The Green Trilemma: Energy Efficiency, Banking Stability and Climate Risk in the ESG Context at World Level

Arnone, Massimo and Leogrande, Angelo

University of Catania, Lum University Giuseppe Degennaro

9 June 2024

The Green Trilemma: Energy Efficiency, Banking Stability and Climate Risk in the ESG Context at World Level

Massimo Arnone

University of Catania, email: massimo.arnone@unict.it

Angelo Leogrande

LUM University Giuseppe Degennaro, email: leogrande.cultore@lum.it

Abstract

In the following article, we analyse the relationships among banking stability, the efficiency of the energy system and climate risks at a global level. We present a detailed analysis of the literature relating to the relationship between the banking system and Environmental, Social and Governance-ESG models. In our research, we try to verify whether it is possible to achieve energy efficiency, stability of the banking system and reduction of climate risk together i.e. the "*Green Trilemma*". The econometric analysis is conducted through the following models: Panel Data with Random Effects, Panel Data with Fixed Effects, Pooled Ordinary Least Squared and Weighted Least Squared-WLS. To estimate the variables we used World Bank data. The analysis shows that ESG growth is negatively associated with energy efficiency and positively associated with banking stability and climate risk. It therefore follows that the Green Trilemma hypothesis is rejected. Countries can only target banking stability and climate risk through ESG models.

Keywords: Banks, Energy and the Macroeconomy, Energy Forecasting, Valuation of Environmental Effects, Climate,

JEL Code: G21, Q43, Q47, Q51, Q54.

1. Introduction

In recent years, a vast literature has developed aimed at estimating the impact of ESG factors on credit risk and market risk. According to these studies, environmental and social risks can compromise creditworthiness and therefore cannot be ignored (Stern 2013).The results achieved are very conflicting due to the high uncertainty that characterizes the occurrence of natural events (Pindyck 2020) and also due to the difficulty of building robust models for measuring such phenomena (Chodnicka 2021). Concerning credit risk it is possible to distinguish the effects of environmental risks on borrowers and financial institutions. On the borrowers' side, for example, recent studies (Höck et al. 2020, Billio et al. 2022, Carbone et al. 2022, Kim et al. 2022, Carrizosa and Gosh 2022, Chen et al. 2021) empirically verify the presence of a negative trade-off between the best performance in terms of environmental sustainability and the credit risk premium. Other studies show that high emissions and low ESG ratings lead to a higher probability of default and higher credit spreads (Kleimeier and Viehs 2018, Capasso et al. 2020, Ehlers et al. 2022). Chava (2014) denotes that financial institutions apply more onerous conditions on loans granted to companies that pay more attention to environmental issues. In contrast, Kim et al. (2014), analyzing the evolution of bank loans in 19 countries, demonstrate that a more ethical behavior of borrowers reduces loan spreads by approximately 25%. This reduction reaches even more significant dimensions (38%) when the financial institution takes on the characteristics of an ethical bank. Degryse et al. (2023) also reported similar results showing that green banks participating in the United Nations Environment Financial Program offer better lending conditions to green businesses. In line with the latter findings, Hauptmann (2017) finds that borrowers with higher sustainability ratings pay lower loan spreads only when the lending bank also shows strong sustainability performance. On the side of financial institutions, Birindelli et al. (2022), show that a greater commitment by banks in managing climate issues leads to a lower risk on the loans granted and a reduction in the reputational risk of the intermediary. Therefore, in the light of these studies, the belief is strengthened that, for greater stability of the financial sector, an assessment of customer solvency is increasingly necessary which is based exclusively on the economic characteristics of the latter. This is because natural events can seriously compromise the returns on bank loans granted.

In this work, the focus is on ESG factors that refer to the problem of climate change. The risks associated with the transition towards a low-carbon economy are increasingly gaining ground in the management policies of banking intermediaries, primarily the risk of climate change. This risk can produce significant effects not only on the solvency of borrowers and therefore on credit risk but also market risk following unexpected and sudden changes in share prices, interest rates, exchange rates, and asset prices. raw material. The focus on these non-financial risks has now had a tradition in the scientific debate for more than 15 years. In this regard, some studies (Dell et al. 2009, Burke et al. 2015, Carleton and Hsiang 2016) have highlighted how the impacts produced by these risks can rather robustly hinder the promotion of economic growth paths, reducing the role of investments by businesses as a driver of wealth production in the economic system. Despite this longevity, only in recent years have studies begun to investigate the impacts of climate change on financial assets and the management of financial institutions (Dietz et al. 2016, Dafermos et al. 2018). In particular, the effects produced by natural disasters manifest themselves with greater intensity to the detriment of SMEs which, representing the foundation of global, national, and local markets, supporting 50% of global GDP, constitute the main source of profitability of banking institutions. In this regard, research by UNDRR (2021) highlights that 75% of the losses produced by natural disasters affect this category of businesses more than any other actor. This also confirms the slower pace with which SMEs can react to the manifestation of the aforementioned risks, unlike larger companies. Despite the proven benefits, SMEs currently do not invest enough in risk prevention and reduction activities.

As already mentioned, such investments have a high profitability thanks to a reduced impact and faster recovery times: an analysis produced by the UNDRR (UNDRR, 2021) suggests that the adoption of resilience measures can reduce up to a third of disaster losses for SMEs. However, despite a strong overall business case, SMEs do not invest enough, with the adoption rate of these investments being 10-20% lower than other businesses, depending on the sector and region.

A first assessment of the degree of awareness of the differences in climate risk compared to financial risks and therefore of the consequent changes in the policies and management of banking intermediaries is contained in a study by Faiella and Malvolti (2020). According to these authors, banks are not yet ready to manage climate risk because they do not have the availability of micro and macroeconomic models that help represent the transmission channels between the climate, the real economy, and the financial markets. The lack of information regarding these links makes it difficult to build new metrics for measuring climate risk and transition risk to achieve a more precise assessment of the institutions most exposed to the aforementioned risks.

Some interesting evidence regarding the reaction of credit institutions towards the physical and transition risk of climate change comes from the Regional Bank Lending Survey conducted by the territorial network of the Bank of Italy on a six-monthly basis (Angelico et al. 2022).

This survey involved over 250 intermediaries, located in the North (150) and the remainder equally distributed between the Center and South and the Islands. Climate risk management is not yet a widespread practice among Italian banks: only 13% of them evaluate the impact of climate risk (physical and transition) in the management of their portfolio compared to a much larger portion of 80%. which intends to do so in the future. Therefore, the integration of climate change risk into the landscape of risks (financial and otherwise) is a real challenge that should not be overlooked for the competitiveness and sustainability of the financial sector. Interventions in favor of this implementation are mainly a prerogative of the larger banks; in fact, around 25% of them have already started analyses on the topic of climate change. The group of banks that are most behind and have not yet undertaken assessments is mainly made up of cooperative credit banks (70 percent of intermediaries that have not yet started any activity). Most analyses were developed internally, with or without consultancy from external vendors. Banks are first and foremost oriented towards monitoring physical and transition risks over a short-medium term time horizon (3-5 years), aligned with the maturity structure of loans to non-financial companies. Scenario analyses, and in particular stress tests, represent the tool most used by banks for climate risk management. This is because these tools adopt a forward-looking approach and allow the impact of different scenarios on the intermediaries' portfolios to be compared. Also, in this case, it is the larger banks (with a volume of loans over 1070 million) that are characterized by a greater ability to construct scenario analyses. The share of banks that have not yet planned to start these assessments is mostly made up of cooperative credit banks. Regarding the inclusion of physical risk in the assessment of customer credit risk, a very small share of respondents takes it into account in the assessment of the counterparty (for example by making use of risk maps), while over 40 percent intend to consider it in the future. The share is higher for banks with greater exposures (over 1070 million) for which it reaches 64 percent, for significant banks (equal to 100 percent of the sub-sample), and for those with registered offices in the North (approximately 50 percent). As regards the assessment of transition risk, over 90 percent of respondents (around 70 percent of the sample) planned to take it into account shortly. In this area, no significant differences are observed based on the exposures or location of the intermediaries. As a measure of transition risk, banks use the carbon intensity of their loans, i.e. the greenhouse gas emissions for each euro of credit disbursed to a certain counterparty. Only four banks declared that they know the carbon intensity of their credit portfolio and among these one is a significant bank. These results confirm the difficulty in finding granular information on the direct and/or indirect emissions of the counterparties. In the previous survey conducted in 2020, 95% of banks responding to the questionnaire stated that they had no information on counterparty issues.

This paper has a structure composed of three sections. After the introductory part, the first section offers a review of the literature on the impacts of climate and environmental risks on the strategies, management policies, and governance and control systems of banking intermediaries. The third section contains several empirical exercises aimed at estimating the effects of the efficiency of the energy system and also the risk of climate change on the stability of the banks present in the World Bank's "Environmental, Social and Governance-ESG" database for 192 countries in the period 2000 -2021. Within this section, a clustering analysis is also conducted through the application of the k-means algorithm optimized with the Elbow method. Finally, we attempted to estimate the future trend of banking stability through a comparison between eight machine learning algorithms. The fourth concludes.

2. Climate Risk and the Effects on Banks: a Review

As highlighted by the ECB, we are still far from the perfect integration of the risks associated with the ecological transition with all the other types of purely financial risks, with the governance, management, and control systems. According to this authority, critical issues emerge in managerial practices, in the management of information and data collection necessary to ensure adequate monitoring of climate risk. These critical issues assess climate impacts on the financial system more difficult and consequently increase the difficulty of conceptualizing how environmental impacts - and policies for their mitigation - are transmitted to the real economy and the financial system. The acceleration to be given to this path is increasingly necessary, above all to be able to guarantee access to credit to those companies involved in sectors particularly affected by the issue of ecological and environmental transition. Businesses may be forced to slow down their investments and therefore their ability to contribute to the economic growth of their territories due to the destruction of their physical capital following environmental damage. This has as a consequence an increase in the physical risk connected to climate change and therefore an increase in debt levels to find further financial resources to complement those necessary for the reconstruction of plants, machinery, etc... Consequently, access to bank credit becomes more complex and banks faced with an increase in the number of non-performing loans can react by significantly reducing the supply of credit. Should these effects take on a systemic dimension, a risk of instability of the entire banking system may become increasingly evident.

More recent works also investigate the relationship between the probability of customer default and bank insolvency mediated by the physical risk associated with climate change (Kousky et al. 2020, Correa et al. 2023). The former demonstrates that following a flood event, the value of the properties used as collateral for bank loans is drastically reduced, resulting in a 2.6-fold increase in the probability of insolvency after two years. This effect would be mitigated in the presence of insurance coverage. Correa et al. (2023), reveal an increase (between 5 and 10%) in the cost of bank loans (spread) applied to borrowers who are most sensitive to this type of risk. In this direction also Do et al. (2021) that banks charge higher interest rates to borrowers located in drought-affected areas. Javadi and Masum (2021) empirically demonstrate that firms located in drought-prone regions pay significantly higher spreads on their bank loans (with a spread compared to firms in other regions of approximately +4.4%). Huynh et al. (2020) demonstrate that the interest rate spread on loans is significantly higher for companies that target a customer segment that is more sensitive to climate risk. This tightening is even more marked (almost + 6%) referring to bank loans with long-term maturities aimed at companies with low ratings. Concerning the real estate market Nguyen et al. (2022) show that credit institutions apply higher interest rates for mortgages on properties located in territorial areas most exposed to the risk of sea level rise (with a differential equal to + 7.5% compared to companies located in less exposed areas). Kaza et al. (2014) find that mortgages for the purchase of highly energy-efficient houses are characterized by significantly lower risks (about less than a third) compared to those for less efficient houses. Guin et al. (2022), taking into consideration a sample of mortgages in the United Kingdom, evaluate how the riskiness of real estate mortgages is conditioned not only by the energy efficiency of the apartments but also by the solvency of the borrowers. They conclude that the energy efficiency of residential properties reduces the frequency of mortgage defaults and that this result does not change when controlling for other relevant determinants of mortgage default, such as borrower income and loan value.

