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## Article

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# THE INTERACTION BETWEEN RENEWABLE ENERGY CONSUMPTION AND THE INSTITUTIONAL FRAMEWORK FROM THE CIRCULAR ECONOMY-BASED PERSPECTIVE

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## Abstract

The European Green Deal describes the vision and strategic orientation of EU members of future public policies, which is designed to harmonize countries' efforts to align national economies with the principles of the circular economy. Among the directions prescribed by the European Green Deal, we find an increase of renewable energy (RE) consumption in parallel with improving energy efficiency and reducing the energy sources that involve significant negative environmental impact in the long run. Our study addressed the association between RE consumption, management decision-making factor, policy landscape addressing energy efficiency, and sustainability innovation capabilities, at a firm-level analysis. For this purpose, we assess the causality between these variables, performing a time series analysis on a sample that covers the period between 2011 and 2019. Regression models are estimated with panel time series FMOLS (Fully Modified Ordinary Least Squares) and DMOLS (Dynamic Modified Ordinary Least Squares) estimation methods. The results underscore that the evolution of renewable energy consumption by firms depends on the management decision, related both to the commitment of managers to sustainable strategies and the effectiveness of governance processes. Nonetheless, our results emphasize the essential role of the country's institutional factor, which should ensure proper regulation, effective enforcement mechanisms, and financial incentives that promote the RE usage.

**Keywords:** circular economy, renewable energy, energy efficiency, regulatory indicators for sustainable energy, Fully Modified Ordinary Least Squares, generalized method of moments.

**JEL Classification:** M14, Q01, Q42, Q56, O13

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## **Introduction**

A new approach is needed in this global context in which the environmental, societal, and governmental (ESG – Environmental, Social, and Governance) aspects demand a solution. According to the concept of double materiality introduced by the European Commission (EC), at the company's level, the analysis must consider both the impact of ESG on financial performance and the impact of economic activities on the environment and society. Climate changes represent one of the most important challenges globally that determined the responsible factors to act. The European Green Pact is one of the European Union (EU) priorities aiming to achieve a competitive, sustainable, and adaptable economy in international context in terms of resource consumption. In this context, an essential pillar of growth, competitiveness, and sustainable development is the permanent access to energy. Because current energy systems are unable to provide energy at affordable prices and on a sustainable basis, renewable energy (RE), also known as “clean energy”, is expected to replace the old methods. Using RE sources has many advantages, such as marketing opportunities, reduction of emissions, and the impact of production processes on the environment or lower energy costs for businesses.

There are many factors, such as energy prices, energy production, energy dependence, economic growth, carbon dioxide use, or trade openness, that contribute to access to RE (Akar, 2017). The development levels of the countries have a significant influence on their interaction. As countries grow and develop, their demand for energy increases. When analyzing the interrelationships between the performance of sustainability indicators like human development index, financial development index, or urban population and economic growth, Sharma et al. (2021) concluded that RE consumption has a negative impact on economic growth, at least in the short run. Moreover, Azam et al. (2021) underline the central role of digitalization along with human factor quality, as there is a bidirectional causality relationship with country economic growth. In the long run, RE seems to have a positive impact on economic growth. The economic development of the EU is attributed to the use of non-renewable energy sources, and this kind of growth is far from sustainable. Towards a sustainable economic growth, the EU should remove the barriers towards implementing a RE based economic approach, a challenge remaining the creation of an economic structure with a significant use of it, involving long-term corporate social responsibility (Ene, 2018).

The question is how firms align to macroeconomic vision and strategic action plan, as the one drawn up by the European Green Deal, as there is a gap between the firms and the state perceptions in terms of energy public policies, including policies in the area of energy efficiency. Another question is about the capabilities of firms in terms of financial and technological resources and about how the human factor is affected by daily operations to ensure a sustainable consumption of energy with a lower negative environmental impact. In our study, we focus on the analysis of the relationship between the level of RE consumption in total revenues and on several fundamental drivers, such as the management decision-making factor, the policy landscape of firms addressing energy efficiency, and innovation capacities for sustainability.

