Article

The Influence of Intellectual capital on economic progress and sustainability

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Abstract: Bio-economy is a major area of the strategy that can afford the European Union to achieve growth: (i) smart, through the development of knowledge and innovation; and (ii) sustainable, based on a greener, more efficient economy in resource management. We believe that the progress of bio-economy cannot be achieved without the harnessing of intellectual capital. Our research aimed to emphasize the benefits of the dynamics of the intellectual capital growth on the evolution of the bio-economy. Thus, the information published by Eurostat (European Statistic Institute) during a period spanning seven years (2011-2018) was used to assess the influence exerted by the conduct of the harness of intellectual capital related to sustainability as well as for the reporting of indicators relevant to appreciating an economic progress and sustainability (renewable waste material, share of renewable energy and energy intensity of the economy). The ultimate goal was represented by the generation of a regression model to see what factor influences mostly the progress of the bio-economy at European and Romanian level. Significant dependency relationships were identified. The results remain robust even after the introduction of certain control variables, such as gross domestic product rate, food production, population growth, urbanization growth and inflation. Our paper sets out to contribute to expanding the specialty literature by highlighting the involvement of intellectual capital as a factor in optimizing sustainability growth and, at a methodological level, by using a multiple regression.

Keywords: intellectual capital; sustainability; harness; bio-economy; global crisis

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1. Introduction

The global crisis that has given society a certain way of manifestation and behavior that is characteristic of emergencies, often defined by unbalanced strategic decisions, has a multidimensional character and includes aspects such as the crisis of the economic domain: energetic, financial, commercial; the crisis of the ecological and biosphere domain, environmental crisis [1-2].

The fundamental evolution that constantly required the development of the human race was based on solving the economic problem, meeting a growing set of needs, given the limited and insufficient resources. In the development of relationships between people and the environment in which they live, as part of nature, were structured diametrically opposite concepts, in analysis and vision. Knowledge of nature without wisdom has led to ignoring the risks of its alteration and to which attention is drawn today. The balance between man and the environment has been broken by technological progress, economic development and the demographic explosion. The law of action and reaction speaks its word. Albert Arnold Gore, the 45th Vice President of the USA, was talking about an environmental holocaust in what Karl Popper, considered to be one of the greatest science philosophers in the twentieth century, considers as an effect of disregarding nature namely the loss of the sense of piety for nature [3].

As long as the quality of human life depends on its natural environment of existence, the artificial environment created by people and the interrelationships between humans, the ecological crisis - an invisible bomb, manifests itself through violence on nature, including man, as in human hedonism on the account of nature, including on behalf of its neighbor [4].

The concept of "bio-economy" represent an appropriate economic order that underpins all economic activities [5]. Georgescu-Roegen who has been studying economics since the 1970s had the same opinion. Essential in Georgescu-Roegen's research on bio-economics was his concern for economic growth without limitation that is incompatible with the fundamental laws of nature [6].

In one of his work, Enriquez argues that the application of genomics discoveries leads to a restructuring of the capacities of all companies and industries in a manner that will modify the world's economic condition. He highlighted the creation of a new economic sector, the "life sciences" [7].

The European Commission has begun to promote this concept a lot in recent years. One of the most important actors in this effort was Patermann, who was program director of "Biotechnology, Agriculture and Nutrition" at the European Commission's Directorate-General for Research, Science and Education. The first Global Bio-economic Summit took place in Berlin in December 2015. Globally, bio-economy has gained great significance in last years as a wide range of benefits have been detected by several countries [8].

In recent decades, globalization has had a major impact on countries, institutions, businesses and individuals, which has led to the development of new technologies and processes [9]. Furthermore, given the impact that globalization has on the environment, appeared increasingly more concerns about sustainability issues. Thus, the notion of sustainability has become one of the most pressing challenges of our century, being a key word in global research and political agendas of the last decades [10]. There are many movements in this area, such as circular economy, the green economy and bioeconomy.

Progress in the field of bio-economy has become a priority objective of the European Union's research, development and innovation policy, coordinated by the principles of sustainability. The realization of this objective has the implicit purpose of developing the biotechnologies that can be used at macroeconomic and global level, so that the classical, high-cost resources are replaced by renewable resources of biological nature [11].

In bio-economy, knowledge is the most important intangible asset, and intellectual property is the currency of exchange. Creating value in knowledge depends on access to intellectual property rights [12].

Consequently, the findings of the bio-economy launches extensive evolutionary processes that require a comprehensive approach where knowledge economy plays a significant role [13].

Ensuring the transfer of knowledge at an advanced and rigorous level will contribute to the exponential increase in the quality of human resources [14].

Intellectual property is the currency of research and technology transfer today, particularly in the form of patents. The creation of research clusters alongside bioeconomic innovation is conditioned by the existence of quality universities. Collaboration between institutions and the economy increases the quality of innovation. The opportunity and mutual benefit of these collaborations is essential to bring real benefits [15]. The higher the number of patents of a university, the more they increase the chances of concluding contracts with businesses thus making it more efficient to exploit the innovative potential [16].

Intellectual capital (IC) in the current economy becomes the new core of economic development, because the impact of financial assets and fixed assets is clearly inferior to the impact sustained by knowledge [17-18]. Reliable measurement of this one has become a major research area for practitioners and researchers since the early 1990s.

In the current "Universal Knowledge Network" [19], with a performance oriented culture [20], the high quality of intellectual capital can provide and motivate the improvement of human capital and the generation of new knowledge for the realization of a sustainable bio-economy.

Bioeconomy includes all the elements that determine the structure of intangible capital: intellectual property (copyright, software, patents, know-how, etc.), infrastructure (technologies and working procedures), human capital (employee skills and knowledge) market segments, distribution channels / value chains). The value of a company subsists in its ability to acquire,

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generate, distribute intangible resources, and strategically and operationally apply knowledge [21-22].