Batten et al. (2016) highlighted the propagation mechanisms of physical risk within the financial sector (figure 1). As can be seen from the red rectangles, the presence of less-performing insurance companies following natural disasters could lead to a reduction in their services and in the value of their securities, some of which are present in the portfolio of other credit institutions. According to Regelink et al. (2017), this ineffectiveness of insurance companies is reflected in the premiums requested in the Netherlands which do not perfectly reflect the extent of the flood risks caused by climate change and due to the presence of information asymmetries between the insurance company and the external consultancy firms that manage the evaluation models of these natural events. As can be seen in the lower part of the figure, in particular from the blue rectangles, if the companies are not insured, the reduction in the value of the assets used as guarantees for the credits entails a potentially greater loss for the banks following a greater insolvency of the customers. If the number of potentially impaired loans were particularly high and concerned increasingly larger territorial areas, this could cause a risk of instability in the entire banking system.

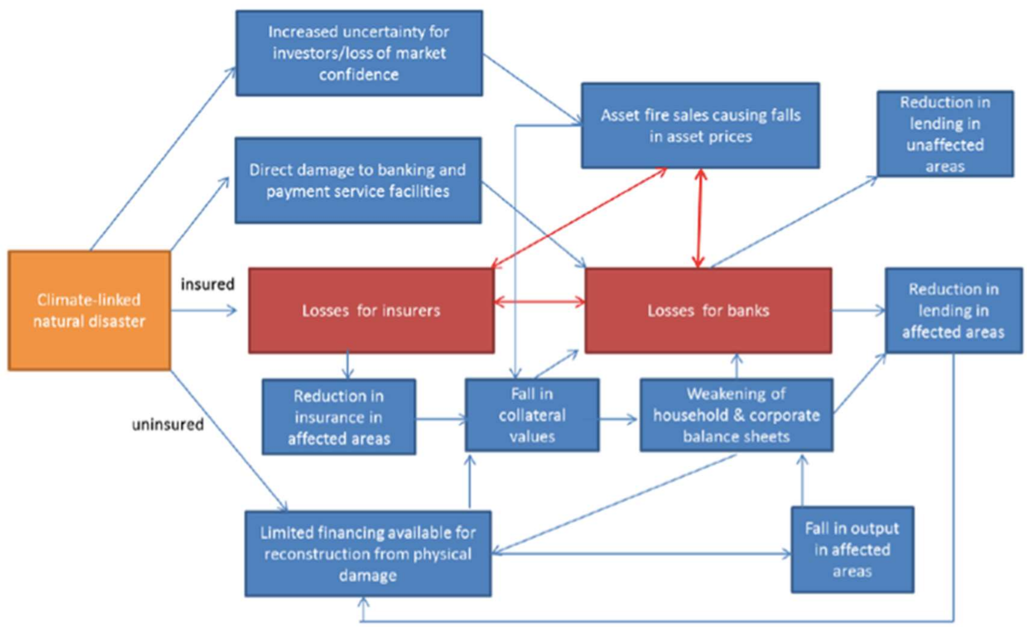
With reference to the second type of climate risk, the so-called transition risk, the inability to contain the emission of greenhouse gases to keep temperatures below 2 degrees centigrade could cause a decrease in the value of energy reserves and the infrastructure for their exploitation. Consequently, there would be an unbridled rush to sell energy securities used as guarantees in bank loans to energy companies. Therefore, both types of climate risk (physical and transactional) can produce significant losses for banking operators. Another important study is the one by Lamperti et al. (2019) from which it emerges that climate change increases the frequency of banking crises, even reaching an increase rate of 148%. The interventions to rescue the banking institutions will entail costs of between 5-15% of the gross domestic product and an increase in the public debt/GDP ratio of 2%. This, causing a departure from the parameters of economic convergence established by the Maastricht Treaty, can put the economic and financial stability of the Member States to the test. According to the authors, approximately 20% of these effects on the real economy are caused by the worsening of the financial situation of the banks. In light of these results, financial intermediaries can play a key role in the assessment of climate impacts, and ignoring them would lead to an incomplete assessment. Furthermore, financial regulation will have to act as a tool for mitigating climate risks. In order not to be damaged by climate risks, banks must quickly re-modulate the maturities of loans within their portfolio. The transmission channel of the effects of climate risk on the other important type of banking risk, i.e. credit risk, acts through the expiry of loans (Acharya et al. 2023). Brar et al. (2021) demonstrate that there are sectors that show greater sensitivity to climate risks. Among these, are primarily the agricultural sector in Canada which requires a more robust assessment by credit institutions of the riskiness of bank loans. This sensitivity is accentuated in the poorest countries in which the agricultural sector produces the majority of the gross domestic product (Kraemer and Negrilla 2014, de Bandt, Jacolin, and Lemaire 2021).

Concerning transition risk, many studies empirically demonstrate the effect of higher risks and spreads on bank loans to businesses and mortgages.

Delis et al. (2023) test whether banks charge higher interest rates to fossil fuel firms. The main conclusions they reach are two: 1) fossil fuel companies obtain loans more easily than non-fossil fuel companies; and (2) more green finance-oriented banks offer higher-priced credit to fossil fuel firms. This type of industry has probably, over the years, shown a greater dependence on bank loans than on risk capital financing (equity securities). All this has generated an increase in the demand for bank loans by fossil fuel companies and consequently this increase in the spread.

Furthermore, as highlighted by several studies (Faiella and Cingano 2015; Faiella and Mistretta 2015, Lavecchia 2015) the transition risk could cause an increase in inflation because climate policies could require the use of alternative energy sources that are currently more expensive. Since energy goods are considered necessary goods for satisfying consumer needs and for business investments (therefore with an inelastic demand) all of this would have the ultimate effect of worsening the vulnerability of these subjects.

Figure 1: Transmission mechanisms of the effects of natural disasters on the financial sector



Source: Batten et al. (2016)

Furthermore, there is also a transition risk of climate change represented by possible effects related to the implementation of new climate and energy policies by companies (primarily a reduction in the value of company assets). Precisely concerning this type of climate risk, Battiston et al. (2017) highlighted that the amount of banks' loans to carbon-intensive sectors (most vulnerable to this type of risk) is higher than their total capital.

Concerning the relationship between the physical risk of climate change and market risk, the pioneering work is that of Bansal et al. (2016). They, looking at the US stock market between 1934 and 2014, demonstrate that positive changes in temperature trends will reduce stock valuations. Lööf and Stephan (2019) identify positive impacts produced by higher ESG scores in terms of higher stock returns for European listed companies in the period 2005-2017 (also with similar results Viviani et al. 2019, Burger et al. 2022). Therefore, ESG factors can be considered fundamental components for reducing the volatility of financial assets. In this regard, Capelli, et al. (2023) propose the construction of a new metric for measuring market risk which, by putting together traditional methodologies (VaR-Value at risk) and ESG factors, can predict unexpected losses more precisely. Furukawa et al. (2020) show that corporate bond and stock prices reflect the physical risk impact of climate change.

However, these prices reflect only a few events that are exceptional in terms of the intensity of their effects rather than all available events. In the same vein, Goldsmith-Pinkham et al. (2022), considering the US municipal bond market, conclude that municipalities exposed to short-term flood risks have premiums that diverge over time compared to those of municipalities far from coastal areas. Recent studies share the conclusion that expectations of climate shocks are not contained in stock prices. Therefore, investors do not fully anticipate the economic impacts of heat as a first-order physical climate risk. In this regard, Hong et al. (2019) demonstrate that drought risk is not a determinant of stock prices of food companies operating especially in those regions/countries that have not suffered severe damage from drought for 20-30 years. Addoum et al. (2023), concerning US companies, show that although their profitability is greatly influenced by rising temperatures, stock prices do not respond immediately to thermal shocks. Pankratz et al. also reach similar results. (2023) taking samples of companies outside the USA as reference. Contrary to the latter results, Alok et al. (2019) demonstrate that portfolio managers consistently devalue stocks related to disaster areas to a much greater extent than managers of distant mutual funds. Concerning the relationship between climate change transition risk and market risk, Bolton and Kacperczyk (2021a, 2021b) demonstrate that investors require a higher expected excess return to invest in the securities of companies with higher greenhouse gas emissions both for those operating in the United States and outside. This creates a certain discrepancy in stock prices between various countries. According to these two authors, this extra return would offset the tax on carbon emissions to be paid or other regulatory measures relating to the transition to a low-emission economy. This carbon tax grows proportionally to the size of companies. Bua et al. (2022) studied the climate risk premium on European stock markets and demonstrated a climate risk premium of 7.05% and 6.14% on average per year after 2015, for transition and physical risk, respectively. Dai (2020) arrives at opposite results, according to which there are no significant differences in the ex-ante returns of securities in terms of companies' greenhouse gas emissions.

According to studies (Aswani et al. 2021, European Central Bank 2022), the presence of excess returns requested by investors in equity securities is strongly conditioned by the quality of the information on climate risk made available not by individual borrowers but rather by banks and third parties who manage financial databases. Disclosures about ESG exposures and issues by companies also impact the equity risk premium by reducing risks for investors (Bolton and Kacperczyk 2022, Krueger et al. 2023).

In addition to impacts on the cost of bank loans, climate risks can also impact loan volumes. Banks could ration credit to businesses located in territorial areas most exposed to natural events, instead of diverting resources to greener areas. In this regard, Pagliari (2023) focuses on territorial banks which, although dimensionally considered to be less significant financial institutions, tend to be more rooted in the territories most subject to flooding and more susceptible to suffering shocks linked to climate change. Concerning the category of local banks, Chavaz (2016) investigates the reaction of the mortgage market to the 2005 hurricane season in the USA. They conclude that local banks have been making more loans to businesses in affected areas, but, at the same time, they are selling a larger share of new mortgages on the secondary market. Other studies investigate how banks' behavior changes following these natural shocks. Blickle et al. (2022) find that disasters increase the demand for loans. Reghezza et al. (2022) find that, following the Paris Agreement, European banks reduced credit to polluting companies. Jung et al also reach similar results. (2023) for US banks. Concerning the relationship between the physical risk of climate change and loan volumes, Meisenzahl (2023) finds that after 2015, US banks significantly reduced lending to the areas most affected by floods and fires. These reductions penalized high credit-risk borrowers and products the most (while low-risk borrowers continued to benefit from increased financing although located in the most affected areas).

