forests

Article

The Macroeconomic Implications of the Transition of the Forestry Industry towards Bioeconomy

Alin Emanuel Artene [1,*], Lucian-Ionel Cioca [2], Aura Emanuela Domil [3], Larisa Ivascu [1], Valentin Burca [3] and Oana Bogdan [3]

1 Faculty of Management in Production and Transportation, Politehnica University of Timisoara, 300006 Timișoara, Romania
2 Department of Industrial Engineering and Management, Faculty of Engineering, Lucian Blaga University of Sibiu, Bd. Victoriei No. 10, 550024 Sibiu, Romania
3 Faculty of Economics and Business Administration, West University of Timișoara, 300223 Timișoara, Romania
* Correspondence: alin.artene@upt.ro

Abstract: In a global economic system where essential resources are limited, demand is increasing and environmental degradation is more pronounced, the only viable option to ensure sustainable development is to create an environmentally friendly and efficient economy in order to produce more economic value with the same or fewer resources. The aim of this paper is to provide insight into the macroeconomic implications determined by the transition to a forest bioeconomy, with a focus on the impact on the national gross value added. More specifically, this analysis assesses the relationship between the potential of the macroeconomic value creation on the forestry industry and the measures of progress on the transition towards sustainable forest management and long-term economic growth. The analysis refers to a period between 2013 and 2019, summing-up 133 observations, data that were reported by Eurostat for 23 European Union members. We propose a model that describes a construct of the potential of the value creation that can be generated by each country included in our sample, translated into an efficiency score determined using the Data Envelopment Analysis(DEA)methodology. The results highlighted that the evolution of economic, social, and environmental (ESG) context positively impacted the efficiency score. This positive evolution in time was mainly driven by the higher awareness of governments, companies, and people on the need for a transition to sustainable economic growth and sustainable forest management. Furthermore, this study highlights that the transition to sustainable economic growth implies negative changes to the cost structure of the economies, which lead to higher operational costs and lower gross value added. Moreover, our study provides more insight, from an econometric methodology perspective, regarding the synergy effect as determined by the transformation of business models in the forestry sector towards sustainable forest management.

Keywords: efficient economy; sustainable development; forest management; value creation

check for updates

Citation: Artene, A.E.; Cioca, L.-I.; Domil, A.E.; Ivascu, L.; Burca, V.; Bogdan, O. The Macroeconomic Implications of the Transition of the Forestry Industry towards Bioeconomy. *Forests* **2022**, *13*, 1961. https://doi.org/10.3390/f13111961

Academic Editor: Peter Elsasser

Received: 24 October 2022
Accepted: 15 November 2022
Published: 21 November 2022

1. Introduction

Considering the evolution of the economy, society, and forestry policies, the transition towards a competitive sustainable economic growth model has always been a challenge, with an important impact on forestry development and the protection of resources. In addition, climate change and environmental degradation are existential threats that highlight the need to amplify interest in sustainable economic development in which natural ecosystems are not ruined by the current, linear way of producing and consuming products. In this sense, in a global economic system where essential resources are limited, demand is increasing, and environmental degradation is more pronounced, the only viable option to ensure sustainable development is to create an environmentally friendly and efficient economy in order to produce more economic value with the same or fewer resources [1].

However, the transition to a green economy does not seem to be an easily process, because it involves fundamental changes in the production and consumption of goods and services so that the needs of the present do not compromise the ability of future generations to meet their own needs [2]. In this context, the actions taken must focus on three fundamental pillars in terms of sustainability, namely, environmental protection and social and economic development. Considered jointly, these pillars point towards a society that fulfils the economic and social requirements needed now and into the future. Based on the idea that sustainable development represents a necessity that can be achieved through the concerted efforts of multiple societal actors and is not just a desideratum of developed countries that have the financial resources and are able to implement environmental conservatism programs that promote sustainable production and consumption patterns, a global commitment to sustainability has been created [3]. This action involves both the significant costs of implementation and compliance [4], which generally translate into various forms of trade-offs between regulatory frameworks, such as the "Paris Agreement on climate change" [5], the "UN 2030 Agenda for Sustainable Development" [6], or the 17 Sustainable Development Goals that were set forth as an urgent call for action in order to create a global vision to address sustainability, and challenges that lead, in the case of most countries, to the prioritization of economic growth, regardless of the value of the long-term environmental costs incurred [7].

The authors of [8,9] state that there is an efficient, resilient, and clean potential for green sustainable development, but the transition is a medium- and long-term process, involving political commitment on the part of states that want a change in the model of economic development.

Our aim in this paper was to fill the gap and provide some new perspectives on the efforts made in order to make easier the transition to a more circular economy, highlighting, at the same time, its impact on macroeconomic output. In this context, the focus of our paper was the analysis of the relationship between the gross value added reported in the forestry industry and a measure of the progress of the transition towards a competitive sustainable economic growth model. Hence, we proposed a model that describes a construct of the potential of the value creation that can be generated by each of the countries included in our sample. Our article comes with additional insights into the literature and fills in the gap through the analysis of the periods of fixed effects, which highlights that the overall evolution in time was mainly driven by structural reforms and action plans, such as that mentioned by the European Green Deal, with all its strategic components.

This paper is structured as follows: In Section 1, we presented the context that determined our study. Section 2 provides the literature regarding actual knowledge in the field and the hypotheses underlying the research undertaken. Section 3 presents the research methodology, Section 4 discusses the obtained results, and the final section, Section 5, summarizes the main findings, conclusions, and avenues for future research.

2. Literature Review

It is known that the future of Europe depends on a healthy planet, and this is why the European Union (EU) makes substantial efforts, proposing holistic and cross-sectoral approaches in which all relevant policy makers contribute to the transition towards a green economy in which renewable biological resources from land and sea are used in order to produce food, materials, and energy [10]. Hence, being a benchmark for all other countries in order to create a climate-resilient society, the European Green Deal, agreed to in 2019, reflects the formalized efforts made by the EU in order to achieve Europe's climate neutrality by 2050, boosting, at the same time, the economy with green technology, ensuring sustainable activities in industry and transport, and reducing pollution [10].

Thereby, the circular economy concept represents an alternative to the current economy of 'take–make–use–dispose' [11], which gains importance for academia, policy makers, and companies, who have become aware of its potential value, which is needed in order to ensure more sustainable economic growth [12], considering the fact that a bioeconomy will help the EU accelerate progress towards a circular and low-carbon economy. On the one hand, there are studies [13,14] that demonstrate that rule of law, economic freedom, and inflation have a significant long-term relationship with sustainable development, with financial regulations being important in order to obtain a sustainable green economy. On the other hand, some researchers [15–18] concluded that in the implementation of the circular economy, there exist barriers that make process more difficult, especially in terms of implementing a circular business model and changing the way they operate. These barriers may come from a lack of managerial capacity, resources, and corporate knowledge [19] or due to the presence of some regulatory aspects that make the implementation process more difficult [20]. Researchers state that the difficulty in adhering to a circular economy is related to training, changes in behavior, and a lack of interest [21].

It seems that despite all costs, barriers, or obstacles, some companies strive to be circular [22]. One example is in the forest industry, a sector that has considerable potential for applying circular economic practices that can be extended to a "forest-based circular economy", which particularly implies a reduction in the input of virgin natural resources in production systems through the reuse and lifetime extension of wood products and recycling via the optimization of potential wood assortments [23], as wood-based products reduce the carbon footprint and replace nonrenewable products [21]. In the forestry sector, the circular economy can be defined as an economy in which raw materials and their value are used as efficiently as possible, transforming the undervalued forest residues and wood waste into value-generating market forest products [24]. Although based on the population growth rate, there is a tendency to convert land to different types of use, reducing forestry areas [25], efforts made at the manufacturing stage to reduce resource consumption have been acknowledged, but the implementation of other circular economy strategies and the gross value added requires further improvements. Hence, more attention must be paid to end-of-life strategies, with targeted support for the development of new and innovative technologies that allow disassembly and deconstruction. In this sense, environmental degradation related to linear resource exploitation as a result of the growing demand can be mitigated through circular economy best practices [26]. Thus, the existing policy framework needs to be refined and extended in order to promote the recovery and reintroduction of materials in manufacturing processes [27], because education, support of public policies, and cooperation in the market represent the main strategies needed in order to encourage the implementation of the circular economy concept [21] Some studies highlight that the level of education of the population affects the sustainable development of forestry resources, namely, highly educated individuals contributing substantially to the growth of resources in this area [28]. Moreover, it has been stated that only through clear legislative frameworks can circular economy ensure the sustainability of forest ecosystem services [29], although studies still reveal a lack of consistency between circular economy concepts and the forest sector that can be associated and applied [23]. Hence, researchers, through data envelopment analysis (DEA), advocate that long term-sustainability and increased economic efficiency can be obtained through substantial improvements in forest management and much more investments in research and development activities [29].

Therefore, we believe that sustainable development represents a precondition for a successful forest-based bioeconomy, and the hypotheses that were tested in this research were the following:

- **H1.** *The potential for value added creation is influenced by the stage of transition to a sustainable economy;*
- **H2.** *The convergence rate of the value added potential is influenced by the stage of transition to a sustainable economy;*
- **H3.** *The potential for creating added value is more influenced by the economic component than by the social and environmental one.*

The rationale behind our choice for this topic was multiple fold.

First, as noted in [30], forests represent an essential natural resource of EU communities. Currently, the forestry industry provides significant contributions to macroeconomic results, with more than 7.1% of the gross value added generated by the industrial sector in EU economies. Furthermore, in [31], the authors underlined the fact that the contribution of forest exploitation to macroeconomic results was beyond the wood-processing industry, consisting mainly of the indirect effects as determined by forestry subsectors on the input–output macroeconomic level.

Therefore, the topic of forest management is rather a complex matter that asks for an interdisciplinary approach, including the analysis of forest management through a lens of social, economic, governance, and environmental implications [32–35]. Additionally, we subscribe to opinions that emphasize the negative effects on public policies of the decision-making process, as there are a lack of studies in the area of sustainable forest management that provide a cost–benefits analysis in financial terms, such as the generation and distribution of socioeconomic value and environmental costs [23,33]. All cost elements translate eventually into a decrease in the value added generated by forest exploitation, redesign, and management of the processes of support. Furthermore, such a discussion is essential for policy makers, as studies on the socioeconomic implications of sustainable forest management represent a basis for the justification of the shift from command-and-control forest management to broader governance schemes that seem to be more visible [36]. Therefore, markets expectations and consumers' preferences oriented on more sustainable wood-based products are expected to determine firms to ensure forest legality, alignment to certification systems, or protocols addressing the requirements of sustainable forest management, and forest management strategies and practice aligned with global and regional climate change objectives drawn-up by Sustainable Development Goals (SDG) 13 [37].

Second, the empirical analysis in our study emphasized how important is the adoption of sustainable forest management conceptual models, frameworks, and practice. Forests are not only sources of income but also providers of ecosystem services. As long as there are no existing studies addressing the economics of forest ecosystems services and their contribution to human well-being, public policies will not be properly calibrated to be aligned with the objectives of forests conservation and general sustainable development of the economies [38]. On those circumstances, forestry operations and related supply chains will fail to contribute to the achievement of national, regional, and global strategies concerning sustainable forest management, as long as there is a lack of created incentives for firms to adopt sustainable forest management(SFM)oriented strategies, corporate policies, and governance mechanisms and tools.

