year Portuguese government bond yields, the variables of macroeconomic performance and liquidity risk lose their statistical significance.

As assessed by the authors, there are no significant differences in the different maturities of the Portuguese government bond yield determinants.

2.2 EPI Score

It is noteworthy that the Environmental Performance Index is a work that is the result of the collaboration between the Yale University (Yale Center for Environmental Law and Policy) and Columbia University (Center for International Earth Science Information Network) with

the support of the World Economic Forum and the Joint Research Centre of the European Commission.

The Environmental Performance Index (EPI) provides a data-driven summary of the state of sustainability around the world. The EPI is based on the Pilot Environmental Performance Index published in 2000 and was created to support achieving the environmental targets set in the UN Millennium Development Goals. The goal of the EPI is to measure the impact that the country's current policies have on the progress toward the desired environmental outcomes.

The EPI indicators give government officials the tools to identify problems, set targets, track trends, comprehend outcomes and facilitate communication with the key stakeholders of the country.

In the 2022 EPI (Wolf, M. J., Emerson, J. W., Esty, D. C., de Sherbinin, A., Wendling, Z. A., et al.), is explained that the EPI is composed of 40 performance indicators that are used across 11 issue categories and 180 countries are ranked by their performance in terms of climate change, environmental health, and ecosystem vitality. EPI's methodology for calculating scores has been evolving over the past few years. Because of this change, it is now impossible to compare the scores from different years in order to evaluate the trend of the policy practices over the years. The authors recommend using the time-series data available for the Environmental Performance Index published in 2020 as a means of addressing this issue. The time-series data is only available for each of the 32 indicators, and the EPI score available is only referent to the year 2020, nevertheless with that time-series data of the indicators and following the methodology available in the 2020 EPI Technical Appendix is possible to calculate the EPI score from 1996 to 2020 using the same methodology for each of the years, please refer to Table 1 to compare the EPI score calculated versus the EPI score published for Portugal. Using EPI calculations, it is possible to track the performance and progress of various countries in relation to two policy objectives, namely the health of the environment and the vitality of ecosystems, and show which countries are improving and which are declining over time. In relation to this thesis, the latter aspect is of the greatest significance, since it allows it to be evaluated if the quality of Portugal's environmental policies has an impact on the cost of its sovereign debt.

Table 1 – EPI score calculated vs EPI score published

Year	EPI calculated	EPI published
1995	50.81	Not available
1996	51.14	Not available
1997	51.36	Not available
1998	53.94	Not available
1999	54.57	Not available
2000	54.54	Not available
2001	55.19	Not available
2002	55.22	Not available
2003	56.52	Not available
2004	57.87	Not available
2005	58.71	Not available
2006	60.41	82.90
2007	62.04	Not available
2008	64.06	85.75
2009	64.75	Not available
2010	67.61	73.00
2011	68.56	Not available
2012	66.21	57.64
2013	66.32	Not available
2014	65.51	75.80
2015	65.12	Not available
2016	65.77	88.63
2017	66.53	Not available
2018	66.75	71.91
2019	67.03	Not available
2020	67.03	67.00

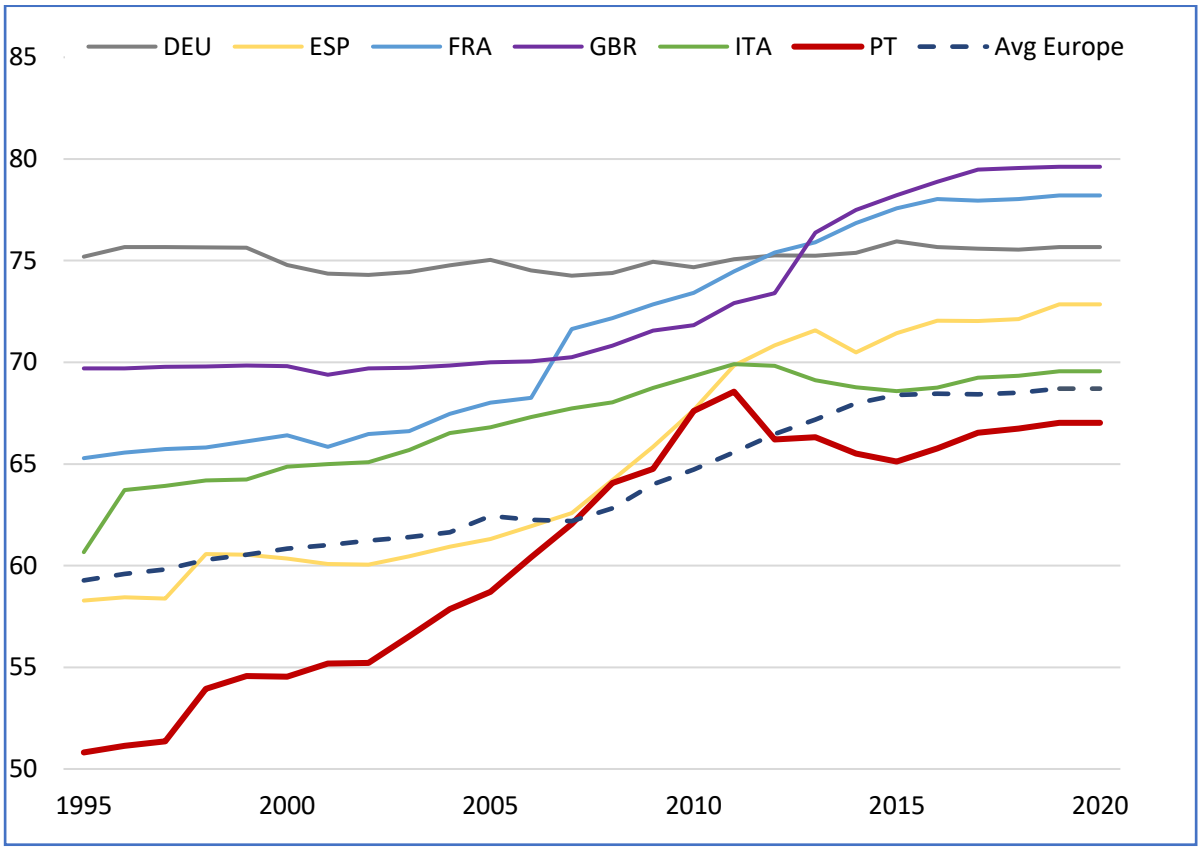
EPI score published data gathered from Socioeconomic Data and Applications Center (sedac).