Accetturo et al. (2022) measure the ability of banks to finance the green transition in Italy by estimating the probability of companies starting green projects conditional on bank lending. Therefore, Italian banks appear to favor the energy and environmental transition. Mueller and Sfrappini (2022) conclude that while US banks appear not to favor the provision of loans to companies less sensitive to the issue of energy and climate transition, European banks reward companies that will instead be more penalized by the new regulation on the subject environmental.

3. Estimating the Green Trilemma

In the following analysis, we took into consideration the analysis of the Green Trilemma. Energy efficiency was estimated using the "*Energy intensity level of primary energy*". Banking stability was approximated through the variable "*Bank nonperforming loans to total gross loans (%)*", and climate risk through the variable "*Land Surface Temperature*". In our analysis, we will therefore try to evaluate whether these elements can all be positively connected with the ESG model. That is, we ask ourselves whether the optimization of the ESG model can be compatible with the simultaneous increase in energy efficiency, reduction of climate risk and increase in banking stability.

3.1 Estimation of the Value of Energy Efficiency within the ESG Model

In the following analysis, we take into consideration the relationship between the value of energy efficiency in the ESG context. In this regard, three different econometric models will be proposed to evaluate the connection between energy efficiency and each of the three components of the ESG model i.e.: E-Environment, S-Social and G-Governance. We will therefore first highlight the relationships of energy efficiency with each of the components of the ESG model and then give an overall opinion on the impact of the ESG model on energy efficiency.

3.1.1. Estimation of the Value of Energy Efficiency with Respect to the E-Environmental Dimension in the ESG Model

Specifically we have estimated the following equation:

$$\boldsymbol{EE_{it} \cong -EIL_{it} = \alpha + \beta_1(CDD)_{it} + \beta_2(SNFD)_{it} + \beta_3(ME)_{it} + \beta_4(FA)_{it} + \beta_5(FFEC)_{it} + \beta_6(TMPA)_{it} + \beta_7(ASNRD)_{it} + \beta_8(GHG)_{it}}$$

Where i=193 and t=[2011;2022].

The results obtained from the model estimation are reported in the table 1 below.

Table 1. Estimation of the relationship between energy efficiency and environment within the ESG model.

	WLS		*Pooled OLS*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	-0.47***	0.12	-494.477***	0.902852
ASNRD	-0.10***	0.02	-0.4571***	0.067838
SNFD	1.45***	0.10	414.616***	0.212706
CDD	16.50***	3.15	28.799***	339.569
FA	0.03***	0.00	0.100057***	0.019313
FFEC	0.04***	0.00	0.047306***	0.014386
GHG	-9.00***	2.04	-738.673***	194.135

ME	1.05***	0.06	257.446***	0.170223
TMPA	-0.09***	0.00	-0.120902**	0.05082
	Fixed-effects		*Random-effects*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	-921.413***	28.802	-807.849***	735.851
ASNRD	-0.778452***	0.0977195	-0.746405***	0.09558
SNFD	311.117***	0.349044	328.237***	0.342084
CDD	377.793***	233.859	272.184***	199.824
FA	274.472***	0.0872986	241.499***	0.081217
FFEC	0.0421787***	0.0126895	0.040211***	0.012495
GHG	-144.629***	174.035	-153.935***	170.602
ME	231.695***	0.263794	241.781***	0.258789
TMPA	-0.134624***	0.0432566	-0.138262***	0.04261

Source: Our elaboration on this database: https://esgdata.worldbank.org/?lang=en, Legend: * p <0,05, **p<0,01, *** p<0,001

We found that EIL is positively associated to:

- CDD: The positive correlation between the "Energy intensity level of primary energy" and "Cooling Degree Days" can be attributed to several interconnected factors. Firstly, as temperatures rise, denoted by higher CDD values, there is a heightened demand for energy-intensive cooling systems like air conditioners to maintain comfortable indoor environments, leading to increased primary energy consumption. Additionally, regions experiencing elevated CDD tend to rely more heavily on energy-intensive cooling technologies such as air conditioning units and refrigeration systems, further amplifying primary energy usage. Economic growth often coincides with warmer climates, driving up industrial and commercial activities that require significant energy consumption for cooling purposes. Moreover, the urban heat island effect in densely populated areas contributes to increased demand for cooling systems, escalating energy intensity levels. Climate change exacerbates this trend, causing more frequent and intense heatwaves, which in turn elevate CDD values and necessitate greater energy consumption for cooling. As such, the positive relationship between energy intensity and CDD is reinforced by factors like increased cooling demand, technological reliance, economic expansion, urbanization, population density, and the ongoing impact of climate change, collectively driving higher energy intensity levels in regions experiencing elevated Cooling Degree Days.
- SNFD: the positive relationship between "Adjusted savings: net forest depletion" and "Energy intensity level of primary energy " can be understood through several interconnected factors. Regions with higher levels of forest depletion often coincide with economies where energy-intensive industries, such as logging and timber processing, play significant roles. These industries, inherently reliant on substantial energy inputs, contribute to a higher energy intensity level. Moreover, countries undergoing rapid economic development phases associated with notable forest depletion may experience increased demand for energy-intensive infrastructure projects and industrial activities, further elevating energy intensity levels. In some cases, lenient environmental regulations in regions with significant forest depletion may also correlate with less stringent energy efficiency standards, allowing for higher energy consumption. Additionally, countries heavily reliant on natural resources like forests may also depend on energy-intensive extraction and processing industries, reinforcing the positive relationship between forest depletion and energy intensity. In essence, the positive

correlation between "Adjusted savings: net forest depletion (% of GNI)" and "Energy intensity level of primary energy (MJ/$2017 PPP GDP)" is influenced by complex interactions among resource utilization patterns, economic development stages, infrastructure demands, policy environments, and resource dependencies.

- ME: The positive relationship between "Energy intensity level of primary energy" and "Methane emissions (metric tons of CO2 equivalent per capita)" is evident through various intertwined factors. Regions with higher energy intensity often rely heavily on fossil fuels for energy production and consumption. These fuels, such as coal, oil, and natural gas, are significant sources of methane emissions throughout their extraction, processing, and utilization stages. Additionally, industries associated with high energy intensity, including manufacturing, agriculture, and transportation, contribute substantially to methane emissions through various processes. Agricultural practices such as livestock farming and rice cultivation release methane, while energy-intensive transportation sectors emit methane during fuel combustion. Furthermore, increased waste generation in areas with high energy intensity can lead to methane emissions from landfills and waste treatment processes. Overall, the positive correlation between energy intensity and methane emissions underscores the critical role of energy consumption patterns in shaping methane emission levels, highlighting the need for sustainable energy practices to mitigate environmental impacts.
- FA: the positive relationship between the "Energy intensity level of primary energy" and "Forest area (% of land area)" suggests a nuanced interplay between energy use efficiency and environmental sustainability. Energy intensity level, a measure of the energy efficiency of a nation's economy, is calculated as units of energy per unit of GDP. A lower energy intensity indicates a more efficient use of energy in producing economic output, which can correlate with less pressure on natural resources, including forests. On the other hand, "Forest area (% of land area)" signifies the portion of a country's land covered by forests, an essential metric for assessing environmental health and sustainability. The positive correlation might indicate that countries which efficiently use their energy tend to have policies or practices that also support the preservation or expansion of forest areas. These could include efforts to reduce energy waste, promote renewable energy sources, and implement sustainable land management practices that encourage reforestation and prevent deforestation. Essentially, this relationship underscores the potential for balanced development strategies that can both fuel economic growth and protect the environment, suggesting that advances in energy efficiency can be an integral part of promoting ecological well-being and preserving forest lands.
- FFEC: The positive relationship between the "Energy intensity level of primary energy" and "Fossil fuel energy consumption (% of total)" indicates an intertwined dynamic between the efficiency of energy usage within an economy and its reliance on fossil fuels for energy needs. The energy intensity level represents the amount of energy used per unit of economic output, with a higher value suggesting less efficiency in converting energy into productive activity. This inefficiency often correlates with a higher dependency on fossil fuels, as these sources of energy are typically less efficient and more environmentally damaging compared to renewable sources. The "Fossil fuel energy consumption (% of total)" metric quantifies the proportion of energy consumption that comes from fossil fuels, such as coal, oil, and natural gas, which are known for their high carbon emissions and contribution to climate change. The positive correlation between these two indicators could reflect a scenario where economies that lean heavily on fossil fuels tend to exhibit lower energy efficiency. This relationship highlights the challenges of transitioning to a more sustainable energy system. It underscores the need for investments in renewable energy technologies and energy efficiency

improvements to decrease reliance on fossil fuels, thereby reducing the energy intensity of economies and mitigating environmental impacts.

We found that EIL is negatively associated to:

- TMPA: the observed negative relationship between the "Energy intensity level of primary energy" and "Terrestrial and marine protected areas (% of total territorial area)" underscores a compelling dynamic in the interplay between energy efficiency and environmental conservation efforts. Specifically, this inverse correlation reveals that as nations improve their energy efficiency—thereby lowering the energy intensity level, which indicates the amount of energy used per unit of economic output—they tend to allocate a larger proportion of their land and marine areas as protected zones. This pattern suggests a broader commitment to sustainable development, where improvements in energy usage not only contribute to economic efficiency but also facilitate a more conscientious approach to preserving natural habitats. Countries that successfully reduce their energy intensity often do so by adopting technologies and practices that are less harmful to the environment, such as renewable energy sources and energy-saving measures. This reduction in dependency on energy-intensive processes naturally aligns with environmental goals, including the expansion of protected areas to conserve biodiversity, protect ecosystems, and ensure the sustainable use of natural resources. Hence, the negative correlation reflects a dual focus on enhancing energy efficiency while also prioritizing the preservation of terrestrial and marine environments, highlighting the synergy between economic and environmental objectives in the pursuit of sustainable development.
- ASNRD: the negative relationship between the "Energy intensity level of primary energy" and "Adjusted savings: natural resources depletion (% of GNI)" highlights a crucial aspect of sustainable economic practices. This inverse correlation suggests that as countries become more efficient in their use of primary energy—indicated by a lower energy intensity level—they experience a decrease in the rate at which their natural resources are depleted, relative to their Gross National Income (GNI). Essentially, lower energy intensity implies that an economy requires less energy to produce a unit of output, often reflecting a shift towards more sustainable and renewable energy sources and more efficient use of energy in industrial processes. This efficiency can lead to a reduced need for extracting and consuming natural resources, which in turn decreases the negative impact on the environment. The metric of adjusted savings, which takes into account the depletion of natural resources as a percentage of GNI, offers a way to quantify this impact. A lower percentage indicates that an economy is achieving economic growth in a manner that is less dependent on the exploitation of its natural resources, thereby promoting sustainability. Therefore, this negative relationship underscores the importance of energy efficiency not only for economic reasons but also for its role in preserving natural resources and ensuring long-term environmental sustainability.
- GHG: the negative relationship between the "Energy intensity level of primary energy" and "GHG net emissions/removals by LUCF (Land Use, Change, and Forestry) (Mt of CO2 equivalent)" illuminates the intricate balance between energy efficiency and its impact on greenhouse gas (GHG) emissions or removals related to land use and forestry. This inverse correlation indicates that as countries become more energy-efficient—thereby lowering their energy intensity, which measures the amount of energy used per unit of economic output—they tend to either emit fewer greenhouse gases or enhance their removal from the atmosphere through LUCF activities. Improved energy efficiency often stems from adopting advanced technologies, transitioning to renewable energy sources, and implementing practices that

reduce energy consumption across various sectors. These changes not only contribute to a reduction in fossil fuel combustion, a primary source of CO2 emissions, but can also support more sustainable land use and forestry practices. Such practices may include afforestation, reforestation, and better forest management, which increase carbon sequestration. Consequently, a decrease in energy intensity can indirectly support enhanced LUCF activities that absorb CO2, contributing to a lower net emission of GHGs. This relationship underscores the pivotal role of energy efficiency improvements not just in reducing direct emissions from energy use, but also in enabling positive changes in land use and forestry practices that contribute to climate change mitigation.

