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Final Thesis

Finance in support of environmental sustainability: Green bonds market analysis.

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Introduction

History and recent events have clarified our ideas and served as a warning to finally understand that our Planet can no longer withstand the rhythms to which we have become accustomed.

The pandemic linked to Covid - 19, in its misfortune, has succeeded in raising investor awareness of issues such as climate change and pollution. To combat this, innovative and responsible investments that ensure improved environmental performance are needed.

The consequences are already disastrous but could potentially reach levels of no return.

In this context, it is intuitable how the role of finance is of crucial importance.

I initially define what is meant by environmental sustainability and what have been, over the years, the most important decisions in this regard at the international level.

Then, I analyse the concept of green finance in greater depth.

I focus on the definition that has been attributed to it and on the various meanings that this term takes in relation to the context.

Next, I examine a new type of instruments that are useful and necessary to this cause: Green Bonds, a relatively new type of debt that is increasingly attracting the interest of private and institutional investors.

Being new instruments, it is necessary to clarify how they are structured and how they are used. Therefore, I describe various methodologies and processes that allow them to be catalogued and certified. This step is fundamental because investors must be sure and have the guarantee that the capital raised with these bonds will be used and spent for environmental efficiency.

We are witnessing a trend; every company is now publicly committed to the fight against climate change. However, this does not always correspond to the truth; in fact, there are numerous cases of companies sponsoring or advertising products with sustainable characteristics that they do not actually possess: “Greenwashing” is harmful from every point of view. Indeed, investors lose confidence and there is no clarity and transparency on the methodologies used to certify a bond as green and they are not sure about the way they are spending their capital. On the other hand, companies raise additional capital that will still be used for projects that are unsustainable in nature.

In the final part of the thesis, I perform an empirical analysis on the financial performance of Green Bonds in relation to conventional bonds.

To do this, I first construct a Yield Curve of these instruments for different rating classes by applying the Nelson & Siegel model, which allows to build the term structure of interest rates from market prices and/or yields.

I analyse the estimated curves for AAA – rated and A – rated Green bonds and then I compare the results with those obtained for indices that group non-green bonds. In particular, I focus on the period relative to Covid -19; this is because I am interested in understanding if this type of instrument is able to react better in periods of stress like the one we are experiencing in these days.

The empirical analysis shows that Green bonds are highly correlated with conventional bonds, but they have reacted better to the Covid-19 related period.

I am convinced that Green bonds, besides being a convenient choice, are a necessary choice. The environmental transition is inevitable and, in my opinion, those who will realize this fact sooner will surely be able to survive and reorganize their business models and processes in a more efficient way.

Chapter I. Environmental sustainability

We often hear about or refer to environmental sustainability ourselves.

Sustainability, in all its aspects, is defined as a pattern fuelled by a balance between resource consumption and resource regeneration.

Trying to understand it even better, sustainability is "the condition whereby the present generation meets its needs without compromising the ability of future generations to meet their own." (Brundtland Commission Report, 1987).

This concept is divided into three basic parts: environmental protection, social development, and economic development.

Thus, environmental sustainability aims to ensure that future generations can use the natural resources available on our planet in the same way as our own.

Social development is concerned with guaranteeing equal rights to the workforce, raising awareness of responsible and ethical behaviours towards workers and the community in which a company operates.

Economic development, on the other hand, ensures the continuity of a business through its profitability.

1.1 Triple Bottom line

The real challenge is to achieve economic development with the first two as reference points.

This means that a business, in addition to being profitable, must respect parameters of environmental and social sustainability.

This approach is called Triple Bottom Line (TBL) and is based on the 3 P's: Profit, People and Planet.

Developed in 1994 by British entrepreneur John Elkington, TBL refers to the way companies add value, not only economically, but environmentally and socially.

Figure 1 - Triple Bottom Line

Source 2 - www.medium.com

Elkington encourages companies to include social and environmental performance in their reports and financial statements so that they can explain their performance not only based on economic variables.
It goes without saying that the human being is the main actor necessary for the success of this model.

1.1.1 Model estimation

The three variables already mentioned are easy to define; it is less immediate to understand how to measure them.
If for the economic part one can easily refer to the dollar rather than the euro, for the other two it is more complicated.
For example, how can we put a price on the extinction of a species?
This problem can be solved, in part, by adopting indices; for each of the three variables we can define in turn the parameters to be included in the calculation.
This method, although subjective, is perhaps the real strength of this model.
The TBL can be used by any type of company or entity: profit or non-profit, governments and private.

Depending on the type of company and depending on the type of project, the variables that best define the three fundamental parameters are included.
The University of Scranton tried to identify and group the variables needed to estimate each measure (Table 1):

Table 1 - TBL Parameters

Social Measures	Median household income, Unemployment rate, Female labour participation percentage, Educational levels/percentages, Crime per capita, Average life expectancy, Average commute time
Environmental Measures	Concentration of nitrogen, Greenhouse gas emissions, Amount of waste generated, Use of post-consumer, recycled material, Fossil fuel consumption, Electricity consumption, Water consumption, Hazardous waste management, Solid waste management, Changes in land use
Economic Measures	Average incomes, Underemployment costs, Job growth percentages, Establishment churn, Percentage of firms in each sector, Employment distribution by sector, Revenue by sector

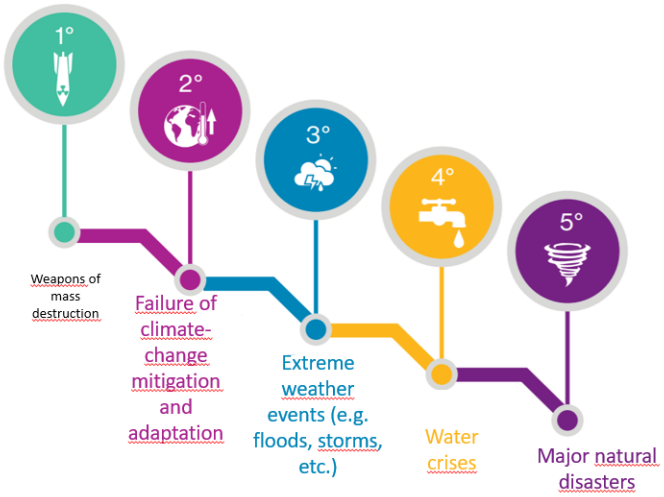
Source 3 - University of Scranton, personal elaboration.

1.2. Climate change

In this section I summarize the major actions and decisions that have been taken over the years to combat climate change and all the damage that comes with it.
The UNFCCC defines climate change as "a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods" (UNFCCC, 1992).
Starting with the definition provided by the UNFCCC, it is necessary to delve into the real risks and consequences that this threat brings.
Very often, these issues are perceived as distant, abstract or, simply, there is a false belief that sooner or later a solution will be found and none of us will be impacted.
Unfortunately, the deadline for our planet is very close and these risks have implicit consequences on the whole economic and financial system.

1.2.1. Damage and consequences

Figure 2 - Top risks by impact



Source 4 - Word Economic Forum (2019)

The Word Economic Forum has included the risks related to climate change within four of the main risks to the planet; they are universally recognized as one of the greatest threats to our planet and to all humanity. The European Environment Agency (EEA) has estimated that the damage caused by climate change by the end of the century in Europe will correspond to a loss of about 190 billion euros equivalent to 1.8% of GDP[1].

1.2 Italian situation

In Italy, it is estimated an increase in temperature of about 2 degrees in the next 30 years going to negatively affect the GDP for a value equal to 8%[2].

It is still stated in the report of the foundation Euro-Mediterranean Center on Climate Change (Cmcc) that, considering the most extreme event of an increase in temperature of 5 degrees by 2100, the costs for risks related to climate change will be about 15.3 billion euros per year.

Italy will become a tropical country; we should get used to drought and heat.

[1] European Environment Agency

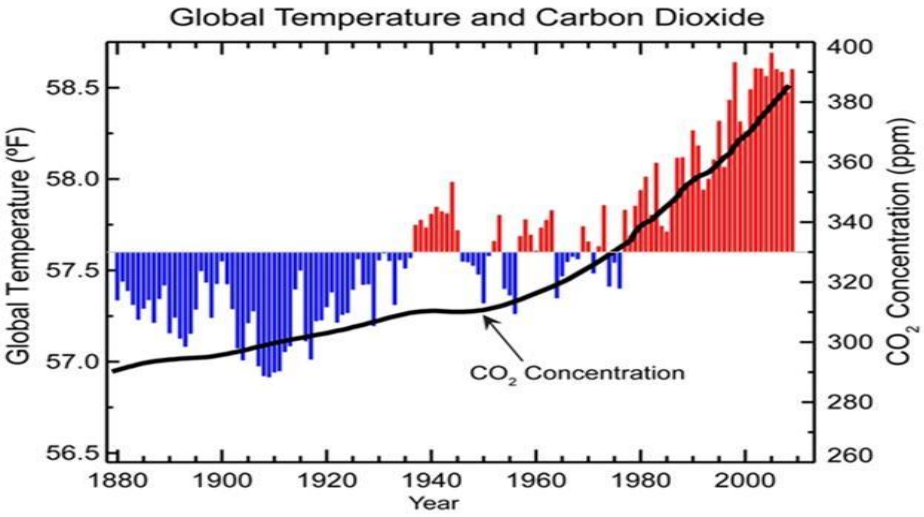
[2] Cmcc Foundation, Euro-Mediterranean Center on Climate Change, and contained in the new report 'Risk Analysis. Climate change in Italy',2020.

Rainfall will be more intense and more aggressive; the risk of fires will increase by 20%. All this will have repercussions on every sector of the economy, on every Italian area and all systems will be put under pressure.
The health system will be affected: more deaths from diseases related to the combination of heat and smog are expected.
In 2018 extreme events resulted in 51 deaths and $4.18 billion in losses (Global Climate Risk, 2020).
Between 1999 and 2018, Italy had 19,947 deaths and $32.92 billion in losses related to extreme events.

1.3 Greenhouse gas

The impact of greenhouse gas emissions on this issue is universally recognized.
Greenhouse gases present in the atmosphere are recognized as the main responsible for the increase of the earth's temperatures.
These gases are present in nature; the greenhouse gases in the earth's atmosphere filter out the sun's rays that are most harmful to human health and obstruct the exit of infrared radiation. The greenhouse effect is what allows life on our Planet, keeping the temperature stable at 15°; without it, the temperature would drop to about -15°.
The problem arises when overheating is exaggerated and ecosystems on Earth are endangered.
For this reason, the two greenhouse effects are defined as natural (natural phenomenon that warms the planet and makes life possible) and anthropogenic (too high values of greenhouse gases in the atmosphere due to the release of CO2 and methane).

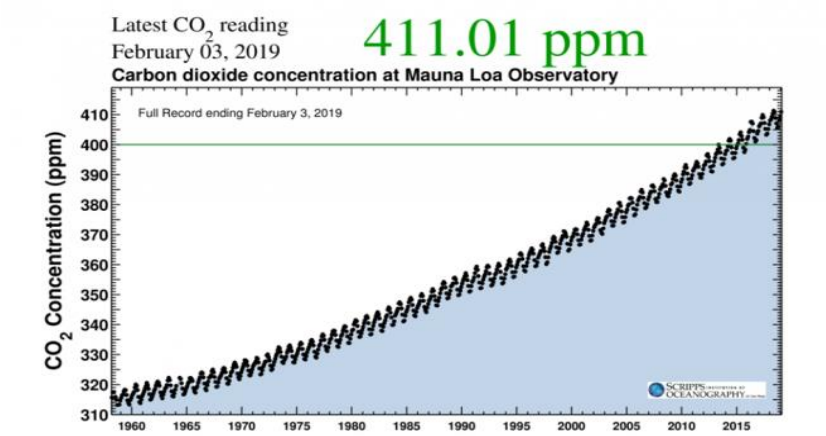
Figure 3 - Global temperature measurement and CO2 concentration.



Source 1 - Rete clima, Cambiamenti climatici: riscaldamento climatico per aumento antropogenico dell'effetto serra natural.

In 2019, the highest CO2 value was recorded, corresponding to 412 ppm (parts per million).

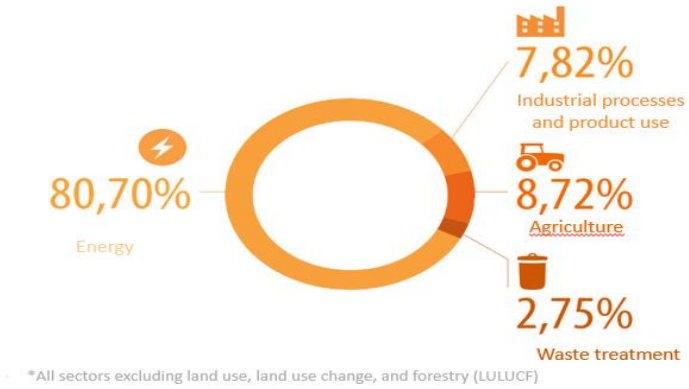
Figure 4 - Exponential growth curve related to the presence of CO2 in the atmosphere (1960 - 2018).



Source 2 - Rete clima - Cambiamenti climatici: storia, cause e conseguenze (2020).

CO2 is present in carbon dioxide (responsible for 63% of man-made global warming), methane (responsible for 19% of man-made global warming), nitrogen oxide, ozone and other chemical gases.

Figure 5 - EU greenhouse gas emissions by sector in 2017.



Source 3 - UNFCCC Data Interface.

The main causes of the increase in greenhouse gas emissions are found in this type of activities (Table 2):

Table 2 - Human activities that cause the increase in greenhouse gas emissions.

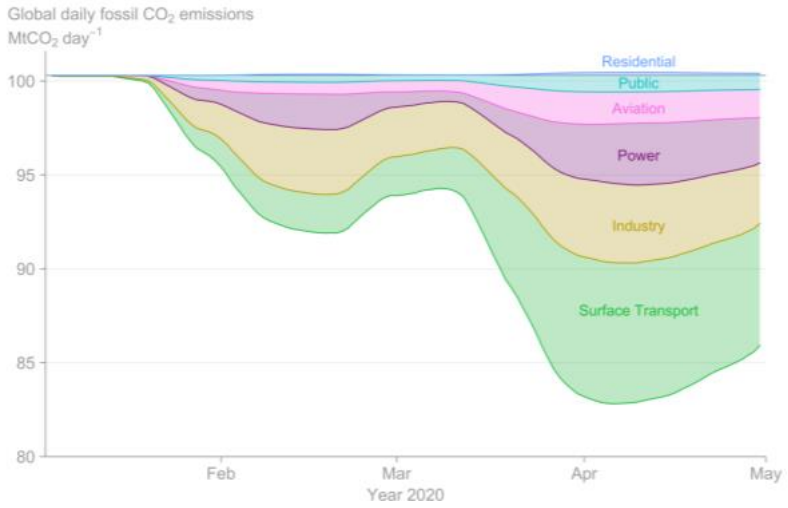
Activity	**Definition**
Use of fossil fuels	Burning coal, oil, and gas produces carbon dioxide and nitrogen oxide
Deforestation	Trees help regulate the climate by absorbing CO2 from the atmosphere. If they are cut down, this action is lost and the CO2 contained in the wood is released into the atmosphere, thus feeding the greenhouse effect.
Cattle breeding	Cattle and sheep produce large amounts of methane during the digestion process. The development of intensive livestock farming causes a large increase in greenhouse gases emitted into the atmosphere.
Nitrogenous fertilizers	Nitrogen fertilizers produce nitrogen oxide emissions.
Fluorinated gases	Fluorinated gases cause a powerful greenhouse effect. EU legislation provides for their phasing out. They are used in stationary refrigeration, air conditioning and heat pump equipment, high-voltage switchgear, equipment containing solvents, stationary fire protection equipment and fire extinguishers.

Source 4 - Il giornale dell'ambiente - Cambiamento climatico: cause, definizione e conseguenze, personal elaboration.

1.5 International agreements

This section aims to illustrate what have been the main decisions and treaties at global level that have been established to combat climate change.
An important reflection must also be made on the current period.
Among the countless tragedies that Covid 19 has brought with it, one or perhaps the only positive note is that it has drastically reduced CO2 emissions.

Figure 6 - Co2 emissions (01/2020 - 05/2020).



Source 5 - Le Quéré et al (2020)

1.5.1. UNFCCC

The United Nations Framework Convention on Climate Change is an international treaty first ratified in 1992 at the Earth Summit in Rio de Janeiro; it represents the first example of an international agreement to discuss, address and remedy issues related to climate change.
The treaty officially entered into force on March 21, 1994 after having received 50 ratifications; today, 197 Parties are part of it.
The ultimate objective of the Convention is to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system." It states that "such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food

production is not threatened, and to enable economic development to proceed in a sustainable manner" (UNFCCC, 1992).

The first decisions of the UNFCCC concerned emission reductions but, due to strong opposition from the United States, there was no real binding agreement but only a non-binding proposal to reduce emissions by 2020.

The first significant decisions were taken in 1995 when, with the Berlin Mandate, the first COP (Conference of the Parties) established that industrialized economies (Annex I Countries) should adopt strategies to reduce GHGs while developing countries, non-Annex I, should follow these decisions later.

Once again, the United States in 1997 made explicit in a Senate resolution a series of conditions that had to be met in order to continue or re-sign a new agreement.

This resolution clearly stated that there should be maximum flexibility in how emissions are reduced and that developing countries should also participate from the beginning.

The Kyoto Protocol did not include this last condition and the United States, in 2001, under the leadership of President Bush decided to exit the protocol.

The Kyoto Protocol was ratified by 37 countries (which became 36 after Canada withdrew in 2001); the problem was that these 36 countries were responsible for less than 20% of the emissions.

The only solution that would have led to a likely reintegration of the United States was to create a second negotiation to correspond with the Kyoto one.

In doing so, the Berlin Mandate was never fully operational because the Annex I countries never made their first move in reducing emissions until they were sure that all other states were included in the program.

The initial actions to reduce emissions were based on a voluntary offer by states, combined with international pressure directed primarily at key countries; this kind of approach was called QELRO (Quantified Emission Limitation or Reduction Objectives).

1.5.2. Kyoto protocol

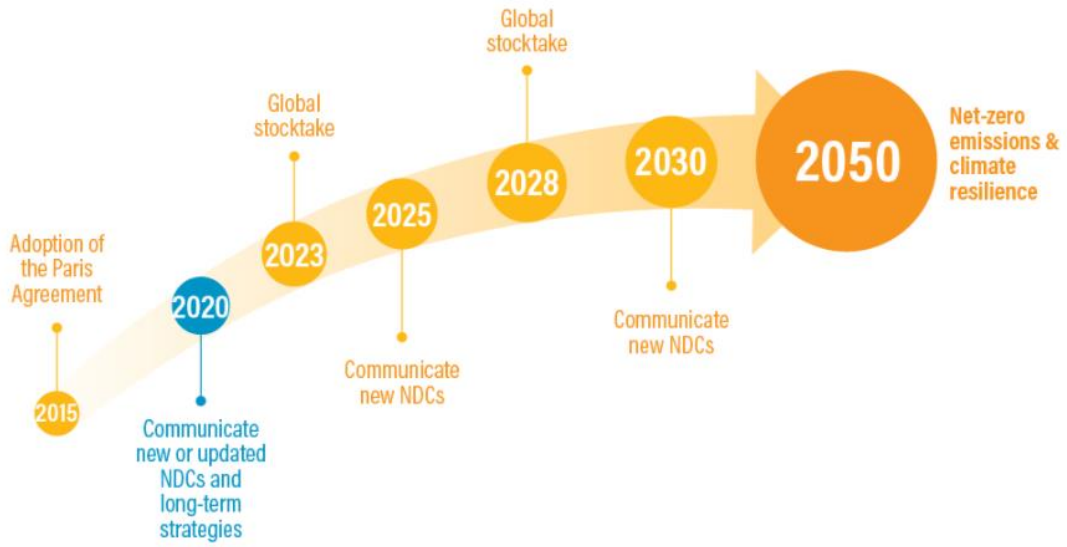
Signed on December 11, 1997 during the Conference of the Parties at Kyoto (COP3), it entered into force only on February 16, 2005 after Russia decided to ratify it (55 countries representing at least 55% of greenhouse gas emissions were required for its entry into force).

The Kyoto Protocol had set its goal to reduce greenhouse gas emissions by an average of 5% of 1990 levels between 2008 and 2012.
This type of objective concerned the most developed countries; with the Paris Agreement the ambition was raised, and these goals were set from a global point of view.

1.5.3. Paris Agreement

During COP 21 in Paris on December 12, 2015, 196 parties signed a binding international treaty on climate change.
It entered into force on November 4, 2106, and to date has been ratified by 190 countries and signed by 195.
The turning point of the Paris Agreement compared to the Kyoto protocol is that, in this case, the participation of all countries is required, making no distinction between developed and undeveloped, rich and not.
Obviously, this mechanism implies greater flexibility; each country can set its own emission targets in relation to its levels of economic and technological growth.
There are no penalties or fines for those who do not meet the targets, but members are continuously monitored and controlled to define a common path for the whole world.
The objective of the treaty is to limit the global temperature increase in this century to 2 degrees Celsius above pre-industrial levels, while pursuing the means to limit the increase to 1.5 degrees.
Targets are set on a five-year basis; the plans that each state sets to implement and the standards it claims to meet are specified in nationally determined contributions (NDCs).
The NDCs can easily be considered the beating heart of the Paris Agreement; they represent the actions and the interventions that each country must communicate where it must be specified what actions it will take after 2020 to combat climate change.

Figure 7 - Paris Agreement path



Source 6 - www.wri.org/ndcs

In June 2017, American President Trump had announced that the United States would withdraw from the agreement; officially, on November 4, 2020, America became the first nation to withdraw from the Paris Climate Agreement. On January 20, 2021, the United States under the leadership of President Joe Biden, re-signed the agreement.
The United States produces about 15% of global greenhouse emissions; therefore, its support and commitment are critical.