In this context, intellectual capital plays an important role in the development of bioeconomic projects. The size and speed of innovation depend on a functional knowledge base as well as on the importance attached to intellectual capital in organizations. The development of intellectual capital has the potential to contribute to developments in the field of bio-economy through the development of innovation capacities resulting from the intensification of investments associated with this form of capital. Innovative capacities will result in opportunities to create new products, services or work practices [23].

Our research aimed to emphasize the benefits of the dynamics of the intellectual capital growth on the evolution of bio-economy. The resulting dimension, bio-economy progress, was disaggregated into three study directions, namely: renewable waste material, share of renewable energy and energy intensity of economy.

The results of our analysis coincide with those of the authors Gârdan et al. [24], namely in a knowledge-based economy the link between sustainable bio-economy and companies is achieved by Intellectual Capital. At European level, between bio-economy and the turnover from innovation as a percentage of the total turnover. At Romanian level the bio-economy is influenced most by the number of Patent applications to the European Patent Office.

This paper approaches at macro level (European level) the factors that determine a sustainable development which fills a gap in the literature. The literature includes articles with microeconomic studies, companies in the field of forestry (13%), chemicals and plastics (3%), paper/pulp (18%) and agriculture (19%). This article is different in terms of the mode of measurement via the proposed variables, being developed in an economic area. Our paper also contributes to the expansion of specialty literature by using a quantile regression for the purpose of increasing the thoroughness of the analyses that were conducted.

The paper is organized into four sections, namely a synthetic literature review on the role of bio-economy and on the importance of intellectual capital in the development of bio-economy, as well as substantiating the working hypotheses (Section 2); the presentation of data, variables and research methods that were used (Section 3); and the interpretation of the results (Section 4). Finally, Section 5 synthesizes the main conclusions, while also presenting the limitations and future research directions.

2. Literature Review and Developing the Hypotheses

Intellectual capital is indissolubly linked to the application of the principles of the knowledge-based economy, which is the basis for the evolution of bio-economy [25-34].

Among other things, the European Union and the Organization for Economic Cooperation and Development (OECD) have highlighted the need for global cooperation to facilitate the growth of bio-economic activities.

In Figure 1 we can see the magnitude to which measures have been taken to create a global economy [35].

Figure 1. Bioeconomic measures worldwide [35]

The number of publications listed in Scopus referring to bio-economy is presented in Figure 2 [36].

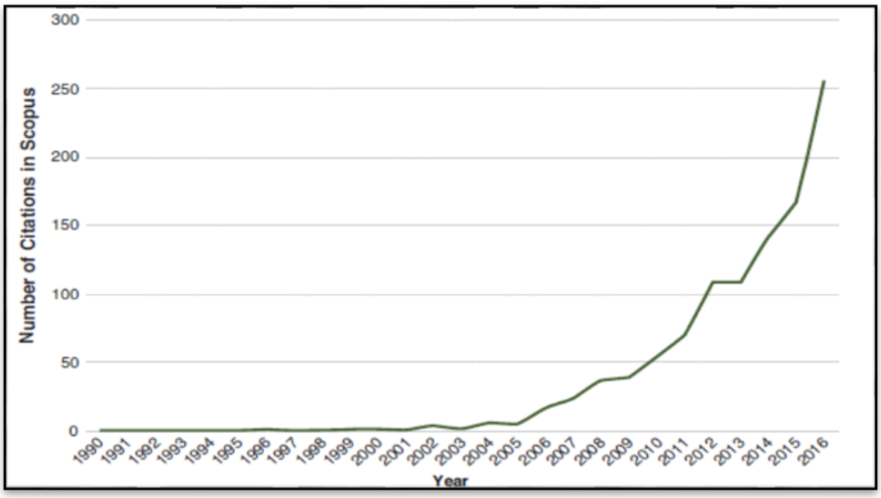

Figure 2. The number of citations listed in Scopus referring to bio-economy [36]

Considering the crisis caused by the current economy, we can state, according to market statistics, that the market value of many large companies is mostly given by intellectual capital rather than by the total value of the assets measured at market value.

2.1. The need to develop bioeconomy and the role of intellectual capital

From the research of the literature review in the field of bio-economy and intellectual capital we identified a series of articles from the Web of Science database, the selection being made according to the following characteristics: (i) published between 2010-2018; (ii) by keywords: sustainability, sustainable development, bio-economy, intellectual capital, biotechnology, innovation, economic development, human capital and relational capital. Thus, 17 articles were extracted from the database, which we grouped by title, year, and authors (see Table 1).

Table 1. Selection of articles from database

Title	Authors	Year
A framework of actions for strong sustainability	Oliveira Neto, G.C.D., Pinto, L.F.R., Amorim, M.P.C., Giannetti, B.F., Almeida, C.M.V.B.D.	2018
Knowledge-based bioeconomy: The use of intellectual capital in food industry of Serbia	Boljanovic, J.D., Dobrijević, G., Cerovic, S., Alcakovic, S., Djokovic, F.	2018
A demand-side perspective of bioeconomy: The influence of online intellectual capital on consumption	Vătămănescu, E.-M., Alexandru, V.A., Cristea, G., Radu, L., Chirica, O.	2018
Bioeconomy development and using of intellectual capital for the creation of competitive advantages by Smes in the field of biotechnology	Gârdan, D.A., Andronie, M., Gârdan, I.P., (...), Iatagan, M., Hurloiu, I.	2018
The University role in developing the human capital for a sustainable bioeconomy	Bejinaru, R., Hapenciuc, C.V., Condratov, I., Stanciu, P.	2018

