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Macroeconomic policies for climate change

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Dedico questo traguardo alla mia famiglia, ai miei genitori, ai miei nonni, ai miei zii ed ad ogni singolo componente che mi ha supportato e fatto capire l'importanza di questi anni di studio e di sacrifici.

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SUMMARY

"*Economics, as it has emerged, can be made more productive by paying greater and more explicit attention to the ethical considerations that shape human behaviour and judgment.*" – Amartya Kumar Sen

INTRODUCTION

In recent years we have all become aware of the fact that the climate is changing. One indisputable fact is the average global temperature, which has been rising for more than a hundred years.
More and more frequently we are witnessing extreme events scattered more or less all over the planet, to name but a few: hurricanes in the United States, in the Philippines, droughts in Iraq, California or Brazil, and incessant rainfall causing considerable damage, particularly in France and north Italy.
Due to extreme weather events, according to the National Centers for Environmental Information (NCEI) the U.S. has sustained 285 weather and climate disasters where the overall damage costs reached or exceeded $1 billion. The cumulative cost for these 285 events exceeds $1.875 trillion.[1]
But why is the climate changing? How can we make an economy more aware of the damage of climate change? What can be done to control (at least partially) and marginalise these phenomena? How to accompany the economy in this context of epochal induced transition?
The world has a finite number of resources, while economic and demographic trends behave as if this limit do not exist.
The cause of this change can be said to be mainly human action, from the consumption of fossil energy to the irrational use of the soil, from the devastation and destruction of forests to excessive urbanisation. An action that began many years ago and is difficult to curb today.
The change we are experiencing today at an environmental level could lead, tomorrow, to much more serious and complex economic damage, to be managed and contained, much more significant even than that of a possible economic crisis, with associated problems of unemployment, pension management and monetary crisis. It is the climate itself that guarantees the stability of the economic systems we have, and the moment this stability fails, everything collapses.
It is therefore our duty to ask: how can we limit climate change?

[1] Adam B. Smith (2021). "*2020 U.S. billion-dollar weather and climate disasters in historical context*". Beyond the data. January 2021

The solution may come by sculpting the behaviour of agents in the economic system, even spending a little more today but with the aim of spending less tomorrow, so as to compromise as little as possible the reality in which we live. Macroeconomic policies have the power to direct, change and above all "educate" the economic system in order to maximise our overall utility. That is why their objective must be to take more account of the effects of climate change.

The purpose of this thesis is to describe and analyse the main macroeconomic policies for mitigating climate change and supporting the economy in a transition context.

The thesis will be structured as follows:

- Chapter I: The first step towards climate change mitigation and the transition to a green economy is to set common and achievable goals. This chapter describes in detail the main long and medium-term global objectives against climate change and beyond. Since the 1990s, empirical evidence of global warming has raised the awareness of the international community. The Kyoto Protocol, from 1997, was a milestone in the recognition of the danger of global warming. More recently, other targets and action plans have been put in place. In 2015 the United Nations Assembly adopted a 15-year global plan of action to end poverty, reduce inequality and protect the environment, through the pursuit of 17 Sustainable Development Goals (SDGs). In the same year, 196 countries adopted, with the Paris Agreement, the first global contract on the environment, setting themselves the objectives of keeping the temperature increase well below 2 degrees Celsius and maintaining the increase at 1.5 degrees Celsius. In the European context respecting the objectives of the Paris Agreement, the Green Deal was introduced, an action plan that will enable the EU to become zero net pollutant emissions by 2050.
- Chapter II: Achieving the targets requires action plans and instruments. The second chapter focuses on the main macroeconomic policies to reduce carbon emissions and to support the economy in this transition period. Starting with fiscal policies to price carbon or green subsidies to promote renewable energy. Moving on to monetary policies to support the economy in the physical and transitional risks caused by climate change. And ending with policies to regulate the financial and non-financial markets, through the imposition of an emissions cap or the promotion of green companies through financial incentives.

- Chapter III: Global warming has real effects on the world economy: an increase in the intensity and frequency of extreme weather events can easily affect the productivity of a country and its sectors, or, in response to climate change, several sectors of an economy could be destroyed by technological transaction. From here we can outline the two main risks to be taken into account when designing economic policies: Transitional and Physical risks. This chapter will give a description of what are the transitional and physical risks caused by climate change. It will then describe how they can be assessed in the financial context to "educate" investors in more climate-responsible actions.
- Chapter IV: The impacts of climate change have direct effects on macroeconomic variables. Think of extreme weather events that destroy entire industrial systems, or households that see their homes demolished as a result of climate disasters. The effects can be measured directly on macroeconomic variables such as consumption, investment or public spending. This chapter will analyse, in order of importance, the main macroeconomic models that attempt to introduce the possible impacts of climate change on economic, social and energy systems. Starting from the large family of Integrated Assessment Models, where many disciplines are integrated, the chapter will conclude with simulations of climate change policies using a DICE model with different climate sensitivity scenarios.

CHAPTER I GOALS FOR CLIMATE CHANGE

The concept of environmental sustainability has been the subject of growing interest in civil society over the years. It is the result of a greater awareness of the exhaustibility of the planet's resources and of the increasing need to preserve the quality of the natural heritage, aiming to promote models of economic and social development that are more balanced than those adopted in the past.

Sustainable development is a multifaceted and multidisciplinary concept proposed as a value or objective, sometimes as a reference model to which to strive in order to overcome the "unsustainable" logic of profit and growth sought so far. The idea of environmental sustainability was born between the 1970s and 1980s, when the world began to realize the need to change the model of global development, moving from the libertine consumerism of a part of the population, which, however, had damaged the natural resources of the entire planet, to a more measured and judicious use of the environment and its products. By environmental sustainability we mean the need to benefit from natural resources in a way that is strictly limited to the capacity of those resources to regenerate themselves, thus respecting the fragile balance of this complex system that is the environment. If we think of a medium- to long-term perspective, it is essential to allow future generations to enjoy the same environmental resources that we have found and from which we have so far increasingly benefited. Over the last 50 years, due to the relentless process of globalisation, the western world has understood development as synonymous with material and quantitative growth, so that the successes achieved in the economic field have entailed huge costs in human, social and environmental terms, demonstrating that development, in the ways pursued so far, must be considered unsustainable.

The widespread poverty and inequality we are witnessing are not the product of failed development, but often the indirect consequence of the same development policies that have produced economic growth for only a few. Today's figures show that only a minority of the world's population has become rich, while the majority, which is increasing in number, has been condemned to poverty, hunger, economic isolation and social and environmental degradation. Bearing in mind that we now number more than 7.8 billion people, and we are exploiting more than 1.75 "Earth" in term of resources consumption.[2] That means we are not following the three conditions of sustainability of Herman Daly, a system can only be environmentally sustainable if:

- The rate at which renewable resources are exploited is less than the rate at which they are regenerated.
- The input of polluting particles and waste into the environment does not exceed its capacity to assimilate them, i.e. its carrying capacity.
- The depletion of non-renewable resources is compensated for by switching to replacement renewable resources.[3]

The repercussions are increasing poverty in a growing part of the planet, North-South inequality and inequality within countries, and worsening environmental damage to the point of jeopardizing the balance of the ecosystem. In the light of the crisis of recent years, the promotion of sustainable development - i.e., as we shall see below, one that combines environmental protection with social and economic development in a way that is sustainable and accessible to future generations - must now be seen as a choice.

The general economic crisis that struck the entire world system ten years ago (2008 subprime mortgages), and from which we have been slowly recovering for some years now, has revealed the limits of a totally deregulated globalised market, of a market based on a system of free competition where state sovereignty has been overtaken by the transnationality of economic power with a one-way development towards material growth. Thinking in sustainable terms means bringing globalisation to politically shared principles: the action of broad institutional structures, e.g. European Union, the United Nations or other governmental powers, must operate with respect for social progress and climate change, legitimizing market action by addressing the basic imbalances created by a process arbitrated only by economic forces.

It is therefore necessary to set common goals for environmental sustainability and to analyze the various policies and instruments of achieving them. In recent decades, following empirical analyses of the impacts of climate change on the economic system, governments and international institutions have mobilized to reach agreements to limit

[2] UN environment program see at https://www.unep.org/news-and-stories/story/were-gobbling-earths-resources-unsustainable-rate
[3] NP4SD See at https://np4sd.org/about/herman-daly/

the advance of this phenomenon. The difficulties in ensuring that these agreements are properly respected, lie mainly in finding the right trade-off between economic and environmental sustainability. As will be discussed later, in addition to the physical and economic damage caused by climate change (extreme natural phenomena, migration, etc.), there could also be damage caused by the economic transition towards non-polluting or low-carbon sectors. This transition, if unregulated, could severely affect the sectors that currently contribute to the country's economy.

In the following chapters, we will describe the main international targets for decreasing, if not eliminating, carbon emissions, thus trying to mitigate the effects of climate change.

1.1 SUSTAINABLE DEVELOPMENT GOALS

On 25 September 2015, the United Nations Assembly adopted a 15-year global plan of action to end poverty, reduce inequality and protect the environment, through the pursuit of 17 Sustainable Development Goals (SDGs). Since the 2012 Conference on Sustainable Development in Rio de Janeiro, Brazil, the SDGs have been built on critical aspects of the MDGs' work on poverty eradication, tackling socio-economic inequalities, decent work and social inclusion, promoting gender equality, risk management and resilience, sustainable use of natural resources, good governance, peace and stability.[4]

The 2030 Agenda for Sustainable Development revolves around five key words - People, Planet, Prosperity, Peace, Partnership - and clearly and explicitly integrates the three dimensions of development - social, economic and environmental - overcoming previous sectoral logics (e.g. health, education) with a predominantly social character. The plan consists of 17 SDGs and 169 implementation targets for their achievement. Although the new goals have some similarities with the MDGs[5], they go much deeper. In fact, the 2030

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[4] United Nations, Report of the United Nations Conference on Sustainable Development, A/CONF.216/16, Rio de Janeiro, Brazil, 20–22 June 2012. The Report of the High-Level Panel of Eminent Persons on the Post-2015 Development Agenda, A New Global Partnership: Eradicate Poverty and Transform Economies through Sustainable Development, United Nations, 2013, Annex I. Open Working Group of the General Assembly on Sustainable Development Goals, Proposal for Sustainable Development Goals, 2014, http://sustainabledevelopment.un.org/content/documents/1579SDGs%20Proposal.pdf.

[5] Millennium Development Goals – they range from halving extreme poverty rates to halting the spread of HIV/AIDS and providing universal primary education, all by the target date of 2015.

Agenda is not only concerned with the social pillar, but also extends to the economic and environmental pillars, clearly stating that international cooperation must be synergetic and comprehensive. The challenges of dignity, socio-economic inequality and sustainable development are global and everyone has to get involved: the 17 SDGs are universal, i.e. they apply to all countries: developed and developing countries. The motto of the 2030 Agenda is "Leaving no one behind".[6]

" Goal 1. End poverty in all its forms everywhere.

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Goal 3. Ensure healthy lives and promote well-being for all at all ages.

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Goal 5. Achieve gender equality and empower all women and girls.

Goal 6. Ensure availability and sustainable management of water and sanitation for all.

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

Goal 10. Reduce inequality within and among countries.

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable.

Goal 12. Ensure sustainable consumption and production patterns.

[6] United Nations, Transforming our world. The 2030 Agenda for Sustainable Development, A/RES/70/1, 2015, https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.

Goal 13. Take urgent action to combat climate change and its impacts.[7]

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.

Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.[8]*"*

In July 2015, the Third International Conference on Financing for Development took place in Addis Ababa, Ethiopia, during which high-level political representatives - following an extensive consultative process involving institutional actors, non-governmental organisations (NGOs) and other private sector entities - reached a negotiated agreement that includes:

1. A new international framework for financing sustainable development that aligns financial and policy flows according to economic, social and environmental priorities;
2. A set of policy actions to be put in place by states, declined in over 100 concrete measures to draw on the resources of finance, technology, innovation, trade, statistics in order to mobilize all possible means for the achievement of the SDGs.

"Multi-stakeholder partnerships and the resources, knowledge and ingenuity of the private sector, civil society, the scientific community, academia, philanthropy and foundations, parliaments, local authorities, volunteers and other stakeholders will be important to mobilise and share knowledge, expertise, technology and financial resources, complement the efforts of Governments, and support the achievement of the

[7] Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.
[8] Sustainable Development Knowledge Platform, website, https://sustainabledevelopment.un.org.

sustainable development goals, in particular in developing countries".[9] *The Sustainable Development Goals* (SDGs) also relaunch *the multi-stakeholder partnership* for global development, operatively involving all the actors that animate the cooperation scenario and beyond. Indeed, the universal value of the new goals, which aim to work towards reducing the inequalities that permeate even the most advanced countries, will in fact involve an even wider range of actors in the challenge for sustainable development, and no longer just for sustainable development cooperation.

The environmental sustainability dimension underpins all SDGs and SDG13 is specifically dedicated to combating climate change. The 2030 Agenda explicitly states that the United Nations Framework Convention on Climate Change (UNFCC) is the privileged forum where the international response to climate change is negotiated intergovernmentally. Here, in December 2015 at the Paris Climate Conference (Conference of Paris-COP21), 197 countries adopted the first universal and legally binding global climate agreement. The Paris Agreement, signed on 22 April 2016, entered into force on 4 November 2016, with 122 states ratifying it. The Agreement sets out a global plan of action to: i) keep the average global temperature increase well below 2°C compared to pre-industrial levels as a long-term goal, aiming to limit the increase to 1.5°C, as this would significantly reduce the risks and impacts of climate change; ii) improve capacities to adapt to the adverse effects of climate, promote climate resilience and reduce pollutant emissions, so that food production is not threatened; iii) ensure that financing is directed towards the first two goals.[10]

As will be noted in the next chapter, the Paris Agreement is a major step forward from the past and an effective and lasting international commitment to managing climate change. Governments have also agreed to meet every five years, to set more ambitious targets based on scientific knowledge, and to publicize as widely as possible the strategies undertaken and progress made, through a system based on transparency and accountability.[11]

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[9] United Nations, General Assembly, Resolution adopted by the General Assembly on 27 July 2015: Addis Ababa Action Agenda of the Third International Conference on Financing for Development (Addis Ababa Action Agenda) (A/RES/69/313), 17 August 2015, par. 10, http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/69/313.
[10] United Nations Framework Convention on Climate Change, website, http://unfccc.int/2860.php.
[11] Paris Agreement, United Nations 2015, http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf.

1.2 THE PARIS AGREEMENT (COP21)

At the Paris Climate Conference (COP21) in December 2015, 196 countries adopted the first universal and legally binding Global Climate Agreement[12]. The Agreement was reached on 12 December 2015 and entered into force on 4 November 2016, following ratification by the EU. The Agreement sets out a global plan of action, intended to put the world back on track, with the aim of avoiding dangerous climate change and seeking to limit global warming to below 2°C. It is applied from 2020.

"The Paris Agreement is a landmark in the multilateral climate change process because, for the first time, a binding agreement brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects."[13]

Specifically, the main points of what governments have agreed to in the agreement are the following[14]:

- Keeping the average global temperature increase well below 2°C above pre-industrial levels as a long-term goal;
- Aim to limit the increase to 1.5°C, as this would significantly reduce the risks and impacts of climate change;
- Ensure that global emissions peak as soon as possible, while recognising that developing countries will need more time;
- Then proceed to rapid reductions in accordance with the most advanced scientific solutions available.

[12] The list of countries that have ratified the Paris Agreement is available at the following link: http://newsroom.unfccc.int/media/632121/list-of-representatives-to-high-levelsignature-ceremony.pdf.
[13] United Nations Climate Change – The Paris Agreement - https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[14] Reference to the European Commission document, (last updated 28 September 2017), "Paris Agreement"

Main elements of the Paris Agreement:

- *Long-term goal*: Governments agreed to keep the global average temperature increase well below 2°C above pre-industrial levels and to continue efforts to limit it to 1.5°C;
- *Contributions*: Before and during the Paris Conference, countries presented comprehensive national climate action plans to reduce their emissions,
- *Ambition*: governments agreed to report their contributions every five years to set more ambitious targets;
- *Transparency*: they also agreed to communicate - to each other and to the public - their achievements in implementing their targets in order to ensure transparency and scrutiny;
- *Solidarity*: the EU and other developed countries will continue to provide climate finance to developing countries to help them both reduce emissions and become more resilient to the effects of climate change.[15]

The Paris Climate Agreement also recognises the importance of addressing the losses and consequences of the adverse effects of global warming and the need for all of us to work together, preparing for emergencies and insuring against risks.

In detail:[16]

OBJECTIVES. The Paris Agreement thus constitutes a global plan of action, with the aim of putting the planet back on track, to avoid dangerous climate change. It seeks to keep global warming well below 2°C and to implement initiatives to try to limit the temperature increase even further to 1.5°C above pre-industrial levels.

CONTRIBUTIONS AND AMBITION. In the run-up to the Paris Conference, countries presented their "*Nationally Determined Pledged Contributions*[17]" (INDCs) to outline their commitment to tackling climate change. But these contributions submitted by 186 countries are not enough to keep the global average temperature increase below 2°C by

[15] European Council, Council of the European Union, (2017), "*Paris Agreement on Climate Change*".
[16] EEA, European Environment Agency - (article published 22/01/2016 - last modified 06/07/2017), "*Climate agreement: towards a low-carbon world capable of low-carbon world capable of responding to climate change*".
[17] See at this regard Nationally Determined Contributions (NDC) and Pledge Pipeline - https://unepdtu.org/publications/nationally-determined-contributions-ndc-and-pledge-pipeline/

the end of the century. Much more needs to be done to achieve long-term goals, both globally and in the EU, and the Paris Agreement recognises the need for further efforts. To this end, governments have agreed to meet every five years to set more ambitious targets that meet the needs identified by science.

TRANSPARENCY AND SOLIDARITY. Countries agreed on the need to share progress in implementing their targets and to ensure transparency and accountability. A robust system based on transparency and accountability will monitor progress over the long term. The Paris Agreement focuses on the principle of transparency, therefore, (just mentioned), and also on the principle of solidarity in the fight against climate change. The EU and other developed countries will continue to support actions to reduce emissions and improve the ability to cope with the effects of climate change in the most vulnerable developing countries.

In the European Environment Agency's 2017 updated document "*Climate agreement: Towards a low-carbon world able to respond to climate change*" (also referred to above), it is also stated that the latest projections of EU Member States show that by 2020 the EU can achieve a 24% reduction in greenhouse gas emissions with current measures, and 25% with additional measures already being planned in the Member States.

However, analysis by the European Environment Agency shows that to achieve this target of a 40% reduction by 2030, new policies need to be put in place, particularly in terms of increased adaptation efforts. An EU-wide adaptation strategy already exists to help countries plan their adaptation activities, and more than 20 European countries have already adopted national adaptation strategies. According to a recent EEA report, most countries stated that extreme weather events are the reason for implementing adaptation measures. In second place, among the most cited reasons for developing national adaptation policies are EU policies integrating climate change adaptation, followed by damage costs and scientific research. An EEA report also from 2017 indicates that 14 countries have systems already in place or under development for monitoring, documenting or evaluating national adaptation policies.

A key element of the Paris Agreement is the transition to clean energy, which requires a reallocation of investment from polluting fossil fuels to clean energy sources, both globally and in Europe. However, this will require a strong involvement not only of countries, but also of cities, businesses and civil society. A carbon-neutral energy system would certainly be the best that could be desired from a global perspective for limiting and reducing greenhouse gas emissions, but these efforts should be placed in the context of a lifestyle that respects the limits of our planet.

1.3 EUROPEAN GREEN DEAL

Focusing on the European context, the focus on climate change and the construction of a zero-emission, green, fair and sustainable European Union has definitely become a key prerogative in recent years. The fight against CO2 emissions and environmental protection are key points of the policy that the European Commission is developing for the coming years. There is now a widespread awareness that it is only with a new growth strategy that places environmental protection at its core that Europe, and the world as a whole, can move towards a better future. The need to act at a community level has been evident for years, and sustainable economic development plays a decisive role in the physical risks caused by rising temperatures because as stated by the European Commission in Europe:

- carbon dioxide levels will double and summer sea temperatures will rise by 2-3° Celsius by 2030;
- one third of ozone depleting gas emissions are produced;
- 50% of the surface area of ecosystems is threatened by management problems and other stress factors;
- an average of 700,000 hectares of forests burn each year, often due to fires caused by “socio-economic factors”, leading to the progressive degradation of forests.[18]

These macro problems - which we will look at later as the main risks of economic default - have been caused by several factors. The factors in question are:

- more than 75% of greenhouse gas emissions are linked to energy production and consumption;
- Europe's industrial sector is responsible for 30% of greenhouse gas emissions;
- building construction and renovation methods implemented to date use 40% of all energy consumed;

[18] European commission - https://ec.europa.eu/clima/change/causes_it

- 20% of food production is wasted;
- industrial centres spend up to €189 billion on the health problems they cause;
- 25% of greenhouse gas emissions come from transport;
- populations of wild species have declined by more than 50% in the last two generations.[19]

Towards a green transition, the Green Deal was presented to the European Commission on 11 December 2019, summarising strategies towards zero greenhouse gas emissions by 2050, thus making the whole continent "climate neutral".

"The European Green Deal will transform the EU into a modern, resource-efficient and competitive economy[20]".

The European Green Deal is an action plan setting out the strategic legislative and economic initiatives that the EU is committed to implementing over the next few decades with a view to the green transition.

The main objective is to play its part in limiting the increase in global warming, which, according to the estimates of the UN's Intergovernmental Panel on Climate Change (IPCC), must remain within 1.5 °C compared to pre-industrial times in order not to cause enormous damage to the planet and therefore to the human species. In order to comply with this limit, set by the 2015 Paris Agreements, the European Union has committed to zero net pollutant emissions by 2050, and to meet interim targets for 2030. In fact, the strategic plan includes a decrease of at least 55% in greenhouse gas emissions. From this main objective, other more specific objectives cascade[21]. The first - and most important - is to clean up electricity production, which currently accounts for 75% of greenhouse gas emissions in the European Union. Another essential objective is to make more sustainable a whole series of human activities that currently consume a large amount of energy, or produce an excessive amount of pollution: it means introducing new rules for building or renovating houses and industries, making production processes less polluting, increasing public and rail transport, promoting biodiversity and making the circular economy even more widespread.

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[19] European Commission - https://ec.europa.eu/commission/presscorner/detail/it/ip_21_3541

[20] European Commission - https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

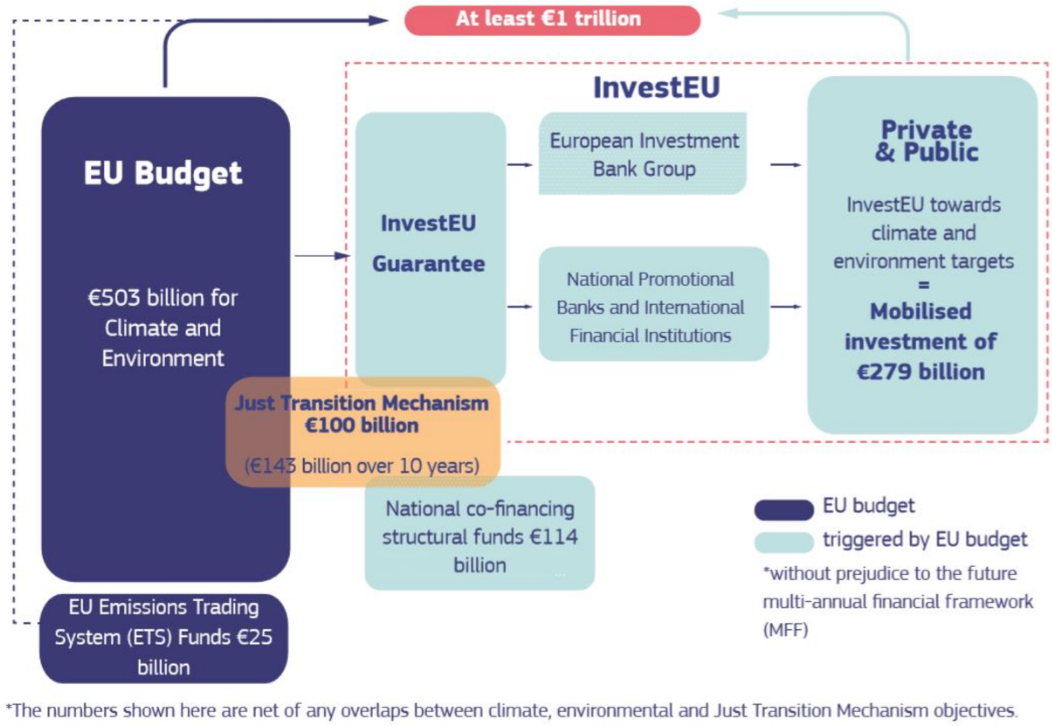
[21] Centro Regionale Di Informazione Delle Nazioni Unite - https://unric.org/it/obiettivo-13-promuovere-azioni-a-tutti-i-livelli-per-combattere-il-cambiamento-climatico/

The Green Deal takes a holistic approach, recognizing that to achieve its goals, action is needed in a number of highly interconnected areas including energy, transport, climate, environment, industry and sustainable finance. Therefore, all EU policies and actions must contribute to achieving the targets. Current EU policies related to the goal of climate neutrality will be reviewed, and if necessary revised, as part of the Green Deal, in line with the increased climate ambition.

These strategies and initiatives must have economic support for their implementation. One of the key points of the Green Deal is its financing plan. The green transition and climate neutrality goals of the European plan require significant public and private investments. With this in mind, the so-called Investment Plan for a Sustainable Europe aims to leverage EU policies and financial instruments. In particular in "investEU", a program to mobilize public investment and private funds that is expected to raise a capital of 1 trillion as explained in the following Figure n.1 . This program is the instrument of the EU's new Multiannual Financial Framework (MFF) [22]for the period 2021-2027 which brings together in a single program the 14 different financial instruments currently available to support investment in the EU. InvestEU consists of an EU budget guarantee of EUR 26.2 billion covering financial products provided by financial partners. The Fund targets projects that are valuable and consistent with EU policy objectives, but whose risk profile would make it difficult to access finance. The EU also aims to create an investment-friendly framework by introducing incentives to unlock and re-orient public and private investment.

[22] Multiannual Financial Framework – MFF – see at https://ec.europa.eu/info/strategy/eu-budget/long-term-eu-budget/2021-2027_en

Figure n.1 *How the investment strategy "InvestEU" works*



Source: European Commission.

1.3.1 FIT FOR 55

On 14 July, the European Commission adopted the "Fit for 55" climate package, which proposes legislation to achieve the Green Deal targets by 2030. In particular, the reduction of greenhouse gas emissions by 55% compared to 1990 levels, with the aim of achieving "carbon neutrality" by 2050. The 55% target is extremely ambitious.[23]For comparison, from 1990 to 2020, emissions in the European Union were reduced by 20%. The Green Deal aims to reduce emissions from 20% to 55% in less than ten years.

The package contains 12 initiatives, both amendments to existing legislation and new proposals.

[23] European Council, *The EU's plan for a green transition* - https://www.consilium.europa.eu/en/policies/fit-for-55/

The amendment of the *Energy Efficiency Directive*[24], reiterates the principle that energy efficiency should be the first priority and requires Member States to reduce primary energy by 39% compared to 1990. This target becomes mandatory and will result in consumption of no more than 1023 million tonnes of oil equivalent by 2030. A key element of energy savings will have to come from buildings, for which Recovery Plan funds can be used.

The revision of the *Renewables Directive*[25], which increases the target for the contribution of renewable energy sources to the energy mix from 32% to 40% by 2030. The more ambitious target will rely on lower costs for renewables, a reduction that has allowed solar and wind to jointly produce more electricity than coal in the EU in 2019.

The revision of the *Emission Trading System* [26](which will be explained later), which operates on the principle of a cap on emissions for the 10000 installations covered by the mechanism. Emissions are reduced each year and installations can surrender or buy allowances depending on whether they have exceeded or decreased their guaranteed emissions. The proposed revision of the ETS increases the annual reduction percentage. An emissions trading scheme has also been created for land transport and buildings.

Various proposals in the transport sector[27], with a gradual reduction of CO_2 emissions from cars and vans to “zero emissions” in 2035. This would imply that no new vehicles, whether diesel, petrol or hybrid, would be sold after that date. Supporters of the initiative advocate a “Fordian” revolution, which would drastically lower the price of electric vehicles through mass production. The proposal is extremely ambitious and has received a very lukewarm reception from both the car industry and several Member States.

The creation of a *Carbon Border Adjustment Mechanism* (CBAM), [28]in practice a CO_2 tax on imports of cement, iron, steel, aluminum, fertilizers and electricity, if they are not

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[24] European Commission, Energy efficiency directive | Energy (europa.eu) see at https://ec.europa.eu/energy/topics/energy-efficiency/targets-directive-and-rules/energy-efficiency-directive_en

[25] European Commission, Renewable energy directive | Energy (europa.eu) – see at https://ec.europa.eu/energy/topics/renewable-energy/directive-targets-and-rules/renewable-energy-directive_en

[26] European Commission, EU Emissions Trading System (EU ETS) | Climate Action (europa.eu) see at https://ec.europa.eu/clima/policies/ets_en

[27] European Commission, Q&A: Sustainable transport, infrastructure and fuels (europa.eu) – see at https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3525

[28] European Commission, Carbon Border Adjustment Mechanism (europa.eu) – see at https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3661

produced to adequate emission standards. The aim is to protect industries from unfair competition from non-European producers who are not subject to environmental standards similar to the Europeans ones. The measure should prevent the relocation of certain production to countries with less stringent environmental standards.

The package also includes a revision of: the Directive on "minimum" taxation of energy products[29], the Regulation on the use of land and forests [30]that can contribute to emissions by capturing or releasing CO_2, and the "Effort Sharing" Regulation[31] for reducing emissions in sectors not covered by the Emissions Trading Scheme.

It is important to stress that the proposals in the "Fit for 55" package are only the initial phase of a round of negotiations with the European Parliament and the Council. The end result will be a compromise between member states with different energy mixes and different sensitivities to the climate challenge.

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[29] European Commission, Revision of the Energy Taxation Directive – see at https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3662

[30] European Commission, Land use and forestry regulation for 2021-2030 | Climate Action (europa.eu) - see at https://ec.europa.eu/clima/policies/forests/lulucf_en

[31] European Commission, Effort sharing 2021-2030: targets and flexibilities | Climate Action (europa.eu) – see at https://ec.europa.eu/clima/policies/effort/regulation_en

CHAPTER II GREEN POLICIES

2.1 FISCAL POLICIES FOR CLIMATE CHANGE

Environmental taxation is an instrument of economic policy used to incentivize community behavior for two purposes:

1. On the one hand, to reduce the (negative) environmental externalities resulting from production, investment and consumption of goods and services that produce harmful effects on the environment;
2. On the other hand, to favor (positive) environmental externalities resulting from production, investment and consumption of goods and services that have positive effects on the environment.

Green fiscal policies use fiscal and budgetary instruments to address global environmental challenges such as Sustainable Development Goals, Paris Agreements and the EU commission net zero 2050. These reforms include instruments to tax activities that cause environmental damages and overuse of natural resources, to redirect public and private investment in fossil fuel use towards low-carbon alternatives, to nurture the development of the green economy and to give the right signals to markets, in order to encourage long-term sustainable investment.[32] Undoubtedly, tax reforms of this kind can increase production costs in the countries adopting them, thus reducing the international competitiveness of companies based in those countries, just as they can penalize certain sectors if they are not properly designed and implemented. In the pursuit of environmental protection and climate change control, regulatory and fiscal frameworks should therefore be adopted in a coordinated manner at the international level to avoid penalizing, in terms of competitiveness, from those countries that have adopted more rigorous environmental policies and to limit their social impacts, particularly in developing countries.

Although there is a wide range of green fiscal reforms available, they often remain unexplored in practice, with governments tending to favor a tax-based approach. In addition to allowing the reinvestment of revenues from environmental taxes in infrastructure, the proceeds of such actions can reduce distortionary taxes and they can

[32] G20 Peer Review of Fossil Fuels Subsidies Self-Report Italy – available here (https://www.oecd.org/fossil-fuels/publication/Italy%20G20%20Self-Report%20IFFS.pdf)

be used to support green research and development. However, despite the many benefits of green taxes, they are not the only possible instrument and it is worthwhile for governments to consider all tax policy options that can contribute to sustainable economic growth.

For example, incentives to invest in renewable energy (such as solar, geothermal, wind) guarantee a fixed tariff for all energy produced and fed into the grid over a given period of time, in order to eliminate the public support as the share of renewables in the energy mix increases and as a consequences of that, their competitiveness with conventional fuels is established. Such initial investment support is crucial to redirecting capital flows that would otherwise go to carbon-intensive energy.

Environmental tax instruments need to be determined through a careful assessment of the relationship between the economic dimension of environmental taxation and the value of the environmental externalities to be reduced (or promoted in the case of positive externalities).

To sum up, in order to implement the different policies of fiscal restriction and expansion for the related fossil fuel and renewable energy sectors, policy makers have mainly two instruments at their disposal: taxes and public spending (subsidies).

