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Economic and financial instruments of forest management in the Czech Republic

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The forest bioeconomy becomes a feature of a climate-neutral economic system, while effective financial support is crucial for sustainable forest management. The main goal of this paper is to explain the impact of economic and financial instruments on the development of the forestry sector in the Czech Republic in the period 2000–2020. For research objectives, the methods of literature review, data analysis, correlation analysis, and regression analysis were used. Several models were established and tested. This paper presents the forest land model (FOLM) and wood biomass production model (WBIOM). In the monitored period, there was an increase in forest land in hectares in the Czech Republic, which was positively influenced by environmental investments in biodiversity and negatively by subsidies from the Rural Development Programme and the price of European Union Allowance. Based on the FOLM model results, 100 million CZK (4.07 million EUR) of environmental investments in biodiversity would contribute to an increase of 228 hectares of forest land. Concerning wood biomass production in cubic meters, it was influenced positively by the whole mixture of economic and financial instruments, such as emission trading, environmental taxation, financial contributions for forest management, state financial obligations, and subsidies. Based on the WBIOM model results, an increase in the price of an emission allowance by 100 CZK Mg^{-1} (approx. 4 EUR Mg^{-1}) would increase wood biomass production by approximately 934,614 cubic meters. Generally, the economic and financial instruments in the Czech Republic have an environmental impact and can influence the forest bioeconomy, at least in the long-term period. Concerning the complex influence of the emission trading on the forestry sector in the Czech Republic, it is ambiguous—in the case of forest land rather negative, and in the case of wood biomass production positive. Therefore, focusing on the policy recommendations, we should underline economic and financial instruments connected with positive motivation in the forestry sector, such as grant schemas, subsidies, and investments in biodiversity.

KEYWORDS

financial instruments, economic instruments, forest management, subsidies, climate change, forestry, forest bioeconomy, Czech Republic

1. Introduction

Environmental and climate policy uses a number of environmental protection tools. The combination of economic and financial instruments, along with other mechanisms, is organized by countries depending on their environmental policy preferences. Financial support for forestry is an essential tool to drive the bioeconomy growth and is expected to shift society to a more sustainable economic regime (Libert-Amico and Larson, 2020). Firstly, financial support for the European bioeconomy is delivered through the Horizon Europe research and innovation program. Ten trillion euros are earmarked for the bioeconomy under Cluster 6–food, bioeconomy, natural resources, agriculture, and environment (European Commission, 2021b). Secondly, the European Circular Bioeconomy Fund (2021) targeted the European bioeconomy and the circular bioeconomy. Thirdly, the Bio-based Industries Joint Undertaking (2023) represents a 3.7 billion EUR public-private partnership involving the European Union and Bio-based Industries Consortium working on fostering bio-based research and innovation, taking the risk out of investing in innovative, circular bio-based production plants and engaging stakeholders along the value chains.

Following the results of Stichting Wageningen Research Netherlands (2021), the taxes, tax relief, grants, subsidies, feed-in tariffs, loans, direct public funding, and tradable permits represent major categories of economic and financial instruments that allow the promotion of the bioeconomy. The report (Leoussis and Brzezicka, 2017) underlines the role of financial support for landowners, and forestry owners. Bio-based Industries Consortium's (2017) report displays the synergy effects of funding programs across the European Union. In addition, financial instruments can also foster innovations. Development of production methods and innovations in goods and services are the most frequent ones (Lovrić et al., 2020). Another study published by Liagre et al. (2021) dealing with forestry financial support is observed.

Rapidly, human behavior has altered the climate system in recent decades (IPCC, 2022). In general, non-human climate changes are slower and less destructive than anthropogenic ones (Ford et al., 2012). The concentration of greenhouse gasses in the atmosphere has been on the rise since the pre-industrial epoch. It is evident that atmospheric carbon dioxide and global surface temperature are deeply interlinked (Webb et al., 2013). Climate change driven by human activities shifts a variety of climate system components (Kirilenko and Sedjo, 2007). Global warming has caused an observed higher frequency, intensity, and duration of extreme weather events, such as droughts, windthrow, heatwaves, etc (Scinocca et al., 2016). Regarding the AR6 Synthesis report (Intergovernmental Panel on Climate Change, 2023), the global surface temperature reached 1.1°C above 1850–1900 in 2011–2020. Moreover, the current economic system running on linear flows of materials and energy generates anthropogenic greenhouse gas and accelerates ongoing climate change. Climate models offer a variety of "what if" scenarios with insight into what the future might look like depending on human choices, helping to understand how the climate system works (Kim et al., 2017: Giorgi, 2019; Hlásny et al., 2021).

Globally, cumulative greenhouse gas emissions amounted to an average of 54.4 gigatonnes of CO_2 equivalent between 2010 and 2019 (United Nations Environment Programme, 2022), with the highest share represented by fossil CO_2, methane (CH_4), and nitrous oxide (N_2O). Global atmospheric CO_2 concentrations continued to speed up and achieved an annual average of 420 parts per million in 2022 (Scripps Institution of Oceanography, 2023). Forests contribute to the carbon cycle through photosynthesis. In the Keeling curve (Keeling, 1958, 1960; Keeling et al., 1976, 1996), CO_2 concentration reaches a peak in May and hits a minimum at the end of the growing season in September. Simultaneously, the annual CO_2 oscillations are repeating with a rising trend. While about half of the CO_2 from fossil fuel burning is in the atmosphere, the second half is dissolved in the oceans, driving down the pH (Keeling et al., 2011). For example, CO_2 emissions reconstructions over the past 66 million years provide a study by Rae et al. (2021).

Reversing this trend, multiple initiatives with a vision to decarbonise the economy have been launched. For example, in 2015, United Nations introduced 17 Sustainable Development Goals (United Nations, 2023). A sustainable pathway for forests and the forestry sector can be found notably in SDG 9—Industry, innovation and infrastructure; SDG 13—Climate actions; and SDG 15–Life on land. An analysis of the impacts of the sustainable development goals on forests and society is carried out in a publication by Katila et al. (2019).

