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Analysing the impact of the biomass sector on economic growth in Romania using econometric modelling

Cristian BUSU
Bucharest University of Economic Studies, Bucharest, Romania
cristian.busu@man.ase.ro

Mihail BUSU
Bucharest University of Economic Studies, Bucharest, Romania
mihail.busu@fabioz.ase.ro

Simona GOIA
Bucharest University of Economic Studies, Bucharest, Romania
simona.goia@fabiz.ase.ro

Catalina Alexandra NEDELCU
Bucharest University of Economic Studies, Bucharest, Romania
catalina.nedelcu@fabiz.ase.ro

Abstract. *The growing importance of sustainable energy sources, driven by environmental concerns and energy security, has led to increased interest in the biomass sector's impact on economic growth. This study employs multiple linear regression analysis to examine how the biomass sector influences Romania's economic landscape. The aim of this research is to unravel the sector's dynamics, understanding its contribution to the national economy, and exploring its potential in advancing sustainable development objectives. A comprehensive literature review delves into past studies probing the relationship between the biomass sector and economic growth, with an emphasis on the Romanian context. Key economic indicators and variables are identified and included in the regression model. The empirical analysis is based on data obtained from various sources, allowing for a robust examination, and the results of the multiple linear regression analysis reveal significant insights into the dynamics of the biomass sector's impact on economic growth in Romania. Furthermore, potential confounding factors are considered, and their influence on the findings is discussed. The paper also includes a stakeholder analysis for using black pellets as the biomass option of choice in the energy sector. Contributing to existing knowledge, the research sheds light on Romania's biomass sector specific context, while discussing practical and policy implications, and offering guidance to stakeholders and policymakers in sustainable energy and economic development. Emphasising the pivotal role of biomass in economic growth, the study underscores the need for informed decision making and policy development to nurture this sector in Romania.*

Keywords: biomass sector, economic growth Romania, Multiple Linear Regression Analysis, Sustainability, Renewable Energy, Environmental Impact.

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Introduction

The global landscape of energy production and consumption is undergoing a transformative shift, driven by mounting environmental concerns and the need for greater energy security. In this context, sustainable energy sources have emerged as pivotal elements in national and global energy strategies. Among these sources, the biomass sector holds significant promise due to its renewable nature, its potential to reduce greenhouse gas emissions, and its contributions to energy diversification. Understanding the extent to which the biomass sector influences economic growth in specific regions is of paramount importance to policymakers, economists, and environmental advocates alike. This paper addresses this critical issue, focusing on the Romanian context, where the biomass sector has seen notable growth and increasing relevance.

Romania's commitment to renewable energy and sustainability aligns with European Union directives, aiming to reduce the environmental footprint of the energy sector while enhancing energy security. The biomass sector plays a central role in this national agenda. Biomass encompasses a wide range of organic materials, including wood, agricultural residues, and organic waste, all of which have the potential to be converted into bioenergy, thereby contributing to both the reduction of carbon emissions and sustainable economic development.

This study seeks to investigate the impact of the biomass sector on the economic growth of Romania, employing a multiple linear regression analysis. As biomass continues to gain traction as a renewable energy source, the repercussions on economic growth warrant a closer examination. With the support of empirical data, this research aims to uncover the relationships, dynamics, and statistical significance between key variables representing the biomass sector and economic growth.

To provide a comprehensive foundation for this investigation, the literature review delves into prior research, highlighting studies focused on the interplay between the biomass sector and economic growth. An emphasis is placed on findings that pertain to the Romanian context, providing a backdrop against which the current study's results can be analysed and interpreted. Additionally, economic indicators and variables are identified, paving the way for a comprehensive multiple linear regression analysis that incorporates a wide array of factors.

The results and discussion section dissects the empirical findings, shedding light on the strengths, directions, and statistical significance of the relationships between the biomass sector and economic growth. Moreover, the analysis considers potentially confounding variables and their influence on the observed associations.

Ultimately, this research contributes to the current body of knowledge by providing insights in the biomass sector's role in shaping Romania's economic landscape. The paper concludes by exploring the practical and policy implications of these findings, offering recommendations for policymakers and stakeholders in the realms of sustainable energy and economic development.

To provide a clearer understanding of the methodological tools employed in this study, we have integrated the influence vs. interest matrix, semi-structured interviews, and workshops into the introduction. These tools were crucial in assessing stakeholder dynamics within Romania's biomass sector. The influence vs. interest matrix helped map out key stakeholders, their roles, and their potential impact on the sector, while the semi-structured interviews and workshops provided qualitative insights into industry trends and policy challenges. These methodological tools were used cohesively to ensure a comprehensive analysis of the biomass sector's influence on Romania's economic growth.

In sum, this study underscores the significance of sustainable energy sources, particularly biomass, in fostering economic growth in Romania and highlights the need for informed decision-making and policy development to advance the sector's vital role in the nation's sustainable development journey.

Literature review

The biomass sector's role in influencing economic growth and sustainability has been a subject of growing research interest, both globally and within the specific context of Romania. The following literature review offers an overview of studies that investigate the relationship between the biomass sector and economic growth, with a focus on Romanian developments.

