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*Original Article*

# Exploring Organizational Growth and Environmental Conservation in Universities in the UK, the US, and Canada

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***Abstract -*** *This study explores how universities in the UK, the US, and Canada can achieve organizational growth alongside environmental conservation through a cross-national analysis. Primary datasets on management performance and environmental impacts have been drawn from 91 universities in these three countries, selected from the top 150 institutions in the QS World University Rankings: Sustainability 2025. Annual data from 2019 to 2023 are analyzed separately, covering the COVID-19 period. Regression analyses grounded in the Environmental Kuznets Curve (EKC) hypothesis confirm a series of turning points in operating Revenue Per Area (Rev/Are), ranging from USD 3.252 Billion to 3.922 Billion/Km², At Which $Co_2$ Emissions, Energy Consumption, and water usage per kilometer ($CO_2$/ARE, ENR/ARE, and AQU/ARE) begin to decline. The results suggest that the EKC pattern in higher education is shaped by three interrelated dimensions: pressures and motivations to achieve higher rankings and evaluation scores assigned by external organizations; universities' positioning as both fund recipients and investors; and a growing emphasis on social engagement and contribution. Reaching these REV/ARE thresholds provides an empirical benchmark for verifying the EKC hypothesis and demonstrates a feasible trajectory through which universities can actively achieve organizational growth alongside environmental conservation, thereby advancing ongoing discussions in environmental economics and higher-education management.*

***Keywords -*** *Environmental Economics, University Governance and Management, Environmental Disclosure, University Rankings, and EKC Hypothesis.*

## 1. Introduction

Environmental accountability has emerged as a key dimension of university governance, reflecting the growing demand for transparency in resource management and environmental performance. The increasing emphasis on accountability in Environmental, Social, and Governance (ESG) performance has encouraged universities to integrate conservation-oriented initiatives into their strategic management.

However, the extent to which these initiatives align with organizational growth and environmental performance remains underexplored, particularly in cross-national comparisons. This study addresses this gap by empirically analyzing the nonlinear relationships between management indicators and environmental performance across leading universities in the UK, the US, and Canada, within the theoretical framework of the Environmental Kuznets Curve (EKC) hypothesis. The findings enable comparison across universities operating under different institutional conditions. Unlike conventional EKC studies that focus on national or regional levels, this study extends the EKC framework—including the inverted N-shaped specification—to the institutional dimension of higher education. A review of existing studies indicates that, although university performance has often been evaluated using metrics such as staffing and financial resources, no prior research has applied the EKC framework to environmental performance based on primary datasets. Consequently, this study offers a novel analytical perspective by applying the EKC framework at the institutional level using original cross-national data and by introducing operating Revenue Per Area (*REV/ARE*) as a benchmark to identify empirically attainable turning points. Regression analyses grounded in the EKC hypothesis confirm a series of turning points in *REV/ARE*, ranging from USD 3.252 billion to 3.922 billion/km², where $CO_2$ emissions, energy consumption, and water usage begin to decline. This study integrates three environmental impacts to capture a broader scope of environmental performance. Reaching the identified *REV/ARE* thresholds provides an empirical benchmark for verifying the EKC hypothesis and demonstrates a feasible trajectory through which universities can achieve organizational growth alongside environmental conservation in the UK, the US, and Canada. By adopting an ESG-informed, *REV/ARE*-centered analytical framework, the present analysis advances ongoing discussions in environmental economics and higher-education management, drawing on methodological insights developed in the author's earlier research. In accordance with the journal's editorial policy, these prior studies are not explicitly cited.

This study explores how universities in the UK, the US, and Canada can achieve organizational growth alongside environmental conservation through an independent cross-national analysis. Using primary datasets on management performance and environmental impacts from 91 universities in the UK, the US, and Canada, extracted from the top 150 institutions listed in the *QS World University Rankings: Sustainability 2025*, the research provides new evidence on how growth and conservation interact within higher education institutions. [1] Annual data from 2019 to 2023 are examined separately, reflecting conditions before, during, and after the COVID-19 pandemic.

## 2. Conceptual Framework, Research Gaps, and Unresolved Issues

### *2.1. Conceptual Framework*

This study first provides conceptual clarifications of key terms used in the analysis, including organizational growth, environmental conservation, $CO_2$ emissions, university governance and management, and the EKC hypothesis.

"Organizational Growth" refers to the expansion of key quantitative indicators—specifically, the number of students and faculty members, operating revenues, and campus areas. These indicators represent the essential dimensions of human and financial resources that underpin a university's institutional capacity.

"Environmental Conservation" in this study refers to actions aimed at preventing or mitigating environmental degradation resulting from human activity, with particular emphasis on reducing global warming and energy consumption, as well as preserving water and natural resources. It represents a shared responsibility among governments, local authorities, public and private organizations, and citizens, emphasizing precautionary management that aligns institutional operations with environmental responsibility and organizational growth.

$CO_2$ emissions in this study represent the sum of Scope 1 and Scope 2 emissions. Scope 1 covers direct greenhouse gas emissions from sources owned or controlled by the institution, while Scope 2 includes indirect emissions arising from the use of purchased electricity, heat, or steam. As some universities fail to provide complete disclosure of Scope 3 data—indirect emissions from external entities involved in institutional operations—these are excluded from the analysis. University governance refers to the institutional and regulatory frameworks that shape universities' responsibilities, accountability structures, and disclosure practices, while university management concerns the strategic and operational decisions through which universities achieve organizational growth alongside environmental conservation.

This study adopts the EKC hypothesis as a conceptual framework to examine the nonlinear relationship between organizational growth and environmental impacts at the university level. The EKC hypothesis, derived from the original theory of Nobel laureate Dr. Simon Kuznets on income inequality, was extended to environmental economics in the early 1990s through the pioneering work of Grossman and Krueger and the World Bank. [2,3] It postulates that environmental degradation rises with economic growth in the initial stage but declines beyond a certain income threshold, forming an inverted U-shaped pattern. Empirical validation of the EKC requires that the linear term ($\beta > 0$) and the squared term ($\beta < 0$) in the regression model reach statistical significance. In this study, the hypothesis is applied to university operations to examine whether organizational growth coexists with reductions in $CO_2$ emissions, energy consumption, and water usage.

Prior research on the EKC hypothesis addresses three principal issues: (1) The empirical validity of the inverted-U pattern, (2) The income level at which turning points occur, and (3) The mechanisms underlying the curve. Despite extensive confirmation of the hypothesis across sectors, estimates of turning points differ according to methodology and the pollutants under examination. For example, Grossman and Krueger estimated the turning point for Sulfur Dioxide ($SO_2$) at USD 4,053, whereas Selden et al. reported a turning point for $SO_2$ at USD 8,916 and for Nitrogen Oxide (NOx) at USD 11,217. [4,5] These studies indicate that the EKC does not stem from a single factor but from complex interactions among governments, firms, and citizens, a process that promotes environmental improvement in parallel with economic growth. Recent studies in the early 2020s have addressed performance related to growth and conservation in higher education; however, applications of the EKC framework at the institutional level remain limited.

Figure 1 illustrates three types of EKC non-linear relationships, with operating Revenue Per Campus Area (*REV/ARE*) as the common explanatory variable. The dependent variables are water usage per campus area (*AQU/ARE)* in 2020, and energy consumption per campus area.

(*ENR/ARE*) and $CO_2$ Emissions Per Campus Area (*$CO_2$ /ARE*) in 2021. (*REV/ARE*) is plotted on the x-axis, while each environmental indicator is plotted on the y-axis.

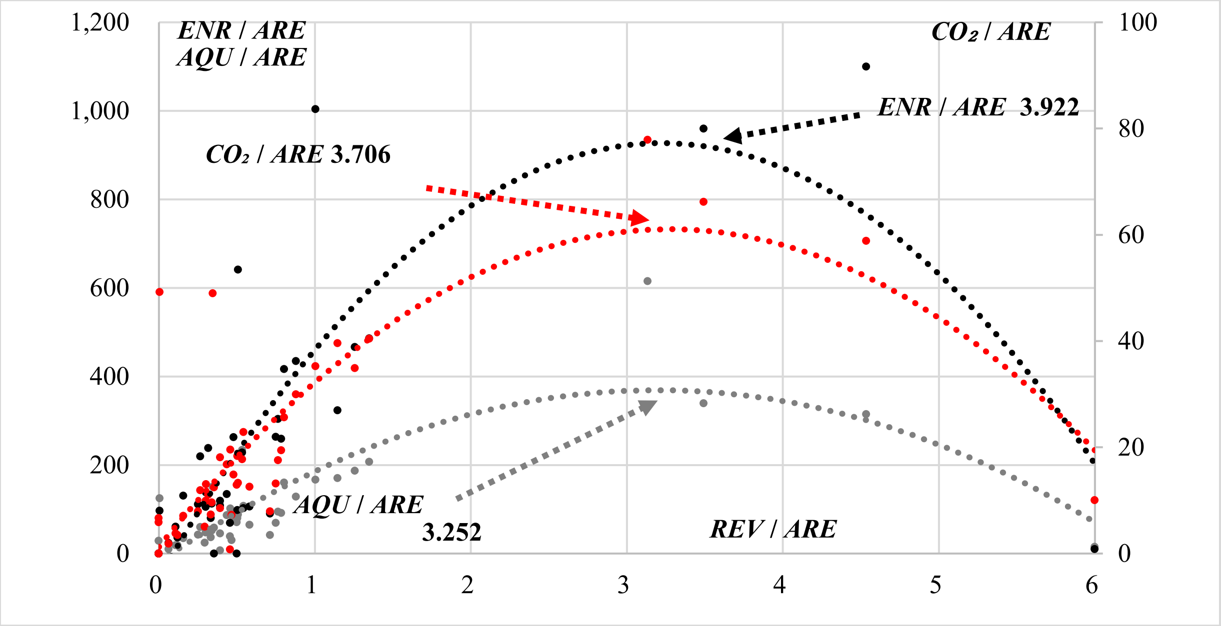

**Fig. 1** **Relationships between environmental indicators per campus area and operating revenue per campus area: (*AQU/ARE*)–(*REV/ARE*) in 2020, (*$CO_2$/ARE*)–(*REV/ARE*), and (*ENR/ARE*)–(*REV/ARE*) in 2021.**

The identified turning points, ranging from USD 3.252 billion to USD 3.922 billion per km², serve as empirical benchmarks for universities seeking to reduce environmental impacts while achieving growth within the EKC framework.

### *2.2. Research Gaps*

To the best of the author's knowledge, no prior study has examined the relationship between organizational growth and environmental conservation by applying the EKC hypothesis to a comprehensive dataset of American, British, and Canadian universities. One of the primary reasons for this research gap lies in the inherent difficulties associated with analyzing reliable environmental and management data across universities.

The disclosure of environmental performance data requires substantial commitments of time and institutional resources. It often entails third-party verification by external auditing organizations and may involve the publication of sensitive internal information. Furthermore, inadequate coordination among regulatory authorities, industry associations, professional bodies, financial institutions, and media outlets has resulted in inconsistent disclosure standards, perpetuating systemic information asymmetries. In many cases, universities release only simplified visual summaries—such as bar charts—without the numerical datasets necessary for rigorous empirical evaluation.

Although ESG-oriented research has expanded across a wide range of sectors—including government, corporate, and higher-education domains—it continues to suffer from methodological limitations that constrain analytical accuracy. A central issue lies in the predominant use of composite ESG metrics, such as alphabetic ratings (e.g., A+, AAA) or numeric scores (e.g., 90/100) published by rating agencies. These indicators often lack methodological transparency and fail to establish objective, reproducible reference standards.