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Consumer Ewom communication: The missing link between relational capital and sustainable bioeconomy in health care services	Gheorghe, I.R., Purcărea, V.L., Gheorghe, C.M.	2018
Intensity of involvement of teachers and researchers from Romanian Universities in bioeconomy knowledge flows	Neştian, A.S., Tiţă, S., Guţă, A.L.	2018
Types of intellectual capital employed in bioeconomic projects - A longitudinal case study	Săndulescu, M.-S., Stoica, D.A., Albu, C.-N., Albu, N.	2018
Intellectual capital and financial performance of biotech companies in the pharmaceutical industry	Anghel, I., Siminică, M., Cristea, M., Sichigea, M., Noja, G.G.	2018
The role of universities in consolidating intellectual capital and generating new knowledge for a sustainable bio-economy	Tiron-Tudor, A., Nistor, C.S., Ştefănescu, C.A.	2015
The role of public subsidies for efficiency and environmental adaptation of farming: A multi-layered business model based on functional foods and rural women	Varela-Candamio, L., Calvo, N., Novo-Corti, I.	2015
Seeds of accumulation: Molecular breeding and the seed corn industry in Hawai'i	Schrager, B., Suryanata, K.	2015
Challenging the bioeconomy: The dynamics of collective action in Argentina	Arancibia, F.	2013
Theorizing the Bioeconomy: Biovalue, Biocapital, Bioeconomics or . . . What?	Birch, K., Tyfield, D.	2013
High technology in emerging markets building biotechnology clusters, capabilities and competitiveness in India	Ahn, M.J., Hajela, A., Akbar, M.	2012
Towards a high-performance bioeconomy determining cluster priorities and capabilities in New Zealand	Ahn, M.J., Meeks, M., Bednarek, R., Ross, C., Dalziel, S.	2010
Patenting human pluripotent cells: Balancing commercial, academic and ethical interests	Bahadur, G., Morrison, M.	2010

The objective of the exploratory study of the Boljanovic et al. was to identify and analyze the indicators of intellectual capital in food industry of Serbia [37]. The paper investigated managers' perceptions of their usefulness, practical application, and factors that influence them. The respondents were surveyed by questionnaire. They were top managers from 18 food organizations, committed to the bio-economy concept. The survey items were divided into three subcategories: human, structural, and relational capital. The results show that all indicators were perceived as very important, relational capital indicators being the most useful of all. The study provides a perspective on managing intellectual capital in bio-economy.

The paper of Vătămănescu et al. aims to address a demand side perspective of bio-economy by laying emphasis on the digitalization of markets and, subsequently, on the consumption patterns at the macroeconomic scale [38]. The study investigates the influences of intellectual capital on the consumption patterns through the lens of bio-economy. The focus is set on the bio products consumption in two European countries relying on a sample of over 700 active online consumers. Processed through a structural equation modeling technique, the data indicated the existence of significant influences among the considered variables.

There are attempts to present the perceptions and opinions of the managers of small and medium enterprises in applied biotechnology on the importance of intellectual capital and the application of knowledge management principles to create and maintain competitive advantages [24]. Enterprises that develop a sustainable knowledge management system that they integrate into their marketing strategy have the most prominent position on the market and gain multiple competitive advantages. The research highlights that the strategic decision regarding the implementation of a knowledge management system and the intelligent use of intellectual capital resources are correlated with variables such as the managers' level of education in the field, thus correlating managers' activity to organizational culture. Knowledge, for new business models, is a good asset that can be capitalized; from this perspective, the implications at the level of marketing strategies are the same time diverse and complex.

The developments in the bio-economy domain should reflect their usefulness regarding the provision of sustainable solutions for future competitiveness growth by using natural resources. Latterly, the relevance of education, training and research in bio-economy domain is obvious because these types of solutions may be generated mainly by educated individuals who contribute to the better specialization of the human capital on this market [39]. The aim of the research is to analyze the influence of universities upon the human capital activating in the bio-economy sectors throughout the transfer of three types of knowledge: rational, emotional and spiritual. The data obtained capture the facets of human capital in interdependence and interrelation with the dimensions of bio-economy. The study can be a starting point to designing strategies for increasing the human capital of organizations in various fields as well as of systems in the bioeconomy field.

The world today faces many challenges that may be solved by using the principles of bioeconomy. Bio-economy had a multi-disciplinary approach with the objective of an integrated scope, namely, to achieve sustainable development. In a knowledge based economy, the link between sustainable bioeconomy and companies is achieved by Intellectual Capital. The intangible assets of Intellectual Capital coming from the external environment of a company in the shape of Relational Capital have great value, as they can offer competitive advantages.

The interdependency between the intellectual capital and the financial performance of biotechnological (biotech) companies was performed for 24 biotech companies during 2002-2014, based on several indicators available on the Thomson Reuters database. The applied tests confirm R&D expenditures as the most suitable indicator to appreciate the intellectual capital for the biotech companies in the pharmaceutical industry [40].

At the base of the transformations taking place in the economy, knowledge will be found under different circumstances - raw material, production factor or finished product. Thus, economic processes will in fact transform and adapt to change and new demands through knowledge [41].

Companies that develop a sustainable knowledge management system that they integrate into their marketing strategy have the most prominent position on the market and gain multiple competitive advantages.

The conclusion to be drawn from the revision of the literature is that knowledge management and intellectual capital are indissolubly linked to the application of the principles of the knowledge-based economy, which are also the basis for the current evolution of bio-economy.

2.2. Substantiation of Hypotheses

Starting from the aim of our research, we considered the following hypotheses:

Hypothesis 1 (H1).

There is a significant association between intellectual capital and economic progress and sustainability estimated via renewable waste material growth.

During past few years, many efforts have been expended on the utilization of renewable resources due to the growing environmental concerns. To this end, Shabman et. al. [42] provided evidence that the utilization of renewable waste material influences sustainable growth in the field of chemicals. Research with a sustainability approach indicated a concern with the importance of the intellectual capital through the substitution of nonrenewable resources with renewable ones, the substitution of toxic inputs by organic inputs, the reuse of waste in different production processes [25]. Musaazi et al. [26] developed organic absorbents with renewable and biodegradable materials, renewable energy, and rainwater. Naughton et al. [27] implemented process efficiency improvements in wood furnaces to improve energy efficiency. Agostinho and Ortega [28] recommended nonrenewable waste resources replaced by renewable waste (biomass replacing fossil fuel) as a specific action for the promotion of strong sustainability. Renewable waste material and energy production involves holding know-how, patent application, supporting R & D expenditure [42].