2.1.1 PIGOUVIAN TAX

Lately, the topic of carbon taxes, plastic taxes, or carbon credit has been gaining a lot of attention as an efficient solution for allocating capital to companies that cause environmental damage. In connection with these instruments it is impossible not to mention the concepts of the Pigouvian tax and externalities, on which the environmental tax policy system is based. Companies carrying out their economic activities cause effects in the environment around them. These effects can be negative or positive both in a narrow economic sense (price changes in the market) and in a social economic sense. The emission of greenhouse gases is associated with the concept of a negative externality, since it is a cost that each company imposes on society (or individuals) for carrying out its activity. In a pure market system, this cost is not compensated (think, for example, of environmental damage and land use). On the contrary, the positive externality is the benefit produced by the activity of the enterprise itself towards individuals and society, without any economic gain. The Pigouvian tax is the instrument through which these two elements are introduced into the real economy. In terms of political economy, what we have said translates into a social marginal cost which, at an abstract level, should influence production volumes so as to define the equilibrium point of efficient production for the society. In order to make this actually happen, the English economist Arthur Cecil Pigou[33] theorized the introduction of a tax (the Pigouvian tax) which on the one hand influences the marginal benefit curve and on the other provides the community with a revenue to develop possible environmental policies aimed at limiting the impact of industrial production on the territory and the community.

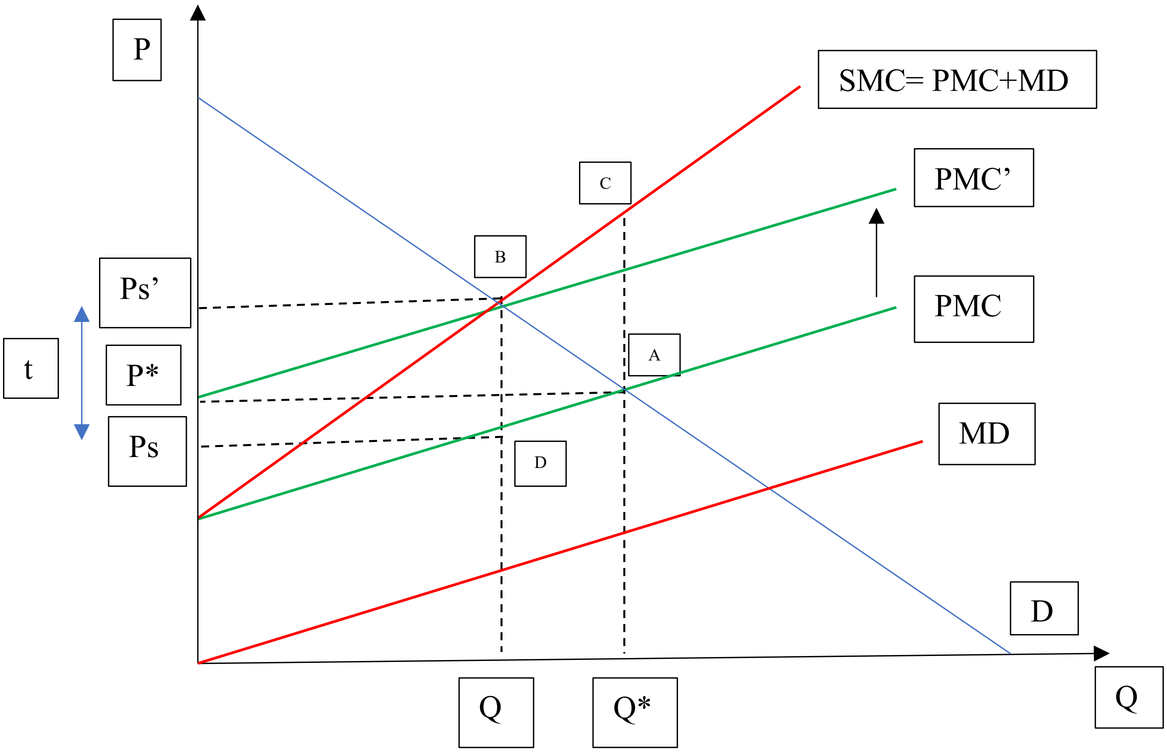
Theoretically, the tax is calculated by deriving the marginal private cost (PMC) of each company and the marginal damage (MD) that is caused to society.

As can be seen from the next Graph n.1, the optimal quantity of the good traded in the market is given by the intersection of the MCp and the demand curve (D), without taking into account the marginal damage created. Social efficiency is obtained in the situation where no individual's situation in society can be improved without anyone else seeing his or her situation worsened; it is also called Paretian efficiency and in the analysis of environmental goods is also defined by the maximisation of the net social benefit (the concept of Paretian efficiency is due to economist Vilfredo Pareto, who argued that any Pareto-efficient allocation can be achieved in perfect competition through an appropriate distribution of resources).

The new socially efficient optimal quantity of output is found instead by adding the marginal damage caused to the private marginal cost curve (PMC +DM = SMC), and then finding the intersection with the demand curve. The new socially efficient quantity causes a lower level of negative externalities, resulting in a net social benefit, a loss of benefit to firms and a dry loss in the market.

[33] Arthur Cecil Pigou was an English economist. As a teacher and builder of the School of Economics at the University of Cambridge, he trained and influenced many Cambridge economists who went on to take chairs of economics around the world.

Graph n.1 *How a Pigouvian Tax works*



Source: *Own production*.

As can be seen from the graph, a tax has to be instituted to achieve the efficient social quantity by shifting the private marginal cost curve upwards and internalizing the externality. The difference between the price (PS') that polluting firms pay and the price (PS) that harmed consumers pay is the Pigouvian tax rate for each unit of good produced. Consequently, the rectangle PS'-PS-D-B represents the revenue created by the tax, triangle A-B-C the net social benefit, and triangle D-A-B the total loss of the firm. Finally, note that at optimality the environmental damage is not zero.

The main benefits, which can also be seen at present with the establishment of the carbon tax, are:

1. Developing the market in a more socially efficient way by incorporating marginal social costs;

2. Discouraging the entry of companies producing negative externalities into the market;
3. Generating tax revenues to be reinvested in activities that promote renewable energy.

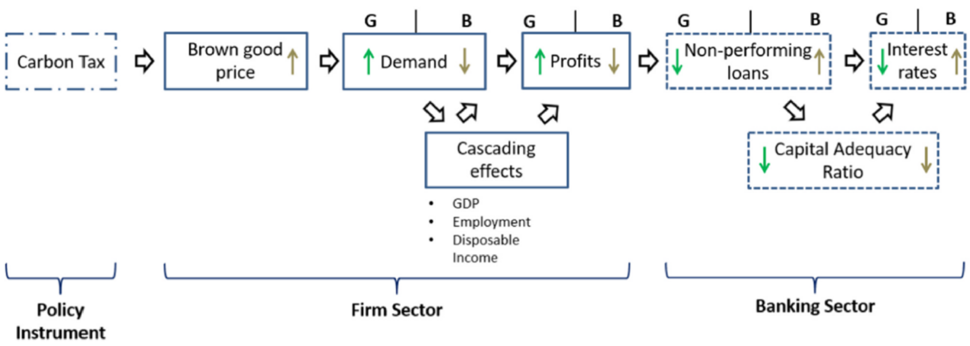
The subsidy, like the tax, produces a different behavior of pollutant producers. It is paid out by government authorities to those who generate positive externalities, creating, in contrast to the case of the tax, a decrease in average costs, which leads to increased production. The increase or decrease in average production costs, on the other hand, has different effects: in the case of a subsidy new firms are encouraged to enter the market (or, from another point of view, less efficient firms can stay in the market); conversely, in the case of a tax, other firms are discouraged from entering the market (or less efficient firms are forced out of the market). Another fundamental difference between the tax and the Pigouvian subsidy is that in the case of the latter a distorting effect on the economy may occur, since it requires a tax levy in other sectors for its financing. The concept of this type of tax is extremely topical in the creation of fiscal instruments for environmental sustainability.

In the next two chapters we will analyze the two main institutions for expansive and restrictive fiscal policies to fight greenhouse gas emissions: carbon tax and green subsidies.

2.1.2 CARBON TAX

Carbon pricing policies are currently the best tools for internalizing the environmental damages done to the market for intermediate inputs, final goods and services. By reducing the demand for fossil fuels, pricing effects exploit behavioral changes of all actors in the economic system, from consumers to companies. Carbon pricing also is able to create cross-cutting incentives for the deployment and development of clean energy technologies, and increases the supply of carbon-free renewable substitutes. Particularly attractive in the current fiscal crisis, carbon pricing can also provide a substantial source of government revenue. Establishing such an instrument requires a careful analysis of its economic fabric and the distribution of the revenue created. For example, the carbon tax transmission channel touch multiple sectors (N. Dunz, A. Naqvi and I. Monasterolo). If we consider an economic system with two firms, ones that produce “green” goods and the other “brown goods”, (in line with Stiglitz et al., 2017) the carbon pricing policy will affect the production cost of the brown good by decreasing its profitability (Figure n.2). This, in turn, will be an obstacle to pay back the interests and principal on their loans to the banking sector.

Figure n.2 *Channel Transmission of a Carbon Tax*



SOURCE: *N. Dunz, A. Naqvi and I. Monasterolo*

Note: G stands for green, B stands for brown capital good firms. Dotted line boxes represent the effects of the CT on the banking sector, while straight line boxes represent implications for the real economy.

The first key consideration in choosing the basis of a carbon tax is to maximize tax coverage on all emitting activities. This avoids implicit or explicit exemptions to significantly polluting activities, as all potential CO2 emissions through different fuel types and users should be taxed at the same rate. Theoretically, carbon taxes should be levied upstream in the fuel supply chain to maximize coverage, e.g. at the point of storage, so as to also discourage the construction and use of fossil fuel plants. And taxes should be applicated in proportion to the carbon content of the fuel to equalize prices between (potential) emissions releases. Uniform carbon pricing alters absolute and relative energy prices, giving companies and households incentives to take advantage of all major opportunities to reduce CO2 emissions from fossil fuels. A uniform CO2 price provides the same incentive at the margin to reduce emissions across all these opportunities, as everyone gets the same savings. Other tax bases include downstream systems that tax the emissions of major stationary sources (e.g. coal and natural gas plants, metal producers).

These can be a more natural extension of earlier local pollution schemes, and include low-cost abatement opportunities. Obviously, the certainty of environmental taxation instruments is a fundamental requirement for the effectiveness of environmental fiscal policies, and the stability over time of the instruments adopted is a prerequisite for guiding behaviors regarding investment choices and actions aimed at reducing environmental externalities. Environmental taxation instruments must be determined through a careful assessment of the relationship between the economic dimension of economic taxation and the value of the environmental externalities to be reduced (or promoted in the case of positive externalities). For this reason, it is important that environmental taxation instruments are determined avoiding the following critical points:

1. Avoid the risk that the instruments overlap with other measures already foreseen for specific environmental externalities through a prior analysis of the environmental Total Tax Rate already adopted with reference to the specific production and/or consumption process;
2. To avoid the risk that the environmental instrument is distortive in terms of technological neutrality, i.e. to avoid that operators are induced to adopt the less cost-effective technological solution in order to remove environmental externalities;
3. Avoiding the risk of solutions being "regressive" in terms of socio-economic impact, with particular reference to the production and consumption of goods with rigid or "necessary" demand (fuels).

The second key consideration concerns the method of calculating the tax, as incorrect weighting and application would create competitive disadvantages for existing businesses, market distortions and inevitably tax inefficiency.

There are two main approaches that the literature has developed to calculate appropriate taxation. The first is the so-called efficient pricing, i.e. the approach that estimates what energy costs should be if they were efficient, i.e. if they fully reflected the environmental and social damage generated by their consumption. This is, strictly speaking, the Pigouvian tax related to externalities linked to CO2 consumption. The second approach is more practical: it calculates the price to be charged on a ton of CO2 consistent with the Paris Agreement's objective of raising temperatures by only 2 degrees Celsius.

2.1.2.1 EFFICIENT PRICING

A paper by the International Monetary Fund ("Getting Energy Prices Right: From Principle to Practice") uses statistical methodologies and econometric tools to quantify the optimal taxation based on externalities caused by fossil fuels in 156 countries in order to design an efficient tax.[34]The study considers three externalities:

- Climate damage related to CO2 emissions;

- Other air pollution related to emissions;

- Congestion, accidents, road surface damage attributable to motor vehicles.

Taking these externalities into account, the authors arrive at an assessment of the remedial taxes that would be levied on a range of fuels. The results suggest that imposing efficient energy taxes would, overall, reduce CO2 emissions by 23% and air pollution deaths by 63%. In addition, it would yield a tax dividend of 2.6 per cent of global GDP, which could be used, for example, to reduce other taxes.

The Table n.1 summarizes the results of this work for a number of countries that together accounted for about 70-90 per cent of emissions in 2010. [35] There is great variability in terms of efficient taxes between countries. Obviously, the damage generated by a ton of CO2 does not depend on where it is emitted. However, the externality generated on air pollution depends on the composition of the industrial fabric and the relative exposure of the population to GHGs, factors that differ greatly between countries. [36] The table shows that, in general, current taxes are substantially lower than optimal, particularly on coal, where the tax is practically absent. In addition, many of the large hydrocarbon producing countries grant subsidies rather than impose taxes, including Iran, Russia, Ukraine, India and Canada. Among consumer countries, petrol and diesel are relatively more heavily taxed, with some countries even exceeding the value of the efficient tax. However,

[34] Parry, I., Heine, D., Lis, E., & Li, S.. "Getting Energy Prices Right: From Principle to Practice", 2014, Washington, International Monetary Fund (available here https://doi.org/10.5089/9781484388570.071).
[35] It is also important to consider that valuing and quantifying environmental and social damages is a sensitive and highly controversial issue. Even using the same methodology and approach as proposed by Parry et al. (2014), slight variations in the assumptions underlying the models and the use of new, more up-to-date data can have a significant impact on the final estimates.
[36] For example, the corrective tax on coal in the US and China is much higher than in Australia because the exposure of the Australian population to pollution is lower as much of the pollution is lost to the ocean.

inefficiencies should also be pointed out here: on average, the corrective tax calculated for diesel is higher than for petrol. This reflects not only higher rates of carbon emissions and local pollution, but also the fact that diesel is used by HGVs, which create more congestion and more damage to the road surface. In principle, therefore, governments should tax diesel at higher rates than petrol. However, data show that governments do, in most cases, the opposite. Among the countries where the effective tax on petrol and diesel differs most from the optimal one are the United States and Japan, the two largest advanced economies. Emerging economies include Nigeria, Iran, Indonesia and India, where in some cases the tax is even negative (i.e. fuels are not only not taxed but subsidized). Big oil producers like Saudi Arabia are other subsidizers of these energy sources. In Italy, as well as in other European countries such as France and Germany, there is a general alignment between optimal and existing tax (and in some cases even the corrective tax is lower than the actual tax).

Tab. n.1 *Estimated corrective and current taxes, by fuel type (2010)*

	Carbon ($/GJ)		Natural Gas($/GJ)		Petrol ($/litre)		Diesel ($/litre)	
	Corrective tax	Current tax	Corrective tax	Current tax	Corrective tax	Current tax	Corrective tax	Current tax
Saudi Arabia	na	0,00	2,08	0,00	0,52	-0,38	0,54	-0,50
Argentina	9,72	0,00	2,08	-1,30	na	0,33	na	0,39
Australia	4,12	0,00	2,04	-0,10	0,55	0,49	0,73	0,49
Canada	4,92	3,00	2,17	-0,20	0,55	0,36	0,64	0,42
China	14,97	0,00	2,82	0,00	0,55	0,39	0,51	0,37
Columbia	4,78	0,00	2,04	0,00	0,72	0,78	0,72	0,29
South Korea	8,07	na	3,20	na	0,98	0,85	1,20	na
Costa Rica	na	0,00	1,97	0,00	0,51	0,31	0,49	0,11
Ethiopia	na	0,00	1,94	0,00	0,41	0,23	0,27	0,00
France	11,13	0,00	2,60	0,00	0,73	1,13	0,95	0,84
Germany	9,35	-1,30	2,57	0,00	0,58	1,20	0,82	0,92
Japan	5,51	0,00	2,76	0,00	1,13	0,75	1,44	0,46

India	8,71	0,00	2,11	-1,00	0,78	0,36	0,54	-0,04
Indonesia	5,71	0,00	2,12	0,00	0,32	-0,13	0,42	-0,35
Iran	na	0,00	2,08	-4,80	0,60	-0,37	0,59	-0,55
Italy	5,85	0,00	2,38	0,00	0,53	1,08	0,75	0,86
Jamaica	na	0,00	1,96	0,00	0,36	0,15	0,35	0,12
Kazakistan	6,40	-0,20	2,15	-0,20	0,57	0,12	0,61	-0,08
Morocco	4,53	0,00	1,98	0,00	0,64	0,61	0,47	0,14
Mexico	3,93	2,00	2,04	0,00	0,31	0,10	0,40	0,10
Nigeria	na	0,00	1,95	0,00	0,22	-0,19	0,22	0,11
Pakistan	7,35	0,00	2,15	-4,10	0,31	0,17	0,29	-0,03
UK	14,70	0,00	2,57	-0,10	0,60	1,20	0,77	1,21
Russia	14,98	0,00	3,07	-0,90	1,05	0,02	2,06	0,02
USA	8,75	2,00	2,66	-0,10	0,43	0,13	0,57	0,14
South Africa	4,59	0,00	1,97	0,00	0,80	0,35	0,65	0,34
Tanzania	na	0,00	1,94	0,00	0,51	0,48	0,33	0,40
Turkey	12,54	-0,50	2,15	0,00	1,11	1,37	1,20	0,97
Ukraine	32,89	0,00	2,82	-1,90	0,39	0,18	0,50	0,06

Source: Parry et al. (2014)

Notes: The corrective tax for natural gas was calculated as an arithmetic average between the corrective tax for gas used for electricity generation and gas used for domestic heating. Current tax estimates were measured in Clemens et al (2013) using the price-gap approach (i.e. comparing differences between domestic and international fuel prices).

In conclusion, countries with major economic interests in a given production sector, be it coal or oil, tend to heavily subsidies the corresponding fossil fuels. Emerging countries contribute strongly to this phenomenon; as developing countries are expected to consume more and more cheap energy, given demographic and macroeconomic trends, the issue of tax subsidies becomes increasingly crucial.

2.1.2.2 THE COST OF DECARBONISATION

Let's move on to the second approach to estimating the right price of CO_2: what should be the tax on emissions to achieve the decarbonization needed to limit global warming to 2 degrees Celsius? It is estimated that the carbon tax that should be imposed in line with the Paris agreements is $75 per ton of CO_2 to be phased in by 2030. [37]

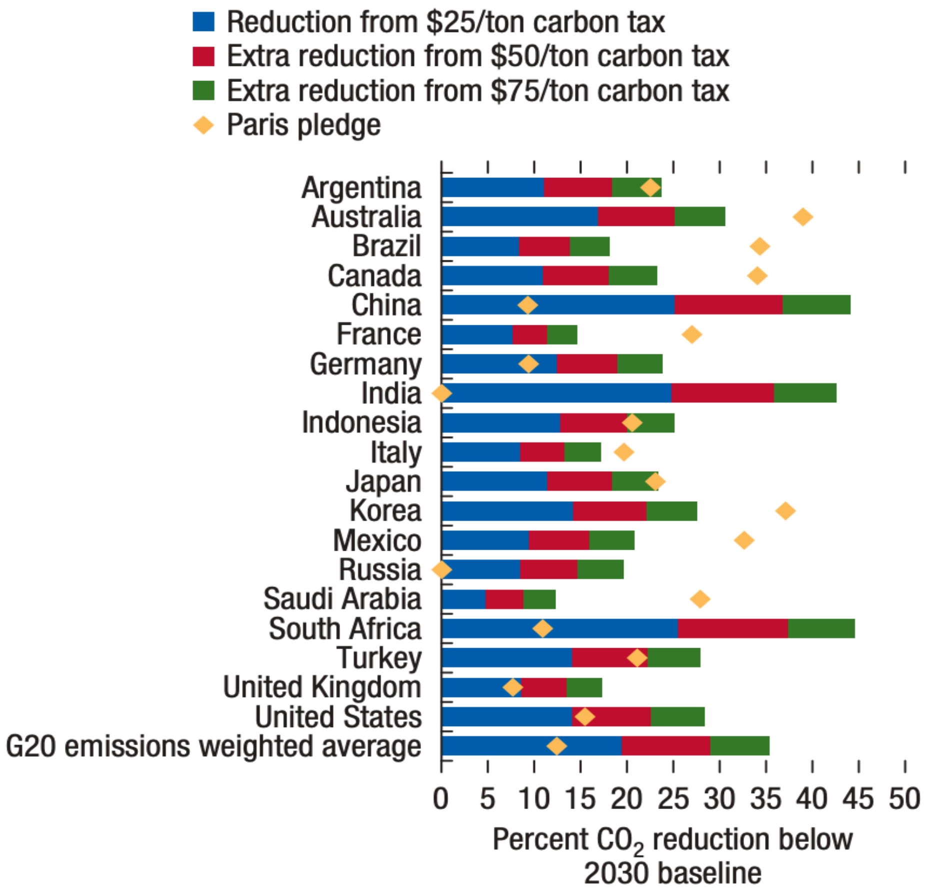
The most recent work using this approach was also published by the International Monetary Fund in the Fiscal Monitor of October 2019. [38]In the Fiscal Monitor, the Fund takes the middle of the range of values that the literature has proposed for elasticity, and from this, simulates three different scenarios. In addition to the optimal tax at $75, it considers two other less ambitious scenarios with taxes at $50 and $25, as it allows for the possibility of combining lower taxation with other tax instruments and as it considers that lower taxes would still be in line with the Paris targets for some countries (e.g. China).

The Figure n.3 shows how different levels of taxation (uniform carbon taxes at $25, $50 or $75 per ton) would reduce CO_2 emissions by 19, 29 and 35 per cent, respectively, in the G20 countries (implying greater use of complementary fiscal instruments in the first two cases to achieve the emission levels required to keep the temperature increase within 2 degrees).

[37] Of course, the required tax depends on assumptions about the price elasticity of demand for polluting products. Based on different assumptions from those in the work cited in the text, Stern and Stiglitz (2017) estimate that the tax should be set at $50-100 per ton by 2030. A similar analysis by the High Level Commission on Carbon Prices estimates that a carbon tax of $40-80 per ton of CO_2 by 2020 and $50-100 per ton of CO_2 by 2030 would be needed.; available on https://openknowledge.worldbank.org/bitstream/handle/10986/32419/141917.pdf?isAllowed=y&sequence=4. See also: https://www.independent.co.uk/environment/climate-change-fossil-fuels-carbon-environment-tax-imf-a9151996.html e https://www.globalcapital.com/article/b1hnbw7xyh3qk0/imfs-carbon-tax-call-not-close-to-whats-needed.

[38] International Monetary Fund (IMF). 2019. Fiscal Monitor: How to Mitigate Climate Change. Washington, October.

Figure n.3 *Different level of taxation and relative CO2 reduction*.



Source: IMF staff calculations.
Note: Paris pledges indicate the percent reduction in CO_2 emissions below the baseline (that is, no mitigation) levels in 2030 if countries' mitigation pledges submitted for the Paris Agreement are met. Bars indicate the percent reduction in CO_2 emissions below baseline levels under carbon taxes with alternative tax levels. CO_2 = carbon dioxide; G20 = Group of Twenty.

Two fundamental points then emerge:

1. While a $25 tax would be sufficient to meet the Paris targets for some countries, a $75 tax would not even be sufficient for others; this reflects the different degree of ambition of the commitments made, as well as the different price elasticity of emissions (e.g. GHGs emissions are very responsive to price in coal-dependent countries such as China and India);

2. This large difference in long-term targets and possible outcomes between countries signals the difficulty in achieving greater cooperation at the international level.

The imposition of a CO_2 tax would have a major impact on certain categories of workers and industrial sectors, in particular those linked to coal, whose level of employment is already expected to fall in any case. The introduction of a carbon tax would speed up these processes, thus exacerbating the short-term conflict between employment and environmental objectives. How can the introduction of a carbon tax be reconciled with these considerations?

The key is to make efficient and effective use of the resources from the carbon tax. In order to make this tax economically and politically feasible, revenue allocation becomes crucial. This tax dividend could be exploited differently, depending on the composition of the industrial production sector, the GHGs emission rates, the exposure of the population.

2.1.2.3 CARBON PRICING SCORE

As shown in the previous chapter, the calculation and establishment of the optimal carbon tax for meeting and achieving environmental targets, such as the Paris Agreement, depends very much on the factor endowment of countries and their economic situation. However, OECD and G20 countries remain far from the taxation needed to meet the Paris Agreement targets, as they are responsible for 80% of global emissions[39]. In addition, countries responsible for most emissions, such as China and the US, lag behind Europe.
For this reason, a recent OECD study "The Effective Carbon Rates – 2021" calculated the *Carbon Pricing Score* (CPS). The CPS measures the degree to which countries approach the decarbonisation target based on the price that carbon should have. In a nutshell, the closer a country gets to the optimal carbon tax benchmark, the closer it gets to a 100% score. For example, a CPS of 100% for a tax of EUR 30 per tonne of CO_2 means that that country or group of countries tax all emissions in their territory at EUR 30 or more. A lower score means that some sources of carbon emissions are not taxed.

[39] OECD(2021). "*The Effective Carbon Rates*" – see at https://www.oecd.org/tax/tax-policy/effective-carbon-rates-2021-brochure.pdf

100% CPS	30 EUR out of 30 of benchmark (Country prices all carbon emissions)
0% CPS	0 EUR out of 30 of benchmark (Country price any emissions at all)

To create this score, the OECD uses the *Effective Carbon Rate* (ECR), a Euro/tonne of CO2 ratio that takes into account three components: Emission Permit Price, Carbon Tax and Fuel Excise Tax.

$$ECR = \frac{(EMISSION\ PERMIT\ PRICE + CARBON\ TAX + FUEL\ EXCISE\ TAX)}{Tonne\ of\ CO2}$$

As of 2018, OECD and G20 countries, responsible for 80 % of global emissions, were achieving an ECR of 19 % against the €60 target. It is estimated that an increase in the Effective Carbon Rate by EUR 1 per tonne of CO2 leads on average to a 0.73% reduction in emissions over time. [40]As the report points out, carbon prices are rising at too slow a rate to meet the targets that individual countries committed to in the Paris Agreement. In particular, there are some sectors where taxation is very low compared to the emissions they cause, such as the industrial, residential, commercial and electricity sectors, while road transport, which is the most "affected" sector, is doing a little better.

The OECD bases these analyses on the so-called *carbon pricing gap*, which measures the gap between the taxation currently applied and that desired to generate a change in gear. Countries that have taken steps to close this gap in recent years (particularly between 2012 and 2015) include France, India, Korea, Mexico and the UK. There are also some key countries that could give a decisive impulse in the total reduction of this gap, such as China, both because of the vastness of their territory and because of the strong industrialisation present. Italy is well placed in the ranking of countries adopting effective

[40] Sen, S., & Vollebergh, H. (2018). "*The effectiveness of taxing the carbon content of energy consumption. Journal of Environmental Economics and Management*", 92, 74-99

solutions, along with Norway, Greece, Spain, Luxembourg, Slovenia, Ireland and the Netherlands.[41]

The reduction of the carbon pricing gap is also an indicator of competitiveness, as it denotes how far a country is moving towards a "decarbonized" and, therefore, more sustainable economy, both for a purely environmental issue and for reduced economic dependence on specific raw materials.

2.1.2 GREEN SUBSIDIES

Public spending is a key strategic lever through which governments can decide the direction of their policies. It can enable them to promote efficiency, equity, transparency and sustainability in their activities, driving the broader economy towards innovation, sustainability and resilience. Subsidies can be provided in various forms, such as the direct transfer of funds (e.g. grants, loans), government revenue foregone (e.g. tax incentives and credits), the provision of goods and services, payments to funding mechanisms and income or price support .[42]

Starting from the definition of an externality produced by an economic individual, in the case of a green subsidy the concept of positive externality is applied, i.e. encouraging production, investment and consumption activities of goods and services that produce positive effects on the environment.

However, a key point that will be explored in more detail later, cost efficiency and the provision of effective and quality services is the key to receiving fiscal support. Indeed, efficiency alone can contribute to sustainable development, particularly in emerging markets. In this case, the power and administration of public spending to support aggregate demand becomes crucial for the effectiveness of the subsidy. In turn, investments in sustainability can save money. This is particularly true when it comes to energy-related investments that often equate to both financial savings and gains in long-

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[41] Salvatore Liaci. 2021."*Il Carbon pricing durante il Covid-19: un confronto internazionale*". OCPI. Giugno 2021.

[42] Annex 2 to The Report to The European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions. Available here https://ec.europa.eu/energy/sites/ener/files/progress_on_energy_subsidies_in_particular_for_fossil_fuels.pdf

term environmental sustainability. Following Keynesian theory, public support for green investments and sustainable consumption creates innovation, jobs, higher wages and tax revenues as well as environmental well-being.

The first phase of subsidy design and consequently of public expenditure planning is the analysis of the structure of the sector or individuals that will be the target of government intervention. This phase is the most delicate and decisive one, since an erroneous consideration of the "target" can lead to distorting effects on the market. The reason is as follows, the economic concept of subsidy is derived from the assumption that the market allocates resources more effectively than any other mechanism, and that a government payment to the producer of a particular good reduces the private cost of the good so that it no longer reflects id social cost - the output that must be foregone in order to make the good. The result is a distortion in the resource-allocating function of the domestic market.[43]

Next, it is necessary to define how the subsidy will be constructed. Depending on the objective, this instrument has the ability to create effects on the cost and revenue structure of companies in a specific sector. In reducing costs, companies can see their average costs decrease due to the social marginal benefit emitted through positive externalities. By doing so, new firms are encouraged to enter the market (or, from another point of view, even less efficient firms can stay in the market). The first key point in favour of cost-cutting subsidies is public support in the private sector for research and development. In this case, the receipt of funds for R&D is of great importance for sustainable development and improving energy efficiency, even though it increases the dependence of research on public support and the resulting financial constraints and lack of market efficiency hinder sustainable development.

From a different perspective, polluting companies could be paid and then subsidized to pollute less, so the portion of the quantity not produced will be supported by government aid. The latter effect is precisely the so-called harmful subsidy. This effect causes both a decrease in polluting units, but also an incentive to enter the market and a competitive disadvantage in other competing sectors, as well as a high opportunity cost for other

[43] Horst Siebert, *Economics of the Environment: Theory and Policy* (Berlin: Springer-Verlag, 1987)

financing choices. Such instruments, as mentioned in the previous chapter on Carbon Taxes, are still used for fossil fuel power generation by countries with large endowments.

Shifting our focus to price changes for the establishment of a subsidy, the instrument can result as an increase in revenues through:

- Price support payment;
- Compensation for lower price;
- Others (sales promotions);

The critical points here could be many without a prior analysis of the consequences. The OECD work "Towards a G7 target to phase out environmentally harmful subsidies"[44] has produced a list of observations that must be taken into account in an analysis prior to the establishment of the instrument. This is because of the complexity of the connections between the effects of subsidies and environmental outputs. Below is the list of considerations proposed by the OECD:

- "*Point of impact. Subsidies are targeted at something – output, firm or household income, profits, variable inputs, or factors of production. For a given amount of money, these points of impact (also called initial or statutory incidence) can affect the economic and environmental consequences of the subsidy, but in turn depend on the market's structure.*
- *Market structure. The final incidence of a subsidy may differ from its initial incidence. [..] Such considerations are especially relevant when removing a subsidy, as they have a bearing on whether flanking measures are needed to avoid social hardship.*
- *Degrees of freedom. Subsidies that stimulate output, but leave the producer (consumer) free to choose its mode(s) of production (consumption), provide more degrees of freedom to choose environmentally benign modes of production (consumption). By contrast, a subsidy that is conditional on using a certain mode*

[44] OECD (2017) , "*Towards a G7 target to phase out environmentally harmful subsidies*" . Available here (https://www.mite.gov.it/sites/default/files/archivio/allegati/sviluppo_sostenibile/background_paper_4_G7_env_OECD_Towards_G7_target_to_phase_out_EHSs.pdf)

of production or certain input is likely to discourage the recipient from looking for more environmentally benign processes or products.