A further obstacle to the effective use of raw ESG data lies in the extensive manual work required for data extraction, normalization, and verification. Financial statements appear in standardized digital formats such as Excel or CSV, whereas ESG-related information from universities appears within lengthy, unstructured reports rather than in machine-readable datasets.

The 91 universities analyzed in this study encompass approximately 2.8 million students and staff, cover 380 square kilometers, hold a combined annual budget of USD 36 billion, and account for 6 million tons of $CO_2$ emissions per year, based on the author's calculations. These institutions constitute leading and influential universities in the UK, the US, and Canada, and therefore form an appropriate subject for academic investigation.

### *2.3. Ongoing Issues*

This section examines concerns, limitations, and unresolved issues identified in prior studies on global environmental sustainability scores and ranking systems, including the QS Sustainability Rankings and the Times Higher Education (THE) Impact Rankings. [1, 6]

Elizabeth and Zhang conducted interviews at 28 universities across 16 countries and reported that participation in sustainability assessments and rankings is perceived to support institutional self-improvement and provide external recognition. [7] Simultaneously, they identified concerns regarding evaluation criteria that overlook financial, geographical, and socio-contextual constraints. Some criteria require substantial investment or fail to reflect regional conditions. For example, the item "Water-conscious planting (e.g., use of drought-tolerant plants)" does not account for climatic differences, disadvantaging universities in humid regions where such measures are unnecessary.

The study further shows that institutional diversity limits the applicability of standardized global indicators. While diversity constitutes a salient issue in the United States, universities in contexts such as Hong Kong do not regard it as a pressing challenge. Consequently, these institutions receive no credit under global ranking criteria, revealing a misalignment between global standards and regional conditions.

One illustrative contrast can be observed between universities with a strong regional mission and those with a highly internationalized student body. Institutions that prioritize educating local high-achieving students and contributing to regional development may enroll few international students and, as a result, receive low scores in the "International Outlook" category of the Times Higher Education (THE) Japan University Rankings. [8] By contrast, universities with a large proportion of international students may achieve favorable evaluations in this category, even when facing challenges in areas such as student–faculty ratios or educational resources. These contrasting cases indicate that, while university rankings have practical relevance for fundraising and the recruitment of students and staff, the direct use of ranking scores or ordinal positions as quantitative inputs in empirical analysis—without careful consideration of institutional mission and regional context—entails substantive limitations.

Simple comparisons based on environmental scores and rankings do not necessarily capture the diverse institutional and physical conditions faced by universities. Differences in campus structure, building age, and regulatory constraints may limit the extent to which environmental performance can be directly compared across institutions. From this perspective, score-based evaluations require careful interpretation, as they may overlook contextual factors that shape universities' capacity to improve environmental performance.

Dickson conducted interviews with sustainability administrators at 16 Canadian universities and found that sustainability priorities are driven by rating rather than ranking systems. [9] All interviewees identified the Sustainability Tracking, Assessment and Rating System (STARS), developed by the Association for the Advancement of Sustainability in Higher Education (AASHE), as a key influence on institutional planning. STARS served as a practical framework that guides incremental improvements in sustainability performance. [10] Dickson reported that internal drivers have greater influence than government drivers and that rating-based governance mechanisms offer greater utility than broad sustainability goals or composite rankings. Global university rankings have notable limitations, yet their utility remains a subject for consideration. Hence, this study treats university rankings as a contextual reference rather than as direct inputs for econometric analysis, and focuses on organizational growth and environmental conservation as a meaningful contribution to academic discourse.

## 3. Verification

### *3.1. Methods*

This study focuses on 91 universities in the UK, the US, and Canada, extracted from the top 150 institutions listed in the QS World University Rankings: Sustainability 2025. The sample consists of 36 universities from the UK, 36 from the US, and 19 from Canada. [1] The sample selection is based on the availability of consistent environmental and management data across institutions.

#### *3.1.1. Data Coverage and Methodology*

This study addresses existing gaps by conducting a cross-sectional EKC analysis of top-ranked universities listed in the QS World University Rankings 2025, using environmental data from the Higher Education Statistics Agency (HESA) in the UK and STARS in North America. The HESA and STARS datasets are employed for their consistency, accessibility, and suitability for cross-national comparison, despite limitations in data completeness. For UK institutions, the QS rankings rely on HESA data and apply filters to ensure consistency with their definitions of faculty and student numbers. [11] Data on management and financial performance are obtained from HESA for UK universities and from the official financial reports of individual universities for US and Canadian institutions. [12-51]

#### *3.1.2. Variables*

Table 1 outlines the dependent and explanatory variables used in this study.

The basic dependent variables comprise three core indicators: $CO_2$ Emissions ($CO_2$), Energy Consumption ($ENR$), and Water Usage ($AQU$).

The basic explanatory variables similarly include three core components: the number of students and academic and Administrative Staff ($PRS$), Operating Revenue ($REV$), and Campus Area ($ARE$).

To enhance analytical precision and ensure comparability, additional dependent and explanatory variables, referred to as advanced variables, are constructed by normalizing these core indicators. Basic variables represent raw values of environmental impact and institutional capacity, whereas advanced variables are derived through proportional transformations using alternative denominators, thereby enabling more nuanced cross-institutional comparisons.

Dependent variables are normalized by placing explanatory variables in the denominator, for example, $CO_2/PRS$, $CO_2/REV$, $CO_2/ARE$, *ENR/PRS*, *ENR/REV*, *ENR/ARE*, *AQU/PRS*, *AQU/REV*, and *AQU/ARE*.

Explanatory variables are normalized by substituting one variable for another, such as *PRS/REV*, *PRS/ARE*, *REV/PRS*, *REV/ARE*, *ARE/PRS*, and *ARE/REV*, capturing relative institutional scale and resource allocation.

### 3.2. Regression Model Specifications

This study estimates 405 regression equations, categorized into two types: 135 in the basic and 270 in the advanced regression models (Table 1).

**Table 1. Combinations of dependent and explanatory variables (abbreviations).**

<table>
<tr><th colspan="2">Basic variables</th></tr>
<tr><td>Dependent variables: 3</td><td>Explanatory variables: 3</td></tr>
<tr><td>(1) $CO_2$ emissions<br>($CO_2$, tons)<br>(2) Energy consumption (<i>ENR,</i> GJ)<br>(3) Water usage<br>(<i>AQU,</i> thousand m³)</td><td>(1) Number of students and academic/administrative staff (<i>PRS,</i> persons)<br>(2) Operating revenue (<i>REV,</i> Million USD)<br>(3) Campus area<br>(<i>ARE</i>, $km^2$)</td></tr>
<tr><td colspan="2">Total 135 regressions;<br>Dependent variables × Explanatory variables<br>× Model specifications (Linear, Quadratic, Cubic)<br>× Yearly observations (5 years)<br>= 3 × 3 × 3 × 5 = 135</td></tr>
<tr><td colspan="2">Advanced variables</td></tr>
<tr><td>Dependent variables: 9</td><td>Explanatory variables: 3</td></tr>
<tr><td>(4) $CO_2/PRS$<br>$CO_2/REV$<br>$CO_2/ARE$<br>(5) <i>ENR/PRS</i><br><i>ENR/REV</i><br><i>ENRARE</i><br>(6) <i>AQU/PRS</i><br><i>AQU/REV</i><br><i>AQU/ARE</i></td><td>(4) <i>REV/PRS</i><br><i>ARE/PRS</i><br><i>(5) PRS/REV</i><br><i>ARE/REV</i><br>(6) <i>PRS/ARE</i><br><i>REV/ARE</i></td></tr>
<tr><td colspan="2">Total 270 regressions;<br>Dependent variables × Explanatory variables<br>× Model specifications (Linear, Quadratic, Cubic)<br>× Yearly observations (5 years)<br>= 3 × 2 × 3 × 3 × 5 = 270</td></tr>
</table>

When constructing combinations of independent and dependent variables, calculations are performed only between terms that share the same denominator. For example, $CO_2/PRS$ – *REV/PRS* is allowed, whereas $CO_2/PRS$ – *PRS/REV*, which involves different denominators, is excluded. The single-year combinations consist of a total of nine cases: three basic combinations and six extended combinations.

In the case of $CO_2$, the basic combinations are $CO_2-PRS$, $CO_2-REV$, and $CO_2-ARE$.

The advanced combinations include $CO_2/PRS-REV/PRS$, $CO_2/PRS - ARE/PRS$, $CO_2/REV - PRS/REV$, $CO_2/REV-ARE/REV$, $CO_2/ARE-PRS/ARE$, and $CO_2/ARE-REV/ARE$.

To ensure numerical precision, most values are reported to three decimal places. When the initial three digits are zeros (e.g., 0.000248636259136151), values are expressed in exponential notation (e.g., 2.486E–04) to enhance clarity and avoid misleading rounding.

In the following presentation of the equations, only a selected subset of variable combinations is reported.

First, the regression framework adopts a linear specification, as outlined below.

$$Y\ (CO_2)\ =\ \alpha\ +\ \beta\ (PRS)\ +\ \varepsilon$$
$$Y\ (CO_2)\ =\ \alpha\ +\ \beta\ (REV)\ +\ \varepsilon$$
$$Y\ (CO_2)\ =\ \alpha\ +\ \beta\ (ARE)\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (ENR)\ =\ \alpha\ +\ \beta\ (PRS)\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (AQU)\ =\ \alpha\ +\ \beta\ (PRS)\ +\ \varepsilon$$
$$\vdots$$
$$(omitted\ for\ brevity)$$
$$The\ \text{“}\vdots\text{”}\ symbol\ indicates\ omissions.$$

Where $Y$ is the dependent variable, $\alpha$ is the intercept, $\beta$ is the coefficient of the explanatory variable, and $\varepsilon$ is the error term. The significance of the intercept is not considered in the analysis.

The above-mentioned formulas for $CO_2$, $ENR$, and $AQU$ are also expressed in per-person unit formats: $CO_2/PRS$, $ENR/PRS$, and $AQU/PRS$.

$$Y\ (CO_2/PRS)\ =\ \alpha\ +\ \beta\ (REV/PRS)\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (CO_2/RRS)\ =\ \alpha\ +\ \beta\ (ARE/PRS)\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (ENR/PRS)\ =\ \alpha\ +\ \beta\ (REV/PRS)\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (AQU/PRS)\ =\ \alpha\ +\ \beta\ (REV/PRS)\ +\ \varepsilon$$
$$\vdots$$
$$(omitted\ for\ brevity)$$

Second, the objective is to evaluate the EKC hypothesis, using the dependent indicators $CO_2$, $ENR$, and $AQU$, which are formulated as follows:

$$Y\ (CO_2)\ =\ \alpha\ +\ \beta\ (PRS)\ +\ \beta\ (PRS)^2\ +\ \varepsilon$$
$$Y\ (CO_2)\ =\ \alpha\ +\ \beta\ (REV)\ +\ \beta\ (REV)^2\ +\ \varepsilon$$
$$Y\ (CO_2)\ =\ \alpha\ +\ \beta\ (ARE)\ +\ \beta\ (ARE)^2\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (ENR)\ =\ \alpha\ +\ \beta\ (PRS)\ +\ \beta\ (PRS)^2\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (AQU)\ =\ \alpha\ +\ \beta\ (PRS)\ +\ \beta\ (PRS)^2\ +\ \varepsilon$$
$$\vdots$$
$$(omitted\ for\ brevity)$$

This study tests the EKC hypothesis by examining environmental indicators on a per-unit basis. $CO_2$ emissions, energy consumption, and water usage are reformulated as normalized Ratios Per Person ($CO_2/PRS$, $ENR/PRS$, and $AQU/PRS$), per unit of operating revenue ($CO_2/REV$, $ENR/REV$, and $AQU/REV$), and per unit of campus area ($CO_2/ARE$, $ENR/ARE$, and $AQU/ARE$).

