

# ANALYZING SHORT-RUN AND LONG-RUN CAUSAL RELATIONSHIPS BETWEEN ENERGY CONSUMPTION, CO<sub>2</sub> EMISSIONS, AND BUSINESS PERFORMANCE IN THE HOSPITALITY INDUSTRY

Stojanović Vojislav<sup>1</sup>

Radivojević Nikola<sup>2</sup>

Owen Abdallah M.<sup>3</sup>

Jahić Adnan<sup>4</sup>

Dorđević Darko<sup>5</sup>

**Abstract:** *This paper explores the long-term and short-term relationships between hotel business performance, energy consumption, and CO<sub>2</sub> emissions by applying the Vector Error Correction Model (VECM), the VEC Granger causality test, and the block exogeneity Wald test. The study is based on a sample of 121 hotels over the period from 2015 to 2024. The results reveal a strong and statistically significant long-run relationship among the examined variables. The findings suggest that when deviations from long-run equilibrium occur—such as when hotel performance diverges from a sustainable level due to excessive*

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<sup>1</sup> Academy of Technical and Educational Vocational Studies, Niš, svojislav211@gmail.com

<sup>2</sup> Academy of Applied Studies Šumadija, Kragujevac, radivojevic034@gmail.com

<sup>3</sup> Faculty of Economics and Engineering Management, University Business Academy, Novi Sad, abdowen84@gmail.com

<sup>4</sup> Faculty of Economics and Engineering Management in Novi Sad, University Business Academy in Novi Sad, Cvečarska 2, Novi Sad, Serbia, adnanjahic@10021989mail.com

<sup>5</sup> Q&A Consulting, Gornji Milanovac, darko.t.djordjevic@gmail.com

*energy consumption or increased CO<sub>2</sub> emissions—the system tends to self-correct over time. This adjustment mechanism implies that unsustainable practices eventually lead to operational setbacks, pushing performance back toward its long-term path. The results also indicate a unidirectional short-run causal relationship between hotel business performance and energy consumption, as well as a bidirectional causality between business performance and CO<sub>2</sub> emissions.*

**Keywords:** *short-run and long-run causality, energy consumption, CO<sub>2</sub> emissions, business performance, hospitality industry.*

## INTRODUCTION

The significant evolution of population and industrial development since the Industrial Revolution has led to an unprecedented increase in global energy demand. This demand, in turn, has intensified the necessity for energy self-sufficiency within nations. In Serbia, a country undergoing economic challenges, addressing basic energy needs has become particularly critical. The national focus on implementing energy-efficient practices and advancing renewable energy solutions reflects the urgency of this issue.

In the context of the hospitality industry, energy consumption and CO<sub>2</sub> emissions are essential metrics that illustrate both operational efficiency and environmental impact (AlDarraji & Bakir, 2020; Zhang et al., 2021; Xie et al., 2020). As hotels are significant consumers of energy, understanding the short-term and long-term interrelations between business performance and energy usage is vital for fostering sustainability. Numerous authors have explored the influence of microeconomic factors on the success of hotel businesses, particularly in relation to energy consumption and CO<sub>2</sub> emissions. However, the literature shows a lack of consensus regarding the nature and extent of these factors' impact on hotel performance (Bresciani et al., 2015; Menicucci, 2018).

The current study aims to examine the dynamics of these relationships specifically within the hotel sector in Serbia. By investigating how hotel success correlates with energy consumption and CO<sub>2</sub> emissions, this research seeks to provide valuable insights into energy management practices that could promote both business performance and environmental protection. Previous studies have established various

linkages between business performance, energy consumption, and CO<sub>2</sub> emissions across different regions. For instance, trends in renewable energy consumption have shown a positive correlation with business performance, while reliance on non-renewable energy sources has often resulted in increased emissions and economic instability. However, the specific context of Serbia's hotel industry remains underexplored. By utilizing the modified Cobb-Douglas production function and employing data from relevant hotel metrics (Ifa & Guetat, 2022), this paper will analyze how financial development impacts energy consumption and CO<sub>2</sub> emissions, allowing for a comprehensive understanding of the contributing factors to hotel performance.