1.5.4. 2030 Agenda for Sustainable Development

In 2015, during the United Nations General Assembly, the 193 countries that are part of the UN, defined 17 goals called The Sustainable Development Goals (SGDs); these represent targets to ensure a more sustainable future.
These goals define guidelines and outline the path to follow for the next 15 years, which implies that the states that have joined are committed to meeting them by 2030.
The 17 SDGs are: No Poverty, Zero Hunger, Good Health and Well-being, Quality Education, Gender Equality, Clean Water and Sanitation, Affordable and Clean Energy, Decent Work and Economic Growth, Industry, Innovation and Infrastructure, Reducing Inequality, Sustainable Cities and Communities, Responsible Consumption and

Production, Climate Action, Life Below Water, Life On Land, Peace, Justice, and Strong Institutions, Partnerships for the Goals (2030 Agenda for Sustainable Development, 2015).

During each month a goal is set to be taken as a reference, called "Goal of the Month"; December 2020 has been the Climate Action month.

On December 12, 2015, the Paris Agreement was signed and today, more and more people are recognizing the importance of needing to take decisive action quickly.

1.5.5. Guide on climate-related and environmental risks

On 27 November 2020, the ECB published the final text of its Guidance on Climate and Environmental Risks for Banks.

The document outlines and explains how the ECB expects banks to manage these risks in a prudent manner; in addition, they must also provide transparent disclosures regarding existing prudential rules.

Specifically, the ECB will ask banks to conduct a self-assessment against the supervisory expectations set out in the guide and to draw up an action plan.

This self-assessment will then be benchmarked; in 2022, there will be a further review where the ECB will act, where necessary, with targeted interventions.

The decisive impact of climate change on the financial system is demonstrated by the fact that the ECB will also take climate risks into account in the stress tests in 2022.

There is still a long way to go; the difference between what a company says and promises to do and what it actually does is, in some case, substantial and, as it is stated on the ECB report on institutions, climate-related and environmental risk it is not always easy to define:

"Although institutions increasingly refer to climate-related risks in their disclosures, around half of the institutions do not demonstrate that they have explicitly considered the potential strategic impact of these risks. Of the institutions that have demonstrated consideration thereof, 84% state that the risks have a strategic impact.

It is worth noting that institutions that do not disclose such considerations have generally not described their risk management processes (68%), have not disclosed any climate metric (70%) and have not in any way described the potential impact of transition risks (81%) or physical risks (83%). Although the materiality of the impact cannot be readily evaluated on the basis of this information, it can be concluded that

institutions within these categories do not offer stakeholders the opportunity to verify the perceived immateriality of the risks." (ECB report on institutions' climate-related and environmental risk disclosures, 2020).

1.6. ND - GAIN Index

Developed by the University of Notre Dame, The Notre Dame-Global Adaptation Index aims to measure the vulnerability of states to climate change.
The development of this index stemmed from the need to delve deeper into the impacts of climate change in relation to factors such as economic development or geographic location.
In addition to this, it also estimates readiness to raise funds and invest to combat these risks.

1.6.1 Index composition

74 variables are used to form 45 indicators to estimate the vulnerability of 182 states and the readiness of 184.
The index precisely explains the vulnerability and readiness of these states.
Vulnerability is understood as the propensity or predisposition of human societies to be negatively impacted by climate hazards (University of Notre Dame Global Adaptation Index, Country Index Technical Report, 2015).
The index measures this parameter by considering six areas important to our lives: health, food, water, human habitat, ecosystem service and infrastructure.
Each area, in turn, is represented by six indicators that define three components: exposure, sensitivity and adaptive capacity.
Exposure is the extent to which society and its leading sectors are affected by future changes in climate conditions. Sensitivity measures the degree of dependence between people and their leading sectors. This factor is influenced by the degree of dependence of sectors that are sensitive to climate change and the proportion of the population that is sensitive to environmental hazards.
The last component, the adaptive capacity, measures the ability of society to counter and reduce potential damage and respond to negative consequences linked to climate events.

The second important parameter analysed is Readiness.

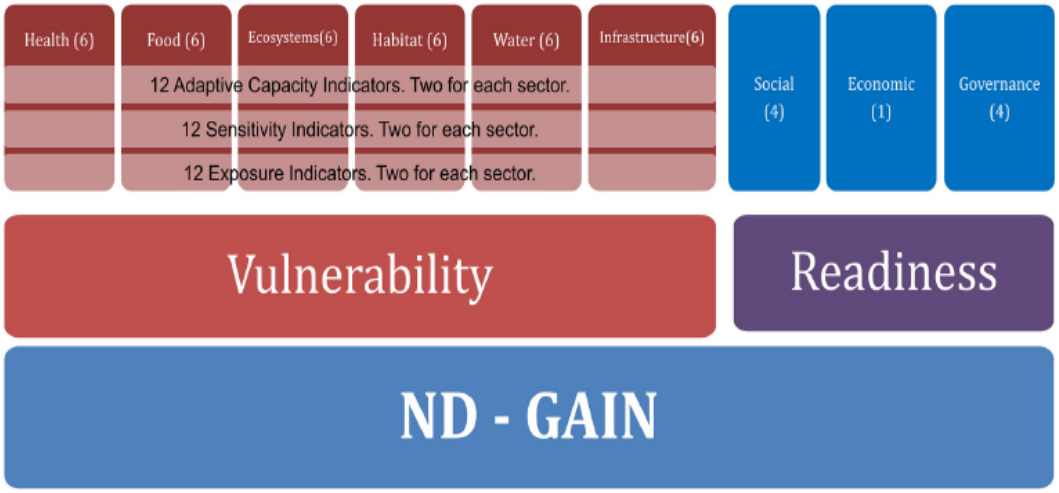
This measures the readiness to invest in actions to adapt to climate change and, implicitly, is also a measure of the efficiency of the business environment.

Again, 3 components are used for estimation.

Economic Readiness, which measures the ability to mobilize capital from the private sector, Governance Readiness measuring the stability of the company that, with a large governmental capacity, can reassure its investors that their investments can grow without alarming disruptions.

Finally, social readiness which helps the company make useful and fair investments.

Figure 8 - ND - GAIN index variables



Source 7 - Notre Dame Global Adaptation Initiative.

It was necessary to identify some main characteristics to build these indices in order to guarantee their consistency, reliability and transparency.

The first, fundamental characteristic, is the availability of data; these must be available for many countries of the United Nations. In addition to this, to study and identify the evolution of trends in the parameters analysed (vulnerability and readiness) it is necessary to have a trace of the past, therefore historical series of data for at least 20 years are necessary (indicators with data from 1995 are preferred).

This index is intended to be helpful to change, so its nature must be public and easily accessible.

Data must be collected by certified organizations that have the authority to vouch for the quality of their data which, must then be presented and illustrated in a clear and transparent manner to allow for easy reading and analysis.

1.6.2. Score calculation

Initially, data is selected, collected and adjusted where necessary.
In the event of missing data for some time period, a linear interpolation is used, while if the missing data concerns an entire year for a particular state, the data is catalogued as "missing".
Subsequently, reference points are set for the calculation of the score that represent the states of perfection.
These points represent zero vulnerability or maximum readiness.
Then, the score is calculated with the following formula (1.1):

$$\text{score} = |\text{direction} - \frac{raw\ data - reference\ point}{baseline\ maximum - baseline\ minimum}| \quad (1.1)$$

The parameter "direction" assumes value 0 in the calculation of vulnerability and value 1 for readiness; this is to indicate that a high score for vulnerability is an index of high vulnerability and a high index of readiness represents maximum readiness.
For each sector, through an arithmetic average of the six indicators equally weighted, the score is calculated and, again using an arithmetic average, the overall score is calculated for both vulnerability and readiness.
Finally, subtracting the vulnerability score from the readiness score, and scaling from 1 to 100, the ND-GAIN Score is calculated with the formula below (1.2):

$$ND - GAIN\ score = (Readiness\ score - Vulnerability\ score + 1) * 50 \quad (1.2)$$

1.6.3. ND-GAIN MATRIX

Figure 9 - ND - GAIN Matrix

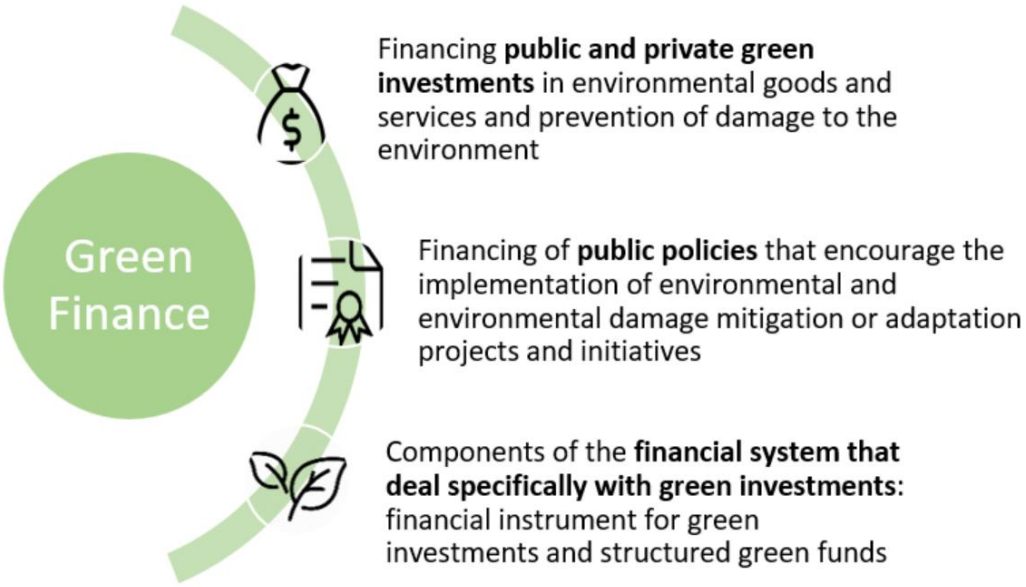
Source 8 - Notre Dame Global Adaptation Initiative.

ND-GAIN Matrix allows to analyse graphically and immediately the results of the score. From a worst-case situation, with extreme urgency to act for more difficult challenges, represented by the red quadrant, one arrives at a situation with less urgency and a less vulnerable situation, represented by the green quadrant.

Chapter II. Green Finance

"Green finance is a broad term that can refer to financial investments flowing into sustainable development projects and initiatives, environmental products, and policies that encourage the development of a more sustainable economy. Green finance includes climate finance but is not limited to it. It also refers to a wider range of other environmental objectives, for example industrial pollution control, water sanitation, or biodiversity protection. Mitigation and adaptation finance is specifically related to climate change related activities: mitigation financial flows refer to investments in projects and programs that contribute to reducing or avoiding greenhouse gas emissions (GHGs) whereas adaptation financial flows refer to investments that contribute to reducing the vulnerability of goods and persons to the effects of climate change" (Höhne / Khosla / Fekete / Gilbert, 2012).

Figure 10 - Definition of Green Finance



Source 9 - Lindenberg, Nannette (April ,2014),” Definition of Green Finance”.

Green Finance therefore refers to all financial activities that have been created to ensure positive environmental growth.

The ultimate goal of Green Finance is to prioritize green investments over traditional businesses that bring with them unsustainable growth paths and strategies.

This inevitably leads to undertake and use more transparent methodologies and processes; moreover, from the point of view of the investment itself, there is a preference for long-term strategies.

Figure 11 - Green investment categories

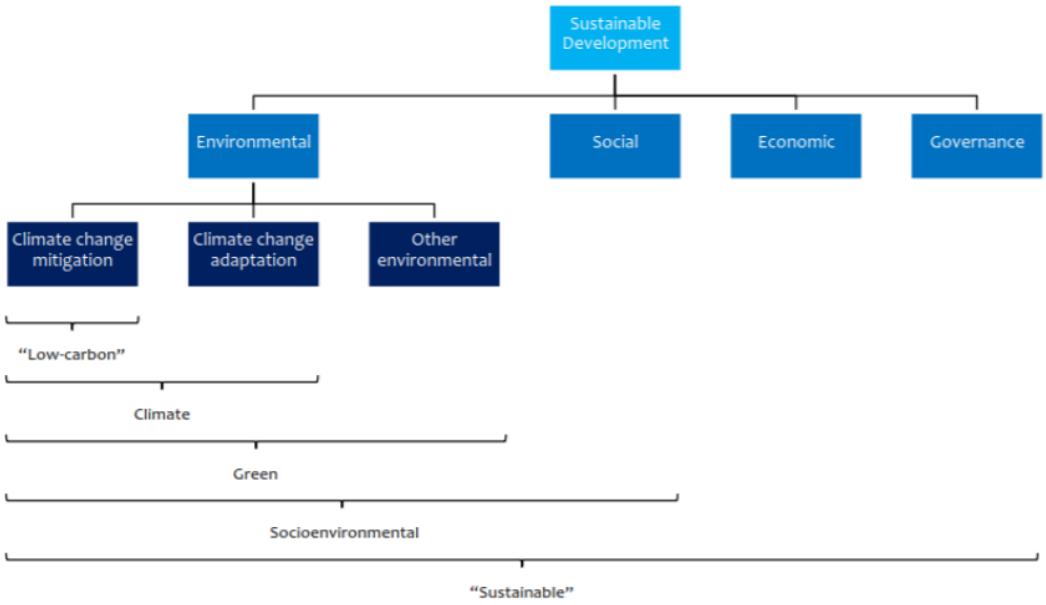
Source 10 - Lindenberg, Nannette (April ,2014),” Definition of Green Finance”

“In other words, Green Finance provides the financial tools required by active agents to increasingly generate activities with positive and durable externalities” (International Trade Center).

There is a risk and a tendency to get confused when trying to define in a practical way what Green Finance is. This is because cataloguing such a broad concept, so relatively new and, above all, constantly evolving, leads to setting restrictions that do not always exist.

Let's start by saying that all types of economics and development models that are in some way related to an objective of sustainability (environmental, economic and social) fall within the great world of sustainable finance.

Figure 12 - Sustainable finance scheme



Source 11 - UNEP Inquiry (2016)

"Sustainable finance generally refers to the process of taking due account of environmental, social and governance (ESG) considerations when making investment decisions in the financial sector, leading to increased longer-term investments into sustainable economic activities and projects" (European Commission).

Within this broader definition there is the subgroup of Green Finance.

One way to define and categorize it is analysing how it is financed. Thus, two distinct categories can be created: Targeted and Untargeted Green Finance.

When talking about Green Targeted financing, refers to situations in which the Use of proceeds are used to finance the development of green technologies, activities and projects. In this section, the most used instruments are green bonds and green loans.

The use of proceeds is collected in a sub-account and are tracked to ensure and provide full transparency on their use.

Untargeted green financing foresees the use of capital by companies that are more concerned about managing ESG issues; this type of finance is mainly used by listed companies or private equity funds where capital is used for more general purposes and where there are no particular restrictions on its use. While this financing strategy helps reduce environmental risks within investors' portfolios, it is very complicated to measure the environmental impact of investments.

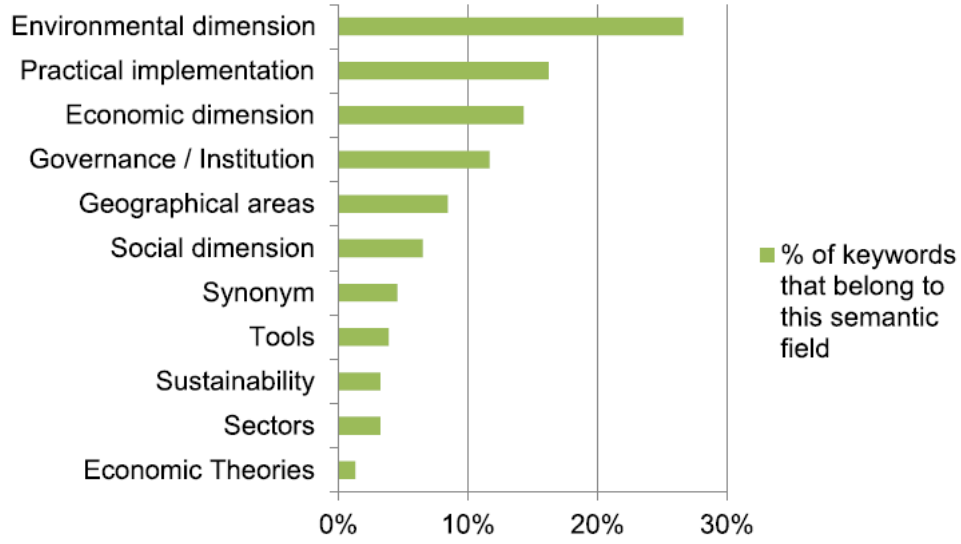
2.1. Green Economics

“Green economics is a methodology of economics that supports the harmonious interaction between humans and nature and attempts to meet the needs of both simultaneously. Green economic theories encompass a wide range of ideas all dealing with the interconnected relationship between people and the environment. Green economists assert that the basis for all economic decisions should be in some way tied to the ecosystem, and that natural capital and ecological services have economic value” (Investopedia).

Starting from this definition it is clear the principles on which this model is based; taking also the definition provided by Treccani:”The Green economy is an economic form in which public and private investments aim to reduce carbon emissions and pollution, increase energy and resource efficiency, avoid biodiversity loss and preserve the ecosystem.
Such investments must be supported by public spending, policy reforms, and regulatory changes aimed at maintaining, improving, and, if necessary, rebuilding natural capital as a critical economic asset” (Treccani), can be sensed in a timely manner that the effort towards economic and social transition must be made, in equal measure, by public, private and governmental institutions.

In (Journal of Cleaner Production 139, 2016) the authors conducted a bibliometric analysis to identify keywords in relation to the term green economy.

Figure 13 - Semantic fields of the keywords related to "green economy"



Source 12 - Journal of Cleaner Production 139 (2016)

The search was carried out using the Scopus database; 877 documents were found in which the term Green economy is mentioned.
This term is accompanied by 157 different keywords that belong to different fields; half of these fall within the environmental dimension and economic dimension.
The first includes issues of climate change, renewable resources, energy and natural capital while, in the second macro-topic, there are issues of development, growth, cost and competitiveness.

As suggested by (Chartered Banker Institute, 2019); "The Green Qualifications Workbook") the terminology concerning green investments collects a multitude of terms; a clarification is necessary to focus on the context in which these words are used and the different meanings they take.
Four problematic macro-areas can be distinguished in which the term green economy is used. The most obvious and tangible one is the Environmental Issues.
In this case reference is made to all aspects of a natural character: loss of biodiversity, emission of greenhouse gases, renewable energies, pollution, waste management and energy efficiency.

Referring to social issues, it involves human rights, health, safety, activities in conflict zones and access to medical facilities.
Shifting attention to a more economic point of view, the impact of investments at local, national and international level are considered.
Finally, it is necessary to consider the area relating to governance policies. This section includes issues relating to board structure, diversity, shareholders' rights and business ethics.

2.2 Actions undertaken by the ECB

From 2021, the ECB accept Green Bonds as eligible instruments to be considered as collateral in credit and monetary policy operations. This radical change is in line with the goals of the 2030 Agenda, one of the pillars of the current European mandate and, with the European Green Deal.
"With our review of the strategy, we will determine where and how the issue of climate change and the fight against climate change can actually have an impact on our policies" (Christine Lagarde, President of the ECB).
The ECB acts primarily in 4 areas: economic analysis, banking supervision, monetary policy and investment portfolios, and financial stability.

2.2.1. Economic analysis

The ECB, recently, has taken countless steps to raise awareness and fuel the European community's sense of responsibility towards actions to be taken to promote sustainable and green finance.
On March 8, 2018, the European Commission unveiled its plan, welcomed by the ECB, to achieve a financial structure capable of supporting sustainable development, the Action Plan.
The objectives agreed in the Paris Agreement, to be achieved by 2030, also require a 40% reduction in greenhouse gas emissions; for this purpose, it is estimated that the additional investments to be made are in the order of 180 billion per year.
The Action Plan, in addition to being a crucial point to implement the Paris Agreement, is part of the Capital Markets Union's (CMU) goal of linking finance with certain

economic needs for the well-being of our planet and our society. Valdis Dombrovskis (Vice - President of the European Commission (2014 – 2019)), responsible for Financial Stability, Financial Services and Capital Markets Union said: "Inspired by the work of the High-Level Expert Group, we are today presenting our plans for a far-reaching reform that could set the global benchmark for sustainable finance. Only with the help of the financial sector can we fill the annual €180 billion funding gap to reach our climate and energy targets. This will help to support a sustainable future for generations to come".

2.2.1.1. Action Plan

In December 2016, the European Commission established The High-Level Expert Group on Sustainable Finance (HLEG), an expert group with the objective of developing guidelines for the development of sustainable finance in Europe.
The main objective is to orient European capital markets towards projects that foster sustainable growth.
On January 31, 2018, the Final report was published where, starting from this last document, the European Commission elaborated the main points addressed and described in the Action Plan. The guidelines and main points of the Action Plan can be summarized in the following macro-areas.
It is necessary to direct capital towards sustainable investments and projects, to have clear and outlined what are the financial risks arising from climate change, environmental degradation, social inequalities and consumption of resources in order to be able to manage them better and improving transparency of economic and financial activities.
Specifically, 10 actions are listed within the document to steer the economy towards a sustainable path.

1. Introduce a "taxonomy" for sustainable finance; in practice, create a kind of shared dictionary to classify products and services considered sustainable.
2. Strengthen market credibility and investor confidence by creating quality certifications for Green Bonds;
3. Increase investment in sustainable infrastructure;
4. With respect to advisory services, require asset managers to consider clients' sustainability preferences;

5. Regarding sustainability indices, adopt more transparent methodologies for their construction and try to harmonize low-carbon indices;
6. For rating companies: encourage the integration of ESG criteria;
7. Conceive a legislative proposal to include sustainability criteria in the definition of fiduciary duty; this with the intention of binding investors to act to improve the interest of beneficiaries;
8. Green Supporting Factor: the idea is to apply a discount on green assets; translated into financial terms it means to weigh less, in terms of risk, an investment.
9. Still about transparency, improve the quality of non-financial reporting by aligning the current guides on climate risks with the recommendations of the Task Force on Climate-related Financial Disclosures of the Financial Stability Board;
10. Encourage the integration of ESG criteria and the adoption of a long-term approach in the decision-making processes of Boards of Directors.