$$Y\ (CO_2/PRS)\ =\ \alpha\ +\ \beta\ (REV/PRS)\ +$$
$$\beta\ (REV/PRS)^2\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (CO_2/PRS)\ =\ \alpha\ +\ \beta\ (ARE/PRS)\ +$$
$$\beta\ (ARE/PRS)^2\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (ENR/PRS)\ =\ \alpha\ +\ \beta\ (REV/PRS)\ +$$
$$\beta\ (REV/PRS)^2\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (AQU/PRS)\ =\ \alpha\ +\ \beta\ (REV/PRS)\ +$$
$$\beta\ (REV/PRS)^2\ +\ \varepsilon$$
$$\vdots$$
$$(omitted\ for\ brevity)$$

The third analytical objective is to assess whether an inverted N-shaped relationship emerges. The indicators $CO_2$, $ENR$, and $AQU$ are specified as follows:

$$Y\ (CO_2)\ =\ \alpha\ +\ \beta\ (PRS)\ +\ \beta\ (PRS)^2\ +$$
$$\beta\ (PRS)^3\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (CO_2)\ =\ \alpha\ +\ \beta\ (REV)\ +\ \beta\ (REV)^2\ +$$
$$\beta\ (REV)^3\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (CO_2)\ =\ \alpha\ +\ \beta\ (ARE)\ +\ \beta\ (ARE)^2\ +$$
$$\beta\ (ARE)^3\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (ENR)\ =\ \alpha\ +\ \beta\ (PRS)\ +\ \beta\ (PRS)^2\ +$$
$$\beta\ (PRS)^3\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (AQU)\ =\ \alpha\ +\ \beta\ (PRS)\ +\ \beta\ (PRS)^2\ +$$
$$\beta\ (PRS)^3\ +\ \varepsilon$$
$$\vdots$$
$$(omitted\ for\ brevity)$$

Alternative normalization units are employed, following the analytical framework used for the EKC hypothesis, to examine the presence of an inverted N-shaped curve. The formulas for $CO_2$, $ENR$, and $AQU$ are defined per person ($CO_2/PRS$, $ENR/PRS$, $AQU/PRS$), per unit of operating revenue ($CO_2/REV$, $ENR/REV$, and $AQU/REV$), and per unit of campus area ($CO_2/ARE$, $ENR/ARE$, and $AQU/ARE$).

$$Y\ (CO_2/PRS)\ =\ \alpha\ +\ \beta\ (REV/PRS)\ +$$
$$\beta\ (REV/PRS)^2\ +\ \beta\ (REV/PRS)^3\ +\ \varepsilon$$
$$\vdots$$
$$Y\ (CO_2/PRS)\ =\ \alpha\ +\ \beta\ (ARE/PRS)\ +$$

$$\beta\,(ARE/PRS)^2 + \beta\,(ARE/PRS)^3 + \varepsilon$$

$$\vdots$$

$$Y\,(ENR/PRS) = \alpha + \beta\,(REV/PRS) + \beta\,(REV/PRS)^2 + \beta\,(REV/PRS)^3 + \varepsilon$$

$$\vdots$$

$$Y\,(AQU/PRS) = \alpha + \beta\,(REV/PRS) + \beta\,(REV/PRS)^2 + \beta\,(REV/PRS)^3 + \varepsilon$$

$$\vdots$$

$$(omitted\ for\ brevity)$$

## 4. Results

Table 2 summarizes the number of significant cases and percentages (%) identified for each year based on linear, quadratic, and cubic regression analyses. Significant monotonicity is observed in five of nine cases (55.6%) in 2019 and 2020, four cases (44.4%) in 2021, six cases (66.7%) in 2022, and seven cases (77.8%) in 2023.

The regression results reported in Table 2 also identify cases consistent with the EKC hypothesis. For $CO_2$ emissions, the EKC pattern appears in four cases (44.4%) in 2019 and 2023 and in three cases (33.3%) in 2020 and 2021. No inverted N-shaped pattern is observed during the study period.

**Table 2. $CO_2$ emissions:**
**Number of significant regression cases and percentages (%).**

| FYs | 1<br>linear | 2<br>EKC | 3<br>inv. N-shaped |
|---|---|---|---|
| 2019 | 5 (55.6%) | 4 (44.4%) | 0 (0%) |
| 2020 | 4 (44.4%) | 3 (33.3%) | 0 (0%) |
| 2021 | 4 (44.4%) | 3 (33.3%) | 0 (0%) |
| 2022 | 6 (66.7%) | 0 (0%) | 0 (0%) |
| 2023 | 7 (77.8%) | 4 (44.4%) | 0 (0%) |

Table 3 presents the number of significant regression cases and percentages (%) for energy consumption, and Table 4 presents the number of significant cases and percentages (%) for water usage. For example, in 2023, the EKC hypothesis is supported in four cases for (*ENR*) and in three cases for (*AQU*).

**Table 3. Energy consumption:**
**Number of significant regression cases and percentages (%).**

| FYs | 1<br>linear | 2<br>EKC | 3<br>inv. N-shaped |
|---|---|---|---|
| 2019 | 4 (44.4%) | 5 (55.6%) | 0 (0%) |
| 2020 | 7 (77.8%) | 2 (22.2%) | 0 (0%) |
| 2021 | 8 (88.9%) | 2 (22.2%) | 0 (0%) |
| 2022 | 6 (66.7%) | 0 (0%) | 0 (0%) |
| 2023 | 8 (88.9%) | 4 (44.4%) | 2 (22.2%) |

**Table 4. Water usage:**
**Number of significant regression cases and percentages (%).**

| FYs | 1<br>linear | 2<br>EKC | 3<br>inv. N-shaped |
|---|---|---|---|
| 2019 | 6 (66.7%) | 3 (33.3%) | 0 (0%) |
| 2020 | 7 (77.8%) | 1 (11.1%) | 0 (%) |
| 2021 | 7 (77.8%) | 1 (11.1%) | 1 (11.1%) |
| 2022 | 5 (55.6%) | 0 (0%) | 0 (0%) |
| 2023 | 7 (77.8%) | 3 (33.3%) | 1 (11.1%) |

In 2020, the COVID-19 pandemic prompted restrictions on non-essential outings in the US, the UK, and Canada. No marked increase or decrease in the number of significant cases is observed in 2020, and the number of cases consistent with the EKC hypothesis remains stable before and after that year.

This section examines combinations of dependent and explanatory variables associated with both institutional growth and environmental conservation and identifies attainable turning points. Combinations in which the hypothesis holds across multiple years are examined, whereas turning points that lack practical feasibility are excluded from consideration.

Table 5 reports the number of cases in which linear, the EKC hypothesis, and the inverted N-shaped patterns are observed, classified by explanatory variable.

**Table 5. Number of significant cases validating linear,**
**The EKC hypothesis and the inverted N-shaped patterns.**

| Segment | (1)<br>linear | (2)<br>EKC | (3)<br>inv.-N | (2) + (3) |
|---|---|---|---|---|
| PRS | 11 | 6 | 1 | 7 |
| PRS/REV | 7 | 0 | 0 | 0 |
| PRS/ARE | 12 | 3 | 0 | 3 |
| REV | 15 | 7 | 0 | 7 |
| REV/PRS | 13 | 7 | 0 | 7 |
| REV/ARE | 14 | 10 | 2 | 12 |
| ARE | 11 | 2 | 1 | 3 |
| ARE/PRS | 8 | 0 | 0 | 0 |
| ARE/REV | 0 | 0 | 0 | 0 |
| Total | 91 | 35 | 4 | 39 |

The Explanatory Variable (*REV/ARE*) identifies 12 cases, representing the highest number of significant cases for both the EKC hypothesis and the inverted N-shaped pattern.

The explanatory variables *PRS*, *REV*, and *REV/PRS* identify seven cases for both the EKC hypothesis and inverted N-shaped pattern; however, the estimated turning points in these cases are impractically high. For example, Figure 2 presents the relationship between $CO_2$ emissions ($CO_2$) and the number of students and academic and Administrative Staff (*PRS*) in 2023. The estimated turning point for $CO_2$–*PRS* reaches 83,691 persons, exceeding a level of practical feasibility.

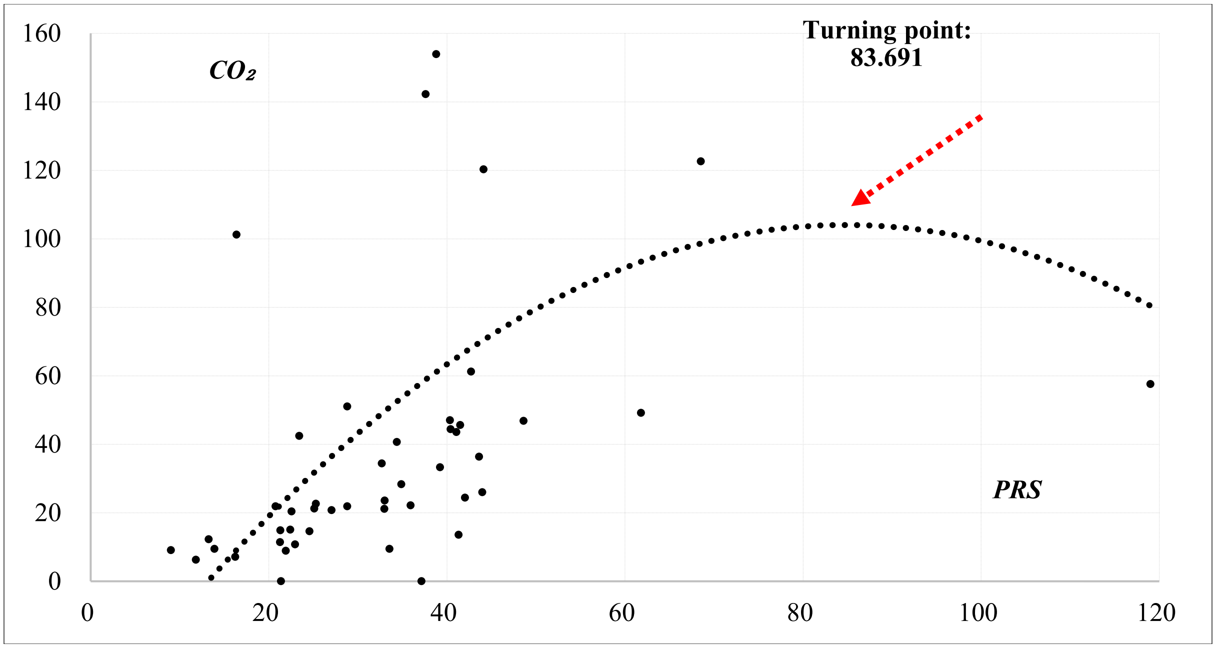

**Fig. 2** Relationship between CO₂ emissions (***CO₂***) and the number of students and academic and administrative staff (***PRS***) in 2023.

$$Y(CO2 - PRS)\ (2023)$$
$$= \alpha + \beta\,(PRS) + (PRS)^2 + e$$
$$= -41{,}152.533 + 3.499\,(PRS) - 2.090E - 05\,(PRS)^{2}$$
$$(p = 0.143) \quad (0.005) \qquad\qquad (0.044)$$
$$+\ 50{,}833.376$$
$$Adj.-R^2 = 0.193, F = 6.507\ (p = 3.344E - 03)$$
$$Turning\ point = 83{,}690.624.$$

Figure 3 presents the relationship between water usage (*AQU*) and the number of students and academic and administrative staff (*PRS*) in 2021 under an inverted N-shaped curve. The second turning point is identified at 108.229 thousand persons, marking the level at which environmental impact begins to decline. This value is not practically feasible for most institutions; therefore, the analysis does not pursue this combination further and instead focuses on attainable turning points.