- *Lock-in effects. Subsidies tend to impose rigidities, especially if they are designed to shelter industries that are not economically viable. […] Once that capital is in place, firms or households will view it as a sunk cost, creating a barrier to changing the resulting production or consumption pattern (see, for example, Naughten et al., 1997[45]).*
- *The supply elasticities of factors of production. Subsidies tend to be capitalised into the price of the least elastic factor of production – land in the case of agriculture, or quotas in the case of fishing. Thus a subsidy can affect the relative prices and use intensity of the relevant factors of production, and hence environmental impacts. This phenomenon leads to "the transitional gains trap" (Tullock, 1975[46]), making reform difficult and costly because removing the subsidy can substantially reduce the capital value of production- or consumption specific assets.*
- *The alternative to the subsidised activity. Once subsidies to an activity are removed, a differing pattern of production or consumption, or both, will emerge. […] This may in turn rearrange patterns of trade, but not necessarily cause a reduction in overall coal use. On the other hand, because of differences in endowments and production techniques, the net effect is indeterminate.*
- *The political and economic environment. Subsidies rarely are provided in an otherwise unregulated context. Various sectoral or environmental policies, and institutional arrangements, including limits on the use of inputs or output quotas, can have a profound effect on environmental outcomes."*

The monitoring of subsidies is also a key step for the continuity and credibility of the fiscal manoeuvre as subsidy measures can influence the adoption of new technologies in the energy sector and the consumption of different energy sources, thus can impose a significant burden on households and companies. Depending on how subsidies are

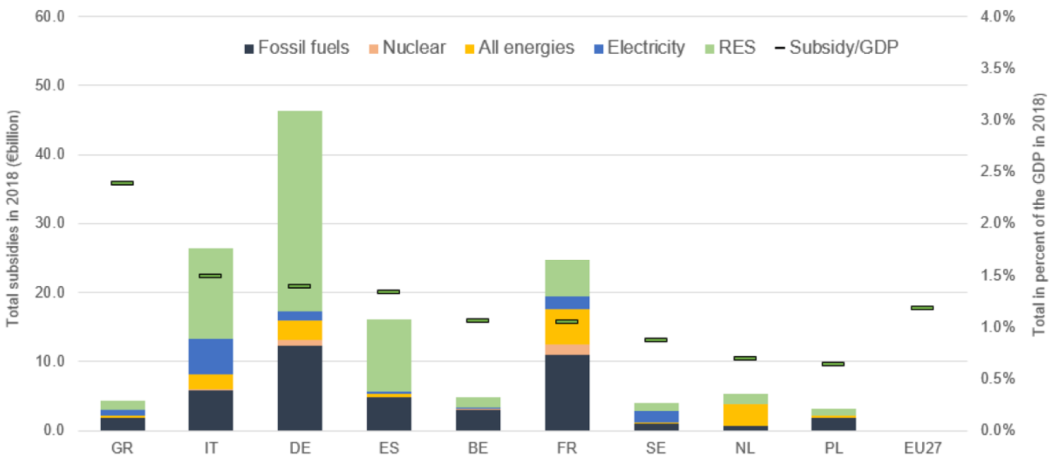
[45]Naughten, B., J. Melanie and J. Dlugosz (1997), "*Modelling 'Supports' to the electricity sector in Australia"*, in Reforming Energy and Transport Subsidies: Environmental and Economic Implications, OECD Publishing, Paris

[46] Tullock, G. (1975), "*The transitional gains trap*", Bell Journal of Economics, Vol. 6/2, pp. 671-678.

structured, they can be a barrier or an enabling factor to promote energy system integration and, more generally, the decarbonization of the energy system.

According to the report to the European parliament, the Council, the European economic and social mentioned above, the largest share of EU subsidies in 2018 went to the energy sector (€ 92 billion), followed by industry (€ 20 billion), households (€17 billion), transport (€ 13 billion), and agriculture (€5 billion).

Figure n. 4 .*Energy subsidies in absolute amounts and as percentage of the GDP in the EU Member States in 2018.*



Source: *Annex to the Report to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions*.

Almost three quarters of the subsidy to the energy sector went to the development and implementation of renewable energies. Renewable energies received almost three-quarters of the subsidies in the energy sector, showing the continued commitment to supporting their deployment and use. Investment costs in recent years have caused a marginal decrease in subsidies for new renewable energy projects, but despite this last statement, the three most important renewable technologies (solar, wind and biomass) received 30%, 22% and 16% of total subsidies to the energy sector respectively.[47]

[47] European Commission (2020) - Annex 2 to the report to the european parliament, the council, the european economic and social committee and the committee of the regions. Available here

2.2 MONETARY POLICIES CLIAMTE CHANGE

In recent years, financial regulators and central banks have increasingly started to recognize climate risks related to financial stability. It is likely that the macro-financial system will suffer profound implications and instabilities caused by climate change (as economic damage to productive activities) and the transition to low-carbon activities (through regulatory or mitigation policies for the market-led structural shift towards cleaner technologies). Fossil fuel companies could see their structural shift due to the low-emission energy transition. This would lead to a decline in the value of their financial assets, resulting in losses for investors, insurance companies and pension funds. Furthermore, economic and transition damages have a direct effect on expectations of price stability and on their macroeconomic indicators such as inflation, output, employment, interest rates, investment and productivity. Damage from climate change also can bring litigation risk to firms (Covington et al., 2016). A rapid re-pricing of these financial assets could have significant implications for the investors holding the assets and for the financial system as a whole.[48] It is therefore obvious that in addition to the fiscal policies and instruments mentioned above, the support of monetary policies for environmental sustainability is of paramount importance. Indeed, the institutions responsible for ensuring financial stability (central banks and financial regulators) have shown concern after recognizing the magnitude of systemic risk to the financial market related to low-carbon transition risk and climate damage. There is therefore a need for financial and monetary policymakers to be aware of these risks and how to mitigate them.[49] The biggest challenge, therefore, will be to implement policies (restrictive or expansionary) to promote sustainable economic growth without destabilizing the market.

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https://ec.europa.eu/energy/sites/ener/files/progress_on_energy_subsidies_in_particular_for_fossil_fuels.pdf

[48] Baron e Discher, 2015; Battiston et al., 2017; Carbon Tracker, 2013; CERS, 2016; Griffin et al., 2015.

[49] Sini Matikainen, Emanuele Campiglio and Dimitri Zenghelis (2017) – "*The climate impact of quantitative easing*" – available here (https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2017/05/ClimateImpactQuantEasing_Matikainen-et-al.pdf)

In the following chapters, we will define how key financial decision-makers can include climate change considerations in their policies, with a focus on the instruments adopted by major central banks, particularly in the European context.

2.2.1 FUNCTIONS AND CHARACTERISTICS OF CENTRAL BANKS

The central bank is responsible for making decisions on the monetary policy of its country. These decisions concern the management of the currency, control of the money supply and the amount of money in circulation. The aim is to ensure price stability with a view to economic growth. It is also possible for the central bank to fulfil its functions with respect to a group of countries adopting the same currency. The most striking example of this is the European Central Bank (ECB), which regulates the monetary policy of all countries in the Eurozone. Besides the ECB, the most important central banks in the world are the US Federal Reserve (FED), the Bank of England and the Bank of Japan. These bodies have the power to influence the markets through their decisions.

One of the fundamental characteristics of central banks is their independence from government bodies. By supervising price stability, central banks create the conditions for a sound and stable economy. If governments were to exercise direct control over central banks, they could try to change interest rates to suit their own objectives, to induce strong economic growth in the short term or to finance popular measures with central bank money. This would, in the long run, have serious repercussions on the economy. [50]The central bank being independent acts exclusively to ensure good macroeconomic performance such as increased price stability. Independence is not only a sign of efficiency but also of credibility. In fact, a bank that is totally unrelated to political interests will be more trusted by its customers because they will know that it only acts in the interests of the area it serves.

Both the Federal Reserve and the European Central Bank enjoy a large degree of independence from political forces. So-called 'financial independence', is an indicator of the degree of autonomy and refers to the source of income. The two banks have different ways of raising financial resources, with the Fed recording its income from securities

[50] ECB see: https://www.ecb.europa.eu/explainers/tell-me-more/html/ecb_independent.it.html

holdings and loans to banks. The ECB, on the other hand, accumulates its capital through payments from the individual national central banks that adopt the euro. The autonomy of both institutions also concerns the choice of objectives and instruments to be used.

The ultimate objectives of economic policy can be manifold, ranging from employment to income growth, price stability and balance of payments equilibrium. One of the main instruments to achieve these objectives is monetary policy, which is the prerogative of central banks. The latter can indirectly influence the final objectives through choices regarding the amount of money in the market. Central banks also play a supervisory role in the financial system by setting soundness requirements for the country's credit institutions and monitoring them periodically. Central banks set out the objectives to be pursued in their statutes, which differ from country to country. On the basis of the different widths of the mandate, there are two types of institutions: those with a broad mandate, i.e. which do not have a priority in the objectives to be achieved, and those with a more limited mandate, which therefore have a preponderant objective over the others.

As already stated several times, one of the main objectives of central banks is to defend price stability. The practical definition of price stability varies in different institutional contexts. In the case of the Eurosystem, i.e. the system consisting of the European Central Bank (ECB) and the National Central Banks (NCBs) of the European States that have adopted the euro, the Governing Council of the ECB has identified a situation of price stability as one in which the 12-month increase in the harmonized consumer price index for the euro area is below but close to 2%.[51] The term harmonized here means that the price index is compiled using homogeneous criteria for all countries in the area. [52]

All other targets are therefore subordinate and can only be pursued if they are compatible with the inflation target. Therefore, the ECB's task is to monitor the quantity of money in the economic system according to the principle of direct proportionality with general prices. (Quantitative Theory of Money). [53]

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[51] Sole 24 ore (08 July 2021), Riccardo Sorrentino - " Eighteen years after the last revision in 2003, the monetary authority in Frankfurt has unanimously decided that its target will no longer be an inflation level "below but close to 2% in the medium term". As of 22 July, the new target is "a symmetrical inflation target of 2% over the medium term"."

[52] Bank of Italy – see at https://www.bancaditalia.it/servizi-cittadino/cultura-finanziaria/informazioni-base/stabilita-prezzi/index.html

[53] Quantity theory of money states that money supply and price level in an economy are in direct proportion to one another. When there is a change in the supply of money, there is a proportional change

Central banks use two instruments to implement their monetary policies. The first is the supply of money through open market operations, i.e. the purchase and sale of government bonds. These operations are carried out by central banks with the aim of regulating the quantity of money in circulation in the interbank market and to expand or reduce the monetary base. Compulsory reserves also contribute to the money supply; a change in the reserve requirement ratio has a direct impact on the change in the money supply.

The second instrument is interest rates, which the central bank influences by changing the interbank rate; since the latter is a very short-term rate, its change affects all the others. Monetary policies can be classified into two categories, restrictive and expansionary. Contractionary policies aim to limit economic growth by reducing investment and therefore aggregate demand and income. In order to do this, the monetary authority carries out the activities of:

- Increasing the short-term interest rate: National banks have the burden of borrowing money to meet their liquidity needs. By increasing the short-term interest rate, central banks increase the cost of borrowing. As a result, national banks raise the interest rates charged on their consumer loans, holding back investments and consumes.
- Raise the reserve requirements: Central banks impose a minimum reserve requirement on their national bank system to ensure a minimum solvency of the credit institution. The central bank can increase reserve requirements in order to decrease the supply of money. In this way national and commercial banks can count on less funds to lend to consumers.
- Expand open market operations (sell securities): The central bank can make use of open market operations by sell government securities from domestic banks and institutional investors. The purpose of this activity is to reduce the monetary base in circulation and to regulate interest rates in period of high inflation rate.

This type of policy is implemented out of fear that inflation will reach excessive levels.

in the price level and vice-versa. See at : https://economictimes.indiatimes.com/definition/quantity-theory-of-money

Expansionary policies, on the other hand, are concerned with increasing the supply of credit to businesses and consumers, thereby facilitating investment and consumption. In times of recession or slowing growth, the Central Bank can support the economy. Formally, the main instruments that are available to implement expansionary monetary policies are:

- Lowering the short-term interest rate: National banks have the burden of borrowing money to meet their liquidity needs. By lowering the short-term interest rate, central banks lower the cost of borrowing. As a result, national banks lower the interest rates charged on their consumer loans, stimulating investment.
- Reducing reserve requirements: Central banks impose a minimum reserve requirement on their national bank system to ensure a minimum solvency of the credit institution. The central bank can reduce reserve requirements in order to increase the supply of money. In this way national and commercial banks can count on extra funds to lend to consumers.
- Expand open market operations (buying securities): The central bank can make use of open market operations by buying government securities from domestic banks and institutional investors. The purpose of this activity is to expand the monetary base in circulation and to regulate interest rates.

The monetary instruments described above are considered to be "conventional", but there are also those that are referred to as “unconventional”, although the differences with those of the first type are often not too marked. The adoption of unconventional instruments occurs almost exclusively during periods of deep financial crisis, the aim being to re-establish the normal functioning of financial and credit markets.

As will be seen later, these policies drive the economy and affect the performance of economic sectors. In this context of energy transition, it is therefore necessary to stimulate investment in the areas of environmental sustainability.

2.2.2 THE ROLES OF MONETARY POLICY IN CLIMATE CHANGE

The monetary policy of central banks is nothing more than a response to shocks affecting the economy. Typically, two categories of shocks can be identified, one on the demand side and the other on the supply side. Shocks of the first type are considered to be demand shocks, and are seen as "benign" and easier to manage because growth, inflation and employment are all going in the same direction, so the central bank does not have to worry about possible side effects of monetary action. [54]

The second category, on the supply side, is less accommodative because it puts output and inflation in opposite directions. The central bank therefore has to manage a trade-off between stabilizing inflation and smoothing fluctuations in output. Based on this distinction, it is possible to say that climate change shocks belong to the second category. Natural catastrophes due to climate change erode production capacities and thus create price tension by raising both input and output prices. As mentioned above, central banks have to decide whether to stabilize inflation or economic activity. The solution to this problem is not unique to all situations but must be calibrated according to the magnitude and expected persistence of the shock.

If the shock is expected to be short-lived and unlikely to affect the medium-term inflation outlook relevant for monetary policy, then temporary effects on inflation are tolerated and no action is taken[55]. If the effects are more persistent and there is a risk that they will expand further through the economy, monetary policy action should be warranted. So far, shocks related to climate and environmental change have been short-lived and contained. However, the situation could worsen and these shocks could increasingly affect inflation and output, thus prompting central banks to review their decisions. It is possible to identify three ways in which climate change may affect monetary policy actions.

The first concerns the possibility that adverse weather shocks affecting the economy may become increasingly difficult to identify and assess. In the future, it is expected that such shocks may make it much more difficult for central banks to understand what data changes will be relevant for assessing the inflation outlook in the medium term. Actions taken may therefore be untimely or even ineffective.

The second correlation relates to the distribution of shocks. If political and economic authorities do not intervene to curb climate change, the risk is that catastrophic events may become more frequent and may have irreversible consequences on the economy.

[54] ECB – see at https://www.ecb.europa.eu/press/key/date/2020/html/ecb.sp200227_2~301776ff2a.en.html

[55] Speech by Mr Benoît Cœuré, Member of the Executive Board of the European Central Bank, at a conference on "*Scaling up Green Finance: The Role of Central Banks*" (2018) – available here (https://www.bis.org/review/r181109f.htm)

Applying the concept of a normal distribution curve, we can therefore state that the distribution of shocks could have fat tails due to their increased frequency[56]. In order to deal with this issue, central banks are concerned that the monetary policy choices that will be made will make use of more and more unconventional instruments.

After the identification and distribution of shocks, the third effect of climate change concerns the persistence of shocks and the trade-off between inflation and output that central banks have to deal with. Central banks have some flexibility in dealing with different shocks in the medium term, but there is a limit to this responsiveness, especially with respect to persistent supply shocks. The elasticity of monetary policy is not infinite, so manoeuvres must be implemented before the risks of large second-round effects materialize.

2.2.3 QUANTITATIVE EASING

Given the difficulty of calibrating monetary policies in relation to climate change risks, there is a need for ad hoc instruments to protect price stability and stimulate the low-carbon transition. One of the best performing instruments in this respect is Quantitative Easing (QE). The meaning of QE is an unconventional policy through which a central institution buys securities, such as government bonds, with the aim of increasing the supply of money in circulation. This instrument has a quantitative easing meaning, aimed at creating new money to stimulate the economy and is classified as ultra-expansive monetary policy. With QE, a central bank (such as the ECB or the FED) creates debt money and injects it into the financial and economic system, all with the aim of boosting confidence and promoting liquidity and lending.

As mentioned, it falls under the umbrella of unconventional monetary policies, a group that also encompasses Forward Guidance [57] (which in turn influences markets by forecasting future trends in interest rates or inflation, etc.). As a form of support for economies, central banks create new money and inject it into the system by purchasing

[56] Weitzman, M. (2011), "*Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change*", Review of Environmental Economics and Policy, 5 (2), pp. 275-292; and Weitzman, M. (2009), "*Additive damages, fat-tailed climate dynamics, and uncertain discounting*", Economics - The Open-Access, Open-Assessment E-Journal 3: 1-29.
[57] Investopedia - see at https://www.investopedia.com/terms/f/forward-guidance.asp.

certain categories of assets. This creates new money that is used to finance new actions and services. Below are the various stages of QE:

1. The central bank creates new money;
2. the money is used by the central bank to buy securities;
3. the price of securities rises, their yield falls;
4. purchase of securities increases liquidity;
5. interest rates are lowered;
6. by offering more money and reducing the cost of borrowing (rates), an attempt is made to stimulate investment and recovery.

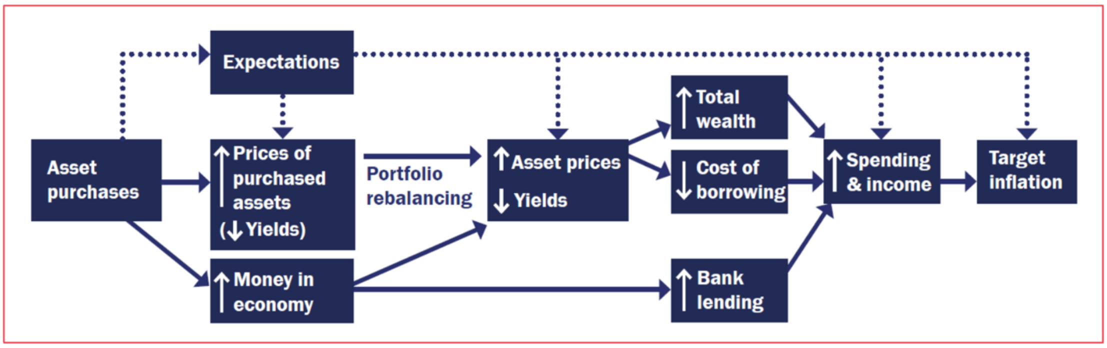
Taking the Eurozone as a reference, the central bank holds auctions of securities in which it obviously aims to buy the cheapest ones. The effects of the auction can be observed both on the account of the institution itself and on the cost of borrowing:

1. On the bank's account: with more money available in the accounts, the bank has more capital available for mortgages and loans, which translates into an increase in economic activity;

2. On the cost of borrowing: if the ECB buys government bonds, the number of bonds on the market decreases; demand increases and the cost decreases, which makes them more attractive.

Below is a concise diagram Figure n.5 of how Quantitative Easing transmission works across the economy:

Figure n. 5 *Transmission Channel of Quantitative Easing*.



Source: *Sini Matikainen, Emanuele Campiglio and Dimitri Zenghelis based on Benford (2009)*[58]

Quantitative easing does not necessarily involve the printing of new money by a central bank. As of today, newly created money is injected into the system electronically, but despite this, QE is generally considered to be a printing operation, as the monetary base of the central bank, e.g. the ECB, is nevertheless extended to stimulate the economy.

As mentioned earlier, the aim of this manoeuvre is not just to create new money, but to give market participants more confidence. A kind of incentive to get the economy moving again in a way that is practically controlled by the central bank itself - which also reduces volatility.

2.2.3.1 EFFECTS OF QUANTITATIVE EASING

Once understood what Quantitative Easing is, it is worth looking at the effects of the monetary policy measure, starting with the negative ones. If a central bank applies QE, i.e. increases the money supply, too quickly the move can result in inflation. Excess money on the market leads to its gradual devaluation and thus to higher inflation. Inflation should not always be regarded as negative, as it can avoid the risks of deflation, which are just as harmful to the economy.

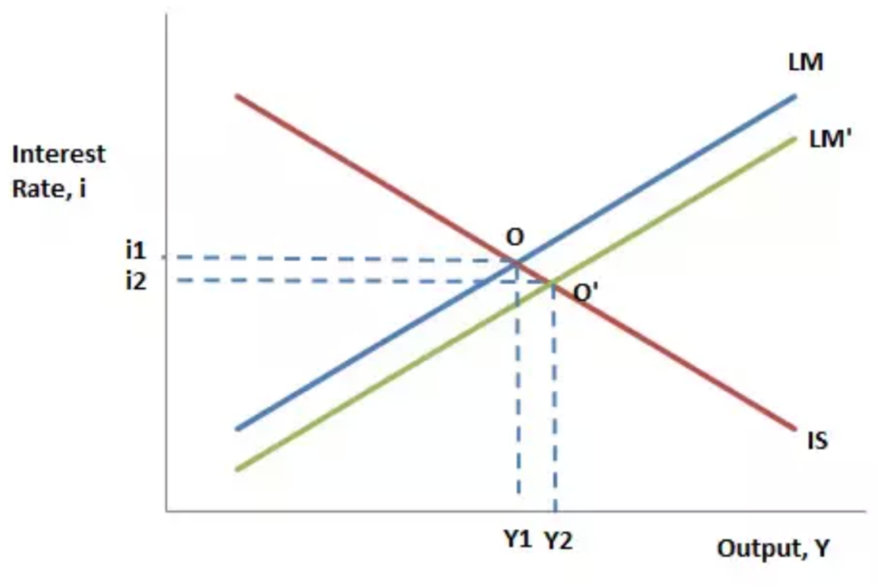
[58] Sini Matikainen, Emanuele Campiglio and Dimitri Zenghelis (2017) - "*The climate impact of quantitative easing*" available at (https://www.lse.ac.uk/granthaminstitute/wpcontent/uploads/2017/05/ClimateImpactQuantEasing_Matikainen-et-al.pdf)

Moreover, central institutions are independent bodies that cannot force banks to lend money to individuals and businesses. This means that if the new money does not end up in the hands of consumers, the instrument is ineffective in stimulating investment and consumption.

As already mentioned, another potentially negative effect of QE is the devaluation of the national currency of the country implementing quantitative easing. The more money is put on the market, the more its value decreases. This can be considered a positive or negative effect depending on the country we are talking about. A depreciation resulting from Quantitative Easing favours exports but not imports.

The effects of quantitative easing are not only negative, quite the contrary. The moment the new money created by the central bank gets into the hands of consumers who spend it, the economy starts to turn again and the goal is finally achieved. To simplify as it can be seen in the Graph n.2, the IS-LM model applied to the QE works as a classic expansive monetary policy:

Graph n.2 *IS-LM model with Quantitative Easing*



Source: own elaboration.

The increase of the money supply cause the LM curve shift towards LM', provoking a lower interest rate at i2 that induces investment and hence, higher output. The IS curve is not touched by the QE program. Hence, the new equilibrium is with a lower interest rate and a higher output.

It is also necessary point out that the beneficial effects of QE can be observed above all from the point of view of the financial market (low rates). The program ends when the target has been reached and monetary policy has been successful.

2.2.3.2 QUANTITATIVE EASING APPLIED TO THE CLIMATE CHANGE

Applying the effects of this monetary instrument to the energy transition context, there may be a potential opposite effect in favoring low-carbon sectors. Central banks mainly buy government bonds to implement their monetary policy decisions, so any ecological consequences of this decision depend on the government's commitment to support low-carbon activities through, for example, the issuance of green bonds. Recently they have extended their Quantitative Easing programmes to incorporate corporate bonds in addition to government bonds. In June 2016, the ECB launched the Corporate Sector Purchase Programme (CSPP[59]) to "provide further monetary policy accommodation and contribute to a return of inflation rates to levels below, but close to, 2 percent" (ECB, 2016c)[60]. As depicted in the paper, no eligibility criteria regarding environmental sustainability are considered in the purchase of financial assets to inject money into the economic system. The securities purchased through QE largely reflect the non-financial corporate bond market, which is disproportionately skewed towards high-carbon sectors relative to the sector's contribution to the European economy, just as the socially optimal distribution of low-carbon investments is significantly smaller.[61] This suggests that QE is not symmetrical as a mechanism for stimulating growth, indeed the transmission channels tend to favour the securities that are bought rather than other assets. In support of this, as

[59] Corporate sector purchase programme : This programme enabled the Eurosystem to buy bonds issued by non-banks established in the euro area. Securities issued by credit institutions and by entities with a parent company which belongs to a banking group are not eligible. ECB - See at : https://www.ecb.europa.eu/mopo/implement/app/html/cspp-qa.en.html

[60] ECB - See at : https://www.ecb.europa.eu/press/pr/date/2016/html/pr160421_1.hr.html

[61] Ivi p.48

shown in the Table n.2 it is clear that the European market for bonds that can be purchased by central banks is excessively skewed towards high-carbon sectors, with bonds from renewable energy companies accounting for only 0.18% of the market.

Table n.2 *Sectoral distribution (%) of EU corporate bond market, Corporate Sector Purchase Programme-eligible bonds, and estimated purchases, by share of total amount outstanding, according to BICS* sector.*

1: BICS sector classification name	2: All Euro corporate bonds (%)	3: All corporate bonds except finance (%)	4: Corporate bonds of eligible maturity (%)	5: Investment-grade corporate bonds of eligible maturity (%)	6: CSPP-eligible (%)	7: Estimated purchases (%)
Communications	4.38	13.10	12.81	10.78	11.54	11.11
Consumer discretionary	5.08	15.20	15.34	12.52	14.37	11.07
Car/automobile manufacturing	*2.16*	*6.47*	*6.19*	*7.98*	*9.85*	*6.84*
Consumer staples	2.35	7.02	7.43	8.43	7.71	8.57
Food & beverage	*1.52*	*4.55*	*4.94*	*5.97*	*7.00*	*6.97*
Energy	2.55	7.64	7.29	8.25	8.63	9.54
Integrated oils	*1.71*	*5.11*	*4.68*	*6.03*	*7.58*	*8.40*
Renewable energy	*0.18*	*0.55*	*0.54*	*0.26*	*0.02*	*0.00*
Financials**	70.72	12.35	11.13	12.30	8.64	8.36
Government***	0.00	0.00	0.00	0.00	0.00	2.62
Health care	1.76	5.26	5.29	5.98	4.31	4.26
Industrials	3.99	11.93	12.72	11.10	11.16	10.63
Materials	3.57	10.69	11.16	8.55	7.62	7.39
Technology	0.64	1.92	1.96	1.64	1.58	1.78
Utilities	4.97	14.89	14.87	20.45	24.45	24.67

*Note: *BICS = Bloomberg Industrial Classification System. **Financial institutions under supervision are excluded from purchase; however, other financial actors such as real estate and financial services are eligible. *** As detailed in Appendix 1, Columns 1–6 are based on a search of ECB-eligible bonds from Bloomberg Terminal, which excludes 'government' bonds as ineligible (using BICS sector classification). Column 7 is based on the list of international securities identification numbers (ISINs) provided by the ECB, in which four government-backed entities appear: Deutsche Bahn, SNCF, Sagess and RATP group. Sources: Bloomberg (2017); ECB (2017), Sini Matikainen, Emanuele Campiglio and Dimitri Zenghelis based on Benford (2009)' own calculations.*

Mainly this imbalance is due to the purchase eligibility criteria provided by central banks, taking the European Central Bank as an example the criteria are as follows:

- the bonds must be denominated in euros;
- they must qualify for use as collateral for credit operations in the euro area; and
- they must be rated as investment-grade by at least one credit rating agency;
- they must have a maturity of between six months and 30 years;
- the issuer must be located in the euro area and must be a non-financial corporation.

These constraints reduce the supply of purchasable financial assets, further limiting the presence of low-carbon corporate bonds in the market. As a result, QE is still seen as an instrument to propel the economy, but with indiscriminate effects that reflect the distribution of corporate bonds in the financial market.

2.2.4 THE ECB ACTION PLAN FOR INCORPORATING THE EFFECTS OF CLIMATE CHANGE INTO MONETARY POLICY

On 8 July 2021, the European Central Bank announced its plan to include climate change considerations in its monetary policies. This statement comes in support of environmental policies in line with the EU's environmental sustainability disclosure and reporting policies.

The plan includes objectives that go beyond price stability and inflation rate regulation, as transition and physical risks could affect the value of assets held on the Eurosystem's balance sheet. The plan also envisages the expansion of its analytical capacity in macroeconomic modelling, statistics and monetary policy in the face of climate change. As stated, the plan will touch on the following areas: "

- *Macroeconomic modelling and assessment of implications for monetary policy transmission. The ECB will accelerate the development of new models and conduct theoretical and empirical analyses to monitor the implications of climate change and related policies for the economy, the financial system and the transmission of monetary policy through financial markets and the banking system to households and enterprises.*
- *Statistical data for analysing climate change risks. The ECB will develop new experimental indicators covering relevant green financial instruments and the*

carbon footprint of financial institutions, as well as their exposures to physical climate-related risks.

- *Disclosures as a requirement for eligibility as collateral and for asset purchases. The ECB will introduce disclosure requirements for private sector assets as a new eligibility criterion or as a basis for a differential treatment for guarantees and asset purchases. These requirements will take into account EU policies and initiatives on environmental sustainability disclosure and reporting and promote more consistent disclosure practices in the market, while maintaining proportionality through appropriate requirements for small and medium-sized enterprises.*
- *Improved risk assessment capabilities. The ECB will start conducting climate stress tests on the Eurosystem's balance sheet to assess the Eurosystem's exposure to the risk of climate change, building on the ECB's economy-wide climate stress test methodology. In addition, the ECB will assess whether the credit rating agencies accepted by the Eurosystem's Credit Assessment Framework have disclosed the information necessary to understand how they incorporate climate change risks in their ratings. In addition, the ECB will consider developing minimum standards for the incorporation of climate change risks into its internal ratings.*
- *Collateral framework. The ECB will consider the relevant risks related to climate change when revising the risk assessment and control framework for assets mobilised as collateral by counterparties in Eurosystem credit operations. [..]Moreover, the ECB will continue to monitor structural developments in the market for sustainability products and is ready to support innovation in the area of sustainable finance within its mandate, as exemplified by its decision to accept sustainability-related bonds as collateral.*
- *Asset purchases in the corporate sector. The ECB has already started to consider the relevant risks of climate change in its due diligence procedures for purchases of corporate sector assets in its monetary policy portfolios. In the future, the ECB will adjust the framework guiding the allocation of corporate bond purchases to incorporate climate change criteria, in line with its mandate. These will include the alignment of issuers with, at a minimum, EU legislation implementing the*

> *Paris Agreement through climate change-related metrics or issuers' commitments towards such objectives.”*[62]

2.3 FINANCIAL AND NON-FINANCIAL POLICIES FOR CLIMATE CHANGE

2.3.1 FINANCIAL POLICIES FOR CLIMATE CHANGE

Climate transition and mitigation policies and related instruments adopted by institutions and governments can affect multiple market sectors. In particular, the financial market can be manipulated to shape and orient investments and investor behaviour. Subsequently, chapter three will look specifically at the financial risks associated with climate change and the green transition from a high-carbon to a low-carbon sector.

In the next chapters, we will analyse financial steering policies to “educate” the market to a more responsible approach and promote sustainable economic development by investing in activities and assets that combat climate change. The introduction of sustainability in the markets, and specifically sustainable finance in the financial sector, has been a response to the need for change by shifting the focus from mere profit to social and environmental gain.

2.3.2 SUSTAINABLE FINANCE

Sustainable finance is a concept that has been developing strongly in recent years; it is a new branch of finance, which includes all those investments (defined as "SRI": Sustainable and Responsible Investment - which will be seen later on) that are oriented to have, in addition to a financial return, a positive impact from an environmental, social and governance point of view.

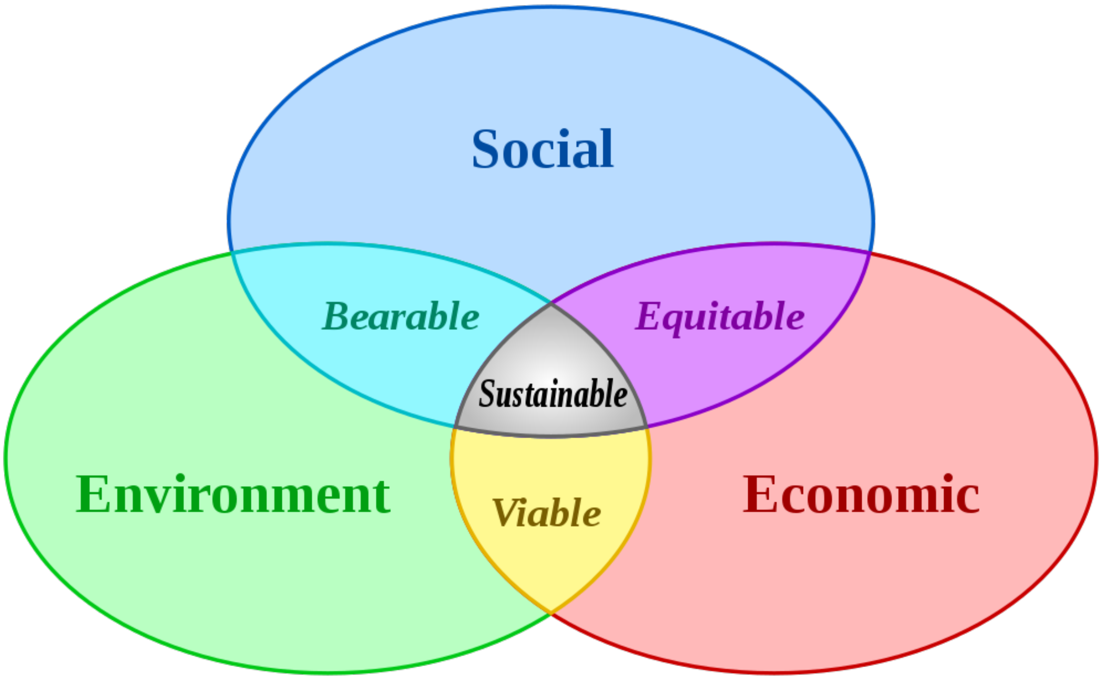
Environmental protection is not only important for the health of the planet, but also for the well-being of all human beings. It is also essential for the stability of the economic-financial system because, generally speaking, the consequences of an environmental crisis do not only create problems for the climate, the ecosystem or natural resources, but

[62] Presse release “ECB presents action plan to include climate change considerations in its monetary policy strategy” (8 jul 2021) full text available here https://www.ecb.europa.eu/press/pr/date/2021/html/ecb.pr210708_1~f104919225.en.html

also have serious repercussions on the financial world. As the concept is still new, there are several definitions of sustainable finance in the literature, which vary significantly from each other and some of them are not very clear. The primary objective is to create value for the investor, but this is accompanied by a second objective, that of benefiting society as a whole. Attention is also paid to all sustainability values, which are, among other things, the main focus during the investment research and selection process.