As noted in the McKinsey report (2022), the objective of reaching net zero emissions by 2050 requires a significant increase in tangible assets, which involves significant investment efforts and relatively high impact on the operational costs structure in the short run (Knopf et al., 2013). In these circumstances, we need to understand if management is willing to make the transition to “clean energy” or sacrifices the long-term benefits generated by the use of

RE in favour of short-term financial performance. Compensating policies can be designed to reduce this cost impact, such as improving knowledge management, providing companies with the ability to create knowledge, manage environmental uncertainty, and supply chains, producing organizational knowledge and intelligence (Civelek et al., 2015). Furthermore, and of the same importance, is the orientation of the vision and strategy of companies that aims at a transition to the principles of circular economy and more sustainable energy consumption. Nevertheless, the institutional organizational dimension should be considered through effective corporate governance processes, policy clarity, and coherence addressing the energy usage or the management commitment to strategies aiming for more sustainable-oriented business models.

Based on this rationale, we perform our analysis with the intention of underlining the causal relationship between RE consumption by firms and a construct that reflects all organizational dimensions that promote the opportunity and need for a redesign of the business model, aligning them to the principles of the circular economy. In this respect, we organize our research paper into five sections, including an introduction, a literature review, a database and research methodology, results and conclusions, and final remarks.

## **1. Literature review**

The awareness of the importance of increasing the use of RE is the first premises that leads to a positive impact on its performance. There are many studies, at least at the macroeconomic level, which confirm the nexus between RE consumptions and economic growth (Șoavă et al., 2018; 2020; Marinaș et al., 2021; Sahlian, Popa, and Crețu, 2021). However, economic factors must not be omitted, as financing resources needed for investments in new RE capacities or projects for improving energy efficiency are significantly affected by the investment risk and investment return (Polzin et al., 2019; Biekša, Zonienė, and Valiulė, 2021). In contrast to the numerous studies that address the nexus between RE use and economic growth on a macroeconomic level (Oliveira and Moutinho, 2021), the effect of increasing the RE use ratio at the firm level is not adequately addressed, which makes management more cautious when deciding to invest in projects of transition to renewable energy, due to high costs and only long-term positive effects on return on invested capital (Knopf et al., 2013).

There are studies that confirmed dual efficiency determined by increasing RE usage leading to better environmental efficiency (Akadiri and Alola, 2019; Kara, Ibrahim and Daneshvar, 2021) and long-term economic growth (Șoavă et al., 2018; Kasperowicz et al., 2020; Marinaș et al., 2021; Sahlian, Popa and Crețu, 2021), especially in the sectors with higher demand for energy (Komarnicka et al., 2021). As a particular case, the research by Chen and Ma (2021) on listed Chinese energy firms during 2008-2017 shows that green investment is significantly and positively correlated with financial performance and should be a part of a long-term strategy. After all, firms' processes are highly dependent on production technologies that dictate the level of energy usage and are conditioned by sustainable energy policies, the maturity of related internal processes, and the effectiveness of governance mechanisms (Elia et al., 2020). This is why managers must be aware of the long-term advantages generated by the transition to RE use, which can become a flawless project only if it is supported by robust policies and governance framework at macro and microeconomic level (Breuer, Janetschek, and Malerba, 2019).

Energy efficiency is not strictly related to macroeconomic output or environmental performance, as the trade-offs of affordable energy from SDG 7 (Sustainable Development Goal 7) conflict with other SDGs, such as quality of life, which does not increase in the same proportion with macroeconomic growth. In addition, the macroeconomic context differs significantly from the firm's competitive environment, either due to the specificity of the sector the firms operate in or as an effect of the particular conditions facing them. Therefore, this conflicting relationship between the objective of energy efficiency and the increase in the RE ratio used persists, at least in the first stage of the transition to a circular economy-based business model. Therefore, it is essential for the state to ensure adequate financing conditions for green energy initiatives, to make project implementation more profitable and attractive to the microeconomic environment (Knopf et al., 2013). Otherwise, the current pattern of energy consumption consisting of the main ratio of conventional energy used will continue, as firms take advantage of the scale economies, due to the already existing equipment and improved technologies.

Energy use also depends on national policies and the internal institutional framework (Hassan, 2019). Sustainable energy consumption can be promoted in real terms only in the presence of active governmental efforts. That is why the institutional framework is important (Simionescu, Strielkowski, and Tvaronavičienė, 2020; Włodarczyk et al., 2021). Chen and Ma (2021) note the different positive moderating impact on green investment that financial performance of companies, environmental tax, technological innovation, and government subsidies have. According to Yang and Park (2020), a democratic government can efficiently allocate public funds, and the implementation of the RE financial incentives policy can make financial resources continuously available to domestic RE producers and investors and ensure the commercial profitability of the projects even without constant aid provision. In terms of state policies, Shin et al. (2016) demonstrate that incentives for investments in RE technologies are means of reducing environmental impact of production processes and diminishing their ecological footprints and energy consumption. However, gaps have been identified across countries, emphasizing that authorities in low-performing countries have to find solutions to overcome institutional and financing issues regarding the increase of RE use (Simionescu, Strielkowski, and Tvaronavičienė, 2020; Włodarczyk et al., 2021). Those gaps could be explained by the trade-offs between different SDGs that reflect on national regulation and governmental policies, since both SDG 8 and SDG 9 objectives are in conflict with many of those already consolidated in time (Pradhan et al., 2017; Kroll, Warchold, and Pradhan, 2019).