We can see that in a broad sense the value of EIL tends to be positively connected with the E-Environment component within the ESG context. However, EIL growth should be considered as negatively associated with energy efficiency. That is, the growth of EIL indicates the presence of low energy efficiency. It therefore follows that the positive relationship between EIL and E-Environment means that there is a negative relationship between energy efficiency and E-Environment value in the context of the ESG model.

3.1.2. Estimation of the Value of Energy Efficiency with Respect to the S-Social Dimension in the ESG Model

Specifically we have estimated the following equation:

$$\boldsymbol{EE_{it} \cong -EIL_{it} = \alpha + \beta_1(PUSMS)_{it} + \beta_2(PO)_{it} + \beta_3(MR)_{it} + \beta_4(AE)_{it} + \beta_5(ACFTC)_{it} + \beta_6(AGRR)_{it} + \beta_7(PA65)_{it}}$$

Where i=193 and t=[2011;2022].

The results obtained from the model estimation are reported in the table 2 below.

Table 2. Estimations of the relationship between energy efficiency and the S-Social Dimension within the ESG model

	Pooled OLS		*Fixed-effects*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	0.53236**	1.09699	103.215***	8.67383
ACFTC	-0.0463615***	0.0193198	8.67383***	0.026761
AE	-0.0464934***	0.0147595	0.026761***	0.0171408
AGRR	-2.04884***	0.3252	0.0171408***	0.322814
MR	-0.0045044***	0.0005689	0.322814***	0.0005328
PUSMS	-0.057072***	0.0134468	0.0005328***	0.104789
PA65	0.770667***	0.0324978	0.104789***	0.823556
PO	0.146085***	0.028703	0.823556***	0.037295

0.0372

	Random-effects		*WLS*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	55.2039***	28.802	0.454106***	0.15861
ACFTC	-0.124912***	0.0977195	-0.00914***	0.0025234
AE	-0.0456983***	0.349044	-0.010468***	0.0016997
AGRR	-1.50971***	233.859	-0.353382***	0.104368
MR	-0.0028992***	0.0872986	0.0138337***	0.0016242
PUSMS	0.786758***	0.0126895	-0.006732***	0.0023471
PA65	-8.63191***	174.035	0.0622182***	0.0185409
PO	0.146047***	0.263794	0.0815035***	0.0036642

Source: Our elaboration on this database: https://esgdata.worldbank.org/?lang=en, Legend: * p <0,05, **p<0,01, *** p<0,001

We found that the level of energy efficiency is positively associated with:

- PUSMS: the positive relationship between the "Energy intensity level of primary energy" and "People using safely managed sanitation services (% of population)" reflects an intriguing aspect of development where improvements in energy efficiency and infrastructure go hand in hand with enhanced public health and environmental services. This correlation suggests that as a country's economy becomes more energy-intensive, possibly indicating growth and industrialization phases where energy use increases, there's also a concurrent improvement in the percentage of the population having access to safely managed sanitation services. This linkage can be attributed to the fact that the development of more sophisticated energy systems often accompanies broader socio-economic development, including investments in public health infrastructure. Energy plays a crucial role in powering sanitation facilities, treating wastewater, and ensuring that sanitation services are reliable and accessible. As economies grow and their energy usage becomes more pronounced, their capacity to invest in and maintain advanced sanitation infrastructure also increases, thereby improving public health outcomes. This positive relationship underscores the multifaceted benefits of economic growth, highlighting how advancements in energy utilization not only drive industrial and economic achievements but also bolster critical services like sanitation, which are essential for sustainable development and the well-being of the population.
- PO: the positive relationship between the "Energy intensity level of primary energy" and the "Prevalence of overweight (% of adults)" can be interpreted through the lens of socioeconomic development and lifestyle changes. Energy intensity level of primary energy is a measure of how much energy is used by a country in relation to its GDP, indicating the energy efficiency of its economy. Higher energy intensity often correlates with industrialization and economic growth, which can lead to increased availability of food and changes in dietary patterns towards more processed foods that are high in fats and sugars. Concurrently, economic development often leads to more sedentary lifestyles, with people engaging in less physical labor and more in occupations that require prolonged sitting. Both these factors contribute to the prevalence of overweight and obesity in the population. Therefore, as countries develop and their energy intensity levels rise, there tends to be an increase in the percentage of adults who are overweight, highlighting a complex interplay between economic growth, energy usage, and health outcomes.
- MR: the relationship between "Energy intensity level of primary energy" and "Mortality rate, under-5 (per 1,000 live births)" intertwines energy use and public health in a complex dialogue shaped by a nation's development trajectory. Generally, a decline in energy intensity reflects enhanced energy efficiency typical of advancing economies, which should concurrently see a reduction in under-5 mortality rates due to better healthcare and living conditions. A positive correlation between high energy intensity and increased under-5 mortality, though counterintuitive, suggests an imbalance where rapid industrialization harms public health, particularly for children, due to pollution and inadequate distribution of economic gains. This analysis points to the importance of holistic development approaches. Effective strategies must harmonize economic growth with environmental stewardship and public health, ensuring advancements in energy efficiency and industrial capability translate into broad societal benefits, including for the youngest and most vulnerable. The key is to foster development that is not only economically robust and energy-efficient but also equitable and

conducive to a healthy populace, ensuring that progress in one area does not detrimentally impact another.

We also find that the level of energy efficiency is negatively associated with:

- AE: the negative relationship between "Energy intensity level of primary energy" and "Access to electricity (% of population)" highlights a developmental trend where countries that achieve greater energy efficiency tend to also expand access to electricity among their populations. As nations invest in energy-efficient technologies and infrastructures, they reduce their energy intensity, meaning they use less energy per unit of economic output. This efficiency makes it more feasible and cost-effective to extend electricity services to broader segments of the population. Essentially, as countries become more energy-efficient, they are better positioned to provide electricity to all their citizens, reflecting a crucial aspect of sustainable development and improved living standards.
- ACFTC: the negative relationship between "Energy intensity level of primary energy" and "Access to clean fuels and technologies for cooking (% of population)" indicates that as countries become more efficient in their energy use (lower energy intensity), they also tend to increase the population's access to clean cooking technologies and fuels. This trend suggests that improvements in energy efficiency are closely linked with broader access to environmentally friendly and healthier cooking options. As nations advance and optimize their energy consumption, they not only enhance their economic output but also make significant strides in public health and environmental protection by reducing reliance on polluting and inefficient traditional cooking methods.
- AGRR: the negative relationship between "Energy intensity level of primary energy" and the "Annualized average growth rate in per capita real survey mean consumption or income, total population (%)" suggests that as countries improve their energy efficiency (lower energy intensity), they often experience economic growth that translates into increased per capita income and consumption. This indicates that advancements in energy efficiency not only contribute to environmental sustainability but also play a crucial role in enhancing economic performance and living standards. Essentially, more efficient energy use within an economy leads to productivity gains, which can boost income levels and consumption capacity for the population, highlighting the importance of energy efficiency as a foundational element of sustainable development and prosperity.
- PA65: the negative relationship between "Energy intensity level of primary energy" and "Population ages 65 and above (% of total population)" suggests that as countries become more energy-efficient (lower energy intensity) and economically developed, they tend to have a higher proportion of elderly individuals. This is likely due to improvements in healthcare and living conditions associated with economic development, leading to increased life expectancy. Essentially, advancements in energy efficiency, which often accompany broader economic progress, indirectly contribute to demographic shifts towards older populations by enhancing the overall well-being and longevity of people. This relationship highlights the complex interplay between energy use, economic development, and demographic changes.

We can see that the value of EIL tends to be negatively correlated with the value of S-Social within the ESG model. However, since the increase in EIL tends to reduce energy efficiency then we can deduce that there is a positive relationship between energy efficiency and the value of the S-Social component. That is, in countries where the value of the S-Social component tends to grow, there is also a growth in energy efficiency measured as a reduction in the EIL value.

3.1.3. Estimation of the Value of Energy Efficiency with Respect to the G-Governance Dimension in the ESG Model

Specifically we have estimated the following equation:

$$\boldsymbol{EE_{it} \cong -EIL_{it} = \alpha + \beta_1(GDPG)_{it} + \beta_2(GE)_{it} + \beta_3(RQ)_{it} + \beta_4(RDE)_{it} + \beta_5(SEPS)_{it}}$$

Where i=193 and t=[2011;2022].

The results obtained from the model estimation are reported in the table 3 below.

Table 3. Estimations of the relationship between energy efficiency and the G-Governance dimension within the ESG model.

	Random-effects		*WLS*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	4.20486***	1.05967	2.01651***	0.096783
GDPG	-0.18085***	0.04967	0.077596***	0.013934
GE	-5.96931***	0.388357	-1.48558***	0.175804
RQ	3.86901***	0.093556	0.751533***	0.163579
RDE	2.63403***	0.302844	0.759216***	0.083698
SEPS	-2.26433***	0.09711	-0.346267***	0.108952

0.0372

	Fixed-effect		*Pooled OLS*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	4.42264***	0.417481	4.70064***	0.411515
GDPG	-0.17367***	0.051146	-0.238789***	0.053751
GE	-6.27513***	0.431551	-6.83889***	0.304034
RQ	3.68409***	0.100121	4.61383***	0.095642
RDE	3.84708***	0.366069	0.604542***	0.191135
SEPS	-2.64404***	0.126169	-2.15656***	0.081863

Source: Our elaboration on this database: https://esgdata.worldbank.org/?lang=en, Legend: * p <0,05, **p<0,01, *** p<0,001

We found that the level of EIL is positively associated to:

- RQ: the positive relationship between "Energy intensity level of primary energy" and "Regulatory Quality: Estimate" indicates that countries with higher energy consumption per unit of GDP are also those implementing stronger regulations to manage energy efficiency and sustainability. This suggests a worldwide recognition of the need for robust regulatory frameworks to transition from inefficient and unsustainable energy systems to more efficient and sustainable ones. The correlation reflects efforts across countries at different stages of development to invest in renewable energy, enforce energy efficiency standards, and adopt sustainable practices, influenced by global climate goals and sustainability targets. Essentially, this relationship highlights the critical role of governance and regulatory quality in steering nations towards sustainable energy usage and environmental stewardship on a global scale.
- RDE: the positive relationship between "Energy intensity level of primary energy" and "Research and development expenditure (% of GDP)" indicates that countries with higher energy intensity are likely investing more in research and development to address and mitigate their energy challenges. This trend suggests a strategic focus on innovation and technological

advancements to improve energy efficiency, develop renewable energy sources, and reduce environmental impacts. Essentially, this correlation reflects an understanding among these nations that significant investment in R&D is crucial for transitioning to more sustainable and efficient energy systems, highlighting the role of innovation in driving sustainable development and economic efficiency.