Hypothesis 2 (H2).

Intellectual capital significantly influences renewable energy share growth.

The use of renewable energy sources is the third sustainability principle [43]. The utilization of renewable sources is important for sustainable development; otherwise the scarcity of non-renewable materials will be a limiting factor in economic development, such as how a lack of petrol can impact industrial activity [30-31]. On the other hand, the existence of renewable resources to use as substitutes for oil will guarantee continued industrial activity, economic development, and job creation [25,42]. This suggests that an action to promote bio-economy is the substitution of non-renewable energy sources with renewable alternatives [10]. According to Agostinho and Ortega [28] nonrenewable energy resources should be replaced by renewable energy as a specific action for the promotion of strong sustainability. To substitute non-renewable energy resources for renewable alternatives needs knowledge, investment in research, innovation and technological performance [32-34].

Hypothesis 3 (H3).

There is a significant association between intellectual capital and the prospect of growing the value of energy intensity of the economy.

Some institutions and authors used Energy intensity of the economy as an indicator for sustainability evaluation of different bio-economy types [44-45]. The results highlight the importance of biotechnology innovation transfer after critical and comprehensive sustainability assessments. Energy intensity was highest for countries where turnover in innovation and the number of patents are increasing [44].

3.Materials and Methods

Considering intellectual capital as a key resource for the expansion of organizational intelligence, economic growth and especially for the development of bio-economics, we have used the following objective (of our methodology) for analysis: *Determining the influence of intellectual capital on the progress of the bio-economy at European and Romanian level*.

3.1. Sample, Data and Variables

The study is based on data collected manually from the Eurostat European Statistics Institute on reports published on indicators of sustainability and intellectual capital over seven years (2011-2018). From these two reports we summarized information on 36 countries in Europe of which 29 remained in the sample to ensure the robustness of the analysis. The countries under analysis are presented in Table 2.

Table 2. Energy consumption by 36 countries [46]

Geo\Time	2011-2018	Geo\Time	2011-2018
Belgium	**35,60**	**Netherlands**	**54,3**
Bulgaria	9,5	Austria	29,7
Czech Republic	25,6	**Poland**	**60,5**
Denmark	14,2	Portugal	15,9
Germany	**205,9**	Romania	20,7
Estonia	2,7	Slovenia	4,8
Ireland	11,8	Slovakia	10,3
Greece	15,8	Finland	23,5
Spain	**79,2**	Sweden	30,2
France	**151,3**	**United Kingdom**	**129**
Croatia	7,2	Iceland	2,7
Italy	**118,3**	Norway	17,5
Cyprus	1,8	Montenegro	0,7
Latvia	3,6	Former Yugoslav Republic of Macedonia	1,7
Lithuania	5,9	Albania	2,3
Luxembourg	4,4	Serbia	8,8
Hungary	16,9	**Turkey**	**86,9**
Malta	0,8	Bosnia and Herzegovina	3,9
Mean 32,75			

The Energy consumption measures the total energy demand of a country excluding all non-energy use of energy carriers (e.g. natural gas used not for combustion but for producing chemicals). Figure 3 shows that 80% of the analyzed countries are below average. Countries that are above the average energy demand were excluded from the analysis.

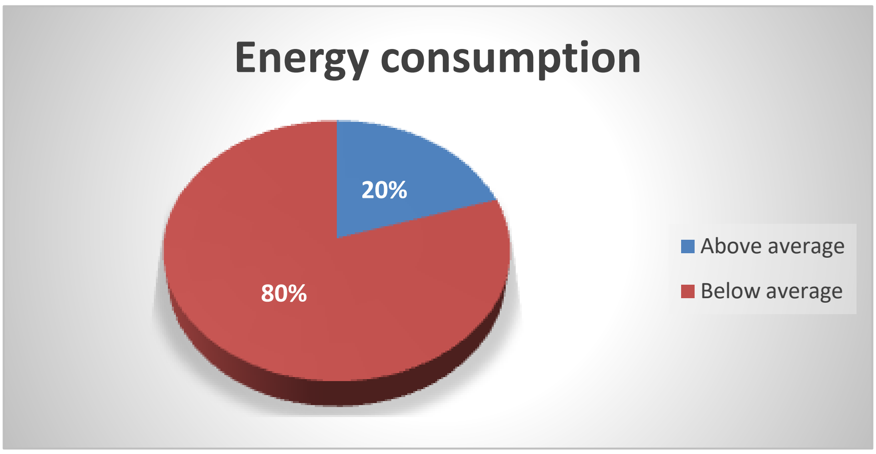

Figure 3. *Energy consumption by 36 countries*

Thus, there were produced 203 observations on each variable involved in the analysis.

The variables substantiated based on the collected information are concentrated in Table 3, which presents the function of their role in the conducted analysis. The resulting dimension, i.e. the bio-economy growth, was broken down into three study directions: renewable waste material growth, share of renewable energy growth and energy intensity of economy growth.

Table 3. Description of variables used in the analysis

Variable	Abbreviation	Description
Dependent variables		
Renewable waste material growth [47]	RwmGr	(RwmGr i,t – RwmGr i, t-1)/ RwmGr i, t-1
Renewable energy share growth [48]	RenGr	(RenGr i,t – RenGr i, t-1)/ RenGr i, t-1
Energy intensity of economy [46]	EIE	Log (CBIE / GDP) CBIE = Total Gross Energy Usage GDP = gross domestic product
Independent variables		
Patent application [49]	CB	Log Number of aplication
Research and development expenditure [50]	R&D	Log total expenditure
Turnover from innovation [51]	CA_INV	Log (CAnew products/CAtotal)
Control variables		
Gross domestic product rate [52]	GDP	(GDP i,t – GDPi, t-1)/ GDP i, t-1
Population growth [52]	POP	(POP i,t – POP i, t-1)/ POP i, t-1
Urbanization growth [52]	URBAN	(URBAN i,t – URBAN i, t-1)/ URBAN i, t-1
Inflation consumer production index [52]	INF	(INF i,t – INF i, t-1)/ INF i, t-1

In the current energy context, sustainable development means ensuring energy needs, but not by increasing its use (except for renewable energy), but by increasing energy efficiency, modernizing technologies and restructuring the economy (EIE). Sustainability growth involves holding know-how, patent application, supporting R & D expenditure [42-43, 32-34, 53].