The objective of this study is to determine the linkages between business performance of hotels, renewable energy consumption, non-renewable energy, and CO<sub>2</sub>. To the best of our knowledge, there has never been an effort to examine in the Republic of Serbia. The Granger causality test was used to examine short-term causality, while the VAR model was used to examine long-term causality.

## METHODOLOGY

This research involved a sample of 121 hotels operating in Republic of Serbia. These hotels have capacities ranging from 15 to 300 accommodation units and are rated between 2 and 5 stars. The appropriate sample size was determined based on the total population, a 95% confidence level, and a permissible sampling error of 5%, which is a common standard in tourism research (Pimić et al., 2023; 2024). The study covered a period from 2015 to 2025. Data were obtained from the Amadeus database and local chambers of commerce, ensuring that the observation period was adequate to identify the differences within the hotels studied. Other words, the observation period is long enough to capture all heterogeneities.

For the purposes of this paper, the success of hotel operations is measured using the coefficient of technical efficiency. This indicator was chosen because it considers the efficiency of using all inputs and outputs as a measure of hotel performance. Mathematically, it can be represented as follows:

$$\hat{\delta}_i = \max_{\hat{\delta}_i, \lambda} \{ \delta > 0 \mid \hat{\delta}_i, y_i \leq \sum_{i=1}^n y_i \lambda; x_i \geq \sum_{i=1}^n x_i \lambda; \sum_{i=1}^n \lambda = 1; \lambda \geq 0 \} \quad (1)$$

where  $\hat{\delta}_i$  is the indicator of technical efficiency for the  $i$ -th hotel,  $y_i$  is the output vector of the  $i$ -th hotel,  $x_i$  is the input vector of the  $i$ -th hotel, and  $\lambda$  is an  $n \times 1$  vector of model constants.

The model's parameter estimation was performed using a data envelopment analysis (DEA) method. Specifically, this study employed the DEA double bootstrapping technique proposed by Simar and Wilson (2007). This method entails using bootstrap estimators from the regression phase to calculate the standard errors of the estimates. By addressing bias in the parameter estimates, this procedure produces more reliable estimates during the second stage of the regression analysis. In summary, the algorithm consists of the following steps (Makuljević & Knežević, 2023):

1. After the efficiency scores are obtained using Equation (1), the maximum likelihood method use employed to estimate the truncated regression of  $\hat{\delta}_i$  on  $z_i$ , resulting in the estimation of  $\hat{\beta}$  and  $\hat{\sigma}_\varepsilon$ ;
2. For each hotel  $i = 1, \dots, n$ , repeat the next four steps (a–d) a number of times to yield a set of bootstrap estimates  $\{\hat{\delta}_{i,b}^*, b = 1, \dots, B\}$ :

Derive  $\varepsilon_i$  from the  $N(0, \hat{\sigma}_\varepsilon^2)$  distribution with left truncation at  $(1 - \hat{\beta}z_i)$ ;