We also found that the level of EIL is negatively associated to:

- GDPG: a negative relationship between "Energy intensity level of primary energy" and "GDP growth (annual %)" indicates that as economies expand, they are becoming more energy-efficient, achieving economic growth with less energy consumption per unit of GDP. This trend is typical for advanced stages of development, where growth is increasingly driven by less energy-intensive sectors like services and technology. It reflects the successful implementation of energy efficiency measures, a shift towards renewable energy sources, and the adoption of technologies that reduce energy use. This relationship underscores the importance of innovation and sustainable energy policies in supporting economic expansion without proportionally increasing energy demand, aligning with goals for sustainable development and reduced environmental impact.
- GE: the negative relationship between "Energy intensity level of primary energy" and "Government Effectiveness: Estimate" indicates that as government effectiveness improves, energy intensity—how much energy is used per unit of economic output—tends to decrease. This suggests that effective governance plays a crucial role in promoting energy efficiency and implementing policies that encourage the use of renewable resources. Effective governments are better at enacting and enforcing energy regulations, investing in infrastructure to support efficient energy use, and executing long-term strategies for sustainable energy use. This correlation highlights the importance of robust regulatory frameworks and government policies in driving the transition towards a more energy-efficient and sustainable economy.
- SEPS: the negative relationship between "Energy intensity level of primary energy" and "School enrollment, primary and secondary (gross), gender parity index (GPI)" at the global level suggests a complex linkage between advancements in a country's energy efficiency and improvements in gender equality in education. As countries become more energy-efficient, reducing the amount of energy used per unit of economic output, this often signals broader economic development and technological progress. Such progress is frequently accompanied by societal improvements, including a stronger focus on gender equality and increased investments in the education sector. Consequently, as nations develop and optimize their energy use, they also tend to create more equitable educational opportunities for both genders, as evidenced by a higher GPI, which measures the ratio of female to male enrollment in primary and secondary education. This pattern reflects the broader trend that with economic and societal development, including more efficient energy use, comes a greater emphasis on and achievement of gender parity in education. The linkage underscores the interdependence of environmental sustainability, economic advancement, and social equity goals at the global level.

We can see that the value of EIL tends to be negatively correlated with the value of G-Governance within the ESG model. However, since the increase in EIL tends to reduce energy efficiency then we can deduce that there is a positive relationship between energy efficiency and the value of the G-

Governance component. That is, in countries where the value of the G-Governance component tends to grow, there is also a growth in energy efficiency measured as a reduction in the EIL value.

3.2 Estimation of the Banking Stability in the ESG Framework

In the following analysis, we take into consideration the relationship between the value of banking stability in the ESG context. In this regard, three different econometric models will be proposed to evaluate the connection between banking stability and each of the three components of the ESG model i.e.: E-Environment, S-Social and G-Governance. We will therefore first highlight the relationships of banking stability with each of the components of the ESG model and then give an overall opinion on the impact of the ESG model on banking stability. We approximate the value of banking stability using the bank nonperforming loans to total gross loans (%).

3.2.1 Estimation of the Value of Banking Stability with Respect to the E-Environmental Dimension in the ESG Model

Specifically we have estimated the following equation:

$$\boldsymbol{BS_{it} \cong BNPL_{it} = \alpha + \beta_1(NRD)_{it} + \beta_2(AFF)_{it} + \beta_3(EIL)_{it}}$$

Where i=137 and t=[2010;2022].

The results obtained from the model estimation are reported in the table 4 below.

Table 4. Banking stability and the E-Environmental component within the ESG model.

	Pooled OLS		*Fixed-effects*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	5.59265***	0.434368	-0.8877***	1.44434
NRD	0.163599***	0.035938	-0.3089***	0.05675
AFF	0.173171***	0.022669	0.40317***	0.0937
EIL	-0.19383**	0.083836	1.07874***	0.24883
	Random-effects		*WLS*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	2.67211**	1.19556	4.37442***	0.12618
NRD	-0.24655***	0.051501	0.13183***	0.02081
AFF	0.247835***	0.059274	0.18046***	0.00894
EIL	0.54826***	0.185698	-0.1074***	0.02099

0.0372

Source: Our elaboration on this database: https://esgdata.worldbank.org/?lang=en, Legend: * p <0,05, **p<0,01, *** p<0,001

We found that BS is positively associated with

- AFF: the positive relationship between "Banking Stability" and "Agriculture, forestry, and fishing, value added (% of GDP)" reflects the interconnectedness of financial health and the economic contributions of primary sectors. In economies where agriculture, forestry, and fishing are significant contributors to GDP, a stable banking sector plays a critical role in supporting these industries through the provision of credit, investment, and financial services tailored to the unique needs of these sectors. Banking stability ensures that farmers, fishermen, and foresters have access to the necessary capital for operations, expansion, and innovation, such as purchasing equipment, investing in sustainable practices, or weathering periods of economic uncertainty. This financial support is crucial for the productivity and sustainability of these sectors, potentially leading to their increased contribution to the economy. Moreover, a stable banking sector can foster a supportive environment for rural development and finance initiatives that further enhance the viability and profitability of agriculture, forestry, and fishing. Thus, the symbiotic relationship between banking stability and the economic output of these primary sectors highlights the importance of robust financial institutions in underpinning sectoral growth and, by extension, national economic health.

- EIL: the positive relationship between "Banking Stability" and "Energy intensity level of primary energy" suggests that a stable banking sector may support or coincide with higher levels of energy consumption relative to GDP. This can occur because banking stability provides the financial infrastructure necessary for investments in various sectors of the economy, including energy-intensive industries such as manufacturing, construction, and heavy industry. Stable banks are more likely to provide loans and financial products that facilitate large-scale investments in infrastructure and industrial projects, which in turn can increase the demand for energy. Additionally, a stable banking sector may also support investments in energy production and distribution infrastructure, leading to greater availability and potentially increased consumption of energy as businesses and consumers take advantage of the reliable energy supply. This scenario reflects how financial stability and access to credit are crucial for economic activities that are energy-intensive, suggesting that banking stability can indirectly influence a country's energy consumption patterns and its overall energy intensity.

We also found that BS is negatively associated with:

- NRD: the negative correlation between "Banking Stability" and "Adjusted savings: natural resources depletion (% of GNI)" indicates that nations with stronger banking systems tend to deplete natural resources less in relation to their Gross National Income (GNI). This suggests that robust financial institutions may prioritize conservation and sustainable resource management. It underscores the potential for leveraging financial stability to promote environmental sustainability and steer economic activity towards more responsible practices.

We found that BS tends to be positively associated to the E component of the ESG model. That is, countries that perform well in environmental terms tend to also perform well in terms of banking stability. This relationship could be a manifestation of the Environmental Kuznets Curve-EKC, that is, that particular rule of thumb that states that countries with high per capita income are more likely to successfully implement sustainable economic policies than countries with low per capita income. Countries with high per capita income also tend to have high levels of banking stability.

3.2.2 Estimation of the Value of Banking Stability with Respect to the S-Social Dimension in the ESG Model

Specifically, we have estimated the following equation:

$$\boldsymbol{BS_{it} \cong BNPL_{it} = \alpha + \beta_1 (PUSM)_{it} + \beta_2 (SEP)_{it} + \beta_3 (UT)_{it}}$$

Where i=137 and t=[2010;2022].

The results obtained from the model estimation are reported in the table 5 below.

Table 5. Banking stability and the S-Social component within the ESG model.

	WLS		*Fixed-effects*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	20.5554***	1.07044	18.4641***	4.0994
PUSM	-0.051933***	0.0029742	-0.073032***	0.0226393
SEP	-0.143225***	0.00975852	-0.123046***	0.0340138
UT	0.394994***	0.0253021	0.773315***	0.0635002
	Random-effects		*Pooled OLS*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	226.934	637.7	22.9878	2.68906
PUSM	-0.145276	0.0615694	-0.053223	0.00831528
SEP	-0.117307	0.0382153	-0.159164	0.0243716
UT	0.842292	0.0709012	0.477631	0.0454143

0.0372

Source: Our elaboration on this database: https://esgdata.worldbank.org/?lang=en, Legend: * p <0,05, **p<0,01, *** p<0,001

We found that BS is positively associated to:

- UT: a positive correlation between "Banking Stability" and "Unemployment, total (% of total labor force) (modeled ILO estimate)" suggests an unexpected scenario where a strong banking sector coincides with higher unemployment rates. This could stem from factors such as conservative lending practices limiting job creation or broader economic stagnation hindering employment opportunities. It underscores the complexity of economic dynamics and the need for comprehensive policy measures to address labor market inefficiencies and promote inclusive growth.

We also find that BS is negatively associated to:

- PUSM: the negative correlation between "Banking Stability" and "People using safely managed drinking water services (% of population)" reveals a complex interaction between financial strength and access to vital resources. While "Banking Stability" reflects a nation's financial robustness, "People using safely managed drinking water services (% of population)" indicates the proportion of the population with access to safe water, reflecting public health and infrastructure development. This correlation suggests that countries with stronger banking systems may encounter difficulties in ensuring safe water access for their citizens. Factors such as limited investment in water infrastructure and economic disparities may contribute to this challenge, despite stable banking sectors. Addressing this issue requires coordinated efforts across financial institutions, policymakers, and public health authorities to tackle underlying socio-economic factors and ensure equitable access to essential services. This underscores the need for holistic approaches that integrate financial stability with broader development goals, prioritizing the well-being and safety of all segments of society.
- SEP: the negative correlation between "Banking Stability" and "People using safely managed drinking water services (% of population)" underscores a complex dynamic between financial robustness and access to vital resources. While "Banking Stability" reflects the strength of a nation's financial institutions, "People using safely managed drinking water services (% of population)" indicates the availability of safe water, vital for public health and infrastructure development. This correlation suggests that countries with stronger banking systems may face challenges in providing safe drinking water to their populations, influenced by factors such as limited investment in water infrastructure and economic disparities. Addressing this issue

requires coordinated efforts among financial institutions, policymakers, and public health authorities to tackle underlying socio-economic factors and ensure equitable access to essential services. Overall, it emphasizes the need for comprehensive approaches that integrate financial stability with broader development goals, prioritizing the well-being and safety of all segments of society.

We found that BS is positively associated with the S component of the ESG model. That is, countries that have a greater orientation towards social policies, inclusion, removal of inequality and fight against poverty also tend to have better results in terms of banking stability. This relationship may be because generally the level of social inclusiveness and well-being tends to grow with per capita income together with banking stability.

3.2.3 Estimation of the Value of Banking Stability with Respect to the G-Governance Dimension in the ESG Model

Specifically we have estimated the following equation:

$$BS_{it} \cong BNPL_{it} = \alpha + \beta_1(LFPR)_{it} + \beta_2(NM)_{it} + \beta_3(PS)_{it}$$

Where i=137 and t=[2010;2022].

The results obtained from the model estimation are reported in the table 6 below.

Table 6. Estimation of the relationship between banking stability and G-Governance dimension within the ESG model.