Within the European Union, the Paris Agreement (United Nations, 2022) is designed to cut greenhouse gas emissions and limit the rise of global temperature. The Green Deal's vision is a climate-neutral European economy by 2050 (European Commission, 2019). The legal obligation to move toward climate neutrality is further defined in the European Climate Change Act (European Commission, 2021e). The Fit for 55 package (European Commission, 2021d) identifies milestones to bring down greenhouse gas emissions by 55% by 2030. Regarding forestry, the revision of the legislation calls for increased adaptability of forests and natural regeneration of forests, together with financial support for sustainable forest management. The new EU Forestry Strategy 2030 (European Commission, 2021c), part of the Fit for 55 package, requires cascading utilization of biomass and financial support for forest owners and rural areas. The sustainable economy policy package complements the first EU Bioeconomy Strategy (European Commission, 2012), the New EU Bioeconomy Strategy (European Commission, 2018), and the New EU Circular Economy Action Plan (European Commission, 2022a). Then the synergies of the various frameworks offer a way toward a more efficient transformation of the European economy.

The bioeconomy is a bridge linking the above concepts and a field with the capacity to face a series of global challenges. Various definitions of the bioeconomy can be recognized, based on different stakeholders, sources, or geographic locations (Carus, 2012; van Leeuwen et al., 2014; Loiseau et al., 2016; D'Amato et al., 2017; Wesseler and von Braun, 2017; Birner, 2018; Bracco et al., 2018; Ramcilovic-Suominena and Pülzlb, 2018; Mittra and Zoukas, 2020; Barañano et al., 2021; Kardung and Drabik, 2021). The European Commission presented the first bioeconomy definition in 2012 (European Commission, 2012) and later updated it in 2018 (European Commission, 2018). Alongside the European bioeconomy definition and strategy, we can observe countless others, mainly at the national level in Italy

(Comitato Nazionale per la Biosicurezza, le Biotecnologie e le Scienze della Vita [CNBBSV], 2019), Finland (Luoma et al., 2011), Netherlands (Langeveld et al., 2016), Germany (Federal Ministry of Education and Research [BMBF], and Federal Ministry of Food and Agriculture [BMEL], 2020), or Spain (Ministerio de Economia y Competitividad, 2021). Bioeconomy consists of traditional sectors (Ronzon et al., 2017), such as agriculture, forestry, aquaculture, and the production of paper and wood-related goods. On the other hand, innovative sectors emerged, especially bioenergy, biofuels, and biochemicals. A comprehensive summary of national bioeconomy policy developments since 2018 displays the EU Bioeconomy Strategy Progress Report (European Commission, 2022b).

As a renewable segment of the circular economy, the bioeconomy incorporates forestry as one of its pillars. Then, the forest bioeconomy becomes a feature of a climate-neutral economic system (Harrison et al., 2022). Besides carbon sinks in the form of carbon sequestration in soils and wood products, forests substitute fossil and non-renewable sources of biomass (Hetemäki et al., 2022). The economic, ecological, and social value of the forests, multifunctional natural renewable resources, can be seen in market and non-market services, such as water control, soil protection, climate regulation, recreation, landscape formation, and wildlife (Farnworth et al., 1981). In many cases, the valuable benefits provided by the forests are public goods and externalities. Forest ecosystem services analyzed Merlo and Croitoru (2005), Sisak (2006), Ciccarese et al. (2012), Börner et al. (2017), and Winkel et al. (2022). The current state of forests is summarized in the Global Forest Goals Report (United Nations Department of Economic and Social Affairs, and United Nations Forum on Forests Secretariat, 2021).

Although climate change is an issue that requires addressing and the bioeconomy, particularly the forest bioeconomy, is relevant, it is still not sufficiently recognized and promoted in some countries (European Commission, 2022b). In this respect, these are mainly Central and Eastern European countries, and the Czech Republic is one of them. Bioeconomy as well as forest bioeconomy, is dedicated to the sustainable management of natural resources, increased use of renewable resources (wood biomass), and the creation of new jobs while striving to adapt and mitigate climate change (European Commission, 2018). Unlocking the potential of the bioeconomy continues to be a worldwide challenge, not least in forestry (Hetemäki et al., 2022). For this reason, this study focuses on the Czech Republic and its analysis of the forest bioeconomy.

In general, the Czech Republic is classified as a non-specialized bioeconomy (Ronzon et al., 2015), and has not yet developed a bioeconomy strategy at a national level. However, there are several documents that address the bioeconomy in a marginal manner. For example, the Strategic Framework of the Czech Republic 2030 (Ministry of the Environment of the Czech Republic, 2021), the Strategy of the Department of the Ministry of Agriculture of the Czech Republic with an Outlook up to 2030 (eAgri, 2023b), Research and Innovation Strategy for the Smart Specialization of the Czech Republic (Ministerstvo průmyslu a obchodu, 2022), and The Czech Republic's Innovation Strategy for 2019–2030 (Úřad vlády, Rada pro výzkum, vývoj a inovace, 2019). The forest bioeconomy performs an essential task in such national strategies.

The Czech Republic operates a rather complex and extensive system of financial support for forestry. The core financial support scheme for forestry is composed of two principal funding sources: (1) national sources based on the Forestry Act No. 289/1995 Coll., on forests and on the amendment and addition of certain laws (eAgri, 2023a), and (2) European funds within the Rural Development Programme (Ministry of Agriculture, 2021).

In the case of the national sources, the ability to support forest management is specified in Section 46 of the Forestry Act. This establishes that the State, in particular through the Ministry of Agriculture, stimulates forest management by providing services and financial contributions or subsidies. We can monitor various subsidy programs (Ministry of Agriculture of the Czech Republic, 2022a) of the Ministry of Agriculture for forestry, such as (1) financial contributions for forest management granted from the budget of the Ministry of Agriculture; (2) state financial obligations under the Forestry Act–mandatory expenditures; (3) subsidies for protection and reproduction of the gene pool of forest trees; (4) support from the Agricultural and Forestry Support and Guarantee Fund; (5) services with which the state supports forest management; (6) partial refund excise duty on diesel fuel consumed during forest management. Table 1 shows the comprehensive summary of financial support from national sources for forestry in the Czech Republic.

TABLE 1 Summary of the financial support from national sources for forestry.

Financial support	Specific type
Financial contributions for forest management granted from the budget of the Ministry of Agriculture	Financial contributions for reforestation, establishment, and tending of forest stands Financial contributions for green and environmentally friendly technologies Financial contributions for the elaboration of forest management plans Financial contributions for forest protection
State financial obligations under the Forestry Act–mandatory expenditures	Improvement and strengthening of wood species Activities of a professional forest manager Costs s for processing forest management plans Improvement and damming of streams in forests
Subsidies for protection and reproduction of the gene pool of forest trees	Gene base support Support of plant parents, ortets, and clones Support for seed sets and clone mixes Support for the activities of the National Bank of Seeds and Explants of forest trees
Support from the Agricultural and Forestry Support and Guarantee Fund	Interest support (reduction of interest burden) of investment loans Direct provision of preferential forestry investment loans
Services with which the state supports forest management	Aerial liming and fertilization, including monitoring Aerial firefighting and fire brigade Monitoring and forecasting the occurrence and development of harmful agents Consultancy Other services
Partial refund excise duty on diesel fuel consumed during forest management	

Source: authors, based on Ministry of Agriculture of the Czech Republic, 2022a.