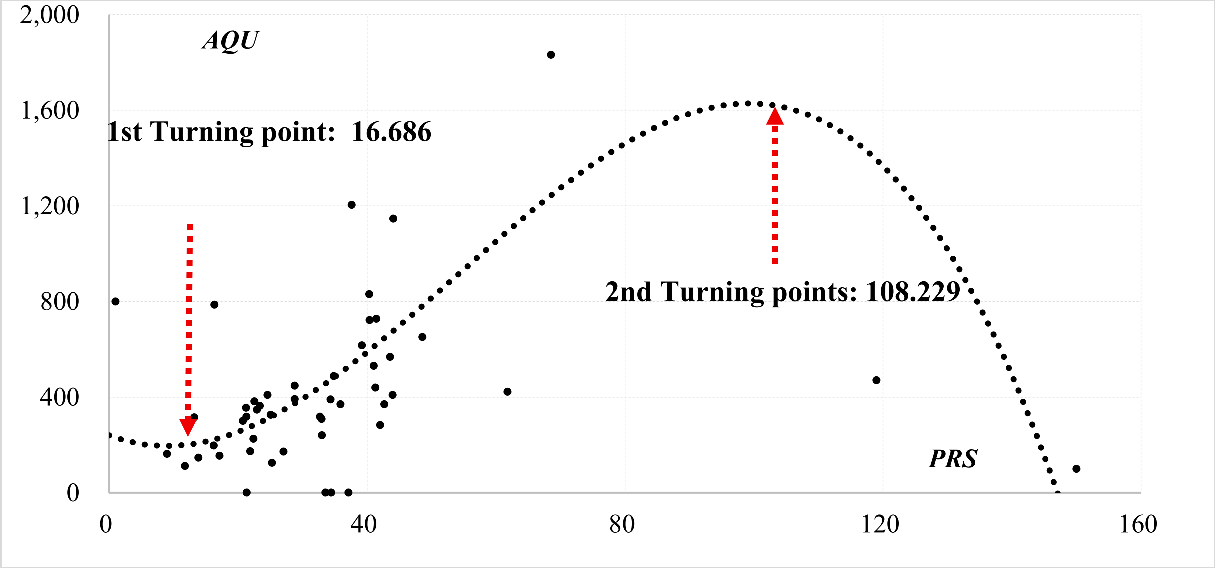

**Fig. 3** Relationship between water usage (***AQU***) and the number of students and academic/administrative staff (***PRS***) in 2023

$$Y(AQU - PRS)\ (2023)$$
$$= \alpha + \beta\,(PRS) + (PRS)^2 + (PRS)^3 + e$$
$$= 895{,}827.641 - 70.434\,(PRS) + 2.111E - 03(PRS)^2$$
$$(p = 0.029) \quad (0.021) \qquad\qquad (0.001)$$
$$-\ 1.300E - 08\,(PRS)^3 + 375{,}424.658$$
$$(4.249E - 04)$$
$$Adj.-R^2 = 0.466, F = 13.525\ (p = 3.083E - 06)$$

$$1st\ Turning\ point\ =\ 16{,}685.903,$$
$$2nd\ Turning\ point\ =\ 108{,}228.881.$$

The turning points identified using operating Revenue Per Campus Area (*REV/ARE*) as the explanatory variable in combination with *AQU/ARE*, *ENR/ARE*, and *CO₂/ARE* fall within a range that is attainable for top-tier institutions. The estimated values range from USD 3.252 billion to USD 3.922 billion.

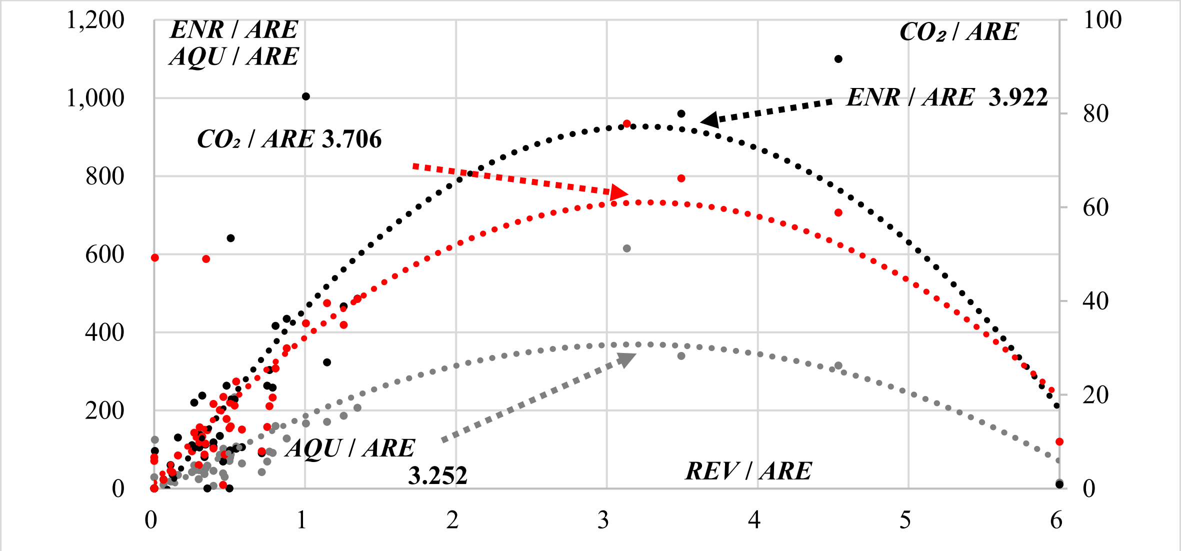

**Fig. 4 Replication of Fig. 1. EKC relationships between environmental indicators per campus area and operating revenue per campus area: (*AQU/ARE*)–(*REV/ARE*) in 2020, (*CO₂/ARE*)–(*REV/ARE*), and (*ENR/ARE*)–(*REV/ARE*) in 2021**

$$
\begin{gathered}
Y(AQU/ARE-REV/ARE)\ (2020)\\
=\ \alpha\ +\ \beta\ (REV/ARE)\ +\ (REV/ARE)^2\ +\ e\\
=\ 70{,}959.836+0.001\ (REV/ARE\ )\\
(p=0.176)\qquad(7.867E-07)\\
-\ 1.061E-13(REV/ARE)^2\ +\ 139{,}674.317\\
(9.472E-04)\\
Adj.-R^2\ =\ 0.741, F\ =\ 46.739\ (p=6.067E-10)\\
Turning\ point\ =\ 3{,}252{,}953{,}330.892
\end{gathered}
$$

$$
\begin{gathered}
Y(CO2/ARE-REV/ARE)\ (2021)\\
=\ \alpha\ +\ \beta\ (REV/ARE)\ +\ (REV/ARE)^2\ +\ e\\
=\ -1{,}123.742+3.506E-05\ (REV/ARE\ )\\
(p=0.552)\qquad(5.990E-11)\\
-\ 4.730E-15(REV/ARE)^2+5{,}100.405\\
(2.059E-06)\\
Adj.-R^2\ =\ 0.887, F\ =\ 131.008\ (p=7.573E-16)\\
Turning\ point\ =\ 3{,}706{,}181{,}199.927.
\end{gathered}
$$

$$
\begin{gathered}
Y(ENR/ARE-REV/ARE)\ (2022)\\
=\ \alpha\ +\ \beta\ (REV/ARE)\ +\ (REV/ARE)^2\ +\ e\\
=\ -10{,}444{,}341.110+0.207\ (REV/ARE)\\
(p=0.591)\qquad(3.342E-06)\\
-\ 2.640E-11(REV/ARE)^2+60{,}260{,}054.065\\
(0.006)\\
Adj.-R^2\ =\ 0.710, F\ =\ 49.871\ (p=2.364E-11)\\
Turning\ point\ =\ 3{,}922{,}963{,}456.523
\end{gathered}
$$

The turning points range from USD 3.252 billion to USD 3.922 billion. Ten universities attain these levels or fall within a close range, including University College London, London School of Economics and Political Science, and Massachusetts Institute of Technology. Table 6 shows universities that attain the *REV/ARE* turning points or fall within a close range around them.

**Table 6. Universities that attain the (*REV/ARE*) turning points or fall within a close range.**

| University | Billion USD/km$^2$ | Year |
|---|---|---|
| Concordia University | 7.939 | 2023 |
| London School of Economics and Political Science | 4.973 | 2023 |
| Massachusetts Institute of Technology (MIT) | 5.810 | 2019 |
| New York University | 88.251 | 2022 |
| Northeastern University | 7.269 | 2019 |
| University of California, Los Angeles (UCLA) | 6.595 | 2022 |
| University College London | 3.515 | 2019 |
| University of Montreal (2021) | 3.134 | 2021 |
| University of Ottawa | 6.412 | 2019 |
| University of Pennsylvania | 9.346 | 2019 |

It is reasonable to place maximum emphasis on *REV/ARE* as the explanatory variable, given both the number of supported EKC cases and the attainability of the identified turning points. These findings suggest that *REV/ARE* provides a realistic benchmark for achieving institutional growth and environmental conservation within the EKC framework.

## 5. Discussion

The background factors underlying the EKC hypothesis consist of three interrelated dimensions. First, universities face pressures and motivations to achieve higher rankings and evaluation scores assigned by external organizations. Second, universities' positioning as both fund recipients and investors shapes their behavior through links to rankings, evaluations, and resource flows. Third, universities place greater emphasis on social engagement and contribution. These three dimensions are distinguishable yet mutually reinforcing, shaping universities' incentives to pursue organizational growth alongside environmental conservation within the EKC framework. The first contributing factor relates to pressures and motivations to achieve higher rankings and evaluation scores assigned by external organizations, including assessments that emphasize ESG-related performance. Table 7 lists the scores and rankings of ten universities that have already attained or nearly attained the turning points of (*REV/ARE*) in the QS World University Rankings: Sustainability 2025. The QS Rankings cover more than 1,500 institutions. [1]

Table 7 lists university names alongside their scores and ranks. The upper row reports the score and rank for the category of the Environmental Impact of the QS Sustainability Rankings, while the lower row presents the score and rank in the overall QS World University Rankings. For example, Concordia University records a score of 78.7 and is ranked 124th in the Environmental Impact category, whereas its overall QS score is 28.7, corresponding to a rank of 415. [1, 52]

**Table 7. Scores and global rankings for the category of the Environmental Impact in the QS Sustainability Rankings and corresponding positions in the QS World University Rankings in 2025.**

| University | Score | Rank |
|---|---|---|
| Concordia University | 78.7 | 124 |
| | 28.7 | 415 |
| London School of Economics and Political Science | 88.3 | 51 |
| | 76.0 | 50 |
| Massachusetts Institute of Technology (MIT) | 96.9 | 8 |
| | 100 | 1 |
| New York University | 85.0 | 70 |
| | 79.6 | 43 |
| Northeastern University | 76.9 | 140 |
| | 29.7 | 396 |
| University of California, Los Angeles (UCLA) | 75.5 | 158 |
| | 79.8 | 42 |
| University College London | NA | NA |
| | NA | NA |
| Université de Montréal | 85.2 | 68 |
| | 51.3 | 159 |
| University of Ottawa | 77.6 | 136 |
| | 47.3 | 189 |
| University of Pennsylvania | 91.0 | 27 |
| | 91.3 | 11 |

*Source: [1, 52]*

Table 8 lists ten universities from the UK, the US, and Canada included in this study that have not reached the EKC turning points but are positioned highly in the Times Higher Education (THE) University Impact Rankings 2025, which evaluated 2,092 universities worldwide based on their contributions to the United Nations Sustainable Development Goals (SDGs). [6]

The upper row reports the score and rank in the THE Impact Rankings, while the lower row presents the score and rank in the overall THE World University Rankings. For example, Arizona State University records a score of 97.1 and is ranked 6th in the THE Impact Rankings, whereas its overall THE score ranges from 55.8 to 58.6, corresponding to a rank band of 201–250. [6, 53]

**Table 8. Scores and rankings in the THE Impact Rankings and the THE World University Rankings in 2025.**

| University | Score | Rank |
|---|---|---|
| Arizona State University | 97.1 | 6 |
| | 55.8-58.6 | 201-250 |
| University of Glasgow | 96.0 | 12 |
| | 67.8 | 87 |
| McMaster University | 95.6 | 14 |
| | 65.2 | 116 |
| University of Victoria | 95.6 | 14 |
| | 51.1-53.6 | 301-350 |
| Western University | 95.6 | 14 |
| | 55.8-58.6 | 201-250 |
| University of Exeter | 94.6 | 28 |
| | 60.4 | 172 |
| Durham University | 94.0 | 34 |
| | 60.4 | 172 |
| Swansea University | 93.8 | 36 |
| | 51.1-53.6 | 301-350 |
| York University | 93.5 | 38 |
| | 46.0-49.2 | 401-500 |
| University of Reading | 92.4 | 50 |
| | 55.8-58.6 | 201-250 |

*Source: [6, 53]*

A common feature of Tables 7 and 8 is that, with a few exceptions, such as MIT, most universities score higher and are ranked more favorably in the Environmental Impact dimension than in the overall rankings. This pattern indicates an alignment between stronger performance in environmental impact measures and lower positions in overall rankings.