In 2019, the ECB implemented measures and tools to adapt to new requirements and reduce its environmental impact. In accordance with European Eco-Management and Audit Scheme (EMAS), during the year, several goals were set to mitigate the impact of daily operations.
In collaboration with the European Parliament, it was decided to reduce CO2 emissions; in addition, the ECB took part in the EU Mobility Week and in Week for Waste Reduction.
The most obvious results are a reduction, compared to 2008, in carbon emission and energy consumption per workplace by 74% and 54%[3].

2.2.2. Banking Supervision

Climate change spares no activity; the banking sector is also exposed to major risks.
These types of risks can be physical: banks can be affected in a direct or indirect way but, in both cases, with a material impact.
This means that severe and increasingly frequent weather events can affect the business in which the bank is involved, as well as, of course, the bank itself.

[3] ECB (2019), "Annual Report 2019"

Then there are the transition risks associated with the urgent need to adapt to a low-carbon economy; this affects strategically important economic sectors such as the fossil fuel industry or all energy-intensive sectors.
For banks, this means they need to act, as soon as possible, to adjust their exposures.

2.2.3. Monetary Policy

2.2.3.1. Asset Purchase Program (APP)

The APP is a support tool used by the ECB to try to achieve one of its primary objectives: the level of inflation below, or at least close to, 2% in the medium term.
Following the financial crisis of 2008, which began with the collapse of American subprime mortgages and then with the European sovereign debt crisis, Europe's largest central banks found themselves having to undertake unconventional monetary policy actions.
It was during this period that "Quantitative Easing" was born, a term coined by Fed Chairman Ben Bernanke, taking up a type of monetary policy adopted in Japan between 2001 and 2006.
In early 2015, ECB President Mario Draghi effectively kicked off the APP.
The program is divided into four subprograms of securities purchases:

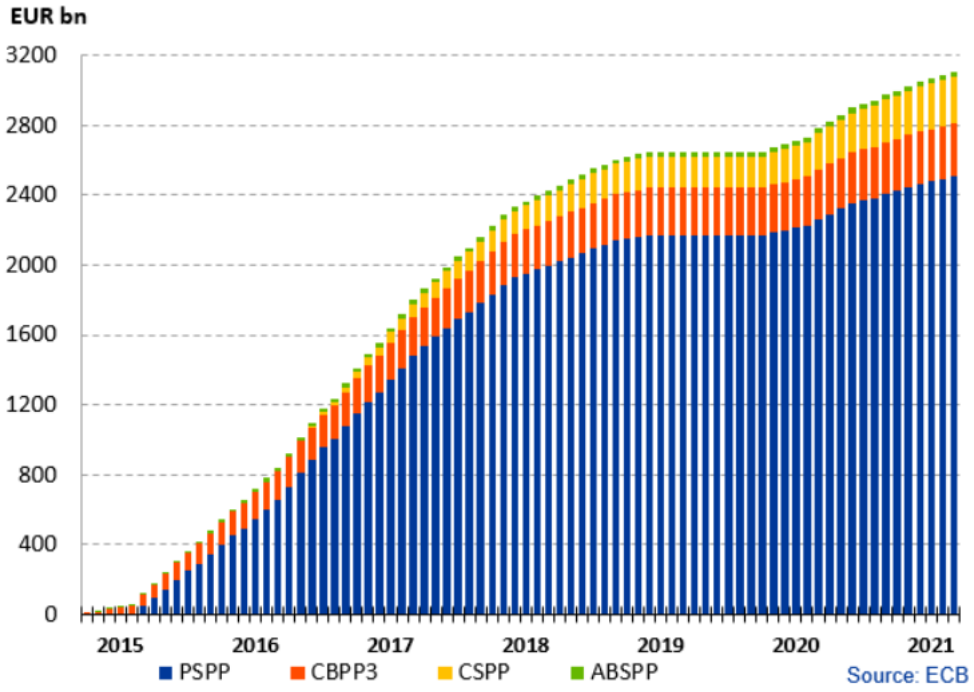
- corporate sector purchase program (CSPP): active since June 8, 2016, it provides for the purchase of bonds; since March 2020, commercial paper issued by non-financial companies from EU countries has also been included;

- the Public Sector Purchase Programme (PSPP): active since March 9, 2015, it provides for the purchase of securities issued by governments, public agencies and international institutions in the euro area;

- the Asset-Backed Securities Purchase Programme (ABSPP): active since November 21, 2014, it provides for the purchase of securities issued deriving from securitizations of bank loans;

- Covered Bond Purchase Programme (CBPP3): active since October 20, 2014, provides for the purchase of covered bank bonds.

Figure 14 - APP net purchases



Source 13 - ECB

With the Corporate Sector Purchase Programme (CSPP), the ECB has activated a corporate bond purchase program. In 2018, under the CSPP program the volume of outstanding eligible green corporate bonds was €31 billion; of these the Euro system holds around 20%.

These figures are in line with the entire CSPP universe; here, too, the Euro system holds about 20%; green bonds represent about 4%of the total[4].

The Euro system has also purchased green bonds issued by sovereigns, agencies and supranational institutions since the start of the PSPP, with a growing presence over time. The volume of eligible green bonds issued by such public sector entities is small relative to the PSPP-eligible universe (less than 1%).

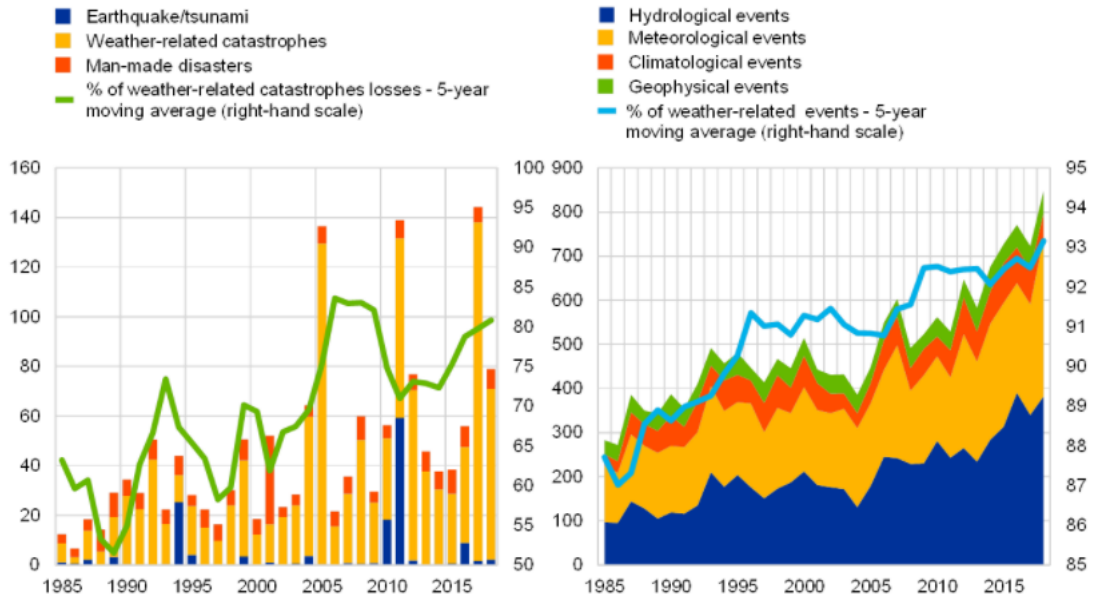
[4] ECB Economic Bulletin (2018)

2.2.4. Financial stability

The risks associated with climate change have the potential to become systematic within the Eurozone. Financial stability can be put at risk both directly and indirectly; directly due to the increasing frequency of disasters and indirectly due to the uncertainty regarding the measures and timeframes that will be necessary to adopt measures aimed at a transition towards a low-carbon economy.

Direct and therefore physical risks particularly affect collateral on insurance liabilities.

Figure 15 - Environmental disasters by category (1985 - 2020)

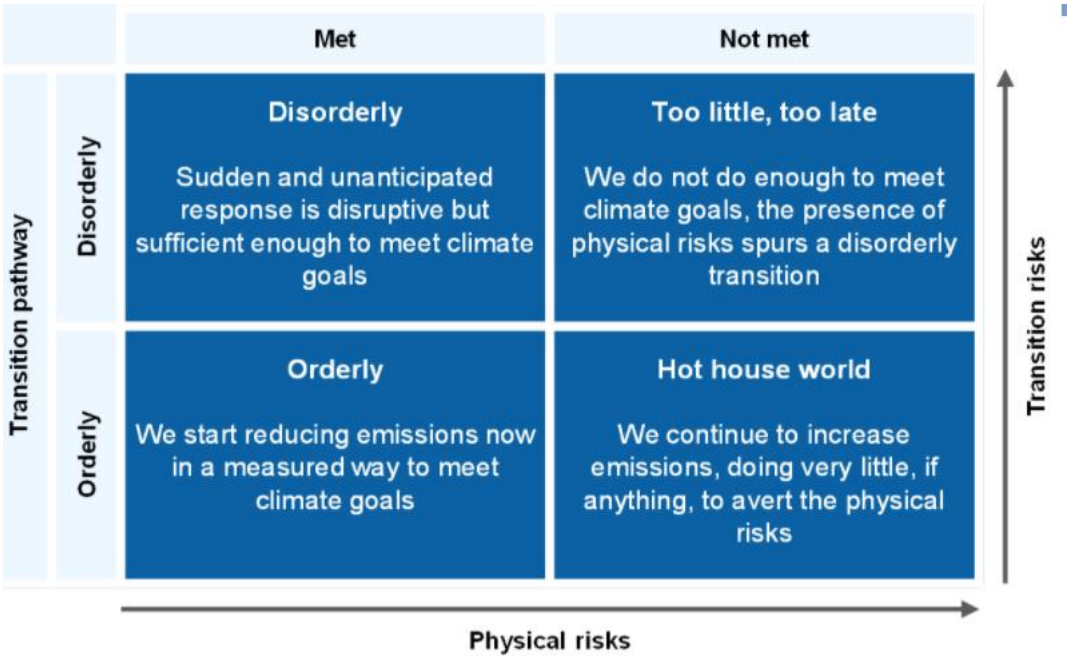


Source 14 - Swiss Re Institute, Munich Re NatCatService and ECB calculations.

From the figure above (Figure 15) it can be seen that, to date, about 80% of insured catastrophe losses are related to weather catastrophe. The problem, especially for insurance companies, concerns the fact that many properties at risk of flooding or hurricane risk are becoming more and more expensive to insure.

The Paris Agreement calls for immediate action and incentives to reduce emissions. From a corporate perspective, the introduction of restrictive policies and a change in investor preference can lead to a disastrous decline in asset prices. All this could imply a sudden sale of these assets creating uncertain market dynamics and liquidity problems.

Figure 16 - Strength of response (Based on whether climate targets are met)



Source 15 - NGFS (2019)

The credit risk for carbon-intensive economic realities creates an increase in default risk; this has enormous repercussions also for those states and therefore for those governments that have a high number of carbon-intensive industries in their territory.

At the base of this reasoning there is a problem regarding the pricing of transition risk; this is difficult to assess correctly because it affects the long term but any error in the assessment forces the investor to re-evaluate his choices if the period estimated for the transaction is greater than the time horizon of the investor.

In addition, there are more and more initiatives, associations and regulations aimed at determining what is effectively a climate-related risk, but unfortunately there is still no globally accepted definition.

2.3. Green Bond Market

The birth of green bonds dates back about 13 years.

In May 22, 2007 the European Investment Bank issued its first green bond; with an amount of 600 million and a five years maturity this is the first example of Climate Awareness Bond.

The EIB linked returns to the then newly set up FTSE4Good Environmental Leaders Europe 40 index.

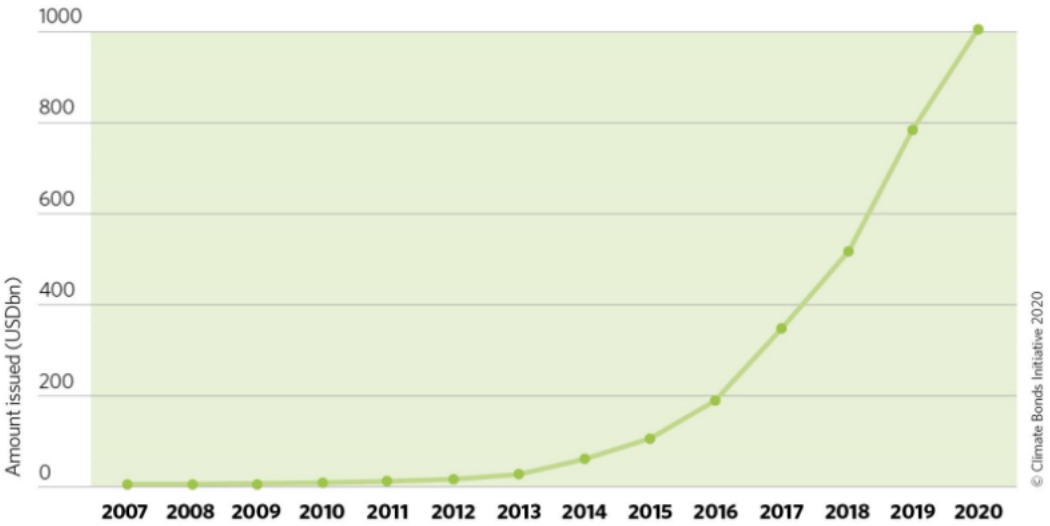
In November 2008, the World Bank issued the "World Bank Green Bond"; this bond had the aim to raise funds for projects with the goal of reducing the effect of climate change. This bond was denominated in Swedish krona (SEK) with a six years maturity; so, while the EIB has been the first issuer of a bond related to sustainable activity, the World Bank is the one that actually created this new asset class. Since 2008, the World Bank has raised more than $13 billion in Green Bonds. This has been a great achievement in many ways; the realization of this project allowed the creation of a new collaborative model between banks, investors, scientists and agencies for sustainable development. In addition, CICERO (Center for International Climate Research) was included as a second opinion provider. In Italy, the first green bond was issued by Hera, a multinational Italian company which provides energetic, water and waste services.

The amount of this bond was 10 million, duration of 10 years, with a 2.375% coupon and 2.435% Yield To Maturity; the orders were about 1.7 billion Euros and it was almost three times the amount issued.

Green bonds have the main objective of drawing attention to the challenges of climate change; this does not give up on returns and also highlights the social value of these.

2020 was a record year for these debt instruments. In fact, a trillion dollars in cumulative issuance since 2007 was reached. In 2020, despite Covid – 19, approximately $ 265 bn in issuance was reached.

Figure 17 - Cumulative green bonds amount issued



Source 16 - Climate Bonds Initiative (2020)

For about 10 years, the Green Bond market has not stopped growing. While issuance in 2020 only grew by $ 3bn (269.5 in 2020 compared to 266.5 in 2019), growth in the previous year, from 2018 to 2019, was about $ 95bn[5].

Figure 18 - Corporate green bonds over time (2013 – 2018).

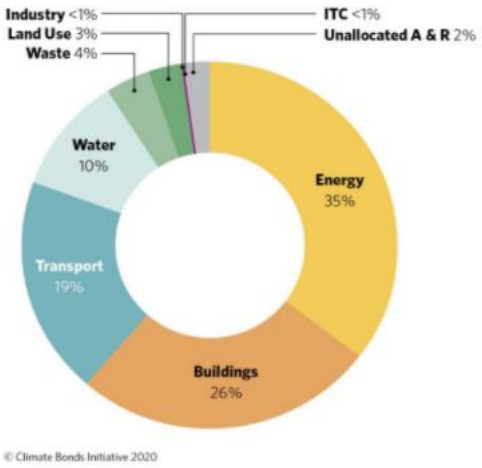
Year	# Bonds	$ Amount (billion)
2013	16	5.0
2014	76	15.4
2015	222	28.7
2016	156	68.7
2017	323	87.8
2018	396	95.7
Total	1189	301.2

Source 17 - Journal of Financial Economics (2020)

[5] Climate Bond Initiative

The energy sector is certainly the one to which more capital has been directed from the Use of Proceeds in 2020 with a value of about $ 93.6bn. This is followed by Low Carbon Buildings ($ 70.6bn) and Low Carbon Transport ($ 63.7bn).

Figure 19 - Use of Proceeds 2020



Source 18 - Climate Bond Initiative (2020)

2.4. Green bond and Covid – 19

2020 has been a swing year. After a first quarter that was in line with growth from previous years, the second quarter was marked by a major setback in green bond issuance. Despite this, the third quarter set numerous records.

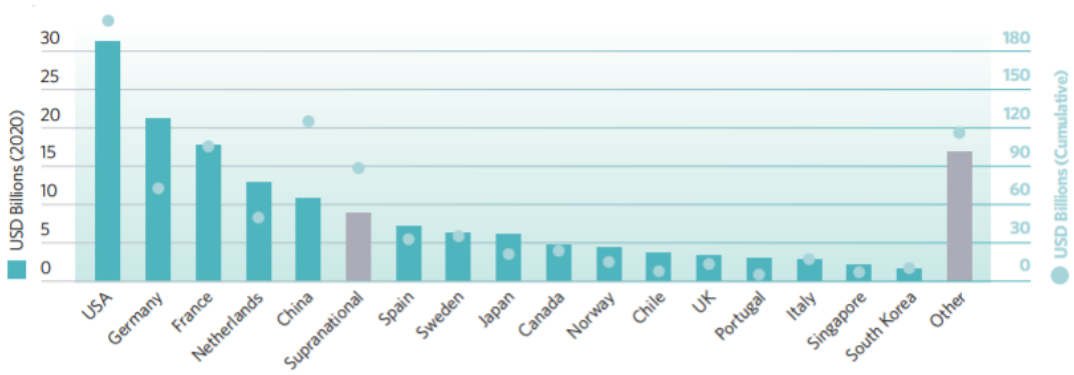
A total of $ 69.4bn was issued, the most ever in a single third quarter, an increase of around 20% compared to Q2 2020.

These numbers stem from the newfound confidence and policies put in place by various governments. In September, Chinese President Xi Jinping declared his intention to reach the goal of becoming carbon neutral by 2060; in fact, China is the second largest issuer of green bonds in the world, behind the United States.

In addition, the European Commission has announced it will issue 225 billion in green bonds. These results and these declarations affect both companies and investors.

The former in fact feel they must align themselves and keep up with the new policies while from an investor point of view there is a growing feeling of confidence in instruments that already have a very solid base.

Figure 20 - Top 2020 countries: Amount issued (2020 vs. Cumulative)



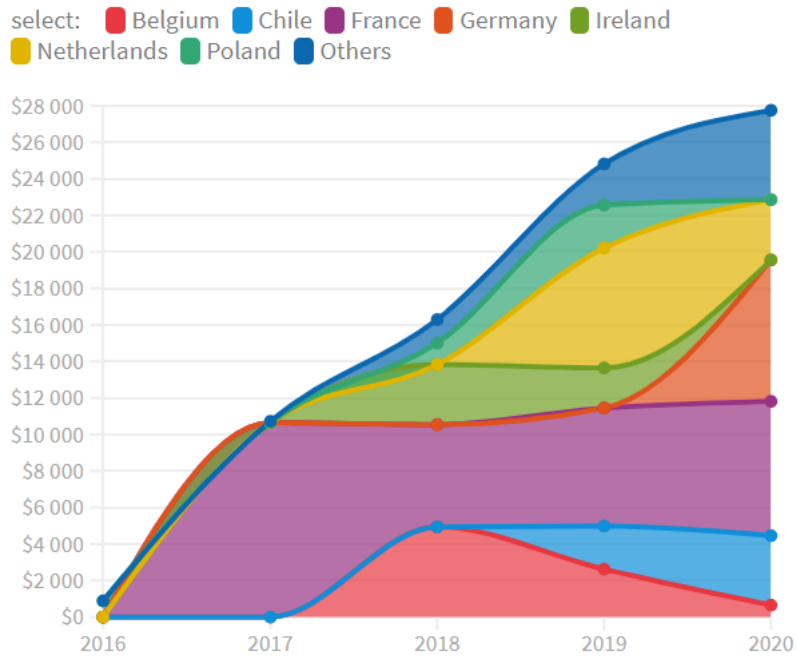
Source 19 - Climate Bonds Initiative (2020), "Green Bond Market Summary Q3 2020"

The U.S. remains number one in the ranking with 32.3bn issued at the end of Q3 2020, followed by Germany (21.4bn) and France (17.8bn).
In 2019, the US issued around 51bn in green bonds, representing around 20% of the entire market.

2.5. Sovereign Green Bonds

Poland was the first government to issue a green bond in December 2016. The proceeds from the Poland sovereign green bond financed the National Renewable Energy Action Plan, with the goal of achieving 15% energy efficiency from renewable energy.

Figure 21 - Sovereign green bond issuance (Total, million USD)



Source 20 - OECD (2020)

To date, sixteen governments have issued green bonds with a value of approximately $ 80bn. Even with Covid -19 governments have continued with their issuances.

However, the size of the market is still extremely small compared to conventional bonds with an amount of around 0.1% of all government debt.

It should be noted that governments started issuing this type of debt relatively late. There are various reasons for this. On the one hand, it must be considered that the market is very young and rightly failed to attract government entities right away.

The turning point is the public pressure that these entities have. Certainly, Covid-19 has been a great help in raising public awareness of these issues; governments issuing green bonds not only bring liquidity to the market but, more importantly, encourage this type of investment at the national level. Showing themselves interested in this type of instrument is as if they certified their validity by attracting more and more investors and capital.