Concerning European funds within the Rural Development Programme, financial support is directed toward diverse aspects of forestry. Specific topics of financial support under the Rural Development Programme 2014–2020 and 2007–2013 are listed in **Table 2**.

Besides subsidies, the Czech Republic implements also other economic and financial instruments, such as emission trading (since 2005, as a part of EU emission trading system ETS), environmental taxation, and feed-in tariffs for renewable energy sources. Feed-in tariffs are distinguished, based on the type of renewable energy source, and are published every year by the Energy Regulatory Office of the Czech Republic.

The issue of financial support for forestry in the Czech Republic has been dealt with in several studies, namely Šišák (2007, 2013), Lojda (2014), Kotecký (2015), and Rinn and Jarský (2022). Subsequently, the Concept of State Forestry Policy until 2035 (Ministry of Agriculture of the Czech Republic, 2020) aims to increase biodiversity and ecological stability of forest ecosystems while keeping industrial manufacturing in line with ongoing climate change. Sustainable forest management and financial support for owners to manage their forests in a sustainable manner is therefore a long-term ambition. In general, the Ministry of Agriculture report (Ministry of Agriculture of the Czech Republic, 2022b) shows an analysis of the current state of financial support in the Czech Republic.

Financial support is necessary for the development of the forestry sector of the bioeconomy. On the other hand, other economic and financial instruments are also important and represent a suitable mix for influencing the behavior of economic subjects. Based on the literature review, the analysis of the simultaneous impact of all economic and financial instruments on the forestry sector in the Czech Republic is still missing. This study tries to fill this gap.

2. Materials and methods

2.1. Materials

For the period 2000–2020, we collected detailed secondary data regarding the impact of current economic and financial instruments on forestry in the Czech Republic. Forestry is represented by 2 indicators, the first is forest land in hectares, and the second is wood biomass production in cubic meters. Subsidies are represented by (1) national public financing of forestry (including state financial obligations under the Forestry Act, financial contributions for forest management granted from the budget of the Ministry of Agriculture, subsidy for protection and reproduction of the gene pool of forest trees) and (2) financial aid co-financed by the European Union (Rural Development Programme 2007–2013, Rural Development Programme 2014–2020). Regarding other economic and financial instruments, they are represented by environmental investments in biodiversity, environmental taxes, and the price of EUA (European Union Allowance). A variety of data sources were employed, in particular from the Ministry of Agriculture, Eurostat (Eurostat, 2022), Czech Statistical Office (Czech Statistical Office, 2022), and Energy Regulatory Office (Energy Regulatory Office, 2021). **Table 3** gives an outline of all data/variables involved in correlation and/or regression analyses reported in this paper, specifying abbreviations, units, and the roles of the variables.

The first key dependent variable is "FOL," i.e., forest land, in total, in hectares. The second one is "WBIO," i.e., wood biomass production, in total, in cubic meters. These variables represent the forestry sector. Forest land is an indicator of the total area of forest and wood biomass production represents total roundwood removals.

Independent variables are selected with respect to their expected influence the on development of the forest bioeconomy. Specifically, independent variables describe economic and financial instruments currently applied in the bioeconomy sector in the Czech Republic, such as state financial obligations under the Forestry Act, financial contributions for forest management granted from the budget of the Ministry of Agriculture, subsidies for protection and reproduction of the gene pool of forest trees and Rural Development Programme, tradable emission allowances (the price of EUA) and environmental taxes (income from environmental taxes imposed in forestry sector).

Table 4 shows the expected impact of variables. Regarding the first dependent variable, forest land, we can expect a positive impact of all grants and subsidies (national public financing of forestry and Rural Development Programme), and a positive impact of environmental investments in biodiversity, similar to studies by España et al. (2022), or Rinn and Jarský (2022). Concerning the impact of revenues from environmental taxes and EUA price on forest land, we can suggest that it is not clear.

Based on Zhurakovska et al. (2021), an increasing tax payment results in an increased volume of harvesting, even though taxes are supposed to motivate the economic use of forest resources. Barua et al. (2012) demonstrate that forestry income taxes might be ineffective in limiting forest loss. On the other hand, carbon payments can effectively reduce forest clearing. It is similar to the results of Kerr et al. (2012), noting the effect of incorporating forestry into the ETS. However, Evison (2017) concluded that participation in the New Zealand Emission Trading Scheme (NZ ETS) is unlikely to deliver positive long-term effects on the forestry sector and appears not to be the appropriate instrument to encourage the planted forest increment. Pukkala (2020) analyzed the carbon pricing impact on optimal forest management and highlighted that rising carbon prices boost the rate of carbon sequestration. Moreover, a payment of 150 EUR per Mg^{-1} of carbon stored in forests would lead to a stop to cutting.

Focusing on the second dependent variable, wood biomass production, the expected impact of all grants and subsidies (national public financing of forestry and Rural Development Programme), and environmental investments in biodiversity is positive. Such expectation is based on Kanzian and Kindermann (2013), Moiseyev et al. (2014), and Locoh et al. (2022).

Wood biomass production represents roundwood removals as a native form of wood extracted from forests from planned harvesting and incidental logging (Forest Europe, 2020). Firstly, wood material can replace emission-intensive ones while storing carbon in long-lived harvested wood products (European Commission, 2021a). The positive effects of material replacement then depend on the substitution factor (Leskinen et al., 2018). The material use of wood brings opportunities for a circular bioeconomy and cascading use of wood biomass,

TABLE 2 Summary of the European funds within the Rural Development Programme 2014–2020 and 2007–2013.