Patent applications listed by European Patent Office (CB) The indicator measures claims for the protection of an invention directed in a direct manner at the European Patent Office (EPO) or submitted under the Patent Cooperation Treaty and designating an EPO (Euro-PCT), whether accepted or not. The data cover the total number of applications listed per country. If an application includes more than one inventor, the submission is equally divided between all and then in their home countries, thus avoiding double counting.

Turnover from Innovation as a proportion of the total Turnover (CA-INV) is defined as the ratio between the turnover of the new products for the company and the new ones on the market as a proportion of the total turnover. It is based on the Community Innovation Survey and covers at least all enterprises with 10 or more employees from 29 European countries during 2011-2018 period. An innovation is considered to be a new or significantly improved product (as good or service) placed on the market or the introduction of a really new or meaningfully improved process in a company.

Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. R&D expenditures

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include all expenditures for R&D performed within the business enterprise sector (BERD) on the national territory of 29 European countries during 7 years.

Control variables such as gross domestic product rate, population growth, urbanization growth and inflation consumer production index were introduced in line with the relevant literature in the field regarding sustainability [52-53].

Quantitative macroeconomic growth has been considered and is still being considered in many cases to be the central prerequisite of multiplication of wealth, safeguarding of jobs, avoidance of distribution conflicts and the financing of our social security systems. At the same time a production expansion is generating a great number of environmental burdens and can thus reach its natural limits. In the case of potentially lastingly lower growth the question arises how those framework conditions may be changed which make the society and the economy presently so dependent on growth. Under discussion are framework conditions for "Macroeconomics for Sustainability" which are ecologically sustainable and socially equitable and which can enable economic stability on the long run.

3.2. Data Analysis Methods

The tools and methods of analysis used in the study are: the collection of the value of each indicator by the method of observation, sorting and grouping of data according to the criteria of the European Union and Romania; creating graphs using the Excel spreadsheet program in the Microsoft Office 2010 package for identified indicator values and then sorting them for 7 years; statistical analysis using ANOVA, SPSS 19.0, and Pearson correlation indices.

The systematization and grouping of data, indices, statistical analysis were used as methods in conducting scientific research.

Regression shows how a variable is dependent on another variable. The equation of the regression model is expressed as follows (1):

$$Bio\text{-}economy = \beta_0 + \beta_1 {*} R\&D + \beta_2 {*} CB + \beta_3 {*} CA\_INV + \sum \beta_j {*} Controls + \varepsilon \qquad (1).$$

where Bio-economy is broken down in three dependent variables: renewable energy share, renewable material waste and energy intensity of economy; controls integrate the conjugated action of control variables for the variance of sustainability: gross domestic product rate, population growth, urbanization growth and inflation consumer production index; while ε is the error term synthesizing the influence of all the factors with impact on bioeconomy progress, but which are not included in the model.

The analysis was carried out at European (Bio-economy-E) and Romanian level (Bio-economy-R).

4. Results and Discussion

4.1. Empirical analysis at European level

It is found that the most significant link is between the Energy Intensity of the Economy and the Turnover from innovation (Table 4). Between the dependent variable - the Energy Intensity of the Economy - and the independent variable - the Turnover from innovation as a percentage of the total turnover - there is really a strong direct link, the value of the correlation coefficient is equal to + 0.954, with a Sig. value less than 0.05.

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Table 4. The link that exists between variables at European level (own processing data using the SPSS 19 statistical program)

Corelations											
		EIE-E	RwnGr-E	RenGr-E	R&D	CB	CA_INV	GDP	POP	URBAN	INF
Pearson Correlation	EIE-E	1.000	-	-	0.726	0.531	0.954	0.823	0.231	0.423	0.015
	RwnGr-E	-	1.000	-	0.826	0.422	0.712	0.632	0.467	0.566	0.320
	RenGr-E	-	-	1.000	0.675	0.520	0.801	0.532	0.513	0.502	0.221
	R&D				1.000	0.822	0.572	0.738	0.692	0.713	0.341
	CB					1.000	0.614	0.784	0.703	0.567	0.089
	CA_INV						1.000	0.674	0.524	0.617	0.208
	GDP							1.000	0.487	0.639	0.316
	POP								1.000	0.705	0.327
	URBAN									1.000	0.175
	INF										1.000
N = 203											
Sig. is less than 0.05											

Table 5 highlights the fact that 95% of the variation of the Energy Intensity of the Economy can be explained by the influence of independent variables. The difference is due to other conjunctural factors.

Table 5. The percentage of the link between European variables (own processing data using the SPSS 19 statistical program)

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error
1	0.957	0.917	0.504	2801.643
2	0.894	0.802	0.702	2132.646
3	0.848	0.712	0.664	1734.801
1. dependent variable: EIE-E, 2. dependent variable RwnGr-E				
3. dependent variable: RenGR-E				

Table 5 shows for each regression model the value of the correlation coefficient (R), the value of the coefficient of determination (R Square) and the standard error. The correlation coefficient (R) increases as many variables are introduced into the model. Model 1 analyzes the correlation between all the variables included in the study. Model 2 and 3 eliminate the variables in order of the weakest influence: R&D and CB, respectively (see Pearson coefficient in Table 4).

The equation (1) of the regression model according to the data presented below is the following (2):

$$EIE\text{-}E = (-2735{,}11) + 36.423*R\&D + 14.067*CB + 63.456*CA\_INV \qquad (2)$$

The Regression coefficients are as stated in Table 6, e.g. β_0 = -2735,11; β_1 = + 36.423; β_2 = + 14.067; β_3 = + 63.456.