The concept of sustainable finance is undoubtedly linked to that of sustainable development, by which we mean development that ensures that the needs of the present generation are met without compromising the ability of future generations to meet their own needs. The concept of sustainability, in this sense, is linked to the compatibility between the development of economic activities and the protection of the environment. The possibility of ensuring the satisfaction of essential needs therefore implies the realisation of an economic development whose main purpose is to respect the environment, but which at the same time also sees the richer countries adopt production processes and lifestyles that are compatible with the biosphere's capacity to absorb the effects of human activities, and developing countries to grow in demographic and economic terms at rates compatible with the ecosystem.

Figure n.6 *Spheres of sustainability*.



Source: Wikipedia [63]

[63] See https://en.wikipedia.org/wiki/Sustainability

In particular, environmental sustainability presupposes a balance between the inputs and outputs of each process, and the natural resources used will have to be continually replenished in order to guarantee their use for future generations; social sustainability, on the other hand, is based on respect for human rights. The financial sector has a key role to play in reaching those goals. It can:

- re-orient investments towards more sustainable technologies and businesses
- finance growth in a sustainable manner over the long-term
- contribute to the creation of a low-carbon, climate resilient and circular economy[64]

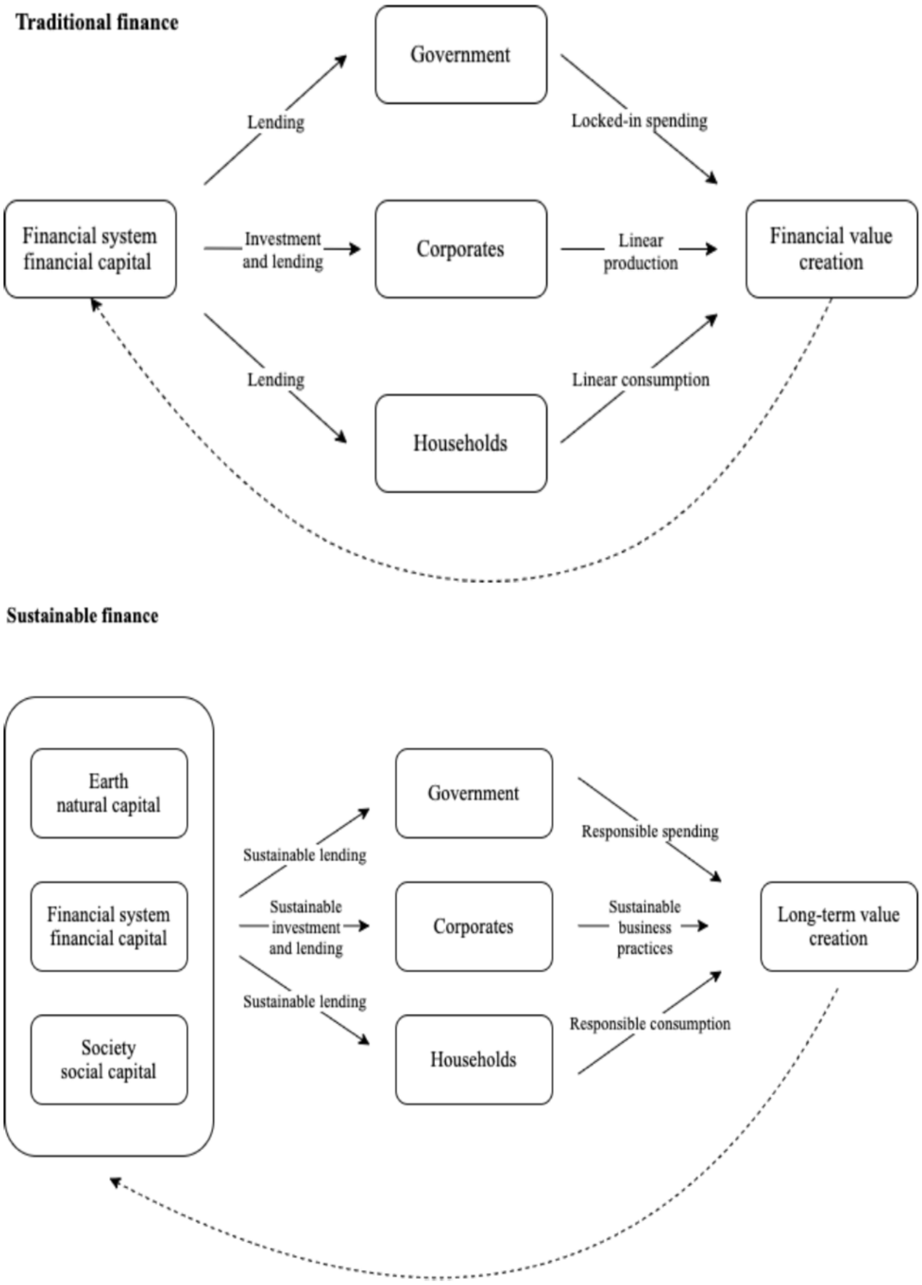
Finally, as far as economic sustainability is concerned, it is important to keep intact the three forms of capital: natural, human and artificial capital as they are considered non-fungible assets. Numerous studies have shown that integrating these environmental, social and governance aspects into traditional financial analysis leads to a better understanding of the risks of a transaction or investment. This can allow both to detect corporate crises in advance, but also to seize better opportunities.

Another important factor to take into account when thinking about sustainable finance is the investment horizon. Investor behaviour is often at the mercy of emotions, such as enthusiasm and fear, which often lead to a preference for short-term returns.

However, a long-term investment is based on careful financial planning, you do not focus on the daily fluctuations of the market, but you can concentrate on your objectives and gain in terms of effectiveness and efficiency. Moreover, the benefits of all these green projects will only manifest themselves in the long term, not on the individual company, but on future generations.

[64] European Commission, Overview of sustainable finance – see at https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/overview-sustainable-finance_en

Figure n.7 *Traditional finance and Sustainable finance*.



Source: *Schoenmaker and Schramade (2019).*

Governments and supranational institutions play a key role in the growth and development of this new type of finance, and must seek to incentivise this type of investment in order to tackle all the environmental and social problems that have arisen

in recent years. Important regulatory work will be needed, new laws (clear, simple, but at the same time complete) will be needed to give the investor all the information he needs and also support throughout the life of the operation.[65]
The actors involved in this type of finance are no different from those who operate in the traditional market: private individuals, banks, institutional investors, international financial institutions, central banks and finally regulatory authorities.

2.3.2.1 INSTRUMENTS OF SUSTAINABLE FINANCE

When we talk about sustainable finance, we are not referring to a single product or a single financial activity, but to a whole system that includes a wide variety of instruments to finance various activities that will generate a high social or environmental impact. The world of finance, in general, should no longer be seen as an enemy of sustainable development but, on the contrary, as a powerful means to be used to ensure that the objectives set are achieved in the shortest possible time.
At this point, it is important to understand which financial products and instruments can be traced back to sustainable finance; there is no need to invent new instruments, but simply to use existing ones in a more innovative way. Due to the growing interest in these topics, a variety of sustainable finance instruments have spread across the market and they will be described as follow.

2.3.2.2 THE GREEN SUPPORTING FACTOR

The Green Supporting Factor is a green incentive tool that would encourage banks to finance environmentally friendly investments, accelerating the transition to a greener, more sustainable economy. The Green Supporting Factor would lower the risk weights applied to sustainable (i.e. green) loans and investments, thereby reducing the capital requirements that banks must have for these particular activities. The minimum amount and quality of capital that a bank must hold in proportion to the aggregate risk associated with its balance sheet is defined by the prudential framework. Accordingly, the higher the risk weight given to a specific asset, the more capital the bank must hold to compensate for the risk associated with that asset. After the great financial crisis of 2007-08, the

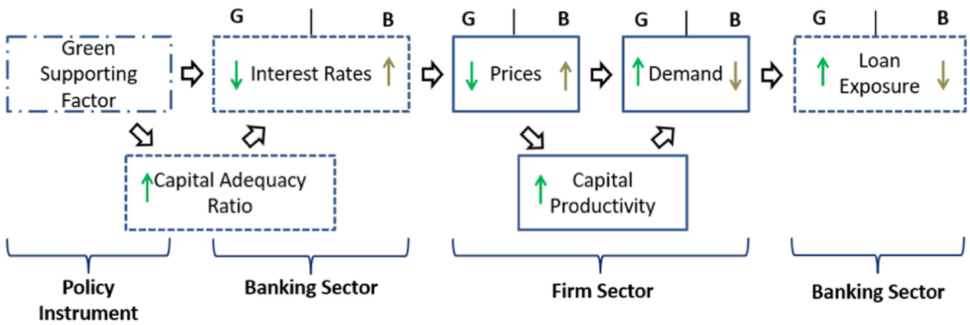
[65] Forum for Sustainable Finance (2018), "*Sustainable finance and the circular economy, guidelines for investors and businesses*", Conai, Milan, available at https://finanzasostenibile.it/wpcontent/uploads/2018/11/manuale-CONAI-per-WEB.pdf

banking sector has to adopt the Basel III regulatory framework[66]. This set of regulations focuses on banks' liquidity, capital buffers and risk exposure with the aim of preserving financial stability. By complying with this framework, depending on the quality and number of transactions in the banking sector (Perez Montes et al., 2016), a minimum capital adequacy ratio must be met CAR. CAR is defined as the bank's equity in risk-weighted loans and indicates the liquidity of the banking sector with respect to loans considered safe. Through interest rate adjustments, the banking sector achieves the CAR target (King, 2010; Martynova, 2015). Since reduced capital requirements would make these loans less expensive for banks, consumers can obtain more advantageous interest rates for their green assets.

Basically, the motivation for the introduction of the green support factor can fall into three main areas;

1. Correcting misjudged climate risks
2. Responding to concentration risk
3. Reasoning for risk-free policy making[67]

Figure n. 8 Transmission channels of the Green Supporting Factor



Source: *N. Dunz, A. Naqvi and I. Monasterolo*

Note: G stands for green, B stands for brown capital good firms. Dotted line boxes represent the effects of the GSF on the banking sector, while straight line boxes represent implications for the real economy.

The GSF concept is based on the perspective of risk diversification. As will be explained later, the financial risks associated with high-carbon activities are numerous, so holding a highly concentrated portfolio in the brown sector could prove to be a threat. The Green

[66] BIS, 2011. Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems. Bank of International Settlements Technical Report.

[67] Green Economy Forum – see at https://greeneconomyforum.info/why-green-supporting-factors-isnt-a-magic-tool-for-climate-financing/

Support Factor, in this respect, could incentivise investment in the green sector and thus disinvest some of the capital held in the brown sector.
Climate change mitigation is greatly helped by the financing of sustainable investments. However, stimulating such investments by adjusting risk weights may have side effects. First of all, lowering the risk weights for green investments does not provide the logical consequence of stimulating investment.
Second, the GFS contributes to the brown penalty factor of discouraging environmentally harmful investments. But the problem is inherent in the fact that it is difficult to divide sectors into two exact categories. Since a variety of different activities lie in between, they are neither strictly environmentally sustainable nor particularly harmful.

2.3.2.3 GREEN BONDS

In the world of sustainable finance, the instrument that has attracted the most attention from investors, analysts and the media is undoubtedly the Green Bond; this interest exploded after the Paris Agreement - around $157 billion worth of green bonds were issued in 2019.[68]
The Green Bond is therefore one of the instruments designed to address these issues; these are fixed income securities, issued with the aim of raising capital to finance or refinance activities that will generate a positive impact on the environment.
They are, to all intents and purposes, normal bonds: debt securities (for the person issuing them) and credit securities (for the person purchasing them) that represent a portion of debt raised by a company or public body to finance itself. They guarantee the purchaser repayment of the principal at the end of the fixed period, plus interest (the remuneration payable by the purchaser of the bonds in exchange for the amount invested). Bonds are issued with the aim of raising capital for investment directly from savers on more advantageous terms than bank loans. The holder of a company's debt securities, although assuming the business risk, unlike the shareholder, does not participate in the management activity of the issuer, not having the right to vote at shareholders' meetings. In return, however, the remuneration of equity risk capital is conditional on the prior payment of interest and capital repayments to bondholders[69].

[68] Investopedia - https://www.investopedia.com/terms/g/green-bond.asp
[69]Borsa Italiana – see at https://www.borsaitaliana.it/notizie/sotto-la-lente/obbligazioni.htm

The only thing that distinguishes Green Bonds from normal bonds is the obligation to use the funds raised exclusively to finance businesses, activities or projects that can be defined as "green", so, for example, everything related to: renewable energy, energy efficiency, sustainable waste management, sustainable land use, biodiversity conservation, use of greener transport, water management or climate change adaptation. [70]This list of "green" activities is not complete and exhaustive; as seen above, there is no single definition of sustainable finance in the literature, just as there is no definition of the term "green" in relation to bonds; it is therefore not always clear, especially for the investor, whether a bond can be defined as green or not. In general terms, a Green Bond is an instrument oriented towards environmental protection and everything that promotes the transition to a sustainable economy.

The Climate Bonds Initiative (CBI) is an international, non-profit organisation dedicated to mobilising the global bond market towards solutions that facilitate the transition to a low climate-altering economy; its analysts have distinguished the Green Bond market into two distinct segments: "labelled and unlabelled Green Bonds". The first segment includes all bonds that are officially labelled as "Green Bonds" because they comply with all the principles set out by the organisation. The second segment includes those bonds that are not directly linked to specific "green projects" but are issued by companies that have initiated some form of change towards renewable sources.[71]

Looking more closely at the Green Bond market, we see that Green Bonds are actually a very small part of the bonds issued in 2018, at around 143 billion compared to 32,341.7 billion for ordinary bonds. However, the most important factor has been their exponential growth: in 2018, they were 175 times those issued in 2008, while ordinary bonds were only 1.6 times larger. In the last two columns of the Table n.3 we see that growth is actually very high. It shows the percentage of Green Bonds in the total bond market, first in dollars and then in numbers.

[70]Quadrante Futuro https://www.quadrantefuturo.it/settori/the-green-bond-market-a-new-green-trend.html
[71] Obbligazioni Verdi – see https://valori.it/obbligazioni-verdi-la-parola-al-mercato/

Table n.3 *The evolution of Green Bonds*

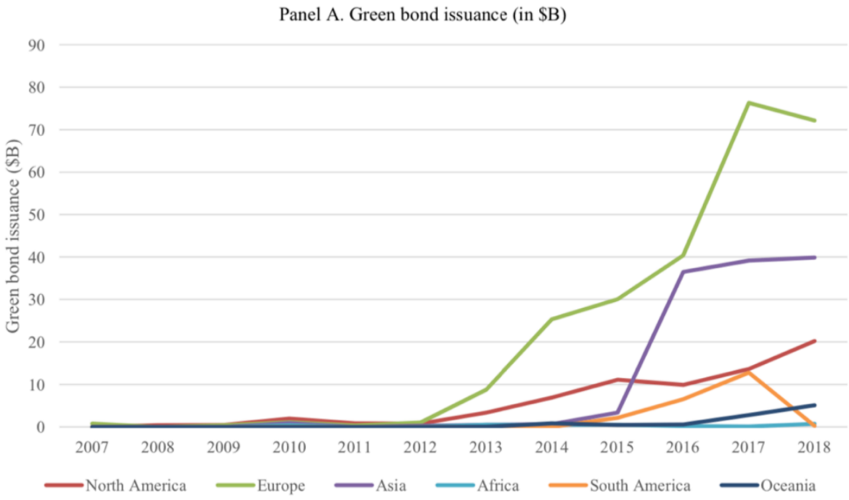
Year	$B Green bonds	# Green bonds	$B Ordinary bonds	# Ordinary bonds	Share of green bonds ($)	Share green bon
2018	143.1	519	32,341.7	191,362	0.441%	0.270
2017	146.6	441	38,893.2	172,645	0.376%	0.255
2016	95.4	263	37,268.9	146,912	0.255%	0.179
2015	47.7	328	31,573.7	132,506	0.151%	0.247
2014	34.5	138	29,300.9	123,106	0.118%	0.112
2013	13.2	39	27,196.3	114,474	0.049%	0.034
2012	2.1	21	30,066.0	100,283	0.007%	0.021
2011	1.2	30	28,125.8	86,096	0.004%	0.035
2010	4.4	55	28,268.9	83,112	0.015%	0.066
2009	0.9	13	28,868.6	86,364	0.003%	0.015
2008	0.4	7	23,686.4	115,269	0.002%	0.006
2007	0.8	1	20,571.3	118,215	0.004%	0.001
Total	490.4	1,855	356,161.8	1,470,344	0.138%	0.126

Source: *Green Bond Standards: "Effectiveness and implications for public policy" ,Caroline Flammer, June 2019*

Geographically in 2018 the main issuers are China with about 84 billion dollars issued in Green Bonds, followed by France and the USA with 58 and 56 billion respectively, followed by mainly European countries. From the Graph n.3 it can be seen that of the total, Europe has been the main issuer of green bonds since 2012, while Asia and North America have taken a dominant position since 2015. Analysing the distribution of issuers by sector in the Graph n.4 we see that governments are the main issuers, followed by financial, commodity and energy companies. Governments can therefore be considered as early adopters of this new financial instrument.[72]

[72] Caroline Flammer "Green Bonds: Effectiveness And Implications For Public Policy", June 2019 – see at https://www.nber.org/papers/w25950.pdf

Graph n.3 *Green Bonds per geographic area*



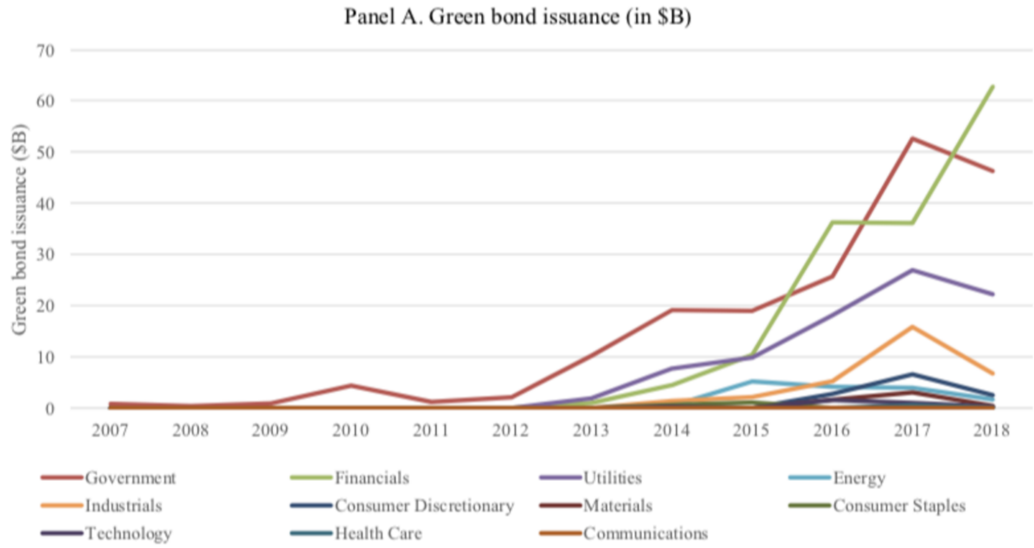
Source: *Green Bond Standards: "Effectiveness and implications for public policy" ,Caroline Flammer, June 2019*

In the beginning, as a new financial instrument for projects with a high social and environmental impact, they were issued by international financial institutions such as the World Bank or the European Investment Bank. Subsequently, as they gained popularity, individual companies began to issue debt instruments to finance projects with high environmental impact.[73]

In summary, the main issuers of Green Bonds are independent nations, municipalities, government agencies, corporate development banks and commercial banks.

[73] Borsa Italiana See https://www.borsaitaliana.it/notizie/sotto-la-lente/green-bond-definizione.htm

Graph n.4 *Green bonds per sector*.



Source: *Green Bond Standards: "Effectiveness and Implications for Public Policy" ,Caroline Flammer, June 2019*

Once Green Bonds have been defined, the various types of Green Bonds under the Green Bond Principles can be explored. According to the document drawn up by ICMA [74]there are four types of Green Bond:

- *Green Bonds with Standard Revenue Use* - in this case we encounter bonds issued directly by the issuer, standard type (recourse to the issuer)
- *Green Bond on revenues* - Non-recourse to the issuer, this type of Green Bond allows the bond to be charged to cash flows which are covered by revenues, fees etc. and where the use of the proceeds is linked to environmental investments linked or not to these flows
- *Project Green Bond* - this type makes it possible to have this product issued for several projects, within which the investor must directly bear the risk of the project itself, having or not the opportunity to use the issuer.
- *Securitised Green Bonds* - these are project-specific guarantee bonds which also include ABS, MBS and other types. The main sources of repayment are the cash flows generated by the generated by the investments.

[74]International Capital Market Association - see https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/green-bond-principles-gbp/

It needs to be reminded that these typologies of bonds must respect each regulatory principle of this category of financial instruments.

2.3.3 NON FINANCIAL REGULATIONS FOR CLIMATE CHANGE

The emission of greenhouse gases, as just explained, has pervasive effects in the economic system. The need to regulate negative externalities according to a more market-based view was one of the first awareness, and first approach used, regarding environmental sustainability. The first literary contribution to market regulation for reducing or eliminating negative externalities came from Ronald Harry Coase (Willesden, 29 December 1910 - Chicago, 3 September 2013), an English economist. In 1960 he published an article in “The journal of law and economics” entitled “The problem of social cost[75]”, which would later become known as Coase's Theorem, in which the economist identified the reason for many market failures as the incorrect allocation of property rights linked to environmental externalities. The competitive market is considered to be the most suitable institution to ensure a socially efficient allocation of resources; however, it has difficulties in considering the opportunity cost of exploiting the natural environment.

The cost of environmental exploitation is a negative externality, i.e. a social cost generated by economic activities that does not manifest itself as a private cost, does not find expression in market transactions, and is therefore difficult to detect. These negative externalities are said to be among the causes of some "market failures" (i.e. they prevent the market, even competitive markets, from ensuring social efficiency in the allocation of resources).

With this theorem the english economist intended to show how through the market, in the absence of transaction costs, in which only agents with equal market power act, one can achieve higher social efficiency by eliminating externalities simply by any arbitrary allocation of property rights and letting the market act with the only condition that property rights are exchangeable between agents.

Obviously, applying this theory to the real and current context, where transaction costs and very high sectoral competitiveness exist, such thinking becomes inapplicable. It is very complex to make Coase's theorem work in the presence of a multiplicity of polluters

[75] Coase. “*The problem of social cost.*” The Journal of Law and Economics, Vol. III, 1960, pp. 1–44 – see https://www.law.uchicago.edu/files/file/coase-problem.pdf

and/or victims of pollution, precisely because of the complexity of the allocation of property rights over the environment. The role of the state, or of an entity superior to companies, thus becomes of fundamental importance in regulating the market and consequently its outputs.

The difficulties for policymakers in this case lie in calibrating the limits and allowable emission quotas without damaging the competitiveness of companies and creating market distortions. So, in choosing to create a market with tradable permits, the state will only have to set the overall amount of pollution reduction. In this way the state is sure of the level of emissions and can, as in the case of the EU, set itself targets. Indeed, under certain conditions, the environmental regulatory framework is not only a source of costs, but also opens up new development opportunities for companies, mainly related to innovation, which would otherwise remain unexplored. In the light of this, understanding whether, in fact, the benefits will be able to compensate for the compliance costs required by environmental regulation is a step of primary importance.

Starting from Coase as a theoretical basis, the following sub-chapters will analyse the main instruments and regulations proposed by countries and supranational institutions to decrease and control CO2 emissions in the markets.

2.3.3.1 THE EMISSIONS MARKET (EMISSION TRADING)

The concept of tradable emission permits was first theorised in 1968 by J.H. Dales [76]. The idea was that, in a system of transferable "pollution rights", the total allowed quantity of emissions would be limited by the number of permits set by the public authority according to the maximum level of pollution that could be produced in a given area. The permits granted by the authority would be distributed to companies, allowing them to emit a given amount of pollutants for a given period of time; finally, the company, in order to reach the permitted emission levels, would have the choice of adopting technological innovations aimed at making its plants “environmentally friendly”, or of purchasing additional pollution permits on the market. Any polluter who achieves less pollution than the number of permits in his possession will receive a certain amount of credits, which

[76] J. H. Dales, Pollution, Property & Prices: An Essay in Policy-making and Economics. Toronto: University of Toronto Press, 1968, pp. vii, 111. – see https://www.cambridge.org/core/journals/canadian-journal-of-political-science-revue-canadienne-de-science-politique/article/abs/j-h-dales-pollution-property-prices-an-essay-in-policymaking-and-economics-toronto-university-of-toronto-press-1968-pp-vii-111/08541C7FEA0D43C183BD6F835AC89630

can be set aside or sold on the permit market. For these reasons, emission trading (ET) is seen as an approach to ensure that the reduction of air pollutant emissions is done in the most cost-efficient way, i.e. there is an incentive to sell permits if the marginal abatement costs are lower than the current permit price, and an incentive to buy them if the abatement costs are higher than the permit price.

The best application of ET is in the case of emissions of greenhouse gases, which are responsible for global warming; since the harmfulness of these gases does not depend on the spatial-temporal distribution of emissions, it does not matter how much an individual company emits, as long as the overall emission limit is respected. This allows the authority to regulate the amount of emissions produced in aggregate by setting an overall cap on the amount of emissions that can be produced, while at the same time allowing companies to flexibly determine how to reach the set targets. By allowing participants the freedom to trade pollution permits on the market, the reduction of overall emissions will be achieved as efficiently as possible. The following Table n. 4 summarises the main theoretical aspects of tradable emission permits.

Table n.4 *Tradable emission permits*.

Basic aims and benefits base	***Better practical conditions***	***Average environmental relevance***	***Limitations***
- savings in compliance costs - possible boost to economic growth - flexibility - international pollution reduction	- differences in marginal compliance costs - fixed maximum pollution quotas - high number of polluters to allow market formation and functioning - possibility of technological innovations	- water: modest prospects - air: favourable prospects - waste: modest prospects - noise pollution: modest prospects	- limited applicability with more than one pollutant at a time - possible exacerbation of pollution hotspots - administrative complexity - difficulties in the initial distribution of permits - high transaction costs in case of many polluters

Source: *own elaboration*.

2.3.3.2 THE KYOTO PROTOCOL AND EMISSIONS TRADING

Emission Trading (ET) is provided for in Article 17 of the Kyoto Protocol[77]. It concerns the possibility of transferring one's own emission rights or buying the emission rights of another country. Trading permits is one of the mechanisms that help optimise the cost-benefit ratio of reducing greenhouse gas emissions. ET can only take place between “Annex I”[78] countries, and officially began in 2005, the year the Protocol came into force; reduction units can only be sold and bought between states, based on bilateral trade agreements. Through the ET, states that reduce their emissions more than their assigned targets can sell these emission allowances to other countries with reduction obligations. The initial allocation of emission allowances, called AAUs (Assigned Amount Units), was done according to the so-called historical approach ("grandfathering[79]"), based on the historical emission levels of individual states[80]; the reference year chosen was 1990, the year of the IPCC's First Assessment Report on Policy and Scientific Responses to Climate Change[81]. Each AAU corresponds to one tonne of CO2 equivalent. Quotations for AAUs fluctuate according to the mass of free units on the market; there is already an emissions trading exchange in London which has set itself rules and already launched auctions.

When the Kyoto Protocol was signed in 1997, each individual “Annex I” country made precise commitments to achieve the Protocol's main objective of a global reduction in greenhouse gas emissions of at least 5% below 1990 levels by 2008-2012. The emission reduction commitments are divided as follows[82]:

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[77] Kyoto Protocol to the United Nations Framework Convention On Climate Change. United Nations, 1998 – Available at https://unfccc.int/resource/docs/convkp/kpeng.pdf

[78] *ibidem*

[79] A policy or provision (usually contained in statute) under which an old rule continues to apply to some existing situations while a new rule will apply to future cases. - https://uk.practicallaw.thomsonreuters.com/1-4221827?transitionType=Default&contextData=(sc.Default)&firstPage=true

[80] *Ivi* P.69

[81] Climate Change: The IPCC 1990 and 1992 Assessments. Intergovernmental Panel on Climate Change – available at https://www.ipcc.ch/report/climate-change-the-ipcc-1990-and-1992-assessments/

[82] Kyoto Protocol. MEMO/04/43. Bruxelles, 4 March 2004 – see https://ec.europa.eu/commission/presscorner/detail/en/MEMO_04_43

Tab. n. 5 *Emissions reduction commitment to achieve the Kyoto Protocol*

European Union	-8%
Japan	-6%
USA	-7%
Russia, Ukraine, New Zealand	0%
Norway	+1%
Iceland	+10%

The European Union has ratified the Protocol jointly, as allowed by Article 4 of the Protocol. EU countries will therefore have to achieve a common target of an 8% reduction from 1990 emission levels, equivalent to a reduction of 336 million tonnes of CO2. Within the EU, the targets for individual Member States are:[83]

Tab. n.6 *Emissions reduction commitment within Europe To achieve the Kyoto Protocol*

Austria	-13%	Italy	-6.5%
Belgium	-7.5%	Luxembourg	-28%
Denmark	-21%	Netherlands	-6%
Finland	0%	Portugal	+27%
France	0%	United Kingdom	-12.5%
Germany	-21%	Sweden	+4%
Greece	+25%	Spain	+15%
Ireland	+13%		

Examining the tables, it can be seen that not all countries have made commitments to reduce their emissions; in some cases, in fact, the commitment made was not to increase their emissions compared to 1990 (e.g. France), or to increase them by a certain amount at most (e.g. Iceland). After assessing the reference situation and considering the commitments made by individual countries, AAUs credits corresponding to the maximum quantity of greenhouse gases that each country can produce during the first commitment period 2008-2012 were allocated and distributed.

[83] *Ibidem*

ET was chosen by the European Community as the main instrument to achieve the reduction commitment undertaken in the Kyoto Protocol; on 13 October 2003, the European Commission published the European *Directive 2003/87/EC* on Emission Trading, better known as the Emission Trading System (EU-ETS).

2.3.3.3 THE EU EMISSION TRADING SYSTEM

The Emission Trading System is one of the flexible mechanisms, it is considered a "market-based instrument", which is more flexible than the classical instruments based on a regulatory approach typical of command-and-control instruments. An advantage of flexible market-based instruments over command-and-control instruments is that they provide an incentive for companies to achieve greater reduction targets than the standards imposed (in the case of the ETS, revenue is obtained from the share of saved emissions that can be sold). The aim of these instruments is to reward virtuous companies and incentivise them to be virtuous thanks to the economic opportunities they could gain from their virtuosity. The European Community did not wait for the official entry into force of the Protocol, which came into force on 16 February 2005, and set up a system regulates the exchange of emission quotas between companies located in member countries in a manner similar to International Emission Trading. The European Emissions Trading System, known as the European Emissions Trading System (EU ETS), sets limits on carbon dioxide emissions for a large number of installations across Europe, but allows the rights to emit carbon dioxide, called European Unit Allowances (EUAs), to be traded. The Emission Trading System, although explicitly referred to in *Directive 2003/87/EC*[84], and is an implementation tool, is a different tool from the Kyoto mechanism (EIT), so complying with the ETS does not necessarily mean complying with the Kyoto Protocol; the actors involved are different, and the timeframe for implementation is also different: with reference to the mandatory nature, the level of obligations under the European ETS is more defined and structured. Moreover, the ETS covers only part of European emissions, creating a separation between ETS and non-ETS activities.
The Emissions Trading System:

[84] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC

- operates in all EU countries, plus Iceland, Liechtenstein and Norway;
- limits emissions from around 10 000 installations in the power sector and manufacturing industry, as well as from airlines operating between these countries;
- It accounts for about 40% of EU greenhouse gas emissions.[85]

In order to achieve the final target of an 8% reduction, a *cap-and-trade* method of regulation was devised, in which the public operator sets a cap on the emissions allowed for the European sectors included in the ETS mechanism (including the most polluting sectors, primarily heavy industry and energy).

The cap on total permitted emissions is reduced step by step; in 2020, emissions covered by the ETS will be 21% lower than in 2005 and in 2030 43% lower. [86]For aviation, there is a separate cap and airlines can use both types of permits.

ETS: Pricing

The volume of emissions is determined by:

- *Weather conditions*: low winter temperatures (high summer temperatures) increase the demand for heating (air conditioning systems) affecting the consumption of fuels used for energy production. Similarly, the level of precipitation affects the amount of water reserves needed for hydropower production, especially in northern Europe.
- *Economic activity*: CO2 emissions from different sectors are closely linked to their level of productivity.
- *Energy prices*: The prices of alternative energy sources - oil, coal, gas, nuclear - affect the level of emissions by virtue of the fact that an increase in the price of these resources favours the supply of alternative resources with a lower level of emissions. In particular, using gas rather than coal saves 1.7 tonnes of CO2 emissions per tonne of energy produced, in terms of the fuel obtained.
- *Emission constraints*: compliance with ETS constraints influences managers' decision-making choices regarding the supply of energy sources and related CO2 production.

[85] EU Emissions Trading System (EU ETS) - see https://ec.europa.eu/clima/policies/ets_en

[86] Questions and Answers - Emissions Trading – Putting a Price on carbon – see https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3542

- *Prices of CER[87]s/ERU[88]s*: the pricing and availability of alternatives to EUAs - projects related to the development of production methods and techniques with a lower emission coefficient, provided for by the Kyoto Protocol (CERs and ERUs) - may influence the choice of different companies in case of permit shortfalls.