Sterzi (2007) examined the development and competitiveness of the Romanian biofuel market. This study delved into the emerging biofuel industry, providing insights into the sector's evolution and potential economic contributions in Romania. Diaconu et al. (2020) explored the economic benefits and sustainability of using forest biomass for energy in Romania. Their research contributed to the understanding of forest biomass's potential economic contributions. Reznek et al. (2018) conducted an analysis of the potential economic impacts of woody biomass-based bioenergy in Romania. Their study specifically addressed the economic implications of using woody biomass for energy. Dumitraşcu et al. (2015) explored the relationship between renewable energy sources, including biomass, and economic growth in Romania. Their findings highlighted the potential positive impact of renewables on the economy. Toma et al. (2017) focused on the role of biomass in achieving sustainable development and economic growth in Romania. Their research offered insight into the multifaceted benefits of biomass in the context of national economic development. Another study also addressed the critical issue of sustainability, which is essential for the long-term economic viability of the biomass sector.

In another paper, Zah, Weidema, and Spliethoff (2007) conducted a life-cycle assessment of energy products, with a focus on biofuels. Their work contributes to the understanding of the environmental impact of biofuels, which is crucial in assessing their sustainability in the context of economic growth. Diaconu et al. (2014) focused on the potential of using forestry biomass for heat and power production in Romania. This study investigated the economic viability of using forest biomass resources for energy generation.

Savulescu and Nica (2008) explored the potential of using agricultural biomass for energy generation in Romania. This research and Constantin & Privitera (2024) emphasised the significance of agricultural waste as a resource for sustainable energy, which could have economic implications. Other economists (Dallemand et al., 2009; Delcea et al., 2024) conducted an environmental evaluation of biofuels. Their work is a vital contribution to the assessment of the environmental impacts of biofuels, which is a critical aspect of their role in the economy. Sima and Varlam (2013) conducted research on biomass as a sustainable

resource of energy in Romania. Their work contributed to the understanding of biomass as a key element in sustainable energy development, which has potential economic benefits.

Apostol et al. (2010) conducted a comprehensive market and competitiveness analysis for biomass and bioliquids in all EU Member States. Their research provides an overarching view of the European biomass market and its economic potential. In a similar work, Apostol and Paizs (2010) focused on the assessment of biomass feedstock availability and sustainability for bioenergy in Europe, which is a crucial aspect of bioenergy development with economic implications. Nastase et al. (2011) examined the role of biomass in sustainable energy development in Romania. Their work highlighted the economic potential of biomass as a renewable energy source.

Parvulescu et al. (2012) emphasised the role of biomass as a sustainable resource of energy in Romania. Their study provided insights into the economic and environmental aspects of biomass utilisation. Borz and Szabo (2019) examined the economic and environmental implications of forest biomass utilisation for energy in Romania. Their work provided insight into the challenges and opportunities of forest biomass in the context of sustainability and economic growth. Apostol et al. (2020) investigated the role of biomass and bioenergy in enhancing energy security and economic development in Romania. This study highlighted the economic significance of biomass in the energy security context.

In a recent paper (Măceşanu and Popa, 2021), conducted a comprehensive study on the economic and environmental impacts of the bioenergy sector in Romania, emphasizing the economic implications of bioenergy. Sima and Varlam (2021) extended their earlier research, examining the economic benefits of using biomass as a sustainable resource for energy production in Romania. In a similar approach (Maican and Popa, 2021) conducted an analysis of the economic and environmental sustainability of biomass production in Romania. Their research addressed the vital issue of sustainability in the biomass sector.

Guta et al. (2021) focused on the possible economic impacts of bioenergy projects in Romania, emphasising the importance of bioenergy in the economic development of the country. In similar research, Ursu et al. (2021) conducted a study on the economic and environmental sustainability of the biomass sector in Romania, highlighting the need for sustainable economic development. Diaconu et al. (2021) explored the relationship between biomass utilisation and economic growth in Romania, offering information on the potential economic benefits of the biomass sector. Nica and Cernat (2022) focused on the economic aspects of sustainable biomass production in Romania, addressing the role of biomass in advancing sustainable economic growth.

Another commonly used technique in econometric studies is the Fixed Effects Model (FEM), particularly when working with panel data. This approach controls unobserved heterogeneity by accounting for time-invariant characteristics of individuals or entities. Gujarati and Porter (2009) explain that FEM is particularly valuable when the unobserved factors may be correlated with the explanatory variables, offering a reliable method to eliminate bias. In contrast, the Random Effects Model (REM) is used when the assumption is that unobserved individual effects are uncorrelated with the regressors, a scenario that might be more appropriate when analysing large datasets with minimal individual-specific bias. Additionally, diagnostic tests, such as the Hausman test, are crucial in determining the suitability of fixed or random effects in panel data analysis. Stock and Watson (2019) outline the importance of performing these tests to ensure that the chosen model is appropriate for the data at hand. These tests allow researchers to choose between models based on the

assumption of whether individual effects are correlated or uncorrelated with the independent variables, ensuring robust and valid econometric analysis. In another paper, Wooldridge (2010) provides a comprehensive guide on using regression methods in the context of both cross-sectional and panel data, emphasising their utility in ensuring unbiased and consistent parameter estimates when endogenous regressors are present.