Rural Development Programme 2014–2020		Rural Development Programme 2007–2013	
No.	Specific support	No.	Specific support
4.3.2	Forestry infrastructure	I.1.2	Investment in forests
8.1.1	Afforestation and reforestation	I.1.2.1	Forestry equipment
8.3.1	Implementation of preventive actions in forests	I.1.2.2	Technical equipment of the establishments
8.4.1	Restoration of forests after calamities	I.1.2.3	Forestry infrastructure
8.4.2	Flood damage repair	II.2.2	Natura 2000 payments in forests
8.5.1	Investment in the protection of ameliorative and reinforcing trees	II.2.3	Forestry-environment payments
8.5.2	Non-productive investments in forests	II.2.3.1	Improving the species composition of forest stands
8.5.3	Conversion of replacement tree plantations	II.2.4	Restoring forest potential after calamities and promoting the social functions of forests
8.6.1	Forestry machinery and technology	II.2.4.1	Restoring forest potential after calamities and introducing preventive measures
8.6.2	Technical equipment for wood processing plants	II.2.4.2	Non-productive investments in forests
15.1.1	Preservation of the stand type of the economic ensemble		
15.2.1	Protection and reproduction of the forest tree gene pool		

Source: authors, based on Ministry of Agriculture of the Czech Republic, 2022b.

TABLE 3 List of variables.

Variable	Abbreviations	Units	Role
Forest land	FOL	Hectares (Ha)	Dependent
Wood biomass production	WBIO	Cubic meters (m^3)	Dependent
Price of European Union Allowance	EUA	CZK Mg^{-1} CO_2	Independent
Environmental investments in biodiversity	INV	Million CZK	Independent
Revenues from environmental taxes imposed in forestry	TAX	Million CZK	Independent
State financial obligations under the Forestry Act (mandatory expenditures)	OBL	Million CZK	Independent
Financial contributions for forest management	CON	Million CZK	Independent
Subsidies for protection and reproduction of the gene pool of forest trees	SUB	Million CZK	Independent
Subsidies from Rural Development Programme	RDP	Million CZK	Independent
Time	TIME	Years	Control

Source: authors.

where closed loops of materials are created, the added value of inputs is maximized, and the lifetime of outputs is extended (Rüter et al., 2016). A synergy of wood biomass usage in downstream industries such as textiles, chemicals, and pharmaceutics is evident and boosts the forest-based bioeconomy (Martinez de Arano et al., 2018). Secondly, wood biomass in place of fossil fuels can achieve greenhouse gases (GHG) emissions cuts and assist in the decarbonisation of the economy (IUFRO, 2005). The value of wood biomass production is maximized by meeting both material and energy requirements using the same raw material (IUFRO, 2014). In this respect, scaling up GHG removals by harvested wood products, as well as decreasing GHG emissions by material and energy substitution can mitigate climate change (Nabuurs et al., 2017).

In terms of material and energy use of wood biomass, the following studies can be found, Martinez de Arano et al. (2018) deal with financing approaches for forest-based products. Lenglet et al. (2017) work with implications of subsidies and taxation on material flows within the forest wood supply chain. Based on raw wood products, Zhai and Kuusela (2022) highlight that taxes generate revenue while resulting in losses in the forestry sector.

TABLE 4 Expected impact of variables in FOLM and WBIOM.

Variable	Abbreviations	Expected impact	
		FOLM	WBIOM
Price of European Union Allowance	EUA	Not clear	Positive
Environmental investments in biodiversity	INV	Positive	Positive
Revenues from environmental taxes imposed in forestry	TAX	Not clear	Not clear
State financial obligations under the Forestry Act (mandatory expenditures)	OBL	Positive	Positive
Financial contributions for forest management	CON	Positive	Positive
Subsidies for protection and reproduction of the gene pool of forest trees	SUB	Positive	Positive
Subsidies from Rural Development Programme	RDP	Positive	Positive
Time	TIME	Positive	Positive

Source: authors.

TABLE 5 Overview of the data statistics.

Variable	Abbreviations	Minimum	Maximum	Standard deviation	Median
Forest land	FOL	2,637,289.00	2,678,804.16	12,967.29	2,658,606.50
Wood biomass production	WBIO	14,374,001.00	35,753,599.00	6,279,539.76	15,882,010.65
Price of European Union Allowance	EUA	41.64	1,355.69	312.67	336.37
Environmental investments in biodiversity	INV	177.63	1,549.00	368.93	422.58
Revenues from environmental taxes imposed in forestry	TAX	526.02	819.16	92.63	645.02
State financial obligations under the Forestry Act (mandatory expenditures)	OBL	185.90	306.90	35.79	237.80
Financial contributions for forest management	CON	176.00	8,187.00	1,923.52	356.5
Subsidies for protection and reproduction of the gene pool of forest trees	SUB	3.93	20.00	5.37	15,13
Subsidies from Rural Development Programme	RDP	9.72	625.95	217.42	403.63

Source: authors.

Jinggang and Peichen (2017) display that a higher carbon price would tend to higher forest carbon stocks. Concerning the impact of revenues from environmental taxes and EUA price on wood biomass production, we can suggest that in the case of taxation, it is not clear. Regarding EUA price, the expected impact is positive. Moiseyev et al. (2014) indicate that a high CO_2 price can support wood biomass production. Caurla et al. (2013) underlined that a carbon tax necessarily reduces consumer surpluses by pushing up the price of wood products. The combination of a carbon tax with sectoral policies is necessary. Based on Lauri et al. (2012), a higher carbon price can increase wood-based energy production. Sasaki (2021) concludes that facilitating global policies, upcoming sustainability markets, and financial stimulus via a carbon tax, environmental tax, and energy tax are able to promote sustainable forest management for long-term timber production and climate change mitigation.

Time represents the control variable. Based on statistics, the expected impact is positive (both forest land and wood biomass production increased in the selected period).

Table 5 summarizes the parameters of all variables described in Table 1. The minimum and maximum values, standard deviation, and median are given for each variable.

2.2. Methods

The main goal of this paper is to explain the impact of economic and financial instruments of the climate change policy on the development of the forestry sector in the Czech Republic in the period 2000–2020.

Keeping in consideration the main goal of the research, the research questions were set as follows. The first research question focuses on forest bioeconomy development (RQ1): Do current economic and financial instruments of the climate change policy have a positive impact on the development of the forest bioeconomy in the Czech Republic?

The second research question observes the drivers of bioeconomy renewable resources (RQ2): Are current economic and financial instruments of the climate change policy stimulating drivers for the increase in the use of bioeconomy renewable resources, such as wood biomass?

The third research question deals with the environmental effectiveness of selected policy instruments (RQ3): Are economic and financial instruments of the climate change policy environmentally effective?

To accomplish the research objectives, we followed the following workflow: (1) literature review and data collection; (2) quantitative analysis; (3) results evaluation and discussion.

Firstly, we conducted a rigorous literature review and collected the necessary data. The data are described in detail in the section "2.1. Materials." We adapted the data and time series to a format suitable for Excel.