As advised by Wolf, M. J., Emerson, J. W., Esty, D. C., de Sherbinin, A., Wendling, Z. A., et al. (2022) and as we can see from the results in table 1, the EPI score should always be calculated using the same methodology in order to be used in a time-series analysis. A closer look at table 1 can show that the EPI results published are much higher than those calculated, mainly due to the fact that they used a more straightforward calculation method with fewer factors.

As a matter of fact, it should be stressed that the real value of the EPI can be found in the comprehensive analysis of its underlying data as well as its performance measures, and not in its numerical rankings alone. By displaying results by issue, policy category, peer group, and country, the EPI can help identify leaders and laggards, emphasize optimal policy practices, and suggest priorities for action. By doing so, we can identify leaders and laggards and determine priorities for action. The Environmental Performance Index is, in general, an effective instrument for guiding environmental investments, refining policy decisions, and understanding how policy decisions affect the outcomes of environmental programs. (Buckland et al., 2005; Stakeholder, 2002).

However, even with the efforts made to improve the methodology and the data used to calculate the EPI score, the EPI score has been criticized for a number of reasons. According to the "Analysis of the Yale Environmental Performance Index (EPI)" published by the German Federal Environment Agency (Umweltbundesamt) the Pilot-EPI (2006) was not able to establish an analytically sound quantitate composite index as had been claimed by the EPI team at the time. The author states "The explanatory power of the cross-country comparison for Germany is low due not only to significant and obvious methodological deficiencies of the composite index but also to a poor data basis. Compared to other regional-specific indicator sets (in particular OECD and EEA), the EPI does not offer any interesting new messages.".

Figure 1 – EPI Score calculated



Using data from the SEADAC (Socioeconomic Data and Applications Center), the EPI was calculated using the 2020 data collected from the SEADAC.

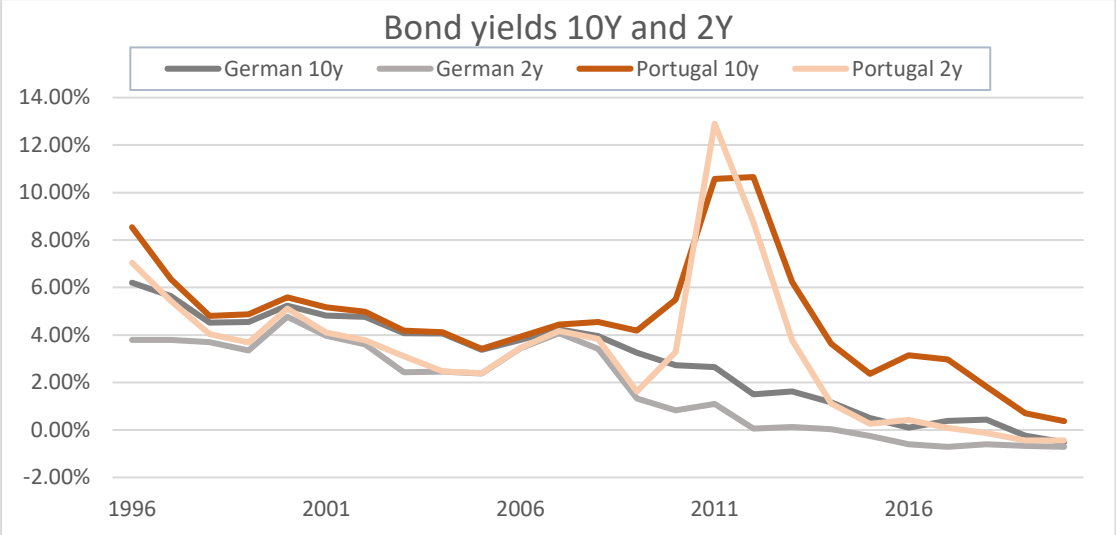
3 Methodology and Variable Construction

3.1 Dependent Variable: Spread of Portuguese sovereign yield

This dependent variable is defined as the difference between the interest rate that the Portuguese government pays on its debt and the interest rate that the German government pays on a debt with a maturity of two years and ten years.