Table 6. The Regression coefficients at European level (own processing data using the SPSS 19 statistical program)

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								Coefficients
Model 1	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	β	Std. Error	β			Tolerance	VIF
(Constant)	-2735.11	0.2441	0	0	0	0	0
CB	14.067	0.0012	0.477	0.16	0.04	0.393	2.632
CA_INV	63.456	0.1234	0.683	0.41	0.03	0.293	2.734
R&D	36.423	0.2132	0.377	0.21	0.05	0.172	1.902
1. dependent variable: EIE-E; independent variables: CB, CA_INV, R&D							

Model 1 reflects the influence of the evolution of the number of Patent applications to the European Patent Office, the Turnover from innovation and the total research and development expenditures, all on the Energy Intensity of the Economy at European level.

From the analyzed model, a few ideas are drawn:

- if we keep constant the Turnover from innovation and the value of Research and development expenditures, a percentage increase in the number of Patent applications listed by European Patent Office generate an increase in the Energy Intensity of the Economy by 14 percent;
- if we maintain constant the number of Patent applications listed by European Patent Office and the value of R&D, a percentage increase in Turnover from innovation leads to an increase in the Energy Intensity of the Economy by 63 percent;
- if we maintain constant the value of Turnover from innovation and the number of Patent applications listed by European Patent Office, a percentage increase in the value of R&D expenditures leads to an increase in the Energy Intensity of the Economy by 36 percent.

Compliance with the hypothesis required by the regression analysis can be graphically checked using the histogram in Figure 4.

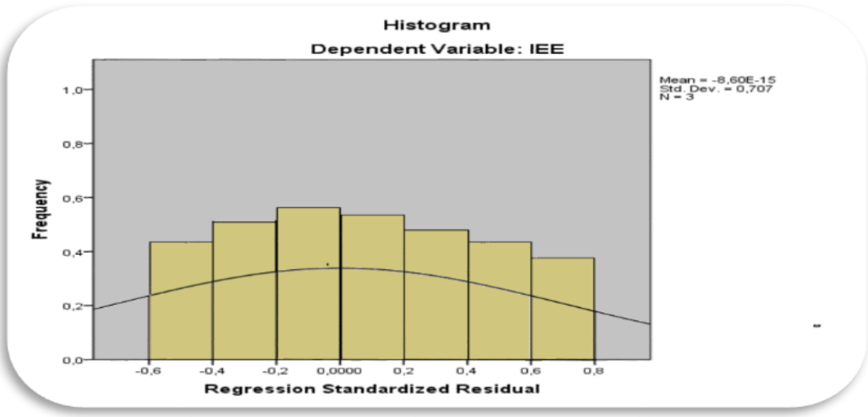

Figure 4. Verifying the normality of the research at European level through the histogram (own processing data using the SPSS 19 statistical program)

4.2. Empirical analysis at the Romanian level

It is noted that the most significant link is between the Energy Intensity of the Economy and the number of Patent applications to the European Patent Office (Table 7). Between the dependent variable - the Energy Intensity of the Economy - and the independent variable - the number of Patent applications to the European Patent Office - there is really a strong direct link, the value of the correlation coefficient is + 0.810, with a Sig. value less than 0.05.

Table 7. The link that exists between variables at the Romanian level (own processing data using the SPSS 19 statistical program)

Corelations											
		EIE-R	RwnGr-E	RenGr-E	R&D	CB	CA_INV	GDP	POP	URBAN	INF
Pearson Correlation	**EIE-R**	1.000	-	-	0.527	0.810	0.754	0.523	0.241	0.323	0.105
	RwnGr-E	-	1.000	-	0.716	0.323	0.613	0.522	0.358	0.452	0.220
	RenGr-E	-	-	1.000	0.568	0.420	0.702	0.432	0.483	0.504	0.331
	R&D				1.000	0.722	0.572	0.739	0.592	0.423	0.351
	CB					1.000	0.599	0.684	0.403	0.667	0.078
	CA_INV						1.000	0.564	0.624	0.717	0.298
	GDP							1.000	0.527	0.612	0.216
	POP								1.000	0.742	0.237
	URBAN									1.000	0.182
	INF										1.000
N = 7											
Sig. is less than 0.05											

Table 8 highlights the fact that 92% of the variation of Energy Intensity of the Economy can be explained by the influence of independent variables. The difference is due to other conjunctural factors.

Table 8. The percentage of the link between the variables at Romanian level (own processing data using the SPSS 19 statistical program)

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error
1	0.928	0.904	0.604	3801.46
2	0.796	0.899	0.713	3032.823
3	0.714	0.811	0.624	1326.522
1. dependent variable: EIE-R, 2. dependent variable RwnGr-E				
3. dependent variable: RenGR-E				

Table 8 shows for each regression model the value of the correlation coefficient (R), the value of the coefficient of determination (R Square) and the standard error. The correlation coefficient (R) increases as many variables are introduced into the model. Model 1 analyzes the correlation between all the variables included in the study. Model 2 and 3 eliminate the variables in order of the weakest influence: R&D and CA_INV, respectively (see Pearson coefficient in Table 7).

The equation (1) of the regression model according to the data presented below is the following (3):

$$EIE\text{-}R = 852.016 + 58.105 * CB + 34.132 * CA\_INV + 22.506 * R\&D \quad (3)$$

The Regression coefficients are as stated in Table 9, e.g. β_0 = + 852.016; $\beta 1$ = + 58.105; $\beta 2$ = + 34.132; $\beta 3$ = + 22.506.