- a. Derive  $\varepsilon_i$  from the  $N(0, \hat{\sigma}_\varepsilon^2)$  distribution with left truncation at  $(1 - \hat{\beta}z_i)$ ;
  - b. Compute  $\hat{\delta}_i^* = \hat{\beta}z_i + \varepsilon_i$
  - c. Construct a pseudo data set  $(x^*, y^*)$ , where  $x_i^* = x_i$  and  $y_i^* = y_i \hat{d}_i^*$ ;
  - d. Compute a new DEA estimate  $d^*$  on the set of  $\wedge$  pseudo data  $(x_i^*, y_i^*)$ .
3. For each hotel, compute the bias-corrected estimate  $\hat{d}_i = \hat{d}_i - (\frac{1}{B} \sum_{b=1}^B \hat{\delta}_{i,b}^* - \hat{\delta}_i)$ ;
  4. Use the maximum likelihood method to estimate the truncated regression  $\hat{\delta}_i$  on  $z_i$ , providing estimates  $(\hat{\beta}, \hat{\sigma})$  of  $(\beta, \sigma_\varepsilon)$ ;
  5. Repeat the next three steps (a–c) a number of times to obtain a set of bootstrap estimates  $\{(\hat{\beta}_b^*, \hat{\sigma}_b^*, 1, \dots, B_2)\}$ :
    - a. For  $i = 1, \dots, n$ ,  $\varepsilon_i$  is drawn from  $N(0, \hat{\sigma})$ , with left truncation at  $(1 - \hat{\beta}z_i)$ ;
    - b. For  $i = 1, \dots, n$ , compute  $\delta_i^{**} = \hat{\beta}z_i + \varepsilon_i$ ;
    - c. The maximum likelihood method is again used  $\wedge$  to  $\wedge$  estimate the truncated regression of  $\delta_i^{**}$  on  $z_i$  providing estimates  $(\hat{\beta}^*, \hat{\sigma}^*)$ .

6. Utilize the bootstrap outcomes to construct confidence intervals.

Given that energy consumption arises from various hotel activities and is affected by the volume of services provided, the efficiency of human capital, the hotel's financial strength, and technical capabilities, energy consumption can be assessed using the modified Cobb-Douglas production function (Y) (Ben-Salha et al., 2018):

$$EC = v(F(Y_t)) \quad (2)$$

In this equation,  $v$  denotes the rate at which energy consumption occurs for hotel activities,  $Y$  represents the modified Cobb–Douglas production function, and  $Y_t = F(K_t, A_t L_t)$ , where the technology factor is endogenously defined by financial development (FD) and is expressed in Equation (3) as follows:

$$A_t = \sigma FD_t^{\beta_3} \quad (3),$$

where presents constant of time stable and

- $Y_t$  - rate of change in the total volume of services in period  $t$  is calculated as the difference between the hotel's income in period  $t$  and  $t-1$ .
- $EC_t$  - rate of change energy consumption
- $A_t$  - effective technology
- $K_t$  - effective capital
- $L_t$  - effective labor
- $FD_t$  - financial development, expressed as the relationship between account balance and total assets.
- $\beta_i$  - elasticity coefficient
- $\sigma$  - parameter

The inclusion of financial development (FD) allows for an assessment of the hotel's financial strength, which facilitates the implementation of innovations and measures aimed at enhancing energy efficiency. Since not all hotel capital is associated with energy consumption, energy consumption can be expressed as follows:

$$EC = \emptyset K_{EC}(Y) \quad (4)$$

Here,  $K_{EC}$  refers to the capital that utilizes energy sources (including electricity, heat from non-renewable sources, fuel, and water). For the purposes of this study, energy efficiency is defined as the rate of change in energy consumption between periods  $t$  and  $t-1$ , noting that the conversion is performed in kW/h based on the conversion coefficients provided by Ašonja and Vuković (2018).

Similarly, since CO<sub>2</sub> emissions result from all hotel activities, they can be calculated using the same principle as energy consumption:

$$CO_2 = \Delta K_{CO_2}(Y) \quad (5)$$

In this equation,  $K_{CO_2}$  represents capital that emits CO<sub>2</sub> and the rate of change in CO<sub>2</sub> emissions between periods  $t$  and  $t-1$  is utilized for the purposes of this paper.