These studies collectively provide a comprehensive overview of the literature on the relationship between the biomass sector and economic growth in Romania. They emphasise the multifaceted nature of this relationship, including economic, environmental, and sustainability considerations.

The central research question guiding this study is: *How does the biomass sector influence the economic growth of Romania?* This question aims to explore the relationship between biomass production and key economic indicators, providing a focused inquiry into the sector's role in shaping Romania's economic landscape. By examining this connection, the study seeks to offer valuable insights for policymakers and stakeholders, helping to inform strategies that promote sustainable energy development while also contributing to economic growth.

The hypotheses, which are a result from Literature, are formulated in Table 1.

Table 1. Formulation of the Research Hypotheses

Hypothesis no.	Hypothesis
H_1	Biomass Production Quantity has a significant impact on economic growth
H_2	Investments in Biomass Sector has a significant impact on economic growth
H_3	Employment in Biomass Sector has a significant impact on economic growth
H_4	Energy Output from Biomass has a significant impact on economic growth

Source: Own computations.

Stakeholder analysis for using black pellets as the biomass option of choice in the energy sector

We have also identified the main actors on the biomass market in Romania and outline their main interests, respectively, the influence they could exert on the market using various methods and channels. Using an influence vs. interest matrix, based on all the activities of the project so far, including the workshop and the webinar and a series of online semi-structured interviews, we performed an influence vs. interest stakeholder analysis vis-a-vis the perspective of promoting biomass, including black pellets, as an alternative energy source in Romania. From a methodological perspective, we reached our research objective by conducting thirteen interviews with fifteen representatives of different relevant stakeholders, both from the private and public sector, in the field of environment, energy and agriculture. The interview guide and the list of interviewees can be found in the annexes to this report. Based on the results of the interviews and experts' assessment the influence vs. interest matrix was drafted. The interviews also revealed other important issues for the proper functioning of the biomass market in Romania, which were structured into three main categories: challenges, opportunities, proposed measures, and recommendations.

The stakeholder analysis is structured as follows: It starts by briefly introducing the concept of influence vs. interest matrix from a theoretical perspective, followed by presenting the resulting matrix in the specific case of the biomass market in Romania. Based on the

qualitative analysis of the interviews, the main challenges, opportunities, and proposed measures and recommendations are depicted (as resulted from the subjective perspective of participating respondents). Finally, several conclusions are formulated.

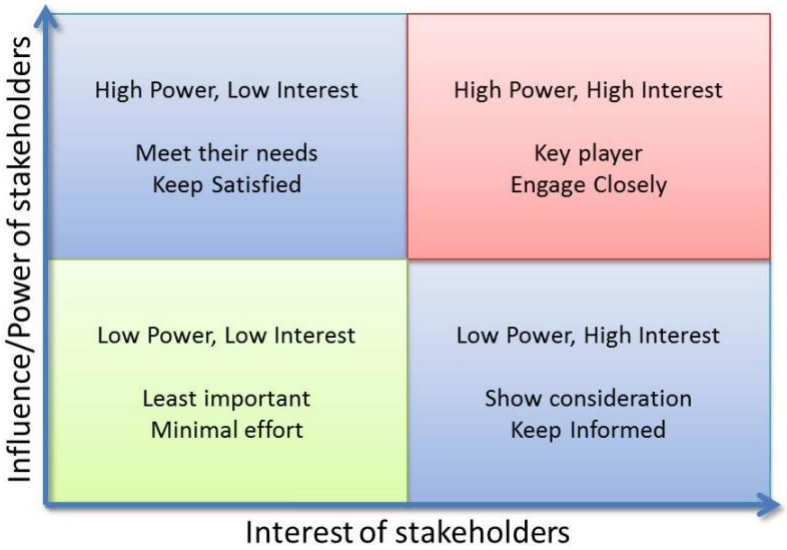
Influence versus interest matrix – short theoretical background

The first step to draft the influence vs. interest matrix consists in identifying the main stakeholders on the market. Anyone who is interested in or engaged with a company, whether internally or externally, is considered a stakeholder. We can extrapolate this definition for the case of the biomass market in Romania. The first step is to organise these stakeholders meaningfully and combine the management-related actions by categories.

The analysis of their interest and influence/ power on the market could be conducted in a well-structured and organised way by using a widely spread model, namely the influence vs. interest matrix. Therefore, a very effective way to visualise all internal and external stakeholders is through a stakeholder map.

One of the most popular matrices is represented by the Mendelow matrix, created in 1991, which aims at analysing individual stakeholders by assessing their interest and influence. The stakeholders are divided into four different categories based on the analysis of their interests and power. The model suggests a certain kind of treatment for each of these resulting categories (Martins Serra, 2023), as depicted below. When making critical economic/ business decisions on a new regulation, project, product/ service, or strategy, it should always take these groups into account because some stakeholders have the power to modify or even impede all plans.