As noted by Hulshof and Mulder (2020), the use of RE does not determine a significant impact on firm financial performance, being more related to social and environmental benefits, the reason why the firm's decision is voluntary and becomes discretionary, especially in the case of countries that provide incentives for companies, through national related policies and frameworks (Hassan, 2019; Caruso, Colantonio, and Gattone, 2020; Simionescu, Strielkowski, and Tvaronavičienė, 2020), or even regional frameworks (Lowitzsch, Hoicka, and Van Tulder, 2020), which rely on strong cooperation between international agencies, energy organizers, governments, and associated bodies to ensure a successful transition to green energy-based economy (Shahbaz et al., 2020).

## 2. Research methodology

### 2.1. Purpose and objectives of the research

Our study aims to emphasize the causal relationship between ER consumption at the company level and the dimensions of corporate governance and management of the companies analysed, promoting the opportunity and the need to redesign the business model, aligning it with the principles of circular economy. The design of the empirical analysis takes into account the main objective of the study, namely, the analysis of the implications of redesigning the business model and implicitly the position of the management factor in the transition to sustainable consumption of green energy. At the same time, the empirical approach aims at an adjacent objective that addresses the modulating role of the state in the evolution of RE consumption. However, the study is limited to the analysis of some association relations described by our research hypotheses. Their operationalization is done by choosing a set of variables selected based on the definition assigned by the Refinitiv database. With this in mind, we consider our research hypotheses, as shown below.

H1: Aligning management to a sustainable development model positively influences the increase of RE consumption in total revenue.

H2: A formalized intention of the company to increase the consumption of RE in total revenue is positively influenced by the existence of a policy aimed at energy efficiency.

H3: The institutional macroeconomic framework outlines the premises for increasing the share of RE consumption in total consumption compared to the level of economic entities.

The first objective aims to analyse the implications of the corporate governance framework and the involvement of the management factor in the corporate consumption of RE and is associated with research hypotheses H1 and H2. The second objective of the paper addresses the role of the macroeconomic institutional framework in promoting RE consumption and is associated with the H3 research hypothesis. Thus, we delimit the marginal impact of public policies and legal compliance mechanisms on RE consumption, the marginal impact of corporate policies, and corporate governance mechanisms. The design of the research framework in this direction ensures the outlining of the essential role of moderator of the state in promoting the consumption of RE, and implicitly in fulfilling the target objectives on sustainable development.

### 2.2 Data collection

We have a two-fold approach as it looks for companies' efforts to increase RE consumption in total revenue and controls the institutional impact of the country on the position of companies toward the use of "clean energy". In order to achieve our objectives, we perform our analysis based on a sample consisting of 177 big-sized listed firms from 22 countries. Approximately 36% of the sample represent firms with headquarters in the EU countries, followed by 23% in the USA, 16% in Japan, 10% in the UK, and 9% in Canada. The remaining 6% represent firms with headquarters in other EU countries, Australia, or Turkey. The selection was made based on the data availability in the Refinitiv database in 2021, as currently there are small numbers of firms reporting transparent and clear information related to circular economy, in general, and RE, in particular. The analysis is made on a total number of 1,565 observations. The period analysed covers nine years, respectively, 2011-2019. The period includes the post-implementation period of the Non-Financial Reporting Directive (Directive 2014/95/EU) leading to increasing firm awareness of the need to transition their business models to a higher orientation towards the circular economy.

Data concerning country institutional framework assessment for RE implementation are extracted from RISE (Regulatory Indicators for Sustainable Energy) database. This indicator designed for RE framework assessment integrate multiple dimensions of implementation of RE initiative, becoming an essential measure of the incentives and non-compliance costs established on a country level.