Third, we considered relevant our analysis in order to assess if there were any synergies or trade-off affects between the SDG 15 targets related to forest management and the SDGs [37], such as SDG 7 setting-up targets on affordable, reliable, and sustainable energy [39,40], SDG 8 related to targets on sustainable economic growth [7,41,42], SDG 12 related to sustainable consumption and production patterns [7,39,41], or SGD 13 addressing targets aimed to combat climate changes and its impacts [7,39]. All of those sustainable development goals influence the elements of revenue and cost of the value added measures analyzed in this study, and they are a reason why this type of association between the construct of potential value creation and the measures of sustainable development provide us with relevant evidence if there is a trade-off or a synergy effect determined by transformation of business models in forestry sector towards sustainable forest management. As the literature does not provide a clear type of association, as both trade-offs and synergy effects are reported between those SDGs, we expect to provide some more insight but this time from an econometric methodology perspective.

Forth, seems that researchers pay an increasing attention on progress on the technological topics related to forest managements [34], which should be intensified in the actual light of extended intention and decisions to implement in Industry 4.0 emerging technologies with applicability in forestry [43,44]. Therefore, strategic thinking, cooperation, and supply chain optimizations are expected to describe the more recent Forest 4.0 concept, which consists of better calibration of the demand for wood-based products, which are characterized by higher quality, longer life cycles, and sold together with additional services, such as refurbishment and re-use. Of those circumstances, a high potential for value creation can be generated through cost reduction and product redesign and process optimization in terms of material use, with implications at the level of deforestation, as long as efficient machines, appropriate technical systems, innovative products, and process redesign together with suitable knowledge management and human capital development are financed by corporations over the long term [45].

Fifth, the study highlights how important a governmental, regional, and global approach for sustainable forest management is, in terms of an institutional framework, in this area, as differences at the institutional level could lead to significant incoherencies [46]. All of these incoherencies resumed in the cost–benefits analysis that circle around efforts to adopt sustainable forest management models. The current macroeconomic contribution of the forestry sector can be sustainable, under actual natural resource constraints, and only through smart and feasible public policies, governments, and people's awareness of the need for sustainable forest management strategies and benchmarked international practice. Furthermore, issuing public policies is expected to generate positive returns in terms of sustainable forest management; yet, this is not sufficient, as there must be implemented effective enforcement mechanisms as well and significant incentives offered to corporate decision makers to comply with the government's direction. Otherwise, the heterogeneity in practice would lead to a decrease in the potential synergy effects at the macroeconomic level, and negative externalities would be generated by public policies and regulation in the area of forest management.

Lastly, but not least, we note the essential role that quality plays in the public policies that governments issue in the area of sustainable development, in general, and sustainable forest management, in particular. There are problems regarding how restrictive and qualitative the national or regional regulation is in the area of sustainable forest management, which may differ between countries either because of an insufficient understanding of the conceptual models of sustainable forest management or because of a lack of experience and expertise within the members of the body that sets standards [47]. Those elements lead to policy incoherence, with implications for the implementation of public policies and control of compliance with sustainable forest management practice under national regulation or requirements addressed through different best practice protocols or certification standards, especially in light of the spatial and time varying particularities of forest management processes [46,48]. Unless governments and professional organizations do not provide a robust sustainable forest management model, positive results in sustainable economic development are less likely, except for a situation such as an institutional framework, national regulation, or public policies addressing SFM, which ensures appropriate correlation between the following directives [49]:

- ➢ Brings more clarity to the conceptual framework of sustainable forest management, enhancing discourse and understanding of SFM;
- ➢ Shapes and focuses the engagement of science to take advantage of innovation and technological advances in SFM;
- ➢ Improves the monitoring and reporting on SFM to facilitate transparency and evidence-based traceability and decision making;
- ➢ Strengthens forest management practices by market-based and regulatory incentives;
- ➢ Facilitates the assessment of progress towards SFM goals;
- ➢ Facilitates forest-related dialog and communication.

Therefore, high incoherence in public policy understanding and implementation could lead to nonpredictable patterns in corporate behavior, with negative implications for long-term forest planning, consumers' behavior modeling, waste reduction, and generated value added. If we add the political factor to this equation, the negative effects on the translation of sustainable forest management objectives in public policies and sustainable forest management practice increase [32]. As long as there is no political consensus and there is a lack of ensured clear directions and monitoring tools, the results are expected to be poor and unpredictable and any changes to be reversible. Relevant to this reality is a comparison between the New EU Forest Strategy for 2030 with the pan-European set of indicators for sustainable forest management, which seem to have significant gaps in terms of the appropriateness of those indicators for the assessment of SFM objectives, goals, or targets [48,50,51].

The progress towards sustainability is visible among all EU member states that have progressed favorably, although not all to the same extent [52]. It seems that huge investments, long-term efforts, and governmental programs can determine real progress in achieving much of the desired sustainable development [53]. In addition, studies highlight that increased economic efficiency can be obtained through permanent improvements in forest management [54], revealing the fact that forest management represents a key issue in any transition towards sustainable societies [4]. Nevertheless, researchers point out the need for additional surveys on optimizing the interaction between forests ecosystems and circular economy, our study fills the gaps, providing more insight, from an econometric methodology perspective, into the synergy effect as determined by the transformation of business models in the forestry sector towards sustainable forest management.

3. Materials and Methods

3.1. Data and Variables Description

Our study aimed to understand the impact of efforts toward the transition to a more circular-based economy on macroeconomic output. In other words, we analyzed the relationship between the gross value added reported in the forestry industry and the measure of progress on the transition towards a competitive sustainable economic growth model. The analysis referred to the period between 2013 and 2019, summing-up 133 observations included in the sample analyzed.

For this purpose, we collected statistical data reported by Eurostat for 23 European Union members: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. While the United Kingdom left the European Union, for the rest of the EU members, we did not have a full set of data available for the period analyzed. In Table 1, we define the variables included in our analysis.

Table 1. Description of variables included in this study.

Name	Description	Database Field Name Considered in the Analysis
	DEA Analysis	
Gross value added (GVA)	The natural logarithm of the gross value added (EUR millions) reported to be generated by the forestry sector; the measure describes the contribution of the forestry sector to the GDP of each country.	Eurostat FOR_ECO_CP__custom_3657896
Employees (EM)	The natural logarithm of the number of employees (thousands of annual working units) working in the forestry sector.	Eurostat FOR_AWU_custom_2183481
Fixed capital (FC)	The natural logarithm of the gross fixed capital formation, which reflects mainly the depreciation (consumption) of the assets used in the operations in the forestry sector.	Eurostat FOR_ECO_CP_custom_2183813
Wood consumption (WC)	The natural logarithm of the value of the roundwood material (wood in rough) removals processed and deliver on the market as wood final products.	Eurostat FOR_REMOV_custom_22000886

Table 1. *Cont.*

Name	Description	Database Field Name Considered in the Analysis
	Econometric analysis	
	Dependent variables	
Efficiency score	A measure of efficiency, determined as an output of the Data Envelopment Analysis performed, considering as input variables the number of employees, the depreciation of the fixed assets affected in the daily operations, and the consumption of the natural resource of wood.	Data Envelopment Analysis score output
	Independent variables	
Business sophistication (BS)	An aggregate sub-index of the global competitiveness index that concerns the quality of a country's overall business networks (i.e., supply chains) and the quality of individual firms' operations and strategies that draw-up clusters.	World Economic Forum
KOF index (KOF)	An index of economic globalization disclosed annually by the KOF Swiss Economic Institute, measuring the overall openness of national economies.	KOF Swiss Economic Institute
GSCI index (GSCI)	This reflects an aggregate index that integrates 131 measurable indicators, concerning five main areas: availability of natural resource, the efficiency and intensity use of the natural resources, availability and quality of intellectual capital, the effectiveness of governance mechanisms, or elements of social cohesion.	Solability
	Robustness analysis	
	Dependent variables	
Growth $\Delta GVA_{i,t}(\%)$	The percentual growth of the gross value added created on the forestry sector, as per relationship $\Delta GVA_{i,t}(\%) = \frac{GVA_{i,t}}{GVA_{i,t-1}} - 1$, where $GVA_{i,t}$ is the gross value added reported in year t by country i; it is used to measure the speed of convergence of the speed of growth of the value added, as per the beta convergence classical economic growth econometric model [55].	Eurostat FOR_ECO_CP__custom_3657896
	Independent variables	
Social capital (SC)	A sub-index of the GSCI index, reflecting social aspects concerning health, social stability, public services, crime, or freedom.	Solability social capital dimension
Resource intensity (RI)	A sub-index of the GSCI index, reflecting the efficiency and the environmental effects of using natural resources, concerning consumption and management of energy, water, or waste, with an impact on climate change and environmental pollution.	Solability resource intensity dimentions
Natural capital (NC)	A sub-index of the GSCI index, reflecting the availability of natural resources, concerning forests, energy, agriculture, minerals, or areas of environmental degradation.	Solability natural capital dimension
Governance capabilities (GC)	A sub-index of the GSCI index, depicting rather the involvement, the effectiveness, and the results of national authorities in terms of infrastructure, governments cohesion, business environment, corruption, or financial stability.	Solability governance capabilities dimension
Intellectual capital (IC)	A sub-index of the GSCI index, integrating a multitude of indicators related to both, the infrastructure, the resources of education, the potential of innovation, the effective positive impact of regulation on the business area, or the solutions of financing R&D initiative.	Solability intellectual capital dimension

Source: authors' projection.

Measuring the readiness of each country for sustainability, is an open topic as the methodological issues seem to persist [56]. The complexity of the concept of sustainability is a fundamental issue that is still not solved, as it raises awareness of the fact that decision makers have to put in balance different relationships, synergies, and trade-offs related to the SDGs, which are reported at the national, regional, and global levels [52,57]. The concept of sustainability, nowadays, leads to bioeconomy, but this suggests as well directs towards economic resilience, both facilitated by continuous improvement and innovation [58]. However, the concept of sustainability concerns not only economic and economic aspects but also social and governance aspects that have become increasingly important in the current context of natural resource constraints.

The forestry industry is not an exception, as it is part of national economies and highly impacted by strengthened and robust networks at the regional and global levels of the economy. Instead, the current literature has brought insufficient insight into the macroeconomic implications of a transition to a bioeconomy for the forestry industry, highlighting a more theoretic approach with irrelevant duplicate results [59]. However, three main concepts have been addressed when talking about a forest bioeconomy: sustainable development, bioenergy production, and climate change mitigation [60].

Those premises have made us determined to find out the aggregate measures of the transition to a sustainable economy, including a bioeconomy. As the concept itself is extremely complex, we appreciated the Solability aggregate sustainability competitiveness index, which was appropriate for our analysis. It is an aggregate measure of five dimensions that are fundamental for a description of transition to bioeconomy and, in general, for transition to sustainable economic growth. This aggregate indicator covers, in a more synthetic way, the essential aspects drawn-up by the UN SDGs, which include, both directly and indirectly, the transition to a forest bioeconomy. Indeed, the forest bioeconomy should represent a key element in each country's strategy for sustainable development, as its contribution is substantial in value creation [61]. The role of the forest bioeconomy, materialized through different channels (e.g., biodiversity, carbon emission mitigation, medical plants, fresh water, and consumers' behavior in the furniture market) is essential [4].