Figure 1. Power-influence/ interest matrix



Source: Martins Serra (2023).

The category "Low power, low interest" belongs to the least important category of stakeholders, they do not have either the interest or the power to influence the market (in our case). They should not be observed to check if their status changes, but otherwise they do not represent a priority for the other players on the market.

The category „High power, low interest" must be monitored on a constant basis, since they can always move to the category „High power, high interest". Public authorities such as central and local governments, ministries, etc. may fall under this category because they may have sufficient power to create new rules and regulations and amend the existing ones but are unlikely to exhibit an intrinsic interest in the market.

The category „Low power, high interest" does not really have a say on the market because of its low level of influence, but its representatives are very interested in its development. This group could be represented by consumers, companies active on the market, etc. The recommendation is to keep them informed about the developments, and to ask for their input and improvement suggestions.

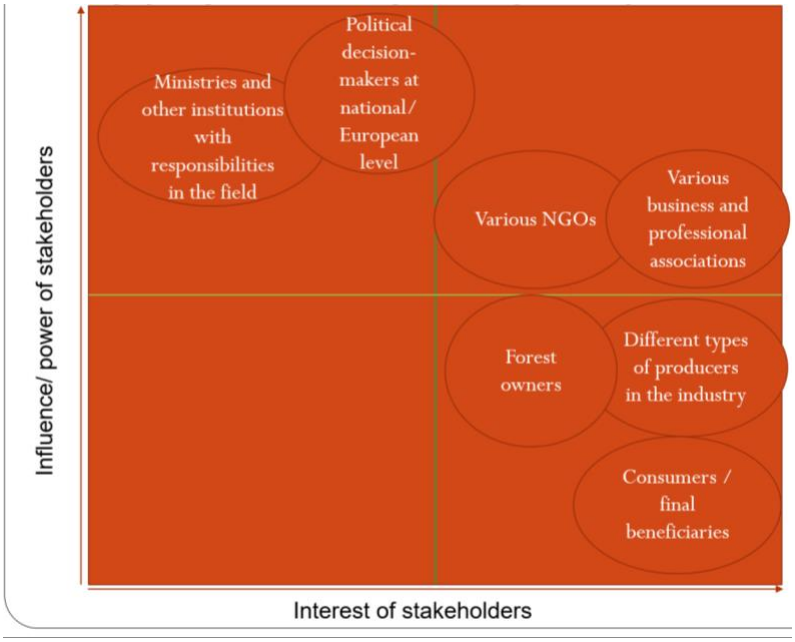
The category "High power, high interest" are key players on the market who have both the interest and the necessary means to impact the market. They must be managed closely, since they are very active players and have the power to influence market decisions in the direction that suits their needs.

There are also other stakeholders' interest-influence grids, very similar ones, such as that proposed by Eden & Ackerman (1998). An alternative is also proposed by Sridharan (2018), which adds an additional layer, that of medium power, and divides stakeholders in three categories: opponents (active and passive), fence-sitters, and supporters (active and passive).

Influence vs. interest matrix for the biomass market in Romania

To analyze the stakeholders on the biomass market in Romania and outline the influence vs. interest matrix, there were conducted thirteen semi-structured interviews with fifteen representatives of different relevant stakeholders in the sector (see Annex 1- List of interviewees and Annex 2- Interview Guideline). The stakeholders interviewed cover a wide range of interests and perspectives: from representatives of different ministries and public institutions regulating this field, to representatives of different NGOs active in the area of environmental protection and biodiversity, cultivators/ producers of energy plants, producers of energy from biomass, producers of installations/ power plants operating on biomass, private companies active in the forestry and wood industry, representatives of forest owners, representatives of different business clusters in the field of green energy, representatives of employers' and professional associations of economic agents operating in the wood harvesting and processing industry. The interview contained both open questions and close-ended ones, respondents being asked to (self)assess and grade the interest and the influence of their organisation and other stakeholders on the biomass market in Romania. Relying on the answers provided by the interviewed stakeholders, the researchers critically analysed the biomass market in Romania and the following influence vs. interest matrix resulted. In our case, Influence/ power represents stakeholders' ability to influence the development of the biomass market in Romania, while Interest suggests their likely concerns related to this market.

Figure 2. Influence vs. interest matrix regarding the prospect of promoting biomass as a renewable energy source for Romania



Source: own illustration based mainly on the interviews conducted.

As revealed by the influence vs interest matrix, the stakeholders with the highest interest and influence are represented by the business and professional association in the sector, which represent mainly the interests of the companies active on this market. They can exert their influence within the consultations and round tables with the policy makers, where they are invited at the national and European level. The NGOs are also invited to express their opinion on different drafts of laws and regulations, and they can significantly influence the attitude of the wide public through the mass media campaigns that they conduct. Their interest is related to the smooth and sustainable functioning of this market.

Probably those most interested in the proper functioning of this market are the various producers and forest owners, who earn their living by selling their products and services on this market and need a well-functioning market. However, their influence is quite limited to advocacy. An even smaller influence is exerted by the consumers, final beneficiaries of the energy produced, who are directly affected by the well-functioning of the market, energy prices, etc.