For the examination of short-term causality between energy consumption and hotel business success, as well as between CO<sub>2</sub> emissions and hotel performance, we should utilize the Granger causality test, provided that the series are stationary. It is crucial that the underlying time series data are stationary before conducting the Granger test, as non-stationary data can lead to misleading results. The mathematical models can be expressed as follows:

$$\hat{\delta}_t = \alpha + \sum_{i=1}^m \beta_i (\hat{\delta})_{t-i} + \sum_{j=1}^n \tau_j (EC)_{t-j} + \mu_t \quad (6)$$

and

$$EC_t = \theta + \sum_{i=1}^p \phi_i (EC)_{t-i} + \sum_{j=1}^q \psi_j (\hat{\delta})_{t-j} + \eta_t \quad (7)$$

$$\hat{\delta}_t = \alpha + \sum_{i=1}^m \beta_i (\hat{\delta})_{t-i} + \sum_{j=1}^n \tau_j (CO_2)_{t-j} + \mu_t \quad (8)$$

и

$$CO_{2,t} = \theta + \sum_{i=1}^p \phi_i (CO_2)_{t-i} + \sum_{j=1}^q \psi_j (\hat{\delta})_{t-j} + \eta_t \quad (9)$$

Otherwise, VEC Granger Causality Test and Block Exogeneity Wald Test will be used. For the examination of long-term causality between energy consumption and hotel business success, as well as between CO<sub>2</sub> emissions and hotel performance, we should use the VAR model, if the series are stationary, that is, if there is no cointegration between them, otherwise we must use the VECM model. The mathematical model can be expressed as follows:

$$\Delta Y_t = v + \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-1} + \varepsilon_t \quad (10)$$

Where are

$\Delta Y_t$  – vector promene zavisnih varijabli u modelu

$\varepsilon_t$  – greška modela

## DATA ANALYSIS AND FINDINGS

As an initial step in assessing the causality is testing for the stationarity of the data series. For the purposes of this research, the Levin-Lin-Chu (LLC) test was used. The value of the Z test is -1.10 with a p value of 0.728, which indicates non-stationarity. Since the series are non-stationary, a cointegration test was performed. The Johansen cointegration test was used. When variables are cointegrated, the standard Granger causality test is incorrectly specified, and it is advisable to utilize the error correction approach proposed by Engle and Granger (1987). This study continues with Granger causality testing in the form of a Vector Error Correction Model (VECM), given that the variables have been identified as cointegrated. The VECM facilitates the modeling of both short-run and long-run dynamics of the variables involved. The error correction term within the VECM indicates the direction of long-run causality, while short-run causality among the variables is assessed using the VEC Granger causality test and the Block Exogeneity Wald test (Sahu & Pandey, 2020).

The first step is to determine the optimal number of lags for the Johansen cointegration test. This selection process involved four different criteria aimed at minimizing the model's value for a specified number of time lags at a 5% confidence level: Sequential Modified LR Test Statistics (LR), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn Information Criterion (HQ). The findings of these criteria selections are detailed in Table 1.

**Table 1.** Selection of Optimal Number of Lags

| Lag | LogL     | LR    | AIC     | SC      | HQ      |
|-----|----------|-------|---------|---------|---------|
| 1   | -1545.5  |       | 20.497  | 22.431  | 21.115  |
| 2   | -1489.3  | 0.000 | 19.386  | 22.091  | 20.041  |
| 3   | -1322.5* | 0.000 | 18.399* | 19.330* | 19.147* |

Source: Authors

According to the obtained values of the information criteria, 3-time lags were used in the analysis. The reason for the rank determination was performed using the Trace Statistic and Maximum Eigenvalue Statistic. The results obtained are displayed in Table 2.

**Table 2.** Johansen Rank Cointegration Test

|   | Characteristic values | Trace Statistic | p-value  | Lmax test | p-value  |
|---|-----------------------|-----------------|----------|-----------|----------|
| 0 | 0.27782               | 1034.5          | [0.0000] | 389.61    | [0.0000] |
| 1 | 0.23837               | 644.88          | [0.0000] | 325.94    | [0.0000] |
| 2 | 0.2339                | 318.94          | [0.0000] | 318.94    | [0.0000] |

Source: Authors

Based on the p-values presented in parentheses, it appears that all tested ranks are statistically significant. The presence of cointegration indicates the conclusion of a long-term relationship among the variables. Considering the previously presented findings, the VECM model was used. The results are presented in Table 3.