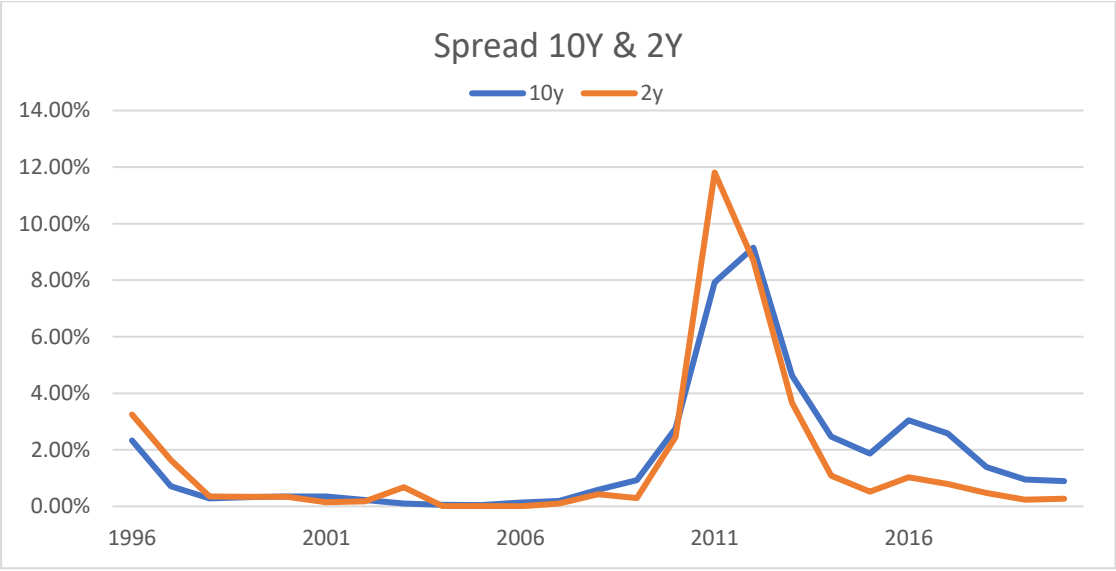
It's worth mentioning the discontinuity caused to the spread on the two and ten years maturities between 2008 and 2012.

Figure 2 – Government Bond yield



Based on information gathered from Thomson Reuters Eikon (2018), which was accessed on the 10th of December 2022.

Figure 3 – Government Bond yield spread between Portugal and Germany



Based on information gathered from Thomson Reuters Eikon (2018), which was accessed on the 10th of December 2022.

3.2 Independent variable: Portuguese EPI score

The independent variable has been developed by the collaboration of YCELP and CIESIN. I used the data from the Environmental Performance Index released in 2020 following the authors' recommendations to use the indicators' time-series data available and calculate the EPI score for the different years using the technical table with the weights for each of the indicators. The 2020 Environmental Performance Index (2020 EPI) is organised around two broad environmental protection goals: (1) reducing environmental stresses on human health and (2) promoting ecosystem vitality and sound natural resource management. Air Quality, Sanitation and Drinking Water, Heavy Metals, Waste Management, Biodiversity and Habitat, Ecosystem Services, Fisheries, Climate Change, Pollution Emissions, Agriculture, and Water Resources are used to assess these. An audit of the EPI data has been conducted by the Joint Research Center (JRC).

3.3 Control Variables: Determinants of the Portuguese sovereign bond yield

There is a large body of literature on the determinants of public debt, as summarised above. In this dissertation, I will use the work done (Pinho, A., & Barradas, R., 2021) as the main determinants of the Portuguese public debt for the selected years, from 1996 to 2020. This work studied the determinants of debt for the three maturities, 1y, 5y and 10y. In my thesis, I decided to measure the short and long-term debt by using the 2 year and 10 years horizons. By doing this, I am able to interpret both the short and long term effects of the EPI score on the Portuguese government bond yield spread.

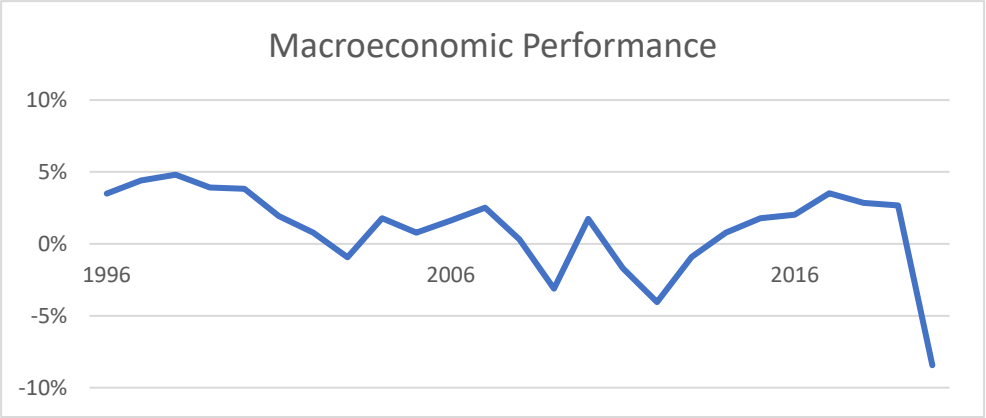
Table 2 – Determinants of the Portuguese sovereign bond yield

Variable	Description
Macroeconomic performance	Measures changes in economic output, inflation, interest and foreign exchange rates, and the balance of payments. Poverty reduction, social equity, and sustainable growth are only possible with sound monetary and fiscal policies. (worldbank.org)
Fiscal Condition	A government's ability to meet its financial and service obligations. (Jimenez 2009; Hendrick 2004)
Foreign Borrowing	money borrowed by the government.

Inflation rate	The rate of increase in prices over a given period of time. (imf.org)
Labour Productivity	Real gross domestic product (GDP) per hour worked. (oecd.org)
Demographic Situation	Ageing population.
Global Risk Aversion	Global tendency to avoid risk.
Liquidity Risk	Liquidity risk is defined as the risk of incurring losses resulting from the inability to meet payment obligations in a timely manner when they become due or from being unable to do so at a sustainable cost. (coebank.org)

3.3.1 Macroeconomic Performance

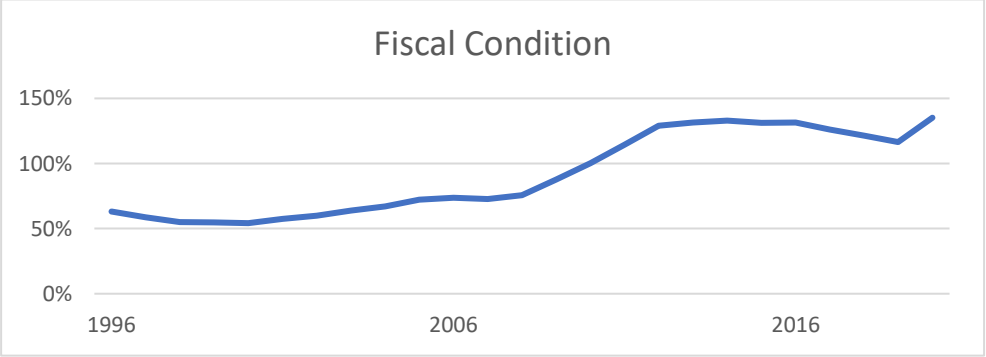
Figure 4 –Macroeconomic performance



This data was gathered from Pordata.