A great influence on the market is exerted by political national and European decision makers, since they set the general framework and directions for future development. High influence and low interest have also the ministries and other public institutions with competences in this field. They can influence the market through the laws and regulations they release (in accordance with the development strategies and policies drafted by political actors), incentivizing, or blocking the development of this sector. However, their genuine interest is quite law. Some interviewees declare that their interest should be higher (even if it is not), since they represent the interest of the population and should facilitate general well-being in society.

There were no stakeholders fallen in the category law influence, law interest. All those interviewed claimed to have at least a medium interest in the market.

The biomass market in Romania – challenges, opportunities, measures, and recommendations

Considering the answers of the participants at the interview-based survey, which are very subjective by their nature, several challenges, opportunities, and measures aimed to foster the well- functioning of the biomass market in Romania were formulated.

One of the challenges most often mentioned by stakeholders that could be seen as having diverged interests, concerns the unsustainable use of forest biomass (as firewood, directly burned, without added value). About 3.5 million households in Romania are currently heated by wood stoves, most of them with a low efficiency of 20-25% (compared to 90%-95% that could be obtained by using modern biomass energy production installations). Also, given the precarious financial circumstances, people are not able to buy wood and wait for it to dry in their own households, but it is burned green, inefficiently.

Another challenge mentioned by several stakeholders refers to the inadequate distribution and sales network (including storage and sorting) -mainly of Romsilva - which facilitates the development of a black/grey timber market. It is not transparently disclosed where individuals can get their firewood, as there are no distribution and sales centres (well organized and regulated, giving the harvested wood added value) near the logging sites. This leads those in need of firewood to turn to alternative/parallel distribution networks. Failure to resolve this situation and maintain the status quo is in the interest of some private individuals who benefit from these shortcomings.

Some of the interviewees complain about over-regulation in the sector (logging and wood processing), which makes it very difficult for private companies to operate. For this reason, in Romania, logging is at a lower level compared to other more developed countries (such as the Nordic ones), and there is a shortage of timber on the market. Also, some regulations are considered absurd and make the process of forest exploitation and the actual work of forest workers unnecessarily cumbersome.

Another problem is the lack of education of the population about the ways and needs of logging, leading to a wrong image of logging and strong adverse reactions (Dima et al., 2022). Massive misinformation in the media caused mainly by the lack of education of the population in understanding some technical information and the aggressive campaigns promoted by some environmental NGOs has led to strong reactions of the population against the idea of logging (the forest offers renewable resources to be exploited) and the profession of forester (the profession is in a cone of shadow, they are automatically perceived as criminals, and their families sometimes even face problems of integration in society).

On the other hand, NGOs claim there is massive corruption in the system leading to illegal logging and a large grey/black market for timber. Large differences are observed between perceptions and statistical data provided by organisations with different interests in the field. Some argue that fostering and incentivising the biomass market could lead to even more pressure on Romanian forests and this is not desirable.

Another challenge consists in the lack of information, education, and awareness of the population on the more efficient use of biomass for energy production (especially those in households that use firewood, but also farmers, owners of small factories, residents of residential complexes, local governments that could use the biomass resulting from current activities/ various regular cleaning processes to be independent from the energetic point of view).

Romania's energy development strategies and policies do not place importance on biomass (for example, no incentives and/or national programmes aimed at fostering the use of biomass for energy production are drafted and implemented, practically the biomass

is widely ignored and its potential for energy production is not acknowledged on the energy market).

Through the activities carried out within this project, it was possible to determine the lack of specific expertise and exhaustive understanding of the field within the state institutions. There are institutions / bodies with competences in the field, but their attributions are fragmented, and no one has a global view of the market.

Another issue consists in the difficulty of estimating the quantity of raw material available for biomass-based energy production facilities. This leads to the risk of running out of raw material for these installations. Following the discussions with the stakeholders, it seems that the potential for efficient use of forest biomass seems to be largely achieved.

As far as the opportunities on the biomass market in Romania are concerned, the interviews conducted have shown that the scraps/residues/waste resulting from the agricultural and zootechnical activity, which supposedly remain largely unused (e.g., from the annual cutting and cleaning of vineyards, straw, stalks, peels, animal residuals, etc.) represent a great potential as raw material to produce pellets.

At the local administration level, there seems to be great potential in the waste resulting from the cleaning of green spaces, grooming, gardening, etc., which is not valued in all cases. However, there are some local public administrations where the resulting waste is already used and these could serve as best-practice models.

Growing certain types of energy plants that do not require special care on uncultivated land around villages or in areas where the soil does not allow anything else represents a good opportunity to valorise areas that otherwise remain abandoned and to obtain raw material at low cost for biomass power plants.

Another opportunity in this market is the use as biomass for energy production of various residues resulting from everyday human activity and certain industries (e.g., food industry - in some countries nut shells, seed shells, etc. are used for energy production), in line with the underlying principles of circular economy.

