Transforming Our World: Interdisciplinary Insights on the Sustainable Development Goals

3nd report of the SDSN Senior Working Group on the European Green Deal

About the SDSN

SDSN mobilizes global scientific and technological expertise to promote practical solutions for sustainable development, including implementing the Sustainable Development Goals (SDGs) and the Paris Climate Agreement. In Europe, over 300 members and 13 national and regional networks of SDSN are part of SDSN Europe, a joint initiative that aims to align the European recovery with the Agenda 2030. Leveraging the research within the networks and the SDSN's work on the Six Transformations and other publications, SDSN Europe will play an active role in shaping a sustainable and resilient Europe.

A special thanks to the SDSN's Senior Working Group, who authored the report, including the following members. Organizations are for identification purposes only.

Chairs:

- Prof. Jeffrey Sachs, President of UN Sustainable Development Solutions Network (SDSN)
- Prof. Phoebe Koundouri, AUEB, DTU, EAERE President, SDSN Europe and SDSN Global Climate Hub Chair

Members:

- Prof. Leonardo Becchetti, University of Roma
- Prof. Simone Borghesi, University of Siena
- Prof. Marzio Galeotti, Fondazione Eni Enrico Mattei (FEEM)
- Ms Laura Cozzi, International Energy Agency (IEA)
- Dr Carlo Papa, Enel Foundation
- Prof. Theodoros Zachariadis, The Cyprus Institute, Manager SDSN Europe

Other authors of the Report

Lead Author:

- Prof. Phoebe Koundouri, AUEB, DTU, EAERE President, SDSN Europe and SDSN Global Climate Hub Chair

Co-Authors:

- Prof. George Halkos, AE4RIA
- Mr Stathis Devves, AE4RIA
- Dr Conrad Landis, AE4RIA
- Mr Angelos Plataniotis, AE4RIA
- Mr Etienne Berthet, DTU
- Dr Mirko Armiento, Enel Foundation
- Dr Maria Lelli, Enel Foundation
- Dr Laura Cavalli , FEEM
- Mr Edward Cruickshank, FEEM
- Mr Ketan Patel, Force for Good
- Mr Christian Hansmeyer, Force for Good
- Mr Daniel Wetzel, IEA

- Dr Candy Anquetil-Deck, NTNU
- Dr Ilaria Fusacchia, Roma Tre University;
- Dr Elisa Chioatto, University of Ferrara
- Prof. Leonardo Becchetti, University of Rome tor Vergata
- Mr Enrico Giovannini, University of Rome tor Vergata
- Dr Francesco Salustri, University of Rome tor Vergata
- Prof. Simone Borghesi, University of Siena
- Dr Ilaria Dibattista, University of Siena
- Prof. Matteo Mazzarano, University of Siena
- Ms Mira Manini Tiwari, University of Siena

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1 Contents

2 Introduction

Today's world stands at the crossroads of major global challenges, ranging from poverty and inequality to climate change and environmental degradation. These pressing issues underscore the essential role of sustainable development in forging a prosperous, equitable, and peaceful future for all.

Building on the insights and findings of our previous reports, namely "Transformations for the Joint Implementation of Agenda 2030 for Sustainable Development and the European Green Deal: A Green and Digital, Job-Based and Inclusive Recovery from COVID-19 Pandemic" (2021), and "Financing the Joint Implementation of Agenda 2030 and the European Green Deal" (2022), this year's report explores in detail the multifaceted nature of sustainable development and offers invaluable insights to guide the policy decisions required to address these challenges.

More specifically, in line with the work presented in 2021's and 2022's Reports, the current report also investigates the complicated web of factors affecting sustainable development. It emphasizes the importance of region-specific approaches to sustainable development, repeating the focus on the European Union's role presented in the previous reports. It explores the potential of the EU to redefine global sustainable development challenges and highlights the necessity of understanding interdependencies among different systems, a topic touched upon in our discussions about the close link between the European Green Deal and Agenda 2030, with the 17 SDGs.

Furthermore, this report expands on the concept of 'natural capital' introduced in 2022's Report, exploring its interconnectedness with social capital, produced capital, and cultural heritage. More specifically, it recognizes the role of aesthetic, historical, social, and spiritual values in shaping sustainable development policies.

In consistence with the previous reports, this report also underscores the significance of green jobs and digital transition as drivers of sustainable development. It goes deeper into the employment trends and skill requirements in the net-zero economy and urges the importance of reskilling policies, reflecting on the job-based recovery discussed in 2021's Report.

Building upon the financial discussion in 2022's Report, this report touches on the private sector's role in financing the SDGs, identifying SDG content in financial asset portfolios, and emphasizing the potential of carbon farming and voluntary carbon markets. These discussions further illuminate the financial strategies necessary for the successful implementation of sustainable development initiatives.

In conclusion, "Transforming Our World: Interdisciplinary Insights on the Sustainable Development Goals" serves as an extension of our previous discussions. By bringing together interdisciplinary insights and understanding the interconnections between different dimensions of sustainable development, this report can guide policymakers and stakeholders to take informed decisions and targeted actions to address the complex challenges of our time, thereby contributing to a more sustainable and equitable future.

3 Executive Summary

This summary provides a comprehensive overview of the key findings and insights presented in the report. The chapters that included in the report explore critical topics in sustainable development, including the EU's opportunity to redefine global sustainable development challenges, the interconnectedness of natural capital and cultural heritage, the potential of green jobs and digital transition, carbon farming and voluntary carbon markets in the EU, private sector funding of the SDGs, and the identification of SDG content in financial asset portfolios.

Each chapter highlights significant considerations and offers policy recommendations for driving sustainable development and achieving the SDGs. Below the key points of each chapter is sumarized:

- **Interdependence, Networks, and Green Deal: The EU's Opportunity to Redefine the Landscape of Global Sustainable Development Challenges**

  This chapter discusses the importance of adopting a region-specific and nuanced approach to drive sustainable development in the European Union (EU) and globally in alignment with the Sustainable Development Goals (SDGs). It emphasizes the significance of understanding interconnected systems and the use of strategic tools like weaponized interdependence for achieving geostrategic objectives.

  The EU Green Deal is highlighted as a key part of addressing externalities like deforestation and work-related accidents. The importance of formulating effective policies and enhancing international cooperation is underlined. The idea of leveraging interconnected networks for designing international sustainable policies is also discussed.

  Furthermore, the document presents a figure from a study in progress on representation of SDG spillovers in a new conceptual framework. The figure is used to demonstrate the role of the EU, Western Europe, Southeast Asia, and East Asia in mitigating the social implications of work-related fatalities through targeted trade measures.

  The chapter concludes that a holistic approach to interlinked challenges, global cooperation, tailored legislation, and understanding specific challenges can lead the international community towards a more sustainable and equitable future.

- **Private Sector Funding of the SDGs**

  This chapter discusses private sector funding of the Sustainable Development Goals (SDGs). It highlights the increasing engagement from the finance industry in funding SDGs and the diversification of their commitments across different goals.

  However, the chapter also points out that private sector engagement on the SDGs remains small compared to the total capital required for achieving the goals. It mentions the increasing alignment of finance industry leaders' SDG financing with critical SDG funding gaps. Despite this progress, several challenges remain in unlocking further private sector commitments:

  - **Competing demands on global capital**: Political and economic events, such as Russia's invasion of Ukraine, have shifted priorities away from sustainability to energy security, food security, and military spending.
  - **Macro-headwinds repricing assets**: The combination of rising interest rates, high inflation, and a global energy crisis has caused changes in global asset prices, affecting sustainable investments.

- **A lack of standards for measurement and reporting**: Confusion regarding ESG performance measurement and incorporation into investment decision-making remains an obstacle in the industry.
- **Increasing awareness of greenwashing**: Questions about the authenticity of ESG commitments and the prevalence of greenwashing raise concerns.
- **Political backlash against ESG and sustainable investing**: Some regions and political groups have shown hostility toward ESG investments, hindering progress in sustainability.
- **Legal risk related to fiduciary duties**: Some institutions are concerned about potential legal risks arising from their involvement in sustainable investing frameworks.

- **ESG Momentum in International equity returns and the SDG content of financial asset portfolios**

This chapter discusses Environmental, Social, and Governance (ESG) momentum in international equity returns and relates this to the Sustainable Development Goals (SDGs) context, particularly in the creation of financial asset portfolios.

It provides numerical evidence on the application of ESG metrics in calculating portfolio returns. It examines a methodological approach in integrating SDGs into ESG framework, highlighting a shift in investment evaluation towards considering the SDGs, and the associated urgency of capital mobilization towards these goals.

After presenting in brief, the existing work connecting the SDGs with European Green Deal policy documents, and with sustainability reporting of companies, the section goes on by explaining the process of mapping ESG categories to SDGs, using a mathematical approach to calculate raw and normalized weights for SDG indicators and their individual KPIs. These weights are utilized in the formulation of SDG scores and factor mimicking portfolios, which reflect risks related to specific SDGs.

Furthermore, a calculation of the SDG footprint of a portfolio using an extended version of the Fama and French 3-factor model, drawing a link between asset sensitivity and portfolio weights, is also explored.

The chapter concludes by emphasizing the significant returns associated with firms performing well in terms of ESGs. It acknowledges the existence of strong ESG momentum in international markets, particularly for big stocks showing improved performance over the last two years. These findings reveal the significant role of SDGs in shaping and determining the value and effectiveness of financial asset pricing.

- **The Interconnectedness of Natural Capital, Social Capital, Produced Capital, and Cultural Heritage in Sustainable Development**

This chapter discusses the interconnectedness of natural capital, social capital, produced capital, and cultural heritage in sustainable development. It presents correlation matrices to show relationships among various factors such as aesthetic, authenticity, historical, social, and spiritual values, as well as tangible and intangible cultural heritage. The study aims to understand the impact of these factors on peoples' willingness to pay (WTP) for cultural values.

The data is divided into two categories - European and non-European countries, which are then analyzed with simple and full specifications, considering tangible and intangible cultural heritage distinctions. The analysis aims to understand the effect of demographics such as gender, income, education, and age on peoples' WTP for cultural values, as well as the impact of the various cultural values themselves.

Through a meta-regression analysis, the chapter concludes that tangible cultural heritage significantly affects European specifications, while intangible cultural heritage affects both European and non-European specifications in a statistically significant way. Aesthetic and spiritual values seem to primarily affect European countries' specifications.

Based on this analysis, it is apparent that cultural and demographic factors have a substantial impact on sustainable development and the perception of cultural heritage. Such information can guide policymakers to make more informed decisions when designing plans to promote the preservation and appreciation of cultural heritage in their respective regions.

- **Carbon farming and voluntary carbon markets in the EU**

  This chapter provides a comprehensive overview of carbon farming and voluntary carbon markets (VCMs) in the European Union. It discusses the key market, emissions, and policy developments that are shaping the field, as well as the challenges and potential of VCMs.

  It also offers a synthesis of policy recommendations to address these challenges. Below some of the key points covered in this chapter:

  1. Local actors should be at the forefront of VCM projects, due to their knowledge, rights, and role in maintaining the project.
  2. Actors, particularly small and family farms, should receive ongoing guidance and support through administrative and financial incentives.
  3. Collaboration must involve safeguards for farmers, communities, and ecosystems, based on scientific expertise, transparency, and land right laws.
  4. VCM efforts should focus on nature-based solutions, integrating social, biodiversity, and resilience through ecosystem restoration.
  5. A harmonized policy and ecological system are necessary to integrate obligations, accounting, and social and environmental objectives.
  6. Ethical, independent, and transparent governance at all levels is crucial for a just implementation of VCMs.
  7. Voluntary carbon markets should supplement dominant funding and work toward becoming obsolete as emissions reductions increase.

  Finally, the chapter also discusses the involvement of the financial sector in climate finance and carbon credit derivatives markets, as well as the development of regulatory mechanisms following negotiations.

- **From Skills to Sustainability: The Potential of Green Jobs and Digital Transition**

  This chapter focuses on green jobs and sustainability within the energy sector, discussing various aspects such as employment trends, skills required, and future prospects. It is separated in two parts: one on *tracking energy employment to ensure good quality jobs in the net zero* and another on *Enhancing the Digital and Green Transitions*.

The first part describes the main findings of the World Energy Employment report, published in September 2022 by the International Energy Agency (IEA) with the support and analytical contribution of Enel Foundation. This section provides statistical data and insights on jobs into different segments of the energy industry. First, it highlights the distribution of energy sector employees in the various clusters of the energy value chain (e.g., manufacturing, construction, utilities, and others), with respective percentages provided for geography. Second, it breaks down the employment figures in the power generation sector, showing that renewable energy sources have significant employment opportunities, particularly in solar PV and wind power. Third, it emphasizes a higher percentage of high-skilled workers in the energy sector compared to other industries. Companies are increasingly looking for workers with specific skills for the clean energy sector, and this also means identifying those skill sets that can be transitioned from traditional to clean energy sectors. Next, it suggests three policy recommendations to meeting the demand for skilled labor—developing energy transition-ready vocational and educational programs through strong partnerships between academia (secondary schools and universities) and energy industries, well-crafted training programs, and involving the unions for proper collective bargaining arrangements and labor transition plans. Last, it gives projections about the energy employment in 2030, based on the IEA's World Energy Outlook 2022 scenarios, which show an increase in energy employment, with renewable energy sources such as solar PV and wind power driving job growth in the power sector.

The second part provides policymakers with valuable insights into the critical aspects of the digital and green transitions and helps them understand better the skills landscape in the green economy. This understanding is essential for developing targeted retraining and reskilling policies that ensure a just transition for communities affected by the shift to low-carbon industries.

Also, the critical role of National Observatories for the Digital Transition is highlighted. These, can be powerful tools for polycimakers to analyze the complexities of digitization, addressing structural deficiencies, and fostering inclusive and sustainable digital transformations. By leveraging the insights provided by these observatories, policymakers can make informed decisions to bridge the digital gaps, enhance connectivity, and drive economic growth in the digital age.

Climate responsibility, eco-anxiety, and perception about governments

This chapter is about climate responsibility, eco-anxiety, and perceptions about government actions towards climate change. Game theory and particularly the prisoner's dilemma and coordination game aspects are used to model ecological interactions, and to study how this affect individual responsibility towards the environment.

The primary focus is to examine whether eco-anxiety and confidence in other governments' efforts to address climate change have an impact on personal responsibility towards climate change. The results show that both eco-anxiety and perception about government efforts positively impact personal environmental responsibility. Interestingly, this contradicts the theoretical free-riding hypothesis expected from game theory models of ecological action.

It is highlighted that both increasing government efforts and better communication about climate change can encourage people to take more responsibility for eco-friendly actions. Additionally, improved awareness and communication about climate change risks, lead to more responsible everyday actions towards the environment.

4 Interdependence, Networks, and Green Deal: The EU's Opportunity to Redefine the Landscape of Global Sustainable Development Challenges

Authors:

Etienne Berthet, Section for Quantitative Sustainability Assessment, Technical University of Denmark (DTU), Kgs. Lyngby, Denmark

Ilaria Fusacchia, Department of Economics, Roma Tre University; Roma, Italy

Candy Anquetil-Deck, Industrial Ecology Digital Laboratory, Norwegian University of Science and Technology (NTNU), Trondheim, Norway

In the context of a global interconnected world, we are confronted with a complex system of transnational flows. These flows span a wide array of elements, including data, energy, human populations, biological entities, commodities, and physical matter. This intricate system engenders novel environmental and socio-economic challenges, carrying out significant repercussions for both the societal structures of human communities and the overall health of our planet's ecosystems **(Liu et al., 2018)**. The escalating interdependence of these diverse global flows has amplified cross-border environmental and socio-economic interactions, blurred geographical boundaries and produced effects that transcend local and national scopes **(Liu et al., 2018) (OECD/EC-JRC, 2021) (Xu et al., 2020)**.

Of particular concern are the international trade-related flows, which give rise to far-reaching spillover-feedback effects (hereinafter as spillover) that bear significant implications for international governance and global frameworks such as the United Nations Framework Convention on Climate Change (UNFCCC) or the United Nations Sustainable Development Goals (SDGs) **(Sachs et al., 2021) (Schmidt-Traub et al., 2019) (OECD/EC-JRC, 2021)**. Consequently, to effectively advance the realization of the SDGs, it is imperative to comprehensively assess the direct and indirect impacts of relevant policy measures to mitigate potential adverse consequences while simultaneously augmenting their beneficial outcomes **(Liu et al., 2018) (Engström et al., 2021)**.

The concept of Weaponized Interdependences (WIs) has been recently formalized and refers to the strategic use of economic, financial, and technological interdependencies as instruments of power and coercion in international relations. It relies on an essential structural condition, a globalized network that creates high levels of interdependence among states **(Farrell & Newman, 2019)**. As such, it involves states leveraging their positions within global networks, such as trade, supply chains, and financial markets, to exert influence, achieve strategic objectives, and potentially coerce other actors. This phenomenon highlights the growing importance of non-military power sources and underscores the complex and interconnected nature of the modern global landscape, where state actors may utilize these interdependencies to pursue their goals and navigate geopolitical competition.

As underlined by **(Drezner et al., 2021)**, the dynamics associated with WIs have recently undergone a remarkable acceleration due to several factors, including the deterioration of relations between the United States of America and China, the readiness of emerging legislative powers to exert coercion, and disruptions in global supply chains amidst the COVID-19 pandemic. Farrell and Newman also point out the anticipated acceleration of these dynamics, regarding a globalization that will become increasingly politicized and the subject of more significant contestation and coercion **(Drezner et al., 2021)**.

In essence, the obstacles presented by global sustainability and the increasing influence of WIs define the shapes of the most important geopolitical challenges of the 21st century. As our current civilizations grapple with existential threats such as biodiversity collapse or global warming, the strategic use of economic and financial interdependencies as instruments of power and coercion has emerged as a potent force in international relations. Consequently, it is crucial to scrutinize matters that necessitate global cooperation, including the SDGs, through a framework that captures the emergent forms of economic and geopolitical duress based on the nodes and networks encompassed by globalization.

The forms of coercion defined by WIs have been debated among policymakers. However, it is worth noting that those discussions have not been as prevalent within academic circles **(Baker, 2013) (Drezner et al., 2021)**. Moreover, these discussions have yet to permeate the academic literature, specifically addressing sustainability concerns. This discrepancy can be attributed to the challenges these forms of coercion present when attempting to align them with existing frameworks and theories in the academic literature **(Wright, 2017)**. Furthermore, this absence is also due to methodological gaps. Despite the significant influence of WIs compared to more traditional theories of international power, it shares the limitations characteristic of structural approaches. Specifically, WIs do not adequately differentiate between power, defined as the ownership of resources, and influence, characterized as the ability to utilize those resources effectively to pursue state policy objectives. However, this ability is also a form of power, as defined by Robert A. Dahl. In the "The Concept of Power", Dahl defined power as the ability of one person (or group) to get another person (or group) to do something they otherwise would not do **(Dahl, 1957)**. With this perspective, a nation's threat to overutilize some resources (for instance, fossil fuels or tropical rainforests) above the thresholds defined by scientists **(Welsby et al., 2021)** could result in irreversible harm to humanity. Hence, it becomes imperative to decode them to employ them effectively and meaningfully.

Farrell and Newman acknowledge this methodological aspect by underlying the importance of "appropriate institutions" to distinguish between power as a possession of resources and influence as the capacity to wield those resources to achieve policy objectives **(Drezner et al., 2021)**. Moreover, Jentleson further expounds on this concept, illustrating that countries can wield those WIs through actions beyond conventional diplomatic means. Similarly, WIs could be used for climate change mitigation or other shared global goals. Like most power manifestations, WIs are not inherently good or malign; their worth is contingent upon how they are employed by the participating entities **(Jentleson, 2021)**, but then it is crucial to decrypt them to use them in a relevant way.

In this chapter, we do not assert that all the different SDGs should be analyzed through the reading grid of WIs, nor that their achievements require a permanent power relationship among nations. Nevertheless, we propose that some of them, particularly when the national and global interests diverge or when there are substantial transnational spillovers, must consider those relations in a framework which is not the traditional framework between economic actors nor the traditional geopolitical framework between states.

In 2021, the European Union (EU) passed the European Climate Law, thereby formally enshrining the goal outlined in the European Green Deal **(European Commission, 2019) (European Commission, 2021a)**. The law targets net-zero greenhouse gas emissions (GHG) by 2050 for the EU's economy and society. The scope of the European Green Deal is way broader than the GHG mitigation only, addressing various sustainability challenges. For example, its official definition emphasizes the necessity for a "cost-efficient" and "socially fair" transition to a sustainable economy. It also tackles deforestation issues, as evidenced by the European Parliament's provisional political agreement in 2022 to ensure that a list of select agricultural and forestry products entering the EU market "will no longer contribute to deforestation and forest degradation in the EU and elsewhere in the world".

While the EU's efforts to operationalize, these intentions are still underway, a comprehensive understanding of the intricate interplay between the EU, other nations and diverse sustainability issues is crucial for formulating effective policies to actualize these intents and enhance international cooperation. Without this understanding, the eventual outcomes may fall short of the EU's stated ambitions.

This chapter is structured in three sections. First, we show how recent advancements in accounting frameworks and resource economics can be utilized to accurately quantify the distinction between power as a possession and influence as the ability to leverage these resources to accomplish policy objectives. In the second section, we apply this framework to the EU's latest unilateral initiative to combat international deforestation, specifically in Brazil, to assess this initiative's effectiveness. Lastly, we employ this framework to examine various social impacts, exploring how this novel approach can contribute to establishing robust bases for policymaking, targeting high-impact flows of different types.

4.1 Traversing externalities and methodological gap: the Throughflow Based Accounting

The SDGs are a set of interconnected global objectives that address various economic, social, and environmental issues. Some of the main challenges to achieving them require a better understanding of the externalities generated by human activities, as it is necessary to minimize the negative externalities (such as air pollution or eutrophication) and maximize the positive ones (such as employment or gender equality) **(United Nations: New York, NY, 2015)**. Furthermore, it is also necessary to precisely delineate their spillover-feedback effects (hereinafter as spillover) between countries, as one country's success for one particular SDG may jeopardize the success of another SDG in another country.

As mentioned in the introduction, the novelty of the approach presented here is to analyze some of those challenges within the WI framework. It is worth reminding that not all the SDGs need to be scrutinized in the context of WI. Some urgent existential threats may drive states to cooperate more closely, fostering a spirit of multilateralism and interdependence. However, pursuing strategic advantage through economic and financial levers can exacerbate existing inequalities, erode trust between nations, and hinder the collective action needed to address those existential threats. Regarding this second option, it is crucial to understand what is (and what is not) included in the WI framework. ***Figure 1*** (which was directly taken and modified from **(Drezner et al., 2021)** summarizes the various channels and targets related to the nature of WI.

Channel \ Target	States	Economic actors
Bilateral	**Asymmetric interdependence** • State actions against geopolitical adversaries through bilateral channels • Targeted states' dependence on the targeting state's economy enables coercion • Examples include National Security Tariffs and traditional sanctions	**Market power** • Bilateral use of economic interdependence for economic purposes • Conditioning market access on compliance with rules or standards • Can reshape foreign businesses' behavior and influence the global economy
Multilateral	**Weaponized interdependence** • States and geostrategic adversaries using networks rather than market access, differing from asymmetric interdependence and points of control. • Powerful states employ choke-point strategies to limit access to global networks, increasing the cost of noncompliance for targeted entities. • Possibility of panopticon strategies, i.e., tapping into information flowing through key economic hubs to monitor adversaries, coupling private economic network reach with state strategies.	**Points of control** • States restricting businesses' or private actors' access to global economic networks. • Networked rather than bilateral actions against firms • This approach involves using choke points in global networks to shape business activity.

Figure 1 This figure is directly taken and adapted from (Drezner et al., 2021). It provides an overview of the varieties of economic coercions and classifies them, indicating the target of coercion and the channel used to apply this pressure.

The WI framework offers a useful lens for analyzing the complex nature of the Sustainable Development Goals (SDGs). However, addressing these interconnected goals necessitates a thorough understanding of the structural geography and network topology that underpin our globalized world. As **Drezner et al. (2021)** note, "The image of globalization as global competition, an increasingly flat world in which everyone plays on the same level playing field, is seductive but dangerously misleading. Networks have their own geographies, which are the consequence of physical geography, investment decisions, and the strategic deployment of state power."

In today's interconnected world, long and intricate international production processes characterize global trade **(Xiao et al., 2020)**. Commodities typically undergo numerous transformation steps involving various industries, many of which are located in different countries **(Beaufils et al., 2023)**. This complexity obscures contributions to joint production efforts and dilutes responsibilities for generating externalities **(Kagawa et al., 2015; T. Wiedmann & Lenzen, 2018)**. Therefore, the topology of the globalization must be delineated to untangle the flows of commodities between countries as well as their environmental and social impacts expressed in the SDG framework. Such impact identification is required to reconsider the use of network rather than bilateral market access and ultimately switch from traditional place-based governance to a more holistic flow-based approach **(Xu et al., 2020)**.

However, methodological gaps have impeded the development of an efficient flow-based approach that captures the full scope of externalities embodied in trade flows. Traditional accounting methods, for instance, do not retain information about flow-transitioning countries **(Wood et al., 2019)**. Hence, a robust framework to assign responsibility for internationally traded externalities was still missing by tracking and managing where the key flows start, progress and end **(Tian et al., 2022)**.

This chapter operationalizes a systemic method for quantifying the social and environmental impacts directly and indirectly associated with consumption within a country's territorial boundaries but produced elsewhere. We employ the Throughflow Based Accounting (TBA) framework (Beaufils et al., 2023) to identify the externalities embodied in imports/exports directly traded between countries as well as those traded through intermediate countries (cf. ***Figure 2***). By translating these findings into the SDGs framework, we can assess the impacts generated by international trade flows more comprehensively, considering producers, consumers, and other relevant partners. This approach lays a solid foundation for addressing the complex challenges of the SDGs in an increasingly globalized and interconnected world.

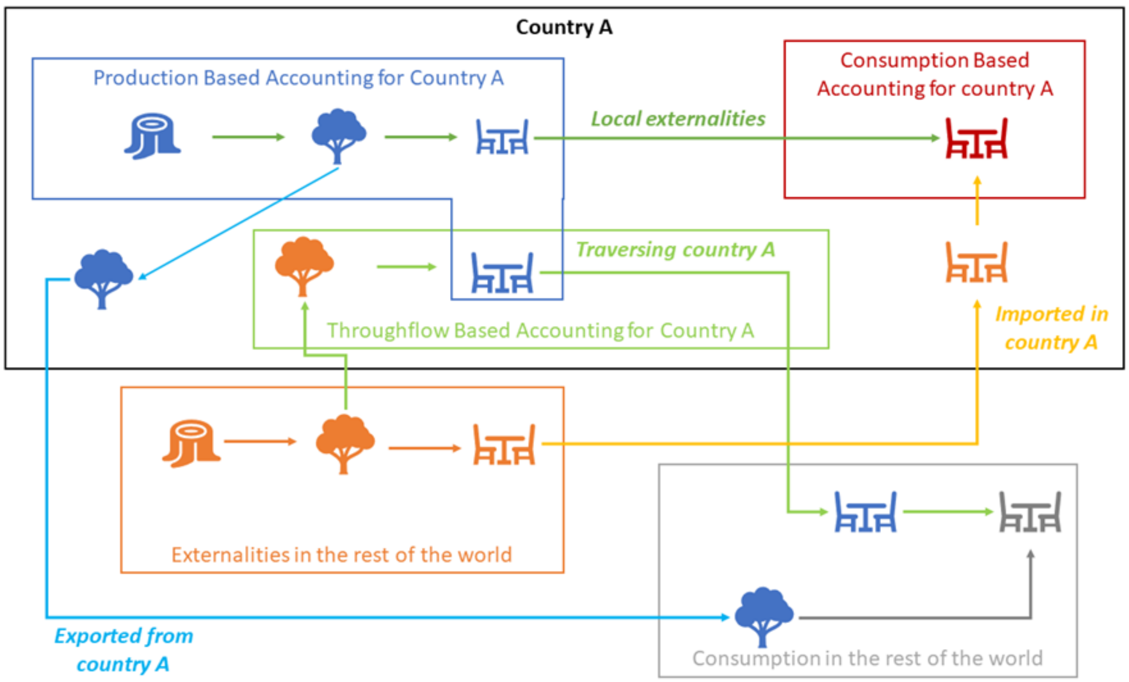

Figure 2 This figure is directly taken and adapted from (Beaufils et al., 2023). It summarizes the concept of Throughflow Based Accounting compared to Production Based Accounting and Consumption Based Accounting, showing the externalities embodied in trade flows for a given country.

The rest of the chapter will demonstrate, using two different examples that the market power, in a bilateral use of economic interdependences for economic purposes, efficiently controls some of the negative spillovers generated by a given consumption and located in another country. However, we will also highlight the limitations of this approach and argue that employing a network-based strategy, focusing on points of control instead of relying solely on bilateral market access driven by political rather than commercial targets, may offer a more efficient means to mitigate these spillovers.

4.2 Can a unilateral initiative deal with a global issue? The example of the EU provisional political agreement on the deforestation

Deforestation remains a critical environmental concern, with considerable implications for biodiversity loss and anthropogenic greenhouse gas emissions (GHGs). Forests across the globe are under significant pressure, with geographical patterns of deforestation varying significantly. Despite evidence of forest regrowth and regeneration in Europe, Eurasia, and North America, certain regions, notably the Amazon and other tropical zones, are dealing with persistent or rapidly increasing deforestation rates (Henders et al., 2015; Hoang & Kanemoto, 2021; Pendrill et al., 2019, 2022; Winkler et al., 2021).

The agriculture and forestry sectors are intricately connected, both critical for achieving sustainable agrifood systems, sustainable development, and food security. Between 2000 and 2018, nearly 90% of global deforestation was caused by agricultural expansion, disrupting vital ecosystem services such as carbon sequestration and biodiversity (DeValue et al., 2022). In this context, the role of trade cannot be understated. Since 1995, the volume of global agricultural exports has more than doubled, significantly impacting these trends (WTO, 2019).

The responsibility to tackle tropical deforestation lies with both producing and consuming countries. Numerous studies have quantified forest degradation with international demand for agricultural and forestry products (Henders et al., 2015; Hoang & Kanemoto, 2021) (Karstensen et al., 2013) (Pendrill et al., 2022). High-income and some middle-income nations, including China and India, have witnessed net domestic forest expansion while contributing to deforestation abroad. Pendrill et al. (2019) disclosed that until 2014, the EU held the most significant deforestation footprint connected to imported agricultural commodities.

Political initiatives to combat deforestation on a large scale have mainly been stagnant until recently. Key initiatives worth noting include the Forest and Climate Leaders Partnership formed during COP 27, building on the momentum from COP 26. Furthermore, the recent push by Brazilian president Lula for an "OPEC for forests" aimed at stronger cooperation between Brazil, the Democratic Republic of the Congo, and Indonesia to establish demands from the international community for forest protection is a significant step forward. These initiatives are crucial in addressing deforestation. However, it is essential to note that they mainly come from producing countries, while the initiatives from consuming countries have remained limited, considering the high stakes involved.

However, a key development occurred in 2022 in the context of the European Green Deal, when the European Parliament reached a provisional political agreement, ensuring that a list of selected agricultural and forestry goods entering the EU market "will no longer contribute to deforestation and forest degradation in the EU and elsewhere in the world". The EU proposal emphasizes European operators' responsibility by broadening the scope of existing due diligence requirements and guaranteeing that the risk associated with non-compliant commodities or products imported or exported within the EU market is minimal (Council of the European Union, 2022). From the SDG perspective, this EU initiative is expected to positively impact Brazil's progress towards SDG 15.2 – "End Deforestation and Restore Degraded Forests".

4.2.1 The Interplay between Unilateral Actions, Global Benefits, and Country-Specific Costs

This EU provisional proposal exemplifies a unilateral market power initiative to fight against forestland use for agricultural production by conditioning EU market access on compliance with standards regulating legal deforestation. Assessing the potential implications of this proposal involves quantifying the extent of agricultural-induced deforestation attributed to the targeted commodities associated with global supply chains both terminating and intersecting within the EU.

To conduct this assessment, we built a map illustrating agricultural-driven deforestation embodied in international trade. Brazil was chosen as a case study due to its significant contribution in deforestation (Pendrill et al., 2019, 2022). Our analysis considers inter-country and inter-sector linkages (Stadler et al., 2018a) based on the most accurate spatial resolution of land use (Winkler et al., 2021) and employs the TBA (Beaufils et al., 2023) to trace deforestation embodied in international trade flows across the global economy, with an emphasis on the EU region. Our analysis focuses on the following economic sectors outlined in the provisional agreement: rice, wheat, corn and other cereals, vegetables, fruits and nuts, oil seeds, sugar crops, fiber crops, grains, other crops, and cattle.

4.2.2 Methodological Approach for Assessing Brazilian Deforestation Commodities Linked to the EU

Multi-Regional Input Output (MRIO) tables are widely used to identify direct and indirect externalities in supplying commodities to end-users (MILLER & BLAIR, 2009; T. WIEDMANN & LENZEN, 2018; T. O. WIEDMANN ET AL., 2015; WOOD ET AL., 2018). In line with this literature, we use data on inter-country inter-sector linkages based on the MRIO EXIOBASE (STADLER ET AL., 2018B).

To delineate specifically the agriculture-driven deforestation embodied in international trade, we used the HIstoric Land Dynamics Assessment+ (HILDA+) global dataset (WINKLER ET AL., 2021) as it is one of the most recent and accurate datasets quantifying the global dynamic of change in land use. We focused on Brazil's geographical territory from 2012 to 2019 to avoid potential biases from the 2008-2009 global financial crisis. Following the worldwide methodology exposed in (FUSACCHIA ET AL., 2022) (BERTHET, FUSACCHIA, ET AL., 2023), we extend the EXIOBASE dataset with the HILDA+ data previously scoped to calculate the agriculture-driven deforestation embodied in international trade originating from Brazil. To do this, we utilized the Food and Agriculture Organization of the United Nations (FAO) data to allocate calculated deforestation to corresponding EXIOBASE economic sectors. The detailed methodology is described in the articles mentioned above. Nevertheless, the mapping table between HILDA+, EXIOBASE and FAO data (FUSACCHIA ET AL., 2022) can be found in the appendix A, **Table 18**.

Lastly, we used the TBA (BEAUFILS ET AL., 2023) to comprehensively quantify the agriculture-driven Brazilian deforestation embodied in international trade passing through or ending in each country/area defined in EXIOBASE. We then calculate the direct consumption (commodities exported from Brazil to a given country and then consumed in this given country) and the indirect consumption (commodities exported from Brazil to a given country, then transformed and re-exported in a third country where they are finally consumed) at the country level (cf. ***Figure 3***).

A

B

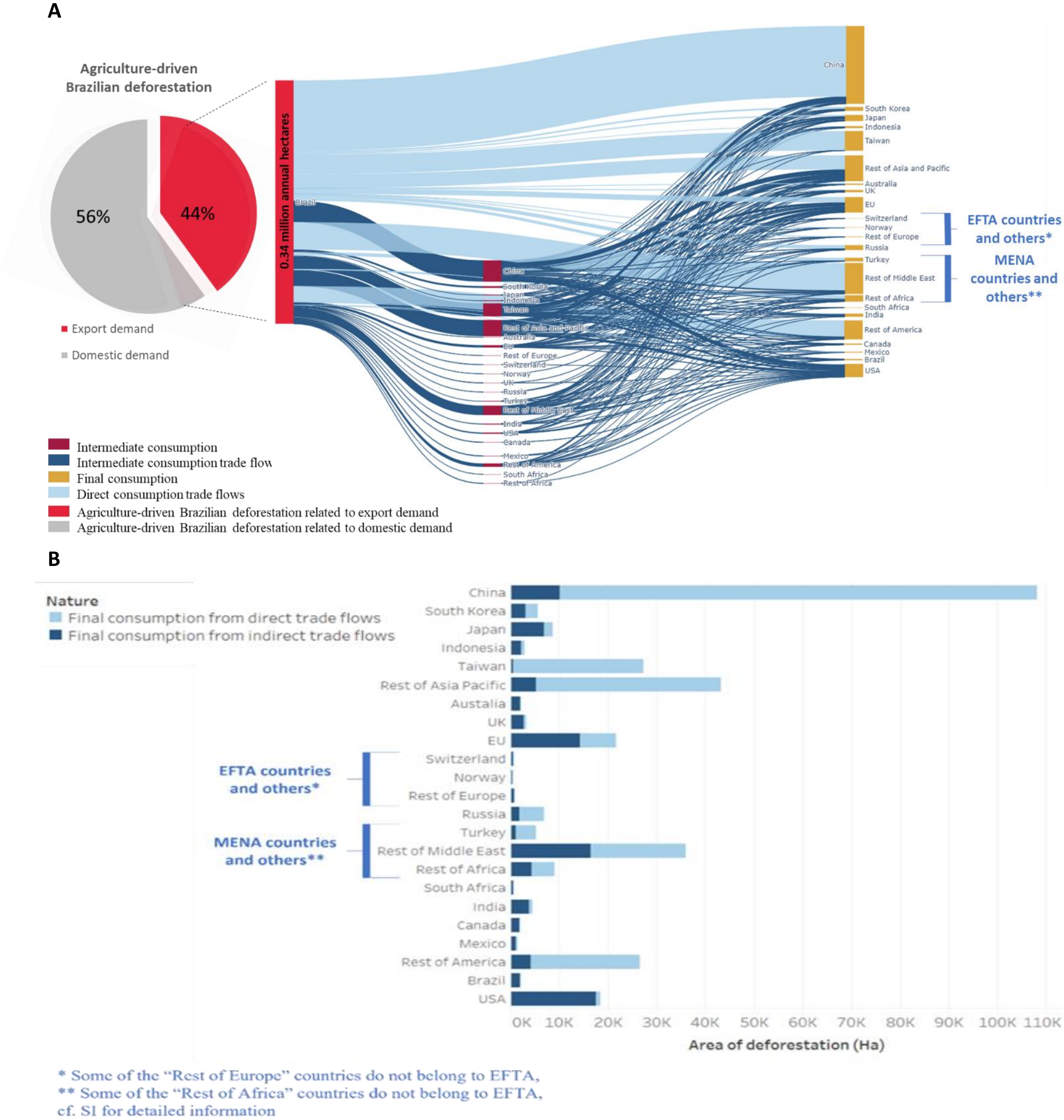

Figure 3 International trade flows embodying agriculture-driven Brazilian deforestation, detailed by their traversing area and their area of final consumption. In light blue, the upper panel (A) represents the direct consumption (commodities exported from Brazil to a given country and then consumed in this given country). In dark blue, the indirect consumption (commodities exported from Brazil to a given country, then transformed and re-exported in a third country where they are finally consumed). The size of the flows is proportional to the embodied agriculture-driven deforestation. The bottom panel (B) details the different flows from panel A by area of consumption in hectares (Ha) of agriculture-driven Brazilian deforestation.