The link between the SDGs and a sustainable forest economy is covered by framework proposed by Solability.

The dimension of natural capital describes the level of natural resource availability. As long as there are constraints on the supply chains related to natural capital, including wood-based products, the process of value creation is negatively impacted. A higher degree of deforestation leads to long-term land degradation, negative impacts on biodiversity, a lower quality of water, pressure on supply chains, increased wood-based products price, and increased levels of environment pollution. Therefore, this dimension incorporates both the synergy effects and trade-offs of different SDGs, such as SDG 1, SDG 6, SDG 7, and SDG 12. That is why we considered it opportune to use this aggregate in our econometric analysis, without isolating the subdimension related strictly related to the forest industry.

A similar approach was considered for the other dimensions as well.

The social dimension is affected by the forestry sector operations along with all of it subdimensions of health, equality, crime, freedom, and satisfaction. The lower the level of deforestation operations, the higher the level of population health, which is in line with SDG 15. In the context of natural resource constraints, the lower the level of deforestation operations for industrial purpose, the higher the chance people can have access to wood resources for personal use (e.g., heating for winter) at affordable prices, which is an aim of SDG 7. Those effects transpose exposure to wood theft, violent conflicts, or even individual happiness.

In the case of intellectual capital and innovation, the subdimensions of education, R&D expenses, or a competitive business environment, described as new comers' influencing the process of gross value creation, are included in forestry. A higher education among the population is expected to lead to opportunities for the more efficient use of natural resources, such as wood, and a higher awareness among the population of the costs and benefits of a model of macroeconomic sustainable growth as well as their willingness to model their consumption behavior in this direction. The higher the level of R&D expenses and investments, it is expected to lead to more intense development of the forestry economy and be less related to extensive development that would suggest higher consumption of natural resources, with negative implications on the sustainability of economic growth.

The dimension of governance efficiency is designed to provide a rough picture of countries' institutional capabilities to apply the rule of law and ensure high-quality regulation meant to support the business environment. The role of this institutional framework is even more important in cases regarding the forestry economy, as here, there is high awareness regarding the unhappy evolution of the reduction in natural resources, which should be slowed down by mature enforcement mechanisms that are defined by high-quality regulation and that are applied by well-prepared government specialists and supported by innovative solutions of tracking and monitoring wood removals.

Nonetheless, this dimension of resource efficiency represents the dimension of appreciation, describing best the readiness of each country to move towards a forest bioeconomy. The subdimensions of this pillar reflect the effort each country has made to ensure the reduction of waste, intensive economic development, or resilient supply chains, especially in an actual environment characterized by a high risk of disruptions. The most relevant evidence is related to the effects of the recent COVID-19 pandemic, which caused significant changes to the market's structure, consumers' behavior, and the design of operational processes along entities operating in the forestry industry.

We limited our research to the EU region, as the study represents just a starting point to analyze the effects of a transition to a green economy for the potential of value creation in the forestry industry. This choice was mainly driven by the fact that those countries subscribe to similar regulations, driven by European directives and regulations that are mandatory for all EU members. The steps in this direction places the EU region as a benchmark for all other countries, especially starting with the moment all those countries' efforts were formalized and agreed through the European Green Deal document in 2019. The period analyzed describes more appropriately the effects from the changes to the EU regulation promoting a transition to a green economy. Under those circumstances, in our analysis, we looked for period fixed effects, as well as checked the overall evolution during that time, which were mainly driven by structural reforms and action plans, such the European Green Deal with all its strategic components.

3.2. Data Envelopment Analysis (DEA)

Designing an optimal measure of value creation in the forestry sector, our aim was to describe a construct of the potential of value creation that could be generated by each of the countries included on the sample analyzed. Therefore, the gap between the countries with a forestry sector generating the highest gross value added were to be considered as benchmarks. Henceforth, comparing each country included in our sample with the "best" performers allowed us to calculate the gap that needed be covered which, from our perspective, could be perceived as the potential for the growth of value added generated by the forestry sector.

The optimal output identified through the gross value added, in the case of the "best" performers, was conditioned by a series of input factors. Following the philosophy of production functions, we considered as input variables for our benchmarking analysis the number of employees working in the forestry industry, the fixed capital affected by operations in this sector, and the natural resources used (raw wooden and intermediate materials), as reflected in Figure 1. For this purpose, we conducted a data envelopment analysis (DEA).

From a mathematical perspective, the DEA model refers to several core concepts: decision-making units, inputs, and outputs. In this direction, we considered countries as DMUs (decision-making units) in a sample of $j = 1, \ldots, n$, counting for $i = 1, \ldots, m$

inputs (x_{ij}), and producing $r = 1, \ldots, s$ outputs (y_{rj}). The DEA model provides a technical efficiency solution for country j_0 compared with n peer group countries' inputs and outputs.

$$\max \sum_{i=1}^{m} v_i \cdot x_{ij} + v_0^+ - v_0^-$$
$$\sum_{j=1}^{n} \lambda_j \cdot x_{ij} - v_0^- = x_{ij0} \text{ , } \forall i$$
$$\sum_{j=1}^{n} \lambda_j \cdot y_{rj} + v_0^+ = y_{rj0} \text{ , } \forall r$$
$$\sum_{j=1}^{n} \lambda_j = 1$$
$$\lambda_j \geq 0, \ \forall j, \ \varnothing \ free$$
$$\max \frac{GVA}{v_1 \cdot EM + v_2 \cdot FC + v_3 \cdot WC}$$

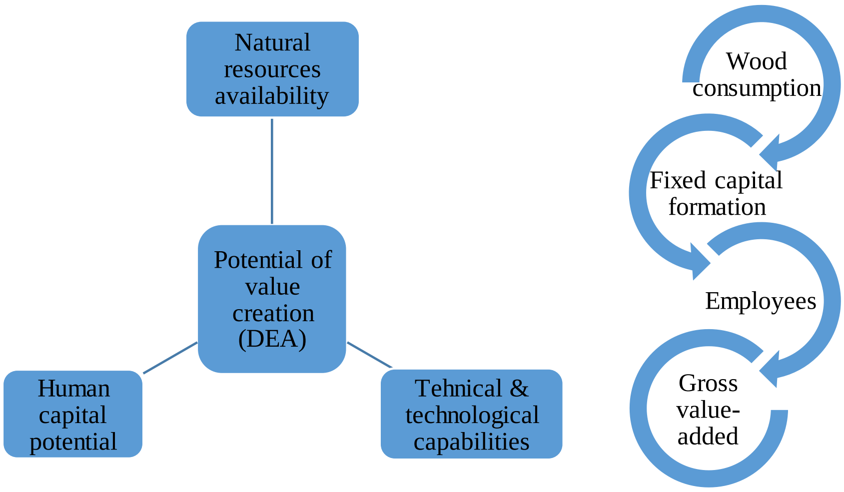

Figure 1. Diagram of the operationalization of potential value creation. Source: authors' projection.

The mathematical model above provides the DEA efficiency measure [62], where λ_j are the related positive weights, while the efficiency ratio function is designed to maximize countries' forestry sector gross value added, considering specific countries' available natural resources and human, technical, and technological capabilities.

This approach is similar to models that are based on the classic production function, which explains the output of a production process based on the consumption of production factors. In this study, the output function variable was related to the gross value added generated by the forest industry, whereas the production factors were resumed to the human capital, fixed capital, and the roundwood removals. However, the DEA provided us the gap score between each country, compared with the best country performer.

3.3. Econometric Models Design

The next step in our analysis consisted of an econometric analysis that described the relationship between the countries' gross value added and the progress towards more sustainable economic growth. It was expected to be a negative relationship, as a transition to a green economy involves significant costs in its implementation and in compliance costs as well [4], which generally translate into various forms of trade-offs among different SDGs, including SDG 15 in relation to the other SDGs [7], which leads, in the case of most countries, to the prioritization of economic growth, no matter the environmental costs incurred over the long-term. However, this could lead to mixed results, as countries have chosen different approaches to address the challenges of sustainable economic growth. A relevant example is the EU region, which can currently be considered a global benchmark in terms of efforts to promote green economies, as they have coordinated their strategic policy efforts through the European Green Deal.

The econometric models estimated in our study are described by the relationships below:

$$Efficiencyscore_{j,t} = \alpha_0 + \alpha_1 \cdot GSCI_{j,t} + \alpha_2 \cdot BS_{j,t} + \alpha_3 \cdot KOF_{j,t} + Period\ effects + \varepsilon_{it}\ (\textbf{Model 3})$$

The notations are described in Table 1. Whereas, ε_{it} is the error term that incorporates the part of the efficiency score that is not explained by the factors included in our econometric models.

The econometric model is designed to reflect the marginal effect of the transition towards a sustainable forest economy on each country's potential to achieve the performance achieved by the country included in the sample with the highest financial results. Therefore, a higher efficiency score translates into closer results of a country to the results reported by the best country performer, with indirect positive impact on the value added, which is expected to be higher in the transition towards a forest bioeconomy and sustainable economic development [4]. Furthermore, we highlighted through this econometric model the role of the globalization phenomenon in the transition towards a forest bioeconomy and directly on macroeconomic output. The more complex and the higher the exposure to international markets of the business models, the higher the production performance and economic results. Therefore, this causal relation suggests a way for countries to achieve financial macroeconomic results closer to that of best performing country as nominated by the DEA results.

The analysis is conducted using panel data sets, checking for fixed or random effects as well, if the relevant statistical tests, such as the Hausman test, the Breusch–Pagan test, or the F tests, confirmed which effects were statistically significant. The models looked only for period fixed effects to reveal trends in the relationship between the potential for value creation and the progress towards a green economy. However, we did not proceed to country fixed effects, as through the DEA we already controlled for countries' economic model specifics.

We included on the estimated econometric models the impact of economic globalization and business sophistication, as those two pillars are expected to represent essential premises for the generation of added value in the context of the role of transnational corporations, which generate significant effects on countries' macroeconomic output by extending and continuously improving complex supply chains. From this perspective, each state should be aware of its contribution to a favorable regulation and enforcement framework that promotes initiatives with a higher potential for added value and discouraging the ones with a lower potential, including in the forestry sector.