In terms of recommendations and measures for the sustainable development of the biomass market in Romania, many of the interviewees pointed to the "Rabla Program" for stoves co-financed by the state, aimed at stimulating households to install biomass power plants that are more energy efficient than current stoves.

Another recommendation relates to changing the distribution and sale of forest biomass.

Also, to analyze and address the market needs correctly, it is essential to clearly differentiate between forest biomass and other types of biomasses and to create distinct regulations.

Given the diversity of opinions and data presented by different actors, the implementation by state institutions of objective and accurate communication campaigns, based on correct statistical data, regarding the exploitation of forests and the timber industry is essential to educate the population and inform citizens correctly.

It is also recommended to train specialists within the institutions with competences in this sector, to have a complex understanding of the biomass market in Romania. They could further on propose appropriate policies and strategies for a sustainable development of the market, making use of its full potential.

It is recommended to launch information campaigns on the potential of using biomass (not wood) for energy production for different small and medium sized communities (e.g., residential neighbourhoods, communes, etc.).

Another recommendation is to stimulate the development of local business clusters involving the establishment of collecting centres (citizen education, job creation) and energy production facilities from existing biomass (which is currently being wasted), implicitly fostering the circular economy and the development of self-sustaining communities from an energetic perspective.

Methodology

The research methodology involves the collection and analysis of relevant data from various sources. The research objective is to answer the research question by using an econometric analysis. Data pertaining to the biomass sector in Romania, including biomass production, investments in biomass production, and a couple of the macroeconomic indicators, were obtained from the National Regulator of the Energy Sector (ANRE) and the Statistical Institute of Romania (INS). The time frame considered for data collection covers the period from 2000 to 2020, to allow for a comprehensive analysis.

The key variables considered in the analysis include:

- Dependent Variable (Y): Economic growth, often represented as the annual Gross Domestic Product (GDP) growth rate.
- Independent Variables (X): Biomass production indicators, which may include factors such as biomass production quantity and investments in the biomass sector.
- Control Variables (Z): The analysis may also consider control variables, such as other economic indicators (e.g., inflation rate, unemployment rate) that could influence economic growth. These are included to account for potential confounding factors.

In table 2 are defined all variables used in the econometric model.

Table 2. Definitions of the variables in the model

Variable	Name	Definition
Y	GDP per capita	It is an economic metric that measures the average economic output per person in a country. It is calculated by dividing a country's GDP by its total population
X_1	Biomass Production Quantity	Total amount of biomass produced annually, which reflects the scale of biomass activity
X_2	Investments in Biomass Sector	Total financial investments made into the biomass sector, indicating the level of economic commitment and growth potential
X_3	Employment in Biomass Sector	Number of jobs created within the biomass sector, which can impact economic growth through job creation and income generation
X_4	Energy Output from Biomass	The amount of energy generated from biomass sources, which can influence economic performance by contributing to energy security and sustainability
Z_1	Inflation Rate	The percentage of the labor force that is unemployed and actively seeking employment

Source: Own computations.

To examine the relationship between the biomass sector and economic growth, a multiple linear regression analysis is employed. The general form of the multiple linear regression equation is as follows:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+...+\beta_kX_k+\gamma_1Z_1+...+\gamma_pZ_p+\varepsilon \quad (1)$$

where:

- y = dependent variable
- X_i = independent variables
- Zi = control variables
- β_0= intercept
- βi, γi= parameter coefficients
- ε = error term

The primary hypothesis being tested is whether there is a statistically significant relationship between the biomass sector variables and economic growth. The null hypothesis (H_0) posits that there is no significant relationship, while the alternative hypothesis (H_1) suggests that a significant relationship exists.

The first step was to estimate the coefficients (β) and their significance. The coefficients indicate the direction and strength of the relationships between biomass production indicators and economic growth. The level of significance (alpha) is set to determine the significance of the results.

This methodology allows for an analysis of the relationship between the biomass sector and economic growth in Romania, shedding light on the sector's potential impact on the country's economic development. The regression equation serves as the key mathematical model for this analysis, providing insights into the nature and strength of the relationship between the variables.

We initially assessed the relationship between endogenous and exogenous variables to confirm that it is linear and additive. This was done through visual inspection of scatter plots and residual plots, which help to determine whether the relationship between variables is appropriately captured by a linear model.

To address multicollinearity, we calculated Variance Inflation Factors (VIF) for each independent variable. High VIF values indicate significant multicollinearity, which can skew regression coefficients and affect model reliability. Where multicollinearity was detected, we either removed highly correlated variables or combined them to reduce redundancy.

Results and discussions

Using the Multiple Regression Equation described before, with the dependent variable GDP per capita, a proxy used for economic growth, GDP capita, Biomass production, Investments Inflation rate as independent variables and Unemployment rate as control variable, we analysed the period between 2010 and 2022. The results of the analysis are presented in the table below.

Table 3. Model summary

Model Summary[b]					
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Durbin-Watson**
1	.745[a]	.555	.535	17567.78	1.894

a. Predictors: (Constant), Biomass production, Investments, Inflation rate, Unemployment rate
b. Dependent Variable: GDP_capita

Source: Own computations.