2.6. Green Bond Certification

With the exponential growth of this market, it is necessary to have an assurance and certification of the actual quality of the issuer and the instrument itself.

The question about these instruments relates precisely to the use of their profits. It is essential to be sure that they are used to finance sustainable projects and not for other projects.

In addition, having a guarantee reassures and, at the same time, attracts investors to this market. The investor is precisely the one who needs to be protected; he must be enabled to make an informed choice about the company's internal management, the issuing process and the quality of the data reported.

Figure 22 - Different green bonds certification

Characteristics of different Green Bond identification and certification schemes — Table 1

	Green Bond Principles	Climate Bond Initiative	Green Bond Indices[1]	CICERO 2nd Opinions	Moody's Green Bond Assessments
Use of funds must be tied to "green" investment	Yes	Yes	Yes	Yes	Yes
Sector-specific eligibility criteria		Yes	Yes		
Ex post monitoring/assessment					Yes
Granular assessments of greenness				Yes	Yes
Quantitative weights for different factors					Yes

Source 21 - Barclays MSCI, Bank of America Merrill Lynch, S&P and Solactive.

The life of a green bond is mainly divided into four phases.

In the first part, the issuer decides on the standards and criteria to be used and the guidelines to be used in reporting.

The most common are the Green Bond Principles (GBP), the Climate Bond Certified (CBC) and the EU GBS. In addition, it is common to ask for the opinion of a second party. This is done because organizations often develop their own frameworks based on those described above so a second opinion and viewpoint are useful in measuring whether these transactions are indeed green and if in line with these criteria.

During the second phase, the issuer determines the technical characteristics of the bond; these include the face value, coupon, and maturity. All this information, along with the Green Bond Framework and performance indicators are described in a prospectus.
These indicators are key to assessing how well the project is doing and its environmental impact.

Once the bond has been issued, its proceeds end up in the coffers of the company, which can begin to use them to work on sustainable projects.
In this third phase, it is clear that this type of bond, unlike a conventional one, must be monitored not only for its performance in terms of yield but also for how its proceeds are used; after all, this is their ultimate goal.
It is necessary to gather as much information as possible, on both sides, to make it available to investors.
The information gathered is then reviewed in order to subsequently write a report.

In the fourth and final stage, performance is reported; the key factor at this stage is transparency. The operations and projects that have been funded must be well specified; not only must the operations be described but also the environmental impact of these, through the use of KPIs.

2.7. EU Taxonomy Regulation

In December 2019, the European Parliament and the European Council reached agreement on the proposed text on the Regulation on the Establishment of a Framework to Facilitate Sustainable Investment - the so-called "Taxonomy Regulation."
The Taxonomy Regulation was published on June 22, 2020 and entered into force on July 12, 2020; its main purpose is providing investors with the appropriate tools to identify the degree of environmental sustainability of different economic activities.
In practice, it includes a classification system of economic activities to protect investors from greenwashing, help companies in the ecological transition and raise awareness of investments towards where it is really needed.
The text defines the minimum necessary criteria that an activity must meet to be considered environmentally sustainable.

The first parameter to be met is related to the environmental contribution of the activity itself, whose objective must fall in one of the following areas: Climate change mitigation, Climate change adaptation, The sustainable use and protection of water and marine resources, The transition to a circular economy, Pollution prevention and control and The protection and restoration of biodiversity and ecosystems.[6]

Second, It does not have to significantly harm ("DNSH") any of the other environmental objectives meaning that if an economic activity actually makes an effort in the direction of the first two objectives, it must not cause significant damage in relation to the other environmental objectives.

Then, it must be carried out in compliance with minimum safeguards set out in the Regulation (including the OECD Guidelines for Multinational Enterprises, the International Labour Organisation, etc.).

This point refers to the role of human right in carrying out a business; the OECD and UNGPs are management tools with the intent to include respect for human rights in business operations.

Some of the tools used are the policy Statement for the responsibility to respect human rights, communicating how they address human rights impacts and behave when faced with situations of human rights violations.

The last point says these activities need to comply with the technical screening criteria developed by the Technical Expert Group in the form of delegated acts; they will be applied from 1 January 2022 for climate-related objectives and from January 1, 2023 for the other environmental objectives.

The Taxonomy will officially come into force from January 1, 2022 for climate change mitigation and adaptation objectives and came into effect from January 1, 2021 for the other objectives.

[6] European Commission

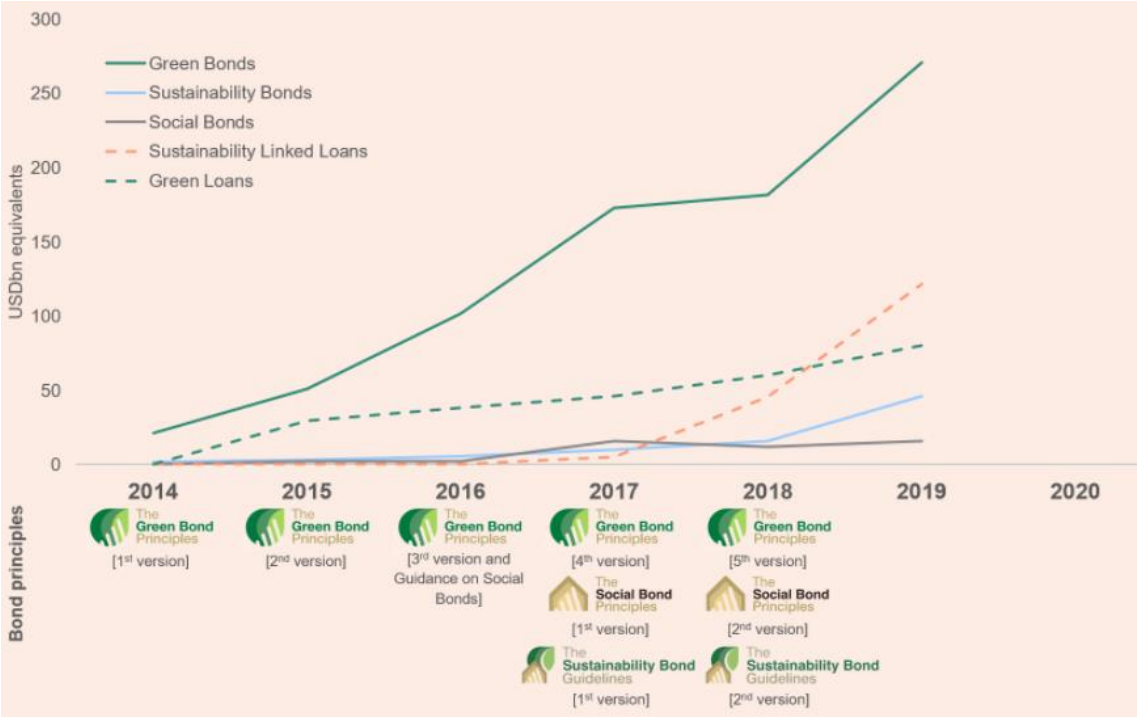
2.8. Different Green Bonds framework

2.8.1. Green Bond Principles

"The Green Bond Principles (GBP) formulated by International Capital Market Association (or ICMA), are voluntary process guidelines that recommend transparency and disclosure, and promote integrity in the development of the Green Bond market" (ICMA).

The GBPs have been formulated and designed to act as guidelines recommending transparency, disclosure and reporting. They are designed for investors to increase the allocation of their capital to certain projects. Bond issues in line with the GBP must provide for and increase the transparency of the investment; through the report made by the issuer on the use of Green Bond proceeds, the tracking of the funds themselves is facilitated and the impact that the project itself has is made known. The GBPs take into account the opinions and contributions of the Members and Observers of the Green Bond Principles and Social Bond Principles and, in general, of the entire stakeholder community. They are updated once a year to account for and reflect market trends.

Figure 23 - Timeline of sustainable fixed income asset supply and publication of related market principles



Source 22 - Nordea (2020)

The target of the GBPs is to provide issuers with the information they need to be able to launch a Green Bond that is credible and, at the same time, provides the information needed to assess its environmental impact.

The determinant of a Green Bond is the use of proceeds which consist of the money paid to the issuer by the purchaser for a new issue of municipal bonds, which will be used to finance a project for which the bonds were issued.

All Green Projects must show a clear improvement for the environment which, if possible, should be quantified by the issuer.

Among the objectives that GBPs recognize for a Green Bond to be classified as such are climate change mitigation, climate change adaptation, natural resource conservation, biodiversity conservation, and pollution prevention and control.

Subsequently, the issuer must state and communicate in a precise and transparent manner the environmental sustainability objectives of the project, the process by which this project is chosen and all guidelines and criteria used; it must also state the process by which it intends to identify and manage potential risks associated with the project.

As GBPs are voluntary, it is highly recommended, and issuers are encouraged to disclose any green standards and certification adopted.

The net proceeds of the Green Bond or an amount equal to them should be tracked by the issuer and linked through an internal process to the investment transactions for the Green Project. As long as the bond remains outstanding, the net proceeds balance should be adjusted periodically in relation to use on Green projects.

If a portion of the net proceeds is temporarily unused, the issuer should let the investor know the intentions for the allocation of these proceeds.

GBP encourages the use of an auditor or third party to verify internal tracking and allocation of funds.

Finally, information regarding the use of proceeds should always be made available to the investor and updated until they are fully allocated; in addition, it should be updated as material developments occur.

A list of selected projects to which proceeds are allocated is included in the annual report, along with a description of them and their expected impact.

Obviously, this discussion must take into account confidential information, competition, and that the presence of a large number of projects may limit the availability of detailed information; the GBPs recommend that disclosure of information in general terms (e.g., indicating the percentage allocated to a category of projects).

Speaking of expected impacts, the GBPs push for the use of qualitative and, if possible, quantitative indicators such as energy capacity, GHG emission reduction, number of people provided with access to drinking water etc.; it is good practice to accompany these indicators with information on the methodologies used to determine them.

The same ICMA in proposing and recommending these principles, also recommends the use of an external auditor with the aim of confirming and aligning the Green Bond program with the characteristics mentioned above.

These voluntary guidelines are intended to be a guarantee of transparency in the review process; they are designed for issuers, underwriters and all other stakeholders.

This guidance is updated periodically to gather feedback from all market participants.

Different categories of companies may provide an external review; ICMA lists five essential elements that must guide a review: Integrity, Objectivity, Professional Competence and Due Care, Confidentiality and Professional Behaviour.

2.8.2. Climate Bond Certified

Bonds and loans that are certified with Climate Bonds Standards are referred to as Certified Climate Bonds.

These standards, proposed by the Climate Bond Initiative (CBI), are more directly applicable than GBPs. They refer to eligibility criteria divided by specific sectors.

The standards contain very strict parameters about the objective of the Paris Agreement to limit global temperature increase to below 2 degrees Celsius.

To obtain certification, it is necessary to be approved by an Approved Verifier who guarantees and certifies that the bond meets the requirements. Once issued, the issuer is required to confirm the Certificate by obtaining another assurance, the so-called Post-Issuance.

Obviously, these standards are in line with GBP and aligned with the EU Green Bond Standard.

2.8.3. Indices

Another recognized method for identifying and investing in Green Bonds is to choose those that belong to the category indices. Indices, by their nature, group together securities that have common parameters.

This allows investors, on the one hand, to be sure of choosing and directing their capital towards this type of instrument and, on the other hand, is given the possibility of diversifying the issuer-specific risk.

In this case, the securities to be incorporated into the index are selected by private organizations (S&P, Bank of America, Merrill Lynch etc.) that make up the index; this means that they are the ones who guarantee the actual quality of the security through standardized verification processes.

The most successful indices in this special section are Bloomberg MSCI Barclays Green Bond Index, S&P Green Bond Index and Solactive Green Bond Index.

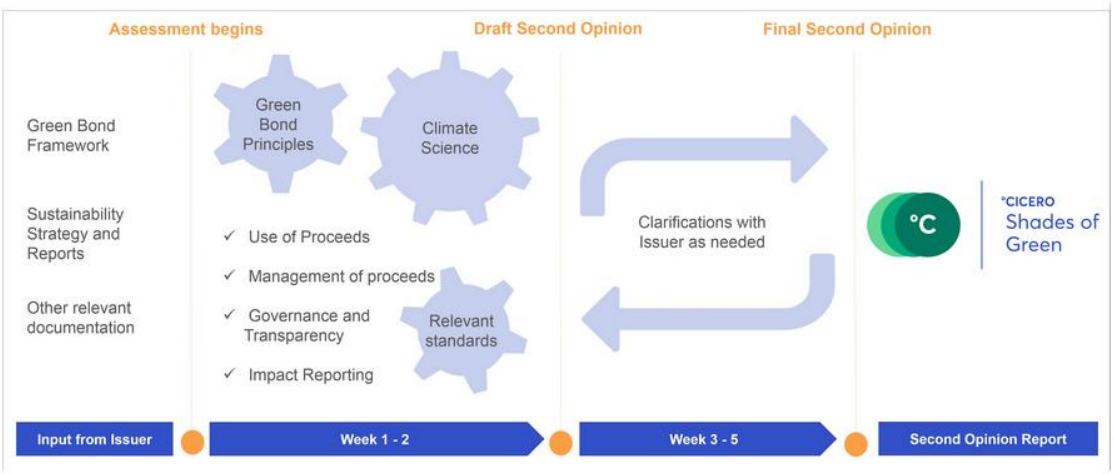
2.8.4. CICERO Second opinions

CICERO (Center for International Climate Research) is the world leader in providing Second Opinions on Green Bonds. As mentioned earlier, CICERO was responsible for Second Opinion for the first Green Bond issued by the World Bank.
“CICERO's second opinion was a key part of the green bond model developed for the first World Bank Green Bond together with SEB in 2008, which has helped the market diversify with integrity” (Heike Reichelt, Head of Investor Relations and New Products at the World Bank).

2.8.4.1. CICERO Methodology

CICERO provides an independent assessment of the issuer's green bond framework and internal governance procedures. Their assessment model is designed to promote sustainable investments without increasing the transaction costs of the financial sector.

Figure 24 - The process of getting a CICERO Second Opinion on a green bond framework

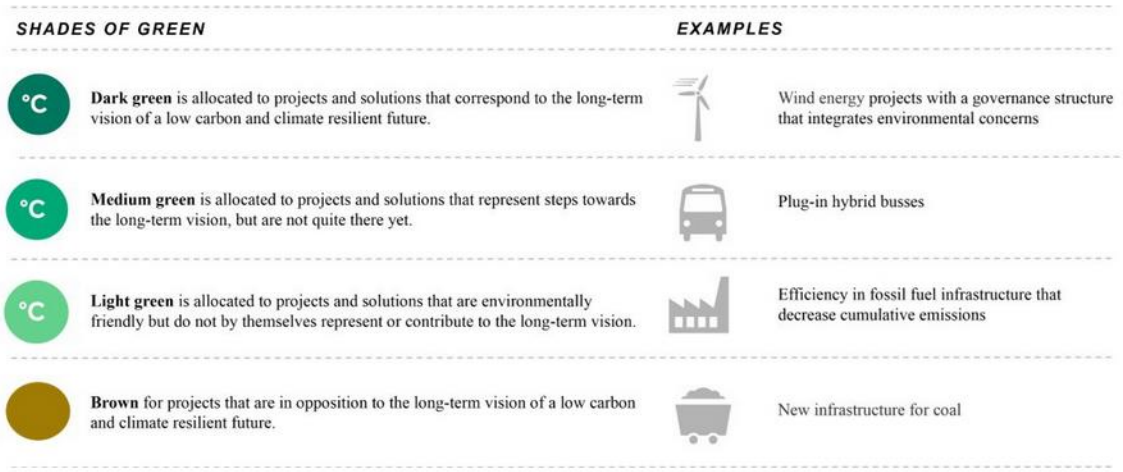


Source 23 - CICERO

In 2015, a "green scale" was introduced to indicate how much a bond actually falls within the parameters and aligns with the goal of a low-carbon climate future. This is to ensure that the assessment is as clear as possible and to take into account the duration of the efforts made; if a company demonstrates emissions reductions in the short term but does

not care at all about the long term, it certainly cannot be assessed in the same way as others implementing a strategy with a longer time horizon.

Figure 25 - Different shades of Green investments



Source 24 - CICERO

Thus, four levels of green have been defined. From Dark green which reflects projects whose strategy and vision in moving to a more sustainable model has been worked out over a longer period of time to Brown; these are projects that do not consider or are in opposition to the long term vision.

2.9. Greenwashing

Greenwashing is the practice of circumventing the consumer about a company's environmental sustainability practices.

"Spending more time and money claiming to be "green" through advertising and marketing rather than implementing business practices that minimize environmental impact" (Leyla Acaroglu).

A company sponsors and publicizes the behaviours and practices it puts in place to benefit the environmental cause but, in reality, is not doing anything it promises.

This practice brings with it numerous problems; in addition to not benefiting environmental or sustainable issues, it confuses consumers who rely on a particular company for those very reasons.

The result is that realities that do not invest in green but only sponsor it, will have a following for actions they have not undertaken.

Basically, a false image of the company is created, even through the manipulation of information, to be perceived as a more sustainable and environmentally conscious company.

This process can be practiced at the level of the company itself (firm-level greenwashing) or about a particular product (product-level greenwashing).

A greenwashing firm usually acts with two different types of behaviours; on the one hand it is careless about the parameters, standards and environmental performance of the company while on the other hand it implements a positive and reassuring communication about them.

Figure 26 - A Typology of Firms based on Environmental Performance

Source 25 – Burbano, Magali (2011); "The Drivers of Greenwashing"

Corporate performance can be grouped into 2 categories (Figure 26): bad performance ("Brown firms") and good performance ("Green firms").

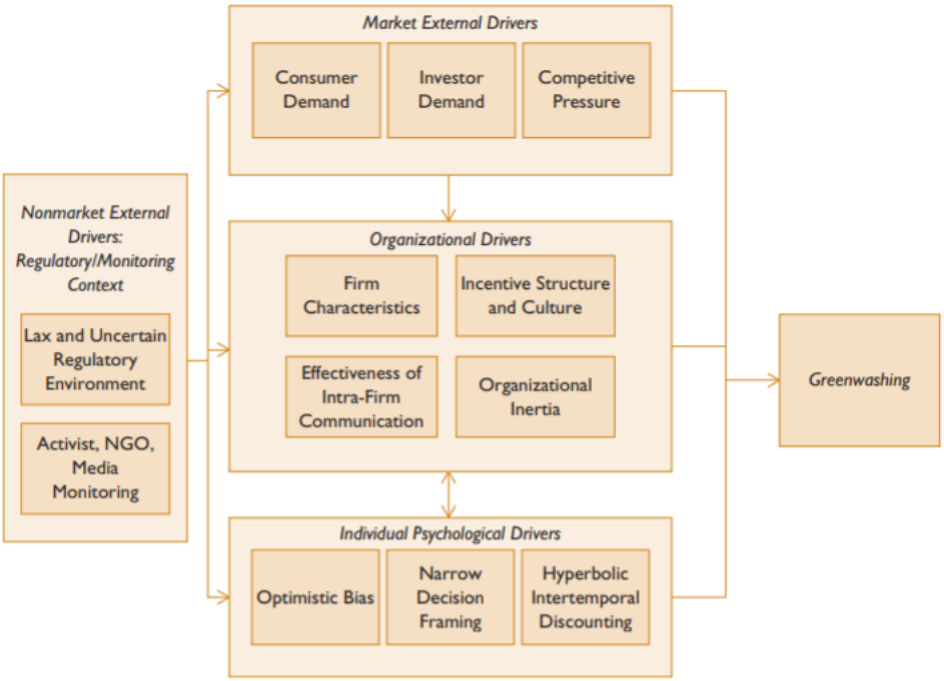
Thus, for a company with bad environmental performance there are two possible ways forward; in the first case they can choose to remain silent and therefore not implement any communication strategy that reflects the way they work. It would be counterproductive to deliberately build a public image based on a lack of concern for certain issues.

The other option is to implement a false communication that does not represent the reality of the facts; it is precisely the latter that are defined as greenwashing firms.

“When companies invest more money and time in marketing where they talk about “green” products, rather than investing them in making the business more sustainable - that's Greenwashing.” (Vitesy)

2.9.1. The Drivers of Greenwashing

Figure 27 - Drivers of Greenwashing



Source 26 - Burbano, Delmas (2011), "The Drivers of greenwashing"

There are several reasons why a firm may be misleading its customers.

At the base of it all, there is, as often happens, a lack of real legislation on the subject.

Since there is still, in some cases, a lot of confusion about what is or is not green, companies feel somehow legitimized to sell a product or to advertise it for what it is not.

Obviously, if they have given wrong indications, they can certainly incur sanctions and measures but most of the time they take the risk of these events because they are highly unlikely.

Another determinant factor are awareness campaigns and information supported by activists and associations with the goal of educating people and consumers about the reality of facts. These campaigns target corporations by bringing concrete, real-world examples of greenwashing operations.

Among the most famous awareness campaigns we find #StopGreenwashing, formed by more than 50 non-governmental organizations, which aims to inform and promote battles to regulate some of the main economic sectors responsible for this practice.
Their fight is aimed at the creation of an EU sustainable taxonomy that can finally pave the way for the development of a sustainable economy.
Their attention is focused on three types of activities:

1. Economic activities for which the criteria need to be tightened;
2. Economic activities to remove from the EU sustainable taxonomy;
3. Economic activities that were rightly excluded and should not be reincluded.

Among the first group are defined those activities for which greater clarity is required in defining the criteria and greater transparency. These for example include the Bioenergy for power and heat, forestry and hydropower.
In the second section, there are activities for which a green taxonomy cannot be considered because they are too polluting and cause irreparable damage.
These activities include intensive livestock activities, the use of biofuels and biogas for transport and the fossil fuel vehicles and vessels.
In the last part are instead reported those activities that have been rightly excluded and that cannot be part of it like, of course, the nuclear power; this contributes to pollution and is responsible, with the complicity of human beings, some of the largest environmental disasters ever recorded. Fossil fuels are also present, producing emissions well above the limits.