3.4. Robustness Analysis

Further, we performed additional robustness analysis. First, we tried to understand if the transition to a sustainable economic growth model has implications on not only the potential of the growth of forestry sectors in terms of value added but also on the absolute value added reported, or if it changed the speed of the convergence of the sector growth between countries with a more developed forestry sector versus countries with a less developed forestry sector. For this purpose, we estimated the models below:

- ➢ Model assessing the impact of sustainability on the forestry sector's reported added value:

$$GVA_{j,t} = \alpha_0 + \alpha_1 \cdot GSCI_{j,t} + \alpha_2 \cdot BS_{j,t} + \alpha_3 \cdot KOF_{j,t} + Period\ effects + \varepsilon_{it}\ (\textbf{Model 1})$$

- ➢ Model assessing the impact of sustainability on the forestry sector's speed of β convergence:

$$\Delta GVA_{j,t}(\%) = \alpha_0 + \alpha_1 \cdot GSCI_{j,t} + \alpha_2 \cdot BS_{j,t} + \alpha_3 \cdot KOF_{j,t} + Period\ effects + \varepsilon_{it}\ (\textbf{Model 2})$$

Relevant for our discussion is also the differentiation that should be made between the estimates obtained using either the sustainability-based competitiveness index or the World Economic Forum-developed global competitiveness index. We considered that this comparative analysis provided more insight into the environmental and the social implications of the economic activity on the macroeconomic level, as the GCI incorporated no aspects of environmental protection, whereas the social aspects integrated were rather related to social aspects with a direct impact on the economic activity and output, such as education [63]. Therefore, in relation to **model 3**, we estimated the model below, incorporating the effect of the GCI index instead of the GSCI index:

$$Efficiency\ score_{j,t} = \alpha_0 + \alpha_1 \cdot GSCI_{j,t} + \alpha_2 \cdot BS_{j,t} + \alpha_3 \cdot KOF_{j,t}\ (\textbf{Model 5}) \\ + Period\ effects + \varepsilon_{it}$$

As a last step in our robustness analysis, we estimated an econometric model that provided us with insight into what contribution was determined by each of the five sub-indexes of the GSCI overall index to understand which pillar was significant and generated the highest marginal effect on the potential of countries' value creation in the forestry sector:

$$Efficiency\ score_{j,t} = \alpha_0 + \alpha_1 \cdot NC_{j,t} + \alpha_2 \cdot SC_{j,t} + \alpha_3 \cdot IC_{j,t} + \alpha_3 \cdot GC_{j,t} + \alpha_3 \cdot RI_{j,t} \\ + Period\ effects + \varepsilon_{it}\ \ (\textbf{Model 4})$$

The period effects were analyzed to identify any substantial changes over time in the institutional framework, technological capabilities, resource availability, global economic growth and environmental premises. It is essential from this perspective to understand that the process of convergence is dynamic and that some gaps could still persist, as the best performers do not necessarily stop from evolving as well.

3.5. Sensitivity Analysis

The last part of our study related to further investigations on the consistency of our results, this time from the perspective of the influence of the distribution of the probabilities of the variables included in the econometric analysis. As the efficiency score did not follow a normal distribution, we verified our OLS results with the regression coefficients determined estimating this time a separate quantile regression model.

$$Efficiency\ score_{j,t} = \alpha_0 + \alpha_1 \cdot GSCI_{j,t} + \alpha_2 \cdot BS_{j,t} + \alpha_3 \cdot KOF_{j,t}\ (\textbf{Model 5})$$

Therefore, in **model 6** we included in the econometric quantile regression model only the variables that were included in **model 3** in order to have a proper basis of comparison for the potential effects of the non-normally distributed efficiency score variable. However, in the case of this model, we did not control for the period effects, as in the case of the estimated quantile regression, the scope of our analysis was rather for checking the consistency of the initial OLS econometric analysis, with no purpose to conduct a tendency analysis.

4. Results and Discussions

4.1. Exploratory Statistical Analysis

Our study was designed to provide insight into the implications of the implementation of sustainable economic growth on the macroeconomic level. Specifically, we looked for an association between the level of gross value added generated by the forestry industry and the level of achievement of the core principles and objectives of sustainability on the macroeconomic level.

In Table 2, we provide summary statistics of the main variables related to measures of economic growth and sustainability performance reported at the macroeconomic level in the context of economic globalization and resource constraints.

The gross value added mean (6.581) and standard deviation (1.144) describe a relatively homogenous structure for the national economies included in our sample, as the deviation explained approximately 17.39% of the mean value. The forestry industry contributed to an overall gross value added of only 0.46%, which did not show a high contribution to the overall GDP. Further, the efficiency of the exploitation of forests land led to higher output that could generate cost-based positive synergy effects in areas such as renewable energy, climate change, public health, or even green tourism [3,4,50].

Table 2. Descriptive statistics.

Variable	Mean	SD	Min.	Max.	Collinearity Statistics		Kolmogorov–Smirnova	
					Tolerance	VIF	Stat.	Sig.
Gross value added	6.581	1.144	4.027	8.340	-	-	0.130	0.000
Efficiency score	0.694	0.250	0.226	1.000	-	-	0.225	0.000
GSCI index	51.49	3.945	42.80	62.10	0.548	1.826	0.059	0.200 *
GCI index	4.868	0.532	3.860	5.845	0.413	2.421	0.514	0.000
KOF index	74.27	18.23	0.077	89.57	0.907	1.103	0.345	0.000
Sophistication	42.82	8.611	27.30	68.80	0.439	2.275	0.138	0.000
Natural capital	48.20	8.253	30.27	67.60	0.979	1.021	0.083	0.058
Social capital	53.44	6.998	37.72	74.60	0.767	1.304	0.053	0.200 *
Intellectual capital	54.27	6.893	34.90	70.78	0.681	1.468	0.042	0.200 *
Governance	55.32	5.906	42.50	69.50	0.905	1.105	0.056	0.200 *
Resource Intensity	48.68	9.332	26.60	69.36	0.784	1.275	0.073	0.186
GDP per capita	12.19	1.437	9.715	14.96	0.794	1.259	0.097	0.012

* This is a lower bound of the true significance. Source: authors' calculation.

However, this contribution varied across countries, depending not only on the area of forests available but also on human capital, techniques, and technologies used along with the industrial processing of wood timber [4]. Essential to this equation is how to ensure intensive economic growth rather than through a model of extensive growth that resumes mainly from the extension of the volume of timber processed from a larger area of forests.

4.1.1. Dynamics on Value Creation Potential from Benchmarking Perspective

The score of efficiency is the measure that provides us with an indication of the potential increase in the gross value added generated by forestry through a combination of all production factors, such as the consumption of timber, the availability of human capital, and the use of modern techniques and technologies to process wood. In Table 2, we can observe the heterogeneity in our sample from the perspective of the efficiency score, as the mean of the DEA calculated score (0.694) was explained by more than 36% of the variation in the sample (0.250). We observed a high widespread on the efficiency score, mainly driven by gaps in terms of the potential of the gross value added between the best performers (1.000) and the lower performers (0.250).

Starting from a sustainable consumption perspective, we understood this gap between countries as capabilities and that economies must generate gross value added in the forestry area by minimizing the use of production factors. Therefore, the 1st quartile (0.482) on this measure suggests that the first 25% of the countries analyzed reported a performance lower than half that of the benchmark countries. In Figure 2, we can see the best performers were Finland, France, Italy, and Netherlands; each economy were considered with a different combination of the production factors. The lower performers were Hungary, Latvia, or Lithuania, who either did not have internal forests areas available or just preferred to follow the model of extensive economic growth, by exploring insufficiently the potential of human capital and emerging technologies, such as IoT, that could bring relevant improvement in terms of planning and monitoring industrial processes.

The information in Figure 3 provide us with relevant insight concerning the association between the efficiency score and the gross value added generated by forestry areas. The representation of both variables suggests a positive relationship from the association, as a higher efficiency score is related to a higher gross value added. This relationship persisted over time, but the increase in the efficiency deteriorated slightly in the period 2018–2019, mainly driven by governments' awareness of the role of public policies and regulation for achieving targets of the SDGs, with a greater focus on SDG 15 [63–65]. Therefore, awareness by the government produces visible effects on forestry, later than the adoption in 2015 of the UN Sustainable Development Goals (SDGs), showing a lower increase in efficiency starting with results reported in 2018.

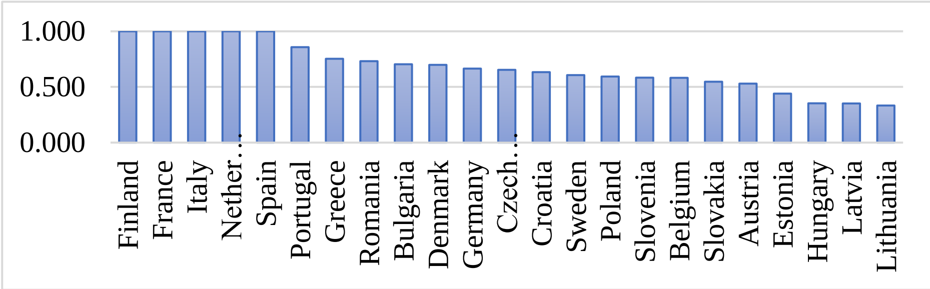

Figure 2. DEA-based efficiency score by country. Source: authors' projection.

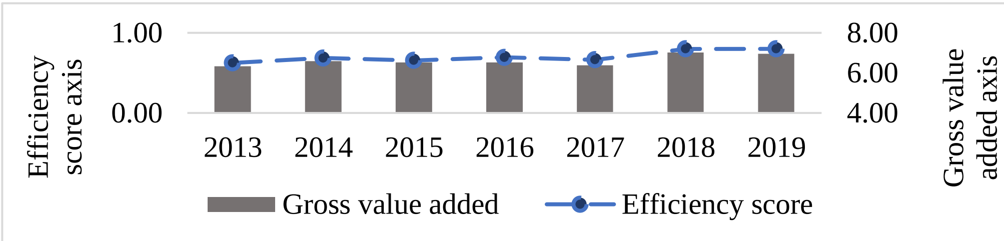

Figure 3. Gross value added (ln) and DEA-based efficiency score. Source: authors' projection.

Starting this year, we observed that the efficiency score slightly decreased, based on additional costs incurred to implement measures of sustainability at the macroeconomic and institutional levels. However, the decrease in the growth of the efficiency score had a lower impact on the increase in the gross value added, as an increasing number of Industry 4.0 emerging technologies were implemented. Therefore, technologies, such as simulation (Sim), geographic information systems (GIS), or radio frequency identification (RFID), generate real positive effects on cost reduction, reduce the complexity of processes, or promote continuous improvement initiatives [44].

4.1.2. Country Based Sustainability Profiles on EU Region

The EU countries included in our sample showed a relatively high level of global sustainability competitiveness index, as the mean value (51.49) was close to the maximum value (62.10). However, there were slight differences across countries, especially from the perspective of some of the sub-indexes included in the GSCI index, particularly concerning the natural capital component and the resource intensity component.

Therefore, a higher variation among countries was shown in the case of those two sub-indexes, as their coefficient of variation was slightly higher: 17.12% for the natural capital component and 19.17% for the resource intensity sub-index. Based on these results, we proceeded to a cluster analysis to group the countries included in our sample using as input criteria the five core pillars of sustainability as proposed by the Solability model. In Figure 4, we represent the mean values of each of the five sub-indexes that were part of the overall sustainability competitiveness index. In this representation, we note the slightly higher difference across the clusters on exactly the pillars placed at the basis of the calculation of this GSCI index.