3.3.2 Fiscal Condition

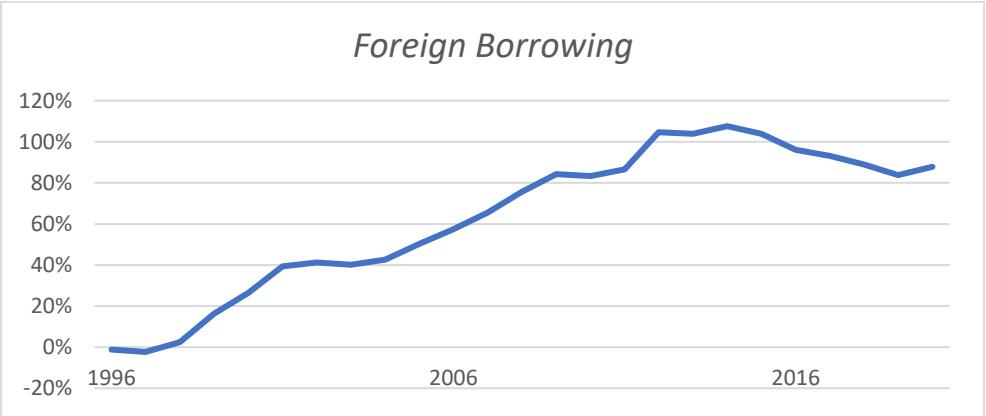
Figure 5 –Fiscal Condition



This data was gathered from the Bank of Portugal.

3.3.3 Foreign Borrowing

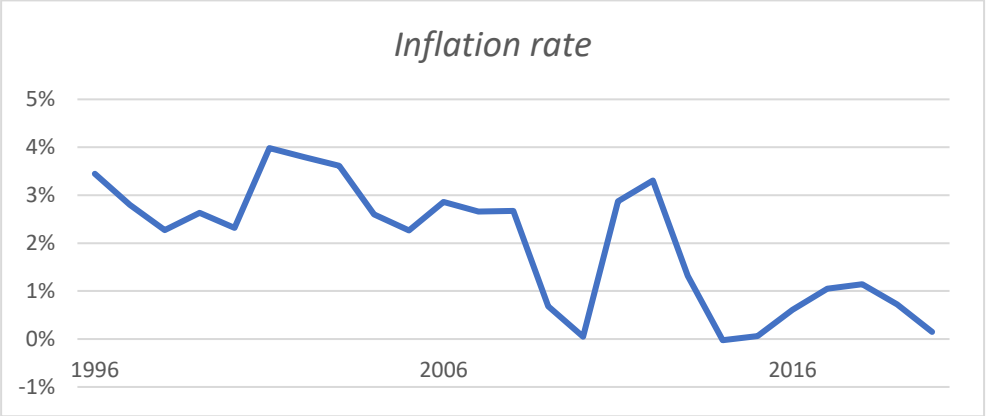
Figure 6 –Foreign Borrowing



This data was gathered from the Bank of Portugal.

3.3.4 Inflation Rate

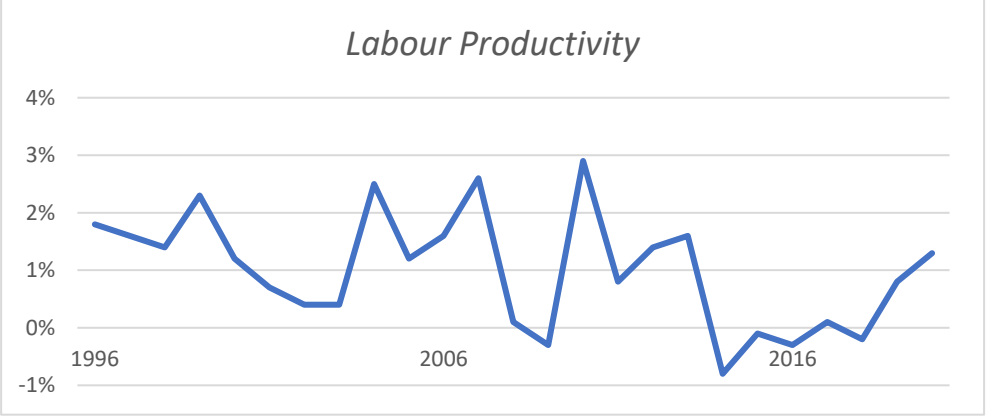
Figure 7 –Inflation rate



This data was gathered from the Bank of Portugal.