Universities that hold higher positions in environmental-related rankings than in overall rankings tend to implement institutional reforms aligned with specific environmental ranking criteria and highlight improvements in their standings through press releases and institutional communications. Institutions such as the University of California, Berkeley (UC Berkeley), and Pennsylvania State

University have issued statements emphasizing their placements in the QS Sustainability Rankings, underscoring the reputational value associated with such recognition.

UC Berkeley expressed appreciation for the recognition on November 9, 2022, following its first-place position worldwide in the QS Sustainability Rankings 2022. Kira Stoll, Chief Sustainability Officer, stated that the ranking reflects the University's leadership in addressing environmental sustainability challenges. [54] The statement noted Berkeley's approach to sustainability across research, education, and campus operations. The release indicated that external rankings reaffirm the University's institutional commitment to environmental sustainability at local and global levels.

On November 18, 2025, the Pennsylvania State University released a statement regarding its performance in the QS World University Rankings: Sustainability 2026. The University tied for fourth place among institutions in the US and ranked 21st worldwide. Sabine Klahr, Vice Provost for Global Programs, stated that the ranking reflects the University's activities in sustainability-related research, education, and operations aligned with the United Nations SDGs. [55] The release also cited findings from a 2024 international student survey reported by QS, indicating that sustainability is a factor considered by prospective students.

The second contributing factor concerns universities' positioning as both fund recipients and investors, which is closely intertwined with performance in external rankings and evaluations. Evidence from the QS and THE Rankings shows that ESG-related performance enhances institutional visibility and credibility, supporting access to external funding. As discussed in Section 2.2, ESG- and SDG-related scores include subjective elements and cannot serve as standalone analytical indicators. Nevertheless, higher ESG evaluations strengthen a university's public standing and are associated with greater capacity to attract philanthropic funding, secure competitive research funding, foster industry collaboration, obtain management-related governmental grants, and support long-term endowment management.

The United Nations Principles for Responsible Investment (PRI) constitute a global framework that shapes investment behavior. [56] Since their inception, the reach and significance of the PRI have expanded over time. The number of signatories increased from 63 institutions in 2006 to 5,261 worldwide by March 2025, while the total assets under management represented by these signatories grew from USD 6.5 trillion to USD 139.6 trillion. This expansion reflects the growing role of ESG-oriented investment principles in global financial markets.

Signatory investors commit to six guiding principles, including the integration of ESG considerations into investment decision-making and the promotion of transparency through ESG disclosure. The PRI serves as an established normative framework. Principle 6 requires signatories to report their implementation efforts under a comply-or-explain approach, including disclosure of ESG integration and stewardship activities.

Within the top 200 institutions in the QS World University Rankings: Sustainability 2025, PRI signatories include 20 universities in Canada, six in the US, and four in the UK. These institutions include McGill University and the University of Toronto, tied for first place in Canada, and Western University, ranked fourth nationally. This distribution points to an association between participation in the PRI and performance in sustainability-focused university rankings.

However, comparable investment information across universities remains scarce. Despite formal adherence to the PRI framework, empirical examination shows that disclosure practices do not produce standardized, portfolio-level data. Principle 6 of the PRI emphasizes reporting on activities and progress but does not require standardized disclosure of portfolio-level investment amounts or allocations. Simultaneously, the disclosure practices of PRI signatory universities remain uneven, which constrains the availability of comparable data and complicates systematic academic comparison. PRI-aligned reporting by universities shows a tendency toward reliance on qualitative descriptions of ESG or SDG considerations, a pattern that constrains cross-institutional comparison.

Among Canadian PRI-signatory universities, McGill University stands out for providing detailed quantitative disclosure of PRI-aligned investments. Western University also reports measurable allocations to sustainable investment strategies, offering a higher degree of quantitative transparency than most peer institutions. As of December 31, 2024, the McGill Investment Pool totaled USD 2.3 billion, of which USD 201.2 million (8.7%) was invested in SDG-aligned assets, rising to 10.4% when unfunded commitments are included. [57] Western University reports USD 155 million allocated to sustainable investment strategies. [58]

While the PRI exerts normative influence on investment behavior, its institutional design limits the availability of comparable quantitative data. Insufficient disclosure alone does not constitute evidence of greenwashing. Given that university resources derive in part from philanthropic donations and public funding, leading institutions bear a responsibility to demonstrate transparency and accountability.

The third contributing factor relates to universities' greater emphasis on social engagement and contribution. It serves as a normative backdrop that reinforces the effects of ranking pressures and financial positioning discussed above. This section examines this normative dimension through an analysis of international agreements and governmental targets, university governance codes, building-level sustainability certifications, and concrete practices in campus waste management.

The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 2015 and entered into force in 2016. Universities are not direct parties to the Paris Agreement; however, they have established a global normative framework through which national targets and policy guidelines shape the behavior of universities, corporations, other organizations, and citizens, encouraging actions compatible with environmental conservation.

The Nationally Determined Contributions (NDCs), as stipulated in Article 4 of the Paris Agreement and recorded in the NDC Registry, specify greenhouse gas reduction targets for the US, the UK, and Canada for the year 2035. Although policy targets remain subject to revision in response to changes in political leadership and international commitments, the governments of the three countries have announced greenhouse gas reduction targets for 2035. These include a reduction of 61–66% below 2005 levels for the US, announced on December 19, 2024, prior to its withdrawal from the UNFCCC framework; at least an 81% reduction below 1990 levels for the UK (January 30, 2025); and a reduction of 45–50% below 2005 levels for Canada (February 12, 2025). [59-61]

The UK Higher Education Code of Governance identifies six primary elements of higher education governance. [62] Element 1 (Accountability) requires higher education institutions to meet all legal and regulatory requirements and expects governing bodies to conduct their affairs in an open and transparent manner. Element 2 (Sustainability) states that institutional resources should be used in a sustainable (financial, social, and environmental), secure, and effective manner.

Whether publicly funded or privately established, universities are not isolated entities but integral components of the broader social system. Societal concern regarding environmental conservation and social responsibility has shaped internal discourse within higher education institutions, contributing to the incorporation of ESG-related perspectives into academic and administrative activities.

This public-minded orientation is also reflected in universities' own narratives. For example, when the Pennsylvania State University was ranked 38th in the 2022 QS World University Rankings, its press release stated: "As a land-grant university, we take sustainability seriously at the local, national, and global levels, and utilize our magnitude to bring long-lasting advancements to our communities." [63]

Together, these cases suggest that, despite differences in legal systems, governance structures, and national contexts, universities are guided by a shared public-minded logic. This logic is reinforced through transnational platforms for knowledge exchange, such as the Academic Network of the PRI. Through this network, academics and practitioners from different countries share research and practices on responsible investment and sustainability, promoting common norms of environmental responsibility across higher education. These cross-border exchanges strengthen the institutional foundations of public-oriented behavior and support the third factor underlying the EKC in higher education.

As one indicator of universities' public-minded commitment to environmental conservation, Leadership in Energy and Environmental Design (LEED) provides an institutionalized framework for translating normative expectations into building-level practices. LEED certification represents a benchmark of sustainability achievement and leadership, with more than 110,000 certified projects worldwide as of the end of 2025. [64]

Although LEED certification is referenced in the context of sustainability-related rankings and evaluations, it does not assess universities at the institutional level. Rather, LEED evaluates the environmental performance of campus buildings, reflecting universities' public-minded orientation as major landholders and energy consumers. For this reason, LEED certification is discussed here under the third factor, rather than within ranking-based evaluation pressures.

Of the ten universities that have attained or nearly attained the turning point identified under the (*REV/ARE*) specification, the University of Ottawa is one of the institutions whose campus infrastructure has achieved LEED Platinum certification. According to the University's official press release on October 28, 2025, the new Faculty of Health Sciences (FHS) building at 200 Lees Avenue was awarded LEED Platinum—the highest level of certification in the program—signifying exemplary performance in sustainable design and construction. "This recognition highlights the University's commitment to reducing its environmental footprint. With its cutting-edge design, FHS stands among the greenest buildings in Canada." [65]

Waste management has a low public profile; however, the systematic implementation of law-mandated and institution-specific waste policies constitutes an important background factor in the emergence of the EKC pattern. Such practices do not produce immediate or visible reductions in $CO_2$ emissions, but their cumulative effects support the transition toward conservation-oriented growth within higher education institutions.

For example, at Imperial College London, Waste generated on campus is categorized as SK Campus (SK) Collected Waste and subdivided into approximately 25 streams, including general Waste, anaerobic digestion, incineration with energy recovery, and waste electrical and electronic equipment. By visualizing the processing pathways of different types of Waste in an accessible chart titled "Waste and Recycling at Imperial," the University promotes awareness and encourages more appropriate waste-sorting behavior. [66] Thus, the results suggest that the EKC pattern in higher education is shaped by three interrelated forces: pressures and motivations to achieve higher rankings and evaluation scores assigned by external organizations; universities' positioning as both fund recipients and investors; and a greater emphasis on social engagement and contribution.

## 6. Conclusions and Implications

This study clarifies how universities in the UK, the US, and Canada can achieve organizational growth alongside environmental conservation. The regression results provide empirical evidence supporting the EKC hypothesis in the period 2019–2023. The analyses identify a series of turning points in operating Revenue Per Campus Area (*REV/ARE*), ranging from USD 3.252 billion to USD 3.922 billion, at which $CO_2$ emissions, energy consumption, and water usage per campus area (*$CO_2$/ARE*, *ENR/ARE*, and *AQU/ARE*) begin to decline.

Reaching the identified range of *REV/ARE* turning points provides an empirical benchmark for verifying the EKC hypothesis and demonstrates a feasible trajectory through which universities can pursue organizational growth alongside environmental conservation. The findings contribute to ongoing discussions in environmental economics and higher-education management.

The findings of this study point to several priorities for future research and policy. Analytical refinement is required to identify realistic and attainable benchmark values for the empirical validation of the EKC hypothesis in higher education. Expanding the set of explanatory and dependent variables would allow future research to estimate turning points that better reflect the practical constraints faced by universities.

Additionally, the background conditions under which the EKC hypothesis emerges differ across countries, regions, social contexts, and individual universities. Future research should therefore examine how legal frameworks, policy instruments, and institutional arrangements shape university behavior, and under which conditions the EKC pattern is likely to emerge.