4.2.3 The Scope of the EU's New Deforestation Proposal and its Limitations

Our results, illustrated in ***Figure 3***, reveal an annual Brazilian deforestation rate of nearly 0.8 million hectares driven by agriculture. During the assessment period, almost 44% of this deforestation is attributed to the production of agricultural goods consumed outside Brazil, thus embodied in trade. Our results are consistent with a recent comprehensive study on tropical deforestation driven by agriculture **(Pendrill et al., 2022)**.

Globally, direct consumption accounts for 87% of the deforestation embodied in trade, leaving a minor role (13%) in indirect consumption. However, substantial disparities occur among countries. For the EU, 66% of the consumption is indirect, indicating that more than half of the Brazilian agricultural commodities causing deforestation during their production and finally consumed in the EU have been transformed and re-exported from a third country before their final consumption.

Looking at supply chains traversing the EU, the primary downstream flows involve the USA, the UK, and China. The EU's role in China and the USA's indirect consumption is minor (3.8% and 3.3%, respectively), yet more substantial for the UK (18.6%). Therefore, any trade restriction stemming from the EU's provisional political agreement would have a minor effect on EU-China and EU-USA trade but a more considerable influence on the EU-UK relationship. Furthermore, the EU plays a significant role in the indirect consumption of EFTA countries, advocating for expanded geographical coverage of this EU provisional agreement related to the Green Deal.

The upcoming implementation of the EU's provisional political agreement will hinge critically on the final scope of due diligence requirements, potentially covering 2.4% to 7.7% of annual trade-embodied, agriculture-driven Brazilian deforestation. This percentage depends on whether the agreement targets only direct consumption or includes indirect consumption and whether its coverage is limited to the EU or extends to the EFTA and the UK. This represents between 0.95% and 3.4% of the yearly agriculture-driven Brazilian deforestation.

While we have not assessed the exact impact of such a decrease on Brazil's SDG 15.2 in a normalized and standardized SDG scale (as such exercise relies on several parameters and assumptions), we can notice that the score of Brazil in the 2021 Global Common Stewardship Index (GCSI) **(Commons & Index, 2021)** on the indicator "Permanent deforestation" is 12.6 points on 100 (100 representing the best score possible and the lowest impact) it appears that with a decrease between 0.95% and 3.4% of the annual deforestation caused by agriculture in Brazil, the EU proposal would not have a significant effect on this GCSI indicator score for Brazil. Thus, while the EU provisional agreement on deforestation sends a solid political message highlighting the need to address global deforestation, our results emphasize that without proactive engagement from other major consumer markets, the agreement may have only a marginal effect on reducing Brazilian deforestation.

4.2.4 Transitioning from a Unilateral Economic approach to Multilateral Political Strategies

Based on the previous results, we can see that the EU's autonomous unilateral initiative may have only a minimal influence on deforestation in Brazil. To overcome this issue, and as expressed in the introduction, the context of the WI framework suggests an alternative approach wherein the EU could harness its diplomatic network rather than solely leveraging market access.

Forests and biodiversity hotspots are predominantly located in low- and middle-income countries. Convincing these nations to accept trade restrictions related to forestland presents a significant challenge, as these countries perceive such limitations as a direct limitation to their economic growth. The EU has previously encountered similar challenges in the case of the Carbon Border Adjustment Mechanism (CBAM), and numerous studies **(Lowe, 2021; Perdana & Vielle, 2022; Szulecki et al., 2022)** underscore the necessity of international cooperation to mitigate the potential negative impacts for lower-income countries.

However, it is essential to note that effective international collaboration does not need to be overly broad in order to produce significant results. A multilateral analysis approach based on such trade flows identification **(FUSACCHIA ET AL., 2022)** reveals that a European trade policy on deforestation, coordinated with only a few key partners (such as the UK and EFTA countries), could lead to a more substantial reduction in Brazilian deforestation caused by agriculture, estimated at 15.5%. This is a significant improvement compared to the modest 0.95% to 3.4% achievable through unilateral measures. Furthermore, this multilateral analysis also reveals that with an appropriate channel of the funds related to this European trade policy to increase the Brazilian agricultural total factor productivity. It would be enough to counterbalance the negative economic impact of the trade costs considered, creating a win-win scenario, increasing Brazilian GDP and decreasing deforestation at the same time.

Another strategy to leverage the network involves pinpointing strategic "chokepoints" within the international trade flows contributing to deforestation. As illustrated in ***Figure 3***, Taiwan and MENA countries emerge as particularly relevant in this context. This perspective could enable the EU to align its geostrategic objectives with these specific deforestation spillovers, potentially positively impacting Brazil's SDGs and global deforestation efforts.

4.3 Addressing Social Issues in the Context of the Sustainable Development Goals

The operationalization of some SDGs is contingent upon the proficient mobilization of resources to achieve defined state policy objectives, which involve unravelling the architecture of intricate networks interconnected through diverse externalities. As indicated earlier, one of the most critical methodological lacunae often pertains to the network structure. Nevertheless, once the structure is determined, integrating and quantifying the target externalities going through this network is relatively straightforward (as we presented above with the deforestation externalities from HILDA+).

However, in some cases, this step also constitutes a substantial challenge that warrants resolution. This particularly applies to externalities associated with social impacts, which are frequently linked to economic and ecological dimensions but remain insufficiently documented in available databases. A critical analysis of the prevailing models dealing with the different sustainability topics (hereafter mentioned as bioeconomic models) **(VERKERK ET AL., 2021)** unearths a conspicuous deficiency in the representation of SDGs related to social issues. In this context, SDG1 (end poverty), SDG3 (ensure health and well-being), SDG4 (provide quality education), SDG5 (achieve gender equality), SDG8 (decent work and economic growth), SDG10 (reduce inequalities), SDG11 (build sustainable cities and communities), and SDG16 (promote peace, justice, and strong institutions) command further attention. Those SDGs underscore distributional disparities among diverse societal strata and households and are either underrepresented or neglected **(VERKERK ET AL., 2021)**.

Given this deficit, there is a compelling need to enhance the sophistication and breadth of social indicators. A viable strategy to address this concern involves the integration of indicators based on distributional data and econometric analyses. This approach delineates a pathway towards a more holistic representation of social goals and indicators. In addition, fostering links with existing social models presents another potential method for improving the current bioeconomic models. The implementation of these strategies can engender a more robust and inclusive modeling framework that sufficiently integrates these crucial social SDGs **(VERKERK ET AL., 2021)**. These endeavors necessitate substantial work within the research agenda of this subject and extend beyond the scope of this present chapter. Nevertheless, an alternative solution to forge connections with social models while bypassing those challenges is to develop solutions thanks to MRIOs.

The use of MRIOs for footprint calculation is not limited to the environmental footprints of countries but can also be used for social footprints through Social Life Cycle Assessment (SLCA) methodology **(C. B. Norris et al., 2013; C. Norris & Norris, 2015)**. SLCA has emerged as a valuable tool for assessing the social and economic impacts associated with geographic locations and stakeholder categories along the life cycle of products. Despite its widespread application and methodological guidelines established in 2009 **(Walsh, 2006)**, the methodology is still in its early stage **(Mancini & Sala, 2018)**. One of the most significant remaining challenges in combining MRIO and SLCA approaches is the accuracy of social data, particularly regarding low-income counties.

In alignment with the foundational goal of the EU Green Deal to promote a "socially fair" shift towards a sustainable economy, this section explores the social implications associated with the EU's consumption patterns. This exploration becomes crucial to formulating further EU Green Deal proposals, considering environmental and social aspects. SDG 8, which promotes decent work and economic growth, provides an effective framework for this analysis. We focus particularly on indicator 8.8.1, which addresses the frequency of fatal and non-fatal work-related injuries segmented by gender and migrant status. This comprehensive assessment could provide a deeper understanding of the broader socio-economic impacts of the EU's consumption and, thus, guide a more socially fair and inclusive transition under the EU Green Deal.

4.3.1 Methodological Considerations

Ensuring social data's reliability is essential in accurately evaluating social and economic impacts across geographical locations, economic sectors and stakeholder categories. Yet, the MRIO model utilized in our research (EXIOBASE) was hindered by out-of-date or significantly proxy fatality statistics, causing potential inaccuracies in our findings. We have comprehensively revised EXIOBASE fatality data to address this shortcoming, incorporating detailed, nation-specific, and up-to-date data. The update includes work-related fatal occupational injuries as well as fatalities associated with occupational exposure to a variety of 18 hazardous substances and conditions such as asbestos, arsenic, benzene, beryllium, cadmium, chromium, diesel engine exhaust, formaldehyde, nickel, polycyclic aromatic hydrocarbons, silica, sulfuric acid, trichloroethylene, asthmagens, particulate matter, gases and fumes, noise, ergonomic factors, and prolonged working hours. Our methodological process is built on three pillars: data acquisition, raw data processing, and computation of fatal injuries by country, gender, year, and EXIOBASE economic sector.

Data were sourced from the World Health Organization (WHO) **(Pega et al., 2021)** and Eurostat databases **(Publications Office of the European Union, 2013)**. The WHO data was carefully screened based on specific criteria such as age above 15 years, gender, and fatal injuries only. Eurostat data provided granular information on work-related fatalities, classified by economic activities in the European Community (or NACE Rev.2 **(Eurostat, 2008)**). The WHO provided aggregate fatality data for 2010 and 2016. The strategy for allocating these deaths across Eurostat categories depended on the countries' geographical location, with different methods applied to European and non-European nations.

For European nations, fluctuations in fatality numbers within a NACE Rev.2 sector mirrored the changes registered by Eurostat. For non-European countries, fatality figures were proportionally allocated across economic sectors split according to the NACE Rev.2 classification, reflecting the workforce size associated with each economic sector. Due to the scarcity of data for nations within Asia, America, or Africa, we adopted a regional approach, computing fatality ratios over each NACE Rev.2 category for each region by integrating data for available countries over a reference year. For 2010 and 2016, the aggregate fatality figures for nations within these three zones were established. Due to the temporal proximity of both reference years, we postulated a linear trend in the fatality count between these two years. The number of fatalities for a specific country, year, and per NACE Rev.2 activity was then calculated by applying the previously mentioned fatality ratio to the total number of deaths for that nation. Last, we applied the European annual ratios to their total mortality figures for the few countries that could not be classified as European or belonging to one of the aforementioned zones.

The result is a comprehensive database that includes the number of fatalities (expressed in the number of deaths for work-related fatal occupational injuries and in Disability-adjusted life years (DALYs), for fatalities associated with occupational exposure to a specific risk factor), detailed at the country, gender, and NACE Rev.2 sector levels from 2008 to 2019, providing insights into work-related fatal injuries across different health effects and geographical regions. The entire database is readily available in the Supplementary Information (SI).

4.3.2 The social impacts of the supply chains traversing the EU are not neglectable

Figure 4.A delineates the work-related fatal occupational injuries linked to goods consumed within the EU (referred to in the figure as Consumption-Based Accounting Framework, or CBA) as well as goods within supply chains traversing the EU (referred in the figure as Throughflow-Based Accounting Framework, or TBA). The occupational fatalities associated with EU consumption are significant, with the annual toll exceeding 10,000 individuals. This means that over 10,000 workers perish annually in producing goods outside the EU that are ultimately consumed within the EU, contributing to the affective well-being of its citizens (Iyer & Muncy, 2016). Although not as pronounced, fatal occupational injuries embodied within EU supply chains are significant, accounting for approximately 20% of work-related fatalities connected to EU consumption, as visualized in ***Figure 4.C***. The leading causes of those work-related fatal occupational injuries are road injuries, falls, and drowning.

Figure 4.B, mirroring the flows and framework of ***Figure 4.A***, reflects the DALYs from three occupational exposures: asbestos, asthmagen, and chromium. Asbestos and asthmagen carry the heaviest burden among the occupational exposures analyzed, linked respectively to approximately 100,000 and 80,000 annual DALYs outside of the EU and associated with EU consumption. The DALYs from these exposures, similar to occupational fatalities, are substantial within supply chains traversing the EU, accounting for about 20% of the total of the DALYs linked to EU consumption, as shown in ***Figure 4.C***. The sectors contributing to these occupational fatalities primarily include construction, transport, manufacturing, and agriculture.

When we focus more particularly on asbestos and asthmagen, the gender gap is particularly significant for both. This is mainly since the economic sectors affected by those exposures are also confronted with important gender gaps in their sociology. Indeed, occupational exposure to asbestos during inhaling asbestos fibres in the workplace **(World Health Organization, 2006)**. As such, workers in the mining, construction and civil engineering, agriculture, automotive, thermal, and other insulation, boat building, ship-breaking and mechanics industrial sectors are at risk of occupational asbestos exposure. Those sectors have a gender gap in favour of men. The link between exposure to asbestos and the related DALYs is established via several cancers, mainly related to lung cancer, ovary cancer, larynx cancer and mesothelioma **(Pega et al., 2021)**.

These fatality figures are not inevitable. Ratifying and implementing measures such as the ILO Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187) **(International Labour Organization, 2006)**, and Occupational Safety and Health Convention, 1981 (No. 155) (International Labour Organization, 1981), could significantly reduce work-related fatalities. Concerning asbestos, eliminating its use in workplaces can mitigate the associated disease burden. Steps towards this goal include incorporating protective measures in national occupational health and safety programs and comprehensive management of existing asbestos. Implementing specific workplace controls, such as engineering and administrative controls and personal protective equipment, can significantly reduce exposure risks **(Pega et al., 2021)**.

Our analysis underlines that the social consequences associated with EU consumption or trade are significant. It suggests that even when direct intervention in imports may be challenging due to political, economic, or geopolitical constraints, strategic improvements in supply chain management could substantially decrease work-related fatalities tied to the production of goods crossing EU borders. This observation amplifies the demand for strategic policy and practical interventions by the EU to safeguard lives within the sustainability framework. A paradoxical situation could arise if the number of fatalities increases in specific sectors due to the implementation of the EU Green Deal proposals while one of the original requirements of the Green Deal is to be "socially fair". For instance, the energy transition in the EU could inadvertently escalate fatalities in mining regions linked to the required extraction of critical raw materials. As such, it's pivotal for the EU to ensure that the efforts towards sustainable development and Green Deal initiatives do not exacerbate the already complex issue of work-related fatalities.

4.A

Commodity	Consumption Based Accounting 2015	2016	2017	Throughflow Based Accounting 2015	2016	2017
Work related fatalities, female	4.290	4.361	4.522	782	778	746
Work related fatalities, male	8.012	7.846	7.679	1.543	1.473	1.375

4.B

Commodity	Consumption Based Accounting 2015	2016	2017	Throughflow Based Accounting 2015	2016	2017
Fatalities related to asbestos exposure, female	21.354	22.709	23.777	5.239	5.733	5.985
Fatalities related to asbestos exposure, male	61.413	61.301	61.215	14.774	15.164	15.409
Fatalities related to asthmagen exposure, female	32.832	34.464	36.837	6.824	7.250	7.543
Fatalities related to asthmagen exposure, male	59.126	61.198	61.750	12.435	12.992	13.047
Fatalities related to chromium exposure, female	403	429	429	119	124	130
Fatalities related to chromium exposure, male	951	1.009	1.012	286	299	314

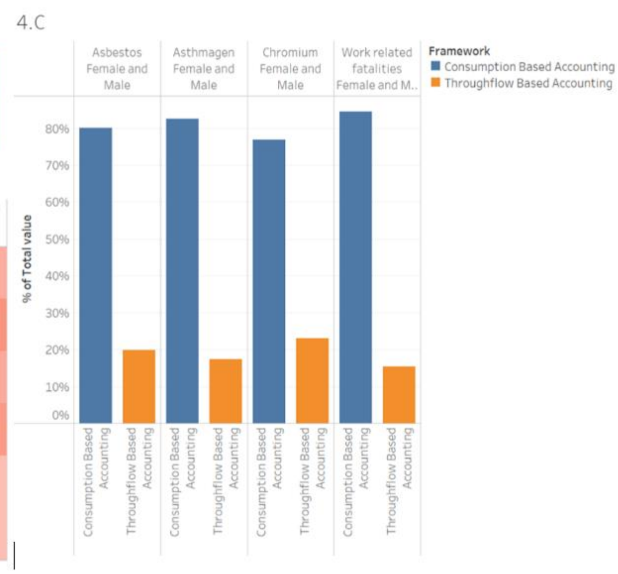

Figure 4 On the top-right panel (Figure 4.A), the number of work-related fatal occupational injuries related goods consumed within the EU as per the Consumption-Based Accounting (CBA) framework, as well as goods within supply chains traversing the EU, as per the Throughflow-Based Accounting (TBA) framework. Results are expressed in the number of fatalities. On the bottom-left panel (Figure 4.B), the number of DALYs related to asbestos, asthmagen and chromium related to occupational fatalities linked to goods consumed within Europe as per the CBA framework, as well as goods within supply chains traversing the EU, as per the TBA framework. On the right panel (Figure 4.C), for each commodity presented in Figure 4.A and Figure 4.B, the proportions detailed per type of framework (TBA vs CBA).

4.3.3 Balancing EU's Social Concerns with Downstream and Upstream Effects

Examining supply chains traversing the EU extends beyond their analysis and into the precise identification of countries positioned in their upstream or downstream parts. ***Figure 5*** illustrates a comprehensive perspective of different flows for two commodities, asthmagen and asbestos, traversing the EU (***Figure 4.B***).

The predominant upstream flows for asthmagen are rooted in Asia and Africa. In contrast, for asbestos, these flows mainly stem from the UK, Russia, and European countries outside the EU. We deliberately excluded intra-EU trade from our analysis to prevent skewing the data. Both commodities demonstrate the USA and China as the two primary consumers.

This level of detailed delineation is instrumental in pinpointing potential allies, partners, opponents, or detractors. It aids in rallying a group of countries for participation in an initiative yielding mutual benefits and identifying strategic leverage points within the supply chain, be they downstream or upstream. The precision of these maps directly empowers policymakers, enabling them to target and devise strategies mitigating specific indirect impacts accurately.

Thus, comprehensive and accurate mapping is critical for policy development and strategic planning. It will equip the EU with the ability to target its efforts effectively, focusing on relevant SDGs and specific countries.

		US	CN	GB	WM	WA	WF	WL	TR	CH	RU	JP	IN	CA	NO	KR	WE	AU	BR	MX	TW	ID	ZA	Grand Total
Asbestos Female and Male (producton area)	GB	1.106	728	801	512	439	260	245	161	168	150	165	115	115	114	116	77	103	110	78	67	34	37	5.701
	RU	398	255	258	254	188	170	108	88	76	83	61	52	61	67	40	72	38	39	33	22	17	12	2.393
	WE	356	268	213	203	159	92	86	86	68	82	54	46	46	44	39	53	38	30	26	25	13	10	2.039
	WA	303	210	176	177	135	96	79	57	52	50	45	38	35	31	34	35	28	28	21	18	11	10	1.669
	US	326	231	174	163	151	73	78	50	46	45	44	40	31	27	33	21	26	29	25	20	13	9	1.655
	TR	265	191	162	155	121	77	68	61	46	50	36	33	28	31	29	28	25	22	19	18	9	7	1.478
	CN	258	183	158	139	115	67	66	47	46	46	37	31	27	27	28	23	24	22	17	16	8	7	1.394
	JP	151	109	88	77	66	34	37	25	25	24	21	18	15	14	16	11	14	13	10	10	5	4	786
	CH	145	108	75	65	57	30	32	21	25	22	23	17	16	13	15	11	14	12	9	9	4	5	728
	CA	78	59	41	42	36	21	19	13	11	11	12	11	8	7	8	7	7	7	6	5	3	2	414
	WM	73	48	42	47	35	25	20	15	12	12	10	9	8	7	8	8	7	7	5	4	3	2	408
	IN	74	51	45	40	32	22	19	13	13	12	11	9	9	8	8	7	7	7	5	4	3	2	400
	ZA	66	53	43	32	26	14	14	11	11	10	10	7	7	6	7	4	6	5	5	5	2	2	345
	WF	61	37	33	33	26	26	16	11	10	8	8	8	7	5	6	6	4	6	5	3	2	1	322
	NO	51	31	38	24	23	18	14	7	8	8	7	6	7	12	5	6	4	5	4	3	2	1	283
	WL	49	34	29	26	21	14	14	7	7	7	8	7	6	6	5	5	4	5	4	3	2	1	266
	AU	49	36	29	26	22	13	12	8	8	7	8	7	6	5	5	4	5	5	3	3	2	2	266
	BR	28	21	16	15	12	9	7	5	5	4	4	4	3	3	3	2	2	3	2	2	1	1	152
	KR	18	13	11	10	8	5	5	3	3	3	3	2	2	2	2	2	2	2	1	1	1	1	98
	ID	10	7	6	5	4	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1	0	0	54
	MX	9	7	6	5	4	2	2	1	2	1	1	2	1	1	1	1	1	1	1	1	0	0	48
Asthmagen Female and Male (producton area)	WA	1.237	885	806	630	550	310	321	200	215	206	190	148	142	134	135	112	119	112	84	75	40	40	6.690
	WF	612	424	413	332	282	203	167	100	108	93	103	76	78	58	66	57	61	58	49	35	24	17	3.418
	IN	483	327	296	237	199	120	114	76	86	78	76	56	55	49	51	46	46	40	34	28	16	14	2.527
	CN	235	169	152	119	107	54	57	40	43	42	37	29	24	24	25	21	22	21	15	13	7	7	1.263
	WM	206	141	129	115	98	59	57	35	34	33	31	26	24	21	22	19	20	19	15	12	7	6	1.131
	GB	227	149	152	104	89	43	47	33	33	30	33	23	21	22	23	14	21	21	15	14	6	7	1.125
	WE	123	94	80	68	54	27	28	27	24	28	18	15	14	15	13	17	13	9	9	9	4	3	692
	ID	108	75	71	56	49	29	28	18	20	19	17	13	13	12	11	10	10	10	7	6	4	3	589
	US	119	77	64	53	50	24	26	16	17	15	17	13	11	10	12	7	10	10	8	7	4	3	572
	TR	80	59	54	42	32	18	18	16	14	14	11	8	8	9	9	8	8	6	6	6	2	2	430
	RU	64	46	41	34	30	18	16	13	11	17	10	9	9	11	7	9	6	6	5	4	2	2	369
	ZA	67	54	46	30	25	13	14	11	11	11	10	7	7	7	7	4	6	5	5	5	2	2	348
	WL	58	41	38	30	27	14	16	8	9	9	10	7	7	7	6	5	6	6	4	4	2	2	317
	JP	34	24	22	16	14	7	8	6	6	5	5	4	3	3	4	2	3	3	2	2	1	1	174
	CH	22	16	12	11	10	5	5	4	4	4	3	3	2	2	2	2	2	2	1	1	1	1	114
	KR	21	15	14	11	8	4	5	4	4	4	3	2	2	2	2	2	2	2	1	1	1	1	111
	BR	20	15	12	10	9	5	5	3	3	3	3	2	2	2	2	2	2	2	1	1	1	1	107
	CA	17	11	9	8	7	4	4	2	2	2	2	2	2	2	2	1	1	1	1	1	1	0	84
	AU	14	10	8	7	6	3	4	2	2	2	2	2	2	1	1	1	1	1	1	1	1	0	75
	MX	12	8	7	5	4	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	0	0	58
	NO	9	6	5	4	4	2	2	1	1	2	1	1	1	2	1	1	1	1	1	1	0	0	48
Grand Total		7.642	5.328	4.877	3.971	3.339	2.036	1.886	1.308	1.291	1.255	1.155	911	870	824	812	725	720	690	547	466	259	226	41.139

Figure 5 This figure represents the annual number of DALYs generated during the production of goods. Those goods present supply chains traversing the EU, which means they are produced outside of the EU, imported and transformed into the EU and then exported to be consumed outside the EU. The results are details for two particular exposures: asbestos and asthmagen. The countries in the lines on the left are where those goods have been produced, and the countries in the columns where the goods have been consumed.

4.3.4 The Significance of Maintaining a Broader Perspective

This methodology offers intriguing prospects for the European Union (EU). However, it is vital not to lose sight of the primary geostrategic objectives in the minutiae of such an approach. As explained above, if the EU employs this form of analysis to foster a socially equitable and environmentally efficient Green Deal, it will curtail its repercussions on other nations and promote a global elevation towards comprehensive and inclusive sustainable development.

However, it is equally critical to maintain a broader perspective and avoid an excessive focus on details that could potentially obscure the achievement of bigger core goals. For instance, the Disability-Adjusted Life Years (DALYs) and fatalities, both directly and indirectly associated with the EU, hold substantial relevance at the European level. Yet, their significance diminishes considerably on a global scale.

In this context, ***Figure 6*** provides substantial insight. Extracted from an ongoing study **(BERTHET, BEAUFILS, ET AL., 2023)** on the portrayal of Sustainable Development Goal (SDG) spillovers within a novel conceptual framework, this figure continues to convey the normalized SDG spillover scores between 1 and 100, akin to the Global Common Stewardship Index (GCSI). However, it also demonstrates how each world region's scores are distributed between points attributed to the concerned externalities' production, consumption, and trade.

As an illustration, SDG Indicator 8.1.1 portrayed in ***Figure 6***, aggregates all the DALYs and fatalities discussed in the preceding sections for all global areas, not just the EU. Indicators indicator represents a "negative" externality, "producer country" points equate to those lost due to spillovers during the production of externalities. In contrast, "consumer country" points represent gains derived from importing externalities and spillovers generated in third countries. Lastly, "Trader Countries" neither gain nor lose SDG spillover points; instead, they denote the number of SDG points transiting through a specific country along its supply chains. The regions are marked, and the size of each sign is proportionate to the total number of points.

From ***Figure 6***, it becomes evident that the EU indeed impacts these exchanges. However, if a global strategy aimed at mitigating the social implications of work-related fatalities through targeted trade measures (like trade bans or coalitions of trading countries) were to be implemented, incorporating Western Europe, Southeast Asia, and East Asia would drastically enhance global efficiency and limit spillovers.

In conclusion, the data underlines that adopting a nuanced, region-specific approach to regulatory reforms could make substantial strides towards achieving the SDGs. Such a strategy would necessitate global cooperation, tailored legislation, and a nuanced understanding of each geographical area's unique challenges and opportunities.

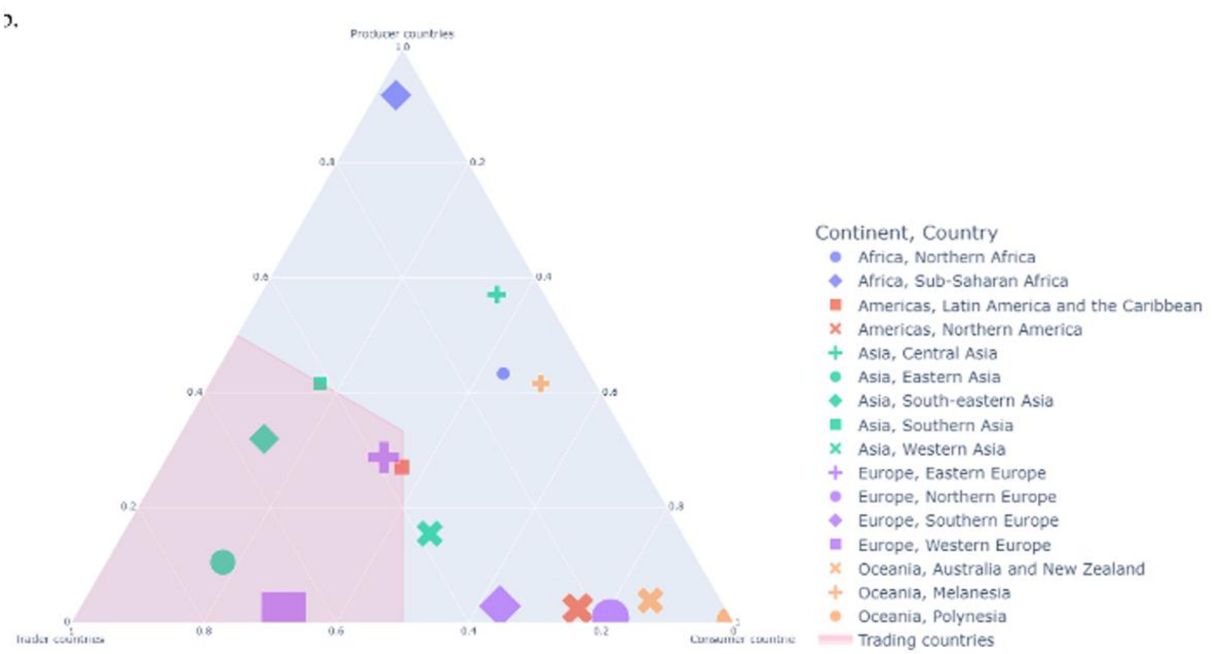

Figure 6 This figure is directly taken from a study in progress (Berthet, Beaufils, et al., 2023) on representing the SDG spillovers in a new conceptual framework. This new framework will indicate the normalized SDG spillover scores by a score between 1 and 100 (like the one used for spillovers in the GCSI). However, it will also illustrate how the score breaks down between the points attributable to the production, consumption, and trade of the externalities concerned. For instance, the SDG indicator represented in this Figure 6 is indicator 8.1.1, which aggregates all the DALYs and fatalities detailed in the sections above. Then, as this is a "negative" externality, the "producer countries" points are those lost due to the spillovers during the production of externalities, the "consumer countries" points are those gained thanks to

the import of externalities and then the spillovers generated in third countries. Last, the "trader countries" are the countries that are not gaining nor losing SDG spillover points but show the number of SDG points that have traversed a particular country through the supply chains running along this country. The regions are indicated, and the size of the signs is proportional to the total number of points.

4.4 Utilizing Policy Tools to Enhance the EU's Pursuit of Sustainable Development Goals

Finally, by investigating interdependence and the technical networks that drive interconnected relations, we have gained an important perspective for advancing some Sustainable Development Goals (SDGs), and the TBA framework is an important tool for deepening our understanding of spillover effects between countries, industries, and externalities. We are not suggesting here that the entire SDGs spectrum should be examined through the lens of the WI framework, nor are we proposing that deciphering the global flows of social and environmental externalities will resolve the research agenda brought by the new WI concept. However, the synergies and complementary aspects between both concepts are undeniable, and they share a common challenge: a better understanding of the world and the underlying networks to comprehend how various actors cooperate, are interdependent, and interact with one another.

This understanding has been illustrated with two examples, showcasing the potentially important role of the EU Green Deal in addressing two global externalities: deforestation and work-related accidents. It also shows that to enhance this role from an important role to a critical role, it is crucial to formulate effective policies that support those intents and improve international cooperation. Furthermore, this concept could be extended further. We could envisage international policies encompassing diverse objectives at the intersections between different networks, such as mitigating climate change, promoting well-being, and preventing tax evasion. This strategy could foster broad coalitions, providing a powerful lever for achieving the SDGs.

Moreover, this strategy provides valuable insight into addressing more contentious issues. For instance, in dealing with global spillovers related to GHG emissions, it is estimated that nearly 60% of oil and gas reserves and 90% of coal reserves must remain untapped to limit global warming to below 1.5 degrees Celsius **(Welsby et al., 2021)**. How should we engage with nations that deliberately endanger humanity by exploiting these fossil fuel reserves? What are the risks of retaliation? What constitutes a just and proportionate response from other countries? As documented in the introduction, WI opens a pathway beyond simple economic coercion, enabling a more careful balancing of potential trade-offs, evaluation of retaliation risks, proportionate use of pressure, and determination of the ideal timing for cessation of such actions.

Utilizing weaponized interdependence should not be regarded as an end in itself but rather as a strategic tool to achieve specific policy objectives. In a reciprocal, mutualistic approach, a better understanding of one aspect can facilitate the resolution of the other, thereby unlocking the potential to design effective international sustainable policies and foster international cooperation. As **Drezner et al. (2021)** defined, "weaponized interdependence is states' use of global economic networks to achieve geostrategic objectives." If these geostrategic objectives align with the SDGs, a holistic approach to these interlinked challenges can lead the international community towards a more sustainable, secure, and equitable future. By leveraging the interconnected nature of our world and applying these strategic tools judiciously, we can navigate the complexities of our interdependent world and make significant strides towards achieving the Sustainable Development Goals.

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5 Private Sector Funding of the SDGs

Authors:

Ketan Patel, Force for Good

Christian Hansmeyer, Force for Good

At the halfway point to the 2030 target date of the UN Sustainable Development Goals, it is increasingly clear that the world is not on track to meet the targets set in 2015. Slow but steady progress across multiple goals, in some cases over decades, has been undone by the global pandemic, current macroeconomic crisis and war in Europe, with c.100 million people slipping into extreme poverty, nearly 200 million more people suffering from chronic hunger, and 100 million more children falling below minimum reading proficiency since the start of the pandemic. And, with the world's current energy, food and security challenges risking pushing back key SDGs even further.

These reversals have a significant impact on the SDG's funding gap, a gap that has been further widened by the war in Ukraine, resulting in food and energy crises, global inflation, and accentuated migration. Further, recent estimates following last year's COP26 meeting on the near-term costs of funding global Net Zero point to significant spending increase requirements, exacerbated by the roll-over of continued underfunding in 2021.

As a result of all these factors, the annual cost of funding the SDGs has increased by US$3-5 trillion over and above the previous most recent estimates[1] to a current total of c.US$15-20 trillion annually, an increase of c.30-40%. The recalculation estimates a total cost to fund the SDGs of US$135-176 trillion to 2030 (***Graph 1***). [2]

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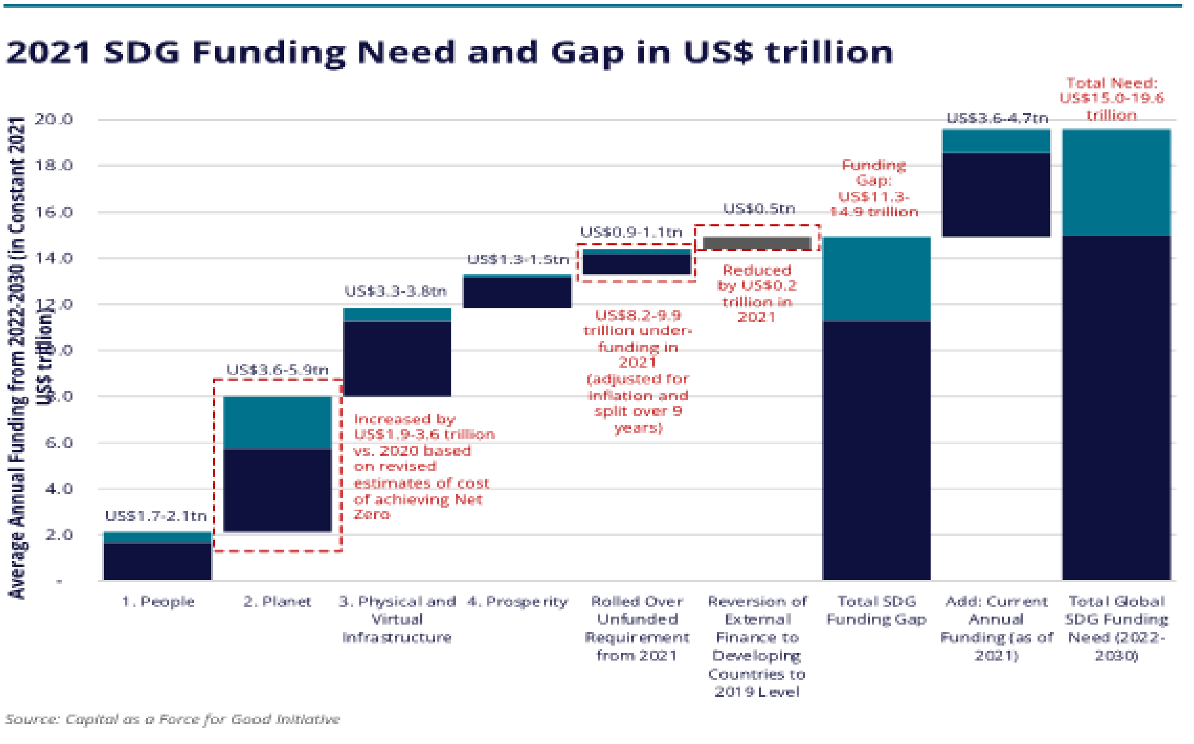
[1] Source: 2021 Capital as a Force for Good report

[2] See 2022 Capital as a Force for Good report Appendix 1.1 for details



Graph 1 Updated SDG Funding Need

Given that only approximately a quarter of the current total need is being funded, the annual funding shortfall is estimated at US$11.4-15.0 trillion, a c.35-50% increase over the same estimate the year before, with a gap of US$103-135 trillion to 2030. The implications are substantial. Given that the world is currently investing 4-5% of its GDP annually towards the SDGs, fully funding the goals would require spending to increase four-fold to 16-20% of 2021 GDP, and this is clearly not likely without other priorities being sacrificed at material scale.

The importance of the SDGs in underpinning peace, prosperity and freedom in the world is well established. The achievement of the SDGs within the next decade is critical for the world to avert the crises that will result from over-exploitation of resources, extreme weather events, pollution and biodiversity loss, poverty and inequality, political and social strife, and mass migration.

Moreover, the total cost of US$135-176 trillion to fully fund the SDGs represents c.30%-40%% of the world liquid assets, which total US$450 trillion.

Governments and public institutions control US$167 trillion, or 38% of the world's liquid assets, most of it in advanced industrialised economies. However, most of this capital is non-discretionary, required to fund domestic public services like healthcare, welfare, pensions, and education, as well as to maintain existing infrastructure, leaving only a fraction for sustainable development, most of which is required in developing countries. This leaves much of the SDG's funding need in the hands of the private sector, which collectively controls US$275 trillion in assets.

While private sector corporations collectively control c.US$60 trillion in assets and may well make considerable strategic investments that impact the SDGs, the vast majority of private sector SDG funding is likely to occur in the form of financial investments. The global finance industry controls or administers nearly US$400 trillion in total assets for public and private asset owners, with institutions deploying capital in their capacity as asset managers, wealth managers, pension managers, lenders, and proprietary investors.