In the next step, we performed quantitative analysis, specifically time series analysis, correlation analysis, and regression analysis. The data and time series were analyzed and their characteristics were evaluated. Since the data have a linear relationship and normal distribution, correlation analysis was performed using Pearson's correlation coefficient (Zimmermannova et al., 2016). The bivariate correlation is used to obtain a correlation coefficient that describes the measure of the relationship between two linear variables. Subsequently, we perform more complex regression analysis and construct regression models to observe also partial relationships of variables. Regression analysis enables to obtain the relationship between the dependent variables and all other variables.

Considering above-defined research questions, the following regression models were constructed and tested:

(1) forest land model (FOLM), focused in particular on the development of the forest bioeconomy;
(2) wood biomass production model (WBIOM), focused in particular on the use of bioeconomy renewable resources, such as wood biomass.

The regression equation of such models is as follows:

$$\begin{aligned} \text{FOL/WBIO} = {} & \beta 0 + \beta 1{*}\text{EUA} + \beta 2{*}\text{INV} + \beta 3{*}\text{TAX} \\ & + \beta 4{*}\text{OBL} + \beta 5{*}\text{CON} + \beta 6{*}\text{SUB} + \\ & \beta 7{*}\text{RDP} + \beta 8{*}\text{TIME} + \text{u} \end{aligned} \tag{1}$$

where:

Y-FOL (forest land, in total, in Ha) or Y-WBIO (wood biomass production, in total, in m^3); X1—EUA (the price of the European Union Allowance); X2—INV (environmental investments in biodiversity); X3—TAX (revenues from environmental taxes imposed in forestry); X4—OBL (state financial obligations under the Forestry Act); X5—CON (financial contributions for forest management); X6—SUB (subsidy for protection and reproduction of the gene pool of forest trees); X7—RDP (subsidies from Rural Development Programme); X8—TIME (time in years); u—random element of the model.

Firstly, the model containing all economic and financial instruments (FOLM or WBIOM) was created. FOLM/WBIOM is the composition of all independent variables (EUA, INV, TAX, OBL, CON, SUB, RDP, and TIME). Secondly, alternative models were run to seek the statistically most significant model with a high index of determination.

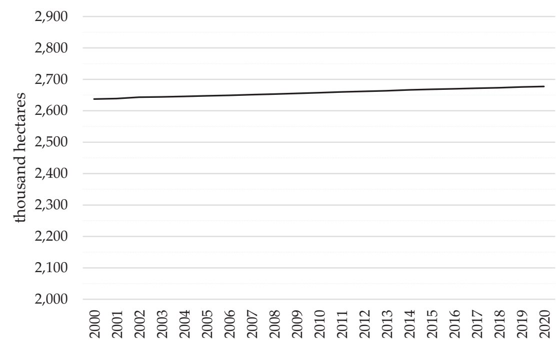

FIGURE 1
Development of total forest land in the Czech Republic. Source: authors, based on (Czech Statistical Office, 2022).

Finally, all results were verified using multiple tests. Based on the tests performed, the models were adjusted to be statistically significant, free of autocorrelation, and with a high degree of determination. In particular, the F-test and Durbin–Watson test were used to test the models developed. The F-test of overall significance examined the fit of the regression models. The Durbin–Watson test (DW) was performed to test for autocorrelation, using Durbin–Watson significance tables (Durbin–Watson Significance Table, 2023). The Durbin–Watson test is a frequently used method for testing autocorrelation, which generates a test statistic within the range of 0 to 4. If the value is close to 2, then the data indicates less autocorrelation. On the other hand, if the value is closer to 0 or 4, it implies stronger positive or negative autocorrelation, respectively.

The details of each model and the corresponding tests are described below in the section "3. Results."

3. Results

3.1. Forest land model

Firstly, **Figure 1** provides the development of total forest land in the Czech Republic in the period 2000–2020. Regarding data, a positive trend is visible. In detail, forest land has a slight growing tendency, and 2.68 million hectares are indicated at the end of the monitoring period.

Secondly, all of the selected variables that were considered to affect forest land were chosen for correlation analysis. In **Table 6**, the outcome of the correlation analysis is presented. According to the correlation analysis findings, we notice a statistically significant negative correlation between FOL and TAX. Besides the above links, negative correlations with lower statistical significance exist, such as INV.

Statistically significant positive correlations can be seen in the case of SUB and control variable TIME. Besides the above links, positive correlations with lower statistical significance exist, such as CON, EUA, and RDP.

For regression analysis, the regression model FOLM was developed. Firstly, the model containing all economic and financial instruments (FOLM) was verified. Secondly, alternative models

TABLE 6 FOLM–correlation analysis.

	FOL	EUA	INV	TAX	OBL	CON	SUB	RDP	TIME
FOL	1								
EUA	0.3102	1							
INV	−0.5548	0.3700	1						
TAX	−0.7642	0.1626	0.1817	1					
OBL	0.0272	0.6517	0.3451	0.3403	1				
CON	0.4907	0.6546	−0.0248	−0.0487	0.6292	1			
SUB	0.8321	0.6417	−0.0560	0.0031	0.6370	0.4930	1		
RDP	0.2941	0.3663	−0.0985	0.3019	0.7925	0.4856	0.7268	1	
TIME	0.9991	0.3382	−0.5415	−0.7562	0.0394	0.5020	0.8442	0.3207	1

Source: authors.

TABLE 7 FOLM–regression analysis.

	FOLM		FOLM1		FOLM2	
	Sig.	Coef.	Sig.	Coef.	Sig.	Coef.
EUA	0.041	−0.761	0.000	−2.498	0.004	−0.809
INV	0.981	0.009	0.004	2.282		
OBL + CON + SUB	0.763	−0.016				
RDP	0.025	−1.002			0.008	1.038
TIME	0.000	2,047.933	0.000	2,053.154	0.000	2,045.343
Constant	0.000	−1,458,298.718	0.000	−1,469,452.780	0.000	−1,453,074
Observ.	17		13		17	
R2	0.999		0.999		0.999	
Signif. F	0.000		0.000		0.000	
Durbin–Watson test	1.722		2.180		1.747	

Source: authors.

TABLE 8 WBIOM–correlation analysis.

	WBIO	EUA	INV	TAX	OBL	CON	SUB	RDP	TIME
WBIO	1								
EUA	0.631	1							
INV	−0.145	0.370	1						
TAX	−0.350	0.163	0.182	1					
OBL	0.507	0.652	0.345	0.340	1				
CON	0.822	0.655	−0.025	−0.049	0.629	1			
SUB	0.722	0.642	−0.056	0.003	0.637	0.493	1		
RDP	0.558	0.366	−0.099	0.302	0.793	0.486	0.727	1	
TIME	0.721	0.338	−0.542	−0.756	0.039	0.502	0.844	0.321	1

Source: authors.

were run to seek the statistically most significant model with a high index of determination (FOLM1 and FOLM2).