The main determinant of the ETS is not the position of individual countries in terms of emission deficit/surplus, but rather the supply/demand of the individual companies involved. A "long" position is defined as a situation in which a company has a surplus of permits (EUAs), so it assumes the role of a potential seller.

On the other hand, a "short" position is defined as a situation where a company has more emissions than its permits, so it automatically becomes a potential buyer. The net position of individual Member States is the difference between "short" and "long" companies. Almost all countries, however, import and export EUAs from other Member States, reflecting the existence of "long" and "short" companies in all countries and the fact that all different companies take advantage of the trading possibilities offered by the ETS.

2.3.3.4 EMISSION TRADING SYSTEM: CAP AND TRADE MARKET

A *cap-and-trade* ETS establishes an emissions cap, which is divided into a certain number of permits (i.e. tradable emission rights, allowances) that are distributed among participants over a limited time period. Allowances can be traded freely among participants in the trading market, but at the end of the period each must surrender a number of allowances equal to their actual emissions. If an entity's permits are less than its actual emissions, a financial penalty will be imposed on the excess emissions. The mechanism of the cap-and-trade type sets an overall cap on the emissions allowed in the European territory in the sectors concerned (cap) to which corresponds an equivalent number of "quotas" (1 ton of CO2eq. = 1 quota) that can be bought/sold on a special market (trade).

Emission allowances can be allocated for free or for a fee. Emission allowances can be allocated for free or for payment. In the first case, they are sold through public auctions

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[87] Certified Emission Reduction (CERs): Credits originating from Clean Development Mechanism (CDM) projects. These projects limit greenhouse gas emissions in countries not bound to the Kyoto protocol. Subject to certain limits, companies and aircraft operators can exchange valid CERs for EUAs and AEUAs.

[88] Emission Reduction Units (ERUs): Credits originating from Joint Implementation (JI) projects. These projects limit greenhouse gas emissions in countries bound to the Kyoto protocol. Subject to certain limits, companies and aircraft operators can exchange valid ERUs for EUAs and AEUAs.

in which accredited entities participate. In the second case, quotas are allocated free of charge to operators at risk of relocating their production to countries with less stringent environmental standards than Europe (the carbon leakage phenomenon, which will be explained later). Free allocations are reserved for manufacturing sectors and are calculated using benchmarks on the emissions of the most virtuous plants.

In essence, those able to reduce their emissions below their targets can sell unused allowances to those who would otherwise be unable to meet them. The Kyoto Protocol's emissions trading mechanism is based on the cap-and-trade principle, as the number of emissions put on the market is defined and limited. Through this system, at the end of each period, the authority responsible for allocating allowances can decide whether to reduce the total number of allowances to be distributed in order to further reduce the level of emissions with the same number of actors involved. In order for a cap-and-trade market to be more efficient, it must meet certain requirements.

Requirements:

- The amount of allowances allocated (the “cap”) must be lower than the baseline scenario without the market (the so-called “business as usual” scenario);
- the initial allocation method must provide a level playing field for participants;
- transaction costs must be low;
- it must be possible to accurately determine and verify for each participant the quantity produced or used of the regulated good;
- it must be possible to detect instances of non-compliance, so the penalty for non-compliance with the rules or limits assigned must be sufficiently high to act as an effective deterrent;
- there must be practical means of achieving the set objective at a lower cost than penalties for non-compliance.

Within the cap-and-trade system, there are different ways of allocating allowances, the choice of which has implications in terms of economic efficiency.

The allocation alternatives can be divided into three groups:

1. distribution by auction;
2. distribution based on emissions with reference to a specific historical period (e.g. 1990 in the case of the Kyoto Protocol) (*grandfathering*);
3. distribution on the basis of emissions with reference to the last available year of observation and subject to annual update.

For the emission-based allocation modes, two different parameters can be used, direct emissions (direct emissions at the installation level) or the sum of direct and indirect emissions (i.e. emissions related to electricity and heating consumption). Modes 2 and 3 can also refer to two alternative ways of measuring the quantity of emissions, namely the inputs used in the production process or the final quantity of output produced.

The three alternative modes differ primarily in the economic efficiency (minimisation of implementation and operating costs) associated with trading. There are cost items that can differ greatly depending on the chosen allocation method, such as compliance, administrative and transaction costs, or possible distortions in the product market and taxation system.

2.3.3.5 THE LIMITS OF ETS: CARBON LEAKAGE

The phenomenon of outsourcing, which has characterised these last few years of strong production expansion, may be the driver of one of the most important limitations of the market regulation in question.

Faced with increasing environmental costs, and in the absence of an international climate agreement, European companies may find it convenient to relocate their production facilities to areas outside Europe not subject to any environmental regulation in order not to bear the environmental costs of monetising emissions in the ETS (Carbon Leakage). A decrease in European emissions as a result of less production (and not less polluting production) would correspond to an increase in non-European emissions, followed by the relocation of production and the subsequent import of products into Europe. If this risk were to materialise, European industry could suffer a loss of competitiveness, to the detriment of economic growth and employment in Europe. All of these costs would be offset by limited and doubtful environmental benefits.

Carbon leakage is measured using a carbon leakage indicator, which calculates the percentage of emissions reductions in one country that are offset by increases in the rest of the world. There are five main channels that influence carbon leakage: fossil fuel competitiveness, policy design, incentives, technology spillovers and demand. Studying the phenomenon is complex: the magnitude of the carbon leakage rate depends on a variety of factors, including the nature of corporate policies, the structure of the economy, climate ambition, etc. However, the topic concerns us all. However, the argument is relevant to all of us: for a climate policy to be effective, it must be effective all over the world and not just in a few countries. In fact, the effectiveness of climate policies risks being called into question by the consequences of carbon leakage.

According to the ETS Directive (Article 10a), [89]a sector or sub-sector is considered to be exposed to a high risk of carbon leakage if:

- the direct and indirect costs generated by the implementation of the directive lead to an increase in production costs, calculated as a percentage of gross value added, of at least 5%; and
- the sector's trade intensity with non-EU countries (imports and exports) exceeds 10%.

A sector or subsector is also considered exposed if:

- the sum of direct and indirect additional costs is at least 30%; or
- the intensity of trade with non-EU countries is greater than 30%.

In this regard, the Commission and the European Parliament had to outline the new European policy in order to reduce the risk of carbon leakage. For this purpose it was necessary to:

1. analyse the impact of the ETS on the competitiveness of regulated industrial sectors;
2. identify objective criteria to establish which economic activities are more exposed to international competition, and therefore to the risk of carbon leakage;
3. to define which remedies could limit this phenomenon, preserving the competitiveness of European industry.

In the first case, it is necessary to determine the extent to which the increase in costs (direct and indirect) caused by the adoption of new, more stringent targets can be passed on to final prices without causing a loss of market share vis-à-vis non-European competitors, the second variable depending on the degree to which markets are opened up to international competition. The combination of the cost increase and the exposure of markets to foreign competition is a criterion to estimate the carbon leakage risk that each sector might face: if firms are not able to recover the cost increase caused by the ETS through a price increase without losing market shares, then the risk of carbon leakage will be substantial.

[89] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC – available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02003L0087-20140430

2.3.4 MARKET REGULATIONS AND COMPETITIVENESS

As mentioned above, there is a great debate among policymakers and economists about the effects of environmental policies and the competitiveness of a country's industry. In the phase of ecological transition, the difficult trade-off between economic and climate objectives has to be taken into account, which may have side effects in the cost-benefit analysis. In the implementation of environmental policies, industries are forced to bear private costs to comply with market regulations. It is commonly thought that these costs are merely a cost item to be amortised over the years in order not to be forced out of the market. The dominant argument is that companies are not aware of certain opportunities and that environmental policy could open the door to new technologies. Industries may be subject to two types of costs:

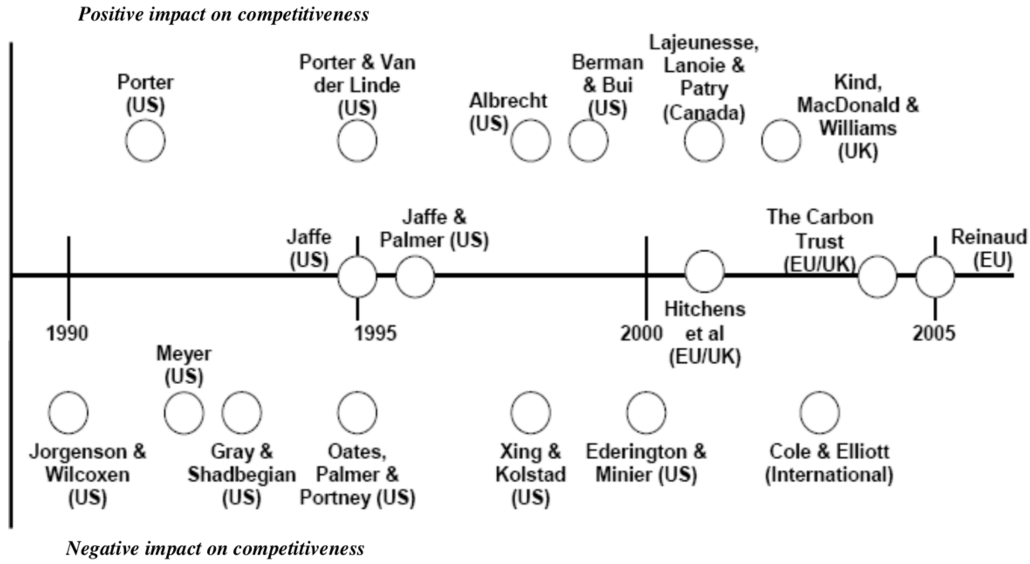
- Direct: This refers to the repercussions that environmental impositions cause directly on the sector(s) for which they are designed. An example would be a tax on harmful emissions for a certain production category.
- Indirect: Refers to the effects that a regulatory intervention for a generic sector has on other related sectors. For example, an environmental standard applied to the energy sector generates additional costs which, if certain conditions are met, can be passed on in sales prices; this would increase the energy expenditure of other sectors, especially energy-intensive ones, raising important issues in terms of competitiveness.

However, as already mentioned, the regulatory framework under certain structural conditions may lead to a mitigation of the cost effect of environmental policy or may even lead to a win-win situation. Market regulations, by providing production limits or guidelines to be respected, open up new development opportunities for companies, essentially linked to innovation, that would otherwise remain unexplored. In this regard, the literature contains numerous studies supporting three different positions: environmental regulation has an impact, no impact or no effect on competitiveness. The reasons presented by each strand are accurate and supported by empirical and quantitative analyses which, in reality, have not contributed to providing a unified view of the phenomenon in question: the results are the most disparate and highly dependent on the starting assumptions and the variables considered. Porter's hypothesis suggests a win-win situation in the sense that environmental policy improves both the environment and competitiveness. The suggestion has received strong criticism from economists driven by the idea that if opportunities exist, firms should not be triggered by an extra cost. Even the integrated models introduced by Nordhaus, [90]which, compared to more traditional economic tools such as cost-benefit analysis or environmental impact assessments, employ more refined methodologies, have led to results that are often different and closely linked to the assumptions made for each reference scenario. With this in mind, three strands of thought have developed in the literature, supporting three different positions:[91]

- Environmental regulation has a negative impact on competitiveness. This type of approach adopts a static view of the economy (Oates, Palmer, Portney, Cole & Elliott);
- Environmental regulation has only a negligible impact on the competitive position of firms (Reinaud, Jeffe, Palmer);
- Environmental regulation does not generate negative effects on productive realities, on the contrary, it favours technological innovation, growth and profitability (Porter and van der Linde). This approach to the problem is known as the "Porter hypothesis" and refers to a dynamic view of the economy.

[90] Which they will be discusses in section n. 4.2
[91] Department for rural and agricultural affairs e SQW – economic development consultants (2006), *Exploring the relationship between environmental regulation and competitiveness: a literature review*, London.

Figure n.9 *Positions in the literature*.



Source: *Department for rural and agricultural affairs e SQW – economic development consultants (2006), Exploring the relationship between environmental regulation and competitiveness: a literature review, London*.

However, it can be argued with certainty that the net effects of environmental policies will depend strongly on how the objectives to be pursued are distributed over time: setting ambitious short-term targets can have extremely important competitive payback effects. Setting ambitious short-term targets can have extremely important competitive paybacks. This means that any target should be commensurate with the effective capacity of companies to meet it in the short, medium and long term.

2.3.4.1 THE PORTER ANALYSIS

Porter was the first author to break the neoclassical view of the relationship between environmental regulation and competitiveness. He introduced a new variable in the more traditional theoretical schemes, namely technological innovation. More in detail, Porter believes that in a situation where firms operate on the basis of cost minimisation and in a static world, environmental regulation inevitably entails additional burdens. If, on the other hand, we assume a dynamic context, technology comes to the rescue: an adequate regulatory framework is able to reduce environmental costs as it pushes companies to invest in new technologies that are more efficient from an economic and environmental point of view, making them more competitive. In other words, the environmental problem and the regulatory constraints on the matter could provide companies with an incentive to innovate that would allow not only a reduction in polluting emissions in this specific case, but also an increase in productivity that in the medium-long term would allow a recovery of investments, a growth in profits and, consequently, a strengthening of the competitive position.

Porter's reasoning is thus based on the consideration that, in a globalised economy, competitiveness is expressed not so much in the availability and accessibility of resources as in the possibility of using them in a more rational manner. Producing a more eco-sustainable good would also justify a higher selling price, which, as such, would better remunerate the investments made. Indeed, at a time when environmental culture is becoming stronger, consumers may be willing to pay an additional price to buy a good with a lower environmental impact, at least in the short term.

In order for this dynamic process to unfold its benefits, however, a specific condition is required: a regulatory framework that is certain, stringent and defined so as not to hinder innovation. From this it can be deduced that Porter's hypothesis is somehow based on the assumption of bounded rationality: only a precise regulation capable of guiding the choices of companies can favour “green” investments.[92]

More specifically, Porter argues that environmental regulation can promote two different types of innovation: one linked to the development of new technologies and production methods aimed, as mitigation, at minimising environmental costs once pollution-related problems arise (e.g. recycling of toxic waste from some productions); the other affecting production processes by influencing ex ante the factors responsible for environmental degradation, as prevention (e.g. increasing the productivity of production factors). However, it is the latter that should be the subject of specific interest. In fact, the author considers that the ex-post environmental costs could, in the long term, become much higher than those incurred by prevention.

Porter goes on to point out that the costs associated with regulatory processes, including environmental ones, are on average high, which is why the regulatory framework is not subject to continuous adjustment. Because of this, companies are often inclined to make the necessary investments with a view to compliance rather than innovation. In addition,

[92] Greaker M. (2003), *Strategic environmental policy; eco-dumping or green strategy?,* in "Journal of Environmental Economics and Management", no. 45. The article also shows that stringent regulation is a prerequisite for fostering innovation even if companies are perfectly rational.

companies frequently make sub-optimal choices, whether due to information problems, opportunistic behaviour or specific lobbying strategies.

Porter again argues that such a low-profile attitude is the result of a static view of the business environment. Companies are often unable to seize the opportunities associated with dynamic innovation. In addition, companies tend to look at environmental issues as external factors: companies often seek advice on energy and environmental issues from external parties. As is well known, a third party has a more limited information set than a member of the company's staff, which is why solutions aimed at adaptation rather than prevention are often suggested. This again suggests that appropriate legislation could help to bring about a change in attitude. In short, a clear and precise regulatory framework is an indispensable tool for managing environmental problems for the following reasons:[93]

- It provides incentives for companies to innovate. In the absence of regulation, firms have no incentive to reduce their economic and environmental inefficiencies. This is because knowledge and the ability to process available information are often limited: firms do not always perceive the benefits of innovation;
- reduces uncertainties related to investments, environmental in this case;
- quickly improves the quality of the environment;
- strengthens the environmental culture of companies and consumers;
- it avoids that some companies can gain an advantage by circumventing environmental legislation.

In light of this, an additional problem arises: what is meant by stringent and efficient regulation. To this end, Porter identifies some properties and characteristics. In detail, regulation should:[94]

- focus on outcomes rather than on technology. The identification of specific technological solutions (such as the best avalaible technologies - BAT or the best available control technologies - BACT) is a deterrent to innovation, as once adopted the firm may have no further incentive to innovate. In other words, with respect to a certain target, the company should still be given some freedom of movement;

[93] Porter M., Van Der Linde C. (1995), *Green and competitive*, in "Harvard Business Review", September – October e Porter M., Van Der Linde C. (1995), *Toward a new conception of the Environment-Competitiveness Relationship*, in "The Journal of Economic Perspective", vol. 9, n. 4.

[94] I*bidem* pag. 124.

- encourage solutions along the entire production chain, acting in such a way that it is the same demand, private but also public offices, to demand eco-sustainable goods;
- identify specific objectives to be achieved gradually, i.e. short-term goals to be included in a long-term strategy;
- promote the use of market-based instruments such as environmental taxes or emission permits;
- be supported by environmental liability schemes[95];
- be as close as possible to, or slightly more stringent than, existing environmental legislation in other countries, with a view to avoiding excessive variations in the competitive framework;
- make the reference framework as certain as possible and its revision mechanisms as predictable as possible. This is the only way to encourage companies to innovate and make new investments;
- involve the various production categories in decision-making processes. This is to encourage cooperation and a proper exchange of information between companies and the regulator and thus reduce the problems of information asymmetry;
- minimise the time and resources required for the regulatory process.

However, the Porterian hypothesis has been subject to several criticisms. In the next section, the most important ones will be briefly discussed.

2.3.4.2 CRITICS ON THE PORTER'S ANALYSIS

Various responses have been made to Porter's hypothesis. A large part of the economic literature supports the opposite position: environmental regulation creates competitive disadvantages. This is because environmental burdens are objectively an extra cost that the firm would not have incurred in the absence of specific regulatory interventions. Not only does environmental regulation entail additional costs but, by forcing firms to invest in environmentally better technologies, it diverts resources away from other uses that could have ensured higher returns, at least in the short term.

[95]For more details see, for example, , a Shavell S. (1993), *The Optimal Structure of Law Enforcement*, in «Journal of Law and Economics», Vol.36, n.1, parte 2.

At the same time, the need to educate management on emerging issues has been noted, reducing the time available for other possibly more profitable activities.[96]
Indeed, the Porterian hypothesis could be subject to some criticism. Stavins[97] argues that Porter's hypothesis is based on unrealistic expectations and that the win-win strategy proposed is not credible: the costs imposed by environmental regulation will never be zero, even in the medium/long term. Bavaria [98]considers that the costs of complying with environmental regulations can sometimes be prohibitive and that innovation is hampered by difficulties in finding resources and by the malfunctioning of the credit market.
Palmer et al. [99]agree with some of the points made by Porter and Van Der Linde, but argue that it is rather difficult to identify cases in the field of companies that have seen their environmental costs reduced solely as a result of the innovation drive induced by environmental regulation: whatever form environmental regulation takes, even if market-based instruments are used, it inevitably generates additional costs.
Cole and Elliott[100], through an analysis of trade flows, argue that environmental regulation impacts competitiveness through a change in the volumes traded between countries with different degrees of environmental constraint. This would favour the relocation of the most polluting firms to countries with no or little environmental regulation (*pollution heaven hypothesis)*.

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[96] At this regard see Walley N., Whitehead B. (1996), *It's not easy being green*, in Welford R., Starkey R., The Earthscan Reader in Business and Environment, London, Earthscan.
[97] Stavins R. (1994), in *The Challenge of going green*, in «Harvard Business Review», July – August.
[98] Bavaria J.L. (1994), in *The Challenge of going green*, in «Harvard Business Review», July – August.
[99] Palmer K., Oates W. E, Portney P.R. (1995), *Tightening Environmental Standards: The BenefitCost or the No-Cost Paradigm?*, in «Jounal of Economic Perspective», vol. 9, n. 4.
[100] Cole M. A. (2003), *Do Environmental Regulations Influence Trade Patterns? Testing Old and New Trade Theories,* Department of Economics, University of Birmingham and School of Ecomic Studies, University of Manchester.

CHAPTER III FINANCIAL AND ECONOMIC RISKS FROM CLIMATE CHANGE AND THE ROLE OF INVESTORS

3.1 TRANSITIONAL AND PHYSICAL RISKS

There are several reasons why climate change must be taken into account when drawing up economic models.

Firstly, the needs of investors and consumers must be analyzed from a microeconomic perspective. Indeed, after years of awareness raising, natural capital plays an important role in today's economy for two theoretical reasons:

- Consumers may have an inherent preference in holding natural capital, and thus it would directly enter the utility functions;
- Moreover, natural resources can be thought of as a risk-free asset and therefore individuals would own them to have a safe value in their portfolio.

Secondly, global warming, mainly caused by greenhouse gases (GHGs), has real effects on the world economy: an increase in the intensity and frequency of extreme weather events can easily affect the productivity of a country and its sectors, or, in response to climate change, several sectors of an economy could be destroyed by technological transaction. From here we can outline the two main risks to be taken into account when designing economic policies.

By physical risk we define the loss of productivity and welfare caused by extreme weather events. Such events could cause real damage to the assets of a country's productive activities or reduce the supply of raw materials. It should be noted that human capital may also be affected by climate change with possible migration to more stable geographical areas. Referring then to Ricardian rent[101], following a decrease in the productivity of natural capital (land, forests, rivers), their price is bound to fall, with a loss of value also in the financial market.

The second risk that economic policies must address with monetary and fiscal policies is the risk of technological transition. This risk indicates the financial loss that an entity may

[101] Ricardo's rent is the expression of the "avarice" of nature: the obstacles, which it opposes to man's efforts, cannot be effectively overcome with adequate investments. It is not an absolute gain that all landowners are entitled to under normal conditions; if all lands were equally fertile, there would be no Ricardian annuity: it is a differential gain in favour of the luckiest landowners.

incur, directly or indirectly, as a result of the adjustment process towards a low-carbon and more environmentally sustainable economy. Such a situation could be caused, for example, by the relatively sudden adoption of climate and environmental policies, technological progress or changing market confidence and preferences. In the context of the green transition, two types of sectors can be outlined:

- FF (Fossil Fuel): sectors in which all economic activities involved in value creation are fueled by fossil fuels, and consequently defined as GHG producers (e.g. extraction, refining, distribution). This sector is identified as having a low level of technological advancement.
- RE (Renewable Energy): Sectors in which all economic activities involved in value creation are powered by renewable energy (electricity from renewables, electrification of transport, energy efficiency buildings). The use of the latter is strictly dependent on research and development in technology by private individuals. Moreover, several barriers prevent the deployment of RE, such as cost-effectiveness, technical barriers and market barriers.

Physical and transitional risk factors have an impact on economic activities, which in turn affect the financial system. This impact may occur directly, e.g. through lower business profitability or asset write-downs, or indirectly through macro-financial changes. As we can see from the following Table n. 7 developed by the ECB, we can notice the real consequences on the economy.

Table n. 7 *Physical and Transitional risks from climate change*.

	PHYSICAL RISKS	TRANSITIONAL RISKS
Credit Risk	Estimates of the probability of default (PD) and loss given default (LGD) for exposures to sectors or geographic areas vulnerable to physical risks may be affected, for example, by lower valuations of collateral in real estate portfolios due to higher flood risk.	Energy efficiency standards could lead to significant compliance costs and lower profitability, possibly resulting in higher PD and lower collateral values.
Market Risk	Serious physical events could lead to changes in market expectations and result in a sudden reassessment of risk, increased volatility and losses for asset values in some markets.	Transition risk factors could result in the sudden repricing of securities and derivatives, for example for products related to sectors affected by stranded assets.
Operational Risk	The bank's operations could be disrupted due to material damage to buildings, branches and data centers as a result of extreme weather events.	Changes in consumer awareness of climate issues may lead to reputational and legal liability risks for the bank due to scandals caused by the financing of environmentally controversial activities.
Other types of risk (liquidity, business model)	The impact on liquidity risk may materialize if customers withdraw funds from their accounts to finance damage repair.	Transition risk factors may affect the economic viability of certain business lines and cause a strategic risk for certain business models in the absence of the necessary adjustment or diversification. Sudden re-pricing of securities, e.g. due to stranded assets, could reduce the value of the bank's high-quality liquid assets, adversely affecting liquidity buffers.

Source:ECB

https://www.bankingsupervision.europa.eu/legalframework/publiccons/pdf/climaterelated_risks/ssm.202005_draft_guide_on_climate-related_and_environmental_risks.en.pdf

These risks also affect the resilience of the institution's business model in the medium and longer term, especially for institutions with a business model based on sectors and markets that are particularly vulnerable to climate and environmental risks. In addition, physical and transitional risks may lead to additional losses resulting directly or indirectly from legal actions (legal liability risk) as well as from reputational damage that arises when the public, the institution's counterparties and/or investors associate the institution with adverse environmental effects (reputational risk).[102] Consequently, physical and transitional risks represent risk factors for the existing categories, in particular credit, operational, market and liquidity risks, as well as risks not included in Table n.7 such as migration risk, banking book credit spread risk, real estate risk and strategic risk. Climate and environmental risks may be simultaneous drivers of several existing risk categories and subcategories.

The size and distribution of physical and transition risks depend on the scope and timing of mitigation measures and whether the transition is orderly or not. Potential losses from these risks depend especially on the future adoption of climate and environmental policies, technological developments as well as changing consumer preferences and market confidence. Nevertheless, some combination of physical and transition risks is likely to be reflected in the balance sheets of euro area institutions and the economic value of their exposures. Current estimates of long-term adverse macroeconomic effects from climate change point to significant and lasting wealth losses. These could be due to slower investment and lower factor productivity in many sectors of the economy, as well as reduced potential GDP growth.[103]

3.2 REAL CONSEQUENCES IN THE REAL WORLD

Climate risk has several characteristics, at the moment we know that it is continuously increasing as is the socio-economic impact it brings. It can be defined geographically, which means that it increases depending on the geographical area being analysed. According to climate science, the only way to drastically reduce this impact is to reduce carbon dioxide emissions to zero. We also know that these climatic events are not linear, they can have a lesser impact in areas that have adapted to these types of situations over the years, but in other situations they can be really destructive such as raising the temperature for crops. The impact of these phenomena can be defined as systematic, which means that their influence does not only fall on the directly affected sector but at

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[102] ECB (May 2020) - Guide on climate-related and environmental risks Supervisory expectations relating to risk management and disclosure. Available here (https://www.bankingsupervision.europa.eu/legalframework/publiccons/pdf/climate-related_risks/ssm.202005_draft_guide_on_climate-related_and_environmental_risks.en.pdf)

[103] "Technical supplement to the First NGFS comprehensive report", NGFS, 2019, and "Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis", IMF working paper, 2019.

the same time can affect related sectors. An example would be flood risks: they directly affect the affected houses, but at the same time they affect the insurance market as the price of an insurance policy for buildings in that area will increase dramatically. At present, climate change is having a much greater impact than we think - there is no comparison in the past for such a rapid rise in temperature. A first driver that can explain the rise in temperatures is the emission of CO2 into the atmosphere along with other greenhouse gases. Is needed to know that 2.5 trillion CO2 have been released into the atmosphere since the beginning of the industrial revolution.[104]

The climate risk defined above is already having a socio-economic impact and can be seen in the five categories listed here, which we will now explore in more detail.

- Livability and workability: hazards such as heat waves can make outdoor work such as agriculture or livestock farming difficult and, if the event is considered severe, could put lives at risk. Not only because of the direct effect it would have but also because of the possibility of shifting the focus of various diseases.
- Food resources: Heat waves, droughts or floods can affect food production both negatively and positively. They will certainly affect the volatility and returns of this sector.
- Physical assets: all physical assets such as buildings, structures, buildings can be damaged by invasive weather events such as fires, floods, etc.
- Infrastructure services: these types of services such as the entire energy system to power buildings or neighbourhoods could be damaged due to high temperatures or floods.
- Natural capital: Forests, glaciers, oceans are all sources of resources for humans, from food to oxygen to raw resources to power our infrastructure. Climatic events such as those that have occurred and are predicted to occur in the future can damage this ecosystem and create many losses.

In the table below Table n. 6 the strategic consulting firm McKinsey and Company estimated the socio-economic damage resulting from natural disasters in the last years.[105]

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[104] IPCC , Global warming of 1.5°C Report - https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf

[105] https://www.mckinsey.com/businessfunctions/sustainability/our-insights/climate-risk-and-response-physical-hazards-andsocioeconomic-impacts

Table n. 8 *Estimations of socio-economic damages*.

Impacted economic system		Area of direct risk	Socioeconomic impact
Livability and workability	1	2003 European heat wave	$15 billion in losses
	2	2010 Russian heat wave	~55,000 deaths attributable
	3	2013–14 Australian heat wave	~$6 billion in productivity loss
	4	2017 East African drought	~800,000 people displaced in Somalia
	5	2019 European heat wave	~1,500 deaths in France
Food systems	6	2015 Southern Africa drought	Agriculture outputs declined by 15%
	7	Ocean warming	Up to 35% decline in North Atlantic fish yields
Physical assets	8	2012 Hurricane Sandy	$62 billion in damage
	9	2016 Fort McMurray Fire, Canada	$10 billion in damage, 1.5 million acres of forest burned
	10	2017 Hurricane Harvey	$125 billion in damage
Infrastructure services	11	2017 flooding in China	$3.55 billion of direct economic loss, including severe infrastructure damage
Natural capital	12	30-year record low Arctic sea ice in 2012	Reduced albedo effect, amplifying warming
	13	Decline of Himalayan glaciers	Potential reduction in water supply for more than 240 million people

Source: *Jonathan Woetzel, Shanghai Dickon Pinner, San Francisco Hamid Samandari, New York Hauke Engel, Frankfurt, Mekala Krishnan, Boston Brodie Boland, Washington, DC Carter Powis, Toronto, "Climate risk and response , Physical hazards and socioeconomic impacts" , McKinsey Global Institute, January 2020*

As with the categories described above, the financial economic system is built to withstand a certain level of risk beyond which it would begin to be vulnerable. Many production chains are developed to be efficient, not necessarily resilient. In fact, many parts or stages of the chain are concentrated in certain parts of the world where resources are better, labour is cheaper, there are fewer state restrictions, less taxes, etc. In the event that these areas were to be taken over, the financial system would be vulnerable. If these areas were to be wiped out because of these climatic events, the entire world supply would be affected.

Similarly, the financial and insurance markets could also be affected. Imagine the real estate market in areas with a high probability of earthquakes or floods. Insurance premiums to protect one's home could increase dramatically.

3.2 THE ROLE OF INVESTORS

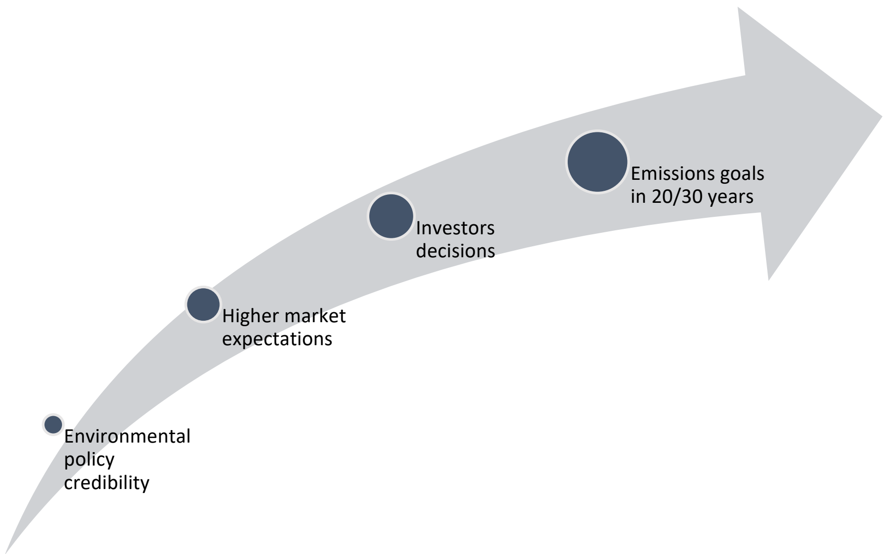
The role of investors expectations of future profitability under climate risk and transition scenarios is gaining research and policy attention. This point is relevant because the banking sector may change its lending conditions for green and brown sectors, with implications for firm performance and the low-carbon transition. Investor sentiments have been studied particularly in the context of credit cycles. However, so far, the analysis of investor sentiment has not considered the role of climate change, the characteristics of climate risks and financial risk, and their interaction. This is a major limitation because, on the one hand, investors' expectations of climate policies could influence the success of policy implementation (through their investment decisions) and thus the achievement of objectives. On the other hand, the impact of the low-carbon transition on financial stability also depends on the banking sectors considerations of climate change and climate-aligned policies in their area of activity. Qualitative insights into the climate sentiments of current investors and their implications on mitigating the financial stability impacts of climate transition risk should be provided. So far, there is a lack of formalization of banks climate sentiments in the context of the low-carbon transition. In this respect, there are gaps in the search for ways to get more information on financial stability in this transition context. There are three main points where in-depth research is lacking: namely the analysis of

- the reaction of the banking sector to policies based on their expectations;
- the channels of risk transmission from changes in policies and regulations to the credit market and from there to economic agents;
- the conditions for the emergence of credit market instability (or resilience) through loan contracts.

Addressing these research gaps would help financial regulators and central banks to identify the financial instability implications of credit risk, and banks to manage their loan portfolios in the face of climate shocks, thereby avoiding the risk of losses caused by stranded carbon assets.