2.9.2. DieselGate

On September 18, 2015, the Environmental Protection Agency (EPA) declared Volkswagen AG, Audi AG and Volkswagen Group of America in violation of the Clean Air Act.

The Clean Air Act, established in 1979 and subsequently updated in 1977 and 1990, is a U.S. law designed to regulate the effects of air pollution and protect human health.

EPA regulates pollutant emissions that "endanger public health and welfare."

Figure 28 - Protest for the DieselGate scandal

Source 27 - Formula Passion

In the Notice of Violation, it is expressed that Volkswagen (VW) installed software to circumvent EPA emission standards in its cars manufactured from 2009 to 20015 with a 2.0-liter Diesel displacement.

On November 2, 2015, the EPA, through a new notice, accused Volkswagen that software to circumvent emissions had also been installed in 3.0 diesel vehicles in the years 2014 through 2016; on the 19th of the same month, Volkswagen informed the EPA that the software had existed in these types of vehicles since 2009.

On January 11, 2017, Volkswagen pleaded guilty and agreed to pay $2.8 billion in criminal penalties. With respect to the civil penalty, VW agreed to pay $1.5 billion; the EPA also provided additional measures to prevent future violations.

This software is designed to detect when there is an emissions test so as to activate pollution control devices to meet quality standards.
When the vehicle is in normal use, the controls are deactivated allowing an improvement in performance but, at the same time, an increase in emissions such as nitrogen oxides (NOx).
Road tests on the incriminated vehicles show NOx emissions 10 to 40 times higher than EPA standards.
About 482,000 vehicles are affected by the scandal.

2.9.2.1. Consequences

Within two weeks, VW shares lost about 40%.
On September 23, 2015, CEO Martin Winterkorn, resigned; however, this move was not accompanied by an apology rather, as he said, "I am not aware of any wrongdoing on my part" (Martin Winterkorn,2015).
He justified this choice by saying that VW needed a fresh start and that he was shocked by the events that had just taken place.
VW embarked on aggressive marketing campaigns to attempt to regain the trust of consumers and investors; it changed its famous logo from "DAS AUTO" which can be understood and translated as "THE AUTOMOBILE" to a humbler and more discreet "Volkswagen".
In addition, VW has spent resources devoted to research and development to publicly apologize through advertisements and announcements.
In April 2016, the CEO personally apologized to President Obama.

The text below represents the letter sent by Volkswagen where, the same car manufacturer admits its mistakes and apologizes to its customers for having betrayed their trust.

Dear Volkswagen Customer,

We regret to inform you that the Type EA 189 engine built into you vehicle with the Vehicle Identification Number XXXXXXXX you submitted, is affected by software that may cause discrepancies in the values for oxides of nitrogen (NOx) during dynometer runs. Your car is safe from a technical standpoint and roadworthy.

We are very sorry to have broken your trust and are working at full speed to find a technical solution Volkswagen will cover the cost relating directly to this repair.

We will be in touch with you directly to explain what steps are required. We'll do any rectification work at our cost.

Yours faithfully,

Volkswagen.

(Apology letter of Volkswagen to its customers, 2015)

Chapter III. Empirical Analysis

3.1. Evolution of term structure analysis

The most popular models for the analysis of the Yield Curve, considering those used by the major central banks in the world (including the ECB) are mainly divided into two categories.

Before listing and delving into the categories used, it is necessary to understand why central banks and the ECB make such reference to this type of curve.

"A yield curve is a representation of the relationship between market remuneration rates and the remaining time to maturity of debt securities. A yield curve can also be described as the term structure of interest rates"(ECB).

Every business day, at noon, the ECB releases several types of yield curves divided by maturity. The main objective is to estimate the term structure of interest rates in order to investigate the market expectation of the monetary policy adopted and the inflation expectation.

Through these tools the ECB acquires information on the various market expectations, evaluating developments in relation to interest rates and inflation.

Figure 29 - Term structure models used by Central Banks

Central bank	Estimation method	Minimised error	Relevant maturity spectrum
Belgium	Svensson or Nelson Siegel	Weighted prices	2 days–16 years
Canada	Exponential	Weighted prices	3 months–30 years
Finland	Nelson Siegel	Weighted prices	1–12 years
France	Svensson or Nelson Siegel	Weighted prices	Up to 10 years
Germany	Svensson	Yields	1–10 years
Italy	Nelson Siegel	Weighted prices	Up to 30 years
Japan	Smoothing splines	Prices	1–10 years
Norway	Svensson	Yields	Up to 10 years
Spain	Svensson	Weighted prices	Up to 10 years
Sweden	Smoothing splines and Svensson	Yields	Up to 10 years
Switzerland	Svensson	Yields	1–30 years
UK	VRP	Yields	Up to 30 years
USA	Smoothing splines 2 Curves	Bills: Weighted prices Bonds: prices	Up to 1 year 1–10 years

Source 28 - Bank for International Settlements, 2005

The table above (Figure 29) shows the models used by the world's major Central Banks to estimate their Yield Curves.

There are precisely two main categories: Spline - based models and Parametric (Parsimonious) models. The first includes the Waggoner cubic spline method and the variable roughness penalty method (VRP) while the second one includes the Nelson & Siegel model and the Svensson model.

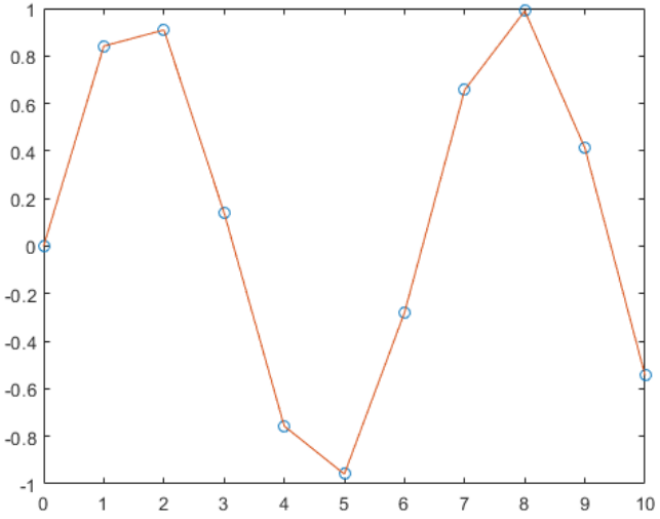
3.1.1. Spline - based methods

Spline - based use a piece-wise cubic polynomial.
A cubic spline is defined as a piecewise cubic function which interpolates a set of data points guaranteeing smoothness.
To define a cubic spline it is necessary to start with the concept of linear interpolation. Linear interpolation is a method of defining a value within a range of two known values. Each pair of adjacent points is joined by a segment calculated independently of the others. Defining two adjacent points $(x_i, x_i)\ and\ (x_{i+1}, x_{i+1})$ the interpolating function is defined as:

$$f_1(x) = \frac{x_{i+1} - x}{x_{i+1} - x_i} * y_i + \frac{x \quad - x_i}{x_{i+1} - x_i} * y_{i+1} \tag{3.1}$$

While providing an acceptable estimate, there are some problems with this method.

Figure 30 - Linear interpolation



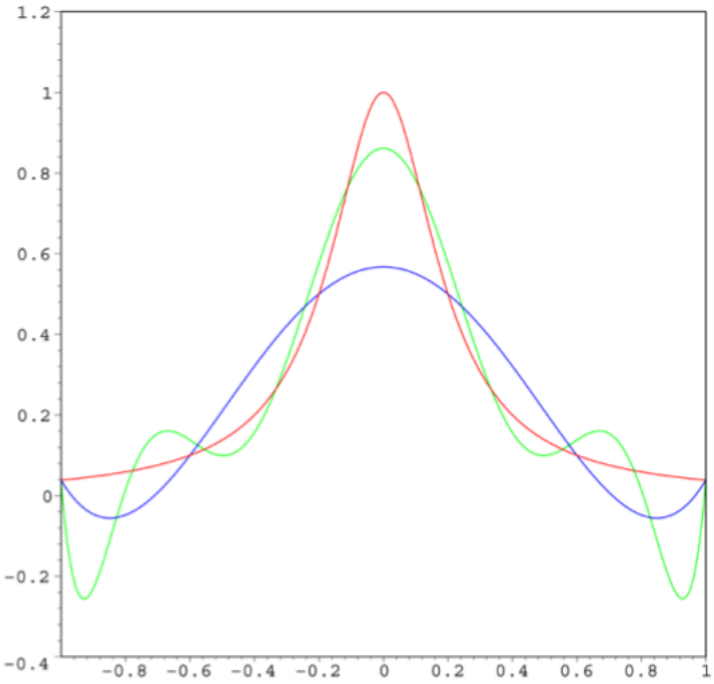
Source 29 - Mathworks

In fact, it is immediately noticed that the curve is not smooth at every point; this happens because it is not always derivable; this leads to a problem of discontinuity.

To solve this problem, polynomial interpolation is used; these polynomials are, by their nature, continuous and indefinitely differentiable in any interval. The drawback of this method is that it is no longer possible to calculate independently the interpolant for each pair of points.

As the degree of the polynomial increases, the Runge phenomenon can be observed; it consists in the appearance of strong oscillations in the interpolant function especially at the edges of the interval to be interpolated.

Figure 31 - Polynomial interpolation and Runge phenomenon



Source 30 - Wikipedia.org

In the figure above (Figure 31) the red line is the Runge function, the blue line is an interpolating polynomial of fifth degree while the green line is an interpolating polynomial of ninth degree.

The result is significant because it indicates that the use of polynomials of higher degree does not always lead to an improvement in accuracy.

To counteract this problem, it was decided to use piecewise polynomials (spline curves). The intuition lies in the fact that, when trying to decrease the interpolation error, instead of increasing the degree of the polynomials used, it can be directly increased the number of polynomials.

Generally, cubic splines are used for this method because they allow to obtain an interpolating function derivable at least twice and therefore continuous with continuous curvature.

Figure 32 - First and Second derivative in cubic spline

Source 31 - Oscar Veliz (2012)

Obviously, there are constraints to be imposed to obtain the required continuity; in addition to having continuous first derivative and second derivative, the equality between the first and second derivatives at the points of contact must be verified.
Each point of the curve is defined by a polynomial:

$$p(x) = ax^3 + bx^2 + cx + d \tag{3.2}$$

So, given n polynomials:

$$p_0(x) \dots p_{n-1}(x)\ with\ n+1\ points\ (x_0, y_0) \dots (x_n, y_n) \tag{3.3}$$

The polynomial must satisfy three characteristics:

Interpolate points: $p_i(x_i) = y_i\ and\ p_i(x_{i+1}) = y_{i+1,}\ for\ i = 0 \dots n-1$;
Have the first derivative continuous: $p'_{i-1}(x_i) = p'_i(x_i), for\ i = 0 \dots n-1$;
Have the second derivative continuous: $p''_{i-1}(x_i) = p''_i(x_i), for\ i = 0 \dots n-1$;

So, every polynomial p_i has 4 unknowns $(a_i + b_i + c_i + d_i)$ with a total of $4n$ unknowns.
Until now, there are just $4n-2$ constraints; $2n$ resulting from passing through the data points and $(n-1) * 2$ due to the continuity of the first and second derivatives.
The last 2 constraints are given by:

$$p''_0(x_0) = 0\ and\ p''_{n-1}(x_n) = 0 \tag{3.4}$$

The application of this method in the construction of a Yield Curve allows to calculate and analyse curve segments that are almost independent from each other; this is

fundamental to define the behaviours of the curve in different regions not being influenced by movements in neighbouring areas.

Fisher, Nychka and Zervos (FNZ) (1995) developed a method for fitting smoothing splines by including a penalty for "roughness". This penalty, which is constant across maturities, reduces excessive oscillations. In their model, the recommended number of nodes was about one third of the number of bonds observed; moreover, the nodes must be as equidistant as possible so as to observe the same number of bonds with maturity between the two adjacent nodes for each segment.

The model was criticized by Bliss (1997) who supported his thesis that the use of a roughness penalty caused the misprice of short-term securities; this is because the constraint tends to affect the flexibility of the curve and therefore the possibility of curvature, especially necessary for lower maturities.

Starting with the FNZ model, Waggoner (1997) developed an approach based on varying the smoothing penalty over maturities.

For his model he chose to use a three-tiered step-wise function where the steps have been set at one-year maturity and ten-year maturity.

This different development allows for smoothing in the long run while still allowing for the necessary flexibility in the short run.

Anderson and Sleath (2001) based on Wagoner's observations developed a variant of his model by including a different form for the roughness penalty.

In his model, Waggoner had to estimate 5 parameters: two related to maturity and three for the step levels (short-term, mid-term and long-terms maturities.).

Anderson and Sleath, decided to exploit the penalty function, making it vary continuously over maturities; their function was more complex but allowed to estimate only 3 parameters.

3.1.2. Parsimonious methods

In the category of Parsimonious models there are the Nelson & Siegel and the Svensson model.
The first one will be treated in depth during the empirical analysis of this paper.
The model defines the instantaneous forward rate as:

$$r(m) = \beta_0 + \beta_1 * exp\left(-\frac{m}{\tau}\right) + \beta_2 \left[\left(\frac{m}{\tau}\right) * exp\left(-\frac{m}{\tau}\right)\right] \quad (3.5)$$

The main purpose of this model is to define a forward rate interest curve capable of representing all the shapes commonly associated with the yield curve: monotonic, humps and S shaped. The construction of the model is based on the idea that, for very high maturity, the expected future interest rate can be taken as indistinguishable.
In fact, this allows to find a method to fit the yield curve that represents the real behaviour of the curve: in reality, yields tend to be at a constant level for maturities that tend to infinity.

Wanting to add flexibility to the curve, Svensson, taking up Nelson & Siegel's model, added a fourth term:

$$r(m) = \beta_0 + \beta_1 * exp\left(-\frac{m}{\tau_1}\right) + \beta_2 \left[\left(\frac{m}{\tau_1}\right) * exp\left(-\frac{m}{\tau_1}\right)\right] + \beta_3 \left[\left(\frac{m}{\tau_2}\right) * exp\left(-\frac{m}{\tau_2}\right)\right] \quad (3.6)$$

Since $\beta_2 = \beta_3$, the additional term is interpreted as the second medium-term component. The Svensson model, adding more flexibility to the curve, allows to fit the term structure having more than one local maximum or minimum along the maturity. In particular, τ_2 define the position of the second hump or through.

3.2. Nelson & Siegel Model description

The Nelson & Siegel model was born in 1987 from the collaboration of two brilliant American economists, Jeremy Siegel and Richard R. Nelson.

Their work "Parsimonious Modelling of Yield Curves" was published in The Journal of Business (The Journal of Business, Vol. 60, No. 4, 1987, pp. 473-489).

Nelson & Siegel (1987) propose a model to fit the term structure using a flexible, smooth and parametric function.

They introduce a model that can represent the shapes generally associated with the yield curve: monotonic, humped and S shaped.

"This paper introduces a parametrically parsimonious model for yield curves that has the ability to represent the shapes generally associated with yield curves: monotonic, humped, and S shaped" (Nelson & Siegel ,1987).

The definition of their model starts from the theory that the shape of the yield curve is defined by the solution of a differential equation.

This is because, if the short rate is generated by a differential equation then the forward rates will be the solution of the equation.

The two authors started from the formula (3.7) which defines the instantaneous forward rate at maturity m as the solution to a second-order differential equation with real and unequal roots:

$$r(m) = \beta_0 + \beta_1 * exp\left(-\frac{m}{\tau_1}\right) + \beta_2 * exp\left(-\frac{m}{\tau_2}\right) \quad (3.7)$$

An instantaneous forward rate (r) is the rate of return for an infinitesimal amount of time (δ) measured at some date (m) for a particular start-value date (M).

The instantaneous forward rate defines the slope of the spot curve at a given point; practically, the forward rate is the average of the instantaneous forward rate with continuously compound rate.

Defining the forward rate $R(m, M, M + \delta)$, the instantaneous forward rate $r(m, M)$ is the limit of $R(m, M, M + \delta)$ when $\delta \rightarrow 0$.

So, the relation between the forward rate and a zero-coupon bond can be written as:

$$R(m, M, T+\delta) = \frac{p(t,T) - p(t,T+\delta)}{\delta p(t,T+\delta)} \tag{3.8}$$

The instantaneous forward rate will be:

$$r(m, M) = \lim_{\delta \to 0} \frac{p(t,T) - p(t,T+\delta)}{\delta p(t,T+\delta)} \tag{3.9}$$

In the second-order differential equation (3.7) there are 5 parameters: β_0, β_1, β_2, $\tau_1$and τ_2.

$\tau_1$and $\tau_2$are time constants while β_0, $\beta_1$and $\beta_2$are determined by initial conditions.

The result of this equation is a series of forward rate curves with monotonic, humped and S shapes dependent on $\beta_1$and β_2 values and having β_0 as an asymptote.

Then, they define the yield to maturity on a zero-coupon bond as the average of the forward rates:

$$R(m) = \frac{1}{m} \int_o^m r(x)dx \tag{3.10}$$

Their conclusions, with this model, show an overparameterization; this problem comes from the fact that $\tau_1$and τ_2 are different and therefore it is possible to obtain the same result even changing the value of β 's.

From this result comes the needed to find a more parsimonious solution to define a model that still generates the three forms of yield curves mentioned above (monotonic, humped and S shaped).

Solving the differential equation in the case of equal roots, the result appears to be:

$$r(m) = \beta_0 + \beta_1 * exp\left(-\frac{m}{\tau}\right) + \beta_2 \left[\left(\frac{m}{\tau}\right) * exp\left(-\frac{m}{\tau}\right)\right] \tag{3.11}$$

By integrating the previous formula (3.11) from 0 to m and dividing by m, Nelson & Siegel were able to obtain a relationship for yield in relation to maturity:

$$R(m) = \beta_0 + (\beta_1 + \beta_2) * \frac{\left[1-\exp\left(-\frac{m}{\tau}\right)\right]}{\frac{m}{\tau}} - \beta_2 * exp\left(-\frac{m}{\tau}\right) \quad (3.12)$$

R(m) can vary from a minimum value equal to (β_0 + β_1) coinciding with lower maturity values, up to a maximum value of β_0 relatively to higher maturities.
Now, considering $\tau = 1$:

$$R(m) = \beta_0 + \beta_1 * \frac{[1-\exp(-m)]}{m} + \beta_2 * \frac{[1-\exp(-m)]}{m} - \beta_2 * exp(-m) \quad (3.13)$$

So:

$$R(m) = \beta_0 + (\beta_1 + \beta_2) * \frac{[1-\exp(-m)]}{m} - \beta_2 * exp(-m) \quad (3.14)$$

Defining than $\beta_0 = 1$ and $(\beta_0 + \beta_1) = 0$:

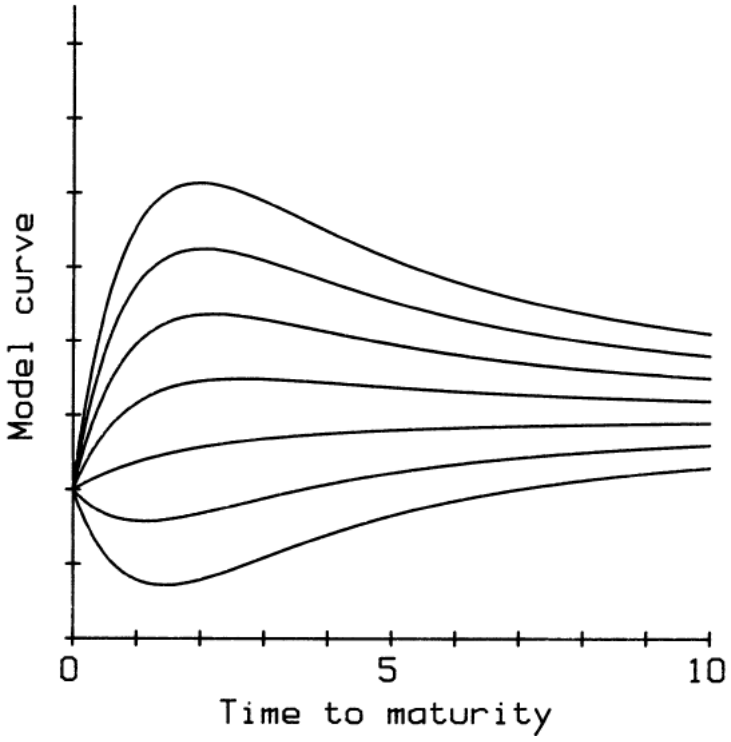
$$R(m) = 1 - (1 - \beta_2) * \frac{[1 - \exp(-m)]}{m} - \beta_2 * exp(-m) \quad (3.15)$$

Replacing β_2 with a:

$$R(m) = 1 - (1 - a) * \frac{[1 - exp(-m)]}{m} - a * exp(-m) \quad (3.16)$$

Note from this function (3.16) that the shape depends only on the parameter a so, to different values of a correspond different curves:

Figure 33 - Different shapes of yield curve

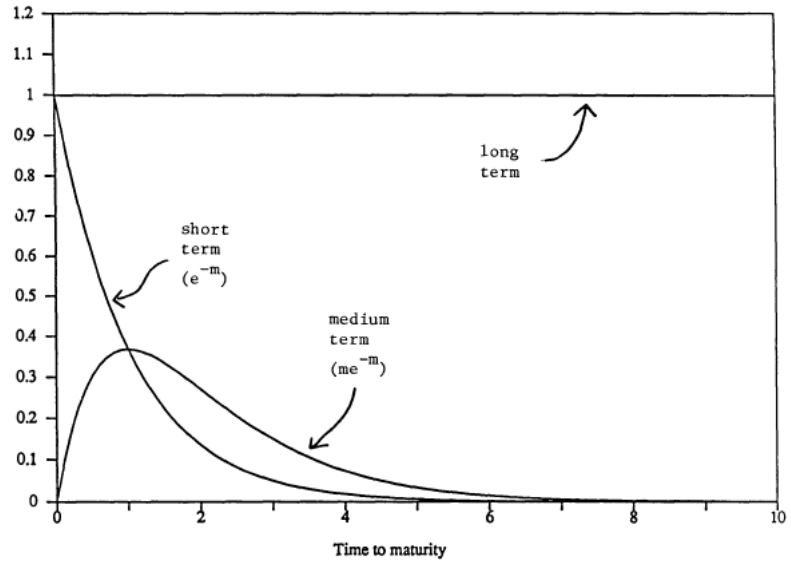


Source 32 - Nelson and Siegel (1987)

The two economists concluded that, in relation to the forms generated, their model could well represent all possible relationships between Yield To Maturity and Maturity without the need to add other parameters.