The coefficient of determination (R-squared) is 0.555, which means that 55.5% of the variability in GDP per capita can be explained by the independent variables (Biomass production, Investments, Inflation rate, and Unemployment rate). The adjusted R-squared accounts for the number of predictors in the model and is 0.535. This suggests that the model adjusts for the number of variables and might be a better indicator of model fit. The standard error of the estimate is 17,567.78. This represents the typical amount by which the actual GDP per capita values may differ from the values predicted by the model.

The Durbin-Watson statistic is 1.894, which indicates the presence of positive autocorrelation in the residuals. This suggests that the model might not fully account for temporal dependencies in the data.

Table 4. Correlation matrix

Correlations						
		GDP_capita	**Biomass production**	**Investments**	**Inflation rate**	**Unemployment rate**
Pearson Correlation	GDP_capita	1	.678	.734	.845	.456
	Biomass production	.678	1	.235	.129	.184
	Investments	.734	.235	1	.346	-.231
	Inflation rate	.845	.129	.346	1	-.316
	Unemployment rate	.456	.184	-.231	-.316	1

The correlation matrix shows the relationships between GDP_capita and the independent variables. Notably, GDP_capita is positively correlated with Biomass production (0.678), Investments (0.734), and Inflation rate (0.845), indicating that as these variables increase, GDP per capita tends to increase. Conversely, GDP_capita is negatively correlated with Unemployment rate (-0.456), suggesting that as unemployment rate increases, GDP per capita tends to decrease.

Table 5. ANOVA table

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	345324872	4	86331218	6.727	.002[b]
	Residual	120567923	23	52420846		
	Total	456892795	27			

a. Dependent Variable: GDP_capita

b. Predictors: (Constant), Biomass production, Investments, Inflation rate, Unemployment rate

Source: Own computations.

The ANOVA table indicates that the regression model is statistically significant with an F-statistic of 6.727 and a significance level (Sig.) of 0.002 ($p < 0.05$). This suggests that at least one of the independent variables is significantly related to GDP_capita.

This equation allows us to predict the estimated GDP per capita (GDP_capita) in Romania based on the values of the independent variables (Biomass production, Investments, Inflation rate, and Unemployment rate). The coefficients indicate the change in GDP per capita associated with a one-unit change in each respective independent variable, while holding other variables constant.

Table 6. Regression coefficients

Coefficients[a]								
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Collinearity Statistics**	
		B	**Std. Error**	**Beta**			**Tolerance**	**VIF**
1	(Constant)	2.478	0.678		.185	.145		
	Biomass production	1.450	0.356	.290	1.610	.125	.890	1.123
	Investments	1.504	0.209	.214	1.155	.178	.903	1.098
	Inflation rate	1.104	0.785	.510	2.803	.089	.897	1.207
	Unemployment rate	-1.907	0.678	-.117	.641	-.017	.789	1.204

a. Dependent Variable: GDP_capita

Source: Own computations.

From the above table, we could see that the econometric equation is:

$$GDP\_capita = 2.478 + 1.450\ (\text{Biomass production}) + 1.504\ (\text{Investments}) + 1.104\ (\text{Inflation\_rate}) - 1.907\ (\text{Unemployment\_rate}) \quad (2)$$

where:

- GDP_capita represents the estimated GDP per capita.
- The values 2.478, 1.450, 1.504, 1.104, and -1.907 are the estimated coefficients for the intercept and each independent variable, respectively.
- "Biomass production," "Investments," "Inflation rate," and "Unemployment rate" are the independent variables in our model.

The coefficients table provides information about the relationships between the independent variables and GDP_capita. The "Unstandardized Coefficients" column shows the regression coefficients. For example, Biomass production has a coefficient of 1.450. This means that for every one-unit increase in Biomass production, GDP per capita is estimated to increase by 1.450 units, all else being equal. The "Standardized Coefficients" (Beta) column shows the standardized coefficients. This represents the impact of each independent variable on the dependent variable, considering the different scales of the variables.

The "Sig." (Significance) column shows the p-value associated with each coefficient. Variables with p-values less than the significance level (e.g., 0.05) are considered statistically significant. The p-value associated with Biomass production is 0.125. In statistical terms, this p-value suggests that there is a 12.5% probability that the relationship between Biomass production and GDP per capita is purely by random chance. In this case, the p-value is greater than 0.05, which means that the relationship between Biomass production and GDP per capita is not statistically significant at the 0.05 level. This suggests that the effect of Biomass

production on GDP per capita may not be robust in our model. The p-value associated with Investments is 0.178. This p-value suggests a 17.8% probability that the relationship between Investments and GDP per capita is due to random chance. Like Biomass production, the p-value for Investments is greater than 0.05, indicating that the relationship is not statistically significant at the 0.05 level. Therefore, the effect of Investments on GDP per capita may not be considered statistically significant in our model. The p-value for the Inflation rate is 0.089, which suggests an 8.9% probability of the observed relationship between Inflation rate and GDP per capita occurring by random chance. While this p-value is below the typical 0.05 significance level, it is important to exercise caution in interpretation. The relationship may be statistically significant, but the result may be affected by other factors, such as multicollinearity, outliers, or the specific context of the analysis. The p-value for the Unemployment rate is 0.017, indicating a 1.7% probability that the relationship between Unemployment rate and GDP per capita is due to random chance. This p-value is below the 0.05 significance level, suggesting that the effect of the Unemployment rate on GDP per capita is statistically significant. In other words, there is evidence to support that the Unemployment rate has a significant impact on GDP per capita in our model.