3.3.5 Labour Productivity

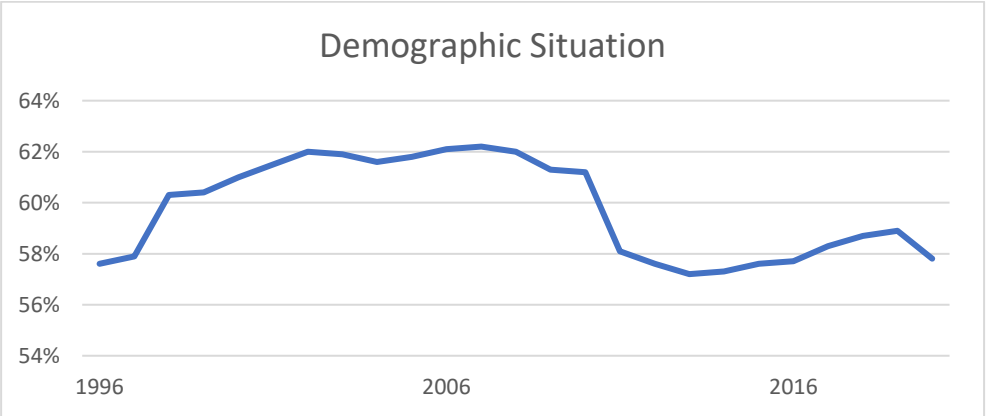
Figure 8 – Labour Productivity



This data was gathered from the Instituto Nacional de Estatística.

3.3.6 Demographic Situation

Figure 9 – Demographic Situation



This data was gathered from Pordata.

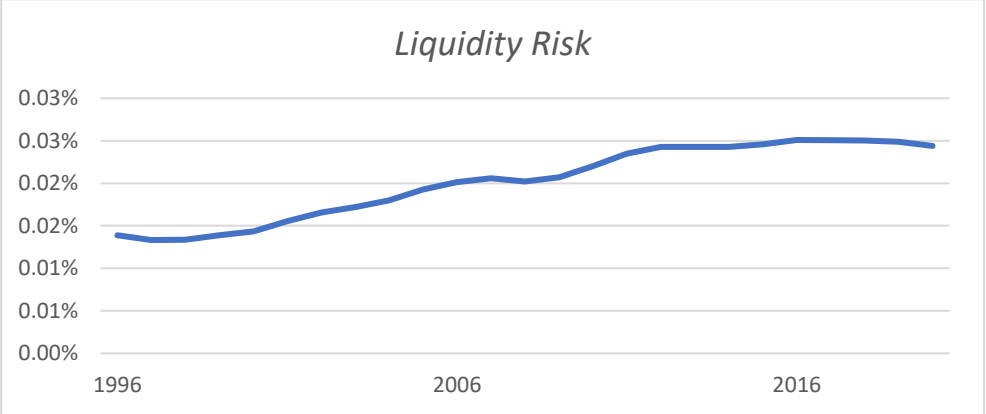
3.3.7 Global Risk Aversion

Figure 10 – Global Risk Aversion

This data was gathered from the Yahoo finance database.

3.3.8 Liquidity Risk

Figure 11 – Liquidity Risk



This data was gathered from Pordata.

4 Methodology

For the purpose of studying the relationship between the EPI score and the Portuguese sovereign bond yield, I used one model for each of the maturity levels following the methodology described in (Pinho, A., & Barradas, R., 2021). In addition to the models, I added a new variable that is the EPI score. It is expected that the EPI score has a negative correlation with the Portuguese sovereign yield, which means that I expect that when the EPI score increases, the Portuguese sovereign yield spread decreases.

The two linear regression models used are:

$$GBY_t^{10y} = \beta_0 + \beta_1 MP_t + \beta_2 FC_t + \beta_3 FB_t + \beta_4 IR_t + \beta_5 LP_t + \beta_6 DS_t + \beta_7 GRA_t + \beta_8 LR_t + \beta_9 EPI_t + \alpha$$

$$GBY_t^{2y} = \beta_0 + \beta_1 MP_t + \beta_2 FC_t + \beta_3 FB_t + \beta_4 IR_t + \beta_5 LP_t + \beta_6 DS_t + \beta_7 GRA_t + \beta_8 LR_t + \beta_9 EPI_t + \alpha$$

Where t is the time period (years), Y GBY10Y are the ten years Portuguese government bond yield spreads, Y GBY2 are the two-year Portuguese government bond yield spreads, MP is the macroeconomic performance, FC are the fiscal conditions, FB is foreign borrowing, IR is the inflation rate, LP is labour productivity, DS is the demographic situation (ageing population), GRA is global risk aversion, LR is liquidity risk, EPI is the Portuguese Environmental Performance Index, and α is an independent and identically distributed (white noise) disturbance term with a null average and constant variance (homoscedastic).

It was decided to add a dummy variable to the model as a result of the discontinuity in the spread trend between 2008 and 2012, as shown in figure 3, in order to be able to assess whether or not the Environmental Performance Index was statistically significant in the new model in light of the discontinuity.

4.1 Data and econometric methodology

Data from the dependent and independent variables were collected on an annual basis, from 1996 to 2020, based on end-of-year data that corresponded to the period and frequency during which the data are available for the dependent and independent variables. All the variables, apart from the Environmental Performance Index and the Government bond yield spreads, were measured using the methodology applied by (Pinho, A., & Barradas, R., 2021) in the paper *Determinants of the Portuguese government bond yields.*

Based upon the definitions and sources of the variables, we were able to acquire the Portuguese and German government bond yields (ten years maturities) from the Refinitiv database that contains government bond yields across a range of maturities. I calculated the arithmetic average of the various government bond yields for each year based on the available data since the data was available on a monthly basis.

To take a snapshot of macroeconomic performance, the annual percentage change in the gross domestic product (at constant prices and in millions of euros) taken from Pordata is used as a proxy for macroeconomic performance on an annual basis.

I use the total general government gross debt (at current prices and in millions of euros) as a percentage of the gross domestic product (at current prices and in millions of euros) acquired directly from the Bank of Portugal database to assess fiscal conditions.

In order to calculate foreign borrowing, I use a percentage of GDP calculated as a percentage of the gross domestic product divided by the total net external debt (at current prices and in millions of euros). Using the Bank of Portugal's database, I was able to retrieve this variable directly from the source.