Various interpretations can be given to the parameters of the model; Nelson & Siegel attribute to the $\beta's$ the measure of the strength of the long, medium and short-term components.

Figure 34 - Components of forward rate curve



Source 33 - Nelson and Siegel (1987)

The long term component (β_0) remains constant over maturity, indicating that its usefulness acts on the entire curve; the medium term component (β_2) starts and ends at zero, indicating that it mainly acts in the medium term maturities but not as influential as the long term component.

Finally, the short-term component (β_1) is the one that decays most quickly to zero because its influence decays marginally as maturity advances.

The parameter τ represents a constant that ensures a specific slope of the yield curve.

A higher value of τ corresponds to a faster decay; in relation to this, it can be deduced that τ is mainly responsible for the final component of the yield curve.

3.2.1. Diebold and Li interpretation

Diebold and Li (2006), building on Nelson Siegel's model, reinterpreted the parameters of the B's.

$$y_t(\tau) = \beta_{1t} + \beta_{2t}\left(\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau}\right) + \beta_{3t}\left(\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau} - e^{-\lambda_t\tau}\right) \quad (3.17)$$

The formula above represents a function that starts at 1 at Maturity 0 and decays to 0 at infinite maturity.

Always considering the three components: long, medium and short term, they have associated the B's with the classification of level (L), slope (S) and curvature (C).

$$y_t(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau}\right) + C_t\left(\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau} - e^{-\lambda_t\tau}\right) \quad (3.18)$$

L_t is multiplied by the constant 1 so it does not change with maturity; this comes from the fact that $y(T=\infty) = \beta_1$ and also because a change in β_{1t} affects each yields.

This implies that a change il L_t would shift the level of the curve.

Diebold and Li (2006) evaluated the short term coefficient S_t (or β_2) as the difference between $y(T = 10\ years) - y(T = 3\ months)$.

The factor of β_2 rapidly goes from 1 to 0, implying that it most affects the short term and so it relates to the slope of the curve.

The two authors defined medium-term factor(β_3) as the responsible for the curvature of the curve; this because of the greater influence it has on the medium range of maturities compared with very small or very high maturity; they define the curvature as:

$2y(T = 2\ years) - y(T = 10\ years) - y(T = 3\ months)$.

Following Nelson & Siegel (1987), they fix λ as constant, allowing the usage of simple and linear ordinary least squares for the computation.

They define λ as the factor that determines the maturity at which the loading of the curvature component reach the maximum.

In conclusion, the forward rate of the model can be rewritten as:

$$f(\tau) = \begin{bmatrix}\beta_0 \\ \beta_1 \\ \beta_2\end{bmatrix}\begin{bmatrix}1 \\ e^{-\frac{\tau}{\lambda}} \\ \left(\frac{\tau}{\lambda}\right)e^{-\frac{\tau}{\lambda}}\end{bmatrix} = \begin{bmatrix}\beta_0 \\ \beta_1 \\ \beta_2\end{bmatrix}\begin{bmatrix}f_0 \\ f_1 \\ f_2\end{bmatrix} \tag{3.19}$$

The model consists of three factors.

β_0 is associated with a constant (f_0), β_1 to an exponential decay function (f_1) e β_2 to a Laguerre function.

The Laguerre functions are the solutions to the equation:

$$xy'' + (\alpha - x + 1)y' + ny = 0 \; with \; \alpha \; and \; n \; parametri \; arbitrary \tag{3.20}$$

The solutions to equation (3.20) are called Laguerre polynomials.

In (3.19) the constant represents the long-term interest rate level; the exponential decay function is the responsible for the slope of the curve: $\beta_1 > 0$ imply a downward slope while $\beta_1 < 0$ an upward.

Finally, the Laguerre function, expressed as xe^{-x} in the model is the one that cause a hump $(\beta_2 > 0)$ or a through $(\beta_2 < 0)$.

As said before, the function representing the spot rate is determined by the mean of the forward rate curve up to maturity:

$$r(\tau) = \frac{1}{\tau}\int_0^{\tau} f(u)du \tag{3.21}$$

and the spot rate function at τ *is:*

$$r(\tau) = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \end{bmatrix} \begin{bmatrix} 1 \\ \lambda(1 - e^{-\frac{\tau}{\lambda}})/\tau \\ \lambda(1 - e^{-\frac{\tau}{\lambda}})/\tau - e^{-\frac{\tau}{\lambda}} \end{bmatrix} = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \end{bmatrix} \begin{bmatrix} r_0 \\ r_1 \\ r_2 \end{bmatrix} \quad (3.22)$$

3.3. Empirical Analysis

The aim of my analysis is to look at the behaviour and performance of green bonds. In particular, I want to study how they have reacted and are reacting in periods of prolonged stress such as the one we are experiencing now related to Covid-19.
To do this, I compared their performance with that of conventional bonds by relating the Yield Curves of Green Bonds with those of European indices of corporate bonds.
To construct my Yield Curves necessary for the analysis I use the model of Nelson & Siegel.

3.3.1. Data collection and processing

For the model I need, for each date, pairs of observations of Yield to Maturity (YTM) and Duration of Green Bonds.
The Duration provides an indication, at each date, of the time required for the bond to repay the initial investment; therefore, are considered in the calculation all the coupons paid during the life of the bond.
This means that a rise in interest rates implies a fall in the price of the bond and an increase in the duration.
Longer durations are correlated to a greater sensitivity to changes in interest rates.
I decided to implement my analysis on two different categories of bonds divided by rating.
As a benchmark for the ratings I used the Bloomberg Index Ratings.
This index groups together the ratings of 4 ratings agencies: Moody's, Standard & Poor, Fitch and DBRS.

For the calculation of the index each agency is assigned the same weight for their rating; through an algorithm a number is defined which will define the final rating.

Table 3 - Bloomberg Index

	INDEX RATING	MOODY'S	S&P	FITCH	DBRS
1	AAA	Aaa	AAA	AAA	AA
2	AA+	Aa1	AA+	AA+	AA high
3	AA	Aa2	AA	AA	AA
4	AA-	Aa3	AA-	AA-	AA low
5	A+	A1	A+	A+	A high
6	A	A2	A	A	A
7	A-	A3	A-	A-	A low
8	BBB+	Baa1	BBB+	BBB+	BBB high
9	BBB	Baa2	BBB	BBB	BBB
10	BBB-	Baa3	BBB-	BBB-	BBB low
11	BB+	Ba1	BB+	BB+	BB high
12	BB	Ba2	BB	BB	BB
13	BB-	Ba3	BB-	BB-	BB low
14	B+	B1	B+	B+	B high
15	B	B2	B	B	B
16	B-	B3	B-	B-	B low
17	CCC+	Caa1	CCC+	CCC+	CCC high
18	CCC	Caa2	CCC	CCC	CCC
19	CCC-	Caa3	CCC-	CCC-	CCC low
20	CC	Ca	CC	CC	CC
21	C	C	C	C	C
22	D	D			

Source 34 - Bloomberg, Index Methodology

The data used in this analysis was sourced from the Bloomberg platform.
First, I filtered the bonds to search for those issued by European companies denominated in Euro.
The second filter applied was the Use of Proceeds.

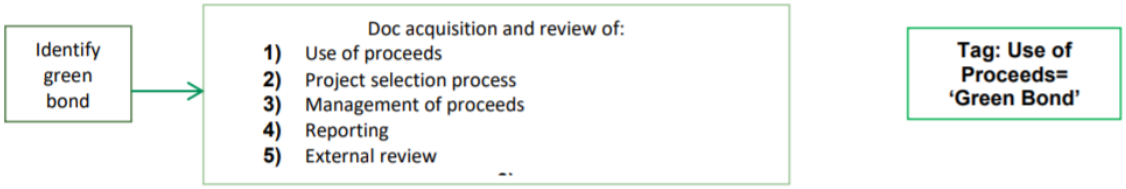
Figure 35 - Bloomberg Use of proceeds classification

Source 35 - Bloomberg platform

Bloomberg uses Use of Proceeds as a metric to label bonds as "Green Bonds"; a bond falls under this category if the issuer self - labels the bond as Green or if there is clear

communication about the use of the funds raised towards activities or projects within the Green Bond Principles (GBP) category.
100% of Use of Proceeds must be devoted to environmental sustainability activities consistent with the GBP Principles.
As a requirement to qualify for this labelling, Bloomberg does not require an additional disclosure but does require a prospectus showing the uses of proceeds.

Figure 36 - Bloomberg Green Bond Labeling Process



Source 36 - Databases and Indices Working Group, June 2018

Once applied these filters I then selected the Rating categories in this way:

1. **AAA Category:** AAA, AA+, AA, and AA- rated bonds.
2. **A Category:** there are bonds rated A+, A and A-.

The final selection includes 49 bonds for the AAA category and 51 for the A one.
The useful data for the analysis is the Yield To Maturity; for each bond I have downloaded the daily observations of the YTM for the period between 02/01/2019 and 18/03/2021.
At this point, for having my database complete, I have retrieved the duration data for the analysed period.
In order to find the time series for the selected period I have applied the following formula in Excel:
=BQL ("Cusip number", "duration (dates=range (-3Y, 0Y, frq=D), pricing_source=BVAL)")

This formula allows you to search for the duration of the security by entering the Cusip number [7], for the reference period and with desired frequency for observations.

[7] Social security number used to identify a security.

Once this phase has been completed, I have 3 different Excel files available containing the historical series for each bond category, for the selected period, of the corresponding values of YTM and Duration.

3.3.2. Model Application

The analysis of the data has been carried out with the software RStudio.
Green bonds are relatively young instruments (in Italy the first green bond was issued in 2014 by the Emilian multiutility Hera) so it was necessary to group them by different duration ranges in order to obtain at most 4 to 5 observations for each bond category.
For the first category I used 5 different maturities (4, 6, 8, 10 and 13 years) and for the second one I used 4 maturities (4, 6, 8 and 10 years).
For each category I decided to exclude observations with duration less than four years because I recorded excessive volatility due to both the increase in the number of trades on that security related to the upcoming maturity and the relative lack of maturity of the security leading to instability.
For each date I have grouped the observations of the yields that had, as corresponding duration, the value within the range and there, for each date, I average the observations in relation to the tenors of duration.
These are all the input values necessary to apply the Nelson & Siegel model.

3.4. Estimation Results

3.4.1. AAA Rated Bonds

This first category is, based on my analysis, the most representative of the entire study. AAA and AA bonds are present in this category; it is therefore possible to obtain a more stable result and more easily comparable with reference indices.

Figure 37 - Time Series (Observed values vs Nelson & Siegel values vs Residuals) for Yield (AAA rated bonds) with 4 years duration

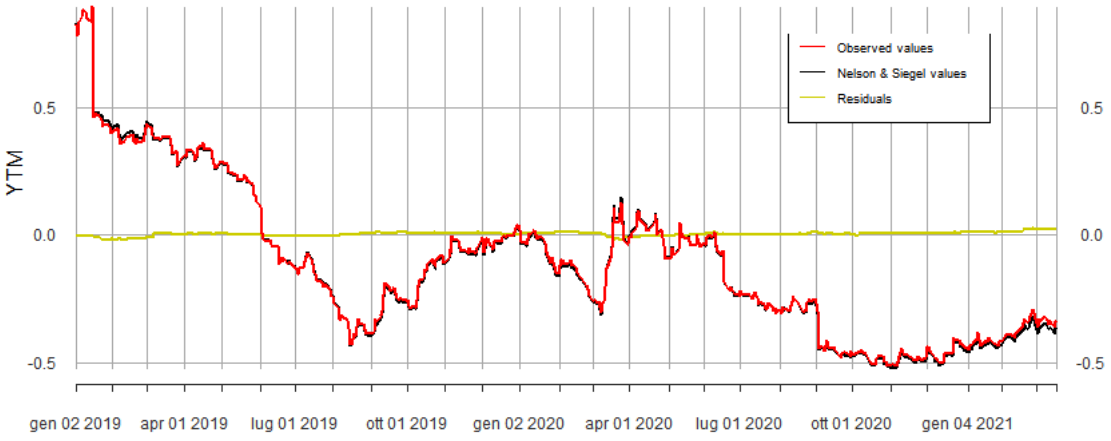


Figure 38 - Time Series (Observed values vs Nelson & Siegel values vs Residuals) for Yield (AAA rated bonds) with 6 years duration

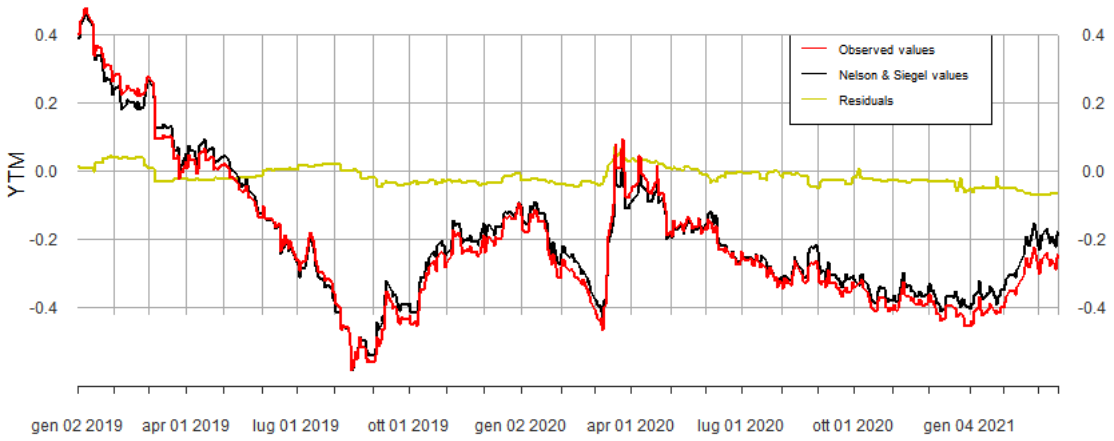


Figure 39 - Time Series (Observed values vs Nelson & Siegel values vs Residuals) for Yield (AAA rated bonds) with 8 years duration

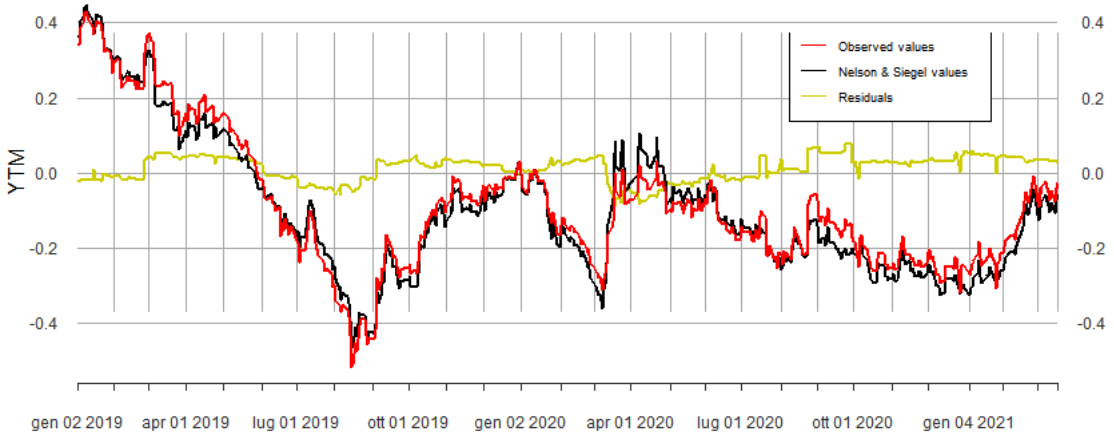


Figure 40 - Time Series (Observed values vs Nelson & Siegel values vs Residuals) for Yield (AAA rated bonds) with 10 years duration

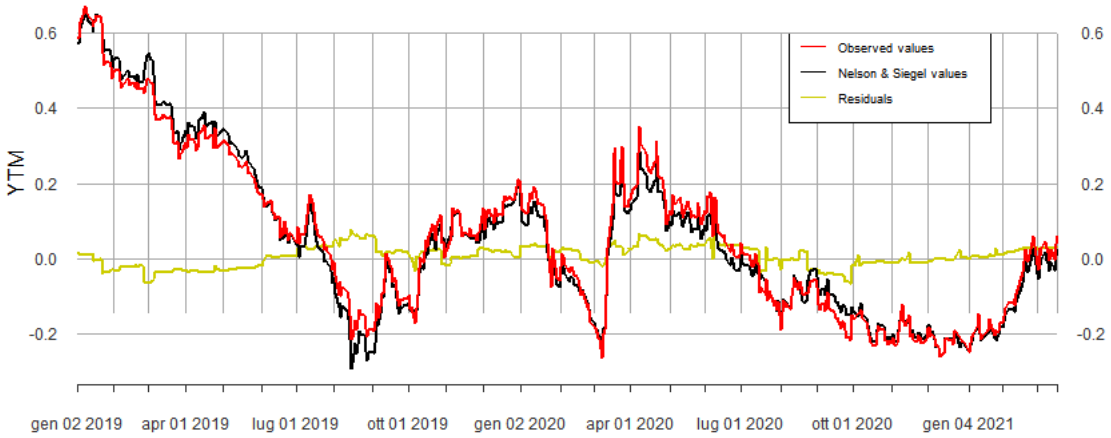
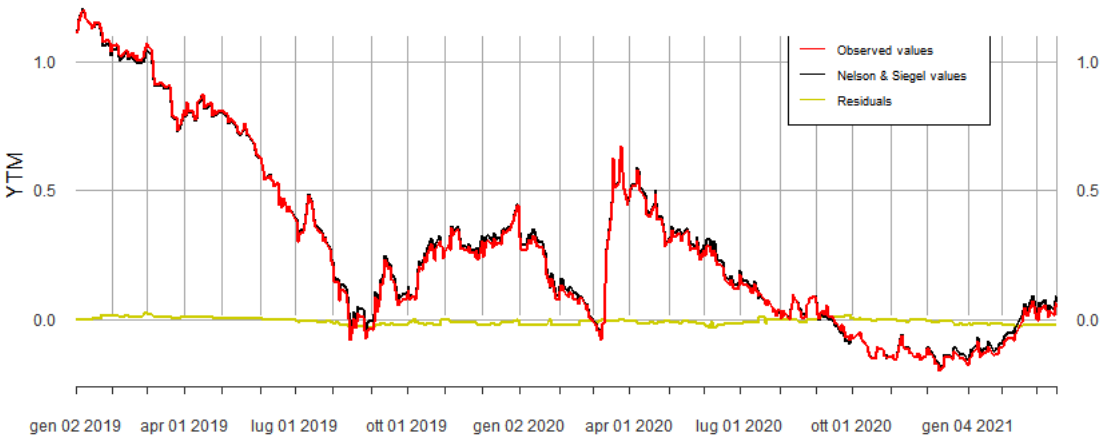


Figure 41 - Time Series (Observed values vs Nelson & Siegel values vs Residuals) for Yield (AAA rated bonds) with 13 years duration



The figures above show the time series of observed and model-fitted term structure for the observed period; in addition, the green line indicates the residuals for each observed date.

For all 5 graphs, the model appears to accurately fit the observed data.

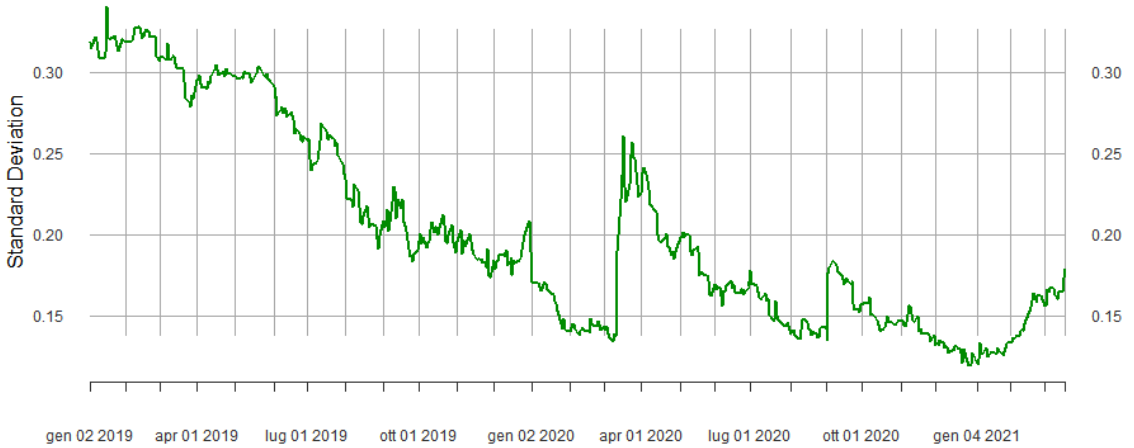
Indeed, by averaging the residuals for the 5 time series and computing their standard deviation it can be seen that the results provide a first evaluation parameter for the "good fit" of the model.