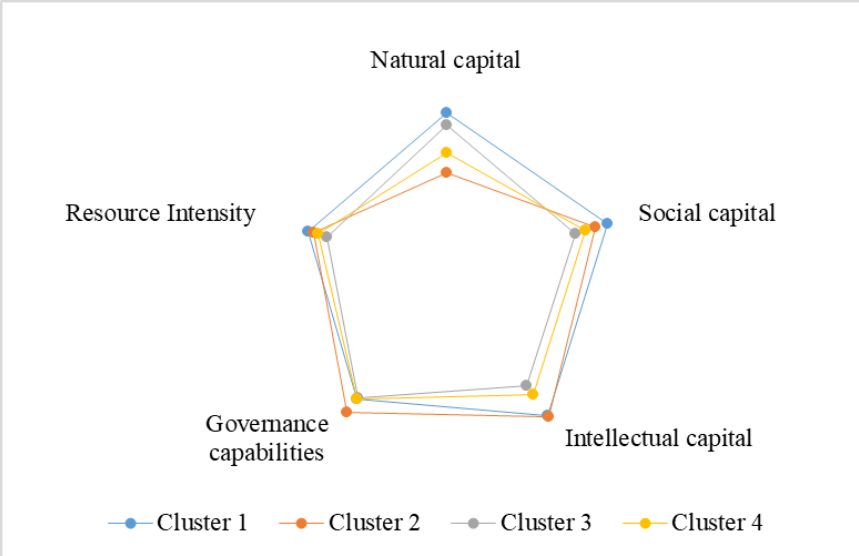

Figure 4. Dendrogram reflecting clusters of the sustainability models. Source: authors' projection.

The highest spread within our sample was recorded with the natural capital sub-index, which reflects a mixture of the availability of natural resources (e.g., population, geography, climate, and biodiversity) as well as the level of depletion/degradation of those resources. Looking at Figure 5, it represents a dendrogram associated with our cluster analysis, note that countries in Northern Europe are clearly delimited in a single cluster, while the fourth cluster includes most of the countries used in our sample. These clusters are similar to the ones estimated in [66–68], where the Northern European countries placed at the top of best performers in terms of sustainability performance.

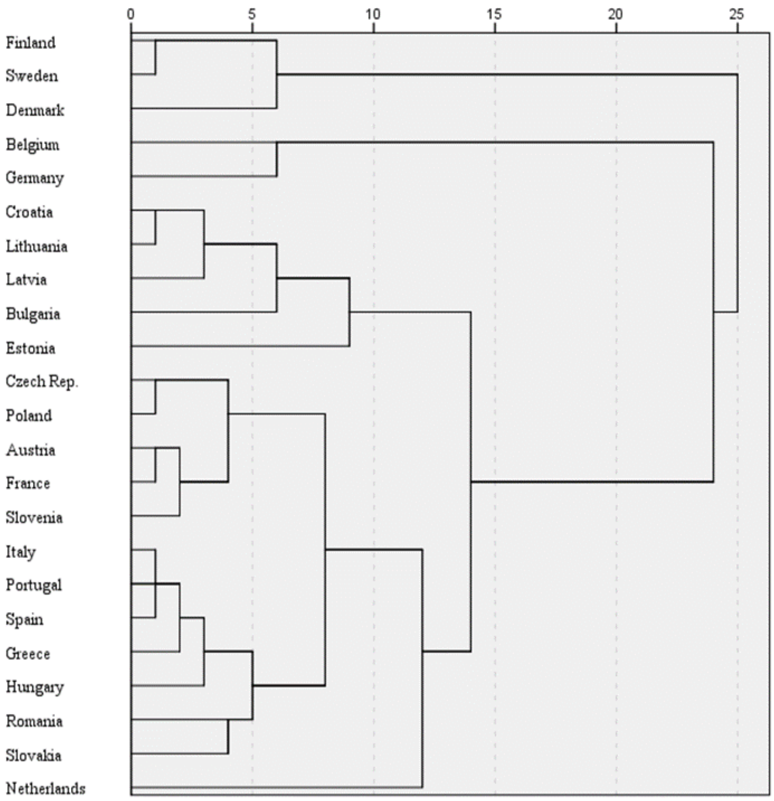

Figure 5. Dendrogram reflecting clusters of sustainability models. Source: authors' projection.

This cluster analysis showed a higher difference between countries in terms of sustainable growth that was indicated by the public policies and institutional frameworks setup in those Northern European countries, which have much more forests land, but they are also on top in terms of countries with higher depletion rate of forests, but their regeneration rates are mainly driven by natural forest regeneration rather than government-driven public policies and projects [69].

In terms of gaps identified concerning the use of the production factors considered in the DEA analysis, we note in Figure 6 that the main gap in forests exploitation across countries was related to fixed capital use, referring to the techniques and technologies used. This result shows us that Northern European countries affect higher amounts of fixed capital for the exploitation of natural resources, mainly driven by higher volumes of wood processed, whereas the other factors considered in the analysis were slightly similar across the countries. Therefore, challenges and opportunities towards better efficiency in forests exploitation obtained by a higher gross value added through minimizing the consumption of natural resources can be found, especially, in the area of implementing emerging technologies.

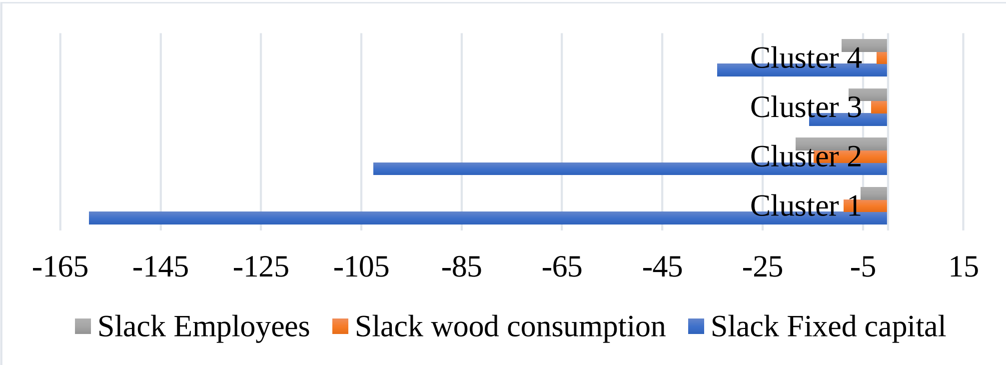

Figure 6. Gaps in the production factors from the perspective of the DEA results. Source: authors' projection.

4.2. Correlation Analysis

In Table 3, we summarize the correlations between the variables considered in the analysis.

Overall, the results suggest statistically significant positive correlations between the efficiency score and the slack on employees working in the forestry industry (0.537). This correlation shows that the gap between the results reported by a country and the results reported by the best performer (slack) positively influences the efficiency score, underlining how important the human factor is within forestry business models, in addition to the technical endowment. Therefore, a higher slack on employees, determined by a higher slack as well on wood consumption (0.509), resulted in a similar one as obtained in [28].

However, the higher correlation between the slack on wood consumption and the slack on fixed capital affected for forestry exploitation (0.781) confirmed again a high level of automation in forestry industrial processes. Instead, a higher endowment with technical capabilities is amplified by the human factor by integration of solutions of emerging technologies that lead to better overall equipment effectiveness (OEE) and higher machine productivity.

Therefore, synergy effects can be achieved by combining equipment, integrating solutions for the implementation of Industry 4.0-based enabling technologies, and using highly qualified human capital. Those synergy effects are suggested as well by the negative correlation between the component of intellectual capital of the GSCI index (−0.419) and slack on fixed capital. This negative correlation shows that countries implementing innovative solutions in the area of operations, lead to better equipment productivity, which place countries closer to the best performers.

Table 3. Pearson correlation matrix.

	Efficiency Score	Slack Employees	Slack Fixed Capital	Slack Wood Consumption	Growth Gross Value Added	Gross Value Added
DEA-based slacks calculated						
Employees	0.537 **	1	0.323 **	0.509 **		
Fixed capital	0.344 **	0.323 **	1	0.781 **		
Wood consumption	0.406 **	0.509 **	0.781 **	1		
Aggregate country indexes						
GSCI index	0.016	0.047	−0.531 **	−0.391 **	−0.232 **	0.398 **
KOF index	0.035	0.084	−0.101	−0.114	−0.037	−0.005
GCI index	−0.104	−0.018	0.028	0.089	0.117	−0.009
Business sophistication	0.192 *	0.188 *	−0.477 **	−0.350 **	−0.152	0.429 **
Sustainability competitiveness pillars country sub-indexes						
Natural capital	−0.064	0.137	−0.252 **	−0.103	−0.022	0.102
Social capital	0.087	0.119	−0.242 **	−0.072	0.035	0.232 **
Intellectual capital	0.084	0.143	−0.419 **	−0.281 **	−0.143	0.336 **
Governance capabilities	−0.210 *	−0.330 **	−0.206 *	−0.291 **	−0.201 *	0.198 *
Resource Intensity	0.128	0.07	−0.207 *	−0.197 *	−0.110	0.191 *

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). Source: authors' calculation.

Despite the expectation that the gap between countries and best performers, in terms of the fixed capital used in operations, is higher in the case of more complex business models, our results show a negative correlation (−0.477). This negative association suggests rather information concerning the impact of the integration of multiple levels of types of operations on the business model. Higher vertical integration of operations that lead to a higher proportion covered on the entire supply chain, requires a more diverse portfolio of equipment and technologies, which leads to higher gross value added (0.429), if the technological capabilities effectiveness is sufficiently high.

Even if at the lower level (−0.210) but statistically significant, a negative correlation between the efficiency score and countries' governance capabilities indicates the role of the institutional framework at the country level. As long as there is proper regulation in place to promote sustainable forests management and effective monitoring and control mechanisms are implemented, governments strategies through public policies concerning forests management can be successfully achieved at lower compliance costs [67].

4.3. Econometric Analysis

4.3.1. Marginal Analysis of the Impact of Sustainability on Value Creation

The potential for value creation generated in forestry areas has become a continuous debate over the last decades, especially in light of the UN adopting the SDGs, which have placed forestry operations as a key element for strategic sustainable economic growth, reflected in SDG 15. Instead, as the authors of [4] noted, public policies in the forestry area as well several trade-offs lead to a decrease in economic performance because of the additional costs implied by the implementation of sustainable policies on forestry operations. The results in Table 4 indicate the impact of these trade-offs on the economic output. However, the results suggest several synergies, such as sustainable economic growth, led to sustainable management of forests, with direct and indirect implications for public health, economic output, or even quality of life.

The econometric models estimated and described in Table 4 were all statistically significant, as the p-values of the F statistic were under the threshold of 0.05, with the exception of models 3 and 5, which still had p-values under an acceptable threshold of 0.10.

Table 4. OLS estimated econometric models.

Models	(1)	(2)	(3)	(4)	(5)
Dependent variable	GVA	Growth		Efficiency score	
Constant	2.271 *** (1.316)	0.3198 * (0.127)	1.614 * (0.362)	1.048 * (0.335)	0.595 * (0.151)
Global sustainability competitiveness index	0.056 *** (0.03)	−0.007 * (0.003)	−0.028 * (0.008)	-	-
Business sophistication	0.044 * 0.014	-	0.012 * (0.003)	-	0.0062 ** (0.003)
KOF index	−0.006 0.005	-	−0.0001 (0.001)	-	−0.0019 (0.002)
Global competitiveness index	-	-	-	-	−0.0021 (0.001)
Gross value added	-	0.012 *** (0.007)	-	-	-
Social capital	-	-	-	0.008 *** (0.005)	-
Resource intensity	-	-	-	0.007 ** (0.003)	-
Natural capital	-	-	-	−0.005 *** (0.003)	-
Governance capabilities	-	-	-	−0.011 * (0.004)	-
Intellectual capital	-	-	-	−0.0035 (0.004)	-
Control on year effects	N	N	Y	N	N
Model validation					
Sample size	132	170	132	113	132
R^2 adjusted	0.201	0.036	0.033	0.095	0.033
F stat	11.98	4.158	2.475	3.353	2.509
p	0.000	0.017	0.064	0.007	0.062
Durbin–Watson stat	0.047	1.614	0.362	0.490	0.359
Period F test	0.651 0.690	2.219 0.044	2.762 0.015	1.815 0.117	1.068 0.385
Hausman test	0.420 0.936	2.550 0.280	12.46 0.006	9.074 0.106	2.886 0.410
Breusch–Pagan test	0.581 0.446	1.588 −0.208	0.539 0.463	0.098 0.755	0.182 0.670

* Significant at the 1% significance level; ** significant at the 5% significance level; *** significant at the 10% significance level. Source: authors' calculation.