### 2.3 Variable definition

The dependent variable in the study is RE, respectively, the size of renewable energy consumption, deflated by the revenues generated by each company on an annual basis. The analysis considers an accumulation of independent variables which describe on the one hand the size of the corporate framework for renewable energy consumption and the size of the macroeconomic institutional framework that promotes and monitors RE consumption. The first dimension analysed considers:

- The corporate dimension of *renewable energy consumption modelling*: (i) energy efficiency policy (*PEE*), as measured by a corporate policy evaluation score designed to address the need for RE consumption; (ii) ESG innovation, measured by a score that reflects the company's ability to reduce costs and environmental burden (*INN*); (iii) the degree of commitment and efficiency of the company to reduce environmental emissions during production and operational (*EM*) processes;
- The corporate dimension of *adopting a sustainable development business model*: (i) the degree of implementation of a sustainable development business model, measured by a score that incorporates both the assessment of the economic dimension, as well as the social and environmental dimension of operational processes (*ESG*); (ii) the need for a clear strategy toward the allocation of sufficient financial resources for activities that integrate economic, social, and environmental issues into its operational decision-making processes (*CSR*); (iii) the degree of implementation of sound corporate governance principles (*GOV*); (iv) the position and degree of involvement of the company's management, measured by a score of management effectiveness in the implementation of the company's strategy, following the principles of corporate governance;
- The *institutional macroeconomic factor size (RISE)*, described by a complex score calculated at the level of each country annually, targeting seven dimensions related to the evaluation of the country's RE framework, regulation, energy planning, supply chain optimization, incentives for RE, energy risk management, carbon pricing, and monitoring.

### 2.4. Time-series analysis

*Panel stationarity testing.* The test for stationarity of time series is performed by running a set of panel unit root tests, respectively: Levin-Lin-Chu t test, Im-Pesaran-Shin test, ADF - Fisher Chi-square test and PP - Fisher Chi-square test. All the methods have a similar principle behind, representing extensions of the traditional augmented Dickey-Fuller (ADF) unit root test for univariate time series modelling, which was restricted to the assumption of individual cross-sectional independency. For example, in the case of the Levin-Lin-Chu test (2003) the assumption is tested that all countries in the panel share the same autoregressive coefficient  $\alpha_i = \rho - 1$ , the estimation model being:

$$\Delta CFP_{i,t} = \alpha \cdot CFP_{i,t-1} + \sum_{j=1}^{p_i} \beta_{ij} \cdot \Delta CFP_{i,t-j} + X'_{i,t} \cdot \delta + \mu_i + \theta_t + e_{i,t} \quad (1)$$

Where:

$\Delta$  – is the first difference operator of the two measures of corporate financial performance;

(CFP) –  $i=1, \dots, N$  indicate each firm analysed;

$t=1, \dots, T$  – indicates the period;

$p_i$  – is the number of lags;

$\mu_i$  – is the unit-specific fixed effect;

$\theta_t$  – denotes the time-fixed effect;

$e_{i,t}$  – is the error terms that follow a stationary invertible autoregressive moving average process for each unit in the panel but is independently distributed across the panels.

If  $\rho < 1$ , the test confirms that the time series is stationary. Otherwise, the null hypothesis  $\rho = 1$  is accepted, showing that each panel has a unit root.

*Panel cointegration testing.* Compared to panel stationarity tests that look for the unit root in a single time series, cointegration reviews the relationship among a group of variables, each having a unit root (Gujarati, 2011). For this purpose, we run the Pedroni panel cointegration battery of tests. The co-integration test starts from the econometric equation:

$$ER_{i,t} = \alpha + \sum_{k=1}^3 \beta_{k,i,j} \cdot VI_{k,i,t} + \mu_i + \theta_t + e_{i,t} \quad (2)$$

where, by VI we express the dependent variables considered in the analysis, previously defined, respectively, the policy energy efficiency (PEE), the environmental technological innovation (INN), and, respectively, the latent variable that describes the management construct, variables that follow a stochastic process  $CSP_{k,i,t} = CSP_{k,i,t-1} + u_{it}$ .

The cointegration testing resumes with testing for the stationarity of the error term ( $e_{i,t}$ ), which is translated into the parametric equation described by  $\hat{e}_{i,t} = \rho \cdot \hat{e}_{i,t-1} + \sum_{j=1}^{p_i} \phi_{ij} \cdot \Delta \hat{e}_{i,t-j} + \varepsilon_{i,t}$ .

If the error term is not stationary, a higher level of cointegration between the analyzed group of endogenous variables requires an unrestricted econometric model, such as FMOLS or DMOLS regressions (Pesaran, 2015).