As US economist Joseph Stiglitz said at the Green Swan Conference in 2021[106], the role of investors is extremely important in achieving the climate objectives of macroeconomic policies. Investment decisions are directly proportional to the expectations created by the credibility of current environmental policies, and these decisions will determine whether climate targets are met in 25-30 years' time.

Figure n.10 *Credibility of environmental sustainability*.



Source: *own elaboration*.

The core of the success of economic policies for environmental sustainability, therefore, is mainly related to the ability to convince investors about their efficiency in the market and especially in their preservation in the future.

J. Stiglitz also states that regulators and central banks have a particularly important role in managing risk assessment in a globalized economy. Due to incorrect valuations by the market and regulators, investors can be misled by the current prices of fossil fuel assets as they do not reflect the post energy transition value at all. As a result, transition risk can take on a systemic market characteristic, affecting not only the companies that own fossil fuel assets, but also other companies that provide support or have an interest in them, such as the distribution, trading or financial sectors.

[106] Joseph Stiglitz – "Green Swan Conference 2021". Coordinate Finance on Climate. BANK FOR INTERNATIONAL SETTLEMENT – available at https://www.youtube.com/watch?v=6kzJujp1-AI

3.2.1 ESG RATING

As mentioned in the previous chapter, the aspect of social responsibility is increasingly becoming a determining factor, especially in investments. This means, first and foremost, a move away from certain securities, such as those relating to arms and alcohol manufacturers, and a greater preference for and active engagement with issues such as the environment, society and corporate governance. [107] This increased focus on ESG aspects can be seen both on the corporate side, where the commitment to ESG is growing, and on the investor side.

The acronym ESG is made up of three words:

- E: Environmental;
- S: Social;
- G: Governmental

These terms refer to three distinct universes of social sustainability.

The word *environmental* refers to the environment, in particular climate change, CO2 emissions, air and water pollution, waste and deforestation[108]. These are increasingly topical issues to which the whole world refers, and not just from a purely economic point of view. At the 2015 Paris Climate Conference (COP21) a series of goals were set to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.[109]

Applying these concepts to the economy, companies are trying to reduce emissions and become greener, also with a view to satisfying investors, who are becoming even more sensitive to these issues.

Social refers to aspects such as gender equality, human rights (of workers in particular, but not only), working conditions and the relationship of companies with the civil community. [110]

Finally, *governance* refers to the corporate governance aspects of the company, i.e.

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[107] https://www.morningstar.it/it/news/148200/cosa-significa-esg.aspx

[108] *Ibidem*

[109] United Nations Climate Change - https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement/key-aspects-of-the-paris-agreement

[110] *Ivi p.*

composition of the board of directors and control policies on the behaviour of top management, with reference to compliance with both the law and ethics. The issue of governance has become particularly important following the 2008 crisis and has therefore undergone significant changes at European level through the Solvency II Directive[111]. In view of these parameters, investors select investments not only with regard to the long-term gains they can make, but also if they allow positive social impacts.
This is referred to as socially responsible investing (SRI), i.e. an approach that excludes certain securities, such as those of tobacco or alcohol companies.
SRI, also known as social responsible investment, is an investment that is considered socially responsible due to the nature of the business the company conducts. Common themes for socially responsible investments include socially conscious investing. Socially responsible investments can be made into individual companies with good social value, or through a socially conscious mutual fund or exchange-traded fund (ETF).[112]

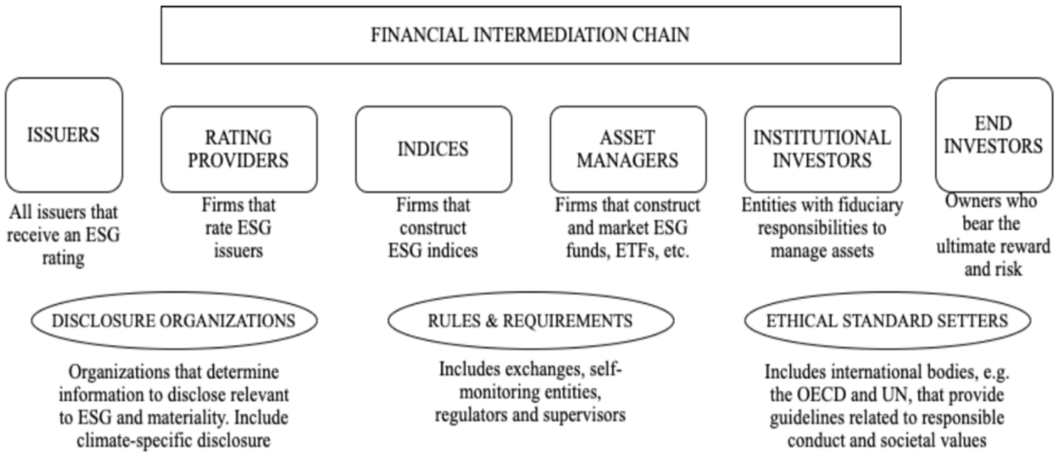
3.2.2 THE ESG RATING FROM THE INVESTORS SIDE

The financial market is the instrument that guides, and almost forces, companies to move more towards sustainability. towards sustainability. Over the years, ESG issues have become increasingly important in supporting the investment decisions of consumers and investors (including institutional investors). These same individuals can in some way guide the choices and policies of companies and, consequently, make them more socially conscious. As we ca see from the Figure n. 11 all the individuals are forming a kind of complex environment where not only the institutional and individual investors are involved, but companies, financial intermediaries and providers and issuers. When it comes to ensuring socially responsible investments for a resource-efficient economy and sustainable growth, institutional investors represent a considerable economic force and source of finance for the economy. Compared to a conventional investment approach, responsible investing not only focuses on the need to achieve sustainable returns from investments over time, but also pays attention to factors such as the stability and health of economic and environmental systems and the evolving values and expectations of the

[111] Solvency II European directive - https://eur-lex.europa.eu/legal-content/IT/ALL/?uri=CELEX:52014AP0155
[112] Investopedia https://www.investopedia.com/terms/s/sri.asp

societies they are part of. Therefore, through this approach, investors increasingly seek to direct their capital towards companies that can achieve the above objectives, such as companies that reduce emissions, or are well governed.

Figure n. 11 *Financial intermediation chain*



Source: Boffo and Patalano (2020).

3.2.3 CLASSIFICATION OF SOCIAL RESPONSIBLE INVESTMENT

With regard to sustainable investments, it is possible to classify different approaches to such investments, as the forum for sustainable and responsible investment said[113]:

1. *Negative/exclusionary screening*: certain sectors or companies are excluded from a fund or portfolio. This exclusion is made on the basis of certain ESG criteria and, where these standards are not present, these companies or sectors are excluded;
2. *Positive/best-in-class screening*: investments are made in selected sectors, companies or projects that perform positively and better than their sector competitors in terms of ESG performance;

[113] USSIF - https://www.ussif.org/esg

3. *Norms-based screening*: investments are selected on the basis of compliance with minimum corporate standards, based on international norms;
4. *ESG integration*: through this strategy, investment managers systematically include ESG factors in the financial analysis of the various assets;
5. *Sustainability themed investing*: investments are selected with regard to activities specifically linked to sustainability (e.g. clean energy, green technology or sustainable agriculture);
6. *Impact/community investing*: targeted investments, generally made in private markets, whose capital is specifically directed to traditionally disadvantaged people or communities, as well as financing provided to companies with a clear socially sustainable business purpose;
7. *Corporate engagement and shareholder action*: shareholders use their power to influence corporate behavior, including through direct engagement with the company (e.g. communicating with senior management and/or company boards), the submission of shareholder proposals and proxy voting that is guided by ESG guidelines.

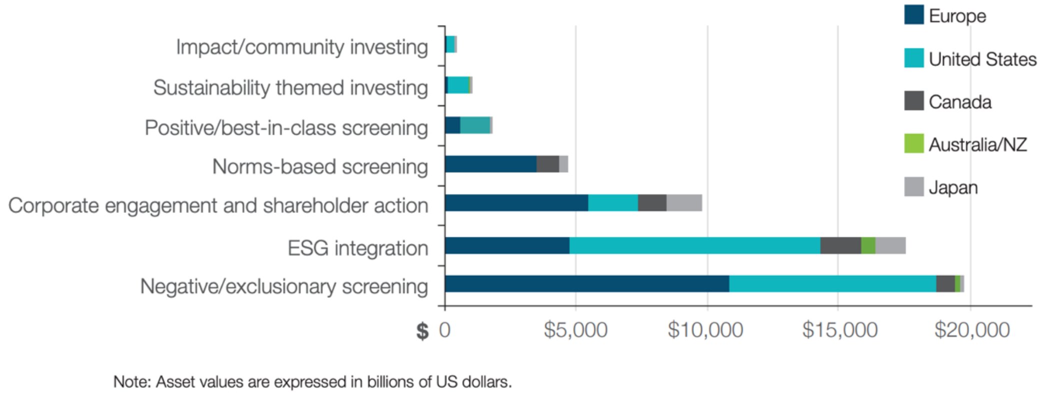
The strategies themselves are not exclusive, so they can also be adopted simultaneously.

3.2.4 SUSTAINABLE INVESTMENT STRATEGIES IN THE WORLD

According to Alliance, 2018 Global Investment Review[114], the largest sustainable investment strategy globally is the negative/exclusionary screening strategy ($19.8 trillion), followed by the ESG integration ($17.5 trillion) and corporate 16 engagement/shareholder action ($9.58 trillion) strategies, as shown in the Figure n. 12. The negative screening strategy is most widely used in Europe, while the ESG integration strategy is most widely used in the United States, Canada, Australia and New Zealand, and Asia, excluding Japan. Japan's main sustainable investment strategy is corporate engagement and shareholder action. The Figure n. 13 show this:

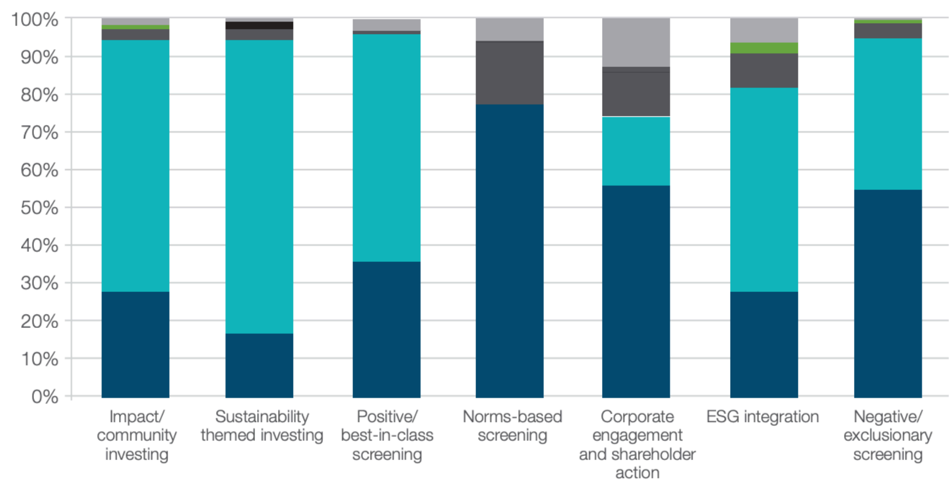
[114] 2018 Global Sustainable Investment Review – available here (http://www.gsi-alliance.org/wp-content/uploads/2019/03/GSIR_Review2018.3.28.pdf)

Fig. n. 12 *Sustainable Investing Assets by strategy and region 2018*



Source: *2018 Global Sustainable Investment Review p-10*

Fig. n. 13 *Regional shares, by asset weight, in global use of sustainable investing strategies 2018*



	Impact/ community investing	Sustainability themed investing	Positive/ best-in-class screening	Norms-based screening	Corporate engagement and shareholder action	ESG integration	Negative/ exclusionary screening
Europe	28%	17%	36%	77%	56%	28%	55%
United States	66%	77%	60%	na	18%	54%	40%
Japan	2%	1%	3%	6%	13%	7%	1%
Canada	3%	3%	1%	17%	12%	9%	4%
Australia/NZ	1%	2%	0%	0%	0%	3%	1%

Source: *2018 Global Sustainable Investment Review p-11*

3.2.5 PRINCIPLES OF RESPONSIBLE INVESTMENTS

In 2006, UN Secretary Kofi Annan invited the world's largest institutional investors to sign up to the six principles for responsible investment. Adherence to these principles is voluntary. The PRI (Principles for Responsible Investment) was created to support this initiative, i.e. an international network of investors, supported by the United Nations, working to put the six principles into practice.[115]
These principles are[116]:

Tab. n.9 *Principles for Responsible Investment*

1. *Integrate ESG issues into analysis and decision-making processes;*
2. *To be active shareholders and incorporate ESG issues into active shareholder policies and practices;*
3. *Demand adequate communication on ESG issues from the entities in which you invest;*
4. *Promote the acceptance and application of the principles in the financial sector;*
5. *Collaborate to improve the effectiveness of the application of the principles;*
6. *Communicate the activities and progress made in the application of the principles.*

It is believed that the application of these same principles can influence companies to incorporate ESG criteria into their strategies.
It is also important to state that these principles don't give an example on how an enterprise should be in order to be environmental or social friendly. Moreover, they do not give a sort of rate of those enterprise that follow the ESG pathway.

[115] UNPRI -https://www.unpri.org/
[116] UNPRI - https://www.unpri.org/pri/what-are-the-principles-for-responsible-investment

3.4 INFORMATION RESOURCES FOR INVESTORS

According to E. Escrig-Olmedo rt al. (2010), [117]sustainability indices and ESG ratings are fundamental information for socially responsible investors. There are various ESG rating agencies, each of which adopts different methodologies in their assessment, which may lead to differences in the scores assigned to different companies. Therefore, it is difficult for investors to fully rely on such ratings, partly due to the fact that agencies reveal little about the criteria used in their assessment. On the other hand, it is also difficult for the agencies themselves to fully understand what factors are relevant to such ratings, due to a lack of standardization and common rules.

Investors may also rely on sustainability indices, with the drawback that such indices do not take into account all the criteria of socially responsible investing. [118]Investors are therefore calling for greater transparency on the part of companies and for them to disclose information on sustainable development more frequently, so that the long-term strategy and possible risks with regard to these factors can be better understood. Legislators are trying to move in this direction, although there is still a long way to go.

At the European level, a number of regulatory requirements have been introduced to enable better disclosure of corporate ESG information. The EU-Reporting Directive 2014/95/ EU on the Disclosure of Non-Financial Information and Diversity[119], also known as the EU NFRD or Accounting Directive, meets this very purpose: this directive legally requires companies with at least 500 employees to publish the "non-financial reporting" [120]as well as additional information. These information can be including information on their management and organizational model, policies on the sustainability

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[117] Elena Escrig – Olmedo et al. (2010) – "*Socially responsible investing: sustainability indices, ESG rating and information provider agencies*"
[118] Elena Escrig – Olmedo et al. (2010) – "*Socially responsible investing: sustainability indices, ESG rating and information provider agencies*" – pp. 459-461.
[119] Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups Text with EEA relevance – available here (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014L0095)
[120] Non-financial Reporting – available here (https://globalnaps.org/issue/non-financial-reporting/)

of their business, risks associated with their business and performance indicators that give a true picture of their results.[121]

In 2015, the World Federation of Exchanges (WFE) published ESG guidelines [122]to be taken into account in market exchanges in order to promote transparent and efficient markets. These include a call for disclosure of a set of indicators, especially with regard to listed companies, that allow for more meaningful engagement between investors and companies on ESG risks and opportunities. The Global Reporting Initiative (GRI) has published the Guidelines for Sustainable Reporting[123]. These guidelines include the principles necessary to define the content of the report (materiality, inclusion of relevant stakeholders, sustainability context and completeness) and the quality of the report. There is also the inclusion of some disclosure standards with regard to strategy and organizational profile, management approach and performance indicators (economic, environmental and social). A further and very recent intervention at European level, also moving in this logic, is that of the *Green Deal*[124], which will increasingly seek to promote a clean economy, passing on to businesses the effort to contribute to this objective, through the commitment to make their production efficient, to increase the use of clean and renewable energy and to reduce emissions.

Although the amount of such publicly available information is steadily increasing, there is as yet no solid regulatory basis that requires ESG information to be disclosed in a systematic way, that requires it to have materiality and predictive aspects. All of this means that these same data are either almost useless or require further processing and analysis, which analysts are not always able to carry out because they are too expensive or because they do not have the necessary means or authorization to do so.

There is also a lack of standardization with regard to this information, again because there is no regulation in this respect, which would allow investors to be able to compare the parameters relating to these aspects, between different companies or between different providers of this information. In the same vein, even ESG rating scores will only be fully

[121] PWC - Direttiva UE 2014/95 - available here (https://www.pwc.com/it/it/services/audit-assurance/assets/docs/direttiva-ue201495.pdf)
[122] The world federation of exchange - https://www.world-exchanges.org/news/articles/world-federation-exchanges-publishes-revised-esg-guidance-metrics
[123] Global reporting Initiative – available here (https://www.globalreporting.org/standards/)
[124] European Green Deal – available here (https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en)

and appropriately usable by the market if the level of validity and transparency of the underlying data and the methodology applied are adequate to meet certain minimum standards, which also allow for comparability by investors.

CHAPTER IV MACROECONOMIC MODELS INCLUDING THE CLIMATE VARIABLE

A macroeconomic model is the "mathematical" underpinning of the scenario, which is also composed of its narrative: it is a set of equations aiming, on the basis of input hypotheses and resolution processes, to represent the functioning of a real system (the climate, the economy of a country, etc.) and its evolution over time.

The characterisation of modelling processes is based on several elements:

- the nature of the variables: "exogenous", i.e. predefined (as often the GDP), and "endogenous" variables which are the result of the model;
- the type of resolution logic: optimisation or simulation logic, for example;
- the type of modelling paradigm: the bottom-up approach (which starts from the detail to the general), or the top-down approach (which starts from the general to the detail) for example.

As modelling processes have developed and been applied, they have become more complex, combining resolution logics and modelling paradigms.

In this chapter, the main macroeconomic models that strive to take climate change into account will be described and classified starting from the most engaged ones. Then, simulations using a DICE model are then presented using different ipothesis and scenarios.

4.1 INTEGRATED ASSESEMENT MODELS

Analysing what has been said so far, the need to integrate the effects of climate change into economic modelling has not been taken seriously by the main institutions. To give examples and explanations, financial regulators, such as the FED and ECB, are obliged by their institution to follow their mission: to defend price and financial market stability. However, the impacts on the financial system that climate change is causing, obliges institutions to change their view on the problem and to integrate multiple disciplines such as climate science, economics and energy science in the development of new models. In support of this, since the 1990s, academic attention has focused on combining the scientific and economic aspects of climate change in order to assess policy choices for climate mitigation. These models are called Integrated Assessment Models (IAMs).

4.1.1 MAIN FEATURES

IAMs represent a wide range of models encompassing multiple disciplines, starting with socio-economics, to assess policy options for climate change mitigation. Essentially, the idea of "integrated climate change modelling" consists of creating models that couple the description of human activities that determine greenhouse gas emissions with climate models whose evolution is dependent on these emissions. In turn, the impacts of the modified climate on the economy in the form of damage or benefits and its influence on the major bio-ecological complexes that participate in the carbon cycle are reported. The central purpose of integrated modelling is therefore to deal, within the same framework, with human actions (emissions and their possible reductions) and the consequences of these actions (the effects of climate change on the economy and the biosphere). It seeks to define the level and nature of desirable actions to protect against Climate Change. All of this activity is backed up by the expertise that has been in place since 1988 within the framework of the IPCC (International Panel on Climate Change). Integrated assessment and integrated modelling are the main methods for organising and making accessible expertise that would otherwise be difficult to synthesise for decision-making purposes. Three main objectives can be given to IAMs[125]:

- To provide assessments of climate change policies. As was done in the Intergovernmental Panel on Climate Change (IPCC, 1990 and IPCC, 1992) for a policy check on sea-rise and impacts on marine ecology.
- Create a structure that effectively integrates the various disciplines that affect climate change. An example of this would be to examine climate sensitivity (the increase in temperature after a doubling of CO2 in the atmosphere) and the discount rate in the same context.
- Quantifying the damage created by climate change, in economic and environmental contexts.

In practice, the course of events in the next century will depend on the combination of phenomena that are detailed and deciphered in the three volumes of the IPCC report. The problem is to know how and at what rate all these phenomena will interpenetrate and influence each other in a dynamic way:

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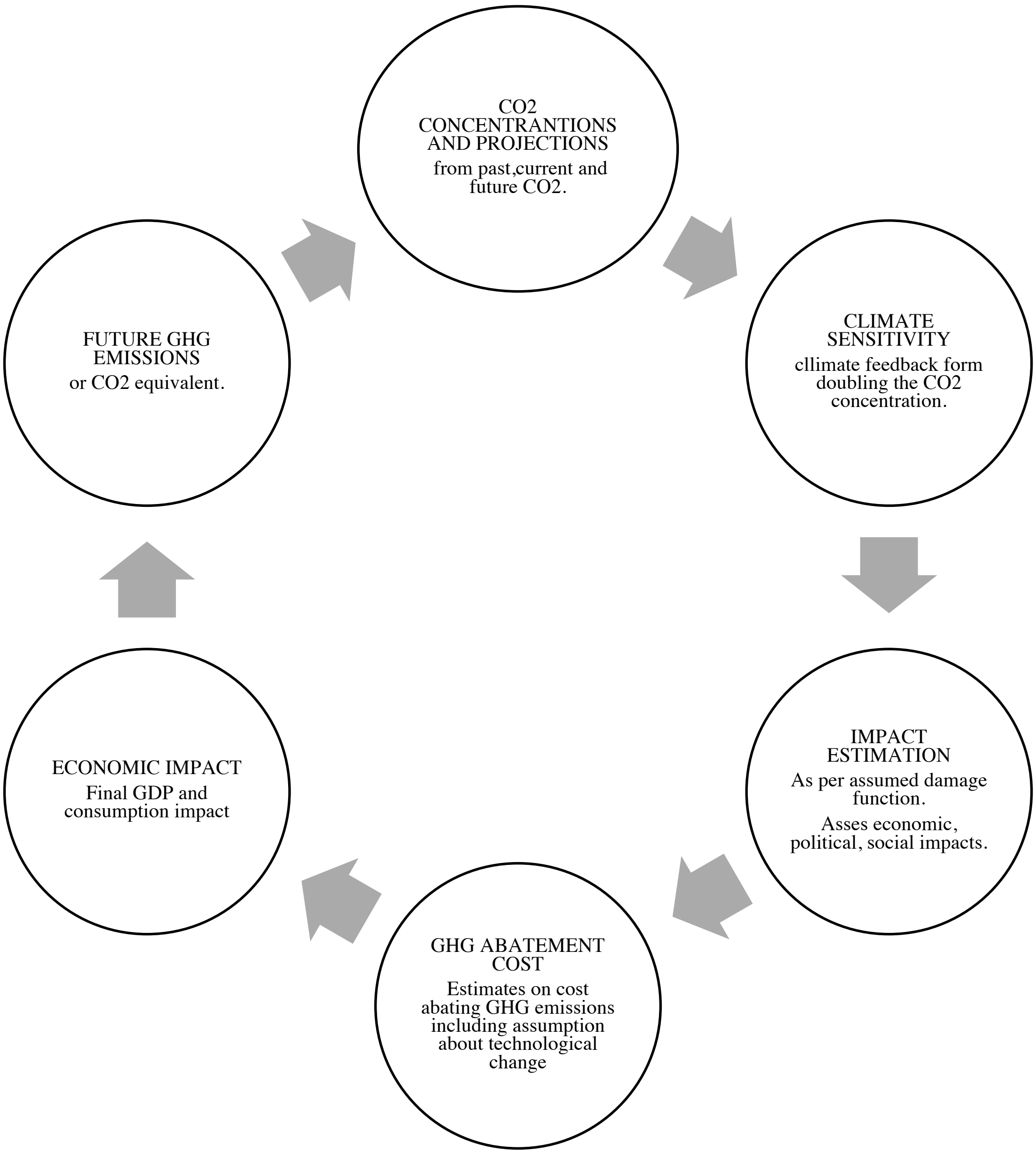
[125] Weyant, et. al. (1996)

- The state of the geophysical environment (climate, ocean current regimes, etc.) will depend on economic decisions and technical developments in energy systems through the concentrations of greenhouse gases emitted by human activities;
- Economic processes will in turn depend on both climate change (e.g. in agriculture) and the extent and cost of preventive measures (emission reduction, adaptation or damage repair);
- Large terrestrial ecosystems and biodiversity will be influenced and will influence the climate; the nature of plant cover and marine biology will determine the sequestration or release of CO2 and methane by ecosystems.

Figure n. 14 *Interactions between climate science and economic science.*



Source*: own elaboration.*

All in all, it is essential to connect the knowledge resulting from the various fields of expertise mentioned above (geophysics, bio-ecology, economics, etc.) in order to derive a dynamic vision of the phenomenon of climate change. It is therefore necessary to define methodologies whose function is, on the one hand, to capitalise on knowledge that is constantly advancing and, on the other, to integrate this knowledge into a dynamic vision of the phenomena. More precisely, integrated assessment requires models that make it possible to combine hypotheses (climatological, economic, ecological, etc.) in a perspective where the various determinants of the phenomena are coupled dynamically to address the temporal evolution of climatic and economic systems in their interactions. (Rotmans J. 1998).

In a broad speaking, Integrated Assessment Models (IAMs) represent the coming together of three different worlds of scientific thought in relation to energy and climate science: energy system models/technological progress, economic system models and climate science models.[126]

Energy system models have always aimed to make predictions about the use of fossil fuel systems and nuclear energy, and about how the law of supply and demand has behaved in the supply of resources from natural capital and society's demand for energy, over periods of time ranging from a few decades to several decades. IAMs, in the context of climate change scenarios, provide a more detailed simulation especially in the long-term period in both regional and global energy systems.

Economic system modelling is based on basic notions of how an economy works on the law of supply and demand, often starting from utopian and purely theoretical assumptions such as perfect equilibrium in global markets and their efficient functioning, perfect information symmetry, decreasing marginal costs. Important considerations need to be made about the forecasting range of period.

Climate science models, as used in IAMs, integrate atmospheric physics and chemistry, atmospheric and oceanic carbon cycling into simplified complexity models designed to translate greenhouse gas emissions and air pollutants into CO2 concentrations. The central idea of IAMs is to capture the interactions between socio-economic, technological and natural systems by combining simplified economic and climate models with more

[126] Bill Hare, Robert Brecha, Michiel Schaeffer (2018)

detailed modelling of regional and global energy systems to make relevant projections of the consequences of policy choices on climate.

4.1.2 CLASSIFICATION

In recent years, the use of integrated assessment models has intensified because of their extreme efficiency and their contribution to studying the impact of climate change on the economy. It should be noted that the term IAM, as already mentioned, has a very broad meaning and includes numerous models that use completely different assumptions, methodologies and purposes. Moreover, the use of the different classes of models involves "political" and scientific thinking issues that split the scientific community in the question of which model is the most appropriate.

A brief classification [127]is proposed here and represented in the Figure n. 15.

Aggregate IAMs: These are based on a long-run model of economic growth and summarise the impacts of climate change using comprehensive global metrics and indicators. The method of aggregate IAMs is to construct the aggregate global damage curve and compare it with the aggregate climate mitigation cost curve. This allows the impacts on productivity, consumption and climate damage to be compared with environmental problems such as temperature rise, the amount of carbon dioxide in the oceans and the total stock of emissions in the atmosphere. The approach then seeks to identify a trade-off between the costs of climate change at time t and the benefits in terms of consumption and damage reduction at time t+1. Examples of aggregated IAMS are: DICE/RICE (W. Nordhaus),FUND (Tol), PAGE (Hope)

IProcess-based IAMs: These are based on projections of long-term energy use and land consumption under the "what if" assumption. The foundation of the approach is the linkages and trade-offs between climate change mitigation and impacts. Indeed, this type of model offers a detailed description, in a sustainable development context, of the long-term analysis of mitigation costs under the "what if" assumption on decision changes. Process-based IAMs are also used more directly in climate policy formulation, including the periodic global stocktake of progress under the Paris Agreement (Grassi et al. 2018).

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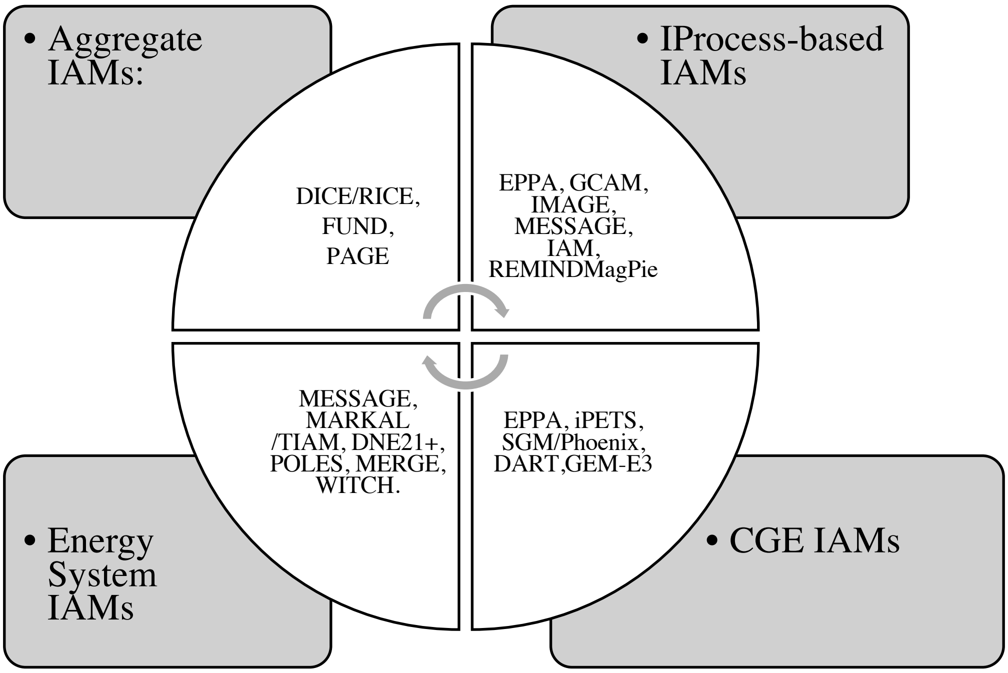
[127] Nikas A., Doukas H., Papandreou A. (2019) A Detailed Overview and Consistent Classification of Climate-Economy Models. In: Doukas H., Flamos A., Lieu J. (eds) Understanding Risks and Uncertainties in Energy and Climate Policy. Springer, Cham. https://doi.org/10.1007/978-3-030-03152-7_1

Intensive use of these models comes from the IPCC in their reports, where all their positions on climate change are based on IProcess-based IAMs.
Examples of IProcess-based IAMs: EPPA (MIT), GCAM (PNNL), IMAGE (PBL), MESSAGE (IIASA), AIM (NIES), REMINDMagPie (PIK)
CGE IAMs (Computable General Equilibrium IAM): These are based on an economy-wide representation with multiple sectors and often include a higher resolution of energy technologies and regional details. Providing a more macroeconomic view, they consider the impacts of specific policies on economic, social and environmental parameters. Endogenous shocks affect the main macroeconomic variables (production function), so the aim of these models is to achieve a general equilibrium in a trade-off between macroeconomic mitigation policies and their impacts.
Examples of CGE IAMs can be: EPPA (MIT), iPETS (NCAR), SGM/Phoenix (PNNL/ Boston/Penn State), DART (IfW), GEM-E3 (NTUA).
Energy System IAMs: Reputed to be a subcategory of partial equilibrium models, they are based on emission reduction rather than climate science. Linear optimisation is used to assess possible technological alternatives, policies and mitigation opportunities. Impacts are not taken into account here, only energy efficiency improvements and related emission reductions are represented.
Examples of such models are: MESSAGE (IIASA), MARKAL /TIAM (ETSAP), DNE21+ (RITE), POLES (IPTS), MERGE (EPRI), WITCH (FEEM).

Fig. n. 15 *IAMs Classification*



Source: *Own elaboration.*

4.2 THE DICE MODEL

The DICE (Dynamic Integrated Climate Economy) model, developed from 1989 onwards and published by the Nobel Prize W. Nordhaus (1992, 1994), is one of the first climate change model that belongs to the IAMs family, more precisely to the aggregate IAMs. Since its initial development, the DICE model has undergone several revisions. The latest published version is DICE-2016R (Nordhaus 2017, 2017a), with a full description (Nordhaus and Sztorc, 2013) and an intermediate version (Nordhaus, 2008). Thus, since the first versions, the DICE model has undergone numerous iterations, updating the theoretical argumentation as well as the economic and environmental data.

4.2.1 MAIN FEATURES

The DICE model is based on dynamic optimisation model (Ramsey, 1928) that seeks to estimate the optimal GHG reduction path (Diemer, 2004, 2015). The optimal pathway can be interpreted as the most efficient pathway to slow climate change, given inputs (Carbon Tax or Environmental Policy) and technologies (VeilleBlanchard, 2007). It can also be interpreted as a competitive market equilibrium in which externalities are corrected using appropriate social prices for GHGs. In the DICE model, emissions include all GHGs, however those associated with CO2 are privileged. GHG emissions, which accumulate in the atmosphere, can be controlled by increasing the prices of inputs (such as energy) or GHG-intensive products. Climate change is captured by the global average temperature, a variable used in most current climate models. The economic impacts of climate change are assumed to increase with the temperature increase achieved.