Forest land model (FOLM) is the composition of all independent variables (EUA, INV, TAX, OBL, CON, SUB, RDP, and TIME). While the entire model is statistically significant, not all of the selected variables are statistically significant. The result of the Durbin–Watson test (DW) for FOLM is acceptable (1.722).

FOLM1 and FOLM2 represent selected variables with a statistical significance of $p < 0.05$. These models are statistically significant models—all of the variables are statistically significant, and the entire model is statistically significant as well. In Table 7, the outcomes imply a high coefficient of determination in both models. Meaning that for FOLM1 and FOLM2, the general formula that is specified explains more than 99% of the variance with less than 5% of random deviations. Variables with a p-value of below 5% are EUA, INV, TIME, and the constant (FOLM1) and EUA, RDP, TIME, and the constant (FOLM2). To the results of the overall F-test, the estimated regression forest land models are statistically

TABLE 9 WBIOM–regression analysis.

	WBIOM1		WBIOM2		WBIOM3		WBIOM4		WBIOM5	
	Sig.	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.	Coef.
EUA	0.015	9,346.138								
TAX			0.044	42,667.350						
OBL					0.001	83,999.409				
CON							0.000	2,008.576		
RDP									0.049	11,193.506
TIME	0.002	776,395.806	0.000	2,177,209.912	0.000	678,486.466	0.003	398,034.953	0.003	817,573.294
Constant	0.002	−1,546,584,115	0.000	−4,392,833,128	0.000	−1,365,270,547	0,003	−783,415,440.5	0,003	−1,629,508,948
Observ.	17		13		22		22		17	
R2	0.835		0.864		0.865		0.896		0.805	
Signif. F	0.000		0.001		0.000		0.000		0.001	
Durbin–Watson test	1.262		0.784		0.614		1.050		0.584	

Source: authors.

significant at 5% (FOLM1 and FOLM2) levels of significance. The finding of the Durbin–Watson test (DW) for FOLM1 shows no positive autocorrelation (DW 2.180 > upper critical value 1.816), and for FOLM2 also no positive autocorrelation (DW 1.747 > upper critical value 1.710).

According to the FOLM1 outputs (Table 7), a statistically significant negative relationship between FOL and EUA and a statistically significant positive relationship between FOL and INV, and TIME is observed.

The following regression equation can be built:

$$Y\ (\text{FOLM1}) = -1,469,453.780 - 2.498\ \text{EUA} + 2.282\ \text{INV} + 2,053.154\ \text{TIME} + u \quad (2)$$

According to the FOLM2 outputs (Table 7), a statistically significant negative relationship between FOL and EUA and RDP and a statistically significant positive relationship between FOL and TIME is observed.

The following regression equation can be built:

$$Y\ (\text{FOLM2}) = -1,453,074 - 0.809\ \text{EUA} - 1.038\ \text{RDP} + 2,045.343\ \text{TIME} + u \quad (3)$$

Based on the results, it can be stated that in the monitored period there was an increase in forest land in hectares in the Czech Republic, which was positively influenced by environmental investments in biodiversity (CZK million) and negatively by subsidies from the Rural Development Programme (CZK million) and the price of EUA (CZK). Thus, 100 million CZK (4.07 million EUR) (Česká národní banka, 2023) of environmental investments in biodiversity would contribute to an increase of 228 hectares of forest land.

3.2. Wood biomass production model

All of the selected variables that were considered to affect wood biomass production were chosen for correlation analysis. In Table 8, the outcome of the correlation analysis is presented.

According to the correlation analysis findings, we notice a statistically significant positive correlation between WBIO, CON, SUB, EUA, RDP, OBL, and control variable TIME.

Besides the above links, negative correlations with lower statistical significance exist, such as INV and TAX.

For regression analysis, the following submodels were developed. Firstly, the model containing all economic and financial instruments was verified (WBIOM). Secondly, alternative models were run to seek the statistically most significant model with a high index of determination. Therefore, the following five submodels were developed: WBIOM1—EUA and TIME, WBIOM2—TAX and TIME, WBIOM3—OBL and TIME, WBIOM4—CON and TIME, and WBIOM5—RDP and TIME.

The results are presented in Table 9.

WBIOM1-WBIOM5 represents selected variables with a statistical significance of $p < 0.05$. These models are statistically significant models—all of the variables are statistically significant, and the entire model is statistically significant as well. In Table 9 the outcomes imply a high coefficient of determination in models. Meaning that the general formula that is specified explains almost 84% (WBIOM1), around 86% (WBIOM2), almost 87% (WBIOM3), almost 90% (WBIOM4), and almost 81% (WBIOM5) of the variance with less than 5% of random deviations. Variables with a p-value of below 5% are EUA, TIME, and the constant (WBIOM1); TAX, TIME, and the constant (WBIOM2); OBL, TIME, and the constant (WBIOM3); CON, TIME, and the constant (WBIOM4); and RDP, TIME, and the constant (WBIOM5). To the results of the overall F-test, the estimated regression wood biomass model WBIOM1-WBIOM5 is statistically significant at a 5% level of significance. The result of the Durbin–Watson test (DW) is acceptable only for WBIOM1, for other models WBIOM2-WBIOM5 the results show positive autocorrelation, and DW is under the lower critical value.

According to the WBIOM1-WBIOM5 outputs, the following regression equations can be built:

$$\text{Y (WBIOM1)} = -1,546,584,115 + 9,346.138\ \text{EUA} + 776,395.806\ \text{TIME} + \text{u} \tag{4}$$

$$\text{Y (WBIOM2)} = -4,392,833,128 + 42,667.350\ \text{TAX} + 2,177,209.912\ \text{TIME} + \text{u} \tag{5}$$

$$\text{Y (WBIOM3)} = -1,365,270,547 + 83,999.409\ \text{OBL} + 678,486.466\ \text{TIME} + \text{u} \tag{6}$$

$$\text{Y (WBIOM4)} = -783,415,440.5 + 2,008.576\ \text{CON} + 398,034.953\ \text{TIME} + \text{u} \tag{7}$$

$$\text{Y (WBIOM5)} = -1,629,508,948 + 11,193.506\ \text{RDP} + 817,573.294\ \text{TIME} + \text{u} \tag{8}$$

On the basis of the results, it can be concluded that in the monitored period there was an increase in wood biomass production in cubic meters in the Czech Republic, which was positively influenced by a mixture of all economic and financial instruments, such as emission trading, environmental taxation, financial contributions for forest management, state financial obligations and subsidies. Thus, an increase in the price of an emission allowance by 100 CZK Mg^{-1} (approximately 4 EUR Mg^{-1}) (Česká národní banka, 2023) would increase wood biomass production by approximately 934,614 cubic meters.