Table 4 - Residuals analysis (AAA rated bonds)

	4y Maturity	6y Maturity	8y Maturity	10y Maturity	13y Maturity
Mean	0.004042069	-0.015785679	0.012435791	0.006787218	-0.007479398
St. Deviation	0.008823825	0.03095346	0.03524802	0.02891938	0.01404963

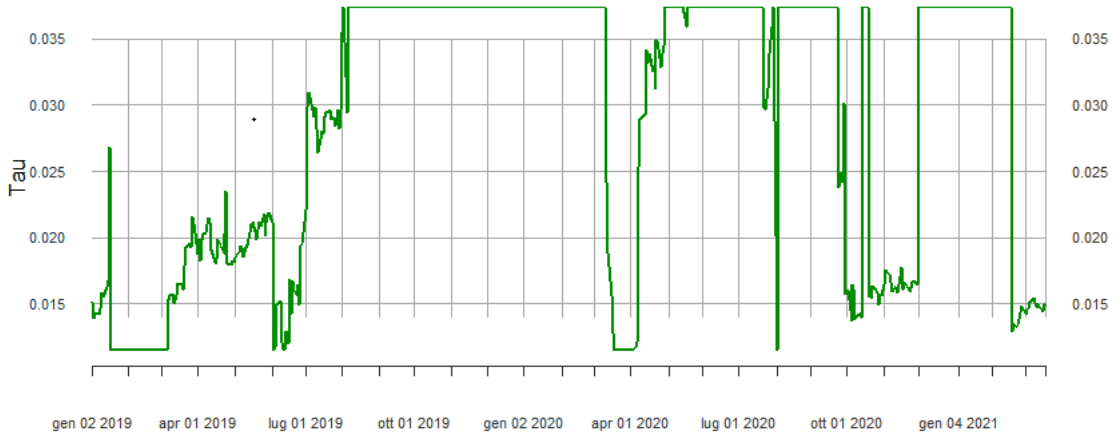
Then, I computed the standard deviation in every date for the fitted values for the analysed period; it is immediately noticed graphically like the course resumes the pattern of the fitted curves.

Figure 42 - Standard deviation for each observable date (AAA rated bonds)



Then, I plot the time series of Tau to understand its behaviour through the period.

Figure 43 - Tau Time Series (AAA rated bonds)



τ determines the maturity at which the loading on the medium-term, or curvature factor, achieves its maximum.

As in Nelson & Siegel (1987) ”Small values of τ imply a rapid decay in the regressors and therefore will be able to fit curvature at low maturities well while being unable to fit excessive curvature over longer maturity ranges”.

Table 5 - Tau descriptive statistics (AAA rated bonds)

	Mean	**Min**	**Max**	**SD**
Tau	**0,02885091**	**0,01149389**	**0,03735375**	**0,01042047**

The R Squared of the model is, on average, equal to 0.9750319.

The R-squared is a measure of the goodness of fit of a linear regression; it indicates the percentage of the variance of the dependent variable that is explained by the independent variable.

Figure 44 - R Squared time series (AAA rated bonds)

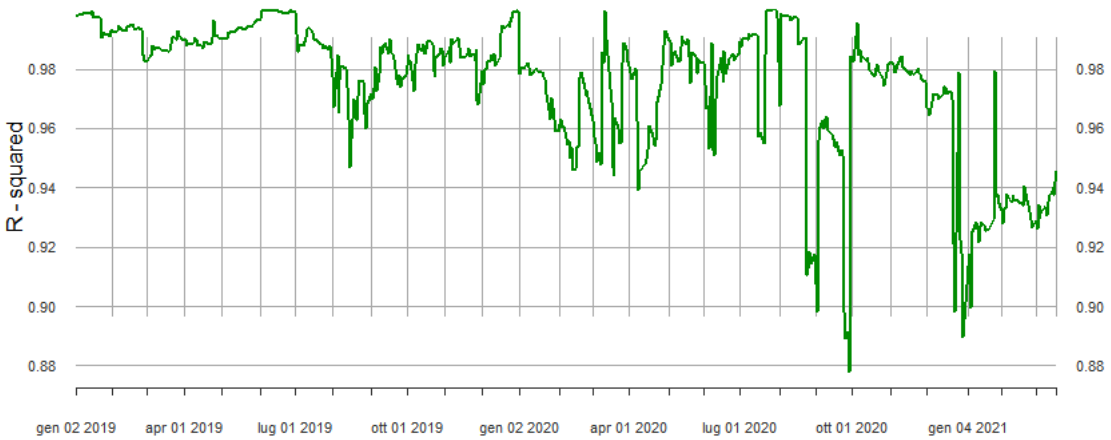
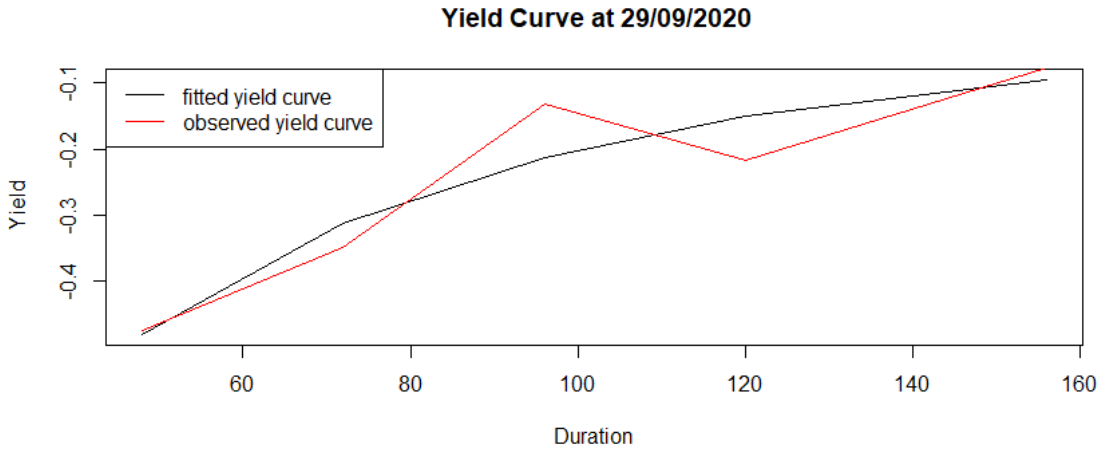


Table 6 - R^2 descriptive statistics (AAA rated bonds)

	Mean	Min	Max
R Squared	**0,9750319**	**0,8780235**	**0,9999981**

The lowest value found is 0.8780235 corresponding to the date 29/09/2020.

Figure 45 - Yield Curve at 29/09/2020

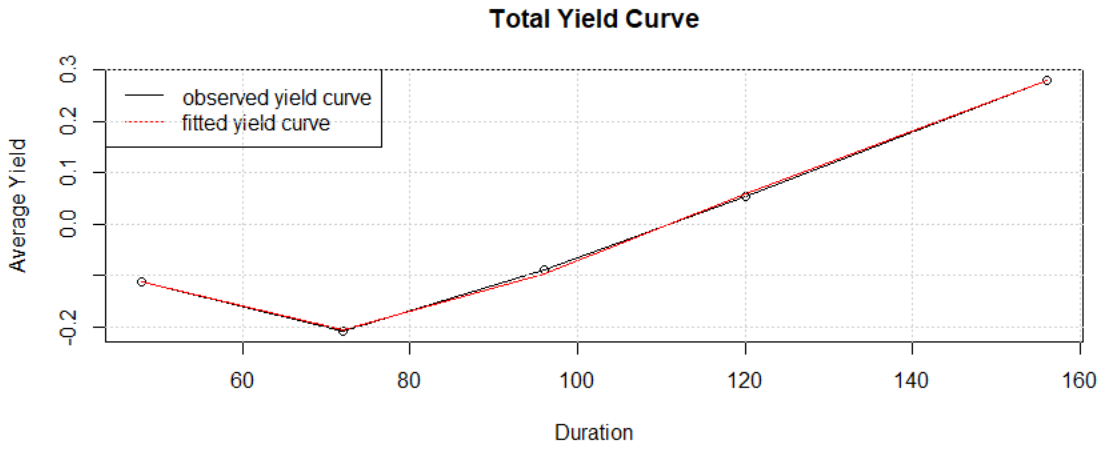


The value of R - Squared in this date, despite coinciding with the minimum found is still very satisfactory.

The thing that is highlighted is how the Nelson & Siegel model, by its nature and its characteristics, tends to fit a curve as smooth as possible.

Finally, for each maturity (4,6,8,10 and 13 years) I computed the average of the observed value. The results are five points corresponding to the average observed value at each maturity. Then, I applied the model to understand the general trend of the Yield Curve in the selected period.

Figure 46 - Average Yield Curve (AAA rated bonds)



The curve is a positively sloped yield curve which is considered the normal shape for a yield curve.

This type of trend shows that, long term bonds have higher yield needed compensate for the extra amount of risk for taking the bond longer.

A slight downward shift in the curve can be noted at the 6-year maturity.

This may be the result of excessive volatility and yields that were too high in the previous period (4 years).

3.4.2. A Rated Bonds

Next, I repeated my analysis for the second category corresponding to the A - rated bonds.

Figure 47 - Time Series (Observed values vs Nelson & Siegel values vs Residuals) for Yield (A rated bonds) with 4 years duration

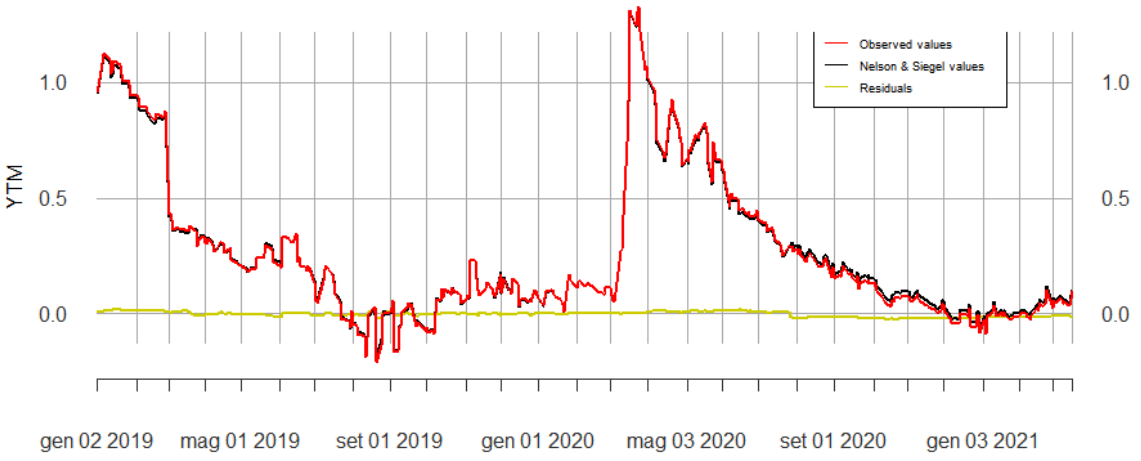


Figure 48 - Time Series (Observed values vs Nelson & Siegel values vs Residuals) for Yield (A rated bonds) with 6 years duration

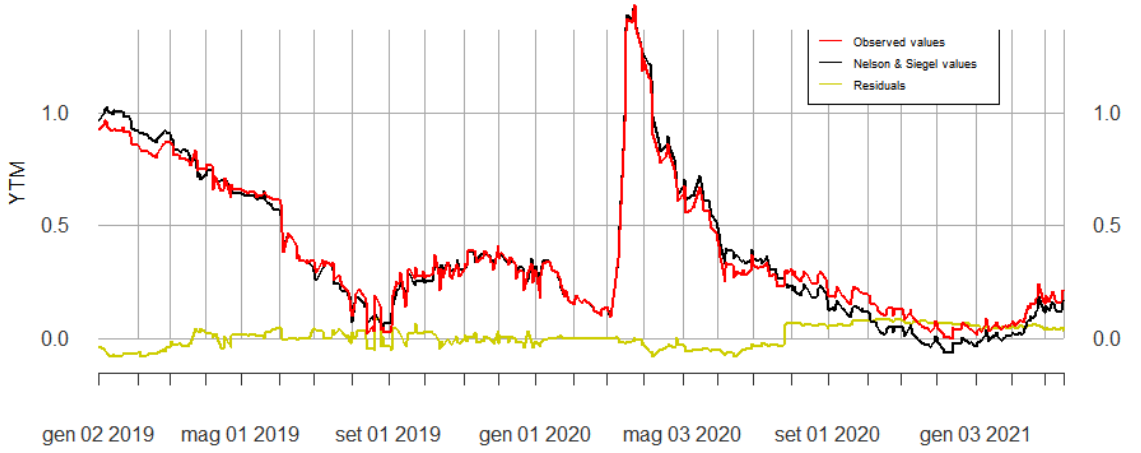


Figure 49 - Time Series (Observed values vs Nelson & Siegel values vs Residuals) for Yield (A rated bonds) with 8 years duration

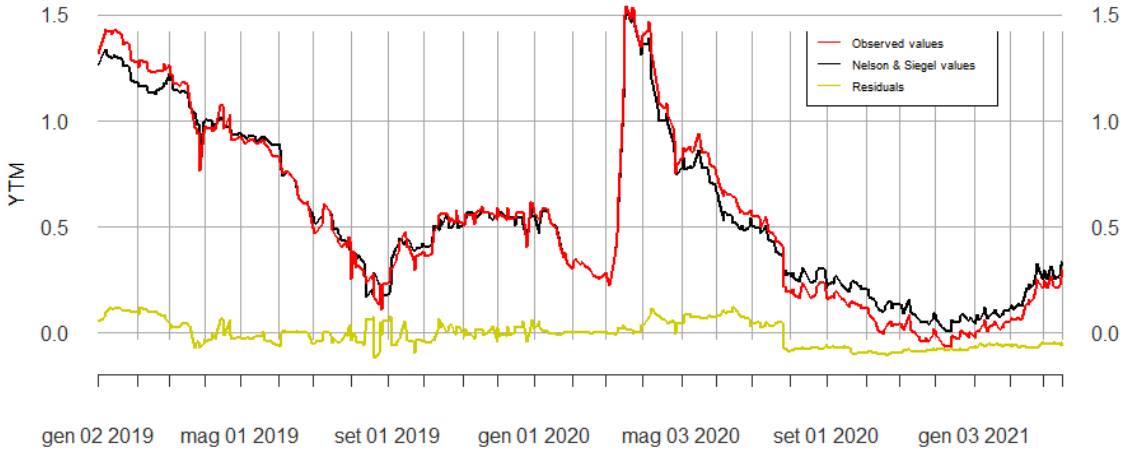
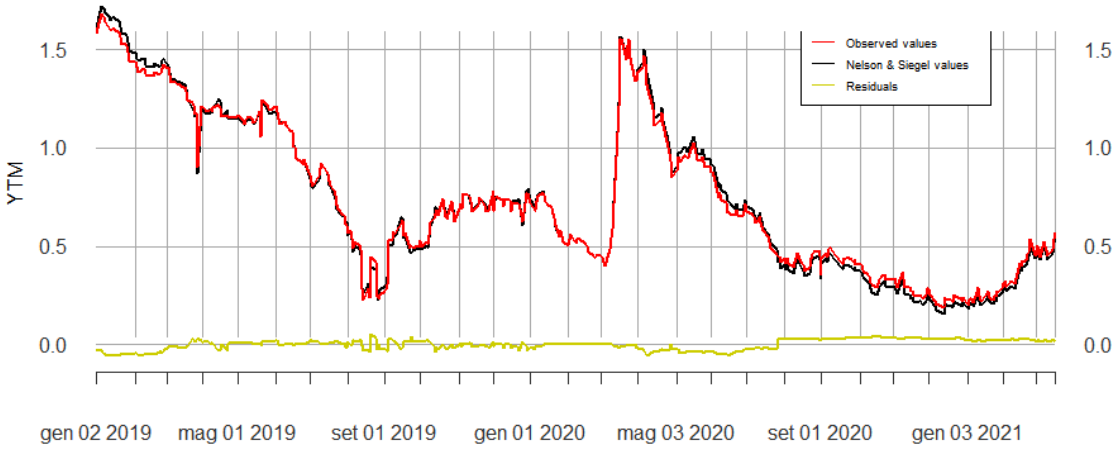


Figure 50 - Time Series (Observed values vs Nelson & Siegel values vs Residuals) for Yield (A rated bonds) with 10 years duration



Again, we note from the analysis of the residuals that the fitted observations do not deviate excessively from the observed observations suggesting the adequacy of the model.

Table 7 - Residuals analysis (A rated Bonds)

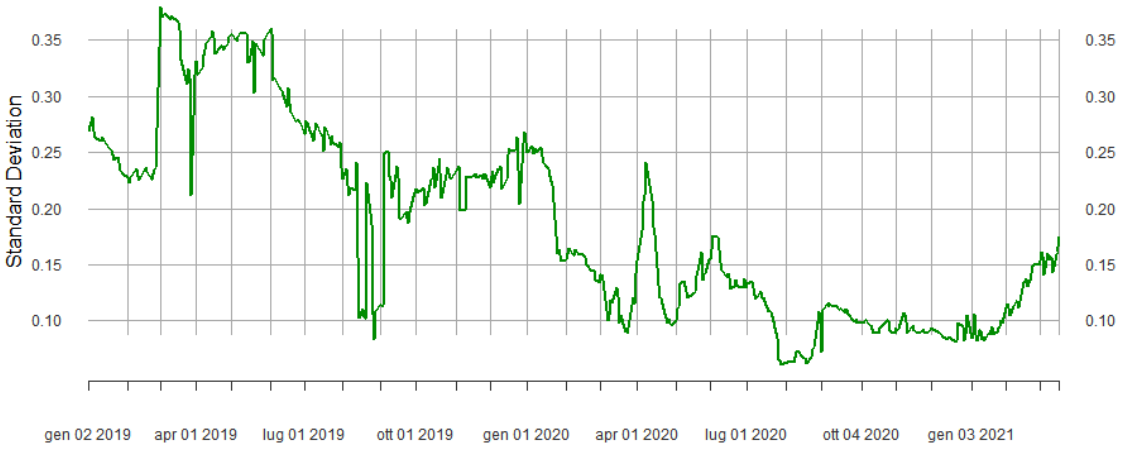
	4y Maturity	6y Maturity	8y Maturity	10y Maturity
Mean	**-0,00328601**	**0,009015466**	**-0,00733007**	**0,001600614**
St. Deviation	**0,01169058**	**0,04605945**	**0,06023161**	**0,02590011**

As in the case of AAA - rated Bonds, I computed the standard deviation in every date for the fitted values for the analysed period; the historical series of the standard deviation follows the trend of the fitted curves.

In this case, however, the historical series has a more discontinuous pattern due to the presence of downward or upward peaks in the fitted observations.

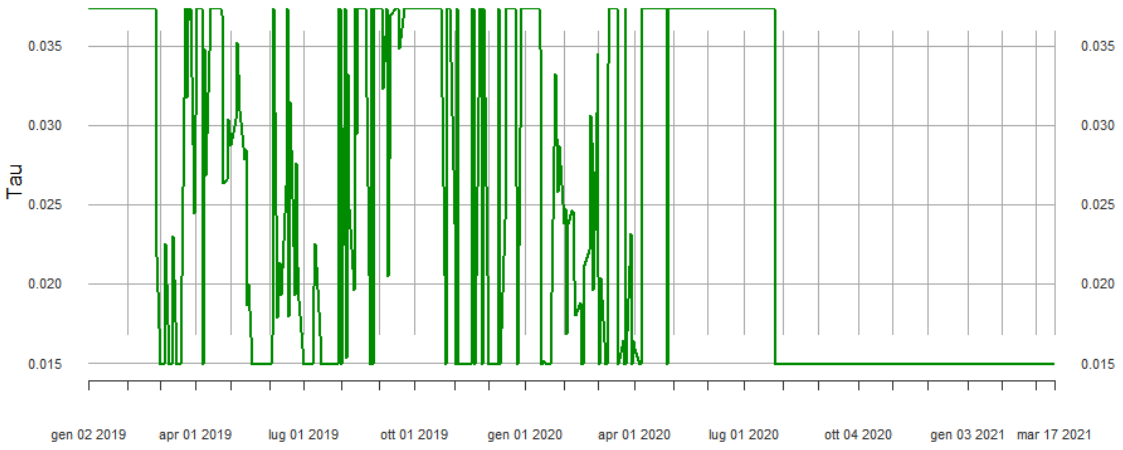
In general, however, its values hover around an average of 0.2015018.

Figure 51 - Standard deviation for each observable date (A rated bonds)



In this situation, Tau values are in line with those observed previously (AAA category).

Figure 52 - Tau Time Series (A rated bonds)



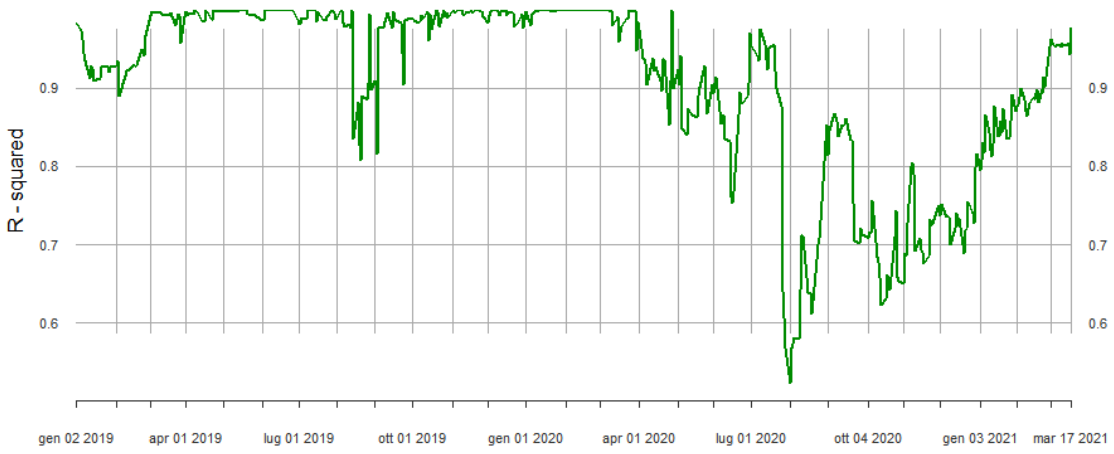
The slightly lower mean (0.02475537 in category A vs 0.02885091 in AAA) indicates that, on average, the maximum point of curve curvature was reached at lower values.