## 2.5. Econometric model design

Once the test of cointegration confirms the long-term relation between RE consumption ratio, management factor, and policy energy efficiency, we continue our analysis with the estimation of the long-run cointegration coefficients using the panel fully modified ordinary least squares (FMOLS) and the panel dynamic ordinary least squares (DOLS) methods.

The panel FMOLS model is described by the relation:

$$RE_{i,t} = \alpha_i + \delta_{it} \cdot t + \beta \cdot x_{i,t} + \mu_{i,t}, \quad (3)$$

where:

$\delta_i$  – it is the coefficient related to year fixed-effects;

$RE_{i,t}$  – is the renewable energy ratio variable;

$\beta$  – is the vector of econometric parameters per year;



$\alpha_i$  – are intercepts;

$\mu_{i,t}$  – are the stationary disturbance terms;

$x_{i,t}$  – is a vector of independent variables, which follows an autoregressive AR(1) process,  $x_{i,t} = x_{i,t-1} + \varepsilon_{i,t}$ , as it describes an I(1) integration order.

The panel DMOLS model is described by the relation:

$$RE_{i,t} = \alpha_i + \beta_1 \cdot x_{i,t} + \Gamma_j = -\rho_{it} \cdot \Delta x_{i,t-j} + \varepsilon_{i,t}, \quad (4)$$

equation which is estimated for each cross section of the panel, the cointegration coefficient for the overall panel being calculated as the average of the DOLS coefficients for each section. This model is estimated considering only the variables of I(1) order of integration, respectively, the RE, the policy energy efficiency, and the ESG innovation. In this way, we overcome the problem of endogeneity, whereas using DMOLS we control for effects on nonstationary data as well. Therefore, the problem of I(1) order is partially covered (Pesaran, 2015).

For robustness analysis, we proceed to the integration of the country measure that assesses the national regulatory, institutional, and economic framework influencing the RE consumption pattern compared to the traditional energy consumption. Therefore, we estimate the above-described econometric model with both with FMOLS and the GMM method. GMM models are recommended in the case of short period samples and a higher number of cross sections (Green, 2020). In the case of FMOLS method, we consider no lag on the model, while for the GMM models, we find two lags in case of the RE variable, based on VAR lag order selection Schwartz criteria that is statistically significant at 5% significance level. Also, we take as instrument variables the I(1) order of integration ones with a lag of one period, respectively, the management factor and the policy energy efficiency variables, to control for any period effects.

### 3. Results and discussion

#### 3.1 Descriptive statistics

As stated above, we focus our analysis on underlining the causal relationship between RE consumption of firms and the latent variable that reflects a measure of management capabilities, including policies in the ESG area, management commitment to the strategy and vision of firms, along with effectiveness of management processes (Table no. 1).

**Table no. 1. Descriptive statistics firm-level variables**

	Mean	St. dev.	1 <sup>st</sup> Q	2 <sup>nd</sup> Q	3 <sup>rd</sup> Q	Tolerance	VIF
ER	140.3	421.0	1.000	1.000	63.68	Dependent variable	
PEE	67.08	5.20	63.21	66.27	71.32	0.788	1.270
INN	48.09	33.55	18.18	57.14	77.69	0.801	1.248
EM	71.54	22.60	57.96	76.44	90.76	0.935	1.070
RISE renewable	65.78	15.65	53.50	64.00	79.00	0.984	1.016
ESG	60.47	15.21	49.39	61.11	72.14	Data reduction performed with PCA	
CSR	68.12	24.86	51.75	74.70	88.23		
GOV	62.00	21.36	45.76	64.71	79.90		
MS	61.55	27.42	40.32	65.43	86.14		

In Table no. 1 we provide descriptive statistics at the company level for the variables included in the study. Overall, our sample seems to be heterogeneous in terms of RE usage to reported

revenue. The mean of 140.3 for RE deflated by revenue, compared with the standard deviation of 421, leads to a high coefficient of variation. These results suggest that the energy consumption model of firms differs significantly based on the business model, the economic context, and the internal framework set up to promote or not energy use, especially RE. Instead, we see that the emission score variable shows lower heterogeneity compared to energy use at the firm level, with a mean of 48.11 million tones for revenues. This could be interpreted as a sign of common efforts firms make to converge to an energy usage model by adopting more recent disruptive technologies aimed at leading to consumption reduction, such as the IoT or other blockchain-based technologies, or through a better supply chain planning that can improve energy efficiency, increase the share of RE and reduce the negative impact of the energy use (Knopf et al., 2013; Xie et al., 2020).