	Fixed-effects		*Random-effects*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	47.5913***	5.34094	28.5893***	3.63336
LFPR	-0.603977***	0.0792168	-0.324525***	0.0528813
NM	-2.77E-06**	1.32E-06	-2.23E-06*	1.23E-06
PS	-2.69162***	0.603103	-1.76267***	0.489933
	WLS		*Pooled OLS*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	15.1992***	0.705438	15.6553***	1.45026
LFPR	-0.141751***	0.010206	-0.129896***	0.0212864
NM	-2.42E-06***	3.77E-07	-1.95E-06*	1.00E-06
PS	-0.933208***	0.115679	-1.38816***	0.256159

0.0372

Source: Our elaboration on this database: https://esgdata.worldbank.org/?lang=en, Legend: * p <0,05, **p<0,01, *** p<0,001

Specifically we found that the level of BS is negatively associated with:

- LFRP: the negative correlation between "Banking Stability" and "Labor force participation rate, total (% of total population ages 15-64) (modeled ILO estimate)" suggests that countries with stronger banking systems tend to experience lower levels of workforce engagement. This implies potential economic challenges such as reduced job opportunities or limited access to credit for businesses, which may hinder labor market participation. Addressing these issues requires policies that promote inclusive growth and address barriers to employment, ensuring equitable opportunities for all segments of society.
- NM: the negative correlation between "Banking Stability" and "Net migration" worldwide suggests that regions with stronger financial systems tend to experience reduced levels of population movement. This indicates that stable banking sectors are associated with more prosperous economies and reduced incentives for individuals to migrate in search of better

opportunities. Addressing economic disparities and fostering inclusive growth can help mitigate migration pressures and promote sustainable development globally.

- PS: the negative correlation between "Banking Stability" and "Political Stability and Absence of Violence/Terrorism: Estimate" suggests that countries with stronger financial systems may struggle to maintain political stability and prevent violence or terrorism. This indicates potential challenges such as economic disparities leading to social unrest or weakened confidence in government institutions. Addressing financial vulnerabilities and strengthening governance structures are essential for promoting stability and mitigating the risk of violence or terrorism.

Results show that the level of BS is negatively associated with the level of the G-Governance component in the context of the ESG model. This result may appear paradoxical. However, we must consider that not all high per capita income countries that generally perform well in terms of BS also perform well in terms of governance. For example, the USA has less than excellent values in terms of Political Stability and other essential indicators for evaluating governance within ESG models.

3.3 Estimate the Value of Climate Risk in the ESG Framework

In the following analysis, we take into consideration the relationship between the value of climate risk in the ESG context. In this regard, three different econometric models will be proposed to evaluate the connection between climate risk and each of the three components of the ESG model i.e.: E-Environment, S-Social and G-Governance. We will therefore first highlight the relationships of climate risk with each of the components of the ESG model and then give an overall opinion on the impact of the ESG model on climate risk. We approximate the value of climate risk using the Land Surface Temperature-LST.

3.3.1 Estimation of the Value of Climate Risk with Respect to the E-Environment Dimension in the ESG Model

Specifically we have estimated the following equation:

$$\boldsymbol{CR_{it} \cong LST_{it} = \alpha + \beta_1(NFD)_{it} + \beta_2(CDD)_{it} + \beta_3(EIL)_{it} + \beta_4(PM2.5)_{it}}$$

Where i=193 and t=[2011;2022].

The results obtained from the model estimation are reported in the table 7 below.

Table 7. Estimation of the Relationship between Climate Risk and E-Environment.

	Pooled OLS		*Fixed-effects*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	14.2027***	0.354035	21.2648***	0.45118
NFD	0.32937***	0.0510244	0.07276***	0.02678
CDD	0.00313***	7.04E-05	0.00196***	0.00013
EIL	-0.3121***	0.0543984	-0.2927***	0.03675
PM2.5	0.09606***	0.0091004	-0.0459***	0.00956
	Random –effects		*WLS*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	20.1822***	0.723282	14.3053***	0.08714
NFD	0.07744***	0.026382	0.35292***	0.01996
CDD	0.00223***	0.0001136	0.0031***	1.85E-05
EIL	-0.2948***	0.0360074	-0.311***	0.00596
PM2.5	-0.0326***	0.0091684	0.09547***	0.00195

0.0372

Source: Our elaboration on this database: https://esgdata.worldbank.org/?lang=en, Legend: * p <0,05, **p<0,01, *** p<0,001

We found that the level of CR is positively associated to:

- NFD: the positive correlation between "Land Surface Temperature" and "Adjusted savings: net forest depletion (% of GNI)" indicates that higher land surface temperatures are associated with increased depletion of forest resources relative to Gross National Income (GNI). This suggests that rising temperatures exacerbate environmental stressors on forests, leading to accelerated deforestation driven by factors such as land conversion for agriculture and urban development. Addressing this correlation requires urgent action to mitigate climate change impacts and implement sustainable land management practices to ensure the preservation of forests and environmental sustainability.
- CDD: the positive correlation between "Land Surface Temperature" and "Cooling Degree Days" signifies that as land surface temperatures increase, there is a corresponding rise in the demand for cooling services. This relationship highlights the necessity for proactive measures to address the escalating need for cooling, particularly in urban areas, through investments in energy-efficient technologies and climate adaptation strategies.
- PM2.5: the positive correlation between "Land Surface Temperature" and "PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)" indicates that as land temperatures rise, so does the level of fine particulate matter in the air. This relationship highlights the urgent need for comprehensive strategies to address air quality issues exacerbated by climate change. Efforts to reduce emissions from various sources and implement sustainable urban planning measures are crucial for minimizing the adverse effects of rising temperatures on air pollution levels and protecting public health.

We also find that the level of CR is negatively associated to:

- EIL: the negative correlation between "Land Surface Temperature" and "Energy intensity level of primary energy" suggests that as land temperatures rise, the efficiency of energy use within an economy improves. This relationship underscores the potential for climate adaptation measures to drive advancements in energy efficiency, such as the adoption of energy-efficient technologies and renewable energy sources. By addressing climate change and promoting energy efficiency, policymakers can simultaneously mitigate the impacts of rising temperatures and foster sustainable economic development.

We find that the level of CR is negatively associated with the E-Environmental component within the ESG model. The level of CR increases with the reduction of the E-Environmental component.

3.3.2 Estimation of the Value of Climate Risk with Respect to the S-Social Dimension in the ESG Model

Specifically we have estimated the following equation:

$$\boldsymbol{CR_{it} \cong LST_{it} = \alpha + \beta_1 (LEB)_{it} + \beta_2 (PA65)_{it} + \beta_3 (SEPS)_{it}}$$

Where i=193 and t=[2011;2022].

The results obtained from the model estimation are reported in the table 8 below.

Table 8. Estimation of the relationship between Climate Risk and S-Social dimension within the ESG model.

	Fixed-effects		*Random –effects*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	-5.96593*	4.17507	2.26568***	4.13443
GI	0.044678***	0.024275	0.051429**	0.023728
LEB	0.161534***	0.045345	0.114337***	0.043663
PA65	0.343516***	0.040977	0.325633***	0.040088
SEPS	6.91337***	2.59966	6.71236***	2.54798
	Pooled OLS		*WLS*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	38.9013***	6.74975	35.0053***	2.92372
GI	0.527093***	0.040164	0.511654***	0.014305
LEB	-0.129547**	0.064497	-0.148606***	0.018851
PA65	-0.392095***	0.069254	-0.357344***	0.0213
SEPS	-23.1713***	7.16983	-17.5547***	3.45928

0.0372

Source: Our elaboration on this database: https://esgdata.worldbank.org/?lang=en, Legend: * p <0,05, **p<0,01, *** p<0,001

We found that the level of CR is positively associated with:

- GI: the positive correlation between "Land Surface Temperature" and the "Gini index" suggests that as land temperatures rise, income inequality tends to increase within societies. This relationship underscores the complex interplay between environmental factors and socio-economic dynamics, with rising temperatures exacerbating economic disparities. Addressing both climate change and income inequality is crucial for building resilient and inclusive societies that can effectively tackle the challenges of a changing climate.

We also found that the level of CR is negatively associated with:

- LEB: the negative correlation between "Land Surface Temperature" and "Life expectancy at birth, total (years)" underscores the profound impact of environmental conditions on public health. As land temperatures rise, life expectancy tends to decrease, primarily due to increased risks of heat-related illnesses and worsening air quality. Addressing climate change as a public health issue is crucial, requiring measures to mitigate the health impacts of rising temperatures through adaptation strategies and improved access to healthcare.
- PA65: the negative correlation between "Land Surface Temperature" and "Population ages 65 and above (% of total population)" suggests that as land temperatures rise, there tends to be a decrease in the proportion of the population aged 65 and above. This relationship indicates potential challenges for elderly individuals living in warmer climates, such as increased health risks and potentially higher mortality rates during extreme heat events. Addressing climate change and its impacts on vulnerable populations is essential for promoting healthy aging and ensuring the well-being of elderly individuals in a warming world.
- SEPS: the negative correlation between "Land Surface Temperature" and "School enrollment, primary and secondary (gross), gender parity index (GPI)" suggests that as land temperatures rise, there tends to be an improvement in gender parity in school enrollment. This indicates that warmer climates may incentivize families to prioritize education for all children, regardless of gender, potentially narrowing the enrollment gap between boys and girls. Addressing climate change and promoting gender equality are essential for ensuring equitable access to education and empowering all children to reach their full potential in a changing climate.

Results suggest that the level of CR is negatively associated with the E-Environmental component within the ESG-Model.

3.3.3. Estimation of the Value of Climate Risk with Respect to the G-Governance Dimension in the ESG Model

Specifically we have estimated the following equation:

$$\boldsymbol{CR_{it} \cong LST_{it} = \alpha + \beta_1(ESRP)_{it} + \beta_2(PS)_{it} + \beta_3(PSHW)_{it}}$$

Where i=193 and t=[2011;2022].

The results obtained from the model estimation are reported in the table 9 below.

Table 9. Estimation of the relationship between climate risk and G-Governance

	Pooled OLS		*Fixed-effects*	
	Coefficient	Std. Error	Coefficient	Std. Error
Const	53.9111***	1.89945	17.1964***	1.26109
ESRP	-12.5277***	0.864124	2.84463***	0.576148
PS	-2.48009***	0.254635	-0.386083***	0.108446
PSHW	-0.104053***	0.0181081	0.0196881***	0.00581146
	Random-effects		*WLS*	
	Coefficient	Std. Error	Coefficient	Std. Error
const	18.803***	1.48365	55.2933***	0.714815
ESRP	2.19236***	0.562156	-13.2819***	0.339867
PS	-0.44747***	0.106892	-2.14692***	0.104095
PSHW	0.0194436***	0.00575138	-0.091281***	0.00667088

0.0372

Source: Our elaboration on this database: https://esgdata.worldbank.org/?lang=en, Legend: * p <0,05, **p<0,01, *** p<0,001

We found that the level of CR is negatively associated to:

- ESRP: the negative correlation between "Land Surface Temperature" and "Economic and Social Rights Performance Score" highlights the intricate link between environmental conditions and the fulfillment of economic and social rights. As land temperatures rise, there tends to be a decrease in the performance of safeguarding economic and social rights within societies. This suggests that climate change exacerbates socio-economic disparities, hindering access to essential services and opportunities, particularly for marginalized communities.
- PS: the negative correlation between "Land Surface Temperature" and "Political Stability and Absence of Violence/Terrorism: Estimate" suggests that as land temperatures rise, political stability tends to decrease. This relationship underscores the complex interplay between environmental factors and governance, with rising temperatures exacerbating socio-economic challenges and increasing vulnerability to political unrest.
- PSHW: the negative relationship between "Land Surface Temperature" and the "Proportion of seats held by women in national parliaments (%)" points to a notable correlation between environmental conditions and gender representation in politics. As land surface temperatures rise, there tends to be a decrease in the proportion of parliamentary seats held by women. This

trend suggests that environmental factors, such as climate change and associated socio-economic challenges, may hinder progress towards gender equality in political representation.