4. Discussion

Based on the results presented in the previous chapter, we can focus on answering our research questions gradually.

> RQ1: Do current economic and financial instruments of the climate change policy have a positive impact on the development of the forest bioeconomy in the Czech Republic?

For this research question, the forest bioeconomy is represented by the indicator "forest land." The regression analysis results displayed a statistically significant negative relationship between forest land and the price of the European Union Allowance and Rural Development Programme. On the contrary, a statistically significant positive relationship between forest land and environmental investments in biodiversity was observed.

Regarding "forest land" variable, we expected a positive impact of all grants and subsidies (national public financing of forestry and Rural Development Programme), and a positive impact of environmental investments in biodiversity, similar to studies by España et al. (2022), or Rinn and Jarský (2022). Concerning the impact of revenues from environmental taxes and EUA price on forest land, we suggested that it is not clear, based on the scientific studies of Barua et al. (2012), Ersoy and Mack (2012), Evison (2017), Pukkala (2020), Zhurakovska et al. (2021), España et al. (2022), and Jensen et al. (2022).

Comparing expectations and results, the positive impact of environmental investments in biodiversity is visible; meanwhile, for the Rural Development Programme the negative impact is demonstrated. The total influence of national public financing is not clear. Contrary to expectations, the impact of the EUA price is negative. The impact of environmental taxes is not clear, which is consistent with the expectation.

Carbon payments can effectively reduce forest clearing, similar to the study by Kerr et al. (2012). Pukkala (2020) analyzed the carbon pricing impact on optimal forest management and highlighted that rising carbon prices boost the rate of carbon sequestration. Moreover, a payment of 150 EUR per Mg^{-1} of carbon stored in forests would lead to a stop to cutting. Based on Zhurakovska et al. (2021), an increasing tax payment results in an increased volume of harvesting, even though taxes are supposed to motivate the economic use of forest resources. Barua et al. (2012) demonstrate that forestry income taxes might be ineffective in limiting forest loss. Regarding forest land, the New Zealand Emission Trading Scheme (NZ ETS) is unlikely to generate positive long-term influences on the forestry sector and would not be the appropriate instrument to promote the planted forest expansion Evison (2017). Results (España et al., 2022) display a statistically and economically significant positive impact of government subsidies on forest cover, causing an expansion of the forested area by approximately 13% in comparison with the alternative scenario excluding subsidies. Similarly, the research (Ersoy and Mack, 2012) identifies that subsidies have a positive influence on the technical efficiency of public forestry firms. Further, Jensen et al. (2022) examine forest owners' voluntary subsidies in the presence of imperfect information. On the other hand, the study by Aoyagi and Managi (2004) concludes that government subsidies have a negative influence on the economic activity of the forestry sector and more subsidized entities have lower levels of efficiency.

Generally, the Czech Republic fits into the European temperate forest zone (Rivas-Martínez et al., 2004). Forest land area in the Czech Republic is constantly rising (Czech Statistical Office, 2022). In 2021, the area of forest land increased by 1,475 hectares compared to 2020. Hence, the total forest land area was more than 2.68 million hectares in 2021, representing around 35% of the land area (Ministry of Agriculture of the Czech Republic, 2022b). In the Czech Republic, management forests dominate, covering 74.1% of forest land. This is followed by special purpose forests (23.9%) and protective forests (2.1%). Considering the composition of the forests, coniferous forests (69.6%) predominate over broadleaved forests (28.7%). The most abundant coniferous species are spruce (48.1%) and pine (16%). For broadleaved forests, the dominant is the beech (9.3%) and oak (7.6%) The ownership scheme differs, while the majority of Czech forests are owned by the state (56%). This is followed by natural persons (19.12%), municipalities and municipal forests (17.19%), legal entities (3.41%), church forests and forests of religious societies (5.32%), and forest cooperatives (1.19%).

In summing up the perspective of the forestry sector in the Czech Republic, a further increment in forest land and economic and financial support can be expected. Regarding forest land, building on previous periods and positive trends (Ministry of Agriculture of the Czech Republic, 2022b) while strengthening the role of sustainable development and the bioeconomy, both at the national and European levels, is evident (Luoma et al., 2011; Carus, 2012; European Commission, 2012, 2018, 2019, 2021b,c,d,e, 2022a; van Leeuwen et al., 2014; Langeveld et al., 2016; Loiseau et al., 2016; D'Amato et al., 2017; Loiseau et al., 2016; D'Amato et al., 2017; Ronzon et al., 2017; Wesseler and von Braun, 2017; Birner, 2018; Bracco et al., 2018; Ramcilovic-Suominena and Pülzlb, 2018; Comitato Nazionale per la Biosicurezza, le Biotecnologie e le Scienze della Vita [CNBBSV], 2019; Federal Ministry of Education and Research [BMBF], and Federal Ministry of Food and Agriculture [BMEL], 2020; Mittra and Zoukas, 2020; Barañano et al., 2021; Kardung and Drabik, 2021; Ministerio de Economia y Competitividad, 2021; Harrison et al., 2022; Hetemäki et al., 2022; United Nations, 2022). According to the economic and financial instruments for the forest bioeconomy, there are crucial elements for moving forward, such as governmental support, oriented research, and technology development (Hájek et al., 2021). Therefore, new knowledge and innovations can be seen as a major driver of the forest bioeconomy progress. This is expected to stimulate an upturn in new jobs related to renewable energy and/or bio-based products (Perunová and Zimmermannová, 2022).

> RQ2: Are current economic and financial instruments of the climate change policy stimulating drivers for the increase in the use of bioeconomy renewable resources, such as wood biomass?

The outcome of the regression analysis indicated a statistically significant positive relationship between wood biomass production and the price of European Union Allowance, revenues from environmental taxes–in forestry, state financial obligations under the Forestry Act, financial contributions, and the Rural Development Programme. However, the DW test is acceptable only in the case of the price of European Union Allowance, other results/indicators show characteristics of autocorrelation.