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Table 9. The Regression coefficients at Romanian level (own processing data using the SPSS 19 statistical program)

Coefficients							
Model 1	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**Collinearity Statistics**	
	β	**Std. Error**	**β**			**Tolerance**	**VIF**
(Constant)	852.016	0.514	0	0	0	0	0
CB	58.105	0.002	0.48	0.23	0.008	0.278	1.373
CA_INV	34.132	0.235	0.63	0.19	0.009	0.288	1.463
R&D	22.506	0.447	0.31	0.24	0.073	0.138	0.885
1. dependent variable: EIE-R; independent variables: CB, CA_INV, R&D							

The model reflects the influence of the evolution of the number of Patent applications to the European Patent Office, the Turnover from innovation and total Research and development expenditures on the Energy Intensity of the Economy at the level of Romania.

Thus, from the analyzed model a few ideas are drawn:

- if we keep constant the Turnover from innovation and the value of R&D, a percentage increase in the number of Patent applications listed by European Patent Office leads to an increase in the Energy Intensity of the Economy by 58 percent;
- if we maintain constant the number of Patent applications listed by European Patent Office and the value of R&D, a percentage increase in Turnover from innovation leads to an increase in the Energy Intensity of the Economy by 34 percent;
- if we maintain constant the value of turnover from innovation and the number of Patent applications listed by European Patent Office, a percentage increase in the value of R&D to an increase in the Energy Intensity of the Economy by 22 percent.

Compliance with the hypothesis required by the regression analysis can be graphically checked using the histogram in Figure 5.

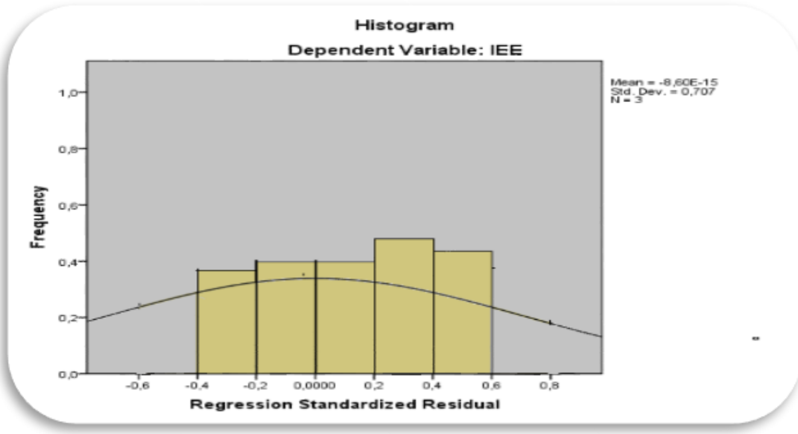

Figure 5. Verifying the normality of the research at Romanian level through the histogram (own processing data using the SPSS 19 statistical program)

3.3. Hypothesis testing using data processed

In this part of the analysis we will perform the test of the force of each hypothesis, testing being done predominantly with the help of figures and graphs from the previous parts of the study.

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Thus, Table 10 systemizes:

- Pearson correlation coefficients to determine whether there is a significant link between the dependent variable aka Energy Intensity of the Economy and the independent variables that characterize intellectual capital: Research and development expentitures, Patent applications listed by European Patent Office and the Turnover from innovation as a percentage of the total Turnover;
- Regression coefficients that determine the degree of influence of independent variables on the bio-economy.
-

Table 10. Systematization of regression coefficients and Pearson coefficients (own processing data using the SPSS 19 statistical program)

Intellectual capital	Pearson coefficients		Regression coefficients	
	European Level	Romanian Level	European Level	Romanian Level
R&D	0.726	0.527	36.423	22.506
CB	0.531	0.81	14.067	58.105
CA_INV	0.954	0.754	63.456	34.132

On the other hand, Table 11 summarizes the assumptions made at the beginning of the research and the decisions regarding their validation or invalidation based on the econometric model used.

Table 11. Validation of hypotheses

Aim	Hypotheses	Decision using the regression model	
		European Level	Romanian Level
Highlighting the benefit of developing intellectual capital in the development of bio-economy	*H1:There is a significant association between intellectual capital and economic progress and sustainability estimated via renewable waste material growth.*	The hypothesis is validated	The hypothesis is validated
	H2:Intellectual capital significantly influences renewable energy share growth.	The hypothesis is validated	The hypothesis is validated
	H3:There is a significant association between intellectual capital and the prospect of growing the value of energy intensity of the economy.	The hypothesis is validated	The hypothesis is validated

Edvinsson and Malone described the intellectual capital as a metaphor. They imagined the firm as a tree. They overlapped the compiled plans of the company, the reports annually and quarterly developed, the brochures and all other documents of the firm as the trunk, as well as the branches and the leaves of the living organism. The wise angle will be the examination from the point of view of fruit production. The biases might evolve from the judging of only the visible side of the tree. Since an important part of the tree is out of sight. Even if we appreciate the tree as being healthy starting from the fruits (tasty and with nice color), it will be of real interest to study the tree's roots in the view of its evolution in the future. Thus might be described the intellectual capital [12].

From 1947 till 2011 there was an important shift in the balance of productive and unproductive economy of US. The starting point of such an analysis was the Marxist theory that the knowledge and information as economic categories are unproductive. The first observed pattern phase, meaning the 1947-79 one, had as absolute priority the productive accumulation. Beginning with the 1980s, there was a fast and important shift toward the unproductive activities (accumulation), taking various developing forms as income, fixed assets and employment. The shining production of explosive knowledge and information became an important proportion of capital stock as well as of unproductive income. The rapid changing of the balance between the stagnant productive accumulation and fast rising of unproductive one gave birth to an enhanced exploitation of productive workers and to a widened inequality of income [29].

One of the most important aspect of modern bio-economy is represented by the digitalization of markets, having as consequence the appearance and development of some consumption patterns visible at the macroeconomic scale. The new tendencies of consumer's behavior, basically based on the reconfiguration of their approaches and expectations, have their origin in the corroboration of new sustainable economy's needs with the advances in digital technologies. The empowering of consumers squeezes out of the emergence of their online communities and of the online intellectual capital. The newest social aggregations of online type allow deepened transformations in actual society, starting from the need of an enhanced communication and flows of information on products of the digital markets which are bio-labelled [38].