**Table 3.** VECM Model

|       | coefficient | std. error | t-ratio | p-value      |
|-------|-------------|------------|---------|--------------|
| const | 0.058       | 0.013      | 4.240   | 2.40e-05 *** |
| EC1   | -0.087      | 0.011      | -7.845  | 9.56e-15 *** |

Source: Authors

The coefficient of the error correction term at - 0.087 is statistically significant, suggesting that there is a robust and meaningful long-run relationship among hotel performance, energy consumption, and CO<sub>2</sub> emissions. In the context of a Vector Error Correction Model (VECM), this negative coefficient implies that if there is a deviation from the long-run equilibrium (for instance, if hotel performance drifts away from its expected or sustainable level due to excessive energy consumption or CO<sub>2</sub> emissions), the system is likely to adjust over time towards the long-term equilibrium. This adjustment process means that when hotel performance becomes unsustainable - possibly due to high energy consumption or high CO<sub>2</sub> emissions - the system has an inherent mechanism to correct itself, effectively bringing the performance back in line with its long-run trend. Thus, the existence of this trade-off indicates that hotels cannot excessively increase energy consumption or CO<sub>2</sub> emissions without eventually facing consequences that will negatively affect their operational success. In practical terms, this finding highlights the importance for hotel operators to implement energy-efficient practices and reduce emissions to maintain not only their environmental responsibilities but also their profitability and long-term viability in the market. Failure to address these elements may lead to a decline in overall performance, as the system actively works to recalibrate itself to align with sustainable operational practices. This underscores the significance of incorporating sustainability into business strategies to enhance both hotel performance and environmental stewardship.

The results of short-run causality test among the variables based on VEC Granger causality test are presented in Table 4. The result of the Granger causality test based on Wald test finds causal relationship among the variables in short run.

**Table 4.** Results of the VEC Granger Causality Test and Block Exogeneity Wald Test

| Direction of causality                    | p-value | Result                   |
|-------------------------------------------|---------|--------------------------|
| $d_{\hat{\delta}_t} \rightarrow d_{EC}$   | 0.145   | Unidirectional causality |
| $d_{EC} \rightarrow d_{\hat{\delta}_t}$   | 0.580   |                          |
| $d_{\hat{\delta}_t} \rightarrow d_{CO_2}$ | 0.026   | Bidirectional causality  |
| $d_{CO_2} \rightarrow d_{\hat{\delta}_t}$ | 0.009   |                          |
| $d_{CO_2} \rightarrow d_{EC}$             | 0.012   | Unidirectional causality |
| $d_{EC} \rightarrow d_{CO_2}$             | 0.237   |                          |

Source: Authors

In the analysis of the relationship between hotel business performance, CO<sub>2</sub> emissions, and energy consumption, it was found that there is a significant causal relationship between hotel performance and CO<sub>2</sub> emissions, where increased performance leads to higher levels of emissions. This phenomenon may result from operational practices that are not aligned with sustainable methods, where more successful hotels may be using more resources, leading to increased emissions. On the other hand, energy consumption is not significantly related to hotel performance, indicating that hotels may not be using energy efficiently or that their business models do not prioritize reducing consumption. CO<sub>2</sub> emissions significantly impact energy consumption, suggesting that higher levels of pollution often come with increased resource usage. These findings highlight the importance of sustainable practices in the hotel sector and the need for strategies that could reduce the environmental footprint while improving business outcomes.

## CONCLUSION

This research provides a critical examination of the short-term and long-term causal relationships among energy consumption, CO<sub>2</sub> emission and business performance within the hospitality sector. The findings indicate a significant long-run relationship characterized by a negative coefficient for the error correction term, suggesting that an increase in energy consumption has a detrimental effect on hotel performance. This implies that when hotels exceed sustainable levels of energy use or emit excessive CO<sub>2</sub>, they are likely to experience declines in their operational success. The

presence of this negative adjustment reinforces the importance of monitoring energy consumption and implementing practices aimed at reducing both energy use and emissions.