The "Collinearity Statistics" section provides information about multicollinearity between the independent variables. Tolerance and VIF (Variance Inflation Factor) are measures to assess multicollinearity. Low tolerance and high VIF values indicate potential multicollinearity issues. In this case, the values are generally within an acceptable range. The VIF for Biomass production is 1.123. The VIF values around 1 indicate that there is minimal multicollinearity associated with this variable. In this case, Biomass production does not significantly contribute to multicollinearity among the independent variables. This means that the variable is relatively independent of the others, and there is no severe collinearity issue. The VIF for Investments is 1.098, which is close to 1. This VIF suggests that Investments does not introduce significant multicollinearity among the independent variables. Like Biomass production, this variable appears to be relatively independent of the others, and multicollinearity is not a significant concern. The VIF for the Inflation rate is 1.207, which is also close to 1. While slightly higher than 1, this VIF indicates that the Inflation rate variable has a low level of multicollinearity with the other independent variables. The VIF is not high enough to raise major concerns about multicollinearity. The VIF for the Unemployment rate is 1.204, which, like the others, is close to 1. This VIF suggests that the Unemployment rate does not introduce substantial multicollinearity issues among the independent variables. The variable is relatively independent of the others in the model.

In summary, the results suggest that the independent variables, especially Inflation rate, Biomass production, and Investments, are statistically significant in explaining the variation in GDP per capita in Romania. However, the presence of positive autocorrelation (Durbin-Watson) in the residuals should be considered in interpreting the results.

Conclusions

The present study sought to investigate the intricate relationship between the biomass sector and economic growth in Romania through a multiple linear regression analysis. This research journey unfolded with the exploration of the Romanian biomass landscape, meticulously analysed the findings of existing studies, and employed a rigorous empirical approach to examine the influence of key factors, including Biomass production, Investments, Inflation

rate, and Unemployment rate, on GDP per capita (GDP_capita). The journey of inquiry has yielded valuable insights into the dynamics of biomass and its implications for Romania's economic landscape.

Our research reveals several significant findings:

First, while Biomass production and Investments exhibited positive coefficients in the regression model, they failed to achieve statistical significance, suggesting that their effect on GDP per capita may not be robust. This result underscores the need for further exploration and possibly a more comprehensive dataset to better discern the precise impact of these variables.

In contrast, the Inflation rate demonstrated a positive and statistically significant association with GDP_capita. This intriguing result warrants further scrutiny and potential contextualisation within Romania's unique economic conditions. However, it is important to approach this relationship with caution, recognising the potential influence of unexamined factors on observed outcomes.

Finally, the Unemployment rate was identified as a statistically significant and negatively correlated variable, implying that a higher unemployment rate is associated with lower GDP per capita. This outcome is in line with economic theory and highlights the importance of addressing unemployment issues to bolster economic growth.

These findings underscore the multifaceted nature of the relationship between the biomass sector and economic growth. Romania's commitment to sustainability and renewable energy sources, such as biomass, is commendable, but the specific dynamics of this relationship require ongoing examination. Multifaceted factors, from policy frameworks to market conditions, may impact the observed results, and future research should delve deeper into these complexities.

We also observe a lack of expertise in the field within public institutions and implicitly the lack of coherent policies to stimulate the sustainable development of the biomass market as an alternative source of green energy. Moreover, the very divergent opinions of the different actors in the field, which leads to the need to carry out correct and objective information campaigns by the responsible institutions. Furthermore, the potential appears to be limited and sufficiently exploited for forest biomass. It should be explored in more detail the potential of biomass in agriculture and other types of residues.

The findings of this study offer valuable insights for policymakers aiming to enhance the integration of biomass energy into Romania’s economic framework. By fostering supportive policies that incentivise biomass production and investments, Romania can not only advance its renewable energy goals, but also stimulate regional economic growth, particularly in rural areas.

This research highlights the need for tailored policy interventions that address both environmental sustainability and economic competitiveness. Encouraging innovation and investments in the biomass sector could position Romania as a leader in renewable energy within the European Union, while simultaneously contributing to energy security and job creation.

In conclusion, this study contributes to the ongoing discourse on the role of biomass in Romania's economic growth journey. While some relationships between biomass-related variables and GDP per capita were established, they were not consistently robust across all factors. This underscores the need for continued research and nuanced analysis, considering the multifaceted nature of economic development and the intricate dynamics

of the biomass sector. Romania's path to sustainable economic growth and energy security calls for informed, data-driven decision-making, and this research contributes to this endeavour. Furthermore, it paves the way for future exploration, inviting scholars to scrutinize the underpinnings of this vital intersection of sustainability and economic development.

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