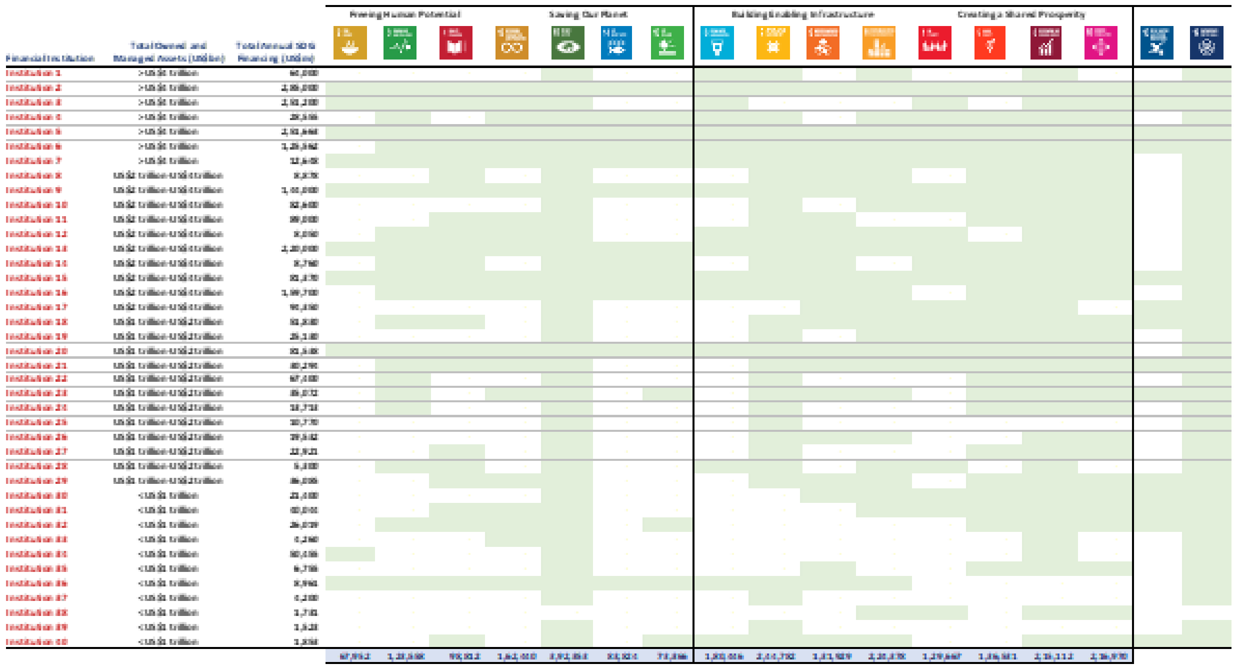
Among other private sector participants, the tech industry has a significant role to play in closing this gap. An analysis of the mass deployment of technology estimates that technology can make a significant contribution to bridging this gap and can also reduce the cost to fund the SDGs by US$55 trillion, solving for c.40% of the SDGs, given that technology is key to 103 of the 169 targets associated with the SDGs.[3] However, this still leaves a significant gap to close and that has brought much focus on the finance industry.

5.1 Finance industry leaders SDG financing increasing significantly

Examining the sustainability funding activities of 125 of the world's largest financial institutions reveals that there is a large common ground between them in terms of their focus on ESG, sustainable finance and stakeholder engagement. For 40 of these financial institutions (which are the public companies with more standardized reporting), their activities reveal that private sector engagement with the SDGs is increasing in both scope and scale (***Figure 7***). Having deployed a total of US$2.1 trillion in SDG aligned financing in 2020, this group of companies increased their funding by 20% in 2021, deploying a record US$2.5 trillion. The detailed breakdown of these leaders' initiatives and commitments points to the increasing breath of their engagement over time (***Graph 2***).

Further, these companies' SDG focus during the past year has continued to diversify. While climate change and renewable energy continue to be areas receiving the most attention, institutions are broadening their focus on SDGs relating to human development, prosperity, and broader planet related goals. The data shows institutional focus increasing across almost all goals, with a significant rise in engagement with SDG3 (Good Health and Wellbeing), SDG 4 (Quality Education), SDG 5 (Gender Equality), as well as SDG 14 (Life on Land), and SDG 10 (Reduced Inequalities), pointing to the fact that leaders have recognized the need for broader engagement with the SDGs, and have identified or developed a broadening set of engagement models to allow them to participate in their funding.

Finance Industry Leader SDG Engagement 2022 vs 2021



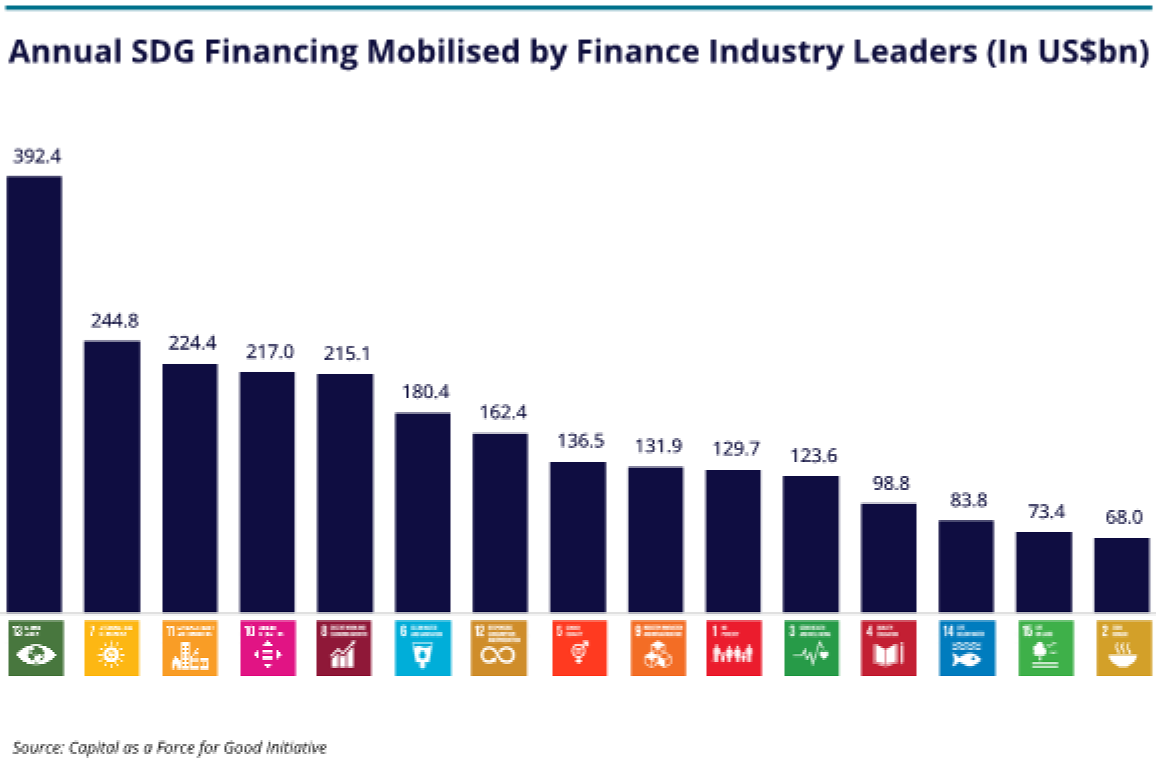
Note: *'Yes' response marked for SDG 16 indicates the institution has explicitly stated targets and 'Yes' response marked for SDG 17 indicates the institution actively partnering for the goals*

Source: Capital as a Force for Good Initiative

Figure 7 Finance Industry Leader SDG Engagement 2022 vs 2021

However, despite these increases, private sector engagement on the SDGs as a percentage of the total capital remains tiny and is highly skewed to a few SDGs backed by strong business cases and high returns potential, with three times as many institutions focused on SDGs like SDG 7 (Clean Energy) and SDG9 (Decent Work and Economic Growth), rather than less focused on(and less profitable) goals such as SDG 2 (Zero Hunger) and SDG 14 (Life Under Water).

In terms of the actual funds deployed to specific SDGs during the past year SDGs, funding to virtually all goals increased, with only SDG 13 (Climate Change) and SDG7 (Affordable and Clean Energy) seeing absolute declines reflecting the greater diversification in finance industry leaders' SDG spending priorities. The two goals' share of total spending accordingly decreased from 40.2% in 2020 to 25.7% over last year. The distribution of the increased spending maps closely to the increasing prioritization of key SDGs laid out above. The biggest absolute spending increases of US$146 billion and US$142 billion went to fund SDG 10 (Reduced Inequalities) and SDG6 (Clean Water and Sanitation), respectively, while SDGs 5 (Gender Equality), SDG 3 (Good Health and Wellbeing), and SDG9 (Industry, Infrastructure, and Innovation) received funding increases of US$60-80 billion each last year.



Graph 2 2021 SDG Funding Breakdown by Industry Leaders in US$ billion

5.2 Finance industry leaders SDG financing is increasingly aligned with critical SDG funding gaps

As previously stated, the total annual funding need for the SDGs has expanded to US$15-20 trillion annually, rising 30-40% year on year, faster than the private sector's spending increases of c.20%. As a result, the annual funding gap in developing countries now runs to total of US$11.4-15.0 trillion, with significant shortfalls across all categories of spending (***Table 1***). The funding need of each category varies significantly with Planet related goals representing over 40% of the total funding need (given the higher estimated cost for meeting Net Zero), and People related goals counting for 16% of the funding gap.

Table 1 Finance Industry Leaders' SDG Funding vs. SDG Funding Gaps

Private Sector SDG Funding vs Gaps

Category	Est. Annual Spending Gap in US$ trillion	in %	2021 Funding US$ trillion	in %
1. People	1.7-2.1	16%	0.3	12%
2. Planet	3.6-5.9	41%	0.7	29%
3. Platforms	3.3-3.8	31%	0.8	31%
4. Prosperity	1.3-1.5	12%	0.7	28%
Total	9.9-13.3	100%	2.5	100%
Add: Rollover Requirement from 2021	0.9-1.1			
Decline in External Finance for Developing Countries 2021	0.5			
Total Developing Country Funding Gap	11.4-15.0		2.5	

Source: Capital as a Force for Good Initiative

The increasing diversification of finance industry leaders' SDG priorities is resulting in an alignment of their spending distribution across the different SDG categories, with the actual SDG funding need. In 2020, industry leaders' SDG spending was still highly concentrated on Planet related goals, at the expenses of People and Platforms spending needs.

During the past year, leaders have significantly diversified their commitments across the goals and have provided nearly equal amounts to Planet, Prosperity, and Platform related goals. As before, private sector financial institutions did not provide direct funding to the fifth SDG category, Peace and Partnership (SDG 16 (Peace, Justice and Strong Institutions) and SDG 17 (Partnership for the Goals)). Given these goals are commonly seen as prerequisites for the deployment of capital, rather than as direct investment opportunities in and of themselves, they typically fall into the remit of national governments to fund (partially augmented by direct foreign aid).

The diversification in spending points to the increasing sophistication of the private sector's engagement with the SDGs, and the critical role that private capital will play in funding them. While industry leaders clearly cannot fund all the SDGs and meet the gap on their own, a task that even if it was possible would require current spending levels to increase approximately five-fold by next year), they are becoming increasingly ambitious and innovative in deploying capital at scale across the world, pointing to the likely direction of travel for the rest of the industry, and as a result, the private sector as a whole.

5.3 Challenges remain to unlocking further capital

There are a number of challenges related to unlocking further private sector commitments in support of the SDG which need to be overcome. Following a plethora of announcements from the industry as leading institutions joined various associations, committed to Net Zero and announced their ESG policies and published impact reports, several issues have arisen for the industry to address:

- **Competing Demands on Global Capital.** Russia's invasion of Ukraine and the subsequent global political and economic dislocations have driven a shift in global priorities towards security at the expense of sustainability, drawing capital, resources, and attention away from the SDGs in favour of energy security, food security, and increased military spending across the globe.

- **Macro-Headwinds Repricing Assets.** The perfect storm of rising interest rates, high inflation, and a global energy crisis has dislocated global asset prices, with technology stocks collapsing and oil and gas stocks rising, leading to a global redistribution of capital across sectors. Net fund flows to ESG funds and new sustainable debt issuances have both slowed down sharply in the first half of 2022, indicating that allocating to tech was the easy decision and the difficult decisions to invest for impact are still ahead.
- **A Lack of Standards for Measurement and Reporting.** Despite efforts by multiple stakeholders to create standards, confusion remains about how to best measure ESG performance and how to incorporate ESG data into investment decision making, with fund managers citing it as the single biggest adoption hurdle. The lack of consistency in ESG scores, differences in disclosures, and constantly changing methodologies, among others, are creating an increasing administrative burden for many institutions.
- **Increasing Awareness of Greenwashing.** The now widespread adoption of ESG systems has led to concerns on whether it is genuinely changing behaviors at these institutions or being used to put a 'green' or 'sustainability' wrapper around business-as-usual. A recent analysis by Morningstar found that c.1,200 funds (or 20% of the total), with over US$1 trillion of AUM, no longer merit an ESG label, and national regulators and authorities have begun cracking down the misuse of ESG and sustainability labels by asset managers.
- **Political Backlash Against ESG and Sustainable Investing.** There has been a growing backlash against ESG from some political quarters, particularly in the United States. States with large oil interests like Texas have threatened to withdraw funds from asset managers looking to reduce their fossil exposure, while other states have prohibited their pension funds from using ESG screening at all.
- **Legal Risk Related to Fiduciary Duties.** Despite a growing body of legal analysis that supports the integration of ESG into institutional investing from a fiduciary perspective, a growing number of institutions is withdrawing from international frameworks for sustainable investing based on concerns that their requirements (and specifically members' potential inability to meet them) open these institutions to legal risks from stakeholders.

In summary, the basic challenge remains that the SDGs are seen as a "cause," a noble and worthy one no doubt, but not as a commercially sound case to fund within the time horizons and risk levels that matter to most private sector investors. Funding the levelling up in the world through the SDGs while generating value commensurate with the requirements of investors will require the participation of a broad set of global stakeholders, both the private and public sector in a far more radical plan that can unlock tens of trillions of dollars, including funding corporations to provide technology and other solutions to address issues and create new markets.

6 ESG Momentum in International equity returns and the SDG content of financial asset portfolios[3]

Authors:

Phoebe Koundouri, School of Economics and ReSEES Research Laboratory, Athens University of Economics and Business; Department of Technology, Management and Economics, Denmark Technical University (DTU); Sustainable Development Unit, Athena RC; Academia Europea; phoundouri@aueb.gr

Conrad Felix Michel Landis, ReSEES Research Laboratory and Msc Banking and Finance, Athens University of Economics and Business; Visiting Faculty, India Institute of Management Rohtak; conrad@aueb.gr

6.1 ESG Momentum

During the last decade, there has been a growing interest in financial investors, asset owners and academics in investigating the impact of Good/ Bad performance relative to the Environmental, Social and Governance criteria (ESG) to the company's financial performance, as expressed by the Cost of Capital **(Bauer and Hann,2010; Schneider, 2011)**, Stock Valuation **(Jiao,2010)** and stock returns **(Gerhard et al, 2015; Kahn et. a, 2016; Henriksson et al, 2018)**.

Although there are many studies which relate good company ESG performance with higher equity returns, **WHELAN et al (2021)** in an extent meta-analysis of the literature report that only:

"26% of studies that focused on disclosure alone found a positive correlation with financial performance compared to 53% for performance based ESG measures (e.g., assessing a firm's performance on issues such as greenhouse gas emission reductions). This result holds in a regression analysis that controls for several factors simultaneously".

Our study contributes to the literature along three important directions. First, we document, strong ESG momentum time series and cross-sectional effects in international stock returns during the years 2002 to 2023. An out of sample monthly rebalancing ESG momentum Factor mimicking portfolio (double sorted on market capitalization and ESG momentum) yields an annualized Sharpe ratio equal to 0.7 for the sample period. Moreover, we underline the importance that both ESG related performance, as well as ESG controversies are important determinants of financial performance. Last by not least, by transposing the ESG framework into a more holistic framework integrating the SDGs, we describe how our models can be used to trivially calculate the SDG footprint of financial portfolios, which is expected to be very relevant the years following the introduction of the CSRD.

This chapter is structured as follows. In **Section 6.2** , we describe the data and methodologies used in our study. **Section 6.3** presents the main empirical results and the implementation of the international ESG and SDG asset pricing factors. **Section 6.4** summarizes and provide concluding remarks.

[3] This chapter is based on results from **Koundouri and Landis, 2023**, "ESG & SDG Momentum in International Equity Returns".

6.2 Data and Methodology

Our ESG sample consists of 11.328 equities listed in international stock exchanges and covers a period of 21,5 years from 31 December 2001 to 31 May 2023[4]. The Regional breakdown is provided in **Table 2**.

Table 2 Number of Companies by Geographical Region

Region	# Companies
North America	4.060
Latin America	389
Europe	2.579
Asia Pacific	4.107
Africa	193
Total	*11.328*

We use Thomson Reuters EIKON Datastream (TDS) to extract daily data for total return indexes[5], market capitalization and a set of static/ descriptive datatypes, as well as a set of ESG related metrics offered by Thomson Reuters Refinitive (TRF). **Table 3** provides a short description of all datatypes included in our study. Daily return and market capitalization data are filtered, following the methodologies proposed by **Landis and Skouras (2021).** Daily returns are aggregated to monthly and expressed at US dollars ($). To avoid any impact of outliers, monthly returns are cross sectionally winsorized to [1,99].

Table 3 Thomson Reuters Datastream datatypes referenced in paper.

We collect and report short definitions for all TDS datatypes referenced anywhere in the paper, summarizing the detailed definitions offered on Datastream Navigator. Detailed Worldscope data definitions guide is available on Thompson Extranet. Following TDS datatype classification panels devide TDS datatypes between time series and descrriptive-static.

TDS Datatypes

Datatype	**Name**	**Definition**
MV	Market Value	Share price multiplied by the number of ordinary shares in issue.
RI	Total Return Index	This describes the growth in value of an investment of 100 local currency units on the base date, assuming that dividends are re-invested to purchase additional units of an equity or unit trust at the closing price applicable on the ex-dividend date. Ex-date detailed dividend data are available from 1988, except USA and Canada where they are available from 1973.

[4] We use all stocks with ESG data coverage in Thomson Reuters Datastream (TDS).

[5] Total Return Index (RI datatype, see http://product.datastream.com/navigator/search.aspx.) describes the growth in value of an investment, assuming that dividends are re-invested to purchase additional units of an equity at the closing price, applicable on the ex-dividend date. Ex-date detailed dividend data are available from 1988, except USA and Canada, where they are available from 1973. The percentage change of TDS's RI datatype is equivalent to CRSP's return variable (daily item id 'ret' item, see www.crsp.com/files/data_description _guide_0.pdf).

EXMNEM	Exchange Mnemonic	Exchange Mnemonic. TDS mnemonics are based on the ISO codes.
GEOGN	Geographical Classification of Company	Country of incorporation.
TR3	TRBC (The Refinitiv Business Classification) Industry Group Code	TR3 returns the Industry Group code from The Refinitiv Business Classification system. Covering over 250,000 securities in 130 countries to 5 levels of granularity, The Refinitiv Business Classifications (TRBC) is the most comprehensive, detailed, and up-to-date sector and industry classification available. Dedicated, local language speaking analysts utilize company filings, Reuters news, and our corporate actions services in order to assign and maintain a company's activity. The basis for our sector indices, TRBC helps you identify, monitor, and analyze companies and industries across global markets. It is the ideal tool for benchmarking, peer comparison and navigation, and building custom sector and thematic indices. TRBC consists of five levels of hierarchical structure. Each company is allocated an Activity which falls under an Industry, then an Industry group, then Business Sector, which is then part of an overall Economic Sector. For more details on the TRBC classification system click here: https://my.refinitiv.com/content/mytr/en/product/thomson-reuters-business-classification.html
TR3N	TRBC (The Refinitiv Business Classification) Industry Group Name	TR3N returns the Industry Group name from The Refinitiv Business Classification system.
TRESGS	ESG Score	Refinitiv's ESG Score is an overall company score based on the self-reported information in the environmental, social and corporate governance pillars.
TRESGCCS	ESG Controversies Score	ESG controversies category score measures a company's exposure to environmental, social and governance controversies and negative events reflected in global media.
ENSCORE	Environment Pillar Score	Refinitiv's Environment Pillar Score is the weighted average relative rating of a company based on the reported environmental information and the resulting three environmental category scores.
CGSCORE	Governance Pillar Score	Refinitiv's Governance Pillar Score is the weighted average relative rating of a company based on the reported governance information and the resulting three governance category scores.
SOSCORE	Social Pillar Score	Refinitiv's Social Pillar Score is the weighted average relative rating of a company based on the reported social information and the resulting four social category scores.
TRESGENRRS	Resource Use Score	Resource use category score reflects a company's performance and capacity to reduce the use of materials, energy or water, and to find more eco-efficient solutions by improving supply chain management.
TRESGENERS	Emissions Score	Emission category score measures a company's commitment and effectiveness towards reducing environmental emission in the production and operational processes.
TRESGENPIS	Environmental Innovation Score	Environmental innovation category score reflects a company's capacity to reduce the environmental costs and burdens for its customers, and thereby creating new market opportunities through

		new environmental technologies and processes or eco-designed products.
TRESGSOWOS	Workforce Score	Workforce category score measures a company's effectiveness towards job satisfaction, healthy and safe workplace, maintaining diversity and equal opportunities, and development opportunities for its workforce.
TRESGSOHRS	Human Rights Score	Human rights category score measures a company's effectiveness towards respecting the fundamental human rights conventions.
TRESGSOCOS	Community Score	Community category score measures the company's commitment towards being a good citizen, protecting public health and respecting business ethics.
TRESGSOPRS	Product Responsibility Score	Product responsibility category score reflects a company's capacity to produce quality goods and services integrating the customer's health and safety, integrity and data privacy.
TRESGCGBDS	Management Score	Management category score measures a company's commitment and effectiveness towards following best practice corporate governance principles.
TRESGCGSRS	Shareholders Score	Shareholders category score measures a company's effectiveness towards equal treatment of shareholders and the use of anti-takeover devices.
TRESGCGVSS	CSR Strategy Score	CSR strategy category score reflects a company's practices to communicate that it integrates the economic (financial), social and environmental dimensions into its day-to-day decision-making processes.

To measure ESG performance we use the TRF metrics and scores. TRF offers one of the most comprehensive ESG databases, covering over the 90% of the global market capitalization, offering more than 600 ESG related metrics, with a history dating back 2002. TRF's ESG scores, cover 10 categories including under the environmental pillar: emissions, environmental product innovation and resource use, under the social pillar: community, human rights, product responsibility and workforce; and under governance pillar: csr strategy, management, and shareholders. The categories scores account for the most material industry metrics (70 to 170 metrics are used for each sector based on a set of 25 themes). The scores are calculated using a percentile rank scoring methodology and are based on the relative performance of stocks with the company's sector (for environmental and social pillar scores), and the country of incorporation (for governance related scores). Moreover, materiality weights are used to aggregate category scores to the three pillars, as well as the overall company's ESG score[6]. Moreover, the performance metrics are supplemented with a data-driven controversy score, which is based on 23 ESG controversy topics, where companies' actions are verified against commitments, to magnify the impact of significant controversies on the overall ESG scoring. Controversies are benchmarked on industry group and a company with no controversies will get a score equal to 100.

Kahn et. al (2016), note that the identification of material items and the use of scores based on industry material items can lead to outperformance of the Good ESG companies relative to Bad. On the same direction ESG scores

[6] For detailed definitions for the Thompson Reuters Refinitive ESG metrics, see: https://www.refinitiv.com/content/dam/marketing/en_us/documents/methodology/refinitiv-esg-scores-methodology.pdf

using material items are also positively correlated with the stock's performance during the year following portfolio construction (HENRIKSSON ET AL, 2018). Consistent with the previous research, we use the scores provided by TRF, which incorporate, as explained earlier, an industry materiality assessment. Moreover, the non-mandatory nature of the corporate sustainability reporting, together with the absence of any third-party auditing reports, constitutes, as discussed later in the chapter, the identification of Controversies to most accurately identify companies that do perform good relative to their industry and country peers.

TRF metrics have found its application to recent academic studies (PARK, 2018; VASILESCU AND WISNIEWSKI, 2019; DORFLEITNER ET AL, 2020), where all studies underline a thin relationship between ESG performance and stock returns, while the heterogeneity of results is strengthened even further with the use of various stock selection criteria.

Table 4 reports the number of stocks per country and per industry in our sample. To be consistent with the calculations of the TRF scores, we use the The Refinitiv Business Classification Codes (TR3 datatype in **Table 3**) to map stocks to industries.

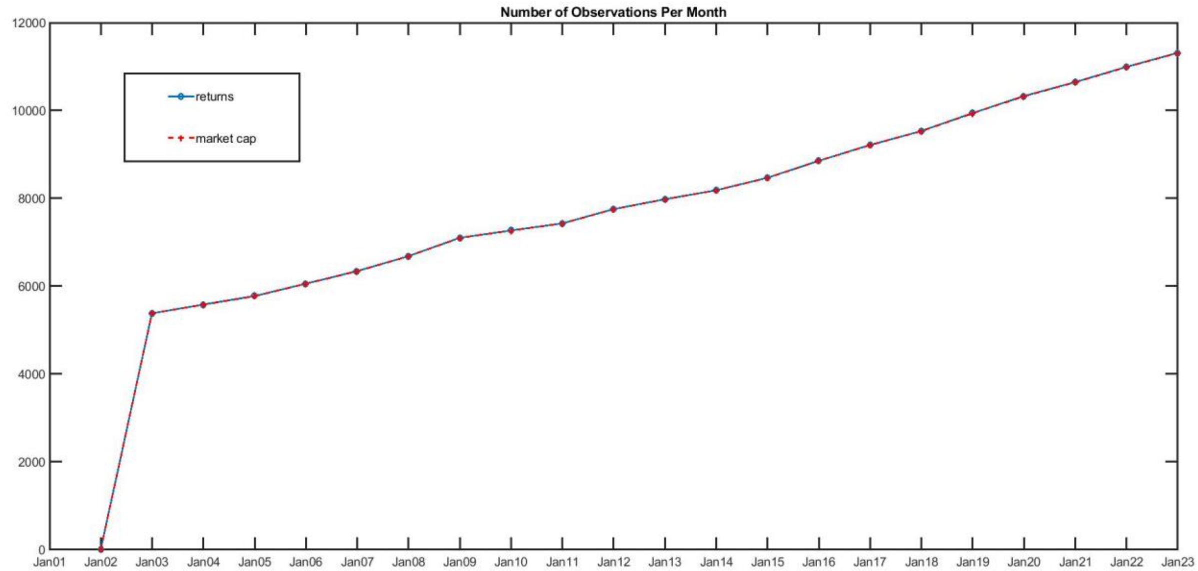
Table 4 Number of Stocks Per Country, per Industry

Market	***#Stocks***	***Share (%)***	***Industry***	***#Stocks***	***Share (%)***
UNITED STATES	3431	30.29	Banking Services	865	7.64
CHINA	1104	9.75	Software & IT Services	722	6.37
INDIA	720	6.36	Machinery, Equipment & Components	591	5.22
UNITED KINGDOM	676	5.97	Metals & Mining	516	4.56
JAPAN	491	4.33	Biotechnology & Medical Research	487	4.30
CANADA	485	4.28	Real Estate Operations	407	3.59
AUSTRALIA	407	3.59	Food & Tobacco	394	3.48
MALAYSIA	347	3.06	Chemicals	384	3.39
SWEDEN	335	2.96	Pharmaceuticals	379	3.35
HONG KONG	309	2.73	Residential & Commercial REITs	374	3.30
GERMANY	303	2.67	Investment Banking & Investment Services	349	3.08
FRANCE	199	1.76	Professional & Commercial Services	340	3.00
SWITZERLAND	188	1.66	Healthcare Equipment & Supplies	295	2.60
THAILAND	178	1.57	Hotels & Entertainment Services	278	2.45
TAIWAN	175	1.54	Automobiles & Auto Parts	266	2.35
SOUTH KOREA	168	1.48	Oil & Gas	263	2.32
ITALY	135	1.19	Construction & Engineering	257	2.27
BRAZIL	132	1.17	Insurance	251	2.22
SOUTH AFRICA	118	1.04	Electrical Utilities & IPPs	249	2.20

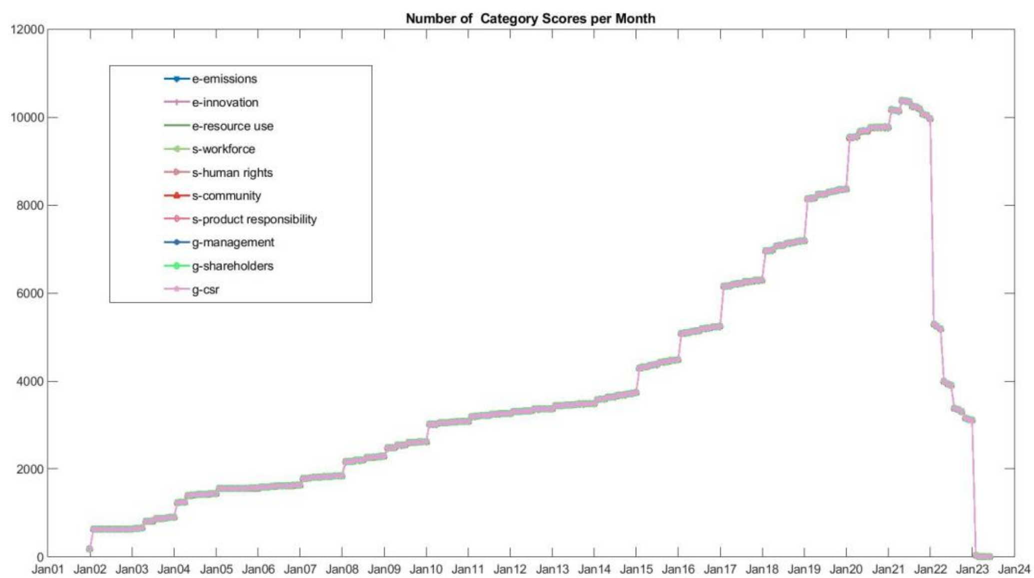
TURKEY	99	0.87	Specialty Retailers	242	2.14
MEXICO	98	0.87	Media & Publishing	217	1.92
NORWAY	95	0.84	Semiconductors & Semiconductor Equipment	211	1.86
SINGAPORE	95	0.84	Freight & Logistics Services	174	1.54
INDONESIA	83	0.73	Oil & Gas Related Equipment and Services	174	1.54
FINLAND	78	0.69	Telecommunications Services	170	1.50
SPAIN	73	0.64	Homebuilding & Construction Supplies	160	1.41
DENMARK	67	0.59	Healthcare Providers & Services	154	1.36
NEW ZEALAND	61	0.54	Textiles & Apparel	142	1.25
ARGENTINA	57	0.50	Electronic Equipment & Parts	135	1.19
NETHERLANDS	56	0.49	Food & Drug Retailing	127	1.12
BELGIUM	54	0.48	Computers, Phones & Household Electronics	111	0.98
CHILE	47	0.41	Beverages	109	0.96
RUSSIAN FEDERATION	45	0.40	Aerospace & Defense	100	0.88
POLAND	43	0.38	Diversified Retail	100	0.88
PHILIPPINES	38	0.34	Communications & Networking	99	0.87
EGYPT	35	0.31	Passenger Transportation Services	99	0.87
PERU	33	0.29	Construction Materials	92	0.81
AUSTRIA	32	0.28	Personal &Household Products & Services	90	0.79
MOROCCO	30	0.26	Transport Infrastructure	90	0.79
GREECE	27	0.24	Household Goods	88	0.78
VIETNAM	26	0.23	Collective Investments	88	0.78
IRELAND	22	0.19	Renewable Energy	76	0.67
COLOMBIA	22	0.19	Containers & Packaging	76	0.67
PORTUGAL	16	0.14	Paper & Forest Products	67	0.59
LUXEMBOURG	11	0.10	Consumer Goods Conglomerates	55	0.49
PAKISTAN	11	0.10	Leisure Products	54	0.48
ICELAND	10	0.09	Natural Gas Utilities	54	0.48
ROMANIA	10	0.09	Coal	47	0.41
HUNGARY	6	0.05	Holding Companies	41	0.36
NIGERIA	6	0.05	Multiline Utilities	40	0.35
CYPRUS	5	0.04	Water & Related Utilities	36	0.32

ISRAEL	5	0.04	Financial Technology (Fintech) & Infrastructure	34	0.30
CHANNEL ISLANDS	5	0.04	Miscellaneous Educational Service Providers	26	0.23
CZECH REPUBLIC	3	0.03	Diversified Industrial Goods Wholesalers	24	0.21
CAYMAN ISLANDS	3	0.03	Office Equipment	18	0.16
BERMUDA	3	0.03	Uranium	15	0.13
SLOVENIA	3	0.03	Professional & Business Education	12	0.11
SLOVAKIA	2	0.02	Integrated Hardware & Software	7	0.06
KAZAKHSTAN	2	0.02	School, College & University	7	0.06
UGANDA	2	0.02			
BULGARIA	1	0.01			
MALTA	1	0.01			
UKRAINE	1	0.01			
JERSEY	1	0.01			
PANAMA	1	0.01			
SRI LANKA	1	0.01			
ZIMBABWE	1	0.01			
KENYA	1	0.01			

Graph 3 and **Graph 4**, depicts the number of return and size (market cap) observations and the number of ESG Category scores for each month in our sample.



Graph 3 Number of Observations Per Month



Graph 4 Number of ESG Category Scores

As global factor mimicking portfolios in our tests, we do use the Fama and French's Developed Markets 3 Factors[7], while all of our univariate or bivariate sorted portfolio, uses the common methodologies of **Fama and French**

[7] French data library, see: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html#International

(2015), and taking into account **LANDIS AND SKOURAS (2021)** considerations for calculating international asset pricing factors and univariate/bivariate sorted portfolios using data from TDS.

6.3 Empirical Results

In order to investigate the cross-sectional relationship between ESG performance and stock returns, we do calculate monthly rebalancing univariate portfolio sorts based on the overall ESG and the ESG controversies scores[8]. Following the common methodology, each month, t, we use stocks with a valid market capitalization for period t-1, and a valid score for month t-6. In other words, in order to ensure that the scores will be available to investors on investment date, t-1, and avoid any instance of look ahead bias, we used scores lagged for 6 months. **Table 5** reports the premium of Good ESG performers relative to Bad performers (Good Minus Bad, GMB), for the case of 5 (quintiles), 10 (deciles), 20, 30, 50, 100 (percentiles), 150 and 200 portfolios, value and equally weighted[9] (vw and ew respectively) using the overall ESG Score (Panel A) and the ESG Controversies Score (Panel B). Focusing on Panel A it is clear that as we move to more extreme Good/Bad Portfolios, the premium of Good performers increase but in line with previous research (Dorfleitner et al, 2020) the differences are not significant (Newey-West Robust standard errors and p-values are also reported in Table). It is Interesting to note that the thin premium shrinks (for instance 13 basis point vs 30 bs focusing on the case of 200 univariate portfolios) when we apply equally weighted returns, which indicates that the difference between Good and Bad performers mostly refers to Large stocks in our sample.

Table 5 Good Minus Bad Performance – Univariate Sorts

Panel A: ESG Score

#Portfolios	***5***	***10***	***20***	***30***	***50***	***100***	***150***	***200***
GMB vw	0.0005	0.0008	0.0021	0.0018	0.0027	0.0021	0.0006	0.0030
se	0.0014	0.0016	0.0016	0.0016	0.0018	0.0025	0.0027	0.0028
p-value	0.7081	0.5959	0.1899	0.2734	0.1311	0.4085	0.8331	0.2938
GMB ew	-0.0007	-0.0003	0.0007	0.0001	0.0015	0.0014	-0.0001	0.0013
se	0.0012	0.0013	0.0014	0.0016	0.0017	0.0024	0.0030	0.0039
p-value	0.7081	0.5959	0.1899	0.2734	0.1311	0.4085	0.8331	0.2938

Panel B: ESG Controversies

#Portfolios	***5***	***10***	***20***	***30***	***50***	***100***	***150***	***200***
GMB vw	-0.0001	-0.0008	-0.0013	-0.0015	-0.0018	-0.0025	-0.0022	-0.0021
se	0.0006	0.0010	0.0011	0.0012	0.0014	0.0019	0.0021	0.0019

[8] **KOUNDOURI AND LANDIS (2023)** provide an extent analysis using all Category and Pillar scores also.

[9] Value weighted portfolios, use the market cap on month t-1.

p-value	0.8952	0.4241	0.2366	0.2108	0.2239	0.2001	0.2899	0.2711
GMB ew	-0.0002	0.0002	0.0001	-0.0003	0.0000	0.0006	-0.0001	-0.0015
se	0.0005	0.0008	0.0009	0.0010	0.0011	0.0016	0.0017	0.0018
p-value	0.8952	0.4241	0.2366	0.2108	0.2239	0.2001	0.2899	0.2711

Also running **Fama Mac Beth (1974)** cross-sectional regression of stock returns to the ESG and ESG Controversies Scores yields insignificant results.

Using data from MSCI ESG database, **Nagy et al (2015)**, document the presence of an ESG momentum. Stocks that increased there ESG performance during the last 12 months, realize higher short term returns for the period 2007 to 2014. On contrary to the results in **Table 5**, we document a strong ESG Momentum for the entire period 2002 – 2023. Stocks which tend to increase their ESG performance during months t-24 to t-1, tend to realize high abnormal returns. Our metric for the ESG momentum is defined as:

$$ESG\ mom_{t-1} = \frac{ESG\ Score_{t-1}}{ESG\ Score_{t-24}} - 1$$

Figure 8 plots the value of 1 $ invested in a value weighted GBM portfolio using 100 univariate sorted portfolios on ESG momentum for the period 2004-2023.

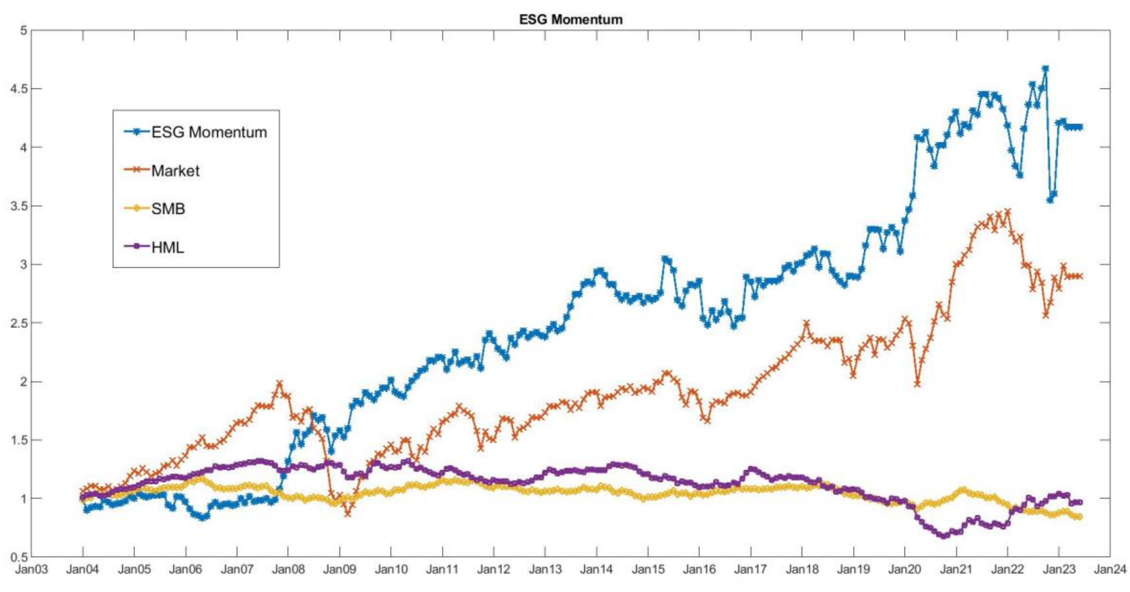


Figure 8 ESG Momentum

The average monthly return of the GBM extreme portfolios is 0.73%, highly significant with a Newey West Robust standard error of 0.0027 (NW t-stat = 2.70), an annualized Sharpe ratio of 0.55. Using the Fama French methodology, a bivariate monthly rebalancing ESG momentum GMB factor mimicking portfolio, sorted on size and ESG momentum is calculated and presented in **Figure 9**. Following the methodology of Fama and French (FF) for the international returns, Big stocks are those in the top 90% of market cap for the region, and small stocks are those in the bottom 10%[10].