Finally, we found that the level of CR is negatively associated with the G-Governance component within the ESG model.

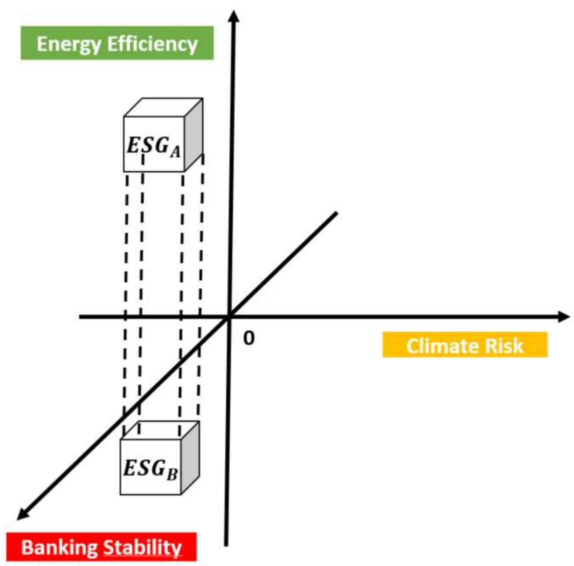
3.4. Can We Solve the Trilemma ? Relationship between the Value of Banking Stability, Energy Efficiency and Climate Risk in the Context of the ESG Model

Below we summarize the equations that we estimated with our model with an indication of the effects for both the individual E, S and G components and the overall impact on the ESG model.

SYNTHESIS OF THE EQUATIONS AND THEIR RELATIONSHIPS EITHER WITH THE SINGLE COMPONENTS OF THE ESG EITHER WITH THE OVERALL ESG EFFECT			
	EQUATIONS	**RELATIONSHIP**	**OVERALL ESG EFFECT**
ENERGY EFFICIENCY AND ENVIRONMENT	$\boldsymbol{EIL_{it} = \alpha + \beta_1(CDD)_{it} + \beta_2(SNFD)_{it} + \beta_3(ME)_{it} + \beta_4(FA)_{it} + \beta_5(FFEC)_{it} + \beta_6(TMPA)_{it} + \beta_7(ASNRD)_{it} + \beta_8(GHG)_{it}}$	NEGATIVE	NEGATIVE
ENERGY EFFICIENCY AND SOCIAL	$\boldsymbol{EIL_{it} = \alpha + \beta_1(PUSMS)_{it} + \beta_2(PO)_{it} + \beta_3(MR)_{it} + \beta_4(AE)_{it} + \beta_5(ACFTC)_{it} + \beta_6(AGRR)_{it} + \beta_7(PA65)_{it}}$	POSITIVE	
ENERGY EFFICIENCY AND GOVERNANCE	$\boldsymbol{EIL_{it} = \alpha + \beta_1(GDPG)_{it} + \beta_2(GE)_{it} + \beta_3(RQ)_{it} + \beta_4(RDE)_{it} + \beta_5(SEPS)_{it}}$	POSITIVE	
BANKING STABILITY AND ENVIRONMENT	$\boldsymbol{BNPL_{it} = \alpha + \beta_1(NRD)_{it} + \beta_2(AFF)_{it} + \beta_3(EIL)_{it}}$	POSITIVE	POSITIVE
BANKING STABILITY AND SOCIAL	$\boldsymbol{BNLP_{it} = \alpha + \beta_1(PUSM)_{it} + \beta_2(SEP)_{it} + \beta_3(UT)_{it}}$	POSITIVE	
BANKING STABILITY AND GOVERNANCE	$\boldsymbol{BNLP_{it} = \alpha + \beta_1(LFPR)_{it} + \beta_2(NM)_{it} + \beta_3(PS)_{it}}$	NEGATIVE	
CLIMATE RISK AND ENVIRONMENT	$\boldsymbol{LST_{it} = \alpha + \beta_1(NFD)_{it} + \beta_2(CDD)_{it} + \beta_3(EIL)_{it} + \beta_4(PM2.5)_{it}}$	NEGATIVE	NEGATIVE
CLIMATE RISK AND SOCIAL	$\boldsymbol{LST_{it} = \alpha + \beta_1(LEB)_{it} + \beta_2(PA65)_{it} + \beta_3(SEPS)_{it}}$	NEGATIVE	
CLIMATE RISK AND GOVERNANCE	$\boldsymbol{SLT_{it} = \alpha + \beta_1(ESRP)_{it} + \beta_2(PS)_{it} + \beta_3(PSHW)_{it}}$	NEGATIVE	

Table 10. Synthesis of the equations applied to estimate the relationships of EE, BS and CR in respect to the components of the ESG model.

The analysis therefore demonstrates the impossibility of solving the Green Trilemma (figure 2). In fact, by implementing the ESG model in the countries considered it is possible to obtain positive results in terms of increased banking stability and reduction of climate risk. However, energy efficiency tends to be negatively associated with value when applying the ESG model. It follows that the application of the ESG model does not allow the achievement of the three indicated objectives at the same time. The analysis also demonstrates that environmental sustainability issues should probably be addressed differently compared to energy issues. In fact, even countries that have an interest in realizing the environmental transition may still have problems in applying models that are sustainable from an energy point of view. The energy issue seems to be the element that risks derailing the application of ESG models on a large scale. Especially in the current international context characterized by Sino-American tension, the Russian-Ukrainian war and Israel's war against Hamas in Gaza.



Solving the Green Trilemma in the ESG context

We define the green trilemma as the possibility of improving energy efficiency, reducing climate risk and increasing banking stability through the optimization of the ESG model.
We can see that in an optimal condition we would find ourselves in position $\boldsymbol{ESG_A}$. That is, in position $\boldsymbol{ESG_A}$ we would have high energy efficiency, low climate risk and a positive value of banking stability. In the $\boldsymbol{ESG_A}$ case it would have been possible to obtain a positive resolution of the green trilemma.
However, as demonstrated by the econometric analysis conducted, only two elements are positively connected with the ESG model, namely the reduction of climate risk and the growth of banking stability. On the contrary, energy efficiency appears to be negatively associated with the optimization of the ESG model. Therefore the green trilemma cannot be resolved within the ESG model. The equilibrium point is represented by the point $\boldsymbol{ESG_B}$.

Figure 2. Our analysis shows the impossibility of solving the green trilemma. Indeed, the implementation of the ESGF model tends to be negatively linked to the reduction of climate risk and the growth of banking stability. However, the application of the ESG model tends to be negatively associated with increasing energy efficiency.

Indeed, in this context we are witnessing significant pressure in the energy markets. Furthermore, the energy question becomes even more decisive, especially in light of the decisions of the USA and the European Union to apply reindustrialisation. The investment in reindustrialization made by both the American administration led by Biden and desired by the European Commission risks creating greater demand for energy in Europe. Furthermore, the need to support Ukraine against Russia through the growth of the military industry could further increase the use of energy for industrial purposes. Added to this significant growth in energy demand in the USA and Europe is also the choice to focus on electric cars, which could require further energy consumption. In short, it seems that there is a contradiction between environmental sustainability and the energy issue that should be resolved through adequate industrial policies. Probably one way to resolve the issue could consist in the split between energy economic policies and environmental economic policies. In fact, it is necessary to consider that the energy sector is strategic for countries, especially in periods of growing political-military tension at an international level. In this sense, it seems very unlikely, at least in the short term, to be able to create an energy production system that is completely compatible with ESG principles, especially from an environmental point of view.

5. Conclusions

In this article we tried to verify whether it is possible to maximize energy efficiency, increase banking stability and reduce climate risk by implementing the ESG model globally. The results show that the application of ESG models allows increasing banking stability and reducing climate risk. However, through the application of the ESG model it is not also possible to increase energy efficiency. We therefore rejected the Green Trilemma hypothesis in connection with the application of ESG models. Our analysis suggests the need to separate energy issues from environmental questions within the ESGF model. In fact, the strategic role of the energy sector for the economic and political development of countries seems to be not completely compatible with the application of the ESG model.

6. References

Accetturo A., Barboni G., Cascarona M., Garcia-Appendini E., Tomasi M. (2022), Credit supply and green investments, Available at SSRN 4093925

Acharya V.V., Berner R., Engle R.F., Jung H., Stroebel J., Zeng X., Zhao Y. (2023). Climate stress testing, *NBER Working Paper* no. 31097, National Bureau of Economic Research, April 2023

Addoum J. M., Ng D. T., Ortiz-Bobea A. (2023), Temperature Shocks and Industry Earnings News, *Journal of Financial Economics*, forthcoming

Alok S., Kumar N., Wermers R. (2019), Do Fund Managers Misestimate Climatic Disaster Risk?. *Review of Financial Studies*, Forthcoming, Indian School of Business, Available at SSRN

Angelico C., Faiella I., Michelangeli V. (2022), Il rischio climatico per le banche italiane: un aggiornamento sulla base di un'indagine campionaria, Nota di stabilità finanziaria e vigilanza, N. 29 Giugno

Aswani J., Raghunandan A., Rajgopal S. (2021), Are carbon emissions associated with stock returns?, *Review of Finance*, forthcoming

Bandt (de) O., Jacolin L., Lemaire T. (2021). Climate Change in Developing Countries: Global Warming Effects, Transmission Channels and Adaptation Policies, *Banque de France Working Paper* No. 822

Batten S., Sowerbutts R. and M. Tanaka (2016), Let's talk about the weather: the impact of climate change on central banks, Bank of England working papers n. 603, Bank of England

Battiston S., Mandel A., Monasterolo I., Schütze F., Visentin G. (2017), A climate stress-test of the financial system, Nature Climate Change, 7, 283-288

Blickle K. S., Hamerling S.N., Morgan D.P. (2022), *How bad are weather disasters for banks?,* (No. 990). *Federal Reserve Bank of New York Staff reports*, January 2022, www.newyorkfed.org/medialibrary/ media/research/staff_reports/sr990.pdf

Billio M., Costola M., Hristova I., Latino C., Pelizzon L. (2022), *Sustainable finance: A journey toward ESG and climate risk, SSRN Working Paper*, April 2022, papers.ssrn.com/sol3/ papers.cfm?abstract_id=4093838

Birindelli G., Bonanno G., Dell'Atti S., Iannuzzi A. P. (2022), Climate change commitment, credit risk and the country's environmental performance: Empirical evidence from a sample of international banks, *Business Strategy and the Environment*, Vol. 31(4), pp. 1641–1655

Bolton P., Kacperczyk M., (2022), The Financial cost of Carbon, *Journal of Applied Corporate Finance*, Vol. 34 (2), Spring 2022, pp. 17–19

Bolton P., Kacperczyk M., (2021a), Do Investors Care about Carbon Risk?, *Journal of Financial Economics,* Vol. 142, Issue 2, November 2021, pp. 517–549.