Universities are encouraged to enhance the disclosure of environmental datasets in formats that enable cross-national and cross-regional comparison. Improved transparency facilitates rigorous empirical analysis and contributes to more credible evaluations conducted by external organizations.

Governments and local authorities play an important role in encouraging universities' environmental initiatives through legal requirements and financial incentives. One possible approach is to link mandatory environmental disclosure to government funding through legal frameworks; however, such arrangements must strike a balance between university autonomy and the public interest in environmental conservation.

Achieving this balance requires ongoing discussion that incorporates the perspectives of multiple stakeholders, including universities, governments, local communities, and citizens, rather than relying solely on quantitative performance indicators.

Moreover, university environmental scores and evaluations involve fundamental limitations, as discussed in Section 2.3. Prestigious universities with substantial academic and policy influence often face a trade-off between environmental performance and the preservation of historical assets, including historically significant campus buildings. As such structures carry cultural value and are subject to preservation requirements, rebuilding or implementing large-scale retrofits—such as comprehensive insulation upgrades or major alterations to exterior and structural elements—is constrained. Thus, opportunities for physical improvements aimed at enhancing energy efficiency and reducing carbon emissions remain limited, placing these universities at a disadvantage in score-based environmental evaluations.

Under these conditions, enhancing environmental performance while preserving historically valuable buildings requires decision-making processes that cannot be guided by numerical indicators alone. Instead, such decisions require consensus-building that incorporates the views of local communities and the broader public, underscoring the role of democratic processes in reconciling environmental objectives with cultural preservation.

The diffusion of digital technologies enables universities to disclose institutional performance with greater transparency. At the same time, the expansion of digital infrastructure increases electricity demand, thereby imposing additional constraints on environmental conservation. These conditions introduce a new dimension to the challenge of achieving growth and conservation. While the analysis is subject to limitations related to data availability and the cross-sectional design, these conditions define the scope within which the estimated turning points should be interpreted.

Despite these academic, institutional, and policy-related challenges, the emergence of turning points in Figure 4 (reproduced from Figure 1) provides clear evidence of meaningful progress toward achieving institutional growth alongside environmental conservation. Establishing consistency in the relationships between $CO_2/ARE$, *ENR/ARE*, *AQU/ARE*, and *REV/ARE* within the identified feasible range of turning points of USD 3.252–3.922 billion offers a refined empirical benchmark for validating the EKC hypothesis. This benchmark demonstrates that institutional growth can be realized while ensuring environmental conservation. Consequently, initiatives aimed at enhancing *REV/ARE* within an ESG-oriented management framework have the potential to contribute to both domestic and global environmental conservation.

Finally, this study's *REV/ARE*-based analytical framework advances research in environmental economics and higher-education management by refining empirical benchmarks and demonstrating the feasibility of achieving institutional growth alongside environmental conservation. Therefore, researchers are expected to continue advancing investigations into achieving organizational growth and environmental conservation.

## Conflicts of Interest

The author declares no conflicts of interest related to this study.

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## Appendix 1: Significant combinations of dependent and explanatory variables

| $CO_2$ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **constant** | **(p)** | **x** | **(p)** | **$x^2$** | **(p)** | **$x^3$** | **(p)** | **st. errors** | **Adj.-$R_2$** | **F** | **(p)** | **1st turning points** | **2nd turning points** |
| *$CO_2$19/PRS-REV/PRS* | 1.209 | 0.008 | 1.637E-05 | 0.002 | | | | | 2.247 | 0.196 | 11.240 | 0.002 | | |
| *$CO_2$19-REV* | 40,629.283 | 0.003 | 1.469E-05 | 0.003 | | | | | 76,296.377 | 0.154 | 10.090 | 0.003 | | |
| *$CO_2$19-ARE* | 43,563.071 | 0.001 | 5,133.925 | 2.486E-04 | | | | | 74,099.656 | 0.239 | 15.778 | 2.486E-04 | | |
| *$CO_2$19/ARE-PRS/ARE* | 32,727.704 | 0.008 | 0.239 | 6.004E-04 | | | | | 72,054.891 | 0.245 | 13.946 | 6.004E-04 | | |
| *$CO_2$19/ARE-REV/ARE* | 4,782.972 | 0.522 | 3.219E-05 | 5.448E-13 | | | | | 43,976.797 | 0.682 | 99.703 | 5.448E-13 | | |
| *$CO_2$19-PRS* | -57,961.435 | 0.065 | 5.087 | 4.159E-05 | -1.945E-05 | 4.891E-05 | | | 73,556.264 | 0.314 | 10.630 | 1.985E-04 | 130,767.228 | |
| *$CO_2$19/PRS-REV/PRS* | -0.523 | 0.292 | 7.516E-05 | 4.450E-07 | -1.826E-10 | 1.369E-05 | | | 1.791 | 0.489 | 21.121 | 5.487E-07 | 205,765.096 | |
| *$CO_2$19-REV* | -15,311.091 | 0.311 | 7.543E-05 | 1.175E-07 | -5.371E-15 | 3.328E-06 | | | 61,404.602 | 0.452 | 21.613 | 2.027E-07 | 7.021E+09 | |
| *$CO_2$19/ARE-REV/ARE* | -12,241.426 | 0.158 | 6.777E-05 | 3.433E-07 | -4.549E-15 | 0.002 | | | 39,917.856 | 0.738 | 65.813 | 5.956E-14 | 7.448E+09 | |
| *$CO_2$20-REV* | 13,406.097 | 0.001 | 1.214E-05 | 0.002 | | | | | 13,907.934 | 0.250 | 12.018 | 0.002 | | |
| *$CO_2$20-ARE* | 18,180.395 | 0.120 | 9,110.434 | 0.019 | | | | | 48,402.898 | 0.116 | 6.010 | 0.019 | | |
| *$CO_2$20/ARE-PRS/ARE* | 14,497.624 | 2.316E-04 | 0.180 | 0.029 | | | | | 16,867.722 | 0.102 | 5.184 | 0.029 | | |
| *$CO_2$20/ARE-REV/ARE* | 6,954.732 | 0.002 | 1.161E-09 | 1.802E-05 | | | | | 8,724.587 | 0.693 | 73.178 | 1.802E-05 | | |
| *$CO_2$20-REV* | -2,047.271 | 0.709 | 4.701E-05 | 7.440E-05 | -1.182E-14 | 0.001 | | | 11,924.060 | 0.449 | 14.442 | 3.697E-05 | 1.988E+09 | |
| *$CO_2$20/ARE-PRS/ARE* | 588.978 | 0.885 | 1.054 | 3.890E-06 | -5.468E-06 | 3.021E-05 | | | 13,295.489 | 0.442 | 15.644 | 1.400E-05 | 96,424.501 | |
| *$CO_2$20/ARE-REV/ARE* | 2,016.715 | 0.511 | 3.118E-05 | 5.085E-05 | -3.592E-15 | 0.045 | | | 8,285.365 | 0.723 | 42.758 | 1.649E-09 | 4.340E+09 | |
| *$CO_2$21-PRS* | -1,419.265 | 0.785 | 0.887 | 6.502E-06 | | | | | 11,223.069 | 0.439 | 28.355 | 6.502E-06 | | |
| *$CO_2$21-REV* | 14,053.205 | 2.251E-04 | 1.033E-05 | 5.498E-04 | | | | | 12,719.250 | 0.279 | 14.548 | 5.498E-04 | | |
| *$CO_2$21/ARE-REV/ARE* | 7,501.880 | 5.997E-05 | 1.492E-05 | 5.216E-12 | | | | | 7,260.987 | 0.772 | 112.581 | 5.216E-12 | | |
| *$CO_2$21/ARE-PRS/ARE* | 8,272.355 | 0.001 | 0.535 | 1.824E-09 | | | | | 11,552.221 | 0.599 | 60.641 | 1.824E-09 | | |
| *$CO_2$21/PRS-REV/PRS* | -0.195 | 0.464 | 4.743E-05 | 4.997E-04 | -3.439E-10 | 0.001 | | | 0.333 | 0.292 | 8.232 | 1.258E-03 | 68,953.480 | |
| *$CO_2$21-REV* | -1,212.899 | 0.787 | 3.940E-05 | 2.990E-06 | -8.437E-15 | 1.193E-04 | | | 10,282.479 | 0.529 | 20.642 | 1.534E-06 | 2.335E+09 | |
| *$CO_2$21/ARE-REV/ARE* | -1,123.742 | 0.552 | 3.506E-05 | 5.990E-11 | -4.730E-15 | 2.059E-06 | | | 5,100.405 | 0.887 | 131.008 | 7.573E-16 | 3.706E+09 | |

Continued on the next page.

**Appendix 1: Significant combinations of dependent and explanatory variables (continued)**

| | **constant** | **(p)** | **x** | **(p)** | **$x^2$** | **(p)** | **$x^3$** | **(p)** | **st. errors** | **Adj. -$R_2$** | **F** | **(p)** | **1st turning points** | **2nd turning points** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *$CO_2$22-PRS* | -32,736.838 | 0.090 | 2.367 | 5.459 E-05 | | | | | 51,399.233 | 0.328 | 20.515 | 5.459 E-05 | | |
| *$CO_2$22/PRS-REV/PRS* | 0.221 | 0.330 | 2.380E-05 | 9.037 E-06 | | | | | 0.886 | 0.393 | 26.245 | 9.037 E-06 | | |
| *$CO_2$22/PRS-ARE/PRS* | 0.738 | 3.866 E-05 | 2,961.664 | 0.044 | | | | | 0.660 | 0.083 | 4.368 | 0.044 | | |
| *$CO_2$22-REV* | 6,500.667 | 0.371 | 2.466E-05 | 1.002 E-09 | | | | | 36,412.309 | 0.620 | 64.684 | 1.002 E-09 | | |
| *$CO_2$22/ARE-PRS/ARE* | 5538.095 | 0.004 | 0.528 | 2.249 E-11 | | | | | 7,716.055 | 0.718 | 92.748 | 2.249 E-11 | | |
| *$CO_2$22/ARE-REV/ARE* | 4475.559 | 0.011 | 1.985E-05 | 1.292 E-19 | | | | | 8,479.037 | 0.898 | 325.427 | 1.292 E-19 | | |
| *$CO_2$23-PRS* | 5,594.113 | 0.735 | 1.216 | 0.007 | | | | | 52,711.148 | 0.134 | 8.129 | 0.007 | | |
| *$CO_2$23/PRS-REV/PRS* | 0.330 | 0.135 | 2.080E-05 | 5.578 E-08 | | | | | 1.020 | 0.481 | 42.659 | 5.578 E-08 | | |
| *$CO_2$23-REV* | 23,184.183 | 0.007 | 1.340E-05 | 5.014 E-06 | | | | | 45,392.886 | 0.366 | 27.011 | 5.014 E-06 | | |
| *$CO_2$23/REV-PRS/REV* | 2.265E-05 | 8.493 E-09 | 0.214 | 0.011 | | | | | 1.107E-05 | 0.120 | 7.001 | 0.011 | | |
| *$CO_2$23/PRS-ARE/PRS* | 0.519 | 0.018 | 7,434.198 | 9.852 E-05 | | | | | 0.954 | 0.315 | 18.927 | 9.852 E-05 | | |
| *$CO_2$23/ARE-PRS/ARE* | -5,956.622 | 0.606 | 1.050 | 1.217 E-09 | | | | | 63,475.772 | 0.616 | 63.654 | 1.217 E-09 | | |
| *$CO_2$23/ARE-REV/ARE* | 15,175.312 | 2.286 E-09 | 7.336E-06 | 9.138 E-37 | | | | | 11,789.935 | 0.987 | 2904.456 | 9.138 E-37 | | |
| *$CO_2$23-PRS* | -41,152.533 | 0.143 | 3.499 | 0.005 | -2.090E-05 | 0.044 | | | 50,883.376 | 0.193 | 6.507 | 0.003 | 83,690.624 | |
| *$CO_2$23/PRS-REV/PRS* | -0.647 | 0.030 | 5.833E-05 | 6.712 E-08 | -1.862E-10 | 7.350 E-05 | | | 0.857 | 0.633 | 39.785 | 1.657 E-10 | 156,602.975 | |
| *$CO_2$23-REV* | -11,198.185 | 0.146 | 4.407E-05 | 9.294 E-12 | -2.173E-15 | 1.625 E-08 | | | 31,559.946 | 0.694 | 51.951 | 3.376 E-12 | 1.014E+10 | |
| *$CO_2$23/ARE-REV/ARE* | 10,866.894 | 3.748 E-06 | 1.202E-05 | 8.695 E-12 | -5.299E-17 | 4.479 E-04 | | | 10,049.244 | 0.991 | 2006.363 | 1.207 E-37 | 1.134E+11 | |
| ***ENR*** | | | | | | | | | | | | | | |
| | **constant** | **(p)** | **x** | **(p)** | **$x^2$** | **(p)** | **$x^3$** | **(p)** | **st. errors** | **Adj. -$R_2$** | **F** | **(p)** | **1st turning points** | **2nd turning points** |
| *ENR19/PRS-REV/PRS* | 5,565.389 | 2.683 E-04 | 0.061 | 3.948 E-04 | | | | | 7,209.363 | 0.254 | 14.962 | 3.948 E-04 | | |
| *ENR19-REV* | 1.719E+08 | 2.291 E-04 | 0.057 | 4.557 E-04 | | | | | 2.510E+08 | 0.212 | 14.168 | 4.557 E-04 | | |
| *ENR19-ARE* | 1.895E+08 | 3.462 E-05 | 2.038E+07 | 7.034 E-05 | | | | | 2.468E+08 | 0.289 | 19.263 | 7.034 E-05 | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *ENR19/ARE-PRS/ARE* | 1.431E+08 | 0.002 | 1,183.856 | 9.742 E-06 | | | | | 2.595E+08 | 0.399 | 26.210 | 9.742 E-06 | | |