Instead, the R^2 was low, varying between 3.3% and 20.1%, which shows that either the efficiency score aimed to reduce forest resources to obtain fixed gross value added, or the gross value added reported in the forestry area were less influenced by the countries' progress to more sustainable-oriented economic growth framework.

However, coefficients related to the GSCI index and business sophistication proved to be statistically significant. Therefore, despite the low influence on the macroeconomic output, the transition to sustainable economic growth was slightly influenced by the measures of the countries' sustainable competitiveness.

4.3.2. Marginal Analysis of Transition to Sustainability on Operations Efficiency

The efficiency score was negatively impacted by a higher level of progress to sustainable economic growth ($Coef. = -0.0028,\ Sig. < 0.01$). To our knowledge, we did not find any study addressing the impact of a transition to sustainable economic growth on an operation's efficiency in the forestry area. However, studies (e.g., [7] or [41]) have underlined the trade-offs between SDG 15 and other SDGs, including SDG 8 and SDG 9, which have become more visible over time. Therefore, environmental protection leads to conflicting relationships with strategies that concern short-term economic growth, implementation of emerging technologies, and the development of infrastructure, which persist along the entire life cycle assessment framework [68].

Instead, if we looked at the marginal effects of the GSCI score sub-indexes on the efficiency score; we noted that the negative effect was mainly driven by the progress towards sustainable economic growth related to the availability of natural resources ($Coef. = -0.005,\ Sig. < 0.10$) and governments' capabilities to design and implement national strategies on sustainable growth [36,49], and through public policies and effective regulation ($Coef. = -0.011,\ Sig. < 0.01$) [32,46,49]. Moreover, the results show a higher negative impact of governance capabilities, which supports our position that governments should be more involved in drafting national regulation, implementing monitoring and control mechanisms, and promoting sustainable consumption and sustainable forests management best practices by granting incentives in various financial and nonfinancial forms [49].

Countries with plenty of natural resources are constrained by the same pressure as those with less abundant natural resources. Therefore, the countries with plenty of natural resources seem to be more relaxed concerning the need to transition towards a more sustainable consumption function. However, the positive marginal effect of resource intensity ($Coef. = 0.007,\ Sig. < 0.01$) suggests that there are regional efforts made for the optimization of the use of resources among all countries, depending on the constraints each country face in terms of the lack of resources and high dependence on technical advances and Industry 4.0-based emerging technologies, leading to a new perspective of SFM—the Forest 4.0 [34,43,44]. Instead, this result emphasizes the opportunity for public policies government should adopt: must promote sustainable consumption, transition to a more bioeconomy-oriented output [69], or initiatives in sustainable forests management, such as the implementation of Industry 4.0-based smart solutions [44]. In the European Union region, there is much attention paid to sustainable growth through the European Green Deal commitments. However, governments' public policies concerning the forestry industry prove to be discretionary across countries, lacking coherence at regional level, and affecting the regional supply chain's sustainable performance, despite the significant compliance costs recommended for forest-based industries [67]. Moreover, even the New EU Forest Strategy for 2030 cannot yet be fully monitored through a comprehensive and robust system of indicators because of the lack of data and insufficient clarity on the mapping of pan-European indicators, with the strategies they are aiming for [50].

Nonetheless, we observed a positive marginal impact of the social components of the GSCI index ($Coef. = 0.008,\ Sig. < 0.01$)), which suggests that better efficiency on forestry operations can be determined by human factor, influencing community involvement, promoting sustainable wood-based products' consumption, or improving labor practices [4,28]. Additionally, we highlight the essential role of the human factor in the design of business models and national economies, especially through their impact on knowledge management, coordinating activities, searching for opportunities, configuring, and reconfiguring resources or the development of adaptability as dynamic capability under an uncertain economic and environmental regional context [70].

In Figure 7, we illustrated the time fixed effects related to the third model estimated. The trend of the increasing marginal effect over time of the evolution of the economic, social, and environmental context impacted positively on the efficiency score. This positive evolution over time was mainly driven by the greater awareness by governments, companies, and people on the need to transition economies to sustainable growth models. It is essential to observe that the positive significant time fixed effects were recorded, especially, in the period 2018–2019, which coincides with the period that shows the most recent effects of the transition towards the sustainable growth of economies since the adoption of the European Green Deal.

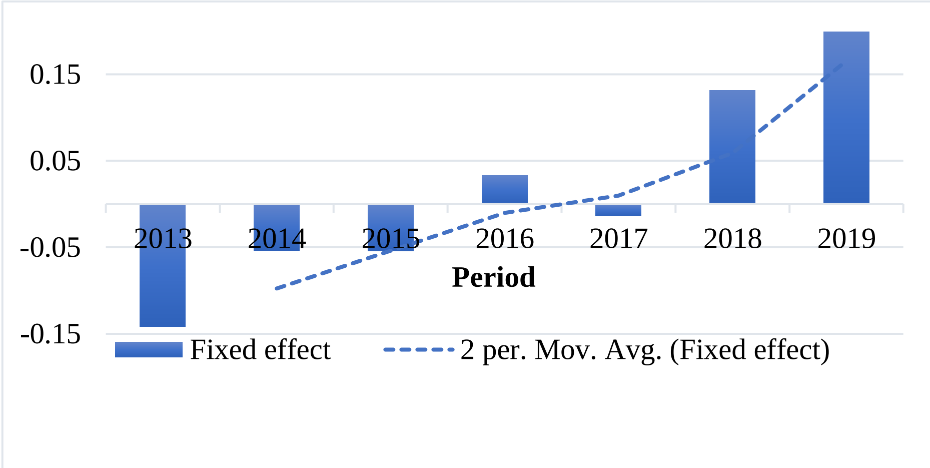

Figure 7. Fixed effects generated by evolution over time. Source: authors' calculation.

We highlighted that the increase in awareness concerning the need for sustainability was possible mainly because of the higher involvement of the EU Commission and national EU members' authorities that had adopted the European Green Deal and further developed more comprehensive specific directions of action, including orientation of EU policies and directing EU grants to initiatives on the circular economy, bioeconomy, or forest sustainable management. However, the transition to sustainable growth and the successful achievement of targets in terms of the globally agreed SDGs had determined disproportionate evolutions across EU countries [71] because of insufficient coherence in public policies and robust monitoring instruments across national economies concerning the transformation of national economies towards sustainable economies [50,58].

4.4. Robustness Analysis

4.4.1. Sustainable Growth's Impact on the Speed of Convergence of the Potential of Value Creation

To check for the robustness of our results presented in the previous section, we proceed to estimate additional econometric models to replace the efficiency score, as a dependent variable, with the level of gross value added reported for the forestry industry. Additionally, we assessed the speed of convergence of the potential of the gross value added by analyzing the effect of the global competitiveness sustainability index on the change rate of the gross value added.

The marginal effect, as determined by the GSCI index, on the gross value added reported for the forestry industry was described by the first model, and it is estimated and presented in Table 4. The results confirmed a positive statistically significant effect ($Coef. = 0.056$, $Sig. < 0.10$)), which demonstrates that a transition to a sustainable economic growth leads to an increase in the absolute value of the gross value added.

However, this relationship did not reveal the fact that the impact of the transition to sustainable growth becomes lower each year, mainly because of the trade-offs between different sustainable development goals, such as the conflicting relationship strengthening over time between SDG 15 and SDG 9 [7]. Therefore, environmental protection leads to conflicting relationships with strategies that concern the implementation of emerging technologies and the development of infrastructure, which persist along the entire life cycle assessment framework [68].

The negative effect on the gross value added was rather suggested by the second econometric model, which started from the classical β convergence model of economic convergence [56]. The results from the model estimate showed a positive impact of the gross value added reported from the previous year on the growth rate of the gross value added ($Coef. = 0.012$, $Sig. < 0.01$), which implies a β coefficient of $-\ln(1 + 0.012) = -0.01119$, as the analysis was made on an annual basis. This coefficient indicates a speed of convergence for the gross value added across countries with a percentage of approximately 1.19%, which means that countries with previous higher reported gross value added in a forestry area record a lower gross value added in the future, whereas the countries with a previous lower reported gross value added are expected to increase their potential of growth for the gross value added in the forestry area, with the same β coefficient.

More interesting with this equation is the role of the transition towards more sustainable growth-oriented economies. The negative effect of the GSCI index on the growth rate of the gross value added $(Coef. = -0.007,\ Sig. < 0.01)$ suggests an amplification of the convergence process on the forestry industry. Therefore, the negative regression coefficient showed a decrease on the rate of growth of the gross value added, especially among the countries with an already higher rate of GVA growth. First, we underline that the reduction in the speed of growth could be mainly determined by the limitations of the current stage of implementation of an emerging technologies and the limited qualified human factor enabling the use of such strategies. Second, the negative effect on the rate of GVA growth could be caused by the increasing the costs of environmental protection, which reduces countries competitiveness in terms of production costs.

4.4.2. Sensitivity of the Results on the Efficiency Score Distribution

As the efficiency score was not normally distributed, we reviewed the results' robustness, if choosing an alternative estimation method that controls for the effects of the dependent variable's distribution on the econometric estimates.

In Table 5 we provide statistics related to the same design of the econometric models presented in Table 4, but this time, it estimated following a quantile regression approach.

Table 5. Quantile regression estimated models (2nd quantile).

Model	(6)
Dependent variable	
Constant	1.919 * (0.475)
Sustainability competitiveness index	−0.036 * (0.01)
Business sophistication	0.015 * (0.01)
KOF economic index	−0.0011 (0.001)
Model validation	
Sample size	132
R^2 adjusted	0.04
Sparsity	0.757
Prob (Quasi-LR stat)	0.022
Quasi-LR statistic	9.608

* Significant at the 1% significance level. Source: authors' calculation.

Overall, the results show robust results in the case of the 2nd quantile, concerning the impact of the GSCI index on the efficiency score $(Coef. = -0.036,\ Sig. < 0.01)$. Therefore, the impact persists to be negative, showing that the transition to sustainable growth implies negative changes on the cost structure of the economies, which lead to higher operational costs and lower gross value added.

However, based on the data represented in Figure 8, we note that the negative effect of the GSCI index on the efficiency score was rather related to the average performers, better described in the 2nd quantile, whereas the 1st quantile and the 3rd quantile showed a slightly positive impact of the GCSI index on the efficiency score.