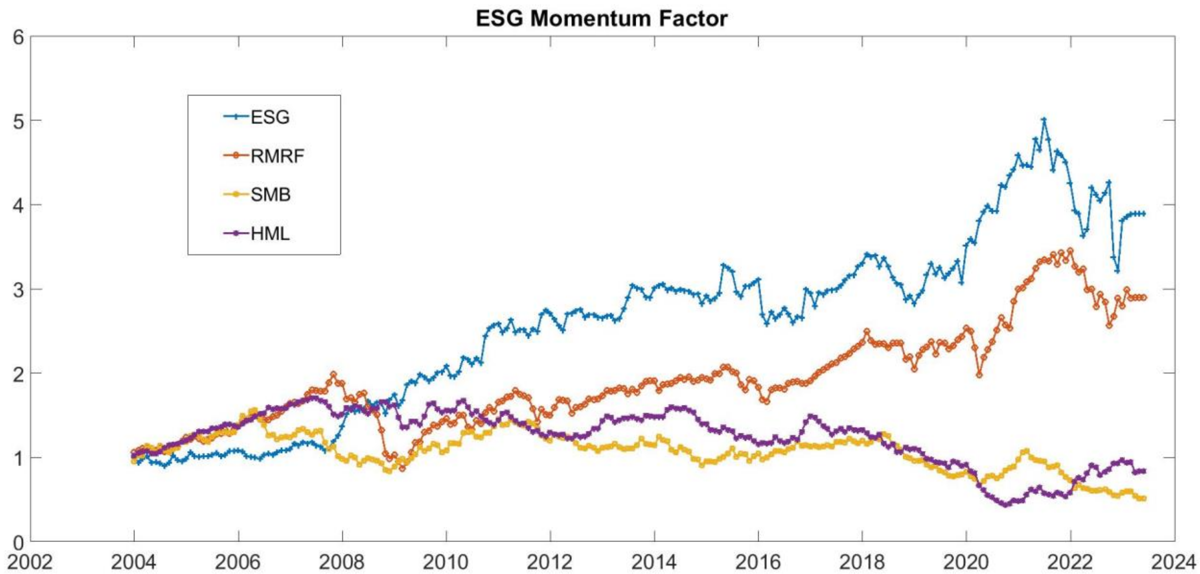


Figure 9 ESG Momentum Factor

Apart from the ESG performance, as measured with the ESG Score, the momentum in the ESG controversies is also a strong effect for the entire sample period 2002-2023.

The controversies momentum is defined as:

$$ESG\ mom_{t-1} = \frac{ESG\ Controversies\ Score_{t-1}}{ESG\ Controversies\ Score_{t-24}} - 1$$

By definition, TRF Controversies Score account for differences between industries and in relation to companies' size, due to the fact that Big companies tend to attract more media attention. In our sample, it is also expected that heterogeneity in countries, possibly in countries and sectors also, would be significant. In this direction, we do calculate the univariate sorted portfolios hedging for country and sector returns. Hedging is applied on the holding returns by subtracting from the monthly stock return, the mean return of all stocks incorporated in the same industry and country.

Figure 10 presents the value of 1 dollar invested in a value weighted GMB Controversies Momentum Portfolio, using 10 univariate sorted Portfolios on Controversies Momentum.

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[10] We rather follow the FF methodology of Momentum factor, which is rebalanced Monthly, on contrary to Market, Size and Value factors which are rebalanced annually.

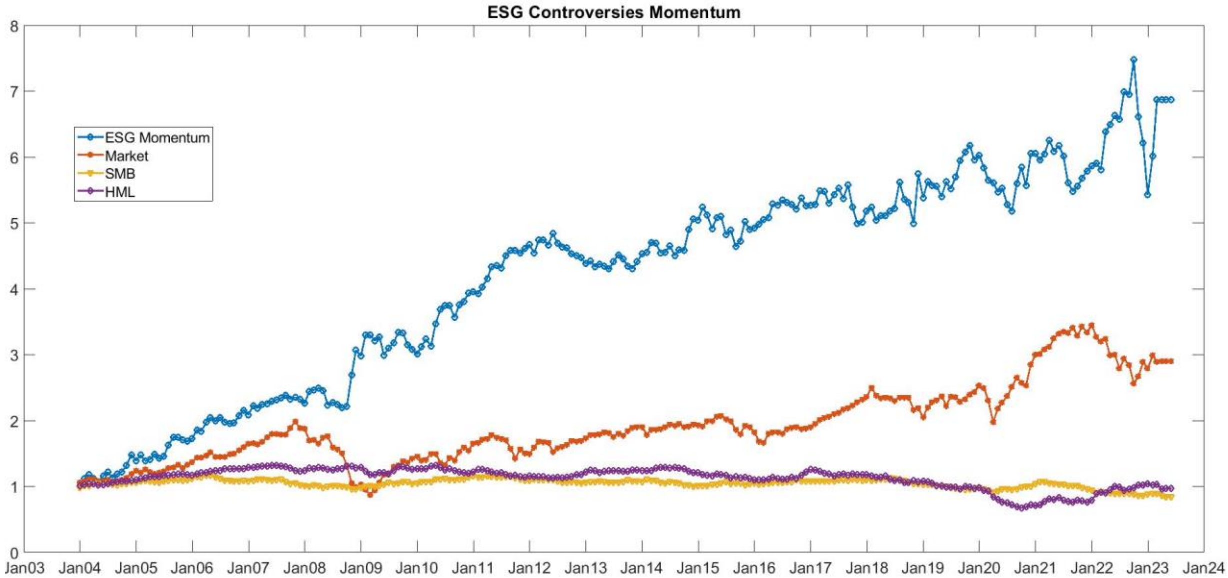

Figure 10 ESG Controversies Momentum

The GMB strategy has an average monthly return of 0.26% with a Newey-West t stat equal to 3.58.

In order to account for both effects, the combined Factor is calculated using the sum of the two scores, that is:

$$ESG\ Combined\ Score_{t-1} = ESG\ Score_{t-1} + ESG\ Controversies\ Score_{t-1}$$

Combined ESG scores are normalized to [0,100].

Figure 11 presents the decile GMB value weighted performance, again hedged against stock's country and market. Portfolio has an average return equal to 0.0028, a t-stat equal to 2.66 and an annualized sharpe ratio equal to 0.55.

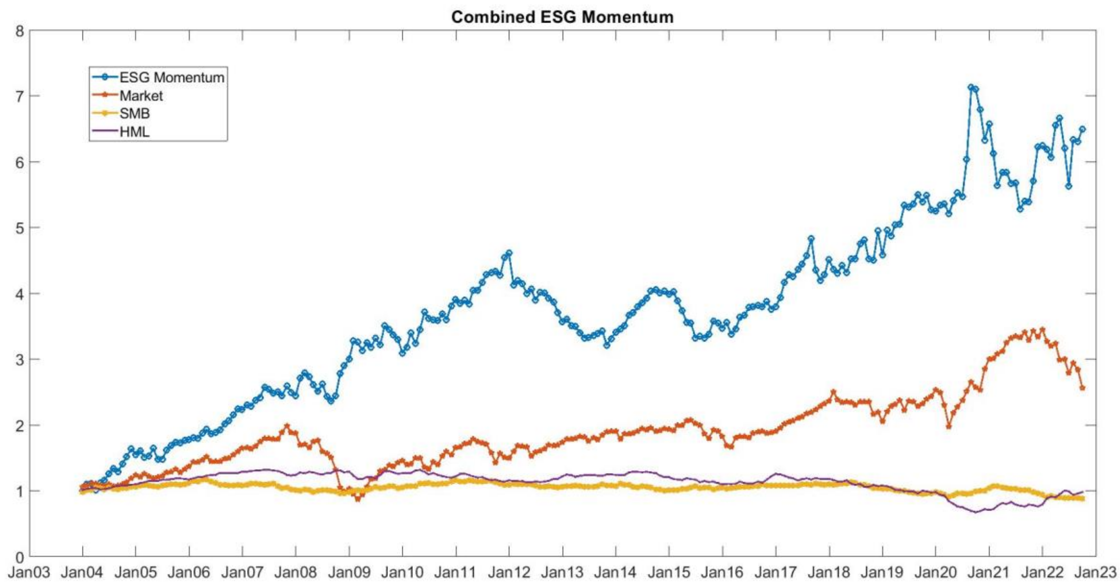

Figure 11 GMB Combined ESG Momentum

Figure 12 presents a double sorted Factor ESG Momentum Mimicking portfolio based on the 90% breakpoint for Size and [30,70] breakpoints for the Combined ESG Momentum.

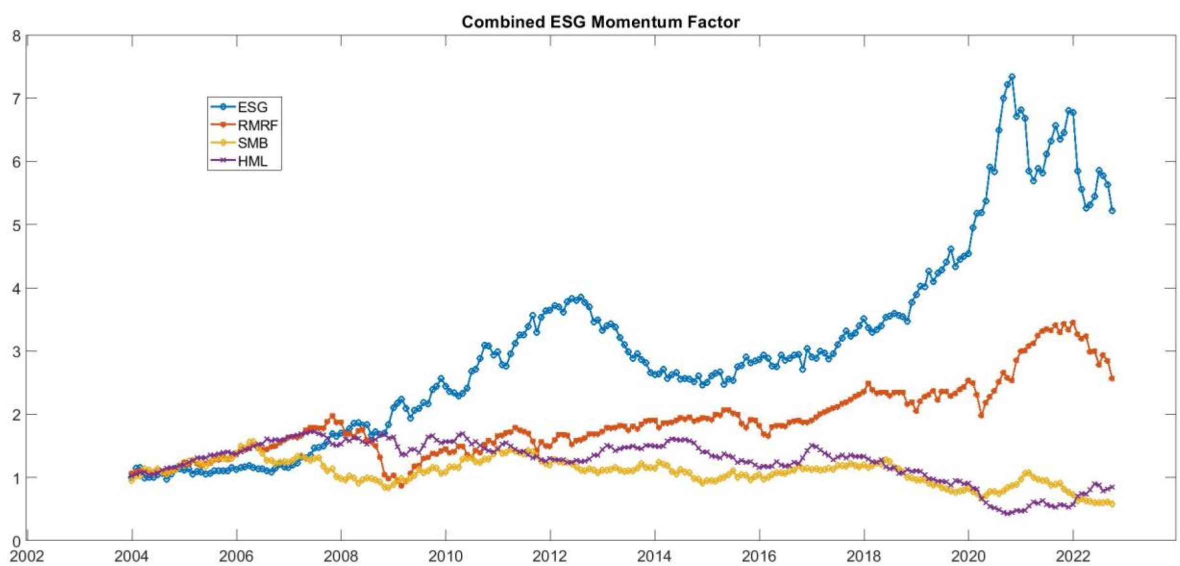

Figure 12 Combined ESG Momentum Factor

Factor has a significant average return of 12bs (t-stat = 2.42) and an annualized sharpe ratio equal to 0.53. A Fama Mac Beth (FMB) cross sectional regression, where the holding period returns for all stocks are regressed to the combined ESG momentum signals, yields an FMB beta equal to 0.01%, with a hac robust tstat of 4.1.

In the same direction with **Henriksson et al (2018)**, we find that the returns continue to increase and be significant for at least 12 months after portfolio formation. **Figure 6** reports the results from FMB cross-sectional regressions of future returns (t+1 to t+12) to ESG Momentum Signals (based on periods t-24 to t-1).

Table 6 ESG Momentum Future Returns

Holding Period	***Beta***	***HAC se***	***HAC tstat***
t	***0.06***	***0.004***	***4.1***
t to t+1	0.03	0.01	4.06
t to t+2	0.05	0.01	4.26
t to t+3	0.07	0.02	4.37
t to t+4	0.09	0.02	4.64
t to t+5	0.11	0.02	4.59
t to t+6	0.12	0.03	4.68
t to t+7	0.14	0.03	4.57
t to t+8	0.15	0.03	4.49
t to t+9	0.15	0.04	4.41
t to t+10	0.16	0.04	4.28
t to t+11	0.16	0.04	4.15
t to t+12	0.16	0.04	4.06

In order to provide an example of the applicability of our factors, we do calculate 20 portfolios univariate sorted on ESG Momentum Controversy, the FF three factor model produces an average absolute alpha of 0.0015 and a GRS test for all portfolios equal to 2.73 (p-value 0.0035), while a 4-factor model expanded to include our Combined ESG Momentum factor exhibits an average absolute alpha of 0.0010 and a GRS test of 2.05 (p-value=0.012).

6.4 Integrate Sustainable Development Goals

Since the Late 2000's ESG integration focused primarily on assessing the ESG policies and processes of companies to evaluate the companies best managing these issues, and which issues were material to the financial prospects of the company, then overweighting or underweighting the companies accordingly.

With the launch of the United Nations SDGs in 2015, this started to change. Endorsed by 193 countries, the SDGs address topics including poverty, hunger, health, education, climate change, gender equality, water, sanitation, energy, environment, and social justice. Achieving the goals requires an estimated investment of USD 5 trillion to USD 7 trillion per year until 2030. For every year that passes, the investment needed to fulfil these goals increases, highlighting the urgency of mobilizing capital. Since 2015, the SDGs are gaining ground as a reference point for investors to align investments and impact goals. This has not only added an additional layer of analysis on top of the traditional exclusion and ESG but underline the need for the creation of a suite of additional attractive investment opportunities that are 'impact-aligned' to the SDGs. Agenda 2030 and the Sustainable Development Goals (SDGs), adopted by all member states of the United Nations in 2015, describe a universal agenda that applies to and must be implemented by all countries and all stakeholders at a local level and in any instance of economic activities. Sound metrics and data are critical for turning the SDGs into practical tools for problem solving. UN SDSN partners with a variety of organizations to assess progress towards SDG achievement at the national level and the local level. Both official and unofficial metrics are used to measure distance to targets for each of the SDGs to identify priorities for action, understand key implementation challenges, track progress, ensure accountability, and identify gaps that must be closed in order to achieve the SDGs by 2030. The SDSN methodology (SACHS ET AL., 2020) was audited by the EU JRC in July 2019.

SACHS ET AL (2019) suggests an approach of making the SDGs operational for governments and policymakers, based on Six Transformational themes, while KOUNDOURI ET AL. (2021,2022) propose a methodology to map European Green Deal policy documents to the SDGs. Further, KOUNDOURI ET AL. (2022) present a methodology to assess the degree that the National Recovery and Resilience Plans (NRRPs) of NextGenerationEU program, support the SDGs, and apply it on the NRRPs of 7 European countries.

KOUNDOURI ET AL (2023B) provides a holistic three step approach for the integration of the Sustainable Development Goals into the sustainability reporting of companies. Process requires the use of an extend set of sector-specific and generic Environmental, Social and Governance Key Performance Indicators (KPIs) based on a series of accounting standards and frameworks, measured across the value chain of the company.

The above framework can be integrated in the portfolio construction, to provide meaningful implications related to the exposure of financial assets to SDGs.

Figure 7 presents the Pillars and the Material categories used in the TRF metrics.

Table 7 TRF ESG Categories

ESG Categories	Material Issues / Categories
Environmental	Emissions
	Environmental Innovation
	Resource Use
	Biodiversity
Social	Workforce
	Human Rights
	Community
	Product Responsibility
Governance	Management
	Shareholders
	CSR

Following a similar methodology to Koundouri et al (2022), we map the ESG categories to SDGs. The mapping methodology refers to map individual key performance indicators to specific SDG indicators using the most updated list of the 169 indicators for the 17 SDGs.

Consider i=1, …. ,17 refers to the 17 SDGs. Also consider k=1,…., K, refers to the Individual KPIs in analysis. Then the raw SDG weights for each kpi refers is calculated as follows:

$$W_{i,k}^{SDG} = \frac{\sum SDG\ Indicators\ mapped\ to\ KPI_k\ under\ SDG_i}{\sum Indicators\ under\ SDG_i}$$

Raw weights are normalized so that the sum of weights to sum to one:

$$\widetilde{W_{i,k}^{SDG}} = \frac{W_{i,k}^{SDG}}{\sum_{k=1}^{K} W_{i,k}^{SDG}}$$

Note that:

$$\sum_{k=1}^{K} \widetilde{W_{i,k}^{SDG}} = 1$$

The holistic interdependent relationship of the 3 Pillars and the 17 Sustainable development goals (SDGs) is presented in using a Sankey diagram in Figure 6.7. The SDG weights for each category/ pillar are calculated as the average weight of all KPIs used in each material issue category/ pillar. Analysis in the SDG context is more holistic and reveals the interconnections between the ESG KPIs, where the most common ESG related scores are agnostic.

Koundouri and Landis (2023) provide an extent set of examples as well as robustness checks for the above methodology.

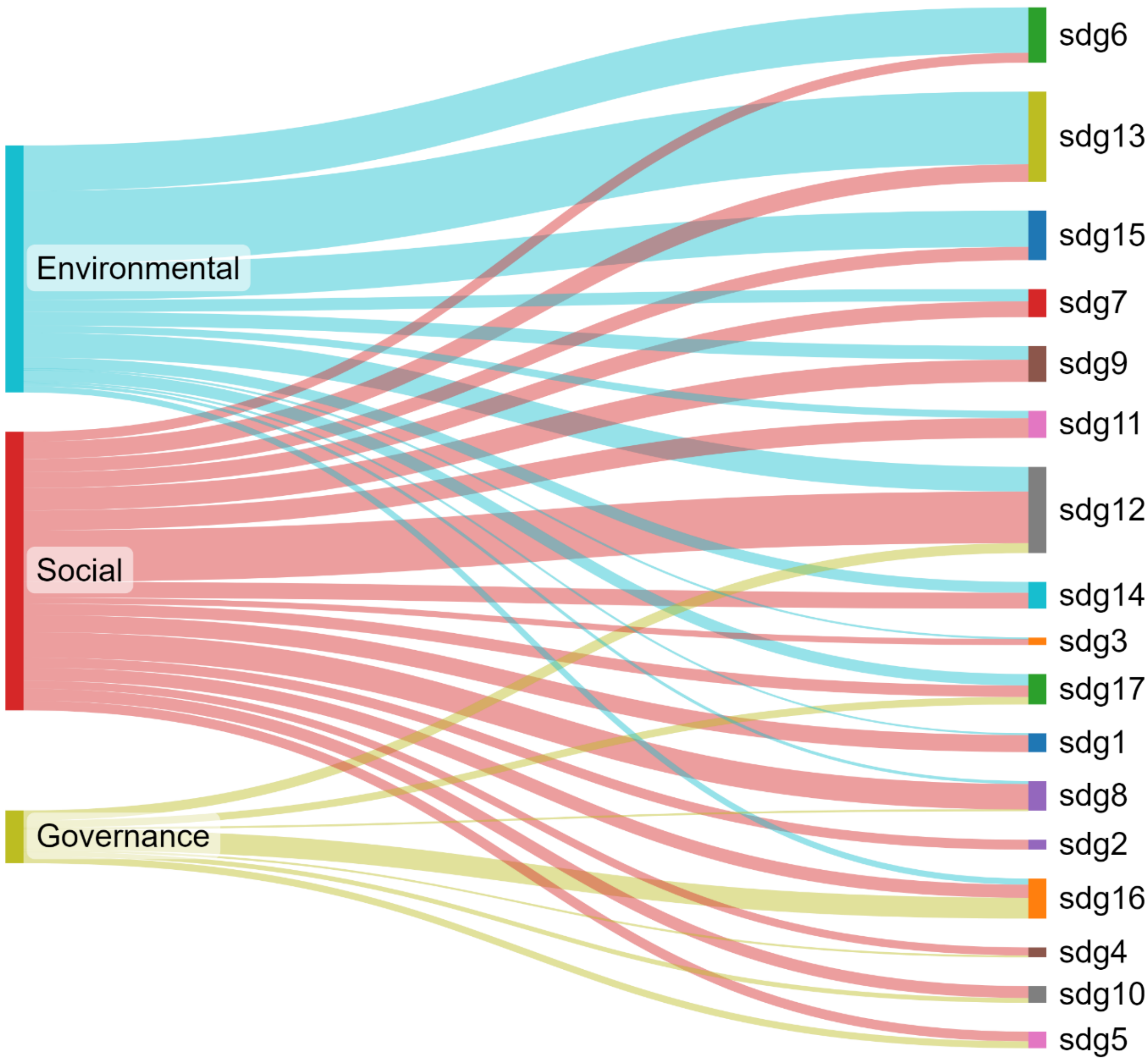

Figure 13 ESG Pillars Map to SDGs 1

The SDG weights are used to calculate the stock specific SDG scores, using the following methodology:

$$Score_i^{SDG} = \sum_{p=1}^{3} \widetilde{W_{i,p}^{SDG}}\, Pillar\ Score_p$$

We use the SDG scores to calculate SDG bivariate factor mimicking portfolios sorted on size and sdg scores, using a 90% breakpoint for the size and a [30,70] breakpoint for the sdg related signals. **Figure 14** depicts the value of 1 dollar invested in the 17 factor mimicking portfolios, which proxy for risks related to the implementation of the 17 SDG goals.

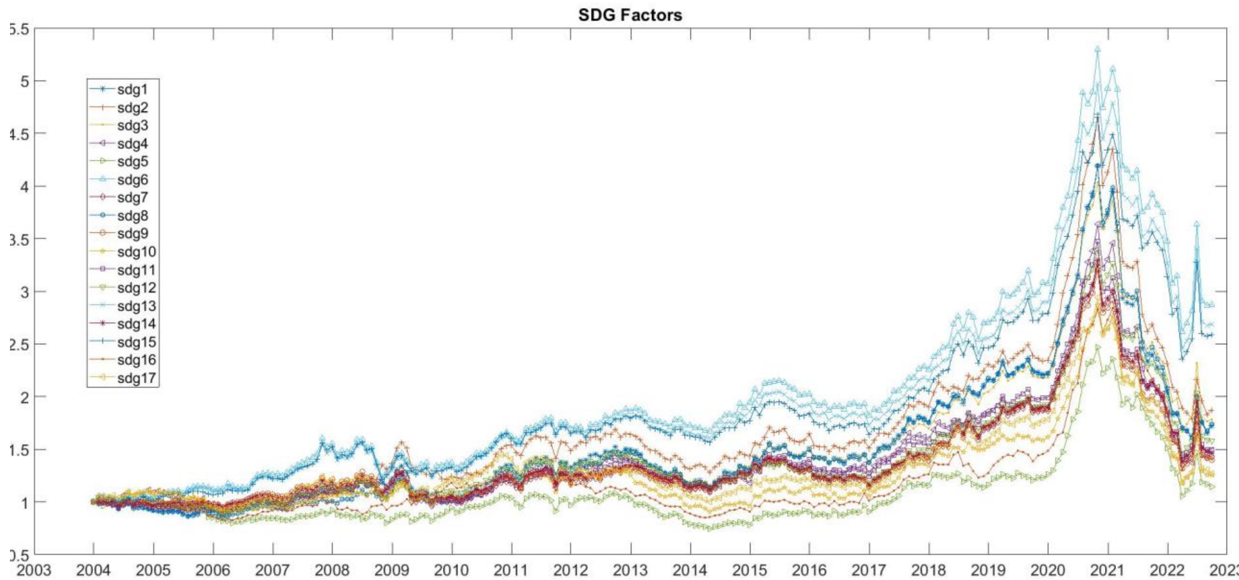

Figure 14 SDG factors

The above set up can be trivially used to calculate the SDG footprint of financial portfolios. We can use an extended version of the Fama and French 3 factor model to estimate the sensitivities of assets to the SDG related factors.

$$r_{i,t} - r_{f,t} = \beta_0 + \beta_1 \left(r_{m,t} - r_{f,t}\right) + \beta_2 \left(SMB_t\right) + \beta_3 \left(HML_t\right) + \sum_{i=4}^{20} \beta_i \left(SDG_{i-3,t}\right) + \varepsilon_t$$

Where $r_{f,t}$, denotes a risk-free rate.

Suppose portfolio contains N shares with weights $a_1, \ldots, a_N$ where $\sum_{i=1}^{N} a_i = 1$,

SDG Footprint of portfolio relative to jth sdg factor can be calculated as the weighted sum of portfolio weights and asset's sensitivity to factor j.

6.5 Conclusion

Our work reveals significant returns associated with recent good performance of companies relative to ESGs. We document a strong ESG Momentum in international marlets; Big stocks that increase their performance during the last 2 years seem to earn a significant premium relative to Bad performers. Moreover, a momentum in the controversies of Companies relative to ESGs is identified, which is strong to both Big and Small listed stocks.

Last but not least, we describe the process of integrating the Sustainable development goals in our asset pricing set up and the calculation of more holistic SDG factors to account for sources of priced risk related to the level of the implementation – controversies of stocks relative to the SDGs.

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7 The Interconnectedness of Natural Capital, Social Capital, Produced Capital, and Cultural Heritage in Sustainable Development

Authors

Halkos G., Chioatto E., Devves S., Landis C., Plataniotis A., Koundouri P.

7.1 Interconnected Capitals: The Foundation of Sustainable Development

The idea of sustainable development aims to achieve an equilibrium between human necessities and environmental well-being. It acknowledges the interrelation among three significant aspects which are natural capital, human capital, and produced capital (***Figure 15***). These components are all interconnected and play a critical role in promoting human well-being while preserving the environment for future generations (**Dasgupta, P., 2021; Trim, I., 2022**).

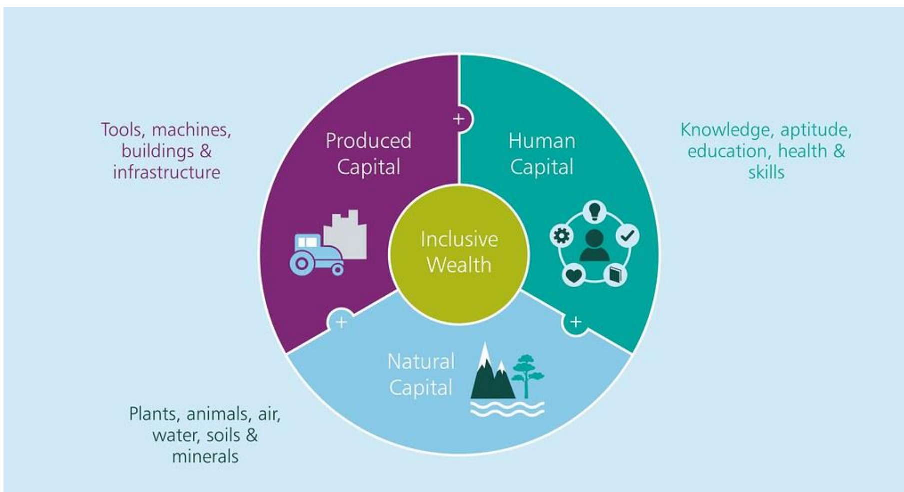

Figure 15 The Interconnection of different forms of Capital. Source: Dasgupta, P. (2021).

Natural capital encompasses the valuable resources that nature provides to support human life. It includes forests, oceans, rivers, as well as all species of plants and animals. These resources not only help people fulfil their immediate needs but also offer crucial ecosystem services that contribute to our overall well-being (**Dasgupta, P., 2021**).

Produced capital includes all the resources and assets that humans create to support their needs, including roads, buildings, infrastructure, and technology (**Dasgupta, P., 2021**).

Human capital, on the other hand, refers to people's capabilities, skills and competencies that allow them to fulfil their objectives and make significant contributions towards the economy and society's welfare (**Dasgupta, P., 2021**). Human capital is supported and improved by investments in education, healthcare, and social services.

Apart from natural, produced, and human capital, sustainable development also relies heavily on two other forms of capital: financial capital, namely the financial resources and assets that individuals, institutions, and governments draw upon to support economic activity and social capital, namely the networks and ties between individuals, groups, and organisations that are responsible for the generation of norms of trust, collaboration, and civic participation (**Chetty, R., Jackson, M.O., Kuchler, T. et al., 2022 ; Setyari, N. P. W., et al. 2022**). By fostering cooperation and collective action, social capital plays a vital role in achieving sustainable development goals (**Adger, W. N. 2010**).

One of the key elements of social capital is cultural heritage, as it contributes to a sense of identity and shared values. According to **UNESCO, 2009,** cultural heritage encompasses a wide range of items and locations, such as artifacts, monuments, architectural collections, and museums, which hold various symbolic, historical, artistic, aesthetic, ethnological, anthropological, scientific, and social values. This includes physical heritage, whether movable, stationary, or underwater, as well as intangible cultural heritage intertwined with cultural and natural heritage objects, sites, or monuments. Notably, this definition does not include aspects of intangible cultural heritage related to other cultural domains, such as festivals and celebrations. It also extends to industrial heritage and prehistoric cave art.

Recently, there has been increasing recognition of the need to identify and assess the value of cultural heritage assets to guide investments in maintenance and restoration programs (**Riganti and Throsby 2021**).

The tangible and intangible benefits of cultural heritage are many, including promoting social cohesion, identity, and a sense of place (**Lenzerini, 2011**). Cultural heritage can also help the economy grow through tourism and help people be more open-minded, creative, and innovative (**Panzera, E., 2022**). Cultural heritage is often closely tied to natural and produced capital, such as historical buildings and landscapes, which can be essential components of a region's tourism industry, or traditional agricultural practices that may contribute to sustainable land use and biodiversity conservation. Therefore, it is very important to keep and protect cultural heritage for both the present and the future.

7.2 Valuing Cultural Heritage

The valuation of cultural heritage is a complex effort that requires considering the interaction of three pillars: environmental, social, and economic sustainability (**Nijkamp, P., 2012**). These pillars encompass various types of capital, including natural capital, human capital, and man-made capital, as described previously.

Economists with the purpose of applying the methodology of economic analysis to the valuation of heritage goods, have interpreted cultural heritage in economic terms, namely as cultural capital, hence an asset that gives rise to both economic and cultural value. The total economic value of cultural heritage goods can be decomposed in use values (i.e., values associated with direct, indirect and future use) and non-use values (i.e. derived from existence, bequest, and altruistic). On the other side, the cultural value, as Throsby (1999) reports, comprises aesthetic, spiritual, social, historical, symbolic, and authenticity. For cultural heritage goods classification, this study refers to the Cultural Heritage Classification from UNESCO (***Figure 16***).

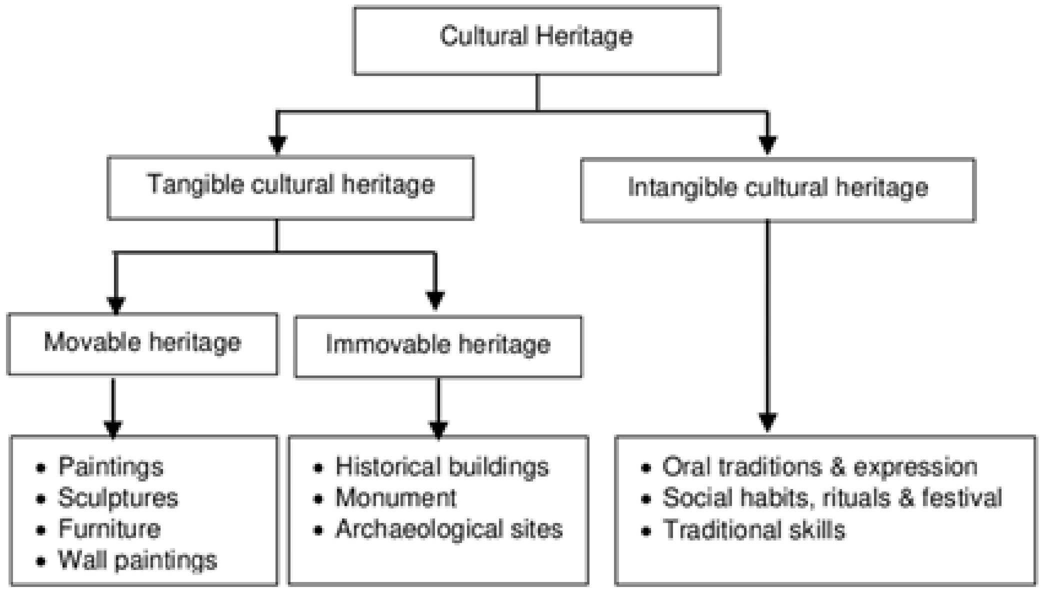

Figure 16 Cultural Heritage Goods classification. Source: UNESCO, 2003

The categorization of environmental values helps understanding the various dimensions of cultural heritage valuation. Anthropocentric values include total economic values, which comprise direct value, indirect value, option value, quasi-option value, bequest value, and existence value. Non-use value is also considered within anthropocentric values. Additionally, non-anthropocentric values, such as intrinsic values, contribute to the comprehensive assessment of cultural heritage.

Several methods are used for environmental valuation, including preferences-based approaches. Revealed preferences methods utilize market-based mechanisms, such as the production cost method, dose-response method, and producer or consumer surplus analysis. Alternatively, hypothetical markets can be created through techniques like hedonic pricing and the travel cost method (***Figure 17***). Stated preferences methods, specifically contingent valuation, and choice experiments, are also employed to estimate values for cultural goods, with contingent valuation being the most applied approach.

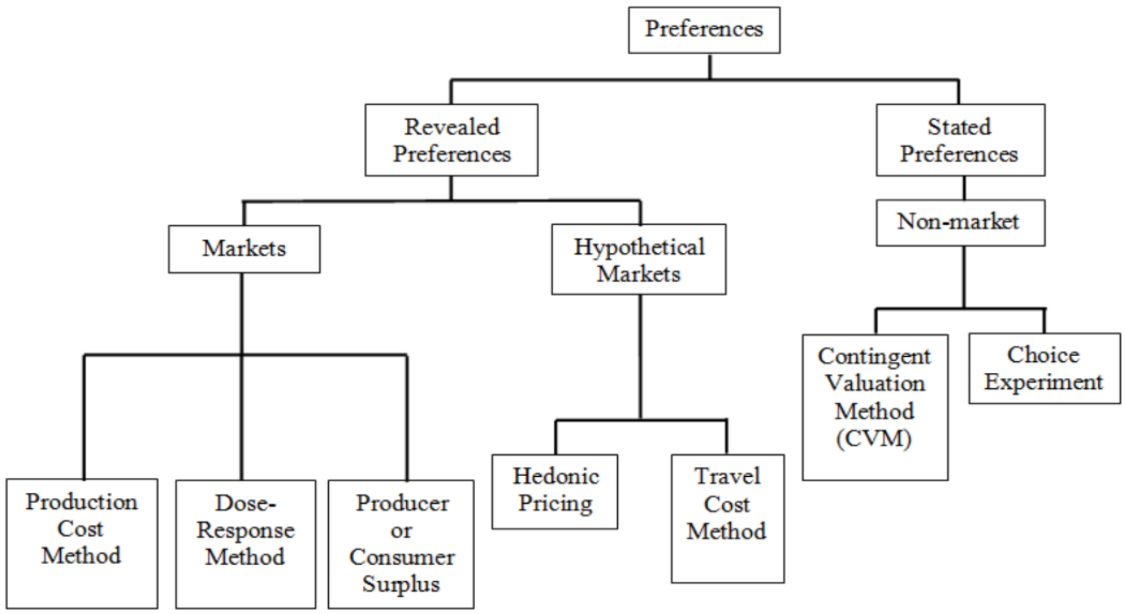

Figure 17 Methods of environmental valuation. Source: Halkos, 2021

It is important to note that quantifying cultural capital is more challenging compared to other forms of capital. Cultural heritage comprises a range of assets and sites that often require maintenance, repair, or restoration. Unlike economic goods, cultural heritage cannot be easily substituted if damaged or lost. Since cultural goods are unique and irreplaceable, they lack markets for valuation purposes, making their assessment more intricate.

The classification of cultural heritage goods by UNESCO distinguishes between tangible and intangible cultural heritage. Tangible cultural heritage includes movable items like paintings, sculptures, furniture, and wall paintings, as well as immovable heritage like historical buildings, monuments, and archaeological sites. Intangible cultural heritage encompasses oral traditions and expressions, social habits, rituals and festivals, and traditional skills.

To determine the total economic value (TEV) of cultural goods, various factors and data are considered. The equation for TEV comprises use value (UV) and non-use value (NUV), which further consist of direct use value (DUV), indirect use value (IUV), option value (OV), quasi-option value (QOV), existence value, intrinsic value, bequest value, and synergistic value (***Figure 18***).

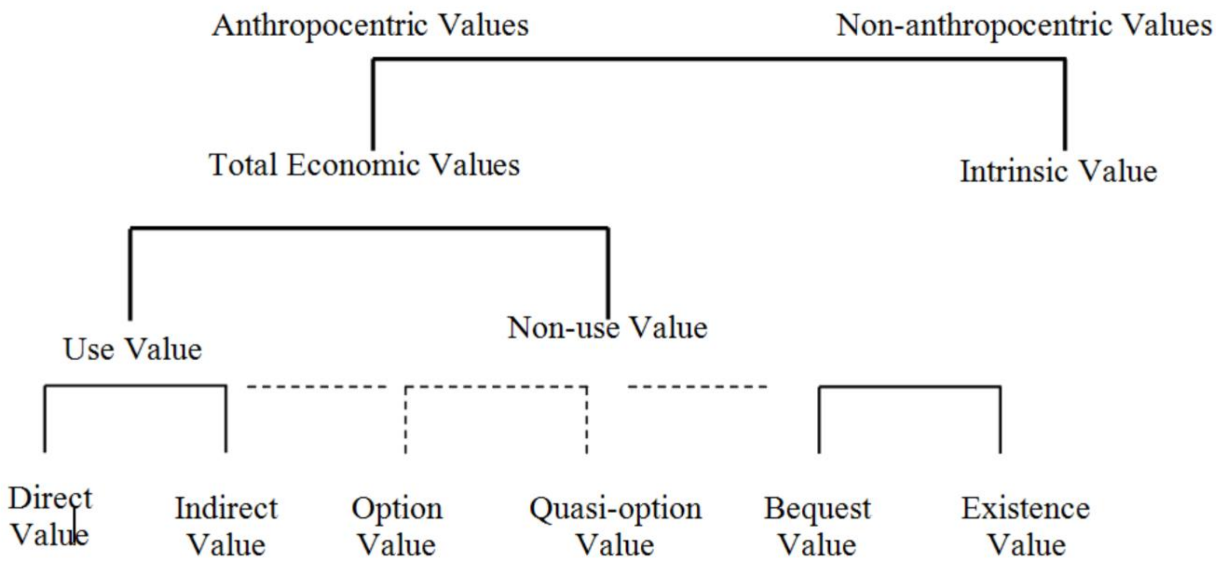

Figure 18 Categorization of Environmental values. Source: Halkos, 2021

7.3 Methodology for Economic Valuation of Cultural Heritage Goods: A Meta-Regression Analysis Approach

Meta-regression analysis function transfer is utilized to synthesize empirical findings from multiple studies, with willingness to pay (WTP) being the dependent variable expressed in euros. This analysis involves estimating parameters for explanatory variables, such as the type of cultural goods (tangible or intangible), specific typologies of tangible and intangible goods, and the valuation method employed.