In practical terms, the approach of an optimisation model is to maximise an objective function, which refers to the economic welfare (or utility) associated with a consumption path. In the DICE model (but also the RICE model), it is assumed that world regions or individual regions have well-defined preferences, represented by a social utility function, which ranks different consumption paths. The social welfare function increases in the per capita consumption of each generation, with decreasing marginal utility of consumption. The importance of the per capita consumption of a generation depends on the size of the population. The relative importance of different generations is influenced by two normative parameters, the pure rate of social preference over time (the 'generational discount') and the elasticity of the marginal utility of consumption (the 'consumption elasticity'). These two parameters interact to determine the discount rate of goods, which is essential for cross-temporal economic choices. The DICE model assumes that economic and climate policies should be designed to optimise the flow of consumption over time. It is important to emphasise that consumption should be interpreted as "generalised consumption", which includes not only traditional market goods and services such as food and housing, but also non-market goods such as leisure, health and environmental services.

DICE is a discrete-time model in which two main groups of equations are defined at each period "T":

- the "*intra-periodic*" equations which link the contemporary variables;
- the "*inter-periodic"* equations which are classical evolutionary equations.

The structure of the system of equations can be summed up as follows:

The "*intra-periodic*" equations:

- Definition of the production from the world capital stock and the world population, this production is weighted by a function which takes into account the damage due to climate change which depends on the average temperature of the globe; it is also weighted by the costs of the reductions in greenhouse gas emissions achieved in each period; finally a term takes into account an exogenous technical progress;

- Economic equilibrium, production in each period is equal to global consumption plus investment;
- Definition of CO2 emissions from world production.

The "*Interperiodic"* equations:

- Evolution of the capital stock from the capital stock and investment in the previous period taking into account the depreciation of capital;
- Evolution of the atmospheric CO2 stock from the CO2 stock and emissions in the previous period;
- Evolution of temperature from the stock of atmospheric CO2 in the current year and the temperature of the previous year (simplified climate model).

The "*Exogenous*" equations and functions:

- Evolution of the world population ;
- Function defining the costs of emission reductions from their level (by econometric calibration);
- Evolution of technical progress, energy and carbon intensity of production;
- Average temperature damage function.

This set of equations is "underdetermined", i.e. the evolution of the system depends on two control variables:

- The first control variable is classical to optimal growth models, it relates to the sharing of production between consumption and investment;
- The second control variable, and here the most fundamental, is the level of emission reduction in each period.

4.2.2 CRITICISMS

In spite of the extreme functionality and advantages that DICE models present, it must be specified that this concept of models presents some well-known weaknesses in the world of literature.

One of the main criticisms in the literature is the lack of detail (Stiglitz et Stern, 2021). [128]In this case one of the main strengths of DICE models - as aggregate models - is also a

[128] N.Stern and J. E. Stiglitz (2021). "*The social cost of carbon, risk, distribution, market failures: an alternative approach*". National Bureau Of Economic Research. February 2021. Working Paper 28472 http://www.nber.org/papers/w28472

strong weakness. The purpose of aggregation is to synthesise very complex information from different disciplines. As will be demonstrated in the simulations in the following chapters, using a small number of damage indicators to condense them into long-term models is difficult. To reduce the complexity of multiples disciplines such as climate science, economics, energy science, demography, into one single model simplification is required. But simplification may cause difficulties in long term modelling. The reason is that some metrics may not be parameterisable within the models.

Another criticism of DICE models may be inherent in the fact that climate change impacts cannot be summarised in a damage or social cost of carbon function. There are other aspects, not purely economic, that are not taken into account. For example, changes in mortality rates, loss of biodiversity and cultural heritage are not taken into account even though they would influence consumption, GDP or climate change damage.

The comparison of impacts over time and between regions, as well as the decisions to assign different weights to the relevant effects, promote further criticism. The decision to use discount rates is made under purely subjective criteria, as no methodology or institution provid guidelines on “what to use” is available in the state of the art (Battiston et al. 2017). Indeed, given that climate change is endogenous in nature, the impacts of mitigation policies depend on how agents react. Important variations in damage assessments can occur in the choice of discount rates. DICE models also do not allow for comparisons across regions. This can lead to an over- or underestimation of effects in the economy in specific regions (see Azar and Sterner, 1996; Fankhauser et al., 1997). For example, the model provides an increase in global temperatures, but does not specify that in some regions this increase may be higher or lower, changing the magnitude of socio-economic and environmental damage. In this regard, J. Stiglitz and N. Stern mentions the vulnerability of the poorer sections of the population that normally live in areas more exposed to extreme events.

4.3 DSGE MODELS

In this chapter, we will analyze and describe the DSGE models that are considered "children" of neoclassical economics. DSGE (Dynamic Stochastic General Equilibrium) models are widely used by contemporary macroeconomists in order to explain aggregate economic phenomena, such as economic growth, business cycles, and the effects of monetary and fiscal policy, on the basis of macroeconomic models derived from microeconomic principles.

4.3.1 MAIN FEATURES

The simplest DSGE was devised by Kydland and Prescott in 1982[129] and represents, in a sense, the benchmark for all models used in the study of macroeconomic variants that have followed since then. According to this 1982 model, the economy is always in a state of equilibrium and can only be affected by real shocks, so recourse to monetary policy is undesirable and sometimes harmful. Nevertheless, many economic theories have taken turns over time to emphasize that even fluctuations in nominal terms can have significant positive effects on the real economy [130]. One of the main reasons why macroeconomists prefer such models over the more traditional SEM or VAR models is that unlike such forecasting models, DSGE models are not vulnerable to Lucas' criticism. In fact, according to Lucas in his famous 1976 article[131], reduced form models make unlikely predictions because they rely on observed past correlations of variables. He argues that these correlations may change with the introduction of new policies, making predictions conditional on previous policies invalid. The parameters of the economic model, in fact, would not be independent of the economic policies adopted by the authorities. According to the US economist, if individuals formulate rational expectations, their behaviour will necessarily be influenced by the economic policy measures announced by the government in time t. At time t+1 the public authority will base its choices on a given economic model composed of equations in which the various target and instrumental variables are linked by parameters. DSGE models in this way overcome Lucas criticism because they are built

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[129] Finn E. Kydland and Edward C. Prescott (1982) – "*Time to Build and Aggregate Fluctuations*" (Vol 50, no. 6)

[130] e.g. the stickiness of the adjustment of nominal prices and wages after a shock can heavily influence real variables such as consumption and investment. This has led to the idea that fiscal policy should be accompanied by monetary policies.

[131] Robert E.LucasJr (1976) – "*Econometric policy evaluation: A critique*"

on the basis of the preferences of agents, who can be asked whether the policies used are pareto-optimal or even how they satisfy other social welfare criteria derived from their preferences. As with other general equilibrium models, the purpose of DSGE models is to describe the behavior of the economy as a whole by analyzing the interaction of many microeconomic decisions. The decisions considered in most DSGE models correspond to some of the main quantities studied in macroeconomics. The decisions considered in most DSGE models correspond to some of the main quantities studied in macroeconomics, such as consumption, saving, labour supply and labour demand. The decision-makers in the model are the "agents", they can be households, firms, governments or central banks. From these theoretical considerations we can outline the 3 main characteristics of dynamic and stochastic general equilibrium economic models:

- *Dynamic*: as they observe the dynamics of variables by investigating their variance.
- *Stochastic*: as they are based on the study of exogenous shocks that can affect the normal course of the system and cause oscillations;
- *General equilibrium*: as they use the assumption that the whole economy tends to reach an equilibrium.

The stochastic nature of DSGE models refers to the fact that the economy, during its evolution, is continuously hit by random shocks such as technological changes, sudden spikes in oil prices and, as we will see, the impacts caused by climate change. When a shock hits a system, how do the aggregate variables react? For example, how would aggregate GDP or the unemployment rate react to a sudden spike in oil prices in a given context?

DSGE models answer these questions by simulating so-called impulse responses, which project the possible future behavior of variables assuming that the shock is completely unexpected by the agents. Indeed, if individuals anticipate the occurrence of a shock, they may adjust their behavior in advance by anticipating purchases. It should be specified that stochastic dynamic models have very different meanings whether the view is short or long term. Both neoclassical and Keynesian thinking agree that in the long run the classical dichotomy applies: changes in the money supply are neutral. However, due to the fact that prices in neo-Keynesian models are sticky, an increase in the money supply (or, equivalently, a fall in interest rates) can increases the supply and decreases unemployment in the short run. Thus, it has to be considered the possibility of the system remaining far from equilibrium for periods that are not short-lived stems from a lack of coordination between the decisions of agents operating in different markets. Of course, in order for the rational expectations hypothesis to work, market forces must operate with sufficient intensity to make the system capable of self-regulation by pushing it steadily towards the long-run equilibrium trend. Thanks to this feature, it is possible to create models that take into account environmental impacts on aggregate macroeconomic variables, since the shocks created by climate change have visible consequences on economic systems after 10-20 years.

It is only in recent years, following empirical evidence of correlation between economic trends and climate change, that economic theory is making an effort to include the "climate variable" within forecasting models.

4.3.2 DSGE CRITICISMS

The firsts main limitations of the DSGE methodology can be traced back to the three main characteristics of such models evident from their name: the DSGE approach requires macro models to be dynamic, stochastic and to analyse general equilibrium. These limitations stem from the naive interpretation of the specific terms that characterise the DSGE approach.[132] Indeed, understanding the meaning of these features specifically in context can highlight the intense limitations of this methodology.

Starting from the definition of dynamic implies that a model following the DSGE approach should be an infinite horizon model. Infinite horizon models allow a much simpler and more efficient understanding than a two-period study. In which the two periods by their nature suffer from asymmetry and are likely to be difficult to interpret.

On the other hand, the implementation of infinite horizon models has both great benefits and costs. The main problem with infinite horizon models is that they require a major effort in the structuring and solving phase. Since an infinite time horizon introduces much more complexity into model resolution, it is extremely complicated to explicitly solve

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[132] Anton Korinek (2015). "*Thoughts on DSGE Macroeconomics: Matching the Moment, But Missing the Point?*"

and structure stochastic infinite-horizon models, which makes it necessary to use computer approximations and simulations even to solve simple DSGE models.

The term stochastic implies two features: first, that the models take uncertainty into account. The second is that external productivity shocks are taken into account as a trigger of uncertainty. Although shocks other than productivity shocks have been theorised with research, such as financial and price instability shocks, productivity shocks are still the primary uncertainty instrument used in DSGE models. This assumption is in stark contrast to the empirical evidence, where most shocks do not arise from productivity. Moreover, as will be explained later, DSGE models do not take endogenous shocks into account.

General equilibrium means that macroeconomic models have to be built from the bottom up on the basis of sound micro-foundations. Starting from microeconomics, the aggregate trend can be obtained by studying individual economic behaviour. The second step is then to maximise each objective (utility or profit), given the constraints they face. However, there are many phenomena in macroeconomic science that are not easily traced or connected with their microfoundations. There are different laws that describe macroeconomic behaviour but which have no value in a micro-economics view, see for example Bernanke and Gertler (1989). In fact, DSGE approach gives a set of restrictions which are in total conflict with microevidence.

Further criticism came from the economist J. Stiglitz, who in his essay "*Where modern macroeconomics went wrong*[133]" deeply criticises the theoretical foundations of the DSGE approach and its use to predict economic and financial crises. The core of his criticism lies in the theoretical foundations of the models in question: the rational behaviour of economic agents and exogenous shocks. These criticisms are mainly supported by the event that has most highlighted the flaws of the DSGE models: " the great recession " of 2007/8 due to the subprime crisis.

For example, in DSGE models, downturns are caused by an exogenous production shock. Taking the agricultural sector into account, a negative production shock can be bad weather or a plague of locusts. But applied to the financial and industrial economy, most shocks are endogenous in origin. Applied to the financial crisis of 2007/8 the shock was internal to the economy, caused by the housing bubble. A phenomenon that the markets

[133] Available here https://academic.oup.com/oxrep/article/34/1-2/70/4781816

themselves created and contributed to its development. To sum up, there are two main faults with the DSGE models:

The first is that the models have failed to predict disaster because they are not structured to simulate shocks of a certain magnitude. Quoting Stiglitz in his analogy, "*what would one think of a medical doctor who, when a patient comes with a serious disease, responded by saying, "I am sorry, but I only deal with colds"?*".

The second is that not only did the DSGE approach fail to predict the bubble, but by following its theoretical assumptions it explicitly stated that such an event should never have happened.

4.3 SIMULATIONS AND SCENARIOS WITH THE DICE MODEL

In this chapter, simulations of the effects of climate change on the economy, environment and society will be produced using a DICE model. To perform these simulations, online software developed according to the 2010 DICE model by Professor W. Nordhaus of Yale University was used. It is important to mention that the choice of using this software was driven by its easy availability and use. Furthermore, thanks to its user-friendly interface, the feedback between climate mitigation policies and changes in CO2 emissions is direct. All simulations were developed using real data and statements adjusted to the input parameters of the software.

4.3.1 WEBDICE

Webdice is a free online software developed by researchers at the University of Chicago that allows users to simulate the effects of climate change on the economy and society, and also to understand how changes to the model's assumptions change these effects.

The software is based on the equations, codes and documentation developed by W.Nordhaus, but due to technical implications the researchers used different language encodings (Pyton). The original codes and useful information are available in the book "*A Question of Balance, Weighing the Options on Global Warming Policies*".

The foundations of webDICE are on a model of the global economy in which emissions are produced by industrial activities, these emissions cause climate change, which in turn has negative effects on the economy. The basic assumptions start from the absence of green policies for climate change mitigation. Most parameters are based on available data and where there is no data, the model is based on assumptions. It should be made clear that most of the assumptions are just assumptions, so the results that will be created can only be seen as possible scenarios.

Citing the programme description, the main assumptions on which the model can be run are 3:

- *Carbon Tax*: It is possible to impose a carbon tax for three different years: 2050, 2100, 2150. The rates are set between these years by interpolation. In a nutshell, for a tax of USD100/tonne CO2 in 2050, the rate is increased from the base year (2005 by default) until 2050 to reach that level. As a default setting, the maximum rate at which the total transition to renewable energy would occur is $200/tonne of CO2.

- *Climate Treaty*: The third hypothesis can be to simulate a climate treaty by setting carbon limits in three years, 2050, 2100 and 2150. The limits are a specified percentage of emissions in the base year 2005 and apply in each time period until the next limit. For example, if the limit for 2050 is 100%, emissions in each year between 2050 and 2100 are limited to the 2005 amount. To make the model more realistic, it is possible to choose the percentage of the world's population that has accepted the treaty by setting the participation fraction. As participation drops, countries subject to the treaty must reduce more aggressively to meet the limit, increasing costs.

- *Optimised policy*: In this mode, the software measures the beneficial costs of emission reductions by finding the efficient amount of tolerable emissions that balance the reduction in productivity. In other words, a maximisation phase of economic performance occurs, given the costs of climate change and transaction costs from a high-carbon sector to a renewable sector. In computation, the utility people get from production is preferred over GDP. More specific information are provided in the chapter 4.3.4

A total of 12 parameters are available and are described in the following Table n. 10.

Table n.10 *WebDice Parameters*

Climate sensitivity	how much will temperature increase in degrees C from a doubling of atmospheric CO2?	***Cost Decline***	The rate of decline in costs of reduction emissions
Productivity	Decline in the rate of growth in productivity over time.	***Energy Intensity***	Reduction in energy intensity per decade. Or the rate of decline in energy use per $ of GDP.
Depreciation	Rate at which physical assets (buildings, machines, etc.) wear out.	***Fossil Fuels***	Fossil fuel reserves remaining, measured in CO2 emissions.
Savings	Savings rate on the GDP per year.	***ETA***	Elasticity of marginal utility. This is the exponent of consumption in the utility function.
Max Population	Maximum level of the global population, in billions.	***RHO***	Pure rate of time preference, and the discount rate applied to utility.
Abatement Cost	Marginal cost of reducing emissions. This represents the additional costs from more abatement.	***Harms***	How large will the harms to the climate be, due to an increase in temperatures?

Source: *WebDice*

4.3.2 SIMULATION WITH A CARBON TAX

In this section a simulation with the introduction of a carbon tax over the 3 period (2050, 2100, 2150) just indicated will be run.

The input parameters will be based on real data approximated for use within the software. As some parameters are not available, the default data will be used.
The first scenario will be structured around the imposition of a carbon tax. As explained in section 2.1.2, carbon pricing is one of the most effective tools available for the climate change transition. By increasing the cost of "brown" energy and all activities that emit CO2, it forces the transition to other energy sources or activities that pollute less.
Based on the OECD report "*Effective carbon rate 2021*", an efficient decarbonisation in 2050 requires the imposition of a tax of $120 per tonne of CO2. This benchmark allows assessing progress towards carbon prices in the near future that are in line with current decarbonisation goals. In subsequent periods, the carbon price will be gradually increased to the software-supported cap of $200/tonne of CO2.
Within this simulation, two sub-scenarios will be developed within the same graphs. Climate sensitivity plays an extremely important role in the determination of climate damage, temperature increase and social cost curves.
In the latest report of the World Climate Research Programme[134], an international team of researchers from multiple climate disciplines theorised a climate sensitivity window of 2.6 °C to 3.9 °C. These results are a narrowing of the predictions of the 2013 IPCC[135] report, which estimated a possible range of 1.5°C to 4.5°C.
The best (2.6°C) and worst (3.9°C) climate sensitivity assumptions will be used in the sub-scenarios.
The imposition of a carbon price policy is structured with a 120 $/CO2 tonne within the 2050, 160 $/CO2 tonne within the 2100 and 200 $/CO2 tonne within the 2150. Then the model is developed with the following parameters Tab n.8.

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[134] WCRP (2020). "*International analysis narrows range of climate's sensitivity to CO2*." Available at https://www.wcrp-climate.org/news/science-highlights/1604-climate-sensitivity-2020
[135] IPCC, 2013: *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324

Tab. n.11 *Model parameters*.

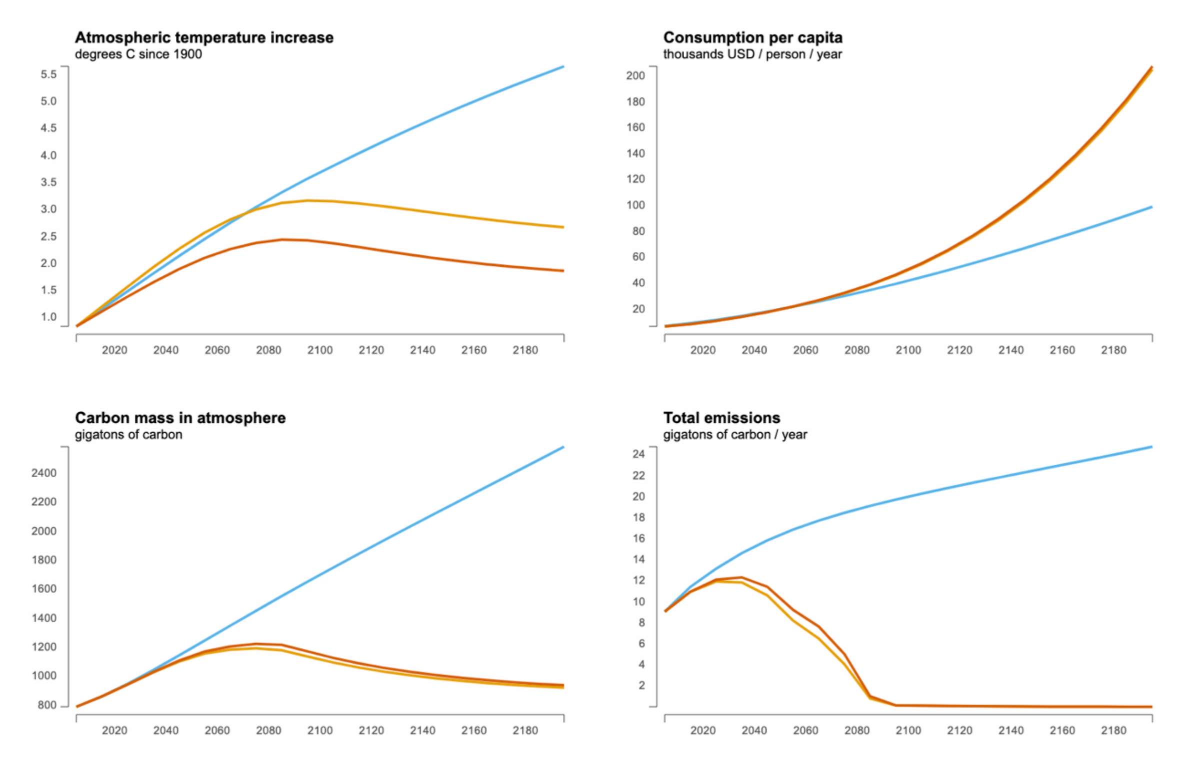
Climate sensitivity	2.6 – 3.9 °C[136]	Cost Decline	10%
Productivity	0.5 %	Energy Intensity[137]	1.5%
Depreciation rate	15%[138]	Fossil Fuels[139]	6000 in GtC
Savings	25%[140]	ETA	1.8
Max Population	11.2[141]	RHO	3
Abatement Cost	2.2[142]	Harms	2

Table n.12 *Carbon Tax scenarios*.

Scenario n.1 Business as usual scenario (no policies for climate change) –––––	Scenario n.2 Scenario with a 3.9°C of sensitivity –––––	Scenario n.3 Scenario with a 2.6°C of sensitivity –––––

[136] The two limits theorized by WCRP (2020). "*International analysis narrows range of climate's sensitivity to CO2.*"
[137] Average of Relative Energy Intensity values of 2016. European Energy Agency. Data and maps. Fig. n.2 Available at https://www.eea.europa.eu/data-and-maps/indicators/total-primary-energy-intensity-3/assessment-2
[138] This value rapresent the average from EY (2018). "*Worldwide Capital and Fixed Assets Guide*". Table n. 2.1
[139] This parameter is extremely high in respect to reality. The Carbon tracker report "*Unburnable Carbon - Are the world's financial markets carrying a carbon bubble?*" estimates that "The fossil fuel reserves held by the top 100 listed coal companies and the top 100 listed oil and gas companies represent potential emissions of 745 GtCO2". The parameter used is the minimum applicable in the software.
[140] The World Bank. Data Bank 2019 Gross savings (% of GDP). Available at https://data.worldbank.org/indicator/NY.GNS.ICTR.ZS
[141] Population forecast in 2100 United Nations (2017). "*The World Population Prospects: The 2017 Revision.*"
[142] Mariyana Y. (2019), "*World bank: Sustainable development costs just 4.5% of GDP*", Renewable Now, Feb 22, 2019

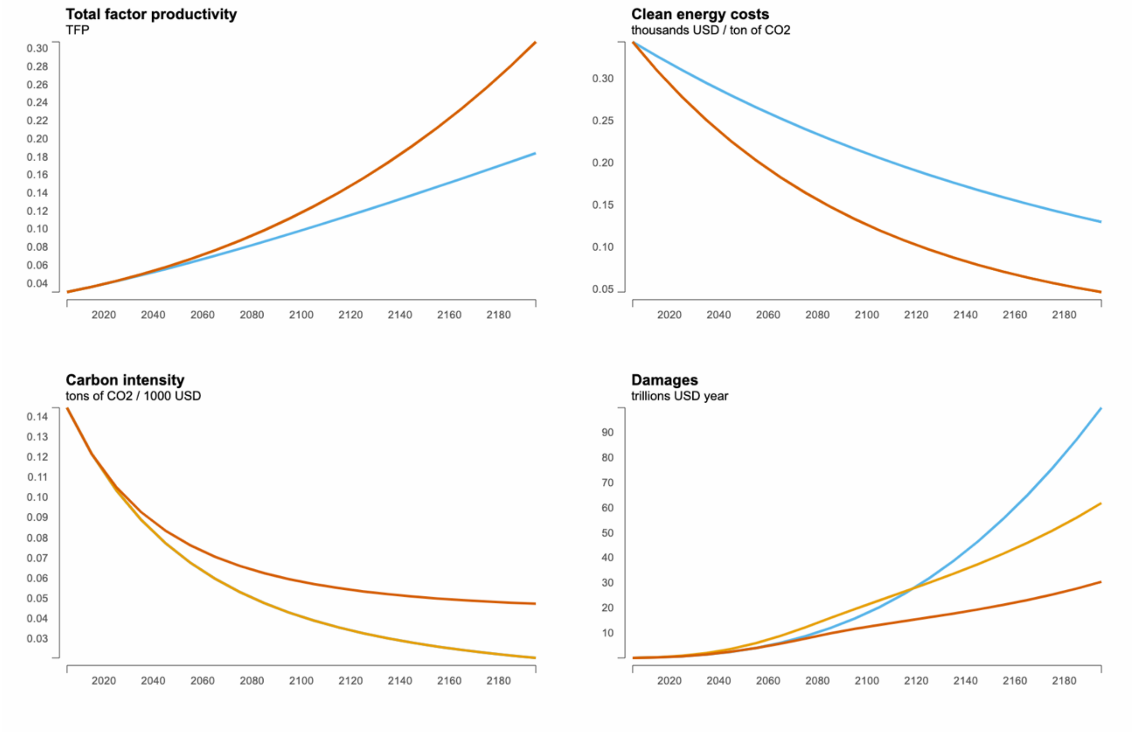
Graphs n. 5 *Essentials results with a Carbon Tax*.



Source: *own simulation with WebDice*.

The graphs show a clear difference in temperature increase in relation to climate sensitivity. Under these assumptions, the main climate change targets are not met. From the year 2005 (base year of the model), the 1.5°C temperature increase target is already exceeded in both scenarios from the year 2030, and the "well below 2°C" target (upper limit imposed by the Paris Agreement) is exceeded in 2040 in the second scenario and in 2050 in the third. It can be seen that in 2080 a huge drop in total CO2 emissions causes values to fall dramatically below one gigatonne.

Graphs n. 6 *Economy results with a Carbon Tax.*



Source: *own simulation with WebDice.*

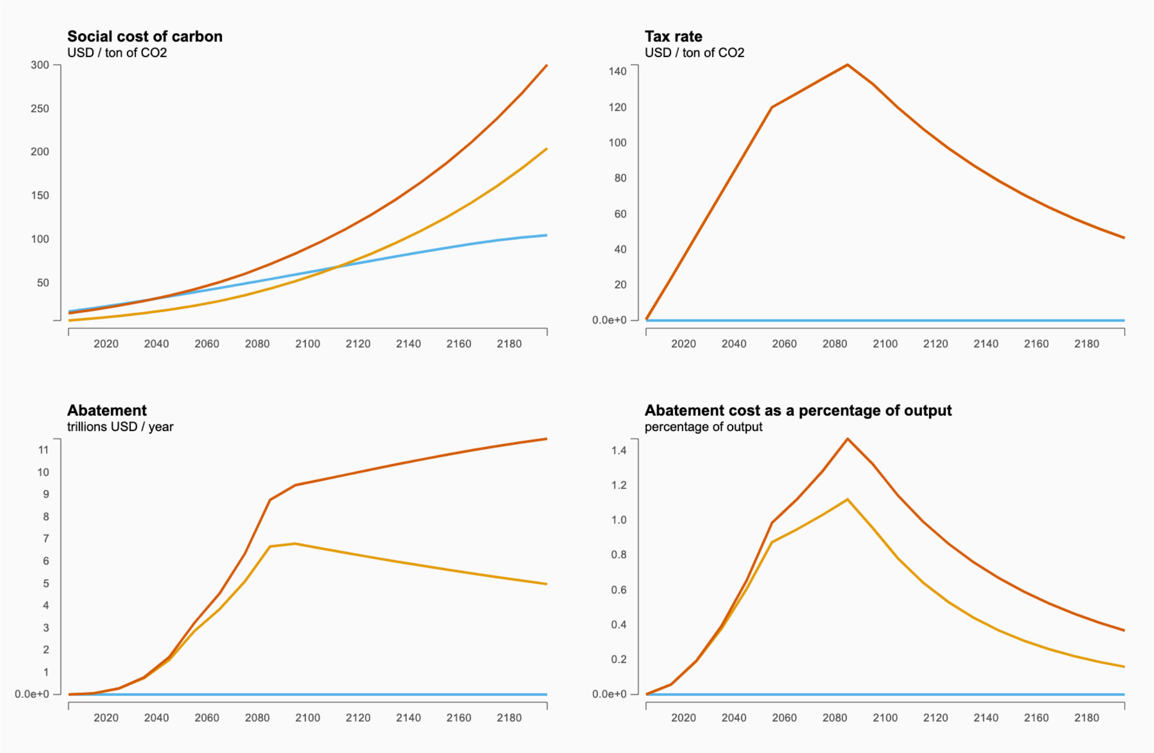
Under the model's assumptions, in both scenarios capital and labour will produce economic output more efficiently, as the total rate of productivity (TFP) will continue to grow but at an ever decreasing rate of 0.5 %.

The cost of renewable energies will decrease as soon as the policy is introduced. This price is set a relatively high level for 2005 of USD 1,260/tonne. The price is assumed to go down over time as our technology improves and the abatement cost decrease. In this case, in both scenarios from 2040 the cost of renewable energy will be $20/tonne CO2.

Economic activities require energy. Today, the largest source of energy comes from fossil fuels: oil, natural gas and coal. As time passes and technology advances, the economy becomes more efficient, i.e. less energy is used to produce the same output. WebDice assumes that energy intensity decreases over time as technological innovation becomes more difficult. At a 1.5 % growth rate in energy intensity, scenario number 1 from 2030 becomes more efficient.

As for the damage caused by climate change, in the scenario with the highest climate sensitivity, it exceeds USD 10 trillion from 2060. For comparison, according to the OECD, the global GDP in 2060 will be 264 500 000 million dollars.[143]

Graphs n. 7 *Policy results with a Carbon Tax*.



Source: *own simulation with WebDice*.

The social cost of carbon (SCC) is a value which estimates the increase in harms from additional emissions. WebDICE calculates the social cost of carbon for each period by sequentially adding the additional ton in each period. Under the model assumptions, the third scenario is the most harmful and expensive alternative, this is caused by the attempt of expenditure to reduce the emissions of CO2 in the best climate sensitivity scenario.

143 OECD Data. Available here https://data.oecd.org/gdp/gdp-long-term-forecast.htm

4.3.3 SIMULATION WITH A CLIMATE TREATY

In this section a simulation with the introduction of a climate treaty over the 3 period (2050, 2100, 2150) just indicated will be run.

WebDice makes it possible to introduce a climate treaty requiring a reduction in CO2 emissions as a percentage of 2005 emissions. In addition to the possibility of changing the percentage of emission reductions, the simulations include diversifying the share of participation in the climate treaty according to the percentage of the global population.

The second simulation will therefore be structured along the lines declared by the major economic powers on decarbonisation. As explained in chapter 1.3, Europe is committed to becoming carbon neutral by 2050, with an intermediate target of 55% emission reduction by 2030. In addition to Europe, many other countries have set themselves the target of cutting emissions by 2050. To name a few: USA, Canada, Chile, Colombia, Argentina, South Korea, South Africa, Japan. [144]These countries represent about 60% of the population.[145] Countries such as China, Australia and India have declared their commitment to reduce emissions to zero in 2060[146], in an undefined year but no later than 2100 and in an undefined year respectively.

Starting from the populations of these countries, the percentage of the population participating in the climate treaty was assumed. Countries such as India and China, due to their demographic weight, account for approximately 18.47% [147]and 17.7% [148]of the global population respectively.

Participation in the climate treaty will thus be stratified according to the 3 periods:

- 2050 60% global participation;
- 2100 80% global participation;
- 2150 100% global participation;

Within this simulation we will always compare the two sub-scenarios of climate sensitivity with ceteris paribus conditions.

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[144] Omri W (2021). "*Race to Net Zero: Carbon Neutral Goals by Country*". Visual Capitalist. June 8, 2021.

[145] This statement is an approximation based on 100% of the world's population and subtracting the major countries with the largest populations: China and India.

[146]

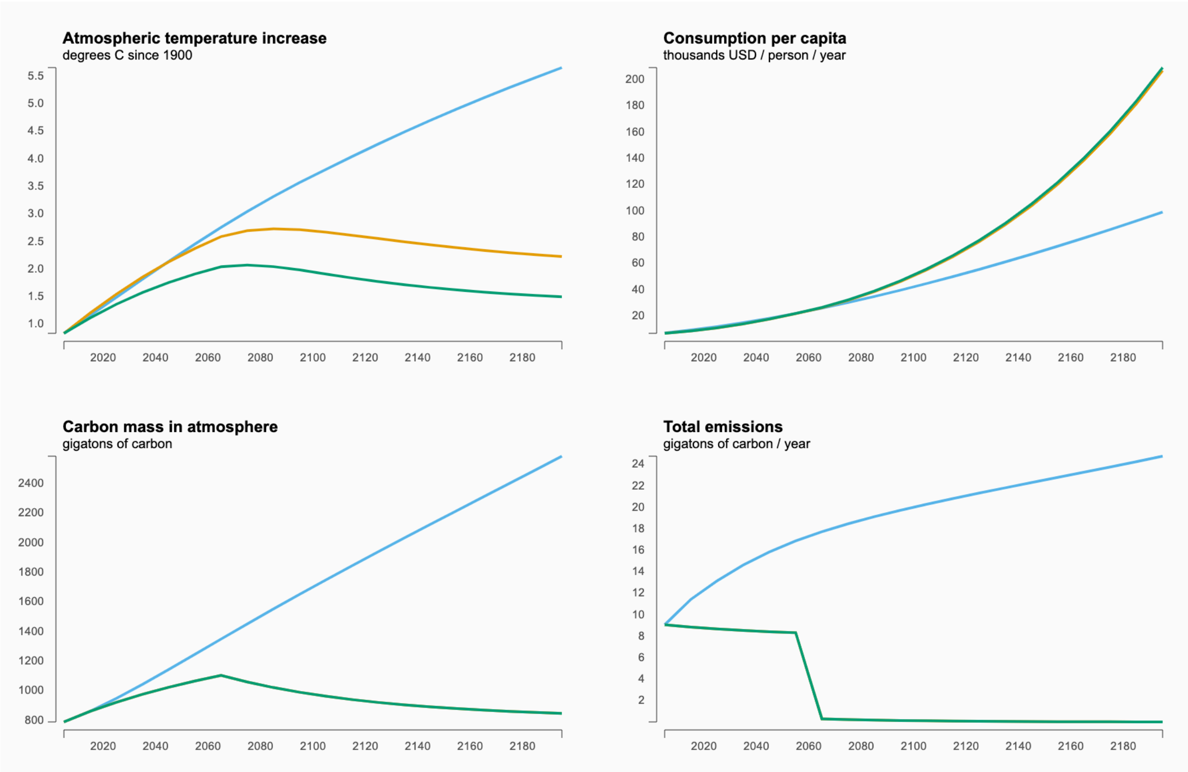
[147] Worldometer - https://www.worldometers.info/world-population/china-population/

[148] Worldometer - https://www.worldometers.info/world-population/india-population/

Tab.13 *Climate treaty scenarios*.