Continued on the next page.

## Appendix 1: Significant combinations of dependent and explanatory variables (continued)

| | constant | (p) | x | (p) | $x^2$ | (p) | $x^3$ | (p) | st. errors | Adj. -$R_2$ | F | (p) | 1st turning points | 2nd turning points |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *ENR19-PRS* | -2.153E+08 | 0.043 | 20,179.965 | 4.779 E-06 | -0.077 | 5.608 E-06 | | | 2.355E+08 | 0.390 | 14.112 | 2.449 E-05 | 131,114.515 | |
| *ENR19/PRS-REV/PRS* | -570.715 | 0.693 | 0.273 | 6.594 E-09 | -6.586E-07 | 4.700 E-07 | | | 5,252.211 | 0.604 | 32.277 | 5.370 E-09 | 207,057.500 | |
| *ENR19-REV* | -2.175E+07 | 0.646 | 0.272 | 7.369 E-09 | -1.898E-11 | 4.968 E-07 | | | 1.933E+08 | 0.532 | 28.900 | 6.542 E-09 | 7.170E+09 | |
| *ENR19/ARE-PRS/ARE* | 5.549E+07 | 0.239 | 4,783.273 | 8.693 E-05 | -0.003 | 0.002 | | | 2.291E+08 | 0.531 | 22.551 | 4.476 E-07 | 738,078.477 | |
| *ENR19/ARE-REV/ARE* | -4.023E+07 | 0.177 | 0.277 | 5.576 E-09 | -1.816E-11 | 3.674 E-04 | | | 1.330E+08 | 0.822 | 102.308 | 7.175 E-17 | 7.639E+09 | |
| *ENR20-PRS* | 4.778E+07 | 0.501 | 4,507.123 | 0.024 | | | | | 2.280E+08 | 0.109 | 5.513 | 0.024 | | |
| *ENR20/PRS-ARE/PRS* | 2,929.398 | 0.111 | 3.752E+07 | 0.016 | | | | | 7,325.623 | 0.134 | 6.430 | 0.016 | | |
| *ENR20/PRS-REV/PRS* | -1,231.193 | 0.130 | 0.210 | 8.610 E-15 | | | | | 3,342.923 | 0.811 | 159.506 | 8.610 E-15 | | |
| *ENR20-REV* | -2.663E+07 | 0.194 | 0.194 | 4.197 E-15 | | | | | 1.030E+08 | 0.818 | 167.422 | 4.197 E-15 | | |
| *ENR20-ARE* | 1.539E+07 | 0.749 | 7.465E+07 | 1.770 E-05 | | | | | 1.908E+08 | 0.406 | 24.901 | 1.770 E-05 | | |
| *ENR20/ARE-PRS/ARE* | 4.377E+07 | 0.002 | 2,401.705 | 6.471 E-07 | | | | | 5.467E+07 | 0.508 | 37.158 | 6.471 E-07 | | |
| *ENR20/ARE-REV/ARE* | 3.808E+07 | 3.321 E-05 | 0.092 | 2.414 E-12 | | | | | 3.413E+07 | 0.793 | 123.573 | 2.414 E-12 | | |
| *ENR20/PRS-REV/PRS* | 5,854.515 | 2.717 E-07 | -0.137 | 0.002 | 2.204E-06 | 2.188 E-10 | | | 1892.446 | 0.939 | 287.526 | 1.894 E-22 | 31,149.344 | |
| *ENR20/ARE-REV/ARE* | 84,624.862 | 0.993 | 0.193 | 7.501 E-11 | -2.763E-11 | 7.707 E-06 | | | 2.473E+07 | 0.891 | 132.269 | 1.317 E-15 | 3.489E+09 | |
| *ENR21-PRS* | -1.937E+08 | 0.022 | 13,224.324 | 7.966 E-07 | | | | | 2.134E+08 | 0.416 | 33.014 | 7.966 E-07 | | |
| *ENR21/PRS-REV/PRS* | 3,063.932 | 0.009 | 0.081 | 5.637 E-04 | | | | | 4,668.259 | 0.226 | 13.879 | 5.637 E-04 | | |
| *ENR21/PRS-ARE/PRS* | 3,851.965 | 4.390 E-04 | 2.291 E+07 | 6.457 E-04 | | | | | 4,735.873 | 0.237 | 13.701 | 6.457 E-04 | | |
| *ENR21-REV* | 1.067E+08 | 0.033 | 0.084 | 0.001 | | | | | 2.334E+08 | 0.205 | 12.341 | 0.001 | | |
| *ENR21/REV-PRS/REV* | -0.609 | 6.066 E-14 | 22,525.589 | 2.444 E-47 | | | | | 0.355 | 0.992 | 5696.479 | 2.444 E-47 | | |
| *ENR21-ARE* | 1.078E+08 | 0.005 | 3.060E+07 | 3.056 E-07 | | | | | 1.944E+08 | 0.472 | 37.634 | 3.056 E-07 | | |
| *ENR21/ARE-PRS/ARE* | 2.260E+07 | 0.072 | 3,622.984 | 9.000 E-13 | | | | | 5.869E+07 | 0.727 | 107.582 | 9.000 E-13 | | |
| *ENR21/ARE-* | 2.260E+07 | 0.072 | 3,622.984 | 9.000 | | | | | 5.869E+07 | 0.727 | 107.582 | 9.000 | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *REV/ARE* | | | | E-13 | | | | | | | | E-13 | | |
| *ENR21-ARE* | 4.182E+07 | 0.334 | 6.298E+07 | 4.790 E-05 | -1.183E+06 | 0.017 | | | 1.828E+08 | 0.533 | 24.410 | 1.335 E-07 | 26.612 | |
| *ENR21/ARE-REV/ARE* | -1.044E+07 | 0.591 | 0.207 | 3.342 E-06 | -2.640E-11 | 0.006 | | | 6.026E+07 | 0.710 | 49.871 | 2.364 E-11 | 3.923E+09 | |

Continued on the next page.

### Appendix 1: Significant combinations of dependent and explanatory variables (continued)

| | Constant | (p) | x | (p) | $x^2$ | (p) | $x^3$ | (p) | st. errors | Adj. -$R_2$ | F | (p) | 1st turning points | 2nd turning points |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *ENR22-PRS* | -2.077E+08 | 0.005 | 12,604.844 | 2.291 E-07 | | | | | 1.855E+08 | 0.497 | 39.543 | 2.291 E-07 | | |
| *ENR22/PRS-REV/PRS* | 487.109 | 0.344 | 0.119 | 2.091 E-13 | | | | | 2027.845 | 0.765 | 124.665 | 2.091 E-13 | | |
| *ENR22-REV* | 3.544E+06 | 0.789 | 0.126 | 4.733 E-23 | | | | | 6.719E+07 | 0.929 | 497.449 | 4.733 E-23 | | |
| *ENR22/REV-PRS/REV* | 0.101 | 0.000 | 1,073.586 | 0.020 | | | | | 0.043 | 0.115 | 5.935 | 0.020 | | |
| *ENR22-ARE* | 6.622E+07 | 0.257 | 4.902E+07 | 0.017 | | | | | 2.390E+08 | 0.123 | 6.210 | 0.017 | | |
| *ENR22/ARE-REV/ARE* | -4.288E+07 | 0.025 | 0.080 | 9.976 E-08 | | | | | 9.262E+07 | 0.538 | 44.005 | 9.976 E-08 | | |
| *ENR23-PRS* | -1.352E+08 | 0.183 | 12,998.324 | 0.004 | | | | | 1.823E+08 | 0.220 | 7.060 | 0.002 | | |
| *ENR23/PRS-ARE/PRS* | 2,952.706 | 0.011 | 3.369E+07 | 5.698 E-04 | | | | | 5,002.991 | 0.252 | 14.146 | 5.698 E-04 | | |
| *ENR23/PRS-REV/PRS* | 1,938.872 | 0.037 | 0.083 | 5.201 E-07 | | | | | 4,163.277 | 0.450 | 35.329 | 5.201 E-07 | | |
| *ENR23-REV* | 1.090E+08 | 0.001 | 0.050 | 5.972 E-06 | | | | | 1.634E+08 | 0.382 | 26.991 | 5.972 E-06 | | |
| *ENR23/REV-PRS/REV* | 0.103 | 0.000 | 1,153.240 | 0.002 | | | | | 0.047 | 0.187 | 10.670 | 0.002 | | |
| *ENR23-ARE* | 9.060E+07 | 0.001 | 3.858E+07 | 6.147 E-09 | | | | | 1.383E+08 | 0.583 | 55.467 | 6.147 E-09 | | |
| *ENR23/ARE-PRS/ARE* | -1.053E+08 | 0.026 | 5,436.782 | 1.019 E-12 | | | | | 2.511E+08 | 0.735 | 108.983 | 1.019 E-12 | | |
| *ENR23/ARE-REV/ARE* | 1.756E+07 | 0.457 | 0.034 | 8.175 E-22 | | | | | 1.421E+08 | 0.917 | 421.309 | 8.175 E-22 | | |
| *ENR23-PRS* | 3.372E+07 | 0.572 | 4,653.204 | 0.004 | -0.076 | 0.045 | | | 1.892E+08 | 0.159 | 9.153 | 4.226 E-03 | 30,645.666 | |
| *ENR23/PRS-REV/PRS* | -1,660.929 | 0.211 | 0.223 | 4.537 E-06 | -6.700 E-07 | 0.001 | | | 3,693.358 | 0.567 | 28.494 | 2.027 E-08 | 166,629.727 | |
| *ENR23-REV* | -2.482E+07 | 0.381 | 0.178 | 2.770 E-11 | -8.611 E-12 | 2.291 E-08 | | | 1.114E+08 | 0.713 | 53.074 | 5.564 E-12 | 1.032E+10 | |
| *ENR23/ARE-REV/ARE* | -3.571E+07 | 0.142 | 0.092 | 2.678 E-07 | -6.552 E-13 | 2.950 E-04 | | | 1.198E+08 | 0.941 | 304.422 | 2.775 E-23 | 6.986E+10 | |
| *ENR23-ARE* | 1.967E+08 | 1.659 E-04 | -6.437E+07 | 9.404 E-02 | 1.584 E+07 | 0.010 | -4.646E+05 | 0.011 | 1.289E+08 | 0.637 | 23.860 | 1.118 E-08 | 2.031 | 22.733 |
| *ENR23/ARE-REV/ARE* | 6.233E+07 | 0.019 | -0.092 | 0.014 | 2.767 E-11 | 6.907 E-06 | -2.975E-22 | 4.706 E-06 | 8.970E+07 | 0.967 | 371.729 | 1.363 E-26 | 1.667E+09 | 6.200E+10 |