We also observe a similar homogeneity within the companies included in the sample when looking for the assessment score of their policies targeting energy efficiency with a standard deviation (5.20) of only 7.8% of the mean (67.08). This homogeneity better describes a common pattern followed by companies that shows that management considers the formal internal framework relevant. The policies drafted, approved, and implemented are a starting point in redesigning operational processes and strategic thinking.

Related to our variables that describe different dimensions of the leadership of firms in a green economy, our sample mainly contains firms with a higher level of CSR strategy score, management commitment score, or ESG score (60.47), compared to the 0-100 allowed interval. The means of all these variables are higher than the level of 50, with the 1st percentile being closer to this interval mean as well, which means that our sample consists of firms that make significant efforts towards a transition to a green economy. This statement is confirmed once again when looking at the mean value of the PE variable, reflecting the score related to firms' energy efficiency policies, for which the first percentile is even higher than the other variables. However, a slightly wider spread of scores is observed in the case of variables that rate corporate governance mechanisms of firms, with the 1st quartile of 40.32 for the management commitment variable (MNG) and 45.76 for the corporate governance variable (GOV). These results show that there is a visible preoccupation for activities related to ESG, however, not adequately supported by the institutional framework of the companies.

### **3.2 Design of management factor construct**

The management factor construct is designed to incorporate information on the firm's ESG score, governance score, CSR strategy score and management score. Running the principal component analysis, we obtain a single dimension that includes all four previously mentioned. This dimension explains more than 64.2% of the variation in the sample, regarding the four dimensions that reflect the institutional framework of the firms.

Based on factor loading analysis, we observe a higher loading identified in case of the GOV score (0.931), followed by the MS score (0.878), ESG score (0.733), and CSR score (0.631). The results confirm that there appears to be a uniform response from the company side to the regional authorities' call to embrace a more sustainable oriented business model, regarding the design and implementation of a dedicated strategy for this specific purpose. However, it seems that the firm's response differs in terms of institutional capabilities, from the perspective of the effectiveness of existing processes that could serve as an essential path to the transition to more sustainable and circular economy-based business models.

### 3.3 Stationarity and cointegration analysis

The results of the stationarity analysis show mixed results, mainly driven by the small period considered in the analysis of only 10 years. All variables are confirmed to be I(1) first order of integration, which allows us to assess the relationship between RE and the other variables included in the analysis on a long-term perspective. In these circumstances, we further use the first difference in the econometric models of FMOLS and DMOLS. As we proceed to the modified OLS econometric estimation methods that consider the dynamic character of the data, we overcome the problem of endogeneity, whereas using DMOLS we control for effects on non-stationary data as well, and the problem of I(1) order is partially covered (Pesaran, 2015).

As noted by Baltagi (2021), the small period considered in the analysis reduces the power of the test. Instead, based on the classical Fischer-type tests (ADF and PP tests) and the cross-sectional ADF based aggregate test (Im, Pesaran and Shin W test), the results indicate that we can use the initial values in case of variables RE and management factor, without any differentiation, as the period covered in the analysis is relatively short in terms of time series analysis. Instead, in case of the policy energy efficiency and ESG innovation variables, only one test statistically significant, whereas at the first difference testing both ADF and IPS tests become statistically significant.

As our variables are of I(1) order of integration, we further test the existence of a cointegration relation between them, which would indicate that there is a long-run relationship to be analysed. The results suggest that there is a cointegration between the variables considered in the analysis, as in the case of at least 4 out of 11 tests we could have rejected the hypothesis that there is no cointegration relationship between RE, management factor, policy energy efficiency, and ESG innovation, considering a significance level of no more than 0.05 (Neagu, Haiduc, and Anghelina, 2021). Additionally, by performing the Kao residual cointegration test, we get a statistically significant test for panel cointegration ( $t\text{-Stat.} = -2.51, \text{Sig.} < 0.01$ ). Therefore, our analysis focuses on reviewing the dynamics on the RE consumption rate determined by the firm's management decision and institutional framework, in the long term. These results are expected, as investment in RE projects involves stakes consisting of investments with positive return forecasted on a long-time horizon.

### 3.4 Firm governance framework relevance

In Table no. 2, we summarize the statistics for estimated econometric models considering time-series panel data. In general, we observe that our models are all statistically relevant as the  $R_{\text{(adj.)}}^2$  explains at least 64.4% from the RE consumption in total revenue, based on the management and governance measures of the firms. These results show that during the analysed period, both management decision and supporting governance mechanisms became significant drivers for the transition to a more circular economy-based oriented business model.