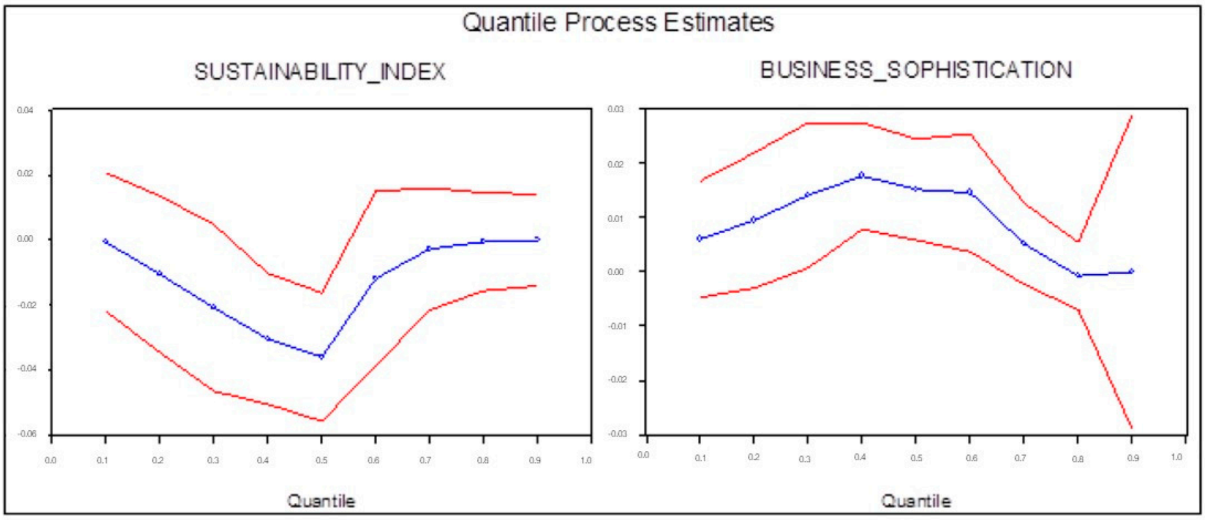

Figure 8. Regression coefficient estimates of the different quantiles. Source: authors' projection.

In the case of the best performers, the most relevant emerging technologies were implemented and the specialization of human capital was already ensured, which means that the current stage of sustainable growth generated benefits which exceeded the costs of sustainability, with direct impact on operational efficiency and indirect positive effects on gross value added generated at the forestry industry level.

Instead, in the case of the worst performers, the positive effect of the GCSI index on the gross value added could be explained by the yet premature stage of the implementation of the sustainability project initiatives, which mainly address the elements of the planning and the processes of the model design, which involve lower cost rates.

5. Conclusions

Nowadays, as we are aware of the effects of climate change and the continuous decrease of natural resources, we notice the need of higher focus on the concept of sustainable development.

Throughout the paper, we aimed to understand how countries' macroeconomic output is influenced by the efforts to change national economies towards circular-based oriented economies. In other words, we analyzed the relationship between the gross value added reported by the forestry industry and a measure of the progress of the transition towards a competitive sustainable economic growth model. We addressed this link between bioeconomy and forestry due to the fact the forest-based sector plays a central role in bioeconomy; it provides materials (i.e., wood and non-wood products), bioenergy, and a wealth of other regulating and cultural ecosystem services [72]. The analysis referred to the period between 2013 and 2019, summing-up 133 observations for 23 European Union members: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. We limited our research to the EU region, as the study represents only a starting point in the analysis of the effects of the transition to a green economy on the potential of value creation in the forestry industry. The choice was mainly driven by the fact that those countries subscribe to similar regulations, driven by European directives and regulations, which are mandatory for all EU members. The steps in this direction places the EU region as a benchmark for all other countries, as all those countries' efforts were unanimously agreed and formalized as the document of the European Green Deal document in 2019.

The results of our study highlight that transition to sustainable growth implies negative changes to the cost structure of economies, which lead to higher operational costs and lower gross value added. Our study revealed that for the best performers, namely, Finland, France, Italy, or the Netherlands, their current stage of sustainable growth generates benefits that exceed the costs of sustainability, with direct impacts on operational efficiency and indirect positive effects on gross value added generated at the forestry industry level. In addition, we underline this gap between countries that exist, as capabilities economies must generate gross value added in the forestry area by minimizing the use of production factors.

Our study has some caveats, given the limitation to the 23 EU member states included in the analysis. However, it would be interesting to perform a comparative analysis between EU countries and countries that do not have a similar SFM framework in order to highlight the importance of public policies and national and regional regulations.

Author Contributions: Conceptualization, A.E.A., L.-I.C., V.B., L.-I.C., A.E.D. and O.B.; methodology, V.B. and O.B.; software, V.B. and O.B.; validation, O.B. and L.-I.C.; formal analysis, O.B.; investigation, O.B. and V.B.; resources, O.B. and V.B.; data curation, O.B.; writing—original draft preparation, L.-I.C., A.E.A., V.B., L.I., A.E.D. and O.B.; writing—review and editing, L.-I.C., L.I., A.E.A., V.B., O.B. and A.E.D.; visualization, L.-I.C., A.E.A., O.B., V.B. and A.E.D.; supervision, A.E.A., V.B., O.B. and A.E.D.; project administration, L.I., A.E.A., A.E.D. and O.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Mikhno, I.; Koval, V.; Shvets, G.; Garmatiuk, O.; Tamošiūnienė, R. Discussion: Green Economy in Sustainable Development and Improvement of Resource Efficiency. *Cent. Eur. Bus. Rev.* **2020**, *10*, 99–113. [CrossRef]
2. WCED, UN. Brundtland Report. 1987. Available online: https://www.britannica.com/topic/Brundtland-Report (accessed on 25 August 2022).
3. D'Amato, D.; Korhonen, J. Integrating the green economy, circular economy and bioeconomy in a strategic sustainability framework. *Ecol. Econ.* **2021**, *188*, 107143. [CrossRef]
4. Baumgartner, R.J. Sustainable Development Goals and the Forest Sector—A Complex Relationship. *Forests* **2019**, *10*, 152. [CrossRef]
5. UNFCCC. The Paris Agreement. 2015. Available online: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (accessed on 25 August 2022).
6. UNGA Reports on Social Development. 2015. Available online: https://www.un.org/development/desa/dspd/publications/united-nations-reports-on-social-development/un-ga-reports-on-social-development-2015.html (accessed on 25 August 2022).
7. Kroll, C.; Warchold, A.; Pradhan, P. Sustainable Development Goals (SDGs): Are we successful in turning trade-offs into synergies? *Palgrave Commun.* **2019**, *5*, 140. [CrossRef]
8. Hu, W.; Wang, D. How does environmental regulation influence China's carbon productivity? An empirical analysis based on the spatial spillover effect. *J. Clean. Prod.* **2020**, *257*, 120484. [CrossRef]
9. Zhao, M.; Liu, F.; Song, Y.; Geng, J. Impact of Air Pollution Regulation and Technological Investment on Sustainable Development of Green Economy in Eastern China: Empirical Analysis with Panel Data Approach. *Sustainability* **2020**, *12*, 3073. [CrossRef]
10. European Commission. 2015. Available online: https://reform-support.ec.europa.eu/what-we-do/green-transition_en (accessed on 25 August 2022).
11. Eberhardt, L.C.M.; Birkved, M.; Birgisdottir, H. Building design and construction strategies for a circular economy. *Archit. Eng. Des. Manag.* **2022**, *18*, 93–113. [CrossRef]
12. Geissdoerfer, M.; Savaget, P.; Bocken, N.M.P.; Hultink, N.J. The Circular Economy—A new sustainability paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768. [CrossRef]
13. Odugbesan, J.A.; Rjoub, H.; Ifediora, C.U.; Iloka, C.B. Do financial regulations matters for sustainable green economy: Evidence from Turkey. *Environ. Sci. Pollut. Res. Int.* **2021**, *28*, 56642–56657. [CrossRef]
14. Bag, S.; Yadav, G.; Wood, L.C.; Dhamija, P.; Joshi, S. Industry 4.0 and the circular economy: Resource melioration in logistics. *Resour. Policy* **2020**, *68*, 101776. [CrossRef]
15. Bjoern, J.; Upadhyay, A. Understanding Barriers of Circular Economy: Cases from the Manufacturing Industry. *J. Enterp. Inf. Manag.* 2019; *ahead-of-print*. [CrossRef]