Table 8 - Tau descriptive statistics (A rated bonds)

	Mean	Min	Max	SD
Tau	**0,02475537**	**0,01493534**	**0,03735375**	**0,01046157**

Analysing the R - Squared, it is clear especially in the final part of the period observed, they tend to decrease compared to the very good initial levels.

Figure 53 - R Squared time series (A rated bonds)



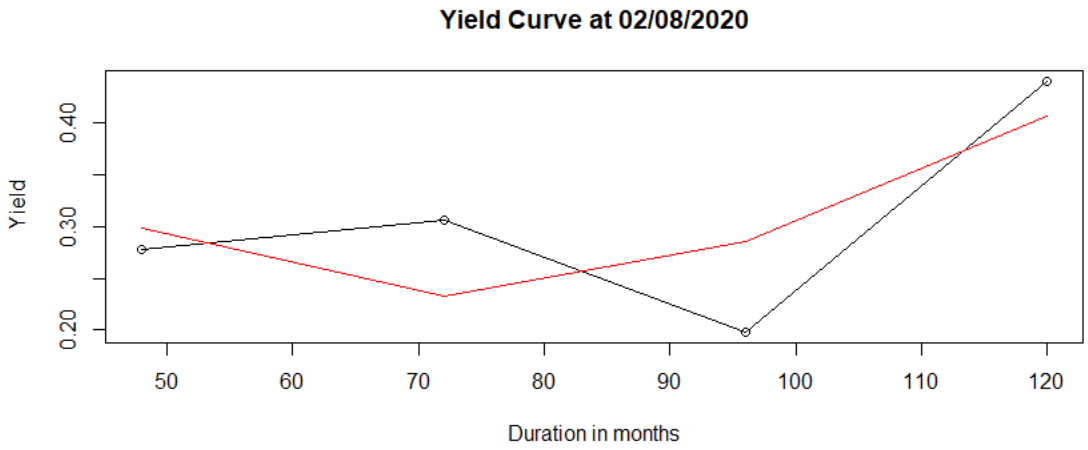
In fact, while the average remains at a good value, the lowest observed value has reached a much lower level than what was observed in the AAA category.

Figure 54 - R Squared descriptive statistics (A rated bonds)

	Mean	Min	Max
R Squared	**0,9067103**	**0,5219035**	**1**

The lowest value found is 0.5219035 corresponding to the date of 02/08/2020.

Figure 55 - Yield Curve at 02/08/2020



Graphically it can immediately be notice how, for some maturities,the fitted values fails to properly explain the behavior of the observed values. In particular, analyzing in detail the values corresponding to the maturity of 6 years, it can be seen immediately that the yield curve shows a trend opposite to that of the observed one.

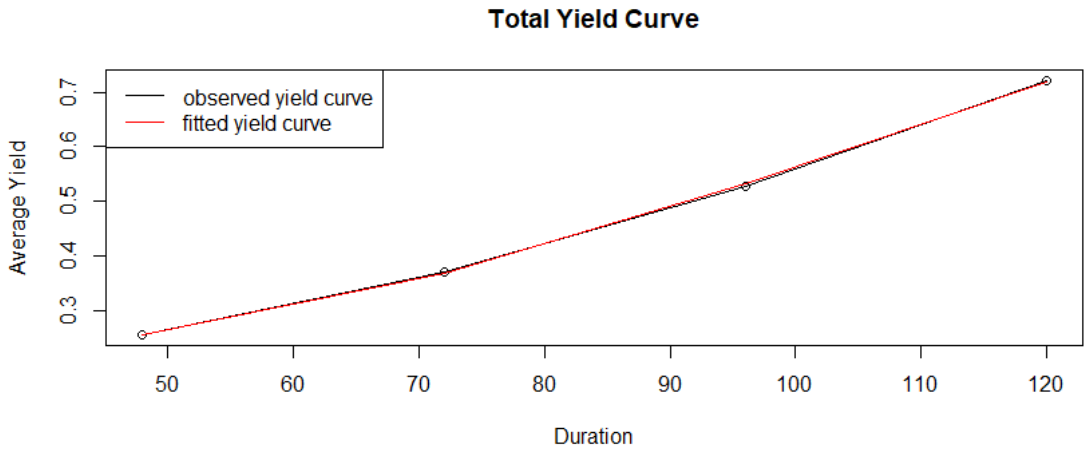
Table 9 - Descriptive statistics at 02/08/2020

	4y Maturity	6y Maturity	8y Maturity	10y Maturity
Observed Values	**0.2778889**	**0.306**	**0.198**	**0.44025**
Fitted Values	**0.2982777**	**0.2325782**	**0.2851711**	**0.4061119**
Residuals 02/08/2020	**-0.02038884**	**0.07342179**	**-0.08717108**	**0.03413813**
(Residuals mean)	**(-0,00328601)**	**(-0,00901546)**	**(-0,00733007)**	**(-0,001600614)**

This behavior explains why, according to the value found of R - Squared, only 50% of the variance is explained by the model.

Finally, I averaged the observations for each date and applied the model to see the overall trend of the curve.

Figure 56 - Average Yield Curve (A rated bonds)



Here, more clearly than in the AAA category, there is a purely positive trend with no downward inflection.

3.5. Index Performance comparison

In this part, I analyse the performance of the instruments described above by comparing their performance with that of conventional bonds during periods of stress such as the current one related to Covid - 19.

Especially, I investigate whether green bonds are more resilient during periods of risk-off.

The coronavirus crisis is raising more and more discussions about the need to implement significant changes in the areas of climate change risk management, social justice and generally rethinking the model of society we are living in now.

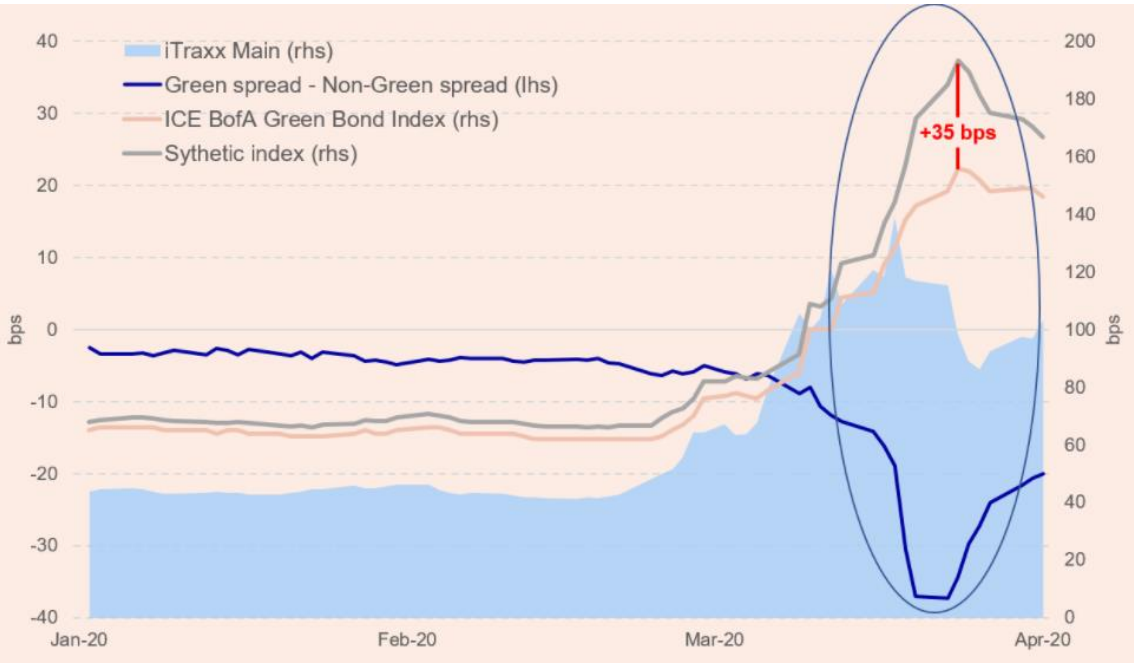
The fundamental point is only one: the planet will not be able to sustain the rhythms to which we have become accustomed for much longer.

This is the starting point of my reasoning and analysis.

Can these tools actually resist periods of crisis and greater uncertainty? Can they be the solution to the problem?

Nordea bank in its analysis shows how the spread between the ICE BofA Green bond Index and a Synthetic index reached its minimum in March 2020, at the peak of the Sythetic Index.

Figure 57 - Green bond performance during the Covid-19



Source 37 - Nordea (2020)

Furthermore, analysing the crisis period prior to this one, the beginning of 2016, where a number of factors including the drop in oil prices and the crash in the Chinese stock market led to a financial situation comparable in uncertainty to the one we have today, the analysis shows that the spread difference between green bonds and non-green spreads also in this case reached its lowest point of the period corresponding to a peak in the iTraxx[8].

Figure 58 - Green bonds performance during Q1 2016

Source 38 - Nordea (2020)

Clearly, there can be various reasons behind these results.

One of the reasons is that green bonds are not issued by oil producing companies and therefore this eliminates all risk from black gold.

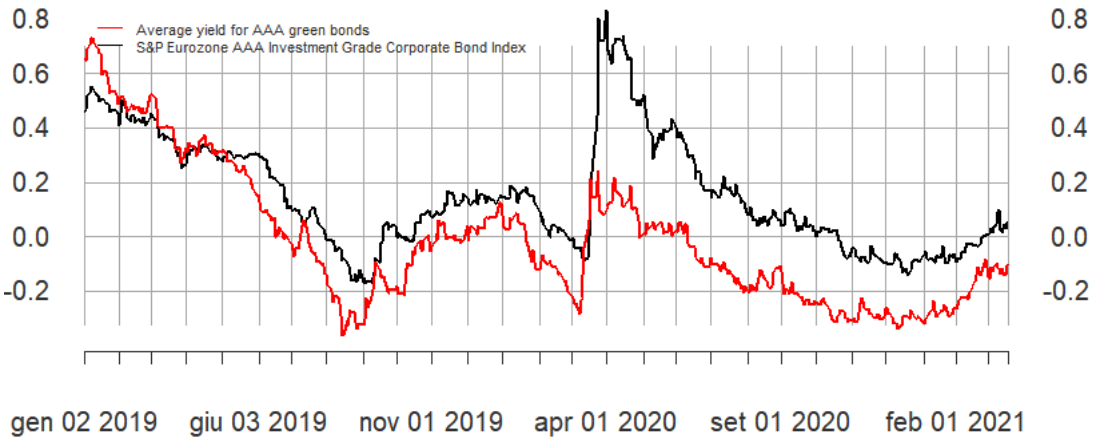
In addition, the issuers of green bonds are mostly very large companies with long-term goals.

The capital raised by green bonds is directly linked to projects of the same type; this makes it clear that this is actually a plus point in times of extreme volatility.

[8] A derivative financial instrument that offers the possibility of taking positions on the probability of default (bankruptcy) of a basket of issued securities.

If, for example, a bond is intended to raise funds for the construction of a wind farm, it will not be affected by the current crisis.
Certainly, delays may occur but the project, its nature and identity remain unchanged.

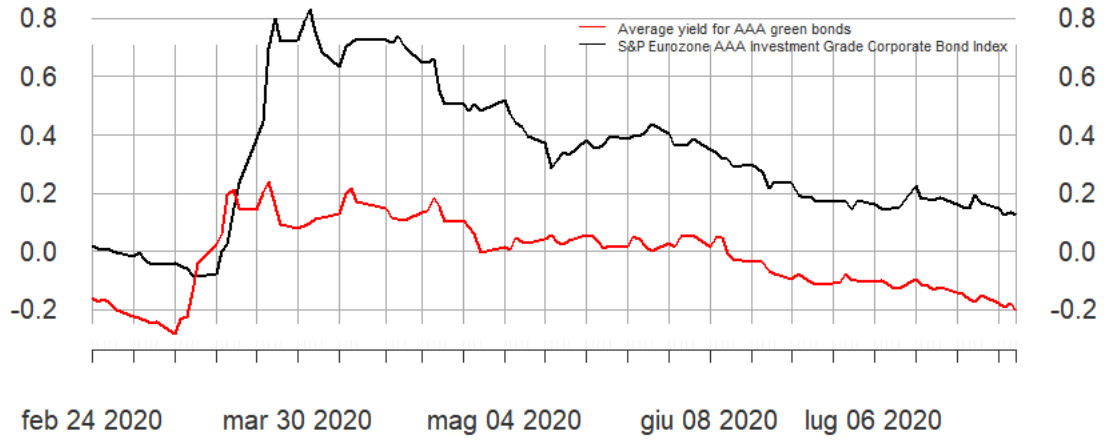
Figure 59 - Comparison between AAA corporate bond index and Average Yield for AAA rated green bonds



In this graph I compare the performance of the S&P Eurozone AAA Investment Grade Corporate Bond Index with that of my data for the selected period.
To do this, I have averaged all the time series for the 5 duration periods examined and then constructed a single curve.
The first meaningful result, visible graphically, is that the trends of the two curves are very similar for all the analysed period.
Indeed, the correlation among the two curves is 0.806004.
This result is not surprising; in fact, both curves are formed by instruments belonging to the same categories (AAA) and, in both cases, the bonds are subject to the same market stimuli. If we can see that the trend between the two lines is similar, considering the period between February and April 2020 we can see differences in their behaviour.

Inspecting the reporting period, between late January and late April:

Figure 60 - Comparison between AAA corporate bond index and Average Yield for AAA rated green bonds during Covid-19



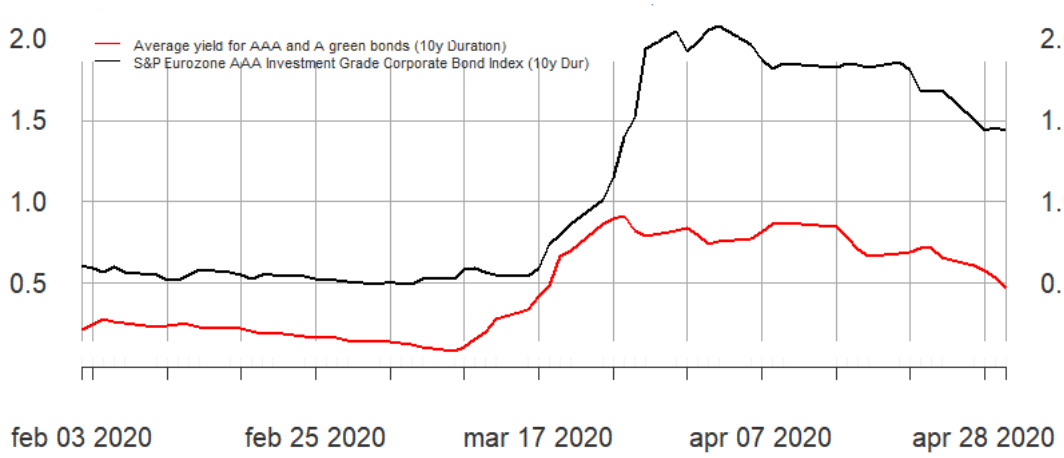
Also, in this case the correlation is high equal to 0.8901914.
The difference between the minimum and maximum reached for the index is 0.915 while that for the Average Yield of AAA bonds is 0.52.

Table 10 - Descriptive statistics of AAA categories index and average green bonds

	Min	**Max**	**Spread**
Average AAA - rated bonds	**-0,28474**	**0,240653**	**0,525393**
AAA rated - bonds Index	**-0,085**	**0,83**	**0,915**

This result provides a first indication of how, in a period of high risk due to global events, green bonds, while suffering price increases, manage to defend themselves better.
Going into more detail, I averaged the yields with a duration of 10 years belonging to both categories (AAA and A) and compared them with the S&P Eurozone 7-10 Year Investment Grade Corporate Bond Index.

Figure 61 - Comparison between S&P Eurozone 7-10 Year Investment Grade Corporate Bond Index and Average Yield for AAA – rated and A – rated green bonds for 10y duration bonds



Again, the spread is higher for index-linked performance.

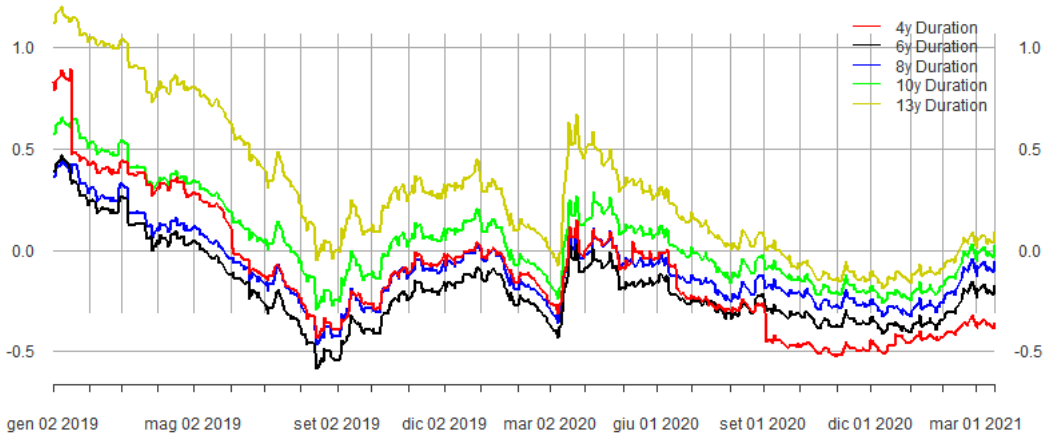
Figure 62 - Descriptive statistics of S&P Eurozone 7-10 Year Investment Grade Corporate Bond Index and average green bonds (10 years duration)

	Min	**Max**	**Spread**
Average AAA/A - rated bonds	0,078202	0,91588	0,837678
10Y Index	0,49	2,08	1,59

Conclusion

In general, comparing all (AAA - rated) curves based on their duration shows that in 2021 they are returning to pre-Covid levels and, even during the second wave, they reacted and are reacting significantly more positively than the first wave.
Certainly, the situations and variables to be considered in this second wave are quite different. The distribution of vaccines has started and there is a greater knowledge and sensitivity towards this disease.

Figure 63 - Fitted Yields for AAA rated bonds

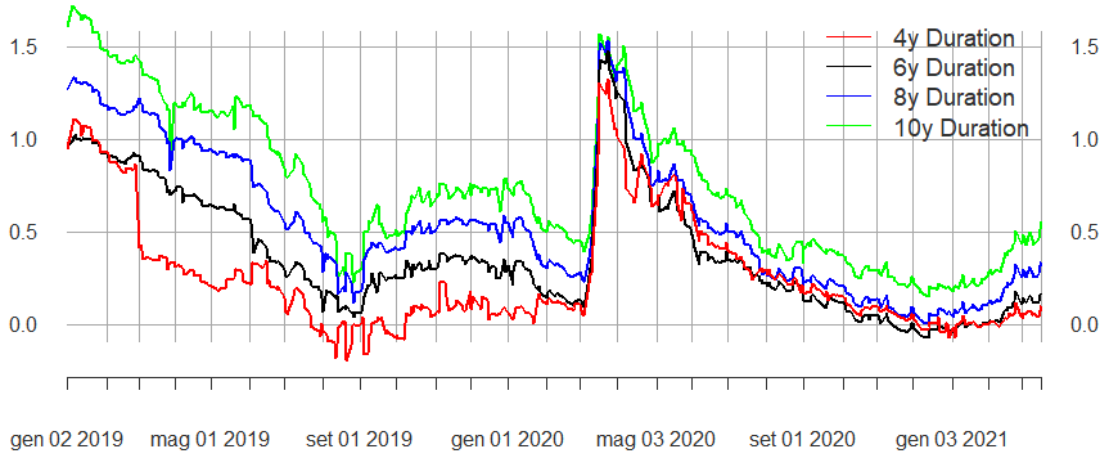


The bonds that have suffered most are those with higher maturities; this is understandable because they have incorporated in their value both their natural risk deriving from the fact of having a higher maturity and the shock linked to the period.

Table 11 - Performance spread during Covid-19 (AAA rated bonds)

	4y Maturity	6y Maturity	8y Maturity	10y Maturity	13y Maturity
Min	-0,3122628	-0,4306178	-0,3591638	-0,2427312	-0,07889951
Max	0,1481474	0,02733796	0,1062274	0,2864864	0,6711254
Spread	0,4604102	0,45795576	0,4653912	0,5292176	0,75002491

Figure 64 - Fitted Yields for A rated bonds



In this case, we do not see a substantial difference between the different maturities. This can be explained by the fact that the performance spreads between the period for Covid-19 and that during Covid-19 are already very high.

Table 12 - Performance spread during Covid-19 (A rated bonds)

	4y Maturity	6y Maturity	8y Maturity	10y Maturity
Min	0,0501203	0,09347272	0,2282271	0,3991344
Max	1,326274	1,475861	1,534218	1,567729
Spread	1,2761537	1,38238828	1,3059909	1,1685946

What I have been able to observe with this analysis has led me to draw the following conclusions.

Green bonds, in an intuitive way, are highly correlated related to conventional bonds.

Anyway, it has been shown that they have reacted better to this Covid-19 period. The reasons for this can be varied.

One of the main assumptions that must be considered is the period we are going through. Every day we are bombarded with news about environmental and climate protection. More and more companies are championing environmental justice by promoting campaigns and sponsoring products.

All this is part of a trend that leads us to consider as safe something that we consider right. It's also true that we all know the consequences of climate change. More and more often we are witnessing environmental disasters and slowly we are finally realizing that this pace cannot be sustained for long.

Indeed, as the analysis shows, these instruments are classified as safer at this time. Whether they can be the solution to new crises or whether they can restart the renaissance is perhaps too early to say.

What we can see, however, is that the Covid - 19 will be overcome and we will be able to defeat it; our planet, on the other hand, will remain and we cannot afford to leave it behind.

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