Bolton P., Kacperczyk M., (2021b), *Global pricing of carbon risk*, *NBER Working paper*, National Bureau for Economic Research, no. 28510, February

Brar J., Kornprobst A., Braun W. J., Davison M., Hare W. (2021), A Case Study of the Impact of Climate Change on Agricultural Loan Credit Risk, *Mathematics,* Vol. 9(23), 3058

Burke M., Hsiang S.M., Miguel E. (2015), Global non-linear effect of temperature on eco- nomic production. Nature, 527(7577):235

Bua G., Kappa D., Ramella F., Rognone L. (2022), Transition Versus Physical Climate Risk Pricing in European Financial Markets: A Text-Based Approach*, ECB Working Paper*

Burger E., Grba F., Heidorn T.(2022), The impact of ESG ratings on implied and historical volatilites , Frankfurt School Working Paper

Capasso G., Gianfrate G., Spinelli M. (2020), Climate change and credit risk, *Journal of Cleaner Production,* Vol. 266, 121634

Capelli P., Ielasi F., Russo A. (2021), Forecasting volatility by integrating financial risk with environmental, social and governance risk, Corporate Social Responsibility and Environmental Management, Volume 28, Issue 5

Carbone S., Giuzio M., Kapadia S., Krämer J. S., Nyholm K., Vozian K. (2022), *The low-carbon transition, climate commitments and firm credit risk, SUERF Policy Brief* 309

Carleton T.A., Hsiang S.M. (2016), Social and economic impacts of climate. Science, 353 (6304):aad9837

Carrizosa R., Ghosh A. A. (2022), *Sustainability-linked loan contracting,* Available at SSRN 4103883

Chava S. (2014), Environmental Externalities and Cost of Capital, *Management Science*, Vol. 60, Issue 9, pp. 2223–2247

Chavaz M. (2016), *Dis-integrating credit markets: diversification, securitization, and lending in a recovery,* (No. 617) *Bank of England Staff Working Paper*

Chodnicka P. (2021), ESG as a Measure of Credit Ratings, Risks, Vol. 9, No. 12

Correa R., He A., Herpfer C., Lel U. (2023), The rising tide lifts some interest rates: Climate change, natural disaters and loan pricing, (No. 889/2023) *ECGI Working Papers in Finance*, March 2023

Dai W. (2020), Greenhouse Gas Emissions and Expected Returns, Available at SSRN: https://ssrn.com/abstract=3714874

Dafermos Y., Nikolaidi M., Galanis G. (2018), Climate change, financial stability and monetary policy, Ecological Economics, 152:219 – 234

Degryse H., Goncharenko R., Theunisz C., Vadasz T. (2023), When green meets green, Journal of Corporate Finance, Volume 78, February 2023

Delis M., De Greiff K., Ongena Iosifidi M. S. (2021), Being Stranded with Fossil Fuel Re-serves. Climate policy risk and the pricing of bank loans, (No. 18-10) *Swiss Finance Institute Research Paper Series*

Dietz S., Bowen A., Dixon C., Gradwell P. (2016), Climate value at riskf of global financial assets. Nature Climate Change, 6(7):676, 2016

Dell M., Jones B.F., Olken B.A. (2009), Temperature and income: Reconciling new cross-sectional and panel estimates. American Economic Review, 99(2):198–204

Do V., Nguyen T. H., Truong C., Vu T. (2021), Is drought risk priced in private debt contracts? *International Review of Finance,* Vol. 21(2), pp. 724–737

Ehlers T., Packer F., de Greiff K. (2022), The pricing of carbon risk in syndicated loans: Which risks are priced and why?, *Journal of Banking & Finance,* Vol. 136, 106180

European Central Bank (2022): 2022 climate risk stress test*,* July

Faiella I., Malvolti D. (2020), The climate risk for finance in Italy, Questioni dii Economia e Finanza Banca d'Italia N. 545, Febbraio

Faiella I., Mistretta A. (2015), Spesa energetica e competitività delle imprese italiane, Economia Pubblica, n. 3, pp. 85-122

Faiella I., Cingano F. (2015), La tassazione verde in Italia: l'analisi di una *carbon tax* sui trasporti, Economia Pubblica, n. 2, pp. 45-90

Faiella I., Lavecchia L. (2015), La povertà energetica in Italia, Politica Economica, n. 1, pp. 27-76

Furukawa K., Ichiu H.,Shiraki N. (2020), How Does Climate Change Interact with the Financial System? A Survey*, Bank of Japan staff working paper*

Goldsmith-Pinkham P., Gustafson Matthew T., Lewis Ryan C., Schwert M. (2022), Sea Level Rise Exposure and Municipal Bond Yields, NBER Working Paper No. 30660

Guin B., Korhonen P., Moktan S. (2022), Risk differentials between green and brown assets?, *Economic Letters Vol. 213*(6)

Hauptmann C. (2017), *Corporate sustainability performance and bank loan pricing: It pays to be good, but only when banks are too*, *Saïd Business School WP*, 20

Huynh T. D., Nguyen T. H., Truong C. (2020), Climate risk: the price of drought*, Journal of Corporate Finance*, Vol. 65

Höck A., Klein C., Landau A., Zwergel B. (2020), The effect of environmental sustainability on credit risk, *Journal of Asset Management*, Vol. 21(2), pp. 85–93

Hong H., Li F.W., Xu J. (2019), Climate risks and market efficiency, *Journal of Econometrics, Vol 208*, no 1, pp. 265–281

Javadi S., Masum A.A. (2021), The impact of climate change on the cost of bank loans, *Journal of Corporate Finance*, Volume 69, August 2021, 102019

Jung H., Santos J. A., Seltzer L. (2023), U.S. Banks' Exposures to Climate Transition Risks*, FRB of New York Staff Report*, (1058)

Kaza N., Quercia R.Q., Tian C.Y. (2014), Home energy efficiency and mortgage, *Community Development Innovation Review*, issue 01, pp. 63–69

Kim M., Surroca J., Tribó J. A. (2014), Impact of ethical behavior on syndicated loan rates, *Journal of Banking & Finance*, Vol. 38, pp. 122–144

Kim S., Kumar N., Lee J., Oh J. (2022), *'ESG' lending*, In Proceedings of Paris December 2021 Finance Meeting EUROFIDAI-ESSEC, European Corporate Governance Institute–Finance Working Paper (No. 817)

Kleimeier S., Viehs M. (2018), Carbon Disclosure, Emission Levels, and the Cost of Debt, Available at SSRN: http://dx.doi.org/10.2139/ssrn.2719665

Kousky C., Palim M., Pan Y. (2020), Flood damage and mortgage credit risk: a case study of hurricane Harvey, *Journal of Housing Research,* Vol. 29, sup1

Kraemer M., Negrilla L. (2014), Climate Change Is A Global Mega-Trend For Sovereign Risk*,* S&P Ratings Services

Krueger P., Sautner Z., Tang D. Y., Zhong R. (2023), The effects of mandatory ESG disclosure around the world, European Corporate Governance Institute–Finance Working Paper, (754), pp. 21–44

Lampertia F., Bosetti V., Roventini A., Tavoni M. (2019), The public costs of climate-induced financial instability

Lööf H., Stephan A. (2019), The Impact of ESG on Stocks' Downside Risk and Risk Adjusted Return, CESIS Working Paper No. 477

Meisenzahl R. (2023). How Climate Change Shapes Bank Lending: Evidence from Portfolio Reallocation, *Working Paper Series* WP 2023-12, Federal Reserve Bank of Chicago

Mueller I., Sfrappini E. (2022), Climate change-related regulatory risks and bank lending, *Economic Letters*, Vol. 220, November 2022

Pagliari M. S. (2023), LSIs' exposures to climate change related risks: an approach to assess physical risks, *International Journal of Central Banking*, March 2023

Pankratz N., Bauer R., Derwall J. (2019), Climate change, firm performance, and investor surprises, *Management Science* (2023)

Pindyck Robert S. (2020), What We Know and Don't Know about Climate Change, and Implications for Policy, NBER Working Paper, No. 27304

Regelink M., R.J. Henk and Vleeschhouwer (2017), Waterproof? An exploration of climate-related risks for the Dutch financial sector, De Nederlandsche Bank

Reghezza A., Altunbas Y., Marques-Ibanez D., Rodriguez d'Acri C., Spaggiari M. (2022). "Do banks fuel climate change?" Journal of Financial Stability, Volume 62, October 2022

Stern N. (2013), Potential Impacts of Climate Change: Grafting Gross Underestimation of Risk onto Already Narrow Science Models, Journal of Economic Literature, Vol. 51, No. 3

Viviani Jean-Laurent, Fall M., Revelli C.(2019), The Effects of Socially Responsible Dimensions on Risk Dynamics and Risk Predictability: A Value-at-Risk Perspective, Journal of International Management, Volume 23, Issue 3

7. Appendix

List of Abbreviations	
Variables	**Abbreviation**
Access to clean fuels and technologies for cooking (% of population)	ACFTC
Access to electricity (% of population)	AE
Agriculture, forestry, and fishing, value added (% of GDP)	AFF
Annualized average growth rate in per capita real survey mean consumption or income, total population (%)	AGRR
Adjusted savings: natural resources depletion (% of GNI)	ASNRD
Bank nonperforming loans to total gross loans (%)	BNPL
Banking Stability	BS
Cooling Degree Days	CDD
Climate Risk	CR
Energy Efficiency	EE
Energy intensity level of primary energy (MJ/$2017 PPP GDP)	EIL

Economic and Social Rights Performance Score	ESRP
Forest area (% of land area)	FA
Fossil fuel energy consumption (% of total)	FFEC
GDP growth (annual %)	GDPG
Government Effectiveness: Estimate	GE
GHG net emissions/removals by LUCF (Mt of CO2 equivalent)	GHG
Gini index	GI
Life expectancy at birth, total (years)	LEB
Labor force participation rate, total (% of total population ages 15-6G) (modeled ILO estimate)	LFPR
Land Surface Temperature	LST
Methane emissions (metric tons of CO2 equivalent per capita)	ME
Mortality rate, under-5 (per 1,000 live births)	MR
Adjusted savings: net forest depletion (% of GNI)	NFD
Net migration	NM
Adjusted savings: natural resources depletion (% of GNI)	NRD
Population ages 65 and above (% of total population)	PA65
PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)	PM2.5
Prevalence of overweight (% of adults)	PO
Political Stability and Absence of Violence/Terrorism: Estimate	PS
Proportion of seats held by women in national parliaments (%)	PSHW
People using safely managed drinking water services (% of population)	PUSM
People using safely managed sanitation services (% of population)	PUSMS
Research and development expenditure (% of GDP)	RDE
Regulatory Quality: Estimate	RQ
School enrollment, primary (% gross)	SEP
School enrollment, primary and secondary (gross), gender parity index (GPI)	SEPS
Adjusted savings: net forest depletion (% of GNI)	SNFD
Terrestrial and marine protected areas (% of total territorial area)	TMPA
Unemployment, total (% of total labor force) (modeled ILO estimate)	UT