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## Appendix 1: Significant combinations of dependent and explanatory variables (continued)

| AQU | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **constant** | **(p)** | **x** | **(p)** | **$x^2$** | **(p)** | **$x^3$** | **(p)** | **st. errors** | **Adj. -$R_2$** | **F** | **(p)** | **1st turning points** | **2nd turning points** |
| *AQU19-REV* | 277,178.976 | 0.003 | 2.703E-04 | 2.326E-11 | | | | | 515,335.757 | 0.601 | 74.843 | 2.326E-11 | | |
| *AQU19/PRS-REV/PRS* | 9.433 | 7.793E-05 | 2.536E-04 | 4.461E-13 | | | | | 11.102 | 0.728 | 110.546 | 4.461E-13 | | |
| *AQU19/ARE-REV/ARE* | 79,944.210 | 0.018 | 3.375E-04 | 5.234E-27 | | | | | 190,404.455 | 0.928 | 582.349 | 5.234E-27 | | |
| *AQU19-ARE* | 468,660.122 | 1.248E-04 | 60,113.431 | 5.858E-06 | | | | | 670,901.228 | 0.355 | 26.370 | 5.858E-06 | | |
| *AQU19/PRS-ARE/PRS* | 15.031 | 1.225E-04 | 61,064.009 | 1.685E-04 | | | | | 18.145 | 0.296 | 17.414 | 1.685E-04 | | |
| *AQU19/ARE-PRS/ARE* | 360,322.965 | 4.939E-04 | 2.773 | 3.217E-06 | | | | | 571,429.582 | 0.424 | 29.719 | 3.217E-06 | | |
| *AQU19/ARE-REV/ARE* | -120.134 | 0.997 | 0.001 | 1.943E-13 | -2.120E-14 | 8.643E-04 | | | 169,038.089 | 0.943 | 375.849 | 5.824E-28 | 1.187E+10 | |
| *AQU19-PRS* | -5.606E+05 | 0.067 | 52.727 | 1.504E-05 | -2.018E-04 | 1.701E-05 | | | 700,446.100 | 0.355 | 12.276 | 7.323E-05 | 130,620.266 | |
| *AQU19/ARE-PRS/ARE* | 162,402.442 | 0.108 | 11.099 | 3.026E-05 | -7.502E-06 | 8.508E-04 | | | 497,261.787 | 0.564 | 26.213 | 8.122E-08 | 739,723.246 | |
| *AQU20-PRS* | -4.211E+05 | 0.002 | 29.529 | 4.706E-10 | | | | | 419,291.097 | 0.645 | 69.958 | 4.706E-10 | | |
| *AQU20-REV* | 30,891.657 | 0.796 | 3.971E-04 | 2.294E-06 | | | | | 525,134.863 | 0.443 | 31.187 | 2.294E-06 | | |
| *AQU20/PRS-REV/PRS* | 4.483 | 0.017 | 2.716E-04 | 3.103E-09 | | | | | 7.647 | 0.607 | 59.730 | 3.103E-09 | | |
| *AQU20/REV-PRS/REV* | 2.242E-04 | 0.018 | 6.016 | 0.005 | | | | | 2.365E-04 | 0.168 | 8.699 | 0.005 | | |
| *AQU20/ARE-REV/ARE* | 74,966.643 | 0.058 | 3.017E-04 | 1.613E-08 | | | | | 165,342.051 | 0.637 | 57.116 | 1.613E-08 | | |
| *AQU20-ARE* | 163,484.913 | 0.321 | 147,002.567 | 0.007 | | | | | 659,031.581 | 0.165 | 8.127 | 0.007 | | |
| *AQU20/ARE-PRS/ARE* | 55,287.411 | 0.136 | 9.588 | 3.903E-10 | | | | | 153,388.399 | 0.680 | 75.238 | 3.903E-10 | | |
| *AQU20/ARE-REV/ARE* | -70,959.836 | 0.176 | 0.001 | 7.867E-07 | -1.061E-13 | 9.472E-04 | | | 139,674.317 | 0.741 | 46.739 | 6.067E-10 | 3.253E+09 | |
| *AQU21-PRS* | -5.530E+05 | 0.034 | 36.352 | 1.061E-05 | | | | | 640,346.937 | 0.352 | 24.857 | 1.061E-05 | | |
| *AQU21-ARE* | 223,344.685 | 0.011 | 86,490.945 | 1.333E-11 | | | | | 467,296.522 | 0.669 | 85.749 | 1.333E-11 | | |
| *AQU21/PRS-ARE/PRS* | 8.957 | 6.434E-05 | 62,395.882 | 3.057E-08 | | | | | 10.558 | 0.519 | 46.377 | 3.057E-08 | | |
| *AQU21-REV* | 193,666.606 | 0.105 | 2.645E-04 | 5.776E-05 | | | | | 566,407.596 | 0.307 | 20.007 | 5.776E-05 | | |
| *AQU21/PRS-* | 7.417 | 0.014 | 2.182E-04 | 4.055 | | | | | 12.201 | 0.242 | 14.765 | 4.055 | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *REV/PRS* | | | | E-04 | | | | | | | | E-04 | | |
| *AQU21/REV-PRS/REV* | -0.001 | 1.816 E-13 | 48.992 | 4.197 E-47 | | | | | 0.001 | 0.993 | 6099.954 | 4.197 E-47 | | |

continued on the next page.

### Appendix 1: Significant combinations of dependent and explanatory variables (continued)

| | **constant** | **(p)** | **x** | **(p)** | **$x^2$** | **(p)** | **$x^3$** | **(p)** | **st. errors** | **Adj. -$R_2$** | **F** | **(p)** | **1st turning points** | **2nd turning points** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *AQU21/ARE-REV/ARE* | 1,157.523 | 0.975 | 6.989E-05 | 0.030 | | | | | 180,139.416 | 0.092 | 5.042 | 0.030 | | |
| *AQU21-ARE* | 13,006.688 | 0.891 | 184,847.028 | 1.374 E-07 | -3,101.076 | 0.001 | | | 412,766.845 | 0.741 | 61.225 | 6.712 E-13 | 29.804 | |
| *AQU21/ARE-REV/ARE* | 126,463.749 | 0.043 | -4.307E-04 | 0.013 | 4.013E-13 | 2.853 E-04 | -6.959E-23 | 1.106 E-04 | 149,529.649 | 0.374 | 8.973 | 1.346 E-04 | 5.366E+08 | 3.845E+09 |
| *AQU22-PRS* | -461,547.130 | 0.015 | 30.476 | 1.064 E-06 | | | | | 480,680.215 | 0.465 | 34.000 | 1.064 E-06 | | |
| *AQU22-REV* | 75,496.468 | 0.090 | 2.666E-04 | 1.568 E-16 | | | | | 218,106.806 | 0.848 | 207.959 | 1.568 E-16 | | |
| *AQU22/PRS-REV/PRS* | 7.615 | 5.533 E-06 | 1.418E-04 | 3.010 E-05 | | | | | 5.585 | 0.370 | 22.772 | 3.010 E-05 | | |
| *AQU22/ARE-REV/ARE* | 67,162.511 | 0.023 | 2.785E-04 | 5.418 E-17 | | | | | 140,876.887 | 0.865 | 231.266 | 5.418 E-17 | | |
| *AQU22/ARE-PRS/ARE* | 52,112.961 | 0.060 | 8.875 | 8.338 E-13 | | | | | 112,847.382 | 0.776 | 122.295 | 8.338 E-13 | | |
| *AQU23-PRS* | 92,392.166 | 0.528 | 12.436 | 0.002 | | | | | 462,812.669 | 0.189 | 11.020 | 0.002 | | |
| *AQU23-ARE* | 233,990.396 | 0.001 | 94,857.959 | 1.022 E-08 | | | | | 343,512.139 | 0.581 | 53.788 | 1.022 E-08 | | |
| *AQU23-REV* | 284,147.421 | 2.397 E-04 | 1.328E-04 | 4.795 E-07 | | | | | 384,539.648 | 0.452 | 35.624 | 4.795 E-07 | | |
| *AQU23/PRS-REV/PRS* | -4.662E+06 | 0.351 | 273.463 | 7.350 E-04 | | | | | 2.284E+07 | 0.227 | 13.321 | 7.350 E-04 | | |
| *AQU23/REV-PRS/REV* | 2.692E-04 | 4.242 E-06 | 4.363 | 0.001 | | | | | 1.677E-04 | 0.207 | 11.957 | 0.001 | | |
| *AQU23/ARE-REV/ARE* | 196,523.997 | 2.487 E-07 | 1.099E-04 | 3.942 E-35 | | | | | 186,760.529 | 0.986 | 2588.005 | 3.942 E-35 | | |
| *AQU23/PRS-ARE/PRS* | -8.339E+06 | 0.097 | 1.832E+11 | 3.946 E-05 | | | | | 2.169E+07 | 0.353 | 21.766 | 3.946 E-05 | | |
| *AQU23-PRS* | -408,896.518 | 0.090 | 37.185 | 6.933 E-04 | -2.262E-04 | 0.013 | | | 433,917.673 | 0.287 | 9.658 | 3.657 E-04 | 82,178.999 | |
| *AQU23-REV* | 88,370.152 | 0.300 | 3.154E-04 | 1.545 E-06 | -1.260E-14 | 0.001 | | | 340,963.465 | 0.569 | 28.731 | 1.839 E-08 | 1.251E+10 | |
| *AQU23/ARE-REV/ARE* | 82,874.467 | 0.009 | 2.586E-04 | 8.186 E-12 | -1.677E-15 | 1.552 E-06 | | | 135,598.044 | 0.993 | 2471.346 | 2.105 E-38 | 7.710E+10 | |
| *AQU23-PRS* | 895,827.641 | 0.029 | -70.434 | 0.021 | 0.002 | 0.001 | -1.300E-08 | 4.249 E-04 | 375,424.658 | 0.466 | 13.525 | 3.083 E-06 | 16,685.903 | 108,228.881 |

*Sources: Author's calculations based on the environmental reports/ESG data of each University.*

As a guide to interpreting the table, *$CO_2$19/PRS-REV/PRS* denotes a significant combination of $CO_2$ per person (*$CO_2$19/PRS*) and operating revenue per person (*REV/PRS*) in 2019.

The data is presented to three digits after the decimal point to ensure rigor. If zero continues after the third digit (e.g., 0.0000163695), it is not presented as 0.000, but as an exponent, 1.637−E05. Due to space constraints, exponential notation is used for some large numerical values.