Short-run dynamics reveal a bidirectional causality between hotel performance and CO<sub>2</sub> emissions, indicating a reciprocal relationship where increases in hotel success may lead to heightened emissions. This dynamic is concerning, as it suggests that operational practices that prioritize growth without considering environmental implications can inadvertently exacerbate the ecological footprint of the hospitality sector. Such findings highlight the need for hotels to strategically align their business models with sustainable methods that reduce emissions while maintaining competitiveness.

In contrast, the results show that energy consumption does not have a significant causal relationship with hotel performance. This lack of connection suggests inefficiencies in energy usage within the sector, indicating that hotels may not fully realize the value of optimizing energy consumption to enhance their operational performance. The absence of a clear link calls for further investigation into how hotels can leverage energy management strategies, such as investing in renewable energy sources and adopting energy-efficient technologies, to boost productivity while diminishing environmental impact.

Furthermore, the significant impact of CO<sub>2</sub> emissions on energy consumption implies that as hotels increase their emissions, there is a corresponding increase in energy resource usage. This relationship poses a dilemma for hotel operators, who must balance profitability with accountability towards sustainable practices. The results urge the hospitality industry to not only improve their operational efficiency but also adopt innovative sustainability measures, such as eco-friendly building designs and renewable energy initiatives, to mitigate adverse environmental impacts and foster long-term viability.

Ultimately, this study contributes important insights for policymakers, hotel managers, and stakeholders within the hospitality sector in Serbia. It emphasizes the necessity of adopting comprehensive strategies that integrate sustainability into the business framework. By doing so, hotels can enhance their environmental stewardship while simultaneously securing economic success. These findings underscore the pressing need for collaborative efforts between the hospitality industry, government, and consumers to promote responsible energy usage and cultivate a sustainable future for the sector. Such partnerships could lead to the

development of policies that support sustainability initiatives, encourage investments in renewable energy, and provide incentives for hotels to adopt practices that benefit both their business and the environment.

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# ANALIZA KRATKOROČNIH I DUGOROČNIH UZROČNIH ODNOSA IZMEĐU POTROŠNJE ENERGIJE, EMISIJE CO<sub>2</sub> I POSLOVANJA U HOTELIJERSTVU

Vojislav Stojanović

Nikola Radivojević

Abdallah M. Owen

Adnan Jahić

Darko Đorđević

**Sažetak:** Ovaj rad istražuje dugoročne i kratkoročne veze između performansi hotela, potrošnje energije i emisije CO<sub>2</sub> koristeći model vektorske korekcije grešaka (VECM), kao i VEC Grangerov test uzročnosti, kao i blok egzogentiti Waldov test. Istraživanje je sprovedeno na osnovu uzorka od 121 hotela. Period istraživanja pokriva vremensko razdoblje od 2015. do 2024. godine. Rezultati analize su pokazali da postoji snažna i značajna dugoročna povezanost između pomenutih varijabli. Nalaz implicira da, ukoliko dođe do odstupanja od dugoročne ravnoteže – kao što je slučaj kada se performanse hotela udaljuju od održivog nivoa usled prekomerne potrošnje energije ili povećane emisije CO<sub>2</sub> – sistem će se tokom vremena prilagoditi. Ovaj proces prilagođavanja znači da, kada performanse postanu neodržive, postoji inherentni mehanizam za korekciju koji vraća učinak hotela u skladu sa dugoročnim trendovima. Ovaj nalaz ukazuje na to da hoteli ne mogu neograničeno povećavati potrošnju energije ili emisiju CO<sub>2</sub> bez suočavanja sa negativnim posledicama koje će uticati na njihov operativni uspeh. Nalazi takođe ukazuju da postoji jednosatna kratkoročna veza između performansi poslovanja hotela i potrošnja energije, odnosno dvostrana uzročnost između performansi poslovanja i emisije CO<sub>2</sub>.

**Ključne reči:** kratkoročna i dugoročna uzročnost, potrošnja energije, emisija CO<sub>2</sub>, performanse poslovanja, hotelijerstvo.