In the case of all estimated models, the evolution in RE consumption in total revenue used in total energy consumption is statistically significant by the management score. The higher the management score, the higher the consumption of RE in total revenue, as policies, strategies, management commitment, and governance mechanisms will prove to be effective in supporting firms' efforts to transform their business model into a green and circular economy. Furthermore, the higher the knowledge management capabilities of the firms and the more flexible the set of firm policies to adjust in time to changes in the economic and energy system, the more successful the transition of the firms to leading use of RE (Rafiq et al., 2021).

Table no. 2. Modified OLS method estimates

Models	FMOLS method				DMOLS method			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PEE	-4.368		-3.564	-3.191	-0.659		-0.376	-1.207
	(3.39)		(3.38)	(3.99)	(3.68)		(4.11)	(3.25)
MS		57.10*	55.27*	36.01***		42.83**	64.67*	11.09
		(15.8)	(15.8)	(20.1)		(20.3)	(20.2)	(18.3)
INN		-	-	0.344		-	-	1.048
				(0.82)				(0.69)
<b>Model validation</b>								
Sample size	1388	1388	1388	1171	1356	1365	1374	1048
R <sup>2</sup> adjusted	0.670	0.672	0.672	0.754	0.689	0.644	0.673	0.776
* 1% significance level; ** 5% significance level; *** 10% significance level;								

The results suggest that the activities of companies in the sustainability area do not significantly impact the consumption of RE in total revenue from the perspective of the innovations acquired and implemented, since in both models in which the ESG innovation score was included, the coefficients are not statistically significant. A similar statement can be made when controlling for the impact of the policy of elaborating the strategy of companies in terms of energy efficiency. Among these issues, we recall the emerging directions highlighted by Zhang et al. (2021), which refer to the transition to biomass energy use and clean energy technologies that ensure improvements in energy efficiency, policy making in the transition to clean energy, promoting the use of 'clean energy' among households, or design and implementation of sufficiently liquid financial instruments that can provide financial resources for major RE projects. Therefore, we note that implementation of a policy addressing the need to achieve energy efficiency does not necessarily have positive financial results or a valid reason to increase the RE consumption ratio in the total energy use at a firm level.

### 3.5 Relevance of macroeconomic institutional framework

Further econometric analysis is aimed at understanding the role of the state in the configuration of the new energy environment, as efforts towards achievement of the SDGs must be properly coordinated on national, regional, and global levels (Table no. 3).

Table no. 3. Robustness analysis estimates

Models	FMOLS		GMM			
	Coef.	St. Dev.	Coef.	St. Dev.	Coef.	St. Dev.
Renewable energy (-1)	-		0.081	0.0	0.266*	-0.01
Renewable energy (-2)	-		-0.217	0	-0.152*	0
PEE	-		-		-6.311*	-0.78
MS	27.39*	-0.03	25.89*	-3.34	9.808***	-5.11
INN	-		-		1.734**	-0.58
EM	-		-		-0.531	-0.36
RISE renewable	2.219*	-0.01	4.720*	-0.29	3.187*	-0.37
<b>Model validation</b>						
Arellano-Bond m-Stat	-		1.839		1.637	
P			0.066		0.102	
R <sup>2</sup> adjusted	0.676		-		-	
* Significant for the 1% significance level; ** significant for the 5% significance level;						

In Table no. 3 we provide estimated models that control for governmental framework efficiency addressing the transition to RE. As the RISE score is only in  $I(0)$  integration order, we run only the FMOLS method for time-series panel data analysis. The results show a positive statistically significant impact on the ratio of RE consumption to total energy use at the firm level, regardless of whether we control the implemented emerging innovation technologies oriented toward sustainability or not. The significant character of the positive impact of the RISE variable included in the econometric model thus validates the H3 hypothesis. In conclusion, an efficient institutional framework has the effect of increasing the consumption of energy from renewable sources.

These results confirm once again what we underlined in the previous section and place the state in a key central position in the efforts to enforce the transition to more circular economy-oriented business models. Considering the survey-based data gathered by RISE, the score considered in the analysis shows the impact of governments capabilities to ensure proper legal framework for RE, to plan the expansion of RE sector inside the borders, to generate relevant incentives for transition to RE, to develop a robust integrated network of demand, usage and pricing and to reduce green gas emissions. All these directions could be transformed by governments into real instruments of macroeconomic competitive advantage, as long as they are correlated.