For robust value transfer, it is crucial that examined studies utilize reliable data and appropriate quantitative methods. Additionally, similarities in characteristics and populations of the studied sites are sought to minimize heterogeneity. The cultural value of heritage goods is often associated with aesthetic, spiritual, social, historical, symbolic, and authenticity factors. Socio-economic variables, including age, income, gender, and education level, are also considered in the valuation process.

7.3.1 Materials and Data

The aim of this study is the performance of an economic valuation of cultural heritage goods by relying on a meta-regression analysis function transfer. Data collection has been conducted by using the accessible literature in databases, such as Google scholar and semanticscholar. Primary literature and reviews related to cultural heritage valuation has been selected.

In total 107 studies published between 1995-2022 have been selected and used to elicit relevant information on actual cultural heritage willingness to pay.[11] Our dataset comprises and providing estimation of cultural heritage goods at the global level, separated into European and Non-European countries. More specifically, the dataset is composed by the following variables:

[11] For the full list of studies please refer to Appendix B

- Study name: contains information about studies' authors, name, journal, and year of publication.
- Willingness to pay is a continuous variable which expresses the annual mean willingness to pay (in euros) for cultural services. In cases in which the value of the willingness to pay was expressed in a currency other than euro, the exchange rate of the current year in which the study was developed was applied. In some studies consumers surplus values have been considered as equal to willingness to pay. In the estimation, the willingness to pay variable will be considered as the dependent variable.
- Year of study development indicates the year of data collection.
- Year of study publication
- Aera: is a categorical variable indicating if the study refers to a cultural heritage site inside Europe or outside Europe
- Country: is a categorical variable reporting the country in which the analysis has been developed
- Location: is a categorical variable reporting the geographical location in which the analysis has been developed.
- Valuation method: is a categorical variable indicating the method used to develop the analysis. For Contingent Valuation and Choice Experiment we assign 1, and 2 otherwise (Stated preference, Travel cost, etc).

Various explanatory variables were considered to identify cultural heritage goods in accordance with UNESCO definition, namely:

- Tangible, Intangible are two dummies' variables, which assume value of 1 if the study provides monetary value for tangible goods or intangible goods, and value of 0 otherwise.
- Paintings, Sculpture, Furniture, Wall, Historical buildings, Monument, Archaeological sites: are dummy variables indicating seven typologies of tangible cultural heritage goods. They assume value of 1 if the study provides monetary value for the specific tangible good, and value of 0 otherwise.
- Oral traditions, social habits, Traditional skills: are dummy variables indicating three typologies of intangible cultural heritage goods. They assume value of 1 if the study provides monetary value for the specific intangible good, and value of 0 otherwise.
- Various explanatory variables were considered to identify the economic and cultural value of heritage goods, in accordance with RIGANTI AND THROSBY (2021) and THROSBY (1999), namely:
    - Existence, Bequest are dummy variables indicating the economic value of cultural capital. They assume value of 1 if the study has derived existence or bequest value, and 0 otherwise.
    - Aesthetic, Spiritual, Social, Historical, Symbolic, and Authenticity.: are dummy variables indicating the cultural value generated by cultural capital. They assume value of 1 if according to authors' interpretation the study represents as a proxy the valuation of the above-mentioned cultural values, and 0 otherwise.

As socio-economic variables, we have considered the following:

- **Age**: is a continuous variable indicating the mean age of the sample population expressed in years. For studies in which age data were not available, we extracted that information from sources like https://www.worldometers.info/ .
- **Income**: is a continuous variable indicating the mean annual income of the sample population in euro. In the studies in which, monthly annual income was provided, the monthly amount has been multiplied per twelve months. In cases in which the value of annual income was expressed in a currency other than euro, the exchange rate of the current year in which the study was developed was applied. For studies in which

income data were not available, we extracted that information from webpages providing official statistics, such as https://ec.europa.eu/eurostat , https://www.ceicdata.com/, https://tradingeconomics.com, and https://www.census.gov. Eurostat database provides mean equivalised net income by year.

- **Gender**: indicates the percentage of male and female in the sample population. It is assumed female =1. For studies in which gender data were not available for the population, we extracted that information from webpages providing official statistics, such as https://www.statista.com and https://statisticstimes.com .
- **Education**: indicates the percentage of the sample population that have a high education level. It is assumed university degree=1. In case in which educational level data were not available, we extracted relevant information from webpages providing official statistics, such as https://uis.unesco.org/ that adopt the International Standard Classification of Education (ISCED).

7.3.2 Empirical Findings

Relying on the above information **Table 8** and

Table 9 provide the basic descriptive statistics, while **Table 10** and **Table 11** presents the correlation coefficients of the variables considered.

Table 8 Descriptive statistics A

	WTP	AGE	CV_AESTHETIC	CV_AUTHENTICITY	CV_HISTORICAL	CV_SYMBOLIC	EDUCATION	EV_BEQUEST	EV_EXISTENCE	GENDER	INCOME_YEAR
Mean	38.463	40.020	0.5200	0.5800	0.5000	0.6400	4.4728	0.3600	0.6600	5.0050	19.389
Median	15.530	40.000	1.0000	1.0000	0.5000	1.0000	4.5000	0.0000	1.0000	5.1000	15.676
Maximum	343.00	53.000	1.0000	1.0000	1.0000	1.0000	14.850	1.0000	1.0000	5.7000	50.000
Minimum	2.4700	28.000	0.0000	0.0000	0.0000	0.0000	1.0700	0.0000	0.0000	2.4000	1.6650
Std. Dev.	56.471	5.2274	0.5046	0.4985	0.5050	0.4848	3.4207	0.4848	0.4785	0.4252	11.404
Skewness	3.4996	0.2604	-0.0800	-0.3241	0.0000	-0.5833	1.2271	0.5833	-0.6755	-4.7881	0.4727
Kurtosis	18.227	2.5953	1.0064	1.1050	1.0000	1.3402	4.5730	1.3402	1.4563	29.702	2.8519
Jarque-Bera	585.12	0.9063	8.3334	8.3563	8.3333	8.5745	17.704	8.5745	8.7671	1676.4	1.9084
Probability	0.0000	0.6356	0.0155	0.0153	0.0155	0.0137	0.0001	0.0137	0.0124	0.0000	0.3851
Observations	50	50	50	50	50	50	50	50	50	50	50

Table 9 Descriptive statistics B

	INTANGIBLE_GOODS	INTANGIBLE_ORAL_TRADITIO	INTANGIBLE_SOCIAL_HABITS	INTANGIBLE_TRADITIONAL_S	TANGIBLE_ARCHEOGOGICAL_S	TANGIBLE_GOODS	TANGIBLE_HISTORICAL_BUIL	TANGIBLE_MONUMENTS	TANGIBLE_PAINTINGS	TANGIBLE_SCULPTURES	TANGIBLE_WALL
Mean	0.5490	0.1372	0.2745	0.4509	0.1372	0.5098	0.3725	0.1960	0.0980	0.1176	0.058824
Median	1.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.000000
Maximum	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.000000
Minimum	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000000
Std. Dev.	0.5025	0.3470	0.4507	0.5025	0.3475	0.5048	0.4882	0.4009	0.3003	0.3253	0.237635
Skewness	-0.1970	2.1081	1.0105	0.1970	2.1082	-0.0392	0.5272	1.5309	2.7034	2.3734	3.750000
Kurtosis	1.0388	5.4448	2.0212	1.0388	5.4446	1.0015	1.2779	3.3439	8.3086	6.6333	15.06250

Jarque-Bera	8.5032	50.482	10.716	8.5032	50.482	8.5000	8.6641	20.174	122.01	75.935	428.7271
Probability	0.0142	0.0000	0.0047	0.0142	0.0000	0.0142	0.0131	0.0000	0.0000	0.0000	0.000000
Observations	51	51	51	51	51	51	51	51	51	51	51

Table 10 Correlation coefficients A

	CV_AESTHETIC	CV_AUTHENTICITY	CV_HISTORICAL	CV_SOCIAL	CV_SPIRITUAL	CV_SYMBOLIC	TANGIBLE_ARCHEOGOGICAL_S	TANGIBLE_GOODS	TANGIBLE_HISTORICAL_BUIL	TANGIBLE_MONUMENTS	TANGIBLE_PAINTINGS	TANGIBLE_SCULPTURES	TANGIBLE_WALL
CV_AESTHETIC	1	0.3179	-0.24	-0.0099	-0.073	0.1134	-0.073	-0.2019	-0.155	-0.22	-0.346	-0.384	0.0741
CV_AUTHENTI	0.3179	1	-0.121	0.168	-0.1237	0.5436	-0.123	-0.1687	-0.168	0.121	0.148	0.189	0.044
CV_HISTORICAL	-0.24	-0.121	1	-0.453	0.288	5.088	0.403	0.640	0.453	0.3	-0.067	-6.8329	0.2526
CV_SOCIAL	-0.0099	0.1686	-0.453	1	-0.277	0.185	-0.159	-0.587	-0.49	-0.123	0.123	0.035	-0.149
CV_SPIRITUAL	-0.07	-0.1237	0.288	-0.277	1	0.0624	0.003	0.1569	0.159	0.086	0.0574	0.028	-0.1019
CV_SYMBOLIC	0.1134	0.543	5.0885	0.1854	0.0624	1	-0.0576	-0.0533	-0.185	0.062	0.111	0.02	0.1894
TAN_ARCH_S	-0.073	-0.1237	0.403	-0.1591	0.003	-0.0576	1	0.3876	0.396	-0.057	-0.134	-0.148	0.14
TAN_GOODS	-0.2019	-0.168	0.6405	-0.587	0.1569	-0.053	0.387	1	0.752	0.48	0.320	0.354	0.242
TAN_HISTO_BUIL	-0.155	-0.168	0.453	-0.490	0.15	-0.185	0.3966	0.752	1	0.432	0.288	0.218	-0.1977
TAN_MONUMEN	-0.2201	0.121	0.3	-0.1236	0.08	0.062	-0.057	0.480	0.432	1	0.5	0.43	-0.1263
TAN_PAINTINGS	-0.3469	0.1485	-0.067	0.123	0.057	0.111	-0.134	0.320	0.288	0.5	1	0.90	-0.084
TAN_SCULPTUR	-0.3843	0.1895	-6.8329	0.0355	0.0283	0.020	-0.1489	0.354	0.218	0.4308	0.902	1	-0.0932
TANGIBLE_WALL	0.0741	0.0443	0.2526	-0.149	-0.1019	0.189	0.1407	0.2427	-0.1977	-0.1263	-0.084	-0.093	1

Table 11 Correlation coefficients B

	CV_AESTHETIC	CV_AUTHENTICITY	CV_HISTORICAL	CV_SOCIAL	CV_SPIRITUAL	CV_SYMBOLIC	INTANGIBLE_GOODS	INTANGIBLE_ORAL_TRADITIO	INTANGIBLE_SOCIAL_HABITS	INTANGIBLE_TRADITIONAL_S
CV_AESTH	1	0.3179	-0.24	-0.0099	-0.073	0.113	0.0771	-0.189	-0.34	0.20
CV_AUTHE	0.317	1	-0.12	0.1686	-0.123	0.543	0.108	-0.123	-0.234	0.346
CV_HISTOR	-0.24	-0.1215	1	-0.4532	0.28	5.088	-0.521	0.0576	-0.0455	-0.483
CV_SOCIAL	-0.009	0.168	-0.453	1	-0.277	0.18	0.682	0.078	0.3701	0.527
CV_SPIRITU	-0.073	-0.123	0.288	-0.277	1	0.062	-0.09	0.169	0.0236	-0.009
CV_SYMBOL	0.113	0.54	5.088	0.185	0.062	1	0.143	-0.057	-0.2203	0.245
INT_GOODS	0.077	0.108	-0.521	0.682	-0.090	0.143	1	0.372	0.547	0.81
INT_ORA_TRAD	-0.19	-0.123	0.057	0.078	0.169	-0.0576	0.37	1	0.5492	0.222
INT_SOCI_HAB	-0.34	-0.23	-0.045	0.37	0.023	-0.22	0.547	0.5492	1	0.209
INT_TRADIT_S	0.206	0.346	-0.483	0.527	-0.006	0.245	0.818	0.222	0.209	1

Next, we performed various stepwise specifications of the variables considered being slightly elastic in the individual statistical significance of the explanatory variables. That is apart from the usual levels (of α=0.05, α=0.01 and α=0.1) we have considered (in such analysis) P-values less than 0.25. We have divided our analysis into European and non-European studies. For the former the number of studies considered was 51, while for the latter we have considered 55 studies.

Based on these, **Table 12** provides the specifications of the variables considered in our analysis. The first column presents the variables considered and various diagnostics. Columns 2 and 3 refer to the specifications for the European countries, while columns 4 and 5 refer to the non-European countries' specifications. Even more, columns 2 and 4 correspond to simplified specifications mainly on cultural values (considered as simple), whilst columns 3 and 5 correspond to more extended specifications with the addition of tangible and intangible cultural heritage distinctions (considered as full). **Table 11** accompanies these specifications with the provision of the correlation coefficients as an initial indication of any possible multicollinearity problems.

Concerning the demographic variables, gender is significant at all levels in the simple European specification, as well as in the simple non-European specification if we allow for P-values higher than the typical ones (as explained before). Income is influential in all specifications, although significant in the non-European and in the European cases of the full specifications. Education significantly affects the European specifications (at all levels in the full and with elastic P-values assumed in the simple), while in the non-European case only in the full specification and is we allow P-values less or equal to 0.25. Finally, age seems to be affecting only the non-European countries setup and with the elastic P-values assumption.

Moving on the cultural values, aesthetic affect significantly the European specifications, while authentication seems significant in the simple non-European specification and marginally in the simple European with the elastic P-values assumed. Spiritual cultural values significantly affect the European specifications and in elastic P-values the full non-European setup. Symbolic and social cultural values seem to affect the non-European countries.

If we consider the intangible classifications then goods, social habits and tradition are significant in the full European and non-European specifications, while oral tradition is significant in the full non-European specification. With reference to tangible distinction, archaeological, historical buildings and paintings are statistically significant in the full European specification.

The expected problem of heteroskedasticity is tested using Glejser and White tests among others with no indication of problems in our specification with only one exception in the case of the full non-European specification and for the Glejser test only. Similarly, there is not any ARCH effect in any of the specifications, Also the R^2 adjusted are higher in the full specifications having values around 0.41-0.51 and lower values in the simple specifications.

The Total WTP is yearly and presents no difference between the simple and the full specifications in European specifications and some difference in the non-European specifications. Specifically, **in the European specifications we have values around €37 (€36.9 and €37.6 for the simple and the full specifications respectively), while in the non-European specifications we have higher and different values of €50.5 and €60.12 for the simple and the full specifications respectively.**

It seems that the distinction of intangible cultural heritage affects statistically both the European and non-European specifications, while the tangible significantly affects the European ones. Aesthetic and Spiritual values affect the European countries specifications.

Table 12 Regression specifications

Variables	European countries (n=51)	European countries (n=51)	Non-European countries (n=55)	Non-European countries (n=55)*
Gender	14.59 [0.0053]	6.0393 [0.3536]	-8,3163 [0.1818]	
Income	-0.7477 [0.3069]	-1.0532 [0.1177]	-0.0772 [0.3506]	-0.2461 [0.0586]
Education	3.311 [0.1787]	8.003 [0.0074]		-10.479 [0.2434]
Age				1.4511 [0.1288]
CV_Aesthetic	-35.206	-63.565		17.808

	[0.0453]	[0.0018]		[0.4664]
CV_ Authentification	-20.902 [0.2503]		72.208 [0.0272]	32.954 [0.2798]
CV_ Spiritual	-42.152 [0.0827]	-50.085 [0.0252]		-40.789 [0.2342]
CV_Symbolic				32.338 [0.2036]
CV_Social			70.156 [0.0313]	38.088 [0.2361]
EV_Existencec			30.725 [0.3462]	
IntangibleGoods		114.31 [0.0114]	52.489 [0.1014]	164.1822 [0.0238]
Intangible Social Habits		-50.523 [0.0582]		-177.96 [0.0551]
Intangible Tradition		-57.203 [0.0512]		147.2847 [0.0164]
Intangible Oral Tradition				-168.75 [0.0034]
Tangible Archaeological		-78.612 [0.0017]		
Tangible Historical Buildings		73.53 [0.0083]		
Tangible Paintings		-77.822 [0.0077]		
R-square	0.15	0.41	0.23	0.51
ARCH effect test	0.1279 [0.7206]	0.0128 [0.9099]	1.0219 [0.3122]	0.126 [0.7226]
Hetersoskedasticity Glejser	0.419 [0.1514]	14.14 [0.2253]	10.513 [0.1047]	21.54 [0.0430]
Hetersoskedasticity White	3.359 [0.7526]	9.665 [0.5607]	9.292 [0.1578]	14.878 [0.1881]
Total WTP	**36.99**	**37.6**	**50.5**	**60.12**

For the last specification HAC standards errors and covariance (Bartlett kernel Newey-West fixes) are used
P-values in brackets

7.4 Conclusions

Our findings show that the significance of intangible cultural heritage varies between European and non-European countries. More specifically, in the case of European countries, intangible cultural heritage is influenced by aesthetic and spiritual values, while in non-European countries, it is affected by symbolic and social values. In terms of income level, it is revealed that it does not significantly affect the willingness to pay in European countries, but this is not the case in non-European countries. And one more differentiation is that, in non-European countries, higher levels of education and younger age are associated with a greater willingness to pay for intangible cultural heritage.

Overall, the study shows that the economic value of intangible cultural heritage varies depending on multiple factors including geographic location, cultural values, income levels, age. Therefore, policymakers should consider the differing cultural values and economic implications of intangible cultural heritage when developing conservation policies. Moreover, they should also focus on promoting and capitalizing the economic value of cultural heritage through accurate measurement and valuation techniques. Furthermore, policymakers should pay attention to the demographic factors that influence willingness to pay for intangible cultural heritage, such as age and education levels. In conclusion, the economic value of cultural heritage is complex and depends on a variety of factors. Therefore, a holistic approach is necessary to assess and promote the economic value of intangible cultural heritage.

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8 Carbon farming and voluntary carbon markets in the EU: An updated guide

Authors:

Ilaria Dibattista, Department of Political and International Sciences, University of Siena, FSR Climate, European University Institute

Mira Manini Tiwari, Department of Political and International Sciences, University of Siena, FSR Climate, European University Institute

Matteo Mazzarano, Department of Political and International Sciences, University of Siena, FSR Climate, European University Institute

Simone Borghesi, Department of Political and International Sciences, University of Siena, FSR Climate, European University Institute

8.1 Introduction

Climate change anomalies are acutely exacerbated by intensive and unsustainable human practices, foregrounded once again in the 6th IPCC report (Lee et al., 2023). Technological innovation and regulations are among the main instruments used to overcome the challenge and enable economic systems to transition to a low-carbon society. Yet, land-based sectors such as agriculture are, for intrinsic reasons, slower in finding solutions to climate change, despite their relevant mitigation potential. Land-based sectors are often tied to local communities, cultural and natural values, and their corresponding needs. The introduction of climate-resilient innovation should coexist with them. Carbon markets, which are trading systems where carbon credits are sold and bought, could satisfy such needs. It is a developing field with heterogeneous practices and definitions. In the agricultural sector, carbon markets are those markets where one side (generally land managers and agricultural firms) has the capacity to absorb greenhouse gases and offers this as a service to a buyer through so-called "carbon farming projects". The past few years have seen a progressive development of studies on carbon farming for the European Union (McDonald et al., 2021; European Commission et al., 2021; Cevallos et al., 2019; Demeyer et al., 2021), which provide comprehensive and expert guidance on the field. Policymakers have noted the utility of carbon markets in the agricultural sector and are developing legislation to support them. The standardisation offered by such regulations reduces the asymmetries of information but can create confusion due to different definitions of similar practices across the world, as well as confusion in the objectives of carbon farming per se. For example, in December 2021 the European Commission adopted the Communication on Sustainable Carbon Cycles, aimed at promoting carbon farming and public financing, advancing the transparency of its mechanisms, and supporting landowners through consultations and help (European Commission, n.d.a). This was followed by the proposal in November 2022 on a voluntary framework for carbon removal certification (European Commission, 2022).

These recent changes have contributed to knowledge fragmentation and the coexistence of several interpretations of policies, guidelines and definitions that need harmonisation. With this chapter, therefore, we aim to integrate both well-established literature and the latest policy evolutions to create an overarching outline of all that concerns Carbon Farming (CF) and Voluntary Carbon Markets (VCMs) in the European Union (EU). The purpose of this work is to provide an up-to-date guide to support policymakers, researchers, students and interested readers in understanding the current international and European landscape.

The chapter begins by providing readers with the foundational definitions of carbon farming, carbon credits, and carbon offsets that are used throughout this chapter. **Section 8.3** then traces the historical and political evolution of voluntary carbon markets, before presenting current regulation and market trends. **Section 8.4** delves deeper into the main topic and sets the context of CF and emissions mitigation in the agricultural sector by presenting data on land share and emissions trends in the agricultural and other land use sectors **(FAO, 2021; IPCC, 2022; EEA, 2021)**. **Section 8.5** presents two key pieces of European regulation for carbon farming: the Effort Sharing Regulation and the proposed framework for carbon farming certification. Then, **Section 8.6** takes a more practical turn by addressing the implementation and governance of VCMs, from the explanation of the main CF activities to the creation of payments for farmers, concluding with VCM types and designs. Finally, **Section 8.7** collects policy and governance challenges that need to be tackled to improve the current system, both at the international and local levels. The next two sections, Sections 8.8 and 8.9 respectively, bring together policy recommendations from authorities on carbon farming in the EU and elsewhere to offer readers integrated and comparative insight, and policy implications, leaving readers with some of the evolutions, questions, and intentions that will be pivotal to VCMs going forward.

8.2 Key terms

Table 13 summarises the key definitions used in this chapter.

Table 13 Key definitions concerning carbon farming and voluntary carbon markets

Carbon Farming	"Carbon farming refers to farm management practices that aim to deliver climate mitigation in agriculture. This involves the management of both land and livestock, all pools of carbon in soils, materials, and vegetation, plus fluxes of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). It includes carbon removal (sequestration and permanent storage of carbon in soils and biomass), avoided emissions (preventing the loss of already stored carbon), and emissions reductions (i.e., reductions of GHGs below current levels of farm emissions). All farming systems can mitigate, although the level of mitigation potential differs across farm types and different geographies. Carbon farming also refers to the business model that aims to upscale climate mitigation by paying farmers to implement climate-friendly farm management practices. Funding can come from public funds such as the [European Union's] Common Agricultural Policy, or private sources via supply chains or carbon markets. These different funding sources offer different opportunities and risks for farmers and for delivering on climate objectives." **(McDonald et al., 2021, p. 7)**
Carbon credit	The acquisition and possession of a unit or carbon removed, avoided, or reduced constitutes a carbon credit if it can be accounted for under national emissions mitigation commitments or on the market. A carbon credit constitutes one tonne of CO_2 or equivalent greenhouse gas (1 t CO_2e).

Carbon offset	When a unit of carbon mitigation (removal, avoidance, or reduction) is bought and accounted for by another actor, the unit becomes carbon offset. The buyer seeks to use the carbon mitigation activities of the original actor to 'compensate for' their own GHG emissions.
VCMs	Markets on which carbon credits are traded.
Double counting	Instances in which a carbon credit is accounted for in more than one jurisdiction or towards more than one actor's obligations or goals.

8.3 Evolution of carbon credits and voluntary carbon markets

8.3.1 From compliance credits to voluntary carbon credits

The concept of carbon credits partially has conceptual origins in the discourse of payments for ecosystem services **(Brunori, 2023; Kotsialou et al., 2022),** namely the act of assigning economic value to an environmental resource or outcome. These credits exist in both the public and private sectors. In the public sector (including both transnational entities, such as UN mandates and national governmental systems), credits are often referred to as compliance credits, given their purpose of enabling actors' compliance with carbon mitigation obligations.

Compliance credits have their roots in a transnational mechanism established under the 1997 Kyoto Protocol that concerned two types of countries: Annex I countries were required to set greenhouse gas emissions reductions; Annex II countries were exempted from these requirements, invoking a rationale of being "too poor to be green". However, since the implementation of GHG emissions mitigation was often more cost-effective in Annex II countries compared to Annex I, the United Nations Framework Convention on Climate Change (UNFCCC)[12] implemented the Clean Development Mechanism (CDM) as part of the Kyoto Protocol, under which Annex I countries can implement emissions reduction projects in Annex II countries. The projects' outputs are quantified in terms of Certified Emissions Reductions (CER) credits, which can be sold and can be counted towards emissions reduction or limitation commitments under the Kyoto Protocol. Joint Implementation (JI) projects allow two Annex I countries to collaborate in emission reduction projects. Emission reductions or limitations achieved in one country can be bought by another, in the form of Emission Reduction Units (ERUs), which can be counted towards the buyer's national Kyoto Protocol commitments. Both mechanisms are designed to give flexibility to polluting countries while they improve their mitigation capacity.

Given the unprecedented nature of this tool, the CDM set commitment periods at the end of which targets, and the market were to be evaluated. Running parallel to the evolution of the CDM, from the late 1990s and early 2000s onwards, governments, NGOs, and private companies began to develop markets to incentivise mitigation measures **(Nogues et al., 2021)**. Market policies for reaching the Kyoto Protocol's targets have been adopted throughout the world **(Tang et al., 2016)**, with the 2005 EU Emission Trading System (ETS) being the world's first international example. As part of this shift, voluntary carbon credit registries came into existence, with key actors

[12] Established in 1992 during "United Nations Conference on Environment and Development" in Rio De Janeiro, and entered into force in 1994 to support international negotiations to combat climate change.

including the American Carbon Registry (ACR), GoldStandard, and Verra, formed by coalitions of businesses and international environmental organisations, ranging from the WWF (in the case of GoldStandard) to the non-profit Winrock (in the ACR).

The CDM commitment period ending in 2012 brought uncertainty for CDM credit holders, leading to a significant shift of actors from the compliance arena towards the voluntary arena **(Spilker and Nugent, 2022)**. However, this shift also entailed greater fragmentation, which in turn brought its own opacity. To improve transparency and certainty, in 2015, the Paris Agreement explicitly institutionalised the exchange of carbon at the market level. It recognised the role of markets in enabling international cooperation on emissions reduction to comply with the newly introduced Nationally Determined Contributions (NDCs), which are binding national commitments to reduce greenhouse gas emissions. This saw the introduction of Internationally Transferred Mitigation Outcomes (ITMOs), which are none other than 'credits' in the UNFCCC context. These ITMOs were to be validated by Corresponding Adjustments (CAs), a centralised mechanism to ensure that a mitigation outcome acquired by a state is accounted for only within their NDCs, and not also counted towards the NDCs of the state that hosts the carbon mitigation project **(Spilker and Nugent, 2022)**. In other words, corresponding adjustments are designed to avoid double counting. However, both verification and certification for CAs are conducted by UNFCCC committees. Despite its authority and consistency, the fact that a single body is performing both results in an opaque system of transactions and measurements **(Roman-Cuesta and Borghesi, 2022)**. A key consequence of this opacity has been the inability of users to reliably track the prices and transactions on the market. In recent years, the transnational Certified Emissions Reduction compliance mechanism has been substituted by national programmes and private international initiatives. Indeed, CDM credits were excluded from the EU's ETS on the grounds of environmental inefficacy and to avoid CDM credits driving down ETS prices.

8.3.2 Turning points in VCM structures

VCMs differ significantly from ETSs at the structural level: actors earn revenue (through carbon credits) for reducing or sequestering carbon emissions, "relative to a counterfactual baseline," instead of paying for their emissions ("i.e., the polluter pays principle") **(World Bank, 2022, p. 13)**. Voluntary carbon markets responded to the mandate for carbon mitigation and trading, created by the compliance system **(Miltenberger et al., 2021; Ahonen et al., 2022; Streck, 2021; Hickman, 2016)**. In doing so, VCMs brought the potential to reach a wider range of actors and increase both carbon mitigation and other positive environmental outcomes **(Ahonen et al., 2022)**. While compliance markets are strictly for emissions mitigation, voluntary markets 'reward' the achievement of other goals *beyond* carbon mitigation, such as biodiversity outcomes **(Roman-Cuesta and Borghesi, 2022)**. These other goals have been formalised in certifications such as Verra's Climate, Community and Biodiversity (CCB) standards: as with carbon credits, they have put an economic value on often marginalised outcomes, but their complexity and fluidity have rendered these valuations particularly susceptible to inaccuracies or fraud, as will be discussed later in the chapter.

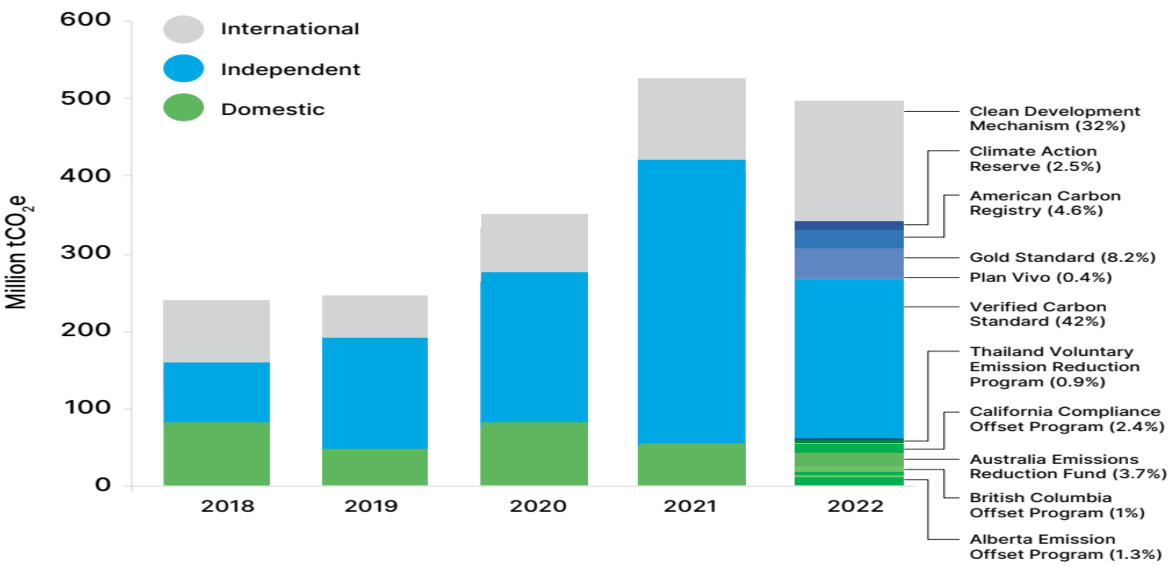
An important innovation in the Paris Agreement is Article 6, which recognises the use of carbon credits, not only between nations but also with private actors, to meet states' NDCs, including for activities beyond emissions reductions. The expansion of VCMs and the prospect of them contributing to national carbon mitigation goals has led to a crucial regulatory requirement, which has yet to be concretised: a global carbon emissions accountability mechanism that addresses the relationship between voluntary carbon mitigation, and national and global targets. VCM bodies are therefore largely in agreement that specific labels certifying corresponding adjustments (CAs) and Article 6 compatibility are necessary **(Gold Standard, 2021; Verra, 2021)**, but there is no consensus yet on whether these should be mandatory **(Ahonen et al., 2022; TSVCM, 2021; Kreibich and Hermwille, 2021)**.

KREIBICH AND HERMWILLE (2021) claim that integration between VCMs and Article 6 should indeed be mandatory, arguing that, to maintain the environmental integrity of carbon offset credits being used to achieve carbon neutrality, the offset must be registered within the project's host country's NDC, necessitating an integration of CAs. Without this structure, they warn that the market risks a 'race to the bottom' for the cheapest projects, with key social and environmental implications discussed later in this chapter. They further note that the CAs, in turn, would need to be aligned in order to avoid creating heterogeneous levels of liquidity between credits. Article 6-compliant credits would likely have stringent regulations, such as not including activities that are required by the law or that would already be economically possible/feasible (AHONEN ET AL., 2022).

While voluntary systems enable exchange between private actors, and international systems (like the CDM or the EU's Emissions Trading System (ETS)) enable exchange between states, **no structure currently exists to enable exchanges between these two types of actors in a reliable and consistent manner, leaving the risk of double counting (TSVCM, 2020) very much intact, particularly between a private actor and a host country**. However, compliance and voluntary credits are not, by default, mutually exclusive: GoldStandard includes credits that are CDM-recognised (CERs) as well as voluntary ones (VER), and Verra's Verified Carbon Standard accepts CDM methodologies (AHONEN ET AL., 2022; ROMAN-CUESTA AND BORGHESI, 2022). At COP26, it was decided that some CDM credits were eligible for helping countries to meet their first NDC targets (World Bank, 2023). At the state level these shifts are highly heterogeneous, with some states expanding the inclusion of carbon credits in their compliance systems, and others limiting them. **While private buyers rely heavily on the VCM, the supply side of carbon credits still lacks a common position** (KREIBICH AND HERMWILLE, 2021).

8.3.3 Market trends

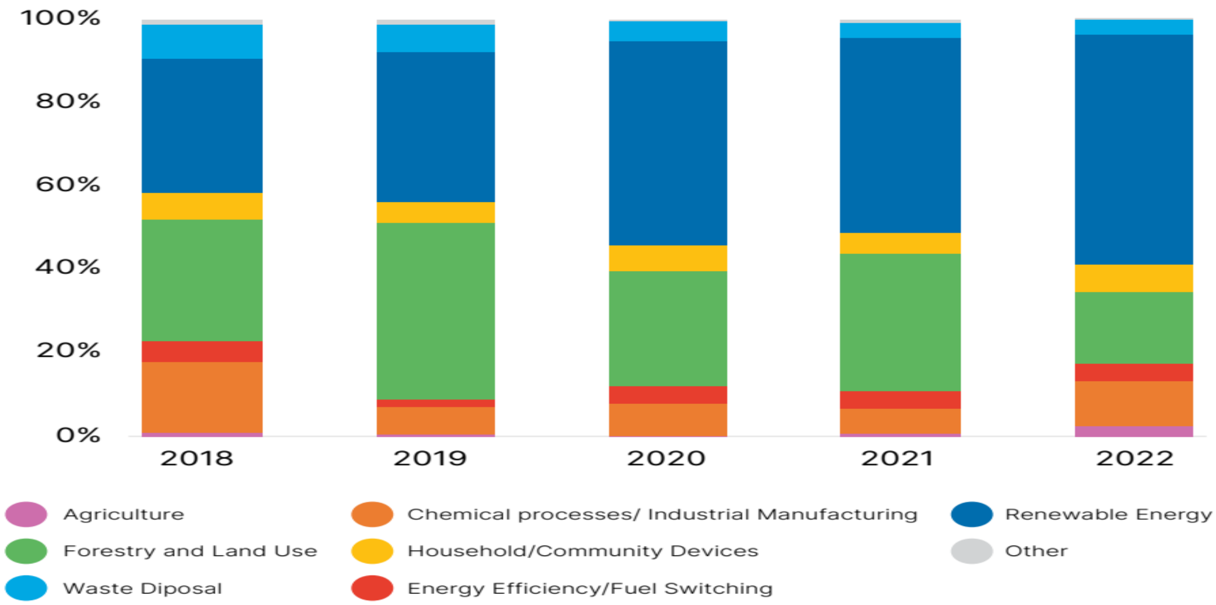
2021 saw the largest annual growth in carbon credits since 2012, a 48% increase on 2020, with both growth and absolute volumes dominated by independent crediting mechanisms (as distinct from national or international mechanisms) (**Graph 5**) (WORLD BANK, 2023). In 2021 credits issued by independent standards rose by 88%, constituting 74% of the year's total credit supply, while CDM issuances rose by 25%, constituting 11% of total issuances (WORLD BANK, 2022). However, this changed in 2022, which saw a 22% drop in carbon credits issued by independent mechanisms. Conversely, there was growth in the demand for and issuance of compliance credits, and the creation of domestic and international mechanisms in which to use them, potentially driven by progress in negotiations on compliance credits at the COP conferences (World Bank, 2023).



Graph 5 Global volume of issuances by crediting mechanism type (2018-2022). Source: World Bank (2023)

The demand for voluntary carbon credits is predominantly driven by corporate net zero commitments (energy; food, beverage, and tourism; consumer goods companies, and financial actors) **(World Bank, 2022)**. Corporate ambitions, expectations of alignment between compliance and voluntary markets, and expanding technologies and nature-based solutions led to predictions of high growth in demand for carbon credits: a 15-fold increase by 2030 and a 100-fold increase by 2050, to reach 1.5-2GtCO2 and 7-13 GtCO2 per year respectively **(World Bank, 2022)**. As shown in **Graph 5**, these predictions have not manifested immediately. 2022 saw a fall in both issuances and retirements of carbon credits. The annual World Bank report, *State and Trends of Carbon Pricing 2023*, proposes the following potential reasons for this drop: wider macroeconomic conditions resulting from global crises, renewed and tangible critiques of the efficacy of carbon credits, and administrative obstacles in verifying new projects and credits **(World Bank, 2023)**.