Focusing on wood biomass production, the expected impact of all grants and subsidies (national public financing of forestry and Rural Development Programme), and environmental investments in biodiversity was positive. Such expectation is based on Kanzian and Kindermann (2013), Moiseyev et al. (2014), and Locoh et al. (2022). Concerning the impact of revenues from environmental taxes and EUA price on wood biomass production, we can suggest that in the case of taxation, it is not clear. Regarding EUA price, the expected impact is positive. Based on the following scientific studies Lauri et al. (2012), Caurla et al. (2013), Moiseyev et al. (2014), and Sasaki (2021).

Comparing results and expectations, the positive impact of all grants and subsidies (national public financing of forestry and Rural Development Programme) and EUA price is visible. Contrary to expectations, the influence of environmental taxes is positive. The findings are compatible with the summaries of various studies. For example, Moiseyev et al. (2014) indicate that a high CO_2 price can support wood biomass production. Caurla et al. (2013) underlined that a carbon tax necessarily reduces consumer surpluses by pushing up the price of wood products. The combination of a carbon tax with sectoral policies is necessary. Based on Lauri et al. (2012), higher carbon prices can increase wood-based energy production. Sasaki (2021) concludes that facilitating global policies, upcoming sustainability markets, and financial stimulus via a carbon tax, environmental tax, and energy tax are able to promote sustainable forest management for long-term timber production and climate change mitigation. In material utilization, wood biomass serves in the manufacture of all sorts of products as a raw material (Carus et al., 2010). In the circular economy, the cascading use of biomass (Keegan et al., 2013) occurs when biomass is converted to a final product and then reused at least one more time as materials or energy. Cascading use leads to increased resource efficiency if compared to direct energy use. Moreover, from an environmental point of view, long-living wood products provide long CO_2 sequestration, and subsequently cascading use can expand CO_2 sequestration (Hong et al., 2021).

> RQ3: Are economic and financial instruments of the climate change policy environmentally effective?

Based on our results, we can observe a relationship between some economic and financial instruments (subsidies, grants, investments, and emission trading) and indicators connected with the quality of the environment. The influence of the emission trading is ambiguous—in the case of forest land negative, and in the case of wood biomass production positive. Generally, the economic and financial instruments in the Czech Republic have an environmental impact and can influence the forest bioeconomy, at least in the long-term period.

According to van Valkengoed and van der Werff (2022) subsidies worked predominantly as an impulse to act. It seems that subsidy schemes are useful to stimulate early adopters who are already motivated to take action, rather than to mobilize individuals who are not yet willing to undertake concrete climate action. Regarding forest carbon, Evison (Evison, 2017) considered that the New Zealand Emission Trading Scheme (NZ ETS) is unlikely to achieve positive long-term effects on the forestry sector and seems not to be the appropriate tool to foster carbon sequestration by forests. Jinggang and Peichen (2017) show that a higher carbon price would drive higher forest carbon stocks and early tax/subsidy-induced net carbon storage diminishes.

Forests are a crucial carbon sequestration and storage contributor. Trees process carbon dioxide through photosynthesis and store carbon in woody biomass. Forests thus represent essential carbon sinks in the climate system. The difference between gross GHG emissions and gross GHG removals is the net flux, then based on the balance of gross flows, a net source (positive) or net sink (negative) is defined. Based on Harris et al. (2021), between 2001 and 2021, Czech forests emitted $12.6 MtCO_2e$/year, on the other hand, removed $-19.8 MtCO_2e$/year. This represents a net carbon sink of $-7.19 MtCO_2e$/year. Forest carbon fluxes are further analyzed by Hansen et al. (2013) and Hong et al. (2021). Roughly, a larger forest area leads to a higher amount of carbon removed from the atmosphere, which seems to be an effective instrument in the effort to mitigate climate change. Long-life wood construction and furniture can be used as temporary carbon sinks (NOVA-Institute, 2017). In European forests, the biomass stock has increased since

1990, by about 1–2% per year, but its growth has stagnated due to aging processes, the rising impact of natural disturbances, and other climatic factors in the last years (Avitabile et al., 2023). Regarding environmental impacts, scaling up GHG removals by forest land and harvested wood products, as well as decreasing GHG emissions by material and energy substitution seems to be an effective way to mitigate climate change (Nabuurs et al., 2017).

In contrast, ongoing climate change is a driver of many changes in forest ecosystems, resulting in negative consequences, such as species distribution shifts or drought-related tree mortality (Mubareka et al., 2023). Forest disturbances are climate sensitive. For example, Seidl et al. (2017) provide an analysis of the impact of climate change on abiotic (fire, drought, wind, snow, and ice) and biotic (insects and pathogens) disturbances.

Conclusion

The main goal of this paper was to explain the impact of economic and financial instruments of the climate change policy on the development of the forestry sector in the Czech Republic in the period 2000–2020. To accomplish the research objectives, the following methods were applied: literature review, data analysis, correlation analysis, and regression analysis. Several models were established and tested, for example, the forest land models and wood biomass production models.

Regarding the findings, and to answer the research questions, a statistically significant negative relationship between forest land and the price of the European Union Allowance and subsidies from Rural Development Programme and a statistically significant positive relationship between forest land and environmental investments in biodiversity was observed (RQ1). Subsequently, a statistically significant positive relationship between wood biomass production and the price of European Union Allowance, revenues from environmental taxes in forestry, state financial obligations under the Forestry Act, financial contributions, and the subsidies from Rural Development Programme was found (RQ2). Overall, economic and financial instruments in the Czech Republic have environmental impacts and can determine the development of the forest bioeconomy. However, the impact of the emission trading on the forestry sector in the Czech Republic is ambiguous—in the case of forest land negative, and in the case of wood biomass production positive. Therefore, focusing on the policy recommendations, we should underline economic and financial instruments connected with positive motivation in the forestry sector, such as grant schemas, subsidies, and investments in biodiversity.

Regarding the following research, we should focus in more depth on the differences between urban and rural areas. The forest bioeconomy affects the carbon budget and has the potential to contribute to decarbonizing economies, and regions, hence mitigating climate change. In addition to environmental benefits, it also influences socio-economic aspects, such as employment. Economic and financial instruments are an integral part of the development of the forest bioeconomy in the Czech Republic, and their effective utilization is crucial. Therefore, a spatial analysis of current financial instruments in forestry with a focus on the regions of the Czech Republic is desirable.

Data availability statement

The original contributions presented in this study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

MP and JZ: conceptualization, validation, writing—original draft preparation, writing—review, and editing. MP: methodology, software, formal analysis, investigation, resources, and data curation. JZ: supervision. Both authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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