The effect of the management factor is confirmed to be statistically significant, with the highest margin determined on the ratio of RE consumption to total revenue. Even when controlling the results for the macroeconomic environment, the management factor maintains its positive marginal effect on the RE consumption in total revenue. Nevertheless, the GMM estimated models show that our results are consistent as well when looking for management factor variable regression coefficients. Therefore, orientation towards sustainability in designing a formal framework of the company (policies, strategies, monitoring, etc.), lead to an increase of the RE consumption in total revenue. Under these conditions, we can validate the research hypothesis H1, according to which the management factor plays an essential role in modelling the behaviour of corporate energy consumption from renewable sources.

Under the design of these econometric models, we observe that the policy energy efficiency score determines a statistically significant impact on the ratio of RE score (Coef.= -6.311, Sig.<0.01). This result suggests that managers still perceive the use of RE as a constraint to the firm's objectives to achieve energy efficiency. However, this result, compared to the results presented in Table no. 3 on the variable PEE, reveals a partial confirmation of hypothesis H2. This result can also be explained by management's perception of the role of the effectiveness of corporate policy in supporting renewable energy consumption, which is indirectly positively influenced by the existence of an institutional framework that either gives rise to substantial punitive noncompliance costs or outlines a number of benefits granted under the conditions of increased consumption of RE. The innovation factor included in our model becomes statistically significant as well (Coef.=1.734, Sig.<0.05), if we incorporate the RISE renewable score into our model. These results suggest that government support in the area of emerging sustainable technologies is fundamental and can generate long-term positive effects, promoting the transition to a circular economy and a higher proportion of RE used in total energy consumption of companies.

## **Conclusions**

Our results reveal that the management team is essential in the projection of future RE use scenarios. Therefore, governments must understand how relevant their participation is to this equation by promoting initiatives aimed at at least supporting a partial transition of energy consumption to renewable energy sources. The issue of an energy efficiency policy internally is not enough to reduce energy use and promote RE, as the degree of implementation of corporate direction is highly dependent on the effectiveness of the corporate governance mechanisms of the firms and the willingness of management to commit to this direction.

The state has a key role in the efforts made to transition to more circular economy-oriented business models by ensuring the proper legal framework for RE, to plan the expansion of RE sector inside the borders, to generate relevant incentives for transition to RE, to develop a robust integrated network of demand, usage, and pricing, and to implement effective enforcement mechanisms to reduce green gas emissions. An efficient institutional framework determines an amplifying effect of the consumption of energy from renewable sources, and this result confirms the results of other studies such as the ones conducted by Hassan (2019), by Simionescu, Strielkowski and Tvaronavičienė (2020), by Włodarczyk et al. (2021) or by Chen and Ma (2021).

On the other hand, companies must get involved in promoting RE consumption by drawing up internal policies regarding the consumption of RE, through which top management transfers their position to the operational level; implementing corporate governance mechanisms to stimulate the management to encourage RE consumption; implementing internal controls to verify the optimization of energy consumption and transition to RE and setting coherent and pragmatic strategies to influence the operational decision and review current processes.

Best practices in the area of RE implementation and common understanding on energy policies of firms that promote the use of RE would be supported and spread locally, regionally, and even globally. All these directions could be transformed by governments into real instruments of macroeconomic competitive advantage, as long as they are designed and implemented in a strong correlation.

Our results are subject to several limitations, which could be transformed for the next period into further research projects. First, we underline that the lack of information provided related to non-financial information concerning efforts made for sustainable economic growth. This situation persists even in the EU region, where members had to implement the so-called Non-Financial Reporting Directive (Directive 2014/95/EU), as mandatory information disclosed does not follow a consistent framework of reporting, leading to proliferation of corporate disclosures, which do not all the time disclose material information. Therefore, our sample is relatively limited to a small number of firms analysed. Second, to better understand any pattern of energy consumption, we will have to extend our analysis for a longer period, which is an opportunity for the next period, when the effects of the different pillars of the European Green Deal will also be reflected on firms' financial and non-financial performance. Third, our analysis related to the management factor is limited to the use of a construct that starts from a set of Refinitiv calculated scores, which do not reflect the best managers' own perceptions about how they see the transition to the green economy.

Under these circumstances, we plan for the future a distinct approach of the topic addressed in the study, by launching a survey to be disseminated by managers, at least in the Romanian

area, that better describes their subjective opinion on the opportunity and the need of transition to green economy and increase of use of RE.

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