Economic growth in modern era is no more related to the growth limits, growth opportunities being far way more important. The last ones are basically involving the developing knowledge, research investments, innovative trends and performance of technology, all known as smart economic growth. On the other hand, sustainable economic growth is based on green energy, policies involving low-carbon emissions and high reduction of collateral effects on environment. There exists important global interdependencies between economic growth, circular economy and the newest trend represented by intellectual capital. All of them when discussing the bio-economy advances. The regression models used to study such interdependencies are including various variables. Thus, the performance of innovation might be quantified using as proxy variable the number of patents. Circular economy would be measured using as dependent variable the added value. Intangible (knowledge/intellectual capital) and renewable resources used in a cascade are highly influencing the sensitivity of economic growth, in turn quantified using the gross domestic product. The intellectual property turned into patents is deepened influenced by the amount of the allocated funds for research and development, as well as by the fiscal freedom. When focusing on added value created in circular economy, there was found an important correlation with the export of recyclable raw material, employment of population in such domain as well as with the rate of the recycling of municipal waste Remarkable is the observed fact that the economic growth in the EU region is positively correlated with the productivity of employees from bio-economy domains [32].

Intangible capital is the structural capital (copyright, software, patents, know-how, etc.), human capital (employee skills and knowledge) and relational capital (brands, market segments, distribution channels / value chains).

In the literature, the link between bio-economics and intellectual capital takes into account human capital because the most valuable assets for achieving a bio-economy are the knowledge, skills and experiences of professionals [33, 54].

The analysis was done for the countries: Bulgaria, Czech Republic, Denmark, Estonia, Ireland, Greece, Croatia, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Austria, Portugal, Slovenia, Slovakia, Finland, Sweden, Iceland, Norway, Montenegro, Former Yugoslav Republic of Macedonia, Albania, Serbia and Bosnia and Herzegovina. These countries were chosen because, from the sample analyzed, they have similar characteristics in terms of energy consumption and innovations.

Our analysis demonstrates that countries where the progress of bio-economy cannot be achieved without harness of intellectual capital are countries that have a low economic and sustainable development.

Intellectual capital is the currency of research and technology transfer today, especially in the form of patents. The creation of research clusters alongside bioeconomic innovation is conditioned by the existence of quality universities. Collaboration between institutions and the economy can increase the quality of innovation. The opportunity and the mutual benefit of these collaborations is essential in order to bring real benefits.

The European Union has recognized universities as an essential resource for innovation by offering to support such activities. Risk Assessment, Design or Market Studies, Exploitation of Intellectual Property [24,55] are some of the actions being taken.

Romania has a great potential to develop an economy based on the concept of bio, because it is a country endowed with a wide variety of natural resources (forests, natural gas, fertile agricultural land - 7.5% of the agricultural area used in the EU - coal and lignite, crude oil, salt, minerals, silver, gold and hydrological networks).

The two-way link between universities, knowledge creators and the economic environment, the knowledge user and the resource generator can be synthesized from the perspective of the development of the Romanian bioeconomy in different ways: transfer of knowledge to companies or experimental functional research for products, technologies, methods, services, as well as significant improvement in the fields of intelligent specialization [55].

Bio-economy should be strongly based on academic research. A strong academic environment can guarantee the existence and management of the resources needed for complex, laborious and expensive research, development and implementation. Starting from these arguments transposed in the context of Europe and Romania, the article supports the idea that the relationship between intellectual capital and bioeconomy is the key to progress in the field.

Starting from these arguments transposed into the context of Romania, the article supports the idea that intellectual capital-bioeconomy is the key to progress in the field, which cannot be achieved without sustained academic research.

5. Conclusions

The intellectual capital of an organization can be successfully exploited through appropriate management strategies, these influencing the transformation of the intellectual capital potential (resources available) into the operational intellectual capital (results that increase the value of the organization). The benefits of optimal management of an organization's intellectual capital are

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numerous and generate an irreversible evolution on the scale of knowledge. Because the field of bioeconomics is a new and extremely complex one, it requires an advanced knowledge base on different niches.

The global crisis characterized by the crisis of the energy, ecology and the biosphere, and the environment requires solving the economic problem, satisfying a growing set of needs, given the limited and insufficient resources.

Bio-economy must be the basis for all economic activities and unlimited economic growth must be compatible with the fundamental laws of nature.

The results of our analysis showed that, in a knowledge-based economy, the link between sustainable bioeconomy and companies is achieved by Intellectual Capital. The intangible assets of Intellectual Capital coming from the external environment of a company in the shape of Relational Capital have great value, as they can offer competitive advantages. At European level, between bio-economy and the turnover from innovation as a percentage of the total turnover, there is a strong direct link, the value of the correlation coefficient is equal to 0.954. At Romanian level the bioeconomy is influenced most by the number of Patent applications to the European Patent Office in proportion of 81%.

The results of our analysis lead to the conclusion that research and innovation play an important role in the evolution of bio-economy both at European level and at the level of Romania.

Significant potential for bio-resources could be exploited through bioeconomic approaches. In order to achieve this capitalization, new solutions are needed for the sustainable intensification of the production of biological resources and for intelligent exploitation of bio-resources.

However, the practical development and implementation of these new solutions implies a significant investment in education and research, bioeconomic branches with high added value, meanwhile being branches of the knowledge-based economy.

The control variables included in the model remove the alternative explanations of the results.

We believe that the progress of bio-economy cannot be achieved without the harness of intellectual capital.

The contribution of this paper to the literature is:

- dividing countries by categories with similar characteristics in terms of innovation and energy consumption;
- expanding the specialty literature by highlighting the involvement of intellectual capital as a factor in optimizing sustainability growth and, at a methodological level, by using a multiple regression.
- proposing to support the research activity of universities as a solution for the development of bioeconomy.

The analysis leaves room for further interpretations and future research through going more in-depth with the analysis using quantile regression for emerging and developed countries cases.

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