A consumer price index (CPI) is used in this calculation to calculate the inflation rate based on the change in the Consumer Price Index (CPI) from the previous year to the current year as retrieved from the Bank of Portugal database. I calculated the arithmetic average of the relevant yearly percentage change for each year (year-over-year) because the variable can only be accessed monthly, so I calculated the arithmetic average of each year's percentage change.

The labour productivity is calculated as the yearly percent change (year on year) in gross domestic product (at current prices and in millions of euros) divided by the total number of people employed in a country (thousands). In order to find out the value of the variable, we were able to use the Portuguese National Accounts, which is available at the Instituto Nacional de Estatistica.

In order to determine the effects of the demographic condition (aging population), it is necessary to calculate the activity rate which is calculated as the number of active people divided by the number of people aged 15 to 64. A variable derived from Pordata's database has been used to retrieve this information.

For the purpose of proxying global risk aversion, I use the natural logarithm of the implied volatility index for the S&P500 (i.e. the so-called VIX index), which has been extracted from

the Yahoo Finance database. I calculated the arithmetic average of the corresponding natural logarithms for each of the years using the variable, since it was created on a monthly basis.

Using a weighted average of Portugal's general government debt and the gross government debt of other nations in the euro zone, we are able to calculate the liquidity risk. This is key for determining Portugal's market share within the eurozone for its public debt. Pordata provides access to both variables. The reason I chose to use the percentage of Portuguese debt in the eurozone government debt in the analysis was due to the fact that it gives information on the size and relevance of Portuguese bonds in the eurozone government debt. In the absence of a high proportion of Portuguese debt, there would be fewer transactions, raising the risk of capital losses as a result of significant price swings.

The 2020 Environmental Performance Index (EPI) is a ranking based on 32 performance indicators that are attributed to each country. As a result of these indicators, we are able to track performance and progress on two broad policy objectives, namely environmental health and ecosystem vitality. As part of my calculation of the Portuguese EPI score from 1996 to 2020, I used the time-series data available on the NASA Socioeconomic Data and Applications Center (SEDAC) and followed the instructions in (Sherbinin, de. 2020) to calculate each year's EPI score based on the indicators. The data was extracted directly from NASA Socioeconomic Data and Applications Center (SEDAC).

Table 3- Organization of the 2020 EPI, with three-letter abbreviations (TLAs) and weights (Wt.) within each level of aggregation.

Policy Objective	Issue Category	TLA	Wt.	Indicator	TLA	Wt.
Environmental Health HLT (40%)	Air Quality	AIR	50%	PM25Exposure	PMD	55%
				Household solid Fuels	HAD	40%
				Ozone Exposure	OZD	5%
	Sanitation & Drinking water	H2O	40%	Unsafe Sanitation	USD	40%
				Unsafe Drinking Water	UWD	60%
	Heavy Metals	HMT	5%	Lead Exposure	PBD	100%
	Waste Management	WMG	5%	Controlled Solid Waste	MSW	100%
Ecosystem Vitality ECO (60%)	Biodiversity & Habitat	BDH	25%	Terrestrial Biome Protection (national)	TBN	20%
				Terrestrial Biome Protection (Global)	TBG	20%
				Marine Protected Areas	MPA	20%
				Protected Areas Representativeness Index	PAR	10%
				Species Habitat Index	SHI	10%
				Species Protection Index	SPI	10%
				Biodiversity Habitat Index	BHV	10%
	Ecosystem Services	ECS	10%	Tree Cover Loss	TCL	90%
				Grassland Loss	GRL	5%

				Wetland Loss	WTL	5%
	Fisheries	FSH	10%	Fish Stock Status	FSS	35%
				Marine Trophic Index	RMS	35%
				Fish Caught by Trawling	FGT	30%
	Climate Change	CCH	40%	CO2 Growth Rate	CSA	55%
				CH4 Growth Rate	CHA	15%
				F-gas Growth Rate	FGA	10%
				N2O Growth Rate	NDA	5%
				Black Carbon Growth Rate	BCA	5%
				CO2 from Land Cover	LCB	2.5%
				GHG Intensity Trend	GIB	5%
				GHG per Capita	GHP	2.5%
	Pollution Emissions	APE	5%	SO2 Growth Rate	SDA	50%
				NOx Growth Rate	NXA	50%
	Agriculture	AGR	5%	Sustainable Nitrogen Management Index	SNM	100%
	Water Resources	WRS	5%	Wastewater Treatment	WWT	100%

Prior to digging into the results section, it is critical to determine how strongly the variables are correlated with each other using the correlation coefficient. Table 4 presents the Pairwise Correlation Matrix.

Table 4 – Pairwise Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Spread	1.000									
(2) MP	-0.372*	1.000								
(3) FC	0.592***	-0.448**	1.000							
(4) FB	0.508***	-0.506***	0.896***	1.000						
(5) IR	-0.051	0.161	-0.713***	-0.633***	1.000					
(6) LP	-0.052	0.138	-0.404**	-0.433**	0.290	1.000				
(7) DS	-0.603***	0.148	-0.714***	-0.371*	0.432**	0.262	1.000			
(8) GRA	-0.146	-0.280	-0.364*	-0.294	0.181	0.036	0.273	1.000		
(9) LR	0.492**	-0.445**	0.938***	0.963***	-0.663***	-0.393*	-0.460**	-0.415**	1.000	
(10) EPI	0.515***	-0.486**	0.878***	0.952***	-0.671***	-0.313	-0.357*	-0.226	0.958***	1.000

Note: **** indicates statistical significance at 1% level, ** indicates statistical significance at 5% level and * indicates statistical significance at 10% level*
MP – Macroeconomic performance
FC – Fiscal conditions
FB – Foreign borrowing
IR – Inflation rate
LP – Labour productivity
DS – Demographic situation
GRA - Global risk aversion
LR – Liquidity Risk
EPI – Environmental Performance Index

Note that with statistical significance at 5%, there are five independent variables statistically significant in terms of correlation with the spread for ten years government bond yield spread, namely: fiscal condition, foreign borrowing, demographic situation (ageing population),

liquidity risk and the Portuguese Environmental Performance Index. The conclusion is precisely the same if we consider the two-year government bond yield spread.