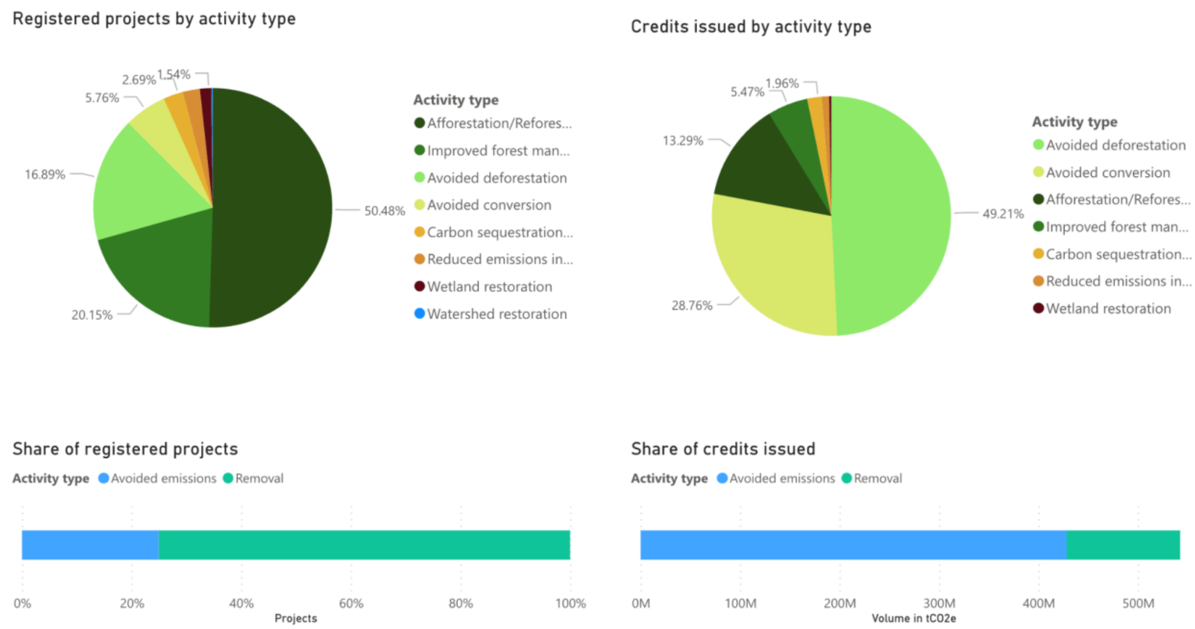
Most voluntary carbon removals and reductions come from forestry and renewable energy respectively (**Graph 6**). Renewable energy has historically dominated carbon credit supply and continues to do so (constituting 55% of credits issued in 2022, and 45% of registered projects) **(Ecosystem Marketplace (2022) in World Bank (2023))**. However, falling costs of renewable energy are making it increasingly affordable without carbon credits. This means that renewable energy projects may no longer meet the financial additionality criterion for carbon credits, and indeed some mechanisms, such as GoldStandard and the Verified Carbon Standard are already phasing out credits on renewables, allowing only those projects in least developed countries **(World Bank, 2023)**.



Graph 6 Percentage of total issuance by project category and year. Source: Ecosystem Marketplace data (2022) in World Bank (2023)

The Task Force on Scaling Voluntary Carbon Markets (TSVCM) (2021) report, too, predicts that nature-based solutions (both avoidance and sequestration) will dominate future supply. Verra's voluntary carbon credit issuances, for instance, are led by AFOLU credits and within that by REDD+ projects (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries, plus the benefits of conservation, sustainable forest management, and carbon stock measurement) **(Roman-Cuesta and Borghesi, 2022)**. However, despite this growth in demand, in 2022 retirements (i.e., 'accounting') of nature-based carbon credits fell from 36% to 23% from 2021 **(World Bank, 2023)**. A key factor, discussed in **section 8.7.5**, will be the integrity of nature-based credits, as revelations around the inaccuracies and inefficacies of several nature-based projects may have been behind the fall **(World Bank, 2023).**

Turning specifically to the agricultural sector, the Voluntary Carbon Market Dashboard on nature-based solutions (**Graph 7**, last updated on 4 May 2023) indicates a relatively small current share of projects and credits issued for carbon sequestration in the agricultural sector and reduced emissions in the agricultural sector. The dominance of forest measures (afforestation, reforestation, and forest management) aligns with the global and European data on emissions reduction trends described in **Section 8.4**. While the majority of projects are based on carbon removal, most credits issued rely on emissions avoidance. A potential reason might be the long-term nature of carbon removal technologies and the time needed to develop the appropriate measurement and certification methods. If so, this could signal an upcoming growth in credits issued for carbon removal. Secondly, avoidance projects might enable greater scale (through large-scale conservation projects) that result in a greater number of credits from a smaller number of projects.



Graph 7 Overview of nature-based solutions. Source: Bravo and Mikolajczyk (2023)

What is certain after this analysis is that the agricultural sector and nature-based solutions will play a major role in climate change mitigation in the following years, but this will happen only in conjunction with technologies and policies that will guide the sector. Indeed, as discussed in the following section, the contributions of the agricultural sector are still insufficient to be considered effective and thus need further attention and transversal efforts and VCMs can contribute to reducing the costs of climate mitigation activities.

8.4 Emissions and mitigation in the agricultural sector

8.4.1 Global

In 2018 emissions from the agricultural sector and related land use constituted almost a fifth (17%) of global greenhouse gas (GHG) emissions, according to statistics by the UN's Food and Agriculture Organisation **(FAO, 2021)**[13], marking a fall of 7% since 2000. This fall in the share of global emissions generated by the sector is predominantly (>80%) due to a fall in deforestation (high IPCC confidence), which accounts for 45% of Agriculture, Forestry and Other Land Use (AFOLU)[14] emissions **(Nabuurs et al., 2022)**. The changes in the sector's respective responsibility is also explained by the faster emissions growth of other sectors **(FAO, 2021)**.

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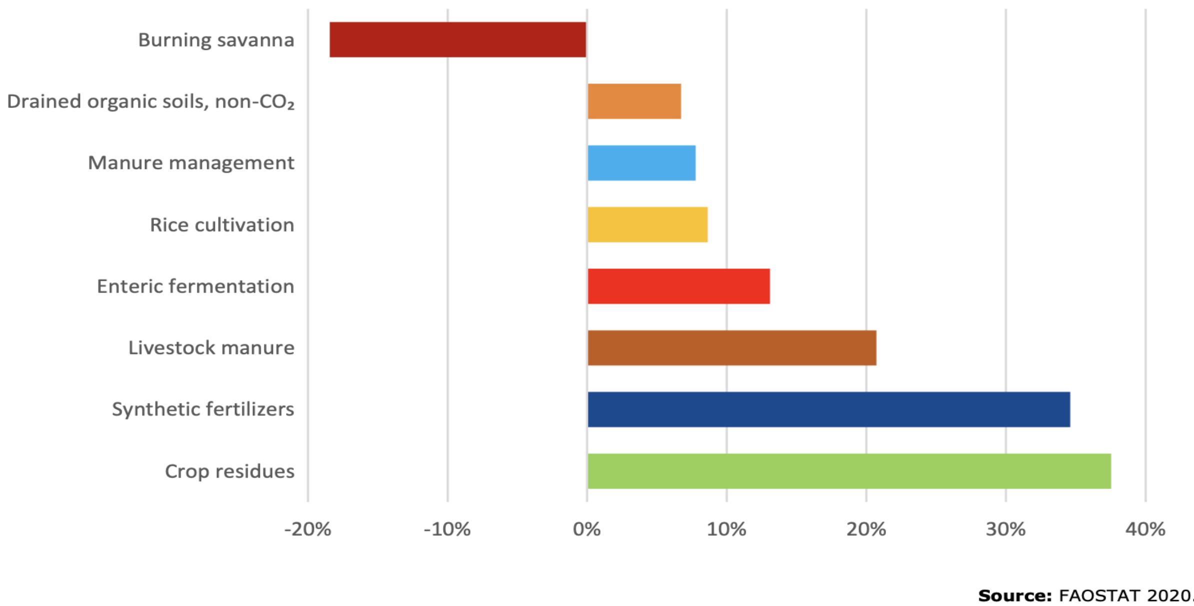
[13] This is in line with the 6th IPCC report findings, which stated that the Agriculture, Forestry and Other Land Use (AFOLU) sector accounted for 13-21% of global total anthropogenic GHG emissions in 2010-2019 (medium confidence) (Nabuurs et al., 2022).

[14] "Agriculture, Forestry and Other Land Use (AFOLU) and Land Use, Land Use Change and Forestry (LULUCF) are categories of activities defined by IPCC in the context of emissions accounting. The AFOLU category includes LULUCF and Agriculture. In the context of mitigation, 'Agriculture' – in accordance with IPCC terminology – includes emissions from enteric fermentation, manure management, rice cultivation, prescribed burning of savannas and grassland, and from soils (i.e., agricultural



Graph 8 Changes in non-CO2 emissions from crops and livestock activities, 2000-2018. Source: FAO, 2020, p. 4

While *absolute* emissions from agriculture and related land use decreased by 4% since 2000, in part attributable to the aforementioned fall in deforestation, methane and nitrous oxide emissions from crops and livestock *rose* by 14% from 2000 to 2018 **(FAO, 2021)**. Figure 4 provides a breakdown of the change in non-CO2 emissions from crop and livestock activities from 2000 to 2018. The 6th IPCC report notes that "**globally, the AFOLU sector has so far contributed modestly to net mitigation**, as past policies have delivered about 0.65 GtCO2 yr^{-1} of mitigation during 2010–2019 or 1.4% of global gross emissions (*high confidence*)" **(NABUURS ET AL., 2022, P. 751)**. The sector is an untapped source for mitigation policies. Only wind and solar energy supersede AFOLU in terms of potential abatement according to the **IPCC REPORT (2022)**, among all types of mitigation options. It must be noted that the mitigation potential is subject to several factors, including the reference technology and emissions and the rate of technological uptake **(FIGURE SPM.7, LEE ET AL., 2022)**. **Given the share of global GHG emissions contributed by the agricultural and other land use sectors, the (estimated) carbon mitigation potential of agricultural land[15], and the share of global land occupied by agriculture** (36.5% of global land area, 46% of habitable land, in 2020 **(FAO, 2021)**, **the agricultural sector offers significant opportunities for carbon emissions reduction.**

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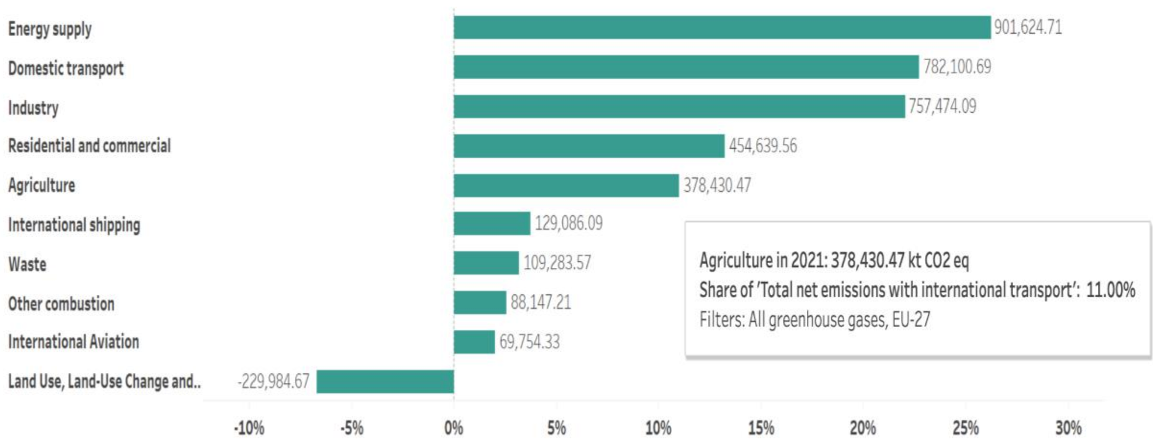
emissions). Emissions related to forest and other land use are covered under LULUCF." (FAO, n.d.) https://www.fao.org/climate-smart-agriculture-sourcebook/concept/module-a2-adaptation-mitigation/chapter-a2-3/en/

Land use change involves the conversion of land to produce food for human consumption or to produce animal feed.

[15] "4.1 (1.7–6.7) GtCO2-eq yr–1 (up to USD100 tCO2-eq–1) from cropland and grassland soil carbon management, agroforestry, use of biochar, improved rice cultivation, and livestock and nutrient management." (Nabuurs et al., 2022:)

8.4.2 The European Union

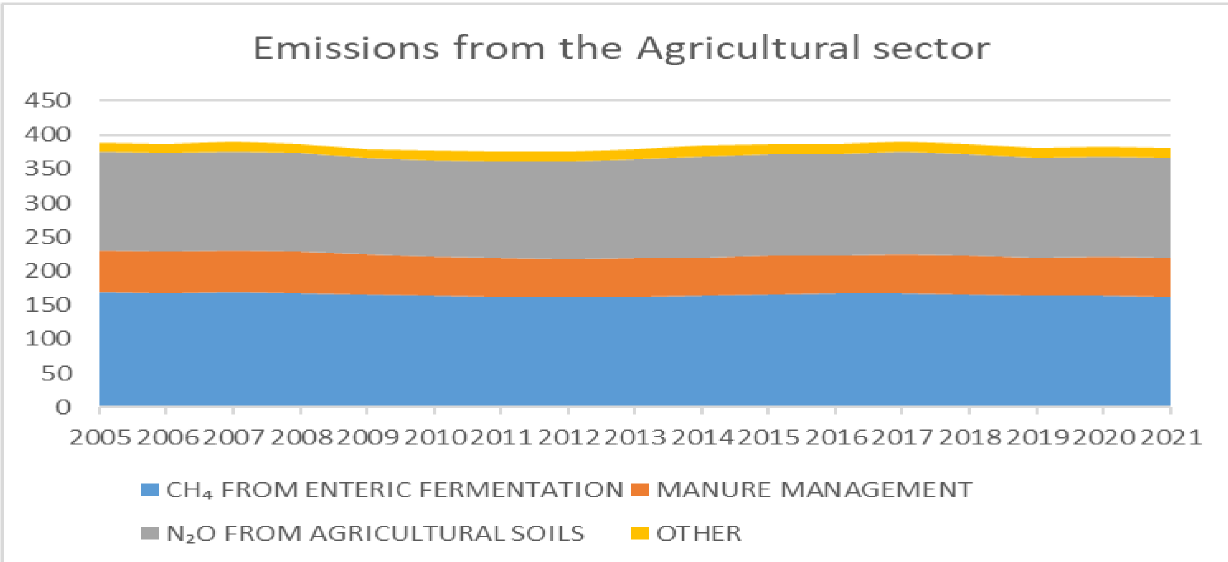
The agricultural sector contributes 11% of total GHG emissions in the EU, according to the European Environment Agency (EEA) (***Graph 9***).



Graph 9 Sectoral shares in EU-27 in 2021. Source: European Environment Agency (2021)

The European Union (EU) exhibits similar trends in agricultural sector emissions to the global ones presented above. *Non-CO2* GHG emissions from the agricultural sector in the EU have been relatively stable since 2005; the EEA notes a 2% reduction between 2005 and 2021. **At the current rate, the EEA expects only a 2% decrease in *non-CO2* emissions by 2030 compared to 2005, which could rise to 6% if currently planned additional measures were implemented (EEA, 2022), highlighting a need to develop further mitigation measures in the sector.** The statistics are slightly better if CO2 emissions are considered: the FAO finds that **Europe's overall GHG emissions from the agricultural sector declined by 8% between 2000 and 2018** (FAO, 2020).

There are three main sources of pollution in the European agricultural sector: fertilisers, mechanical equipment, and enteric digestion. 58% of emissions in the sector originated in animal activities, of which the majority comes from digestion processes. This is followed by nitrate emissions from soil management such as fertilisers that amount to 38% of the sector's emissions. Finally, less than 5% of CO2e emissions come from mechanical processes in agriculture (***Graph 10***, European Environmental Agency, 2022). The emissions are standardised in terms of CO2 equivalence, since the climate-forcing potential varies according to each gas.



Graph 10 Non-CO2 emissions from the agricultural sector in the EU. Source: Eurostat

In Europe **73% of agricultural emissions are due to crop and livestock production**, slightly above North America and Asia, but lower than Oceania, while in Africa and South America emissions are dominated by land use and land use change processes **(FAO, 2020)**. This ratio in European agricultural emissions indicates **the need for agricultural practices more efficient in terms of emissions reductions.**

8.4.2.1 European agriculture from a geo-demographic point of view

Figure 19 indicates that since 1990 **cropland has held a significant responsibility for GHG emissions from the LULUCF sector** (39.2% in 2020), followed (and only in 2016 slightly exceeded) by those from settlements (urban trees, parks, or other above-ground biomass in human settlements).

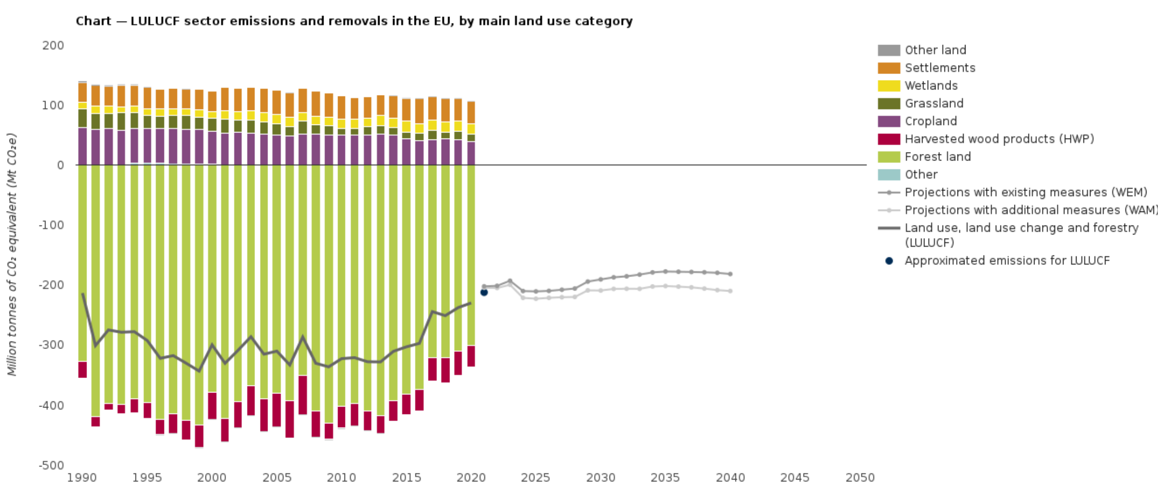


Figure 19 LULUCF sector emissions and removals in the EU, by main land use category. Source: European Environment Agency. Emissions data for each land use category are taken from the" National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism" dataset.

Farms (at utilised agricultural area (UAA), excluding wooded areas (5.9%) and other farmland not used for agriculture (2.2%)) constituted **38% of the EU's total land area in 2020** (Eurostat, 2022). **The majority of these**

farms (63.8%) were small, at less than 5 hectares, in line with the finding that the vast majority **(94.8%) of EU farms in 2020 were family farms**, i.e., where family members provide at least half of the farm's regular agricultural labour force. In terms of area coverage, land is dominated by a small number of larger farms: 68.2% of the EU's utilised agricultural area (UAA) is covered by farms that are 50 hectares or more, but these constitute only 7.5% of the EU's farms. However, the share of land held by large farms looks to be growing. While the total area of land used for farming has remained stable, **the number of farms decreased steeply (37%) between 2005 and 2020, 87% of which were small farms** (less than 5 hectares). This reduction is in part due to changes in some Member States' definitions of the minimum land area to be counted as a farm. Nonetheless, the shift is resulting in a trend towards a smaller number of larger farms in the EU, with the number of largest farms in the EU increasing.

The EU therefore presents a context in which:

- More than a third of its land is agricultural;
- The majority of this land is owned by a small number of large farms;
- The majority of farms are family-owned, and more than half are small farms;
- Agriculture contributed 11.63% of the EU's GHG emissions in 2020 and its share since 2000 has remained relatively stable;
- Emissions from the LULUCF sector have gradually increased since 2005.

The European regulations that govern these emissions will be discussed in the following section to better understand the current state-of-art and the future directions.

8.5 European regulations

8.5.1 Effort Sharing Regulation

Agricultural emissions in the EU are regulated by the Effort Sharing Regulation (ESR) **(European Council, 2023)**. The ESR sets targets for national institutions on emissions reductions in all sectors that are not covered by the EU's Emissions Trading System (ETS)[16]. The European Union has established a system of equivalence between the ETS, the ESR, and the LULUCF regulation, which governs carbon removals in the land use, land use change, and forestry sector. Under the LULUCF regulation Member States have targets for carbon removals, which are then recognised in the form of land use credits **(Böttcher et al., 2019)**.

All member states can *use* up to 262 million credits from the land use sector (131 million credits in each of the periods 2021-2025 and 2026-2030) to meet their national agricultural emissions targets. There is an even higher credit access for member states whose agricultural sector constitutes a large share of their emissions. The mechanism is based on the assumption of a lower emissions mitigation potential in the agricultural sector, and with the aim of stimulating greater action in the LULUCF sector **(European Commission, n.d.-b)**. It effectively results in an 'internal offset' system, whereby Member States can meet their ESR compliance requirements by 'offsetting' their agricultural emissions through carbon removals in the land use sector. Likewise, in reverse, Member States can compensate for sub-target LULUCF carbon removals by 'deleting' or lowering their annual emissions allocations under the ESR **(Böttcher et al., 2019)**. This integration has been strongly criticised by actors

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[16] Current Member State targets: https://climate.ec.europa.eu/eu-action/effort-sharing-member-states-emission-targets/effort-sharing-2021-2030-targets-and-flexibilities_en#:~:text=The%20Effort%20Sharing%20Regulation%20establishes,agriculture%2C%20small%20industry%20and%20waste.

warning against the dilution of climate ambitions and the unreliability of carbon sequestration in the LULUCF sector, compared with carbon mitigation **(Carbon Market Watch, 2016)**.

Furthermore, under the ESR, nine member states[17] are allowed to use a percentage of their ETS allowances, within limits[18], to offset emissions in effort-sharing sectors from 2021 to 2030. Eligible Member States are those that "have national reduction targets significantly above both the Union average and their cost-effective reduction potential, or which did not allocate any EU ETS allowances for free to industrial installations in 2013" **(European Commission, n.d.-b)**.

8.5.2 European Carbon Removals Certification (CRC) framework

In November 2022 the European Commission adopted a proposal to develop a voluntary certification framework for carbon farming **(European Commission, 2022)**, building on the Commission's and Parliament's research over the preceding years into carbon farming in the EU. The framework and its accompanying targets aim to expand the EU's shrinking land sink by 20% by 2030 to -3120Mt CO_2e **(European Environment Bureau, 2022)**. **Falconi (2023)** notes that, on the one hand, this directive offers an important change of approach towards the agricultural sector, recognising its capacity to mitigate emissions, as opposed to exclusively being a high emitter. The proposal sets out QU.A.L.ITY standards for carbon farming that aims to be accurate and effective **(European Commission, 2022)**, where the acronym stands for:

- **QU**antifiability: Carbon farming outcomes should be quantifiable
- **A**dditionality: Outcomes should be in addition to outcomes that would already have occurred through existing practices
- **L**ong-term: Carbon removals should be permanent
- Sustainabil**ITY**: Carbon farming activities should contribute to the wider sustainability of the area.

After providing the political landscape that guides the adoption and scaling up of carbon farming, in **Section 8.7** we will delve deeper into the deriving practical implications, and we will discuss how voluntary carbon markets work by presenting the actors involved and how they act and interact.

8.6 Implementation of carbon farming projects and VCMs: governance and practices

The aim of CF is to incentivise farmers to implement carbon mitigating agricultural practices through private funding provided by those entities that want to offset or compensate for their emissions. Carbon farming practices are issued via projects of removal, avoidance, and reduction of emissions. To produce carbon offsets, a carbon farming project needs to be additional (i.e., producing results that would not have happened without it),

[17] Austria, Belgium, Denmark, Finland, Ireland, Luxembourg, the Netherlands, Malta and Sweden.

Iceland and Norway are also eligible as they have agreed with the EU to implement the Effort Sharing Regulation

(European Commission, n.d.).

[18] Malta can use allowances equivalent to up to 7% of their Effort Sharing emissions in 2005. This limit is 4% for Ireland, Luxembourg, and Iceland, and 2% for Belgium, Denmark, Finland, the Netherlands, Sweden, and Norway.

permanent (long-term monitored efficiency), reliable (accuracy in mitigation calculation) and avoid carbon leakage (which would entail a failure to reduce, avoid or remove carbon) (**European Commission et al., 2021; Scheid et al., 2023; Kim and Pierce, 2018**). This means that there must be an *action* or a *change in practices* with quantifiable mitigation outcomes. Every action or change has a different mitigation potential (**European Commission et al., 2021**) and requires different assessment methodologies. In the following subsections, the types of CF projects and the relevant economic aspects of implementation will be discussed. Then, some case studies will be presented to analyse how carbon farming and voluntary carbon markets have been implemented in practice.

8.6.1 Types of carbon farming projects

There are two criteria to classify carbon farming projects: the emissions mitigation outcome they produce and the type of activity they concern. Regarding the first, there are three main alternative projects available to generate offsets in the agricultural sector: *emissions avoidance*, *emissions reduction*, and *carbon removal*. *Avoidance projects* aim to conserve forests, grasslands, wetlands, peatlands, and other natural storages of carbon from existing threats in their surrounding areas. The premise of success for such a project is that the local environment would degrade if the project (which avoids deforestation and/or degradation) were not implemented. *Emissions reduction projects* aim at changing the carbon footprint of local business models by adopting different technologies that reduce their greenhouse gas emissions, including renewable energies and rendering existing technologies more energy efficient.

Removal (or enhanced sequestration) projects actively aim at removing CO2 emissions from the atmospheric stock and can take different forms according to the nature of the instruments. For instance, they can be nature-based initiatives, which use the environment as a tool to capture emissions and store them stably for a long-term duration, such as afforestation, reforestation, forest restoration, blue carbon such as mangrove restoration, peatland restoration, soil carbon sequestration, and fire management. There are also technological solutions for absorbing CO2, including Direct Air Capture (DAC), or Bioenergy, Carbon Capture (Use) and Storage (BECCUS). These are anthropogenic measures and often intend to feed the captured emissions back into the economy in the form of input for production or material outputs.

Concerning the second criterion of classification, there is no official taxonomy of carbon farming activities. For example, the **European Commission et al., (2021)** identify the following as CF activities: peatland restoration and rewetting; agroforestry; maintaining and enhancing Soil Organic Carbon (SOC), livestock and manure management; managing SOC on grasslands. However, in New Zealand, afforestation and permanent forest management are also considered carbon farming. In this chapter, we include and refer to all activities belonging to the AFOLU sector.

8.6.2 Economic aspects of the implementation of a carbon farming project

There are several economic aspects to consider when deciding to set up and maintain carbon farming activities. In this section, the practical functioning of VCMs and CF projects will be discussed to identify the economic elements that must be taken into account to make a carbon farming activity effective and efficient in the long run.

8.6.2.1 The market: types of VCMs

Figure 20 shows how a voluntary carbon market works: it all starts from the standards used to monitor, report and verify (MRV) the project and the carbon credits created. Monitoring refers to the measure of a decrease in emissions or increase in sequestration. Reporting deals with the communication of these processes. Finally, verification is linked to the ability of third parties to verify and ensure the accuracy and truthfulness of these results. Accuracy and truthfulness can enable fair procedures and provide trust to end buyers and land owners, avoiding what we can define as "carbon grabbing," namely, claiming carbon offsetting without guaranteeing adequate remuneration to farmers and/or just treatment of the land and its inhabitants.

MRV procedures follow two approaches, which are direct measurement and modelling. While the former is more accurate but also definitely expensive, the latter refers to estimations based on proxy data and scientific relationships and has significantly lower costs. The most commonly used standards are the Verified Carbon Standard (VCS) by Verra, the Gold Standard, the Clean Development Mechanism (CDM), the Climate Action Reserve and American Carbon Registry **(KIM AND PIERCE, 2018)**. However, the quantity and geographical spread of standards create criticalities in the fungibility and traceability of carbon credits.

In general, a VCM uses the standards to organise the MRV of carbon credits that are issued by a CF project. Every project is started by project developers, which can be public, private entities, or a combination of these **(EUROPEAN COMMISSION ET AL., 2021)**. The project involves landowners or farmers who act to reduce, avoid or remove emissions from the atmosphere with the aforementioned CF activities. The farmers or landowners are paid for this emission reduction, which is sold to end buyers through financial institutions, start-ups, and private or public intermediaries, assuring that the project respects the standards. Once the carbon offset issued is claimed as an emission reduction, the credit is defined as retired.

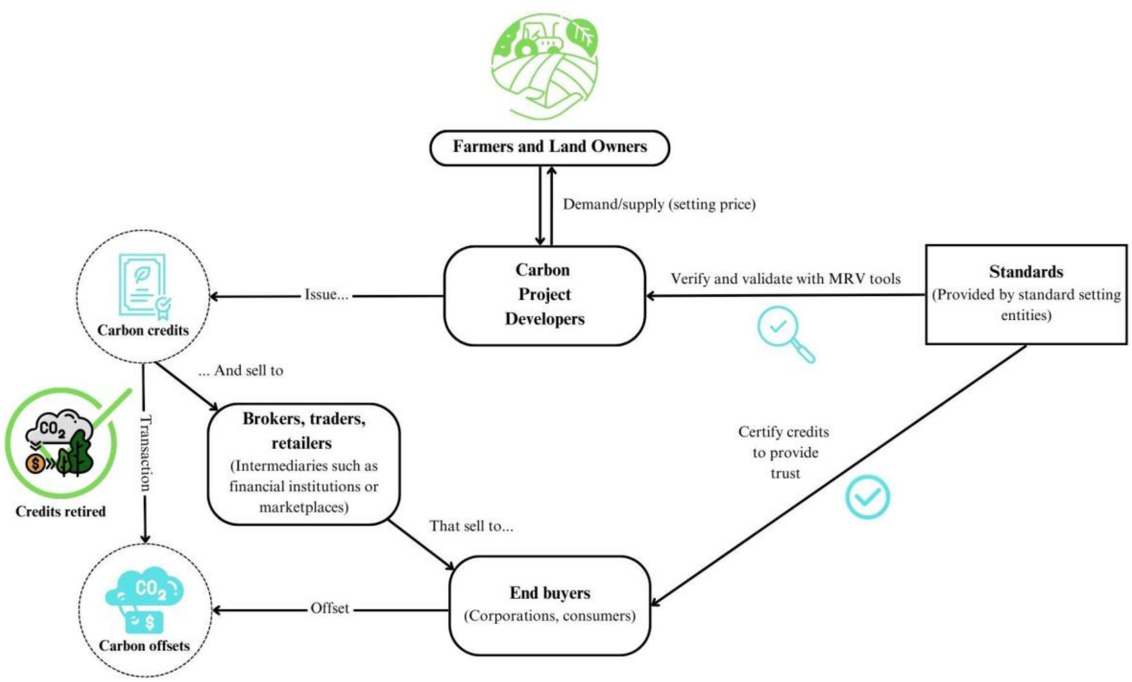

Figure 20 A mapping of the mechanisms of voluntary carbon markets. Authors' adaptation of Shen and Singh (2022) and Favasuli and Sebastian (2021)

In the literature **(EUROPEAN COMMISSION ET AL., 2021; MCDONALD ET AL., 2021)**, two main distinctions are made in the classification of VCMs. In the first place, a VCM can be *public*, when promoted and developed by a public entity (like in the case of CarbonAgri by Label Bas Carbone, in France), or *private*, when it is promoted and developed by a company or a non-profit organisation (like in the case of Moorfutures, in Germany). The second distinction is between *VCMs with an intermediary* and *exchange based VCMs*. In this case, the difference is in the intervention of an intermediary, who helps in the project development, covering the initial costs and selling credits when they are issued. The intermediary may operate a registry to track credits but remains responsible for the integrity of the credits (the case of Peatland code schemes), which are usually not fungible and tradable with other markets. In exchange based VCMs, different project developers refer to a central registry and issuer to track credits, allowing fungibility and traceability among credits coming from different sectors of CF activities (like in the Green Deal scheme in the Netherlands). The credits produce payments for farmers participating in projects, the calculation of which is explained in the following paragraph.

8.6.2.2 Payments

The ultimate economic purpose of carbon farming is to generate remuneration for farmers, i.e., their payment. Since farmers' payments depend on the environmental outcome, MRV of the level of emissions mitigation or removal **(McDonald et al., 2021)** has become a fundamental element of carbon farming projects. Payments can be of three types: action-based, results-based, or hybrid.

Action-based. Farmers receive payment for taking a specific action, for example, complying with a farming practice or implementing carbon farming technologies (nature-based or technology-based solutions, such as anaerobic digesters or nitrification inhibitors). They are relatively simple and have low monitoring requirements, both for farmers and administrators, but they have an uncertain impact on the actual mitigation deriving from the action.

Results-based. The payment depends on the quantification and verification of the mitigation outcome (i.e., the tonnes of CO2 emissions that are sequestered or not emitted), aside from the action taken. This kind of payment is more certain from an environmental point of view but is more expensive and complex.

Hybrid. These payments consist of a) guaranteed, up-front (for implementation costs or financial risk reduction) or low-risk payment for farmers for implementing specific farm management actions; b) additional payments coming from the measurement of mitigation results **(Falconi, 2023)**. This last model can lower risk and provide flexibility to farmers, providing real results against climate change. The box below summarises the advantages and disadvantages of results-based carbon farming mechanisms, which have been adopted in the EU's proposed carbon removal certification mechanism **(European Commission et al., 2021, p. 17)**:

Advantages of a result-based scheme for carbon farming:

- flexibility for the farmer – encouragement of adaptability, innovation and entrepreneurship;
- clearer link between payment and carbon impacts for buyers – higher credibility/appeal and potential for higher additionality;
- carbon impacts are an objective, and not a side-effect of sustainable agriculture – potentially higher effectiveness;
- lower adverse selection of parcels with lower yields by farmers (i.e. with lower opportunity costs);
- educational role for farmers and wider society.

Challenges and limitations of a result-based scheme for carbon farming:

- potential higher financial risks/uncertainty for farmers;
- potential higher transaction costs for developers;
- challenges related to monitoring, reporting and verification of climate mitigation results (costs, degree of reliability/robustness);
- challenges of ensuring additionality and of securing permanence of the carbon impacts;
- the time needed for change in reliable measurements is potentially long, and in some cases the change is appreciable only after the project life span;
- higher flexibility given to farmers also means that strong advisory support needs to be built into scheme design; however, capacity or resources for this may be lacking.

8.6.2.3 Costs

Every project development involves costs. The literature analysed (McDonald et al., 2021; European Commission et al., 2021) shows that the uncertainty and costs of MRV, which are decisive when deciding to start a CF project, vary according to different CF sub-categories (managing peatlands, soil carbon on mineral soils, agroforestry, and livestock and manure management) *(***Table 14**).

Table 14 Costs and uncertainty of sub-categories of carbon farming. Source: McDonald et al. (2021)

Carbon farming sub-category	MRV		
	Type of monitoring	Uncertainty	Costs
Managing peatlands	Modelling	Medium	Medium
	Measurement	Low-medium	Very high
Soil carbon on mineral soils	Modelling	High	Medium
	Measurement	Medium	Very high
Agroforestry	Combined	High	High
Livestock and manure management	Modelling	Medium	Low-medium

Looking at **Table 14**, only measurement in peatland carries low-medium uncertainty. This is because open-air measurements are extremely difficult, and scientific research is still working on developing precise and scalable methods to allow the quantification of emissions reductions. High costs are also due to this limitation and constitute a significant obstacle to implementation.

The costs can be borne by administrators or by farmers and depend on the phase of the project (set-up or ongoing). These are summarised in the table below, taken from the work of McDonald et al. (2021).

Table 15 Set-up costs and ongoing costs for administrators and farmers in a voluntary carbon market. Source: McDonald et al. (2021)

Actors	Set-up costs	Ongoing costs
Administrators	Mechanism design Scientific research/data collection Baseline setting and validation Outreach and training	Monitoring and verification Mechanism administration Funding*
Farmers	Learning costs Baseline setting* Implementation costs	Implementation costs Opportunity costs Transaction costs*

*costs that can be borne by administrators or farmers, depending on the mechanism design.

Set-up costs are usually fixed costs. For this reason, they will generally be lower in larger mechanisms or when considering existing data and research, and higher in more complex mechanisms that involve new on-site measurements. As can be seen in ***Table 15***, these costs concern:

- Mechanism design, which refers to the development of the methodology and all operating and governance regulations (this will be expanded upon in the following section);
- Scientific research and data collection, which consists of methodologies for appropriate calculations of local mitigation;
- Baseline setting and validation, which is the cost of setting farmers' baselines such as sampling or consultant visits (that can be borne by farmers or administrators) or the validation of new participants or projects (borne only by administrators);
- Outreach and training, which from the administrators' point of view, are the costs of attracting farmers, and from the farmers' point of view, are the costs of learning new skills and knowledge;
- Implementation costs that farmers bear to implement carbon farming actions, such as buying technologies and equipment, planting trees, or rewetting.

Ongoing costs are variable: they can increase when the number of farmers participating in a project is higher, unless economies of scale are implemented, or when there is high complexity, which leads to higher administrative costs. Moreover, transaction costs for farmers also depend on MRV requirement levels: they may be expensive and thus unbearable for small farms.

This is a particular issue where mechanisms require on-site visits and sampling to measure baselines and changes in, e.g., soil carbon stocks. This varies considerably according to the carbon farming mechanism model: Label bas Carbone CarbonAgri estimates that the cost of consultant site visits is €2000 per farm every five years; GoldStandard projects face between USD 67,500 and 87,500 of verification, validation, and registry costs in the first five years (European Commission et al., 2021); and the LIFE CarbonFarmingScheme (McDonald et al., 2021) estimates project validation, verification, and market registration costs of €110,000-240,000 within the first five years. In addition to reducing net benefits, these high MRV costs can mean that only large farms or farmers can participate in high-MRV mechanisms.

8.6.2.4 Case studies

The lack of regulation and the wide range of CF activities give project developers the opportunity to structure VCMs with different combinations of elements. For example, some projects may use MRV standards promoted by registries (like VCS by Verra); others may develop and use their own methods and models; some may act locally; and others may be international, resulting in different prices and mechanisms. For these reasons, transparency and comparability among projects are hindered and lead to three main issues: i) both sellers and buyers may encounter obstacles in selecting the projects to participate in (an obstacle resolved by the intermediary); ii) the scalability of VCMs is complicated; iii) there is high uncertainty over actual emissions reduction.

When project developers or intermediaries use the same standards, these issues are more under control. This is witnessed, for example, by the Berkeley Carbon Trading Project, a research project aimed at assessing the effectiveness of carbon offset projects to support programme design. The project's outcome is a dataset containing all the carbon offset projects, credit retirements and credit issuances belonging to four major registries, which are Verra (VCS), Gold Standard, American Carbon Registry (ACR) and Climate Action Reserve (CAR) (So et al., 2023). Every registry uses their own certified methodology, increasing standardisation among projects within a registry and, consequently, comparability and transparency. However, when a project does not refer to one of those registries, the aforementioned issues (obstacles in selecting project, hindered scalability and high uncertainty) persist. Moreover, even though the four registries generate almost all the world's voluntary market offsets, the map provided by Berkeley's project shows that there is a high concentration of projects in India, U.S. and China. Our desk research, mostly focused on Europe, shows instead that the growing interest in political agendas towards CF and VCM is increasing the number of local VCMs developing their own methodologies and mechanisms.