16. Tura, N.; Hanski, J.; Ahola, T.; Ståhle, M.; Piiparinen, S.; Valkokari, P. Unlocking circular business: A framework of barriers and drivers. *J. Clean. Prod.* **2019**, *212*, 90–98. [CrossRef]
17. Vermunt, D.A.; Negro, S.O.; Verweij, P.A.; Kuppens, D.V.; Hekkert, M.P. Exploring barriers to implementing different circular business models. *J. Clean. Prod.* **2019**, *222*, 891–902. [CrossRef]
18. Bocken, N.M.P.; Short, S.W. Towards a sufficiency-driven business model: Experiences and opportunities. *Environ. Innov. Soc. Transit.* **2016**, *18*, 41–61. [CrossRef]
19. Galvão GD, A.; Evans, S.; Ferrer PS, S.; de Carvalho, M.M. Circular business model: Breaking down barriers towards sustainable development. *Bus. Strategy Environ.* **2022**, *31*, 1504–1524. [CrossRef]
20. Galvão, G.D.A.; de Nadae, J.; Clemente, D.H.; Chinen, G.; de Carvalho, M.M. Circular Economy: Overview of Barriers. *Procedia CIRP* **2018**, *73*, 79–85. [CrossRef]
21. Tedesco, M.; Simioni, F.S.; Sehnem, S.; Soares, J.F.; Moreira Coelho, J.J. Assessment of the circular economy in the Brazilian planted tree sector using the ReSOLVE framework. *Sustain. Prod. Consum.* **2022**, *31*, 397–406. [CrossRef]
22. Michelini, G.; Moraes, R.; Nobre da Cunha, R.; Costa, J.; Ometto, A. From Linear to Circular Economy: PSS Conducting the Transition. *Procedia CIRP* **2017**, *64*, 2–6. [CrossRef]
23. Lazaridou, D.C.; Michailidis, A.; Trigkas, M. Exploring Environmental and Economic Costs and Benefits of a Forest-Based Circular Economy: A Literature Review. *Forests* **2021**, *12*, 436. [CrossRef]
24. Tavares, C.S.; Martins, A.; Graça, M.; Carvalheiro, F.; Duarte, F.D.; Gameiro, J.; Figueiredo, A.; Roseiro, L. Bioproducts from forest biomass II. Bioactive compounds from the steam-distillation by-products of *Cupressus lusitanica* Mill. and *Cistus ladanifer* L. wastes. *Ind. Crops Prod.* **2020**, *158*, 112991. [CrossRef]
25. Place, F.; Otsuka, K. Population, Tenure, and Natural Resource Management: The Case of Customary Land Area in Malawi. *J. Environ. Econ. Manag.* **2001**, *41*, 13–32. [CrossRef]
26. Castellani, V.; Sala, S.; Mirabella, N. Beyond the Throwaway Society: A Life Cycle-Based Assessment of the Environmental Benefit of Reuse. *Integr. Environ. Assess. Manag.* **2014**, *11*, 373–382. [CrossRef] [PubMed]
27. Gagnon, B.; Tanguay, X.; Amor, B.; Imbrogno, A. Forest Products and Circular Economy Strategies: A Canadian Perspective. *Energies* **2022**, *15*, 673. [CrossRef]
28. Han, X.; Geng, Y. Research on the Income Growth of Workers in Northeast State-owned Forest Regions after the Comprehensive Banning. *Acad. Exch.* **2014**, *30*, 135–139.
29. Modolo, R.C.E.; Senff, L.; Ferreira, V.; Tarelho, L.A.D.C.; Moraes, C.A.M. Fly ash from biomass combustion as replacement raw material and its influence on the mortars durability. *J. Mater. Cycles Waste Manag.* **2018**, *20*, 1006–1015. [CrossRef]
30. Lovric, M.; Leskinen, P.; Tuomasjukka, D. How Does Forest Management and the Use Ofwood Contribute to Economic Prosperity and Employment, K2A Knowledge to Action. 2022. Available online: https://efi.int/forestquestions/q10 (accessed on 28 August 2022).
31. Li, Y.; Mei, B.; Juvenal, T.L. The economic contribution of the world's forest sector. *For. Policy Econ.* **2019**, *100*, 236–253. [CrossRef]
32. Lazdinis, M.; Angelstam, P.; Pülzl, H. Towards sustainable forest management in the European Union through polycentric forest governance and an integrated landscape approach. *Landsc. Ecol.* **2019**, *34*, 1737–1749. [CrossRef]
33. Holmgren, S.; D'Amato, D.; Giurca, A. Bioeconomy imaginaries: A review of forest-related social science literature. *Ambio* **2020**, *49*, 1860–1877. [CrossRef]
34. Nummelin, T.; Hänninen, R.; Kniivilä, M. Exploring Forest Sector Research Subjects and Trends from 2000 to 2019 Using Topic Modeling. *Curr. For. Rep.* **2021**, *7*, 267–281. [CrossRef]
35. Klinger, S.; Bayne, K.M.; Yao, R.T.; Payn, T. Credence Attributes in the Forestry Sector and the Role of Environmental, Social and Governance (ESG) Factors. *Forests* **2022**, *13*, 432. [CrossRef]
36. Sheppard, J.; Chamberlain, J.; Agúndez, D.; Bhattacharya, P.; Chirwa, P.; Gontcharov, A.; Sagona, W.; Shen, H.; Tadesse, W.; Mutke, S. Sustainable Forest Management Beyond the Timber-Oriented Status Quo: Transitioning to Co-production of Timber and Non-wood Forest Products—A Global Perspective. *Curr. For. Rep.* **2020**, *6*, 26–40. [CrossRef]
37. WBCSD. Forest Sector SDG Roadmap. 2021. Available online: https://www.wbcsd.org/Sector-Projects/Forest-Solutions-Group/Forest-Sector-SDG-Roadmap (accessed on 28 August 2022).
38. Garcia, S.; Abildtrup, J.; Stenger, A. How does economic research contribute to the management of forest ecosystem services? *Ann. For. Sci.* **2018**, *75*, 53. [CrossRef]
39. Fuso Nerini, F.; Tomei, J.; To, L.S.; Bisaga, I.; Parikh, P.; Black, M.; Borrion, A.; Spataru, C.; Castan Broto, V.; Anandarajah, G.; et al. Mapping synergies and trade-offs between energy and the Sustainable Development Goals. *Nat. Energy* **2018**, *3*, 10–15. [CrossRef]
40. Vera, I.; Wicke, B.; Lamers, P.; Cowie, A.; Repo, A.; Heukels, B.; Zumpf, C.; Styles, D.; Parish, E.; Cherubini, G.; et al. Land use for bioenergy: Synergies and trade-offs between sustainable development goals. *Renew. Sustain. Energy Rev.* **2022**, *161*, 112409. [CrossRef]
41. Pradhan, P.; Costa, L.; Rybski, D.; Lucht, W.; Kropp, J.P. A Systematic Study of Sustainable Development Goal (SDG) Interactions. *Earth's Future* **2017**, *5*, 1169–1179. [CrossRef]
42. Fonseca, L.M.; Domingues, J.P.; Dima, A.M. Mapping the Sustainable Development Goals Relationships. *Sustainability* **2020**, *12*, 3359. [CrossRef]
43. Feng, Y.; Audy, J.-F. Forestry 4.0: A framework for the forest supply chain toward Industry 4.0. *Gestão Produção* **2020**, *27*, e5677. [CrossRef]

44. He, Z.; Turner, P. A Systematic Review on Technologies and Industry 4.0 in the Forest Supply Chain: A Framework Identifying Challenges and Opportunities. *Logistics* **2021**, *5*, 88. [CrossRef]
45. Schweier, J.; Magagnotti, N.; Labelle, E.R.; Athanassiadis, D. Sustainability Impact Assessment of Forest Operations: A Review. *Curr. For. Rep.* **2019**, *5*, 101–113. [CrossRef]
46. Blattert, C.; Eyvindson, K.; Hartikainen, M.; Burgas, D.; Potterf, M.; Lukkarinen, J.; Snäll, T.; Toraño-Caicoya, A.; Mönkkönen, M. Sectoral policies cause incoherence in forest management and ecosystem service provisioning. *For. Policy Econ.* **2022**, *136*, 102689. [CrossRef]
47. Breuer, A.; Janetschek, H.; Malerba, D. Translating Sustainable Development Goal (SDG) Interdependencies into Policy Advice. *Sustainability* **2019**, *11*, 2092. [CrossRef]
48. Linser, S.; Wolfslehner, B.; Asmar, F.; Bridge, S.R.J.; Gritten, D.; Guadalupe, V.; Jafari, M.; Johnson, S.; Laclau, P.; Robertson, G. 25 Years of Criteria and Indicators for Sustainable Forest Management: Why Some Intergovernmental C&I Processes Flourished While Others Faded. *Forests* **2018**, *9*, 515. [CrossRef]
49. Linser, S.; Wolfslehner, B.; Bridge, S.R.J.; Gritten, D.; Johnson, S.; Payn, T.; Prins, K.; Raši, R.; Robertson, G. 25 Years of Criteria and Indicators for Sustainable Forest Management: How Intergovernmental C&I Processes Have Made a Difference. *Forests* **2018**, *9*, 578. [CrossRef]
50. Lier, M.; Köhl, M.; Korhonen, K.T.; Linser, S.; Prins, K.; Talarczyk, A. The New EU Forest Strategy for 2030: A New Understanding of Sustainable Forest Management? *Forests* **2022**, *13*, 245. [CrossRef]
51. Linser, S.; Wolfslehner, B. National Implementation of the Forest Europe Indicators for Sustainable Forest Management. *Forests* **2022**, *13*, 191. [CrossRef]
52. Carrillo, M. Measuring Progress towards Sustainability in the European Union within the 203Agenda Framework. *Mathematics* **2022**, *10*, 2095. [CrossRef]
53. Wang, H.; He, M.; Ran, N.; Xie, D.; Wang, Q.; Teng, M.; Wang, P. China's Key Forestry Ecological Development Programs: Implementation, Environmental, Impact and Challenges. *Forests* **2021**, *12*, 101. [CrossRef]
54. Neykov, N.; Krišt'áková, S.; Hajdúchová, I.; Sedliaciková, M.; Antov, P.; Giertliová, B. Economic Efficiency of Forest Enterprises—Empirical Study Based on Data Envelopment Analysis. *Forests* **2021**, *12*, 462. [CrossRef]
55. Iancu, A. Economic Convergence. Applications—Second Part. *Rom. J. Econ. Forecast.* **2007**, *4*, 24–48.
56. Böhringer, C.; Jochem, P.E. Measuring the Immeasurable—A Survey of Sustainability Indexes. *Ecol. Econ.* **2007**, *63*, 1–8. [CrossRef]
57. Mensah, J. Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Soc. Sci.* **2019**, *5*, 1653531. [CrossRef]
58. Zupanic, N. Systematic Literature Review: Inter-Reletedness of Innovation, Resilience and Sustainability—Major, Emerging Themes and Future Research Directions. *Circ. Econ. Sustain.* **2022**. [CrossRef] [PubMed]
59. Halonen, M.; Näyhä, A.; Kuhmonen, I. Regional sustainability transition through forest-based bioeconomy? Development actors' perspectives on related policies, power, and justice. *For. Policy Econ.* **2022**, *142*, 102775. [CrossRef]
60. Paletto, A.; Bernardi, S.; Pieratti, E.; Teston, F.; Romagnoli, M. Assessment of environmental impact of biomass power plants to increase the social acceptance of renewable energy technologies. *Heliyon* **2019**, *5*, e02070. [CrossRef] [PubMed]
61. Linser, S.; Lier, M. The Contribution of Sustainable Development Goals and Forest-Related Indicators to National Bioeconomy Progress Monitoring. *Sustainability* **2020**, *12*, 2898. [CrossRef]
62. Lotfi, R.; Kheiri, K.; Sadeghi, A.; Tirkolaee, E.B. An extended robust mathematical model to project the course of COVID-19 epidemic in Iran. *Ann. Oper. Res.* **2022**, 1–25. [CrossRef]
63. Arce, J.J. *Forests, Inclusive and Sustainable Economic Growth and Employment*; United Nations: New York, NY, USA, 2019.
64. Global Competitiveness Report. 2020. Available online: https://www.weforum.org/reports/the-global-competitiveness-report-2020/ (accessed on 25 August 2022).
65. Ricciolini, E.; Rocchi, L.; Cardinali, M.; Paolotti, L.; Ruiz, F.; Cabello, J.M.; Boggia, A. Assessing Progress Towards SDGs Implementation Using Multiple Reference Point Based Multicriteria Methods: The Case Study of the European Countries. *Soc. Indic. Res.* **2022**, *162*, 1233–1260. [CrossRef]
66. Martín, C.J.; Carnero, M.C. Evaluation of Sustainable Development in European Union Countries. *Appl. Sci.* **2019**, *9*, 4880. [CrossRef]
67. Aggestam, F.; Pülzl, H. Coordinating the Uncoordinated: The EU Forest Strategy. *Forests* **2018**, *9*, 125. [CrossRef]
68. Sahoo, K.; Bergman, R.; Alanya-Rosenbaum, S.; Gu, H.; Liang, S. Life Cycle Assessment of Forest-Based Products: A Review. *Sustainability* **2019**, *11*, 4722. [CrossRef]
69. UNECE. State of Europe's Forests. 2020. Available online: https://unece.org/info/Forests/pub/22007 (accessed on 25 August 2022).
70. Cyfert, S.; Dyduch, W.; Zastempowski, M. The Impact of Resources on the Adaptability of State Forest Companies. Some Evidence from the State Forests National Forest Holding. *Forests* **2022**, *13*, 355. [CrossRef]
71. Jędrzejczak-Gas, J.; Barska, A.; Wyrwa, J. Economic Development of the European Union in the Relation of Sustainable Development—Taxonomic Analysis. *Energies* **2021**, *14*, 7488. [CrossRef]
72. Wolfslehner, B.; Linser, S.; Pülzl, H.; Bastrup-Birk, A.; Camia, A.; Marchetti, M. *Forest Bioeconomy—A New Scope for Sustainability Indicators*; From Science to Policy 4; European Forest Institute: Joensuu, Finland, 2016.