5 Results

In this section, I look at the determinants of Portugal's government bond yield spread from 1996 until 2020. To understand if there is a difference in the short and long-term Portuguese government bond yield spread determinants, I use the difference between the Portuguese government bond yield with two years and ten years maturity and the German government bond yield with two years and ten years maturity. Table 5 refers to the linear regression using Portugal's government bond yield spreads with two years and ten years of maturity.

The high R-squared and the Adjusted R-squared suggest that the models fit exceptionally well with the evolution of the Portuguese government bond yields with ten years of maturity through time.

The data suggest that the macroeconomic performance, fiscal conditions, financing borrowing, labour productivity, demographic situation and global risk aversion variables are not statistically significant to explain the dependent variable.

The inflation rate variable is one of the variables that the data suggest that can explain how the dependent variable behaves. A positive sign in the inflation rate was expected and followed the results obtained in the study (Pinho, A., & Barradas, R., 2021).

Another independent variable that the data suggests is statistically significant is liquidity risk. The negative sign of the coefficient is the sign that was expected, meaning that a higher liquidity risk would mean a higher government bond yield spread. Please note that in this dissertation, the liquidity risk variable is measured by the % of Portuguese debt within the government debt of the euro area, meaning that an increase in the variable means an increase in the liquidity therefore reducing the liquidity risk.

The last independent variable in the regression is the EPI Score. This is the variable at the core of the analysis in this thesis. The data suggest that the EPI is statistically significant in explaining the dependent variable behaviour. However, the EPI's sign suggests a negative relationship between the government bond yield spread and the environmental performance index. This result suggests that a higher EPI score means a higher governmental bond yield

spread. The results suggested by the linear regression presented in the Table 5 do not follow the results in literature previously reviewed (Capelle-Blancard, G., Crifo, P., Diaye, M.-A., Oueghlissi, R., & Scholtens, B. 2016), where the authors reached the conclusion that above average ESG performance leads to lower sovereign bond spreads. It is important to state that the analysis done for this dissertation is only taking in consideration one country, Portugal, and as had been stated previously in the time period between 2008 and 2012 there was a huge increase in the government bond yields which was caused by external factors such as the subprime crisis and Portuguese government debt crisis. To better understand this, this dissertation includes a linear regression done adding a dummy variable with value 1 for the years between 2008 and 2012, which suggests that the EPI score for long term government bond yield spreads is not statistically significant. This relationship is further detailed in the discussion section.

Table 5 refers to the linear regression using Portugal's government bond yield spreads within two years and ten years of maturity. The results from the government bonds yield spread with two years of maturity have the same output as the results from the government bonds yield spread with ten years of maturity. The data suggests that the macroeconomic performance, fiscal conditions, financing borrowing, labour productivity, demographic situation and global risk aversion variables are not statistically significant to explain the dependent variable. The inflation rate, liquidity risk and EPI variables are statistically significant and have the same signs as the ones obtained from the analysis for the ten years maturity.

Table 5 – Two year and ten years government bond yield spread regression

VARIABLES	Spread 2y	Spread 10y
MP	-0.153	-0.00560
	(0.158)	(0.110)
FC	0.00626	0.0921
	(0.107)	(0.0749)
FB	0.0173	0.0439
	(0.0413)	(0.0289)
IR	1.949***	1.550***
	(0.407)	(0.285)
LP	0.0628	0.164
	(0.387)	(0.271)
DS	-1.209*	-0.519
	(0.659)	(0.462)
GRA	-3.386	-2.662*
	(2.043)	(1.431)
LR	-1,693**	-1,631***
	(686.1)	(480.5)
EPI	1.317***	0.835***
	(0.303)	(0.212)
Constant	31.78	7.973
	(42.87)	(30.02)
Observations	25	25
R-squared	0.856	0.899

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
MP – Macroeconomic performance
FC – Fiscal conditions
FB – Foreign borrowing
IR – Inflation rate
LP – Labour productivity
DS – Demographic situation
GRA – Global risk aversion
LR – Liquidity Risk
EPI – Environmental Performance Index
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5.1 Results including a dummy variable

As it is possible to observe in figure 2, there is an apparent discontinuity in the trend of the government bond yield spread between 2008 and 2012. This was due to the subprime crisis and the government debt crisis. As a robustness exercise, I added a dummy variable that equals 1 for the year between 2008 and 2012 and that equals 0 for the remaining.

From the linear regression that includes a dummy variable presented in the Table 6, we can observe that for the short-term government bond yield spread (for two years maturity) the variables' demographic situation and Liquidity Risk are no longer statistically significant, and that the EPI variable is no longer statistically significant at a significance level of 99%.

For the long-term government bond yield spread (ten years maturity), we can notice that the variable fiscal condition, global risk aversion and liquidity risk are now statistically significant at a significant level of 95% and that the variable EPI is no longer statistically significant at any level of significance.