In order to test comparability among projects that do not necessarily follow registries' standards, we reviewed seven VCMs (summarised in **Table 16**) that were not included in Berkeley's list. We took information coming both from desk research (project's websites and informational material) and from the literature **(McDonald et al., 2021; European Commission et al., 2021; Scheid et al., 2023)**. As expected, all projects use different methodologies and comparability is limited.

Table 16 Case studies, elaboration of the authors

Project Name	**Scope**	**VCM Type**	**Reduction/ removal**	**Methodology**	**Country**	**Management (trademarked by)**	**Total credits issued (tCO2-e)**	**Price (per tCO2-e)**	**Sources**
Moorfutures	Peatland rewetting	Intermediary - Public	Reduction and removal	VCS Kyoto Protocol	Germany	State of Mecklenburg Western Pomerania"	69,000 (by 2060)	€40-80	McDonald et al. (2021)
UK Peatland Code	Peatland rewetting	Intermediary - Public	Reduction	Independent validation for each project.	UK	Executive board on behalf of IUCN UK National Committee	6,268,139	£15-25	Scheid et al. (2023)
CarbonAgri (Label Bas	Livestock and manure	Intermediary	Reduction and	LCA &	France	Ministère de la Transition	137,000	€40	https://www.france-

Carbone)	management	- Public	removal	CarbonAgri CAP'2ER®		Écologique			carbon-agri.fr/page-1/
Acorn	Agroforestry	Intermediary - Private	Removal	PlanVivo	The Netherlands	Rabobank	236,091	€31	https://acorn.rabobank.com/en/
Life Carbomark	Afforestation	Intermediary - Public	Removal	IPCC VCS	Italy	Veneto Region, Department for Forest and Mountain Economy	350	€35	https://www.lifegoprofor-gp.eu/best-practice/104/ita
Permanent ForestNZ	Afforestation (permanent forests)	Intermediary - Public (the VCM is public, NZ ETS)	Removal	Permanent Forest Sink Initiative (PFSI)	New Zealand	Consultancy company	3,000,000	$80	https://www.permanentforests.com/
New Zealand Carbon Farming	Afforestation (permanent forests)	Intermediary - Public (the VCM is public, NZ ETS)	Removal	Permanent Forest Sink Initiative (PFSI)	New Zealand	Consultancy company	27,256,670	$80	https://nzcarbonfarming.co.nz/

8.7 Policy and governance challenges

The policy and governance challenges of voluntary carbon markets extend from the transnational level to the project level, and arguably even more so in the agricultural sector. Internationally, policymakers have yet to determine if and how to connect binding emissions reductions and accounting with offsets on the voluntary carbon market. Within the market, there are significant market imbalances, with actors' mitigation ambitions exceeding the supply of projects to enable these mitigations, the supply of projects/credits exceeding real demand for them due to the lack of obligations to use them, and the issuance/demand for credits exceeding their eventual accounting or 'retirement'. These imbalances are exacerbated by the sheer fragmentation of the market across several scales, registries, and certifications, leading to opacity in prices and efficacy. Carbon farming can offer co-benefits for ecosystems and societies but can equally have severe socioeconomic and environmental negative externalities, even more so in agriculture, given its role as the foundation of natural and human systems. Inadequate knowledge and transparency, preparation, safeguarding, and local rootedness have resulted in projects that either have limited positive impact or even do harm, adversely affecting the integrity and impact of VCMs. This section details these challenges before proceeding to discuss potential policy responses. It provides a specific focus on the challenges of the EU's Carbon Removal Certification (CRC).

8.7.1 International governance

As explained in Section 8.3, the transnational policy arena currently faces the challenge of how to navigate the interaction (or lack thereof) between voluntary credits and nationally determined contributions (NDCs) under the UNFCCC.

Kreibich and Hermwille (2021) outline three international policy alternatives that emerge:

1. Not aligning voluntary credits with NDCs: leaving the current blurred lines between what does and doesn't constitute NDC progress and not enabling the voluntary market to build on emissions reduction ambitions.
2. Corresponding adjustments: this is likely to lower the demand for voluntary credits but raise their long-term quality, integrity, and benefit for states' decarbonisation
3. An additional certification or label for NDC-contributing projects: this is infrastructurally difficult as it entails creating a new product, but it could offer reputational benefits for companies, and address the market sector that is sceptical of carbon offsets' environmental integrity.

At the national level, if CAs are to be pursued, states need bilateral agreements and strong public policy positions that render them obligatory, both by host countries and credit issuers.

8.7.2 International market actors and imbalances

There are three structural imbalances. First, actors often *promise* levels of emissions reduction and offsets that exceed the availability of projects to meet these goals **(Miltenberger et al., 2021; Kreibich and Hermwille, 2021)**, leading to a perception of progress that exceeds capacity. Discussions at the COP27 conference paid particular attention to the need for greater accountability and transparency in non-state actors' targets and claims **(World Bank, 2023)**. The second imbalance concerns *actual demand* and supply. Despite the growing demand for carbon credits, supply continues to exceed demand, as actors are not universally obliged to meet certain reduction targets.

Lastly, the third imbalance is a result of carbon credit retirement being far below their issuances. Data on VCMs that focuses only on issuances therefore paints an unrealistic picture of the real amount of carbon mitigation **(So et al., 2023)**. After a carbon credit has been traded, it must eventually be **retired**, i.e., removed from the market and accounted for in the buyer's targets or obligations. A credit can only be retired once the carbon removal, avoidance, or mitigation has taken place. Credits issued from projects that have already been completed can be retired immediately. Credits issued from projects that are currently underway cannot be retired until the carbon farming outcomes have been achieved. The rate of *retirement* of carbon credits is therefore far below the rate of their *issuance* (see **Graph 6** above and **Figure 21**). For example, just over half of the issued offsets are retired in the case of Verra and just under half for GoldStandard **(Roman-Cuesta and Borghesi, 2022)**. The key issue emerges in terms of how these are labelled and reported. In the absence of specific labelling and accounting mechanisms, some actors make sustainability claims that have not in reality been fulfilled or, returning to the first imbalance, that cannot be fulfilled. As long as this prevails, the integrity and validity of the mitigations, both in terms of amount and quality, remain uncertain.

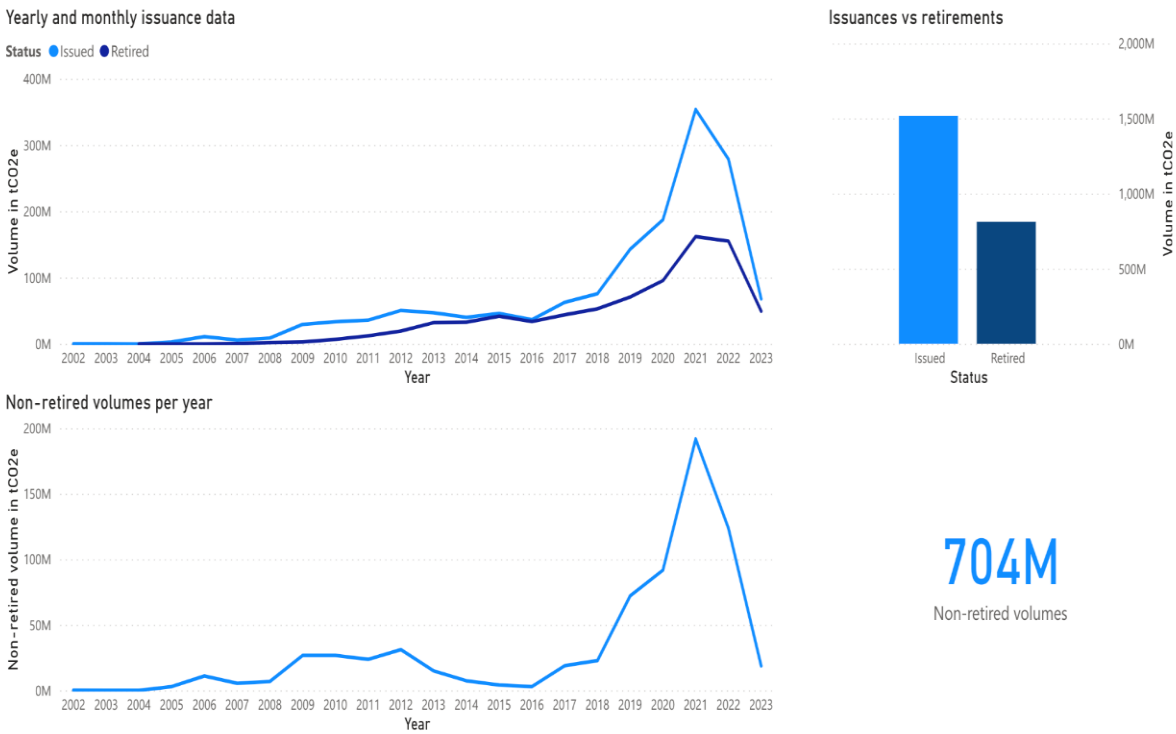

Figure 21 Voluntary carbon credit issuances on versus retirements as of 4 May 2023 Source: Bravo and Mikolajczyk (2023)

There is thus a triangulation of **ambitions that exceed the supply of projects and credits**, a **supply of credits that exceeds the demand for them**, and a **demand for credits that exceeds their rate of retirement**. A further layer of complexity is that, although the infrastructure is not in place to match the current stated commitments, **the level of commitments themselves fall short of the Paris targets** **(Kreibich and Hermwille, 2021; World Bank 2023)**. These challenges apply both within the voluntary and compliance sectors, as well as at their intersection **(Michaelowa et al., 2019)**.

8.7.3 Heterogeneity and fragmentation

Carbon emissions reduction or offset projects can be expensive due to the costs of the technology and materials required and the MRV or intermediary services needed to obtain certifications, maintain environmental integrity, or operate on the market. This creates the first layer of fragmentation, i.e., the at times prohibitive costs of participating in a VCM. The constant evolution of the sector and the appearance of new taxonomies and definitions threaten the possibility of developing a high-quality market infrastructure capable of attracting investments and new actors, especially at the local level. This has been a recurring issue in carbon markets, starting from the early days of the CDM, which was flooded with new offset projects. Unstable climate policies can seriously affect the climate and market efficiency of VCMs and damage both local communities and the environmental performances of companies. Standardisation and unifying certification can play an important role in stabilising the market, granting more transparency, and guaranteeing a sustainable business model **(World Bank, 2023)** for the agricultural sector. The EU's CRC is a step in this direction but is currently very much at a nascent stage, with the first expert group meeting only taking place in the first quarter of 2023.

Project heterogeneity in terms of technology, geography, methodology, rigour, and type, creates a lack of market transparency that renders it difficult to determine what the 'true' or 'fair' market price is **(Chen et al., 2021)**. Without clear and consistent verifications of the integrity of a project, credits can be sold without any guarantee of a carbon reduction impact. Markets include projects implemented in the past that had less stringent, or absent, evaluations of their methodologies and impacts, and transactions in which a project developer risked being underpaid due to incomplete information on the current fair market value of carbon removals (Spilker and Nugent, 2022). As discussed above, intermediary platforms for carbon credits can create greater standardisation and reliability between their projects. At the same time, a proliferation of separate platforms or registries (as we are seeing now (World Bank, 2023)) can create fragmentation in its own right.

Furthermore, fragmentation between market structures, regulations, and jurisdictions is a key driver of double counting. Double counting can take two main forms. The first involves the carbon mitigation being simultaneously counted towards the mitigation requirements (compliance) of *two* actors. This leads to greater net emissions, as both actors claim mitigations and act accordingly. The second form is when the mitigation is counted towards compliance for one actor, and towards carbon neutrality by another actor. This need not necessarily result in greater emissions but can do so indirectly by causing a relaxation in carbon mitigation ambitions (based on assumed progress on compliance) and an increase in demand for high-carbon products (based on assumed neutrality) (Kreibich and Hermwille, 2021).

8.7.4 Measurement and quality

It is not yet clear how to quantify removals in a way that is affordable, accurate, and locally relevant, given the high costs of direct measurement and the geographical variability of models; what constitutes, and how to ensure, sufficiently long-term removals; and how to measure co-benefits such as those for society or biodiversity. Measurement and modelling to determine carbon mitigation outcomes can be costly and, moreover, suffer from the initial challenge of determining the baseline from which to measure additionality and permanence (Michaelowa et al., 2019; Chen et al., 2021; World Bank, 2023). LULUCF sector projects are particularly susceptible to miscalculating baselines and or 'overcrediting' (World Bank, 2023). Static baselines estimate the discrete GHG stocks of a project, while dynamic baselines consider the impacts of extreme weather, climate, and other natural risks and fluctuations. Carbon can be re-released due to human-induced reversals such as changes in ownership, policy, or market dynamics (European Environmental Bureau, 2021, Miltenberger et al., 2021). The fundamental challenges of determining baselines and additionality in line with local environmental practices, understanding real carbon removals, and taking into account fluctuating social and political situations that alter what is a 'given' and what is 'avoided' are central to enabling credits that genuinely contribute to carbon mitigation. The European Environmental Bureau (EEB) (2021), which was involved in extensive research into the prerequisites for effective carbon farming through soil management, finds the CRC severely lacking in terms of clarity on the permanence of carbon storage and related liabilities and on how to accurately monitor and report carbon farming activities. Furthermore, the EEB highlights and critiques the inclusion of emissions reductions *as part of* carbon removal certifications instead of distinguishing between reductions and removals.

8.7.5 Integrity and impact

From a climate perspective, most VCM initiatives and organisations providing support (e.g., the Task Force on Scaling Voluntary Carbon Markets (the TFSVCM), the Science-based Targets Initiative, and the Oxford Principles for Net Zero Aligned Carbon Offsetting consider offsets as an auxiliary measure to assist companies in building a carbon-neutral economy. Furthermore, emissions abatement and decarbonisation should be the primary concern for polluting companies, while offsets should reduce the hard-to-abate forms of emissions. Market actors – including project proponents, programme administrators and buyers – generally recognise that carbon credits are only helpful in achieving net zero targets if they have environmental integrity and, more specifically, if they distinguish between mitigation action that leads to emission reductions from compensatory carbon removals that address unabated emissions. Otherwise, they do not function to reduce corporate emissions, but instead result in greenwashing (Yu, 2020), where companies prefer to pay for their emissions rather than acting on abating them but make claims of carbon mitigation or neutrality (World Bank, 2023).

It can be cheaper and far less disruptive to buy external offsets, but it defeats the mitigation goals and breaks the trust in corporations and organisations, bringing with it reputational damages. As a result, many companies prefer to buy high-quality carbon removal credits – credits representing carbon dioxide that is removed from the atmosphere and stored either in the biosphere (e.g., in forests, soil or the oceans) or in geological formations, rather than credits representing avoided emissions. Achieving these high-quality returns to the aforementioned challenge of accurately measuring actions while keeping the mechanism accessible and affordable. In 2022 a journalistic investigation (Greenfield, 2023) shed light on the invalidity of the majority of Verra's rainforest offset credits, which dominate the global market for forestry offsets. Whether due to malevolence, structural opacities, or insufficient grounding in local and scientific knowledge and practices, these at best cast doubt on the credibility of VCMs, and at worst cause real environmental and social damage. Lee et al. (2018) found that, unlike in the compliance market, stringent regulations or standards do not guarantee strong credit transaction performance on a voluntary registry, which raises concerns about how to simultaneously ensure high standards and increase demand. The EEB criticises the implied link between the proposed CRC and the inclusion of offset credits sold on voluntary carbon markets, highlighting the risk of actors not truly reducing their emissions, despite claiming to do so. The resulting risk of 'greenwashing' has been brought to the forefront of policy dialogue with the 2023 proposal for a European 'Green Claims' directive, which obliges actors to explicitly distinguish between their own GHG mitigations and those from offsets, and between emissions reductions versus carbon removals, with more stringent and clear methodologies for all mitigation methods (European Commission, 2023).

8.7.6 Social externalities and co-benefits

The development of VCMs has profound local implications. While VCMs risk having the aforementioned negative outcomes, they can also bring co-benefits in terms of positive social and environmental externalities such as job creation, conservation and biodiversity protection, and achieving local community goals such as preserving and sustainably managing their forests. Co-benefits consider the non-market values of VCMs. Lee et al. (2018) found that the presence of co-benefits makes voluntary carbon credit transactions more appealing, suggesting that their integration will be a lasting integral element of the VCM. This tendency is in part corrective, responding to discoveries that many carbon offset or removal projects compelled indigenous or local people to leave their land, or destroyed local biodiversity, resulting in both social and environmental harm. Streck (2021) argues that the risks of the VCM can be managed if the VCM complements government regulatory action. Furthermore, the author specifically highlights the essential role of local communities, especially given the current distribution of VCMs largely consisting of western organisations funding projects in economically poorer countries. This dynamic leads at times to a neo-colonial appropriation of materials and labour (Beymer-Farris and Bassett, 2012) for the purposes of one's own carbon declarations, the aforementioned 'carbon grabbing'. On the derivatives market, the CME Group's futures trading in carbon credits currently requires projects to possess specific additional co-benefit labels, such as Verra's CCB label (Spilker and Nugent, 2022). Streck (2021) emphasises the potential for public-private partnerships to develop the accuracy and legitimacy of registries' metrics and labels for co-benefits.

Falconi (2023) calls for greater clarity and alignment across directives on the use of farmland for renewable energy and farmland for carbon farming, to avoid competing claims on farmers' resources. The EEB (2022) critiques the lack of alignment between the CRC and related European targets and policies, namely the Nature Restoration Law, the Biodiversity and Forestry Strategies and the Land Use, Land Use Change and Forestry

(LULUCF) Regulation, and the absence of provisions to prevent land grabbing or negative social externalities, which must be integrated to enable a sustainable and socially and environmentally just policy structure.

In conclusion, the emerging European policy landscape appears to be:

- **Driving carbon farming and removal practices;**
- **Reshaping the role of agricultural actors, through carbon farming and other environmental practices like renewable energy and biodiversity conservation;**
- **Creating a network of regulations that target interconnected issues (biodiversity, social justice, and carbon mitigation), but without these necessarily being formally connected or harmonised;**

A formal recognition, but not an encouragement, of offsets, namely their inclusion in the CRC, with the requirement for them to be used far more stringently and declared transparently, given their uncertainty and risks.

8.8 Policy responses

A crucial element of knowledge fragmentation is the range of potential policy responses to tackle governance challenges, from the project level to the transnational level (**Table 17**). This section integrates proposed policies and responses to core challenges in VCMs from the policy papers and guides, most of which were developed in preparation for the EU's carbon farming directive.

Table 17 Potential responses to policy challenges in governing voluntary carbon markets; authors' elaboration

Challenge	**Policy responses**
Ambitions exceeding capacity	Mandatory science-based targets for ambitions, declarations, and offset usage (Kreibich and Hermwille, 2021; Miltenberger et al., 2021)
Greenwashing	Prohibiting the use of carbon removal certificates in place of emissions reductions; public disclosure of GHG emissions; linking credits to mitigation evidence; a social licence for firms to operate (EEB, 2022; Miltenberger et al., 2021).
Price uncertainties	Price guarantees by organisers; alignment with EU carbon pricing mechanisms and adjustment to national costs of living (European Commission et al., 2021; EEB, 2022).
Compliance credits	Prohibiting the inclusion of offsets/removal credits from the LULUCF sector in the compliance market; increases in compliance LULUCF targets to account for offsets bought by actors on the VCM; explicit links between domestic standards and national and local climate targets; mechanisms that enable interoperability of VCMs and compliance systems to mitigate the risk of VCMs oversupplying the market (EEB 2021; 2022; Cevallos et al., 2019; Miltenberger et al., 2021).
Uptake	Involvement of farmers in the creation of VCMs; ongoing knowledge and practical implementation exchange and support; environmental technologies for monitoring and decision making; explicit, binding emissions reductions targets for the agricultural sector; financial and administrative benefits for smaller farmers; not rendering carbon farming mandatory; ex-ante credits (European Commission et al., 2021; EEB, 2021; Demeyer et al., 2021; Miltenberger et al., 2021; McDonald et al., 2021; Cevallos et al., 2019).

MRV costs	Environmental monitoring and decision-making technologies; dedicated public funds for improving climate and carbon farming models (Miltenberger et al., 2021; EEB, 2021).
MRV heterogeneity	Emphasis on local knowledge and locally appropriate monitoring data to enable systems to be scaled; multidisciplinary teams for MRV and planning; environmental monitoring and decision-making technologies that increase rigour and scope (European Commission et al., 2021; Miltenberger et al., 2021).
Baselines and carbon mitigation additionality	'Individualised' baselines and associated local additionality demonstrations, with a discount applied to projects that use cheaper national baselines and additionality and that have greater windfall risk; dynamic baselines that take into account natural risks, climate fluctuations, and human-induced reversals through buffer pools; project-wide due diligence; meta-governance bodies: and blockchain (Cevallos et al., 2019; Miltenberger et al., 2021).
Financial, social, or cultural additionality	Multiple funding streams; allowing small projects to apply for group certification of financial, social, or cultural additionality, to enable them to share the administrative and economic burden (while legal certifications must be done separately for each project); diversification of third parties involved in validation and verification (Miltenberger et al., 2021; Cevallos et al., 2019).
Permanence	Hybrid action- and results-based models that mitigate against the risk of non-delivery; allowing shorter-term permanence in regulations; 'no deterioration' obligations for carbon stocks; only certifying high-quality removals (McDonald et al., 2021; Miltenberger et al., 2021; EEB, 2021; 2022).
Enabling co-benefits and limiting negative externalities	General sustainability requirements (in line with the SDGs, Global Standard for Nature-based Solutions or project or regional criteria); transparency and scientific evidence requirements; mandatory stakeholder involvement; lists of permitted/prohibited lands and practices with associated requirements; monitoring tools and policies; multiple payments (Scheid et al., 2023: EEB, 2021; McDonald et al., 2021; Miltenberger et al., 2021).

While many of the policy responses are either complementary or are alternative methods of achieving the same aim, some key governance tensions emerge, namely:

1. Whether or not to render carbon farming or agricultural emissions mitigation mandatory;
2. Whether or not to integrate voluntary carbon market credits into compliance markets;
3. Whether to make permanence requirements more or less stringent.

The above divisions are foundational questions of the governance of voluntary carbon markets. However, the policy responses do offer clarity on certain aspects:

1. Firstly, local actors must be at the forefront of the creation of voluntary carbon market projects, for their rights as local communities, their knowledge of local ecosystems, and their role in maintaining the project.
2. To enable this, actors (especially the small and family farms that dominate the EU landscape) must receive ongoing guidance to navigate the policies and be supported by administrative and financial incentives. The European Environmental Bureau (2021) defines this distinction as collaboration rather than commodification, i.e., involving "actors across supply chains or in regional partnerships [in the] longer term, and [combining] monetary reward and knowledge exchange" (EEB, 2021, p. 25).
3. This collaboration must involve safeguards for farmers, communities, and their ecosystems, based on scientific expertise, transparency, and land rights laws.

4. Just as safeguards must be built into the system, so must co-benefits be integrated from the outset. This entails pursuing carbon farming not merely as a quantification or commodification of carbon, but rather as a nature-based solution, focusing on integrating social benefits, biodiversity, and resilience through ecosystem restoration **(EEB, 2021; 2022)**.
5. This means harmonising a policy and ecological system that integrate obligations, accounting, and social and environmental objectives.
6. To achieve this at a global level, harmonisation must occur not only within given contexts but also internationally, requiring a strong stance on corresponding adjustments. Leading actors in the VCM field have trialled forms of 'meta-governance', such as the Integrity Council for the Voluntary Carbon Market (ICVCM), the International Carbon Reduction and Offset Alliance, and the Offset Quality Initiative **(Ahonen et al., 2022; Hickman, 2016)**. Ethical, independent, and transparent governance at all levels is essential for enabling a just implementation of VCMs.
7. Lastly, voluntary carbon markets must only *supplement* dominant funding from the public and private sector (outside the carbon market): a successful VCM is one which increases rather than weakens emissions reductions, and which eventually becomes obsolete.

8.9 Conclusion: directions and implications

There is growing research on the role of the financial sector a) in climate finance and funding carbon mitigation technologies **(World Bank, 2023)** and b) in the financial derivatives market for carbon credits (Spilker and Nugent, 2022). The current state of futures contracts provides an indication of significant faith in voluntary carbon markets, both in terms of higher prices and longevity **(Spilker and Nugent, 2022; World Bank, 2023).** However, the involvement of financial actors can entail speculative, and at times manipulative, behaviour where real environmental and social impacts are at stake. Furthermore, as we have seen in this chapter, catalysing carbon pricing need not be positive, if prices are too low, projects are ill designed or monitored, offsets replace real mitigations, or accounting and reporting are flawed. Shifts in regulation, such as the International Financial Reporting Standards Foundation's guidance on climate disclosures for public companies, the Green Claims Directive, Environmental, Social, and Governance regulations, or new mechanisms designed to protect against negligence and fraud have the potential to move the sector in the right direction **(World Bank, 2023).**

Following negotiations at COP26 and COP27, two regulatory mechanisms are underway: one for accounting for ITMOs, and another for credits generated through Article 6 that can be used for domestic carbon pricing, voluntary action, or results-based climate finance **(World Bank, 2023)**. These will have implications for carbon credits in the agricultural sector, setting out the potential benefits for project owners, and potential international support for contexts worst affected by climate change.

There is still a long way to go to make VCMs reliable, as emerges from our review of the extant literature and existing case studies. Many policy issues need to be addressed. In this regard, **Kreibich and Hermwille (2021)** pose some of the fundamental questions that policy needs to study, incorporate, and regulate:

- How do nations align carbon offsetting with NDCs that should already be the "highest possible ambition"?
- How do we avoid offsets being used to entrench further long-term emissions, e.g., building highly efficient coal power plants?
- How do we address the risk of lowering emissions based on current levels, but locking in emitting industries and technologies and their consumption?

- Are offsets being used simply as an excuse for high-carbon activities and taking the attention away from low-carbon innovation (e.g., oil and gas companies continuing to look for new reserves)?

Crucially, in designing and implementing voluntary carbon markets, it is imperative to recognise the transitory, auxiliary nature of these systems. The aforementioned phasing out of carbon credits for renewable energy projects is an example of this, i.e., ceasing to operate when they no longer serve an additional environmental gain. While emissions from ESR sectors in the EU have fallen since 2005, emissions from sectors in the ETS have fallen more steeply **(EEA, n.d.).** This reinforces the role of voluntary carbon markets operating as an interim, top-up policy in addition to real emissions reductions. Furthermore, their ultimate goal must be environmental impact, not the market itself. Given the challenges of measurement, validity, and integrity explained above, VCMs must be approached with cautious optimism: as mechanisms that can contribute to furthering emissions mitigations, if formally linked to national and transnational obligations, while bringing financial support for farmers, and co-benefits for the surrounding society and ecosystems. However, without international cooperation on linking mechanisms, stringent regulations on quality, putting local communities and ecosystems at the forefront, and on-the-ground support to develop accurate baselines and support for farmers, VCMs risk becoming a mere abstraction of emissions mitigation that can be harmful, both locally and globally.

Policy therefore needs to turn to governance frameworks for community-managed common pool resources, as proposed by **Miltenberger et al. (2021, p. 4):** "wider inclusion of stakeholders, adaptive management, and fairly allocating cost-benefits… to transform VCMs from market arrangements that abstract GHG values to resource management that integrates their value". Specifically in the context of agriculture and land use, where nature-based solutions are central (and predicted to lead the market in the near future, as discussed above), practices and structures must rely on an in-depth, systems understanding of the biodiversity, climate, and community relationships that live and breathe around the carbon cycles that can so easily be reduced to a label.

The present chapter is among the first to offer an introduction to the key market, emissions, and policy developments that shape the field at this crucial juncture. Furthermore, we collect and provide two key elements that thus far have not been consolidated: an overview of the nature of lesser-known voluntary carbon markets,, and a synthesis of policy recommendations in response to the challenges of VCMs. We therefore hope that this up-to-date guide will support practitioners and policymakers in understanding the current international and European policy and governance landscape, potential and weaknesses of VCMs, and the range of available recommended policy responses. Further research will be needed in the future to build solid theoretical foundations and provide robust empirical evidence to the policy debate in the field.

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9 From Skills to Sustainability: The Potential of Green Jobs and Digital Transition

9.1 The World Energy Employment report: tracking energy employment to ensure good quality jobs in the net zero

Authors:

Enel Foundation

International Energy Agency

The inaugural edition of the World Energy Employment (WEE) report **(IEA, 2022)** – published in September 2022 by the IEA with the support and analytical contribution of Enel Foundation – is the first comprehensive inventory of the global energy workforce. It provides, with unprecedented granularity, a snapshot of employment across the entire energy value chain. The report aims to be an essential resource for energy and labour policymaking in the coming years, especially for policies related to the just transition of workers out of fossil fuel industries in decline, and cultivating the workforce needed in growing clean energy industries.

The study looks at energy employment across three main segments: fuel supply (coal, oil, gas, and bioenergy), power sector (generation, transmission, and distribution) and end-uses (vehicles manufacturing and energy efficiency for buildings and industry). The report also estimates the distribution of energy workers across different traditional economic activities to give a picture of the full energy value chain ranging from raw materials; software, IT, data, and business services; manufacturing of equipment; construction; operation, repair, maintenance; transport, distribution, and delivery. The study also looks at the skill level of workers (high, medium, and low), based on the ISCO-08 classification used by ILO and on the education level.

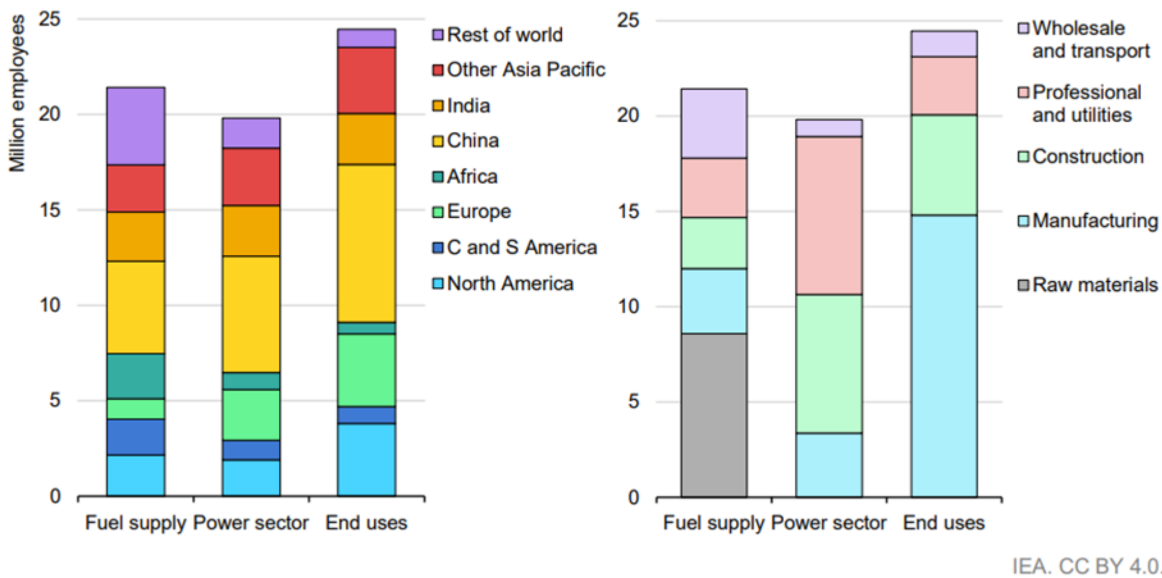
In terms of methodology, the WEE uses IEA energy investment and spending data, data on energy production and consumption, power capacity and electricity generation, as well as technology stocks and sales as the basis to estimate global employment. These modelled estimates are calibrated against official labour statistics to ensure accuracy. Finally, estimates are tested with companies within IEA's Energy Business Council, peer reviewers, academics, industry groups and international organisations (such as the International Monetary Fund and ILO). In addition, interviews were conducted with firms in the energy space to check the modelling results and gather narratives in the industry. The report assesses energy employment in 2019 to avoid the labour impacts caused by the Covid-19 pandemic.

9.1.1 Energy employment trends, 2019-2022

The WEE report shows that over 65 million people were employed in the energy and related sectors in 2019, accounting for almost 2% of formal employment worldwide. As of 2021, the report estimates over **half of the energy workforce is employed in clean energy technologies**, reflecting the rapid build out of new clean energy infrastructure**. Virtually all the growth in the energy workforce since the pandemic has been in clean energy segments.** Energy sector employment in 2019 is divided approximately into thirds among fuel supply, the power sector, and energy end-uses.

Energy jobs are greatest in regions that are rapidly expanding their energy infrastructure and use. The total number of employees employed per unit invested or energy unit produced is higher in regions with lower prevailing wages, where more people are employed for the same overall costs. Jobs are also concentrated in energy manufacturing hubs and producer economies (***Graph 11***). Accordingly, China has the largest number of energy workers, near 20 million (around 2.5% of the total workforce in the country), whereas in the Middle East and Eurasia, the energy workforce makes up a relatively higher share of economy-wide employment, averaging 3.6%. North America has 7.9 million workers in energy, equivalent to 3.4% of total employment; Europe has 7.5 million workers in energy, or 2.4% of total employment).

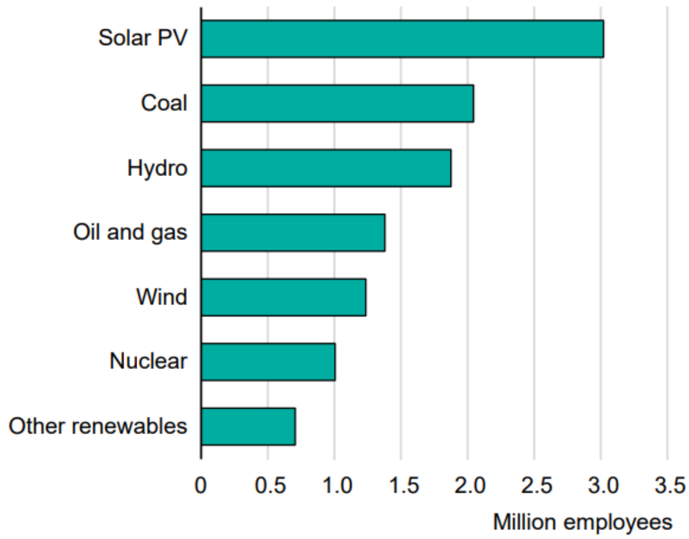
The energy jobs worldwide cover the entire energy value chain and encompass different economic activities. Those working in the production of raw materials, which includes mining and extractive sectors for fuels and agriculture for the production of bioenergy, total over 8.5 million. In the mining sector in particular, energy workers make up 15% of global employment. Over 21 million energy sector employees work in manufacturing and approximately 15 million are in construction, making up 5-6% of their respective sectors. An estimated 14 million work in utilities and other professional services. Other types of jobs, such as wholesale traders and energy transport, make up the balance (***Graph 11***).



Graph 11 Energy employment by region and supply chain step, 2019. Source: IEA, 2022, World Energy Employment.

9.1.2 A focus on power sector

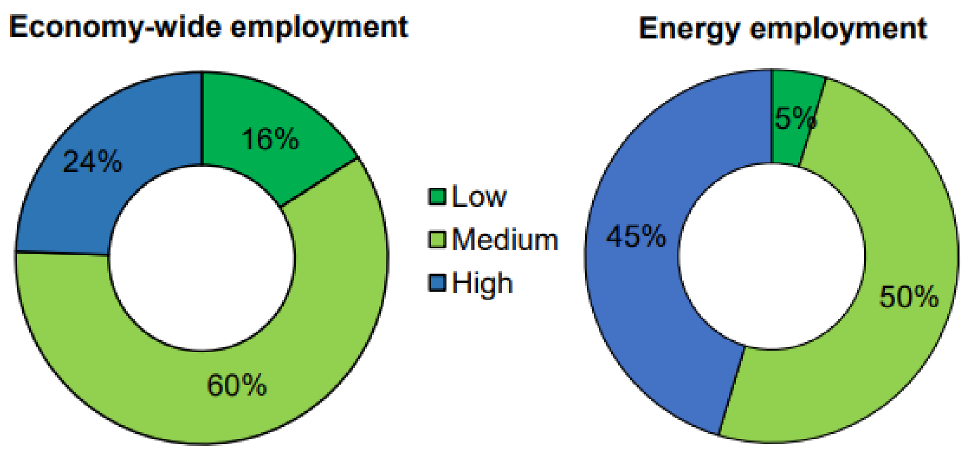
Power generation employs 11.2 million worldwide, of which 6.8 million are in renewables. The power sector has the potential to reshape global energy demand and supply through the electrification of end-uses combined with the ongoing transition towards low-emissions sources of electricity. Power generation employment totalled 11.2 million in 2019, comprised of 3 million in solar PV, 2 million in coal power, and 1.9 million in hydro. Wind power, including onshore and offshore, employed 1.2 million and nuclear power 1 million. Oil and gas employed 1.4 million workers. Employment in other renewables totalled some 710 000 employees (***Graph 12***). Over 60% of workers are employed in the deployment of capacity additions, while the other almost 40% work in the operations and maintenance (O&M) of existing facilities. Overall, power generation employment includes 2.6 million workers in manufacturing transformers, turbines, compressors, and solar panels, 4.0 million in construction (i.e. building power plants, dams, mounting systems), 3.8 million employed in utilities and in professional roles such as project finance and procurement and 0.8 million in wholesale and trading.



Graph 12 Employment in power generation by technology, 2019. Source: IEA, 2022, World Energy Employment.

9.1.3 Skills in the energy sector

The energy sector demands more high-skilled workers than other industries, with 45% of the workforce requiring some degree of tertiary education, from university degrees to vocational training certifications. The percentage of low-skilled labour is also lower than in other sectors. Low-skilled workers are more common in Emerging Markets and Developing Economies, as is the prevalence of informal workers (**Graph 13**).



Graph 13 Global employment by skill level, 2019. Source: IEA, 2022, World Energy Employment.

A granular analysis of the skills required in the energy transition provides a better understanding of how employment in the energy sector will evolve. In many parts of the energy sector there are **concrete possibilities to successfully redeploy highly skilled workers from traditional energy sectors to emerging clean energy sectors.** This includes workers within engineering, procurement & construction (EPC) firms to build clean energy assets, workers in oil and gas to clean fuel production, HVAC specialists to heat pumps installation and servicing, and car manufacturers to EV production. This can help limit the amount of training required to meet growing demand for skilled labour in clean energy sectors, which **grow in all IEA scenarios.** This is also confirmed by the surveys conducted within the framework of this study, where three quarters of the clean energy companies surveyed replied that they plan to hire new staff in the next three years (2022-2024), while the remaining ones had already hired substantially in recent years. Companies interviewed that operate both in the renewables and conventional energy sectors mentioned they do not plan to lay off staff in the coming few years.