Scenario n.1 Business as usual scenario (no policies for climate change) ———	Scenario n.2 Scenario with a 3.9°C of sensitivity ———	Scenario n.3 Scenario with a 2.6°C of sensitivity ———

Graphs n. 8 *Essential results with a Climate Treaty*.

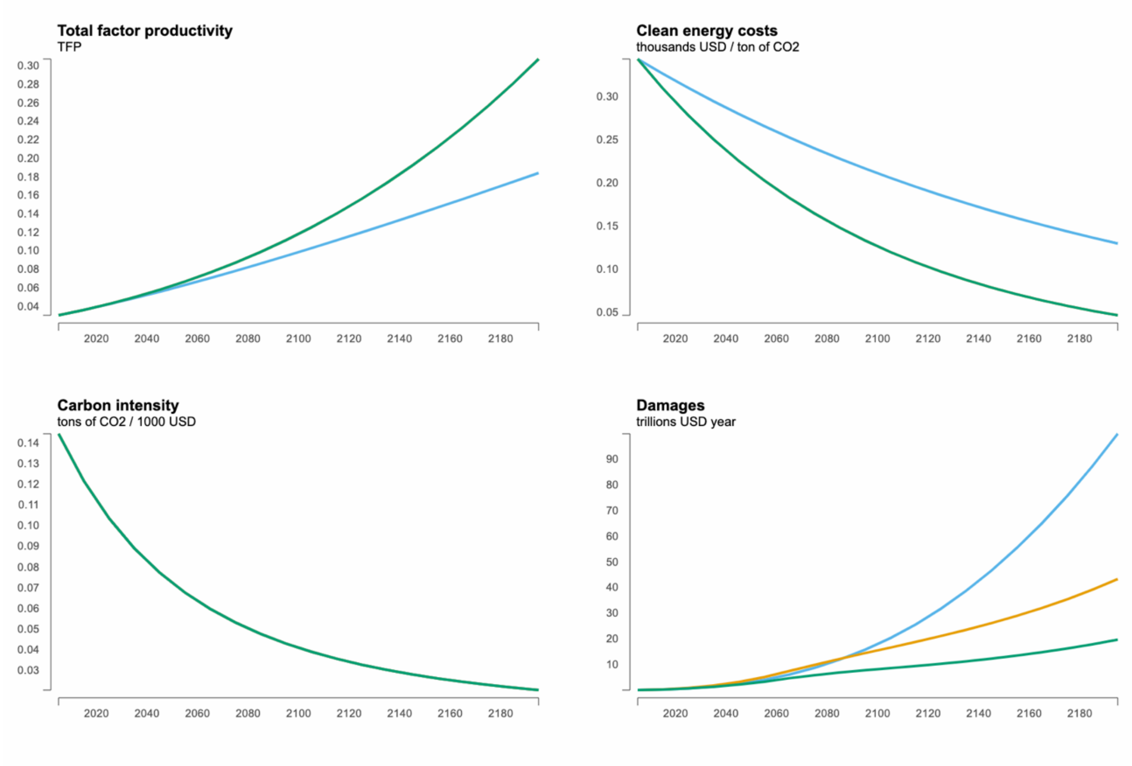


Source: own simulation with WebDice.

Important progress can be seen with regard to rising global temperatures and total emissions. The temperature increase limit of 2 °C is exceeded by 0.6 degrees in the most optimistic climate sensitivity scenario. The limit is only exceeded in 2075 where the curve peaks and then falls to below 1.9°C in 2100.

In both scenarios it can be seen that in 2060, thanks to the adherence of more than 60% of the population, there is a dramatic fall in total emissions to below 0.231 GtC.

Graphs n. 9 *Economy results with a Climate Treaty*.

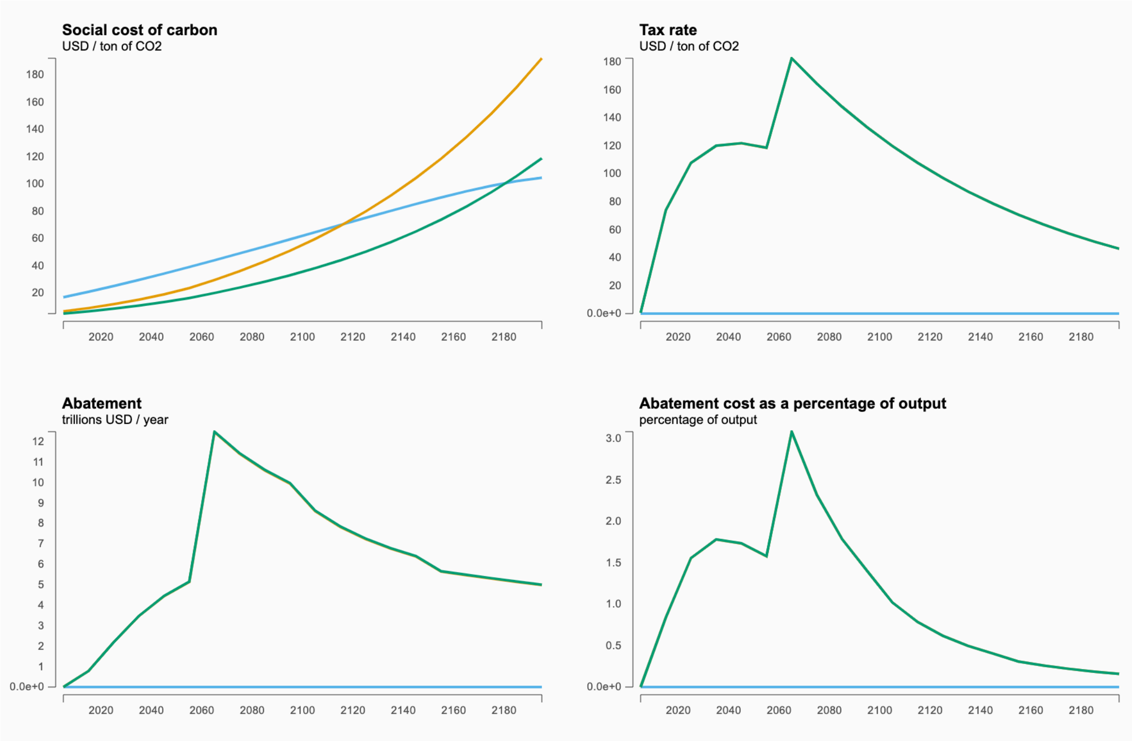


Source: *own simulation with WebDice*.

Climate sensitivity, as shown in the graphs, does not affect productivity, renewable energy cost and carbon intensity. This is mainly due to the absence of carbon appreciation, a key difference in determining the use of fossil fuels and the transaction cost towards green energy.

The damage curve is shown to be much flatter than in the simulation of a carbon tax, but still increasing. The reason is related to the smaller amount of emissions produced.

Graphs n. 10 *Policy results with a Climate Treaty*.



Source: *own simulation with WebDice*.

The social cost of carbon, the increase in damage caused by an additional tonne of carbon dioxide, varies widely across environmental policy scenarios. In the most optimistic scenario (scenario N. 3), the social cost of carbon remains well below the business-as-usual scenario and the most pessimistic scenario, only starting to increase and exceeding the first scenario in 2180.

In the transition cost abatement scenario, there is a peak in costs in 2070 both as a percentage of GDP and as an absolute value in trillions of dollars. This value is given by the percentage of the population participating in the climate treaty, which approaches 70% by 2080.

4.3.4 SIMULATION WITH A OPTIMISED POLICY

The third simulation will be developed with the "optimised policy" function in the periods 2050, 2100 and 2150.

This function allows to find the best economic performance given the transition costs to reduce emissions and the costs of climate change. By optimising emission reductions, the software uses the utility functions that people derive from the output, rather than just GDP. Indeed in optimisation mode, WebDice finds the path of emissions reductions that maximises the objective Function 1:

$$W = {}^{max}_{t=1}\Sigma\, U[L_t]R_t \quad \text{Function 1}$$

Where U is the utility, L_t is the population and R_t is the discount factor determined by the pure rate of time preference p (Function 2) :

$$R_t = \frac{1}{(1+p)^t} \quad \text{Function 2}$$

It then translates this into a carbon tax that achieves those reductions.

$$\tau(t) = BC_t u_t^{\theta-1}\, for\ \varphi = 1 \quad \text{Function 3}$$

Where $\tau(t)$ is the Carbon Tax $/tonne Co2, BC cost of backstop technology[149] housands of 2005 US dollars per ton of CO2 and $u_t^{\theta-1}$ emissions reduction rate as a percent of total emissions, while $\theta - 1$is exponent of emission reduction rate in abatement cost function and θ ∈ [2, 4].

This function has an important feature regarding the development of the two climate sensitivity scenarios.

[149] A backstop technology is defined as a new technology producing a close substitute to an exhaustible resource by using relatively abundant production inputs and rendering the reserves of the exhaustible resource obsolete when the average cost of production of the close substitute falls below the spot price of the exhaustible resource.

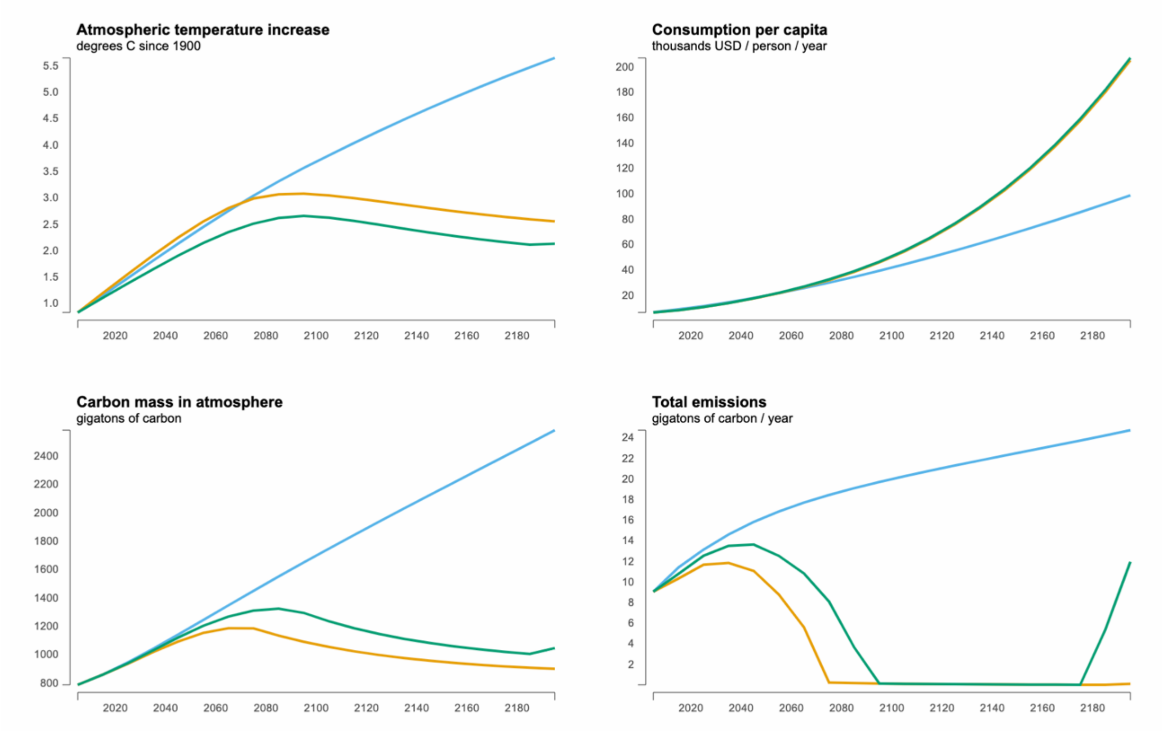
- With a pessimistic scenario (high climate sensitivity), the need for emission reduction is more compelling, optimising costs more.
- With a more optimistic scenario (low climate sensitivity), the need to reduce emissions will be less important, resulting in less cost optimisation.

All the other parameters are same as before.

Tab. 14 *Optimised policy scenarios*.

Scenario n.1 Business as usual scenario (no policies for climate change) ———	Scenario n.2 Scenario with a 3.9°C of sensitivity ———	Scenario n.3 Scenario with a 2.6°C of sensitivity ———

Graphs n. 11 *Essential results with an Optimised Policy*.



Source: *own simulation with WebDice*.

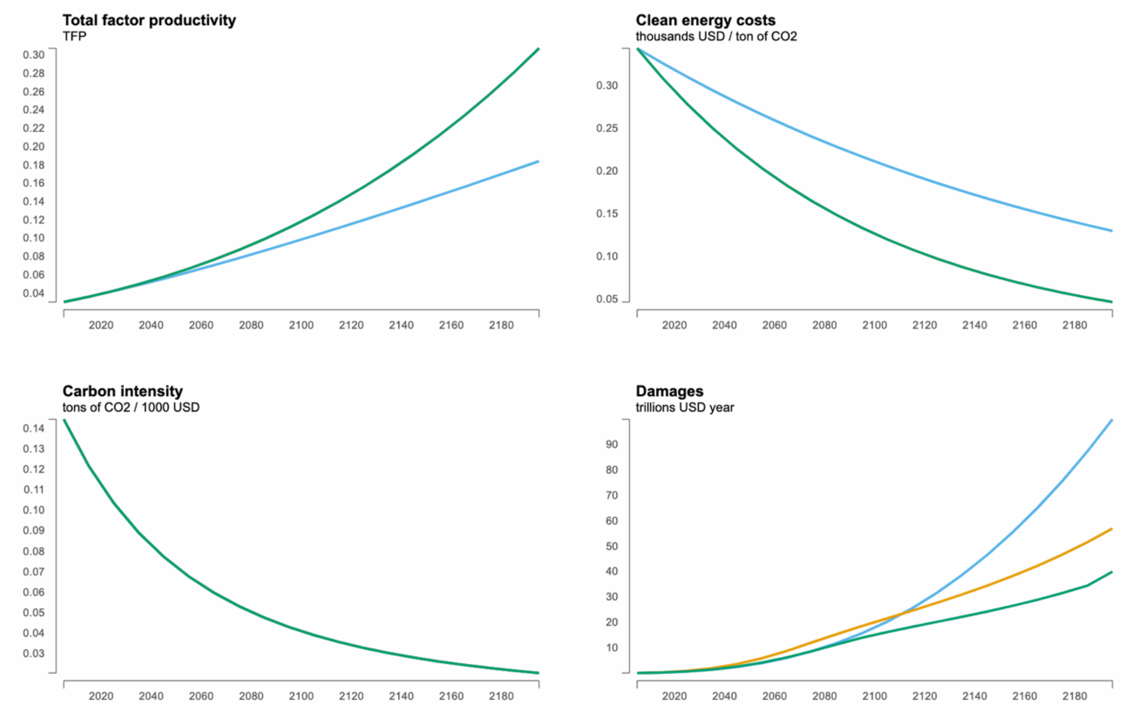
As can be seen in both scenarios (Scenario N. 2 and N. 3), the increase in temperatures goes far beyond the targets imposed by international climate treaties.

What stands out in particular is the soaring increase in total emissions in 2180. This is caused by the decrease in the optimal carbon tax created by the model, as it can be seen in the tax rate drop (Graphs n. 13 tax rate). Since the optimisation option is utility-based, the appreciation of coal is based on the willingness to pay one unit more today for a greater benefit in the future. This carbon tax is in fact influenced by two elements: the pure rate of time preference and the elasticity of marginal utility of consumption.

Pure rate of time preference and elasticity (RHO): determines how we count people living at different times when estimating the effects of climate change and policies to reduce climate change.

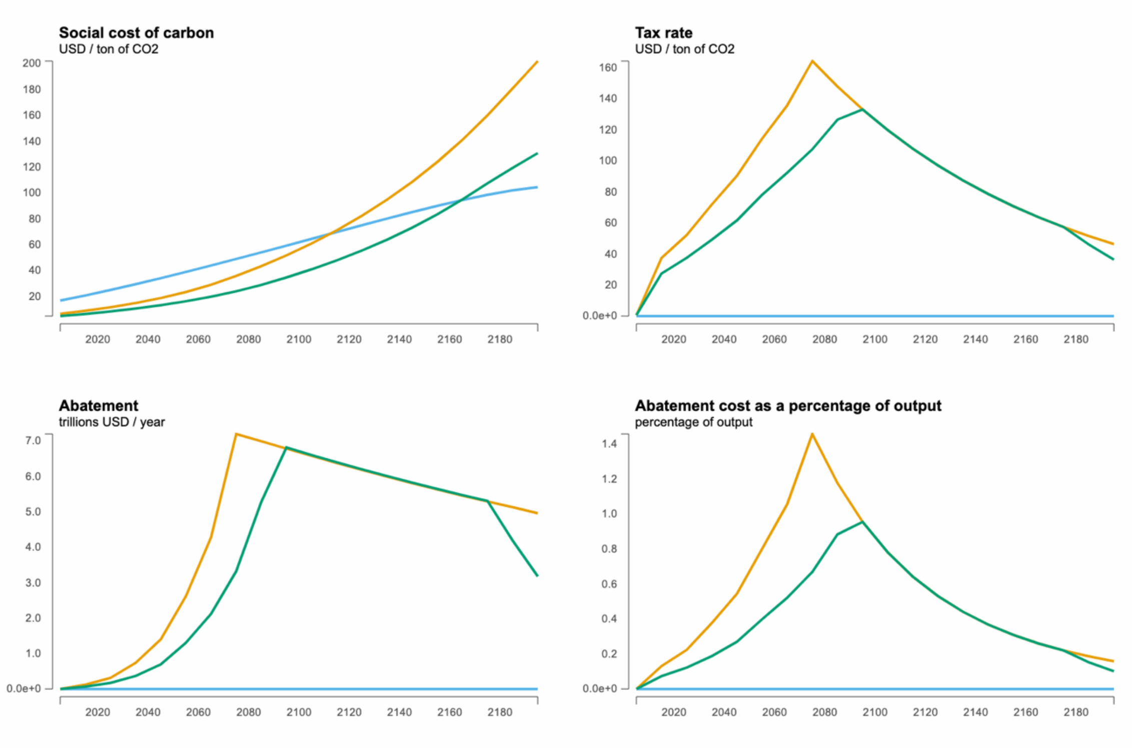
Elasticity of marginal utility of consumption (ETA): the percentage change in marginal utility that results from a unit percentage change in consumption. Consequently, if you increase ETA so that the gains from getting richer are smaller, the optimiser will put less weight on the wealthy and more on the poor.

Graphs n. 12 *Economy results with an Optimised Policy*.



Source: *own simulation with WebDice*.

Graphs n. 13 *Policy results with an Optimised policy*.



Source: *own simulation with WebDice*.

As anticipated earlier and as can be seen from the graphs, the peak of the carbon tax corresponds in both scenarios with the peak of abatement costs as a percentage of GDP. The subsequent sharp drop in the carbon tax consequently explains the increase in total emissions in 2180.

4.3.5 THE IMPORTANCE OF TIME PREFERENCE

In this chapter, a set of simulations is proposed taking into account the marginal utility of time.

The importance of intertemporal evaluation plays a key role to express the relative value of consumption tomorrow as compared to consumption today.

The RHO will be used as the discount rate to calculate people's future utility in today's terms. Climate change directly influences people's utilities by creating physical damage, extreme events, rising sea levels or species extinction. To limit these damages we need to spend now, decreasing our current utility.

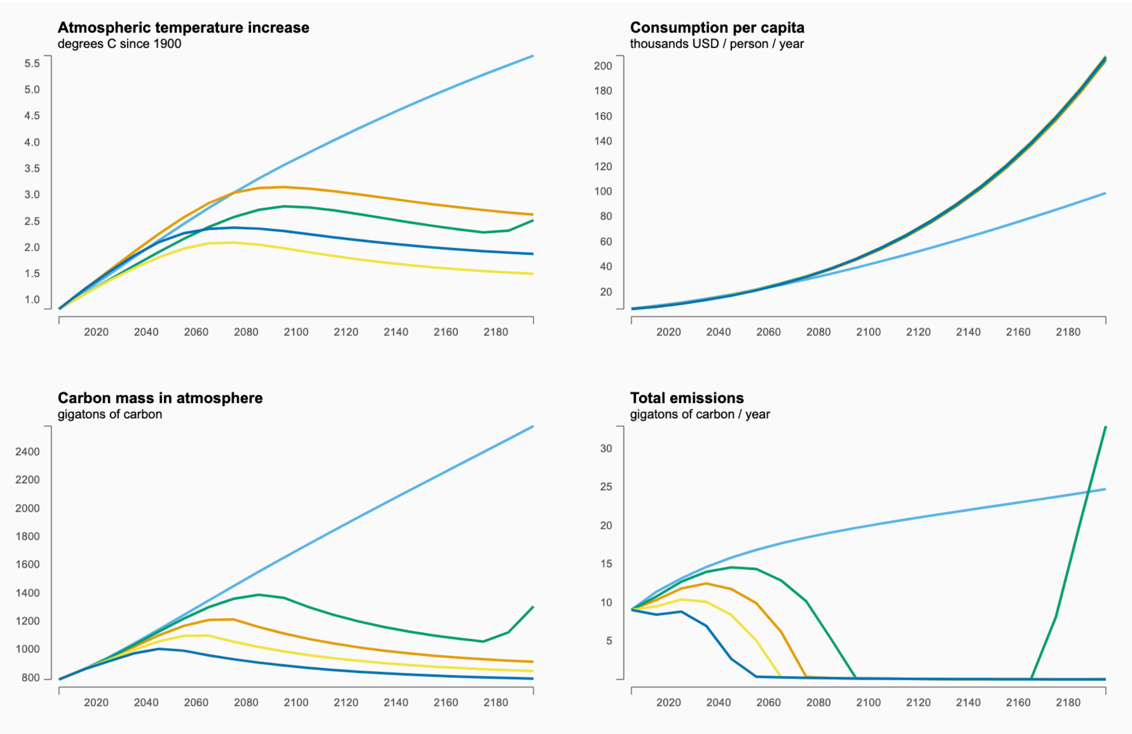
As explained above, the rate of pure time preference applied to the context of climate change dictates the rate of preference between spending a USD unit now to have a future benefit of USD 2 in terms of consumption and reduced damage from climate change. Consequently, by increasing the discount rate, one decreases the utility of future benefits, preferring not to spend now (thus not to see one's utility decrease now) in order to have any future benefits.

As has already been stated, at the state of the art there are no methodologies, sciences or institutions that sanction the correct RHO to be used because each of us can give a different value to time.
So far, a RHO of 3 has been used, as shown in the parameter table (Tab n.11).
It is now proposed to decrease this value to 1 - hence decrease the discount rate - and use the WebDice optimised policy function to relate the various climate sensitivity scenarios to compare the results.

Tab. n. 15 *Optimised policy scenarios with time preference.*

Scenario n.1 Business as usual scenario (no policies for climate change) ——	Scenario n.2 Scenario with a 3.9°C of sensitivity and RHO 3 ——	Scenario n.3 Scenario with a 2. 6°C of sensitivity and RHO 3 ——	Scenario n.4 Scenario with a 3.9°C sensitivity and RHO 1 ——	Scenario n.5 Scenario with a 2.6°C sensitivity and RHO 1 ——

Graphs n.14 *Essential results Optimised policy scenarios with time preference.*

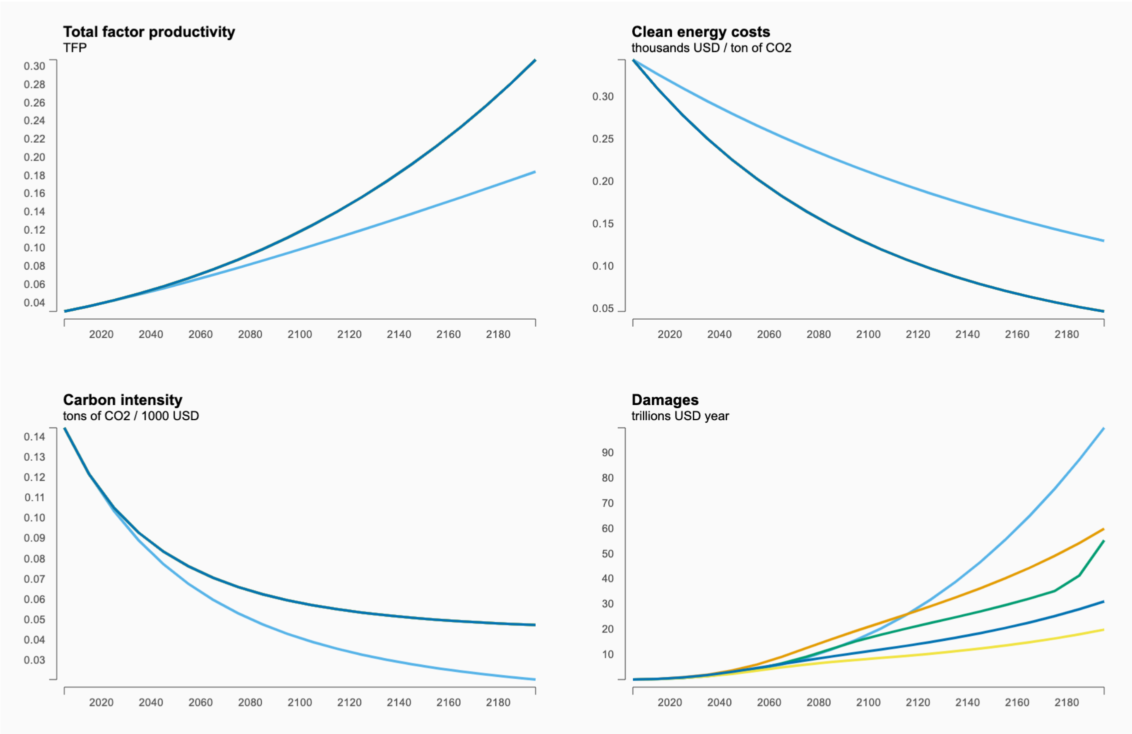


Source: own simulation with WebDice.

It is easy to see that the discount rate has a direct effect on the importance of climate change. The value we place on the future dictates the commitment to current mitigation policies.

The graphs show that in scenarios with an RHO of 1, climate performance is significantly more optimistic than in previous scenarios. Climate sensitivity plays a complementary role in the production of total emissions and the implementation of mitigation policies. Indeed, it is recalled that in this WebDice function, the aim is to optimise the utility of the population by reducing emissions. Consequently, the higher the climate sensitivity, the more stringent policies will be applied.

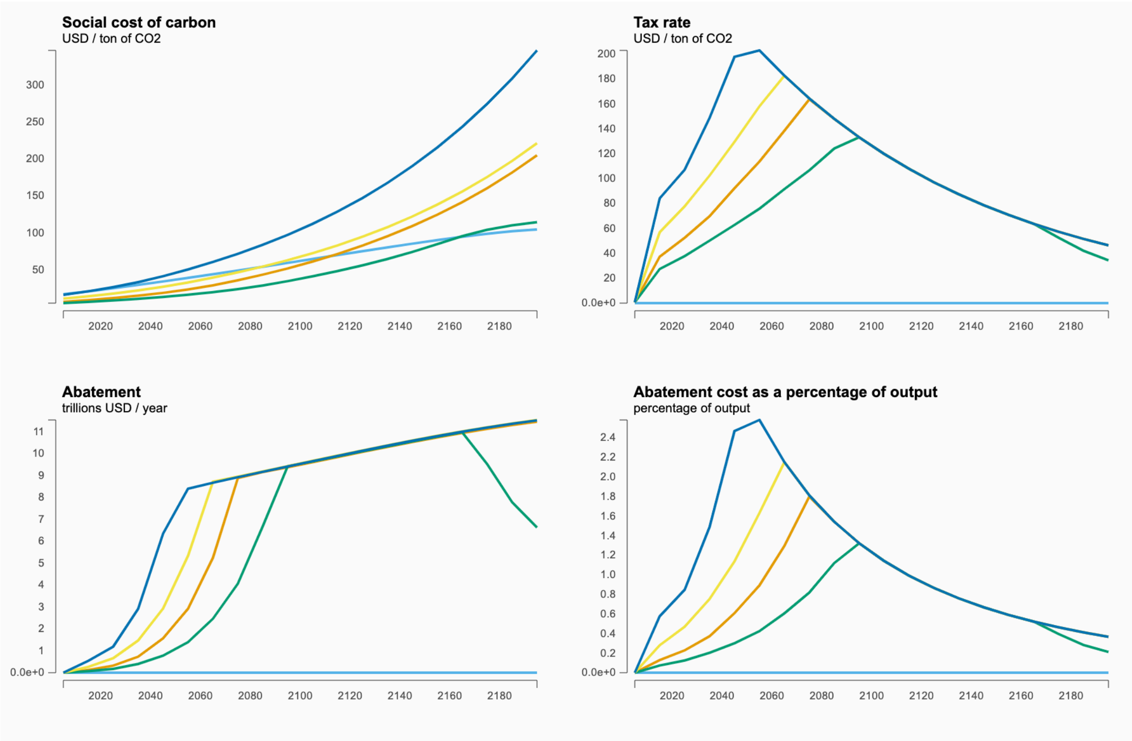
Graphs n. 15 *Economic results Optimised policy scenarios with time preference.*



Source: *own simulation with WebDice*.

The results show that utility will not affect productivity, clean energy cost and carbon intensity. Instead, damages will depend on mitigation policies and climate sensitivity. Since policy implementation is a maximisation of the population's utility, damages in scenarios 4 and 5 do not exceed USD 20 trillion in either case withinthe 2200, in contrast to the rest of the scenarios.

Graphs n. 16 *Policy results Optimised policy scenarios with time preference.*



Source: *own simulation with WebDice*.

In these results it can be seen that utility directly influences climate change mitigation policies.

As explained above, lowering the discount rate puts a higher value on future benefits, so spending one unit of USD now to get 2 USD in the future produces a higher utility. This concept is easily seen in these graphs. The Tax rate becomes higher by increasing climate sensitivity, requiring more spending to lessen its effects.

In fact, the abatement cost curves are all squashed towards the first 60 years of the simulation, peaking in 2060.

Interestingly, although absolute carbon abatement costs grow slowly and linearly over time, their share of GDP decreases dramatically over the years. This is because consumption increases and costs remain more or less constant.

CONCLUSIONS

In this thesis, we have tried to outline the way forward in addressing the challenge of climate change from the perspective of mitigation policies. Despite the fact that, as we have seen, positions and trade-offs on the topic are many and sometimes conflicting.
Climate change mitigation policies and relative instruments are subject to important decisions by policy makers, who have the delicate task of calibrating and assessing transitional and physical risks. Now is the time to act, but without damaging the economic fabric that feeds the economy. On the contrary, it is necessary to accompany industries, the financial system and other agents in this transition phase. This is the reason why more attention on assessing these risks and evaluating possible damages is needed.
The imposition of a carbon tax alone, for example, will not provide climate change mitigation unless it is designed in such detail as to cover the total emissions produced. Again, if a carbon pricing policy is not coordinated with other supportive policies such as expansive monetary policies or subsidies for renewable energies, the only effects will be a decrease in industrial productivity and a general increase in prices.
According to scientific organisations, the climate change we are witnessing has now reached an advanced stage and can no longer be underestimated. If the origin of climate change is therefore mankind (according to the IPCC's V Report of 2013), it is mankind in the first place - through institutions and others - that must intervene in order to limit its disastrous impacts. As long as profits and the focus on political consensus are given priority over human well-being and the preservation of the planet, there will always be those ready to exploit problems and the weakest and to fudge data and results for political and economic gain. Finally, such behaviour will be to the detriment of all, regardless of social position, because no one will be able to escape the inevitable.
Simulations have shown that global action on climate mitigation policies has positive effects on the economy, increasing productivity, consumption and reducing emissions. Technological innovation decreases the marginal costs of renewable energy and increases energy efficiency in industrial processes.
However, it should be noted that in this study, as in most studies in the literature, only one climate change phenomenon was taken into account: the increase in temperature. The increase in temperature is not the only problem to be taken into account. In fact, climate change entails a further series of complications, including: the acidification of the oceans,

the rise in sea levels, the melting of glaciers and the increase in the number of extreme events.

These phenomena are certainly essential variables to analyse in order to better understand the damage that the global economy is and will suffer.

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