Table 6 – Two year and ten years government bond yield spread regression including dummy variable

VARIABLES	Spread2y	Spread10y
MP	-0.0846	0.0697
	(0.149)	(0.0810)
FC	0.0591	0.150**
	(0.102)	(0.0554)
FB	-0.00835	0.0158
	(0.0401)	(0.0218)
IR	1.747***	1.328***
	(0.388)	(0.211)
LP	0.141	0.250
	(0.357)	(0.194)
DS	-0.796	-0.0659
	(0.641)	(0.349)
GRA	-3.223	-2.483**
	(1.877)	(1.021)
LR	-1,193	-1,082**
	(679.8)	(369.8)
EPI	0.817**	0.286
	(0.378)	(0.206)
Dummy	2.536*	2.785***
	(1.300)	(0.707)
Constant	23.71	-0.892
	(39.57)	(21.52)
Observations	25	25
R-squared	0.887	0.952

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
MP – Macroeconomic performance
FC – Fiscal conditions
FB – Foreign borrowing
IR – Inflation rate
LP – Labour productivity
DS – Demographic situation
GRA - Global risk aversion
LR – Liquidity Risk
EPI – Environmental Performance Index

6 Discussion

It is in this section that I will briefly discuss the independent variables that were identified in the literature review to explain the government bond yield spread and add a deeper discussion on the independent variable EPI, which serves as the cornerstone of this dissertation.

In both the two-year and ten years maturity cases, the data suggests that three of the nine independent variables are statistically significant (P-value greater than 0.05): inflation rate, liquidity risk, and environmental performance index.

The inflation rate has a positive effect on government bond yield spreads because it is regarded as a proxy for uncertainty and instability by investors, which results in a positive effect on government bond yield spreads. In turn, this leads to a rise in interest rates and, consequently, a higher level of risk premiums (Cantor & Packer, 1996; Baldacci et al., 2008; Kumar and Baldacci, 2010 cited by Pinho, A., & Barradas, R., 2021).

Government bond yields are also influenced by liquidity risk since investors demand a higher risk premium for riskier assets (such as illiquid government bonds), which raises interest rates (Haugh et al., 2009). In this dissertation, we have a negative sign due to how the liquidity risk is measured, but the results obtained for both maturities follow the literature, and the data suggests that lower liquidity risk means that government bond yield spreads will also decrease.

The Environmental Performance Index is suggested by the data to have a positive relationship with the government bond yield spread for Portugal on the data from 1996 to 2020. Even though during the literature review, I mention the study (Capelle-Blancard, G., Crifo, P., Diaye, M.-A., Oueghlissi, R., & Scholtens, B., 2016) mentioning the negative relationship between Environmental policies and government financing costs the linear regression performed in this dissertation suggest a positive relationship between the EPI variable and the government bond yield spread variable. This result can be caused by external factors, taking into account the results obtained with the inclusion of the dummy variable, this argument gains more plausibility because, excluding the period of great market instability where there was a very significant increase in government spreads, the EPI variable is no longer considered statistically significant.

Possibly, one of the explanations can be found in the fact that between 1996 and 2011 there was a continuous increase in the Portuguese EPI score. It should be noted, however, that this

was the time when the Euro was introduced as well as a period when changes took place to the institutional context of the Portuguese government bonds in relation to their evolution. There has probably been some uncertainty created among investors because of this, which has resulted in higher yield spreads on government bonds. In the period of 2011 to 2020, the Portuguese EPI score decreased until 2016, at which point it began to increase again until the end of the period (2020). However, it still must be noted that the score for 2020 is lower than it was for 2011. This decrease may be attributed to the fact that Portugal was severely affected by the global financial crisis as well as the sovereign debt crisis in the euro area during that period. In this period of great economic difficulty for Portugal, it is possible that the government has shifted its focus toward policies that can help fast-track the economy, and not as much on policies that can help the environment in the medium to long term. Furthermore, despite the fact that the economic outlook in European countries was not the best for quite some time, a number of factors, including the intervention of the International Monetary Fund in Portugal as well as the accommodative monetary policy of the European Central Bank, were the main contributors to the decrease in the yield spreads on Portuguese government bonds. It is possible that some of these external factors might be one of the explanations for the results obtained in this dissertation.

7 Conclusion

The purpose of this dissertation is to explore the impact that environmental policies can have on government borrowing costs, specifically in the case of the Portuguese government. The topic of this dissertation is one that gains weight every year, in a world where climate change seems to be becoming more and more evident each year and in which the effects of climate change on the real economy can be of immense proportions. For instance, the UN mentions in one of its goals, goal 13, "Climate change is affecting every country on every continent. It is disrupting national economies and affecting lives. Weather patterns are changing, sea levels are rising, and weather events are becoming more extreme.”. By preparing and managing this environmental risk better, the countries will be better placed to avoid damage to their national economies as a result of this change.

In this dissertation, I used the Environmental Performance Index as a proxy of the Portuguese governmental policies to address the environmental risk and used the difference between the Portuguese and the German government bonds as a calculation method of the Portuguese government bond yield spread. With this approach I intended to study the real impact of the

environmental policies on the government cost of borrowing. The results of the analysis performed in this dissertation are that the environmental policies have an opposite effect than the one expected, being associated with an increase, rather than a decrease, in the government cost of borrowing. Although, when adding a dummy variable to the regression the EPI score for the long-term is no longer statistically significant as it was without the dummy variable. This adds further strength to the argument that is possible that these results are directly attributable to external factors that occurred during the time period studied than to the effects of the Portuguese governmental policies to address the environmental risk.

As a continuation of the study started in this dissertation, it might be interesting to break down the time period from the introduction of the Euro, the subprime crisis and the government debt crisis, but include similar countries so that a larger number of observations can be analised. Also, using the EPI score to make a comparison between comparable countries with similar economies but with different EPI scores in a defined time period could help to understand better the relationship between environmental policies and the cost of borrowing for the governments. In the literature review section, it has already been mentioned that the Environmental Performance Index is constantly evolving over the years, both in terms of the quality of the data used as well as the method by which it is calculated. Based on this consideration, it is presumed that using new versions of the Environmental Performance Index as a measure of government environmental policies will enhance the quality and reliability of the analysis that is based on the EPI indicators.

Lastly, considering the COVID-19 and the Ukrainian war that caused an energy crisis in the past two years, it would be interesting to assess whether the countries have changed their environmental policies and, if so, how this impacted both the short- and long-term yields of government bonds.

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