On the other hand, the interviews also revealed that the growing demand for workers with increasingly specific skills in the energy sector can, however, become a concern for companies as it is not matched by an adequate supply. Many firms interviewed said they faced a very competitive environment for hiring candidates with the requisite skill sets. This was particularly true for skilled workers in construction, where many countries already face strong hiring challenges. This is followed by high-skilled workers in the fields of science, technology, engineering, and mathematics (STEM), followed by project managers and other technical roles. The energy transition, indeed, require a more intensive use of STEM skills with respect to the past and in particular to jobs in traditional energy sectors **(POPP, D., ET AL., 2022)**. Companies also expressed concern about the high turnover of workers with the most in-demand competences, which has increased throughout the Covid-19 pandemic.

In order to avoid these and other potential bottlenecks due to the fact that specialized workforces are not on tap, it becomes necessary acting along the following directions:

1. **Energy transition-ready vocational and educational programmes.** Private companies are best placed to train and upskill their workforce based on market and technological developments. Yet, educational programmes promoted and sustained by partnerships between public institutions and private companies can ensure all *curricula* keep pace with technology and regulatory evolution of the energy markets. It is indeed important for academia to have a greater awareness of the skills required by the clean energy labour market. This will also help address the STEM skills shortage. Indeed, secondary schools can play a key role in the career and university orientation for new graduate students. Universities, on the other hand, can refine their curricula according to the knowledge and skills required for the energy transition.

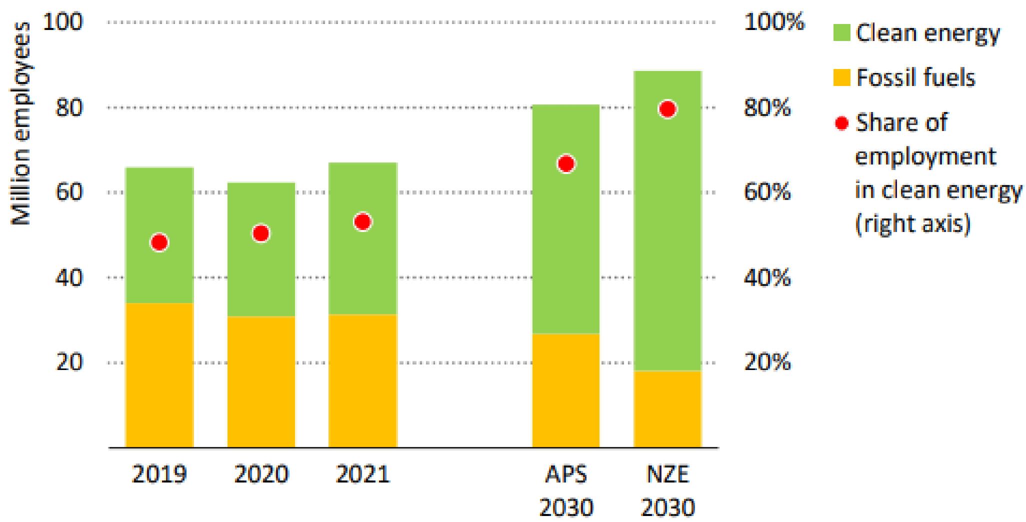
2. **Well-crafted training programmes that build on existing certification schemes**. These programmes should be designed taking into account the needs of the local labour markets and delivered in cooperation with players along the entire value chain. Furthermore, targeted training programmes are more effective than broad training programmes, which is why a granular analysis of data on the specific skills required in the clean energy sector is essential.

3. **Involvement of the unions.** Enabling the co-designing proper collective bargaining arrangements where international labour standards, as well as diversity and inclusion aspects, have been taken into the right consideration. In addition, labour transition plans have been a successful policy measure adopted by most of the companies surveyed.

9.1.4 Energy employment in 2030

Finally, it is worth mentioning that, starting with the 2019 global employment data provided in the WEE report, the World Energy Outlook 2022 **(WEO 2022)**, analyses the employment impacts in two scenarios: the Announced Pledges Scenario (APS) where all announced climate pledges were met on time and in full, and the Net Zero Emissions (NZE) by 2050 Scenario, which is consistent with limiting global surface temperature warming to 1.5 °C by 2050. In the NZE Scenario, total energy investment more than doubles to 2030, driving up the demand for skilled workers across the energy sector. Energy employment expands to almost 90 million in 2030 from around 65 million today (**Graph 14**). Job growth in the APS is less dramatic, but energy employment still reaches 80 million in 2030. Fossil fuel supply jobs decrease by 7 million by 2030 in the NZE Scenario, with coal supply seeing the sharpest decline as mechanisation and decarbonisation efforts lead to further downsizing of the coal industry, but in both scenarios job growth more than offsets a decline in traditional fossil fuel supply sectors.

The power sector leads the way in the NZE Scenario in terms of job growth to 2030, with around 9 million additional jobs in power generation complemented by 4 million new jobs in power grids and electricity storage. Employment opportunities related to solar PV and wind power increase by around 10% each year to keep pace with steady growth in capacity additions, while power grids maintain 4% annual employment growth thanks to rising electrification rates and new investment in grid upgrades and expansion. Employment also increases substantially in vehicle manufacturing and in businesses concerned with improving the efficiency of equipment, industry, and buildings.



Graph 14 Projected growth of energy employment. Source: IEA, 2022, World Energy Outlook.

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9.2 Enhancing the Digital and Green Transitions: National Observatories and Targeted Reskilling for Policy Action

Authors:

Dr. Laura Cavalli, FEEM

Edward Cruickshank

In the journey towards a sustainable future, policymakers are confronted with the intertwined challenges of the digital and green transitions. This chapter explores two critical components that illuminate the way forward: the task-based approach for understanding the skills landscape of green jobs and the establishment of National Observatories for the Digital Transition.

The first part illustrates the significance of a task-based methodology in comprehending the skill requirements of green occupations, highlighting the need for a nuanced definition and the identification of essential skill sets. By understanding the distinctive characteristics of green jobs, policymakers can devise targeted retraining and reskilling policies that empower communities facing the disruptive impacts of transitioning to low-carbon industries.

The second part, on the other hand, highlights the pivotal role of National Observatories in driving the digital transition. These observatories serve as powerful tools for analyzing the multifaceted dynamics of digitization, identifying areas of improvement, and fostering inclusive and sustainable digital transformations. By exploring the following sub-sections, policymakers can glean insights into how task-based insights and national observatories can synergistically propel the digital and green transitions, forging pathways to a more sustainable and prosperous future.

9.2.1 Risks and opportunities of the Green Economy's jobs: a task-based approach

The transition towards a low-carbon economy raises questions around the potential effect on the demand for different types of skills in labour market, beyond the energy sector alone. Yet, accurately understanding and measuring what characterises green jobs vis-a-vis traditional jobs remains a challenge. The definition of a green job can vary depending on the industry and the context. For example, a job in renewable energy production is clearly related to environmental objectives and can be identified relatively easily in existing schema, while a data analyst for a transportation company that is trying to figure out where the largest source of emissions that they produce comes from may only be indirectly related. Therefore, although the ILO has its own definition **(ILO, 2016)**, a working definition of green jobs that captures all these nuances and that is applicable across all sectors still lacks.

Following the task-based approach proposed by **Autor et al. (2003)**, **VONA et al (2018)** propose a methodology to identify skills prominent in green occupations. By using O*NET data, they have been able to: first, distinguish jobs having a significant share of green specific tasks over total tasks; and second, specify the sets of general skills also associated with these jobs. The aim was to evaluate the similarity of labour skills across occupations, in order to understand whether there are any skills differences for employees who are more prone to displacement due to environmental regulations.

The main conclusion of the authors is that the task-based approach provides the most reliable and accurate estimate of the real size of green employment. Moreover, they found that the difference in skill sets between green jobs and brown jobs among the same occupation groups is generally small, although there are exceptions for specific sectors: for example, in the construction and extraction sector green engineering skills are becoming increasingly important; however, these sectors include also workers in the oil and mining industries, and these differences are of relevance for climate policy. In addition, the study suggests that the two most characterising sets of skills of green jobs with respect to traditional jobs are: engineering skills for design and production of technology, and managerial skills for setting up and monitoring environmental organisational practices.

However, in a recent application of the methodology which aimed to characterise trends of low-carbon jobs in the US, the authors found that the cost of reallocating workers in communities that were historically reliant on fossil-fuel industries will be higher: in fact, limited overlap between locations where low-carbon job creation is happening and where job destruction is more likely to be concentrated is detected **(Saussay et al. 2022)**. Therefore, in order to support a successful and just transition, distressed communities will require specific retraining and reskilling policies that are tailored to their location.

The methodology presented here, easy to be replicated and flexible, could be used as a toolkit for policymakers to design targeted retraining and reskilling policies within green deal packages.

9.2.2 Proposal for the creation of national observatories for the digital transition

In 2021, The European House - Ambrosetti, in collaboration with Fondazione IBM and Fondazione Eni Enrico Mattei, launched the Observatory on the Digital Transformation of Italy, a centre aimed at analysing both the structural and context-specific dynamics of digitization in Italy.

The need for an Observatory on digital transition in Italy finds two major justifications: on the one hand, Italy lags behind in the digitization of citizens, public administration and businesses (especially SMEs) as indicated by the country's low ranking on the DESI index (18th out of 27 EU countries in the DESI Index and last among the large economies of Europe); this delay is mainly due to structural deficiencies regarding digital skills, connectivity and data sharing. On the other hand, the digital transformation of production activities represents a unique opportunity for the country to boost its productivity and thus the growth and competitiveness of the country, which have all been stagnant for the last two decades.

However, the underlying goals of the Observatory are more far-reaching, and their rationale extends outside national boundaries. Indeed, the real novelty of the Observatory is the attempt to explore those aspects that are not fully captured by traditional digital indicators and to draw future scenarios and identify the best strategies in order to support and accelerate the ongoing transition according to ethical, inclusive and sustainable principles. Moreover, there are at least two other reasons that puts the digital transition at centre of the political agenda of every European country: the twin transition (i.e. the interconnected nature of the green and digital transitions) and the strong investments towards the digital mission of European National Recovery Resilience Plans (NRRPs).

The twin transition is at the core of the European Union strategy to guarantee sustainable growth, ensure innovation and mitigate the impact of climate change and environmental degradation. If the implicit potential of the interconnected nature of these two transitions were properly exploited, it would help to reduce Europe's carbon footprint and meet emissions targets, which are key priorities for the EU, by transitioning to renewable energy and reducing energy consumption through digital technologies. Indeed, the digital transition can enable the green transition by providing the necessary tools and technologies, such as smart grids, energy management systems, and digital platforms for tracking and reporting emissions. The digital transition also enables to improve energy efficiency and increase the integration of renewable energy sources into the grid. At the same time, the Twin transition can also drive economic growth and create jobs in the EU: the shift towards a green economy can generate new business opportunities and jobs in areas such as renewable energy, energy efficiency, and sustainable transportation; similarly, the digital transition can drive innovation and create jobs in areas such as software development, data analytics, and e-commerce.

The EU recognizes that the digital transition is a key driver of economic growth and competitiveness and its commitment to “a Europe fit for the digital age” is also demonstrated by the heavy investments towards digitization. In fact, 21% of all the funds of the NextGenerationEU (NGEU) must be channelled towards digital related actions. By investing in digital technologies such as 5G networks, artificial intelligence, and the Internet of Things, the EU aims to support the development of new business models and increase the productivity of existing industries. On top of this, investments in digitization would be one way to address the economic and social challenges brought by the COVID-19 pandemic. For example, the NGEU aims to support the digitization of small and medium-sized enterprises (SMEs) and the acceleration of the shift to e-commerce, which can help businesses adapt to the new economic reality, as well as the roll-out of high-speed internet in rural and remote areas, which can help bridge the digital divide and improve access to education, healthcare, and other services. Finally, the EU also sees the digital transition as an opportunity to enhance the EU's strategic autonomy in the field of technology and reduce its dependence on third countries.

The creation of National Digitization Observatories can become a useful tool to serve and direct policy makers in addressing the ethical, inclusiveness and sustainability challenges of the digital transition through the analysis of national Key Performance Indicators and the creation of strategies to direct policy action. This would imply the establishment of roundtables with expert groups and the launching of nationwide surveys to delve deeper into the digitalization-related changes taking place in organizations, the strategies adopted and the related impacts, including industry-specific approaches. Greater European collaboration and standardization in data collection activities related to digitization in areas where there is less data availability may also be promoted.

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10 Climate responsibility, eco-anxiety, and perception about governments

Authors:

Leonardo Becchetti, University of Rome "Tor Vergata"

Francesco Salustri, Roma Tre University & UCL

10.1 Introduction

10.1.1 Individual actions for the environment: key for the transition, still costly

Climate change is notoriusly cause by human activities and, therefore, citizens-driven actions to modify their behaviours and fight climate change represent an essential part of a complex solution. The International Energy Agency has recently recommended the transition to a circular economy, the adoption of low-emission technologies, the substitution of fossil fuels with renewable or nuclear energy sources, the promotion of sustainable mobility alternatives, and the replacement of fossil fuel boilers with heat pumps, among other measures **(Bouckaert et al., 2021)**.

Changing behaviour, however, may be costly at both individual and collective level. Environmentallly reponsibile actions may be more expensive, longer to implement, and they may require coordination among citizens. However, people may also play a pivotal role in facilitating the success of the necessary transition through their consumption and investment choices.

Given the importance of responsible consumption and investment, also highlighted by the Goal 12 of the Sustainable Development Goals, a large body of the literature has explored the determinants of individuals' willingness to pay for environmental sustainability. Among the socio-economic characteristics, not surprasingly education and social capital have been found as key drivers. More specifically, **Kalkbrenner and Roosen (2016)** have shown that trust, social norms, and environmental concerns have a positive influence on individuals' willingness to participate in energy communities. To further understanding environmentally respoinsible actions, empirical evidence has focussed on the link between declared willingness to act for the environment and their actual behavior. While earlier studies have found that stated willingness to pay overestimates actual willingness to pay **(Brown et al., 1996; Seip and Strand, 1996)**, more recent studies using experimental methods indicates that the two measures do not substantially differ **(Carlsson and Martinsson, 2001; Zabkar and Hosta, 2013)**.

10.1.2 Citizens-driven solutions as a multiplayer prisoner's dilemma

The citizens-driven solutions to the climate thread can be model as a multiplayer prisoners' dilemma, where people can choose whether to act responsbilty, this choice may be costly, and all citizens and the environment will benefit from higher number of responsbile actions. As strategic interactions, people make ecological choices based on what they know about other people choices. An insightful characterisation of games which model climate negotiations has been provided by **DeCanio and Fremstad (2013)**. The authors highlight the conditions that may make the climate problem similar to a prisoner's dilemma or a coordination game. A similar apporach has been followed by **Becchetti and Salustri (2019)**, who modelled environmentally responsible choices using a social dilemma framework and discussing key variables that let mutually responsible actions constitute a Nash equilibrium. Other research have also used a game theoretic approach: for instance, **Magli and Manfredi (2022)** emphasised the inherent prisoner's dilemma nature of ecological interactions when short- and long-term preferences do not match, and ALVAREZ ET AL. (2019) have used cooperative game theory to inform prevention and management strategies of river flooding risks.

Our analysis relies on the model as in BECCHETTI AND SALUSTRI (2019) and aims at empirically test whether eco-anxiety and confidence in other governments effort to fight climate change have an impact on personal responsibility towards climate change. The prisoner's dilemma hypothesis predicts that self-interested people are more likely to free ride should other actors behave pro-environment. According to this hypothesis, if people beliefs other governments are acting well against climate change, their personal responsibility should be low. Similarly, if people are worried about climate change, they shold feel themselves more responsible to act ecologically.

The rest of the analysis is structured as follows: the second section explains the methodology, with a description of the dataset, and the econometric model adopted for our study. The third section illustrates the results of our analysis. The last section concludes.

10.2 Methods

10.2.1 Theretical model

10.2.1.1 Data

We use the data from the 10th round of the European Social Survey (ESS Round 10). These data collect information on a representative sample of adults living in Europe about their attitudes towards the environment. The sample includes approximately 32,000 respondents located in 19 countries and the relevant variables for our analysis are captured by the answers to the following questions:

1) Responsibility: "to what extent you feel it is your personal responsibility to reduce climate change?" (From 0 = not at all to 10 = a great deal);
2) Eco-anxiety: "how worried are you about climate change?" (Not at all worried, very worried, somewhat worried, very worried, extremely worried);
3) Governments: "how likely governments in enough countries take action to reduce climate change" (0 = not at all likely, . . ., 10 = extremely likely).

In addition to these key variables, the dataset also collects several socio-economic characgteristics, such as sex, age, income, education, job status, marital status, and houshold size of the respondent. Moreover, the survey asks a set of questions regarding preferences and satisfaction (namely, political preferences, whether people have voted in the last election, health satisfaction, and income satisfaction), and we also exploit this information for our analysis. The interviews have been conducted betwee n 2020 and 2022.

10.2.1.2 Descriptive statistics

Figure 22 shows the distribution of our variables of interest. The large majority of the respondents feel responsible for reducing climate change (**Figure 22 , A**) and anxiouse about climate change (**Figure 22 , B**). Differently, the responsibility of other governments is almost normally distributed (the variable has been recorded into 0-4, 0-7, or 0-10 likert scale for different countries and has been normalised into 0-10, and this explains the lower observation for the mid-value 5).

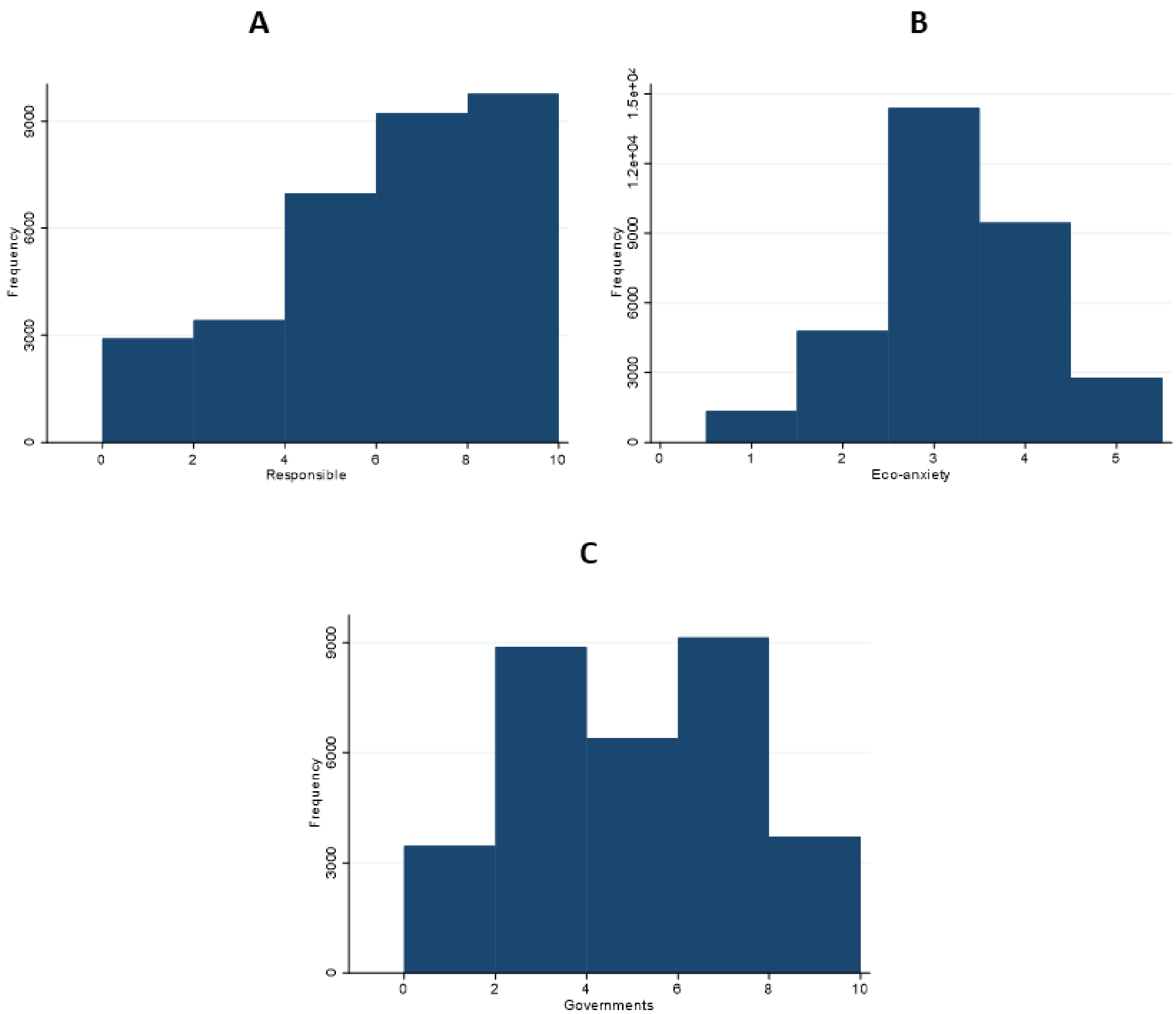

Figure 22 Distribution of Responsibility, Governments, And Eco-Anxiety

Figure 23 shows the average values fo our variables of interests by country. Responsibility displays a large heterogeneity, with people in France and Switzerland feeling more respoinsible and people in Montenegro, North Macedonia, and Czech Republic feeling less responsible, on average. The other variables show less heterogeneity overall, with some differences between the extremes, though. People in Greece and Hungury believe more than those in Switzerland that other governments are acting enough to reduce climate change. With respect to econ-anxiety, Portugal and Slovenia have the highest values and Estonia and Slovakia have the lowest ones.

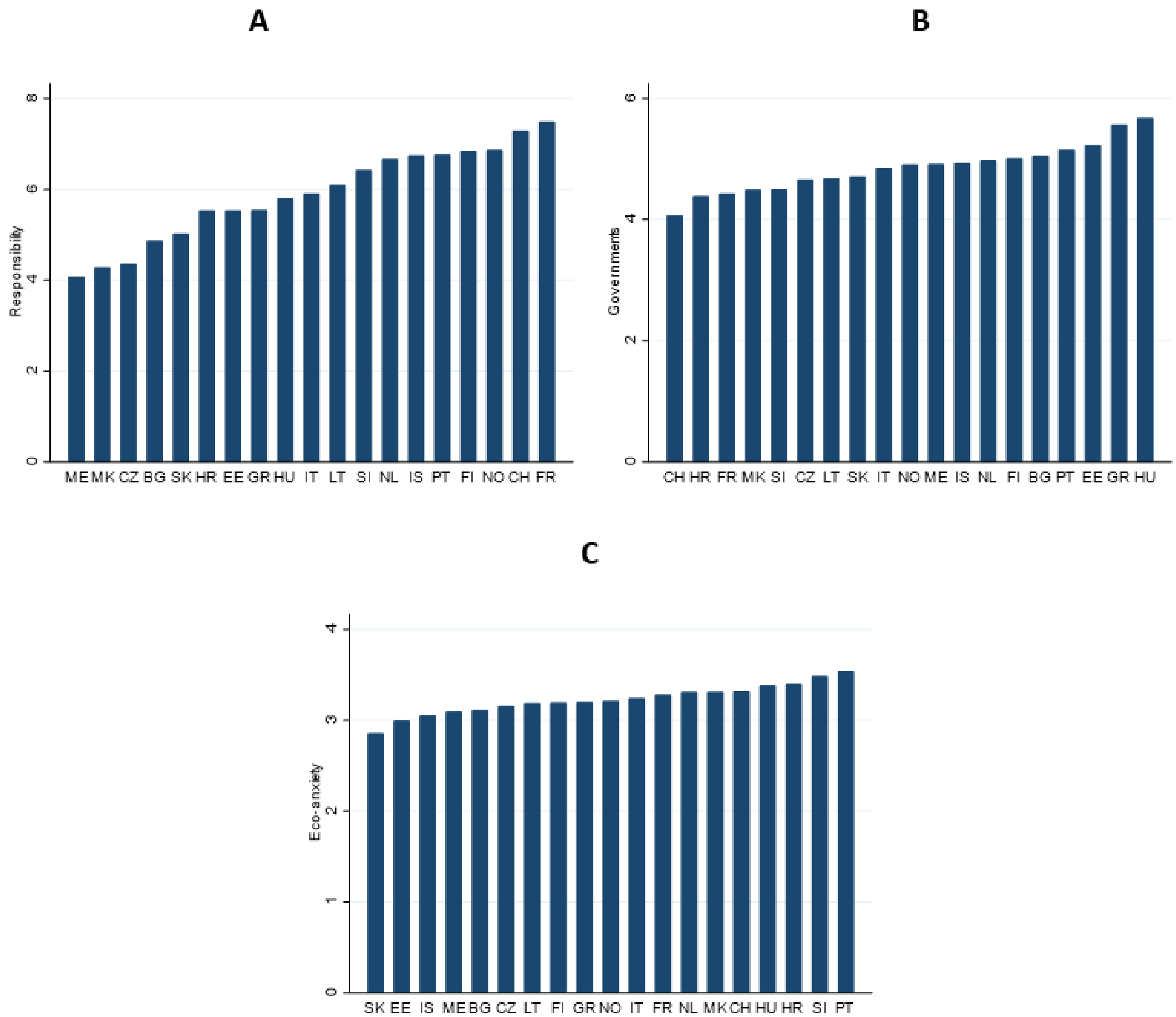

Figure 23 Country Average of Responsibility, Governments, And Eco-Anxiety

A deeper inspection at the role of Eco-anxiety and Governments in shaping Responsibility feeling is provided by **Figure 23**. We notice that the more worried people are, the more responsible they feel about climate change. This is consistent with the self-component in our theoretical model. Interestingly, when we look at the Governments variable, we observe that the more people believe government are acting well, the higher they feel responsible. This contradicts the free-riding option that people may perceive higher when other governments are already fighting against climate change.

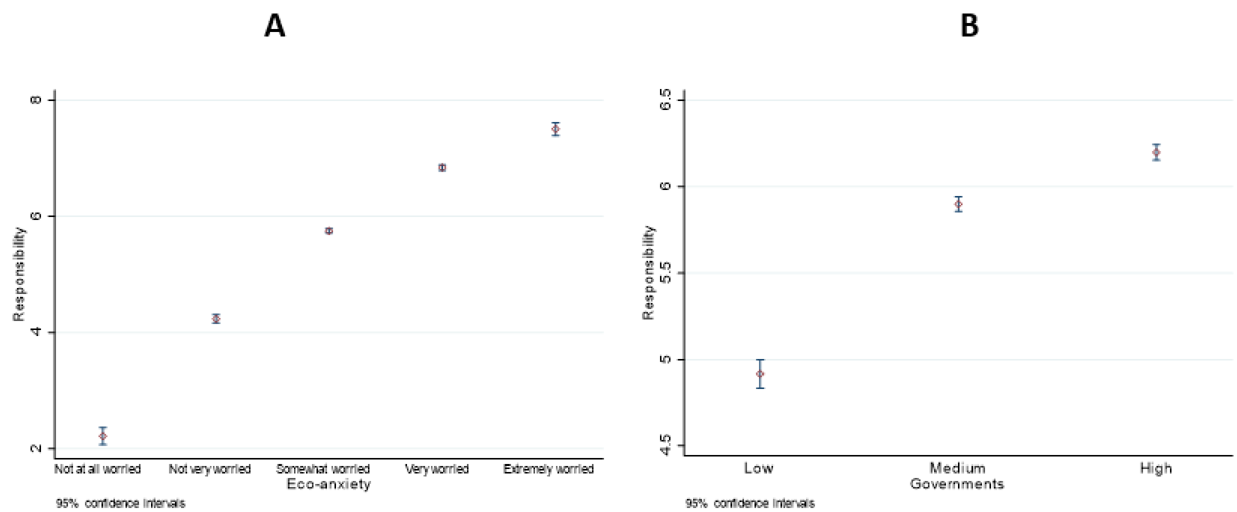

Figure 24 Responsibility by Levels of Eco-Anxiety and Governments

10.3 Econometric model

To test the effect of Eco-anxiety and Governments on Responsibility, we run the following linear model.

$$\mathbf{Responsibility_i = b_0 + b_1Worried_i + b_2Governments_i + b_hSocioeconomic_i + b_kPreferences_i + b_cCountry_i + u_i}$$

where Socioeconomic captures sex, age class, education, income, job status, and marital status, Preferences captures self-assessed health, income satisfaction, political preferences, and participation to the last election, and Country include country dummies.

Figure 25 shows the estimated coefficients of the main explanatory variables. The results for the two variables of interest, i.e., Eco-anxiety and Governments, confirm what found and discussed at descriptive level. First, eco-anxiety is positive and statistically significant, suggesting that the more anxious, the more responsibility people feel. Second, the coefficient for Governments is also positive and statistically significant, and this invalidate the free-riding hypothesis that the more likely people perceived governments are acting against climate change, the lower responsibility they feel for themselves to act.

Among the socioeconomic characteristics, females and highly educated people are positively associated with higher respinsibility, while age does not play any significant role. Income also plays a significant and positive effect on Responsibility, though very small in magnitude.

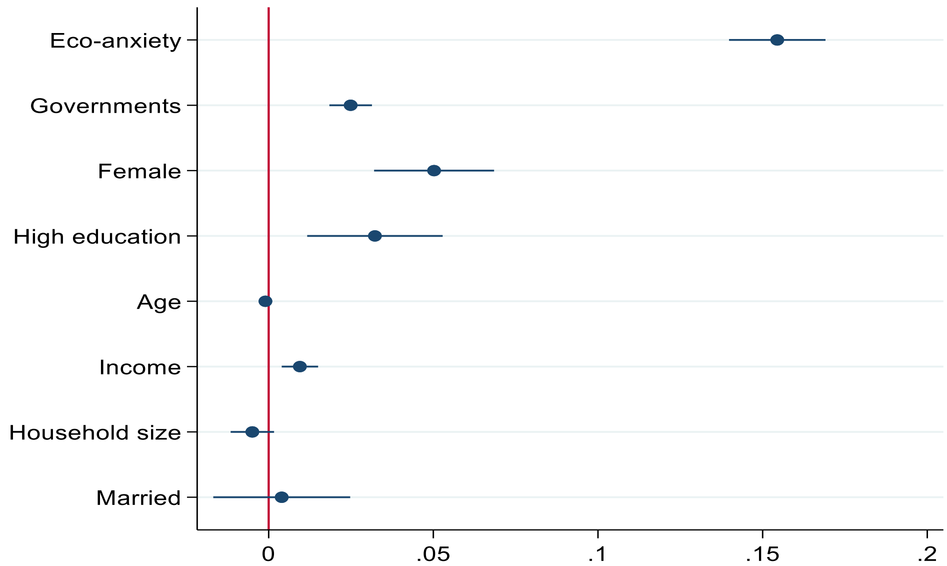

Figure 25 The Determinants of Responsibility

10.4 Conclusions

In this study we have analysed the impact of eco-anxiety and perception about other government effort in takling climate change on personal responsibility toward ecological action. We have found that both eco-anxiety and perception about government effort have a positive and statistically significant effect on feeling responsible to act against climate change. These results partially confirm the theoretical free-riding hypothesis postulated by game theoretical model of ecological actions. Our results have relevant policy impliactions. First, increasing govnerment efforts and better communicate it have significant positive externalities on ecological actions of the people. Second, the more people are aware about the climate threat, the more they feel responsible and are likely to acti ecologically. This calls the whole scientific community to improve communication about the risks of climate change and therefore let people feeling more responsible through their everyday actions.

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11 Appendix A

Table 18 Mapping table between HILDA+ categories, FAO commodity and EXIOBASE economic sectors. This mapping has been directly taken from (Fusacchia et al., 2022).

HILDA+	FAO commodity	EXIOBASE economic sector
Cropland	Almonds, in shell	Cultivation of vegetables, fruit, nuts
	Apples	Cultivation of vegetables, fruit, nuts
	Avocados	Cultivation of vegetables, fruit, nuts
	Bananas	Cultivation of vegetables, fruit, nuts
	Barley	Cultivation of cereal grains nec
	Beans, dry	Cultivation of vegetables, fruit, nuts
	Brazil nuts, in shell	Cultivation of vegetables, fruit, nuts
	Broad beans and horse beans, dry	Cultivation of vegetables, fruit, nuts
	Buckwheat	Cultivation of wheat
	Cantaloupes and other melons	Cultivation of vegetables, fruit, nuts
	Cashew nuts, in shell	Cultivation of vegetables, fruit, nuts
	Cashewapple	Cultivation of vegetables, fruit, nuts
	Cassava, fresh	Cultivation of vegetables, fruit, nuts
	Castor oil seeds	Cultivation of oil seeds
	Chestnuts, in shell	Cultivation of vegetables, fruit, nuts
	Cocoa beans	Cultivation of crops nec
	Coconuts, in shell	Cultivation of vegetables, fruit, nuts
	Coffee, green	Cultivation of crops nec
	Figs	Cultivation of vegetables, fruit, nuts
	Grapes	Cultivation of vegetables, fruit, nuts
	Green garlic	Cultivation of vegetables, fruit, nuts
	Groundnuts, excluding shelled	Cultivation of oil seeds
	Jute, raw or retted	Cultivation of plant-based fibers
	Kenaf, and other textile bast fibres, raw or retted	Cultivation of plant-based fibers
	Lemons and limes	Cultivation of vegetables, fruit, nuts
	Linseed	Cultivation of oil seeds
	Maize (corn)	Cultivation of cereal grains nec
	Mangoes, guavas and mangosteens	Cultivation of vegetables, fruit, nuts
	Maté leaves	Cultivation of crops nec
	Natural rubber in primary forms	Cultivation of crops nec
	Oats	Cultivation of cereal grains nec
	Oil palm fruit	Cultivation of vegetables, fruit, nuts
	Olives	Cultivation of vegetables, fruit, nuts
	Onions and shallots, dry (excluding dehydrated)	Cultivation of vegetables, fruit, nuts
	Oranges	Cultivation of vegetables, fruit, nuts
	Other fibre crops, raw, n.e.c.	Cultivation of plant-based fibers
	Other nuts (excluding wild edible nuts and groundnuts), in shell, n.e.c.	Cultivation of vegetables, fruit, nuts
	Other oil seeds, n.e.c.	Cultivation of oil seeds
	Other stone fruits	Cultivation of vegetables, fruit, nuts
	Other tropical fruits, n.e.c.	Cultivation of vegetables, fruit, nuts
	Other vegetables, fresh n.e.c.	Cultivation of vegetables, fruit, nuts
	Papayas	Cultivation of vegetables, fruit, nuts
	Peaches and nectarines	Cultivation of vegetables, fruit, nuts
	Pears	Cultivation of vegetables, fruit, nuts
	Peas, dry	Cultivation of vegetables, fruit, nuts
	Pepper (Piper spp.), raw	Cultivation of vegetables, fruit, nuts

	Persimmons	Cultivation of vegetables, fruit, nuts
	Pineapples	Cultivation of vegetables, fruit, nuts
	Pomelos and grapefruits	Cultivation of vegetables, fruit, nuts
	Potatoes	Cultivation of vegetables, fruit, nuts
	Pyrethrum, dried flowers	Cultivation of crops nec
	Quinces	Cultivation of vegetables, fruit, nuts
	Ramie, raw or retted	Cultivation of plant-based fibers
	Rape or colza seed	Cultivation of oil seeds
	Rice	Cultivation of paddy rice
	Rice, paddy (rice milled equivalent)	Cultivation of paddy rice
	Rye	Cultivation of cereal grains nec
	Seed cotton, unginned	Cultivation of plant-based fibers
	Sesame seed	Cultivation of oil seeds
	Sisal, raw	Cultivation of plant-based fibers
	Sorghum	Cultivation of cereal grains nec
	Soya beans	Cultivation of oil seeds
	Strawberries	Cultivation of vegetables, fruit, nuts
	Sugar cane	Cultivation of sugar cane, sugar beet
	Sunflower seed	Cultivation of oil seeds
	Sweet potatoes	Cultivation of vegetables, fruit, nuts
	Tangerines, mandarins, clementines	Cultivation of vegetables, fruit, nuts
	Tea leaves	Cultivation of crops nec
	Tomatoes	Cultivation of vegetables, fruit, nuts
	Triticale	Cultivation of cereal grains nec
	Tung nuts	Cultivation of vegetables, fruit, nuts
	Unmanufactured tobacco	Cultivation of crops nec
	Walnuts, in shell	Cultivation of vegetables, fruit, nuts
	Watermelons	Cultivation of vegetables, fruit, nuts
	Wheat	Cultivation of wheat
	Yams	Cultivation of vegetables, fruit, nuts
Pasture	Cattle	Cattle farming

Table 19 Mapping table occupational exposures and occupational injuries and their related health outcomes from the WHO database used in this mapping of work-related fatalities.

Risk Factor	Health outcome
Occupational exposure to asbestos	Trachea, bronchus, and lung cancers
Occupational exposure to asbestos	Ovary cancer
Occupational exposure to asbestos	Larynx cancer
Occupational exposure to asbestos	Mesothelioma
Occupational exposure to arsenic	Trachea, bronchus, and lung cancers
Occupational exposure to benzene	Leukaemia
Occupational exposure to beryllium	Trachea, bronchus, and lung cancers
Occupational exposure to cadmium	Trachea, bronchus, and lung cancers
Occupational exposure to chromium	Trachea, bronchus, and lung cancers
Occupational exposure to diesel engine exhaust	Trachea, bronchus, and lung cancers
Occupational exposure to formaldehyde	Nasopharynx cancer
Occupational exposure to formaldehyde	Leukaemia
Occupational exposure to nickel	Trachea, bronchus, and lung cancers
Occupational exposure to polycyclic aromatic hydrocarbons	Trachea, bronchus, and lung cancers
Occupational exposure to silica	Trachea, bronchus, and lung cancers
Occupational exposure to sulphuric acid	Larynx cancer
Occupational exposure to trichloroethylene	Kidney cancer
Occupational asthmagens	Asthma
Occupational particulate matter, gases, and fumes	Chronic obstructive pulmonary disease
Occupational noise	Other hearing loss
Occupational injuries	Pedestrian road injuries
Occupational injuries	Cyclist road injuries
Occupational injuries	Motorcyclist road injuries
Occupational injuries	Motor vehicle road injuries
Occupational injuries	Other road injuries
Occupational injuries	Other transport injuries
Occupational injuries	Poisoning by carbon monoxide
Occupational injuries	Poisoning by other means
Occupational injuries	Falls
Occupational injuries	Fire, heat, and hot substances
Occupational injuries	Drowning
Occupational injuries	Unintentional firearm injuries
Occupational injuries	Other exposure to mechanical forces
Occupational injuries	Pulmonary aspiration and foreign body in airway
Occupational injuries	Foreign body in other body part
Occupational injuries	Non-venomous animal contact
Occupational injuries	Venomous animal contact
Occupational injuries	Other unintentional injuries
Occupational ergonomic factors	Back and neck pain

12 Appendix B

For the meta-regression analysis in **chapter 7** we used the following list of studies. We have separated them into EU and Non EU area. Some studies provide WtP values for more than one cultural